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November 29, 2011

Mr. Christopher Black
U.S. EPA Region 5
Corrective Action Section 2
Remediation and Reuse Branch, LU-9J
77 West Jackson Boulevard
Chicago, IL 60604-3590

RE: Five-Year Groundwater Corrective Measures Implementation Review, Chevron Cincinnati Facility, Hooven, Ohio

Dear Mr. Black:

Chevron Environmental Management Company (Chevron) is submitting the *Five-Year Groundwater Corrective Measures Implementation Review, Chevron Cincinnati Facility, Hooven, Ohio* to the United States Environmental Protection Agency (USEPA) in accordance with the November 1, 2006 Administrative Order on Consent. This report presents results of the remedial systems construction, operations, and routine monitoring conducted between January 1, 2008 and June 30, 2011 at the former Gulf Oil refinery located approximately 20 miles west of Cincinnati, Ohio. The final corrective measures for groundwater at the former refinery entails two primary components. The near term (approximately first decade) will focus on engineered source removal from the light non-aqueous phase liquid (LNAPL) smear zone during naturally low water table conditions, referred to as high-grade pumping. The second component will occur over the long term (subsequent 30 years) and depletion of remaining petroleum hydrocarbons within the smear zone will be accomplished through natural attenuation, referred to as natural source zone depletion (NSZD). It is understood that NSZD processes will drive petroleum hydrocarbon degradation and mass removal over time until remedial objectives are achieved. Overall, this first *Five-Year Groundwater Corrective Measures Implementation Review* demonstrates that the groundwater remedy at the Chevron Cincinnati Facility is continuing to reduce hydrocarbon mass and saturations throughout the smear zone through engineered measures and intrinsic processes. Specifically, three primary criteria have been achieved:

1. The final groundwater remedy is functioning as intended and LNAPL recovery efficiency has been improved via implementation of the near term remedy resulting in removal of more than 270,000 gallons of LNAPL via pumping and horizontal soil vapor extraction (HSVE) system operations during three high-grade events performed in 2007, 2009, and 2010 through early-2011. Operation of the Gulf Park biovent system continues to deplete the smear zone beneath the Park. Additionally, natural processes continue to degrade hydrocarbons within the saturated and vadose zone across the smear zone footprint.

2. The final corrective measures remain protective of residents and commercial workers in Hooven and the Southwest Quad, as well as sensitive receptors within the Great Miami River. Additionally, the smear zone limits and dissolved phase plume remain stable and the vapor intrusion pathway remains incomplete.
3. Progress is being made towards the interim and final remedial end-points and these end-points remain valid. The first of the primary end-point criterion (frequency of occurrence of LNAPL greater than 0.1-foot within wells) was met within the Southwest High-Grade Area, but not the Central Area. The second primary criterion (change in hydrograph ranking) was not met in either high-grade area; although there has been significant progress towards achieving this criterion within the Southwest Area since 2003 with a decrease in the ranking (and thus occurrence of LNAPL) within most of the monitoring wells, indicating an overall decrease in LNAPL saturations across the Southwest High-Grade Area. Furthermore, concentrations of constituents of concern in vapor, groundwater, and LNAPL demonstrate first order degradation across the smear zone. This rate of depletion of the source is more pronounced at its limits compared to the core, demonstrating the expectation of "outside-in" weathering of the smear zone. In other words, the final remedy goals (USEPA Maximum Contaminant Levels) are expected to be achieved in the up- and down-gradient portions of the smear zone before they are reached within the central portion.

As always, Chevron appreciates your support with this project. In addition, Chevron would like to meet with the USEPA to discuss the progress of the final remedy at the former Gulf refinery. In order to provide the USEPA adequate time to review the enclosed documents, we are proposing to meet sometime in February 2012, either in your offices in Chicago or here at the former refinery outside of Cincinnati. If you have any questions, please feel free to contact Gene Choquette at (713) 432-2631or Paul Michalski at (513) 353-1323, ext. 28.

Sincerely,

Gene Choquette – Site Manager
Chevron Cincinnati Facility
Chevron Environmental Management Company

500-018-014

Attachment

cc: Mark Lyverse, Chevron
Matt Mitchell, Trihydro

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

November 29, 2011

Project No.: 500-018-014

PREPARED BY: Trihydro Corporation

1252 Commerce Drive, Laramie, WY 82070

SUBMITTED BY: Chevron Environmental Management Company

Chevron Cincinnati Facility, 5000 State Route 128, Cleves, Ohio 45002

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EXECUTIVE SUMMARY

This report presents results of the remedial systems construction, operations, and routine monitoring conducted by Chevron Environmental Management Company (Chevron) between January 1, 2008 and June 30, 2011 at the former Gulf Oil refinery located approximately 20 miles west of Cincinnati, Ohio. This report is being submitted five years following execution of the 2006 Administrative Order on Consent (2006 AOC, Docket No. RCRA-05-2007-0001) for implementation of final groundwater corrective measures.

The final corrective measures for groundwater at the former refinery entails two primary components. The near term (approximately first decade) will focus on engineered source removal from the LNAPL smear zone during naturally low water table conditions, referred to as high-grade pumping. The second component will occur over the long term (subsequent 30 years) and depletion of the remaining hydrocarbons within the smear zone will be accomplished through natural attenuation, referred to as natural source zone depletion (NSZD). It is understood that NSZD processes will drive petroleum hydrocarbon degradation and mass removal over time until remedial objectives are achieved. It is important to note that the use of the terms natural attenuation, intrinsic biodegradation, and NSZD are all synonymous herein.

Five-year reviews are generally required whenever constituents will remain in the subsurface at levels that limit potential reuse of a property, both during and following implementation of the final corrective measures. The purpose of a five-year review is to evaluate the implementation and performance of the corrective measures to determine if the remedy is functioning as intended and remains protective of human health and the environment. There are three primary criteria that should be demonstrated as part of the five-year review as described in this summary. These criteria have been achieved and will become the baseline for future five-year reviews.

IS THE REMEDY FUNCTIONING AS INTENDED?

The LNAPL conceptual model and corrective measures designed to reduce petroleum hydrocarbon mass and concentrations at the former Gulf refinery remain sound with only minor refinements gained through routine operations and monitoring over the first five years of the groundwater remedy implementation. Three high-grade recovery events have been performed since November 2006, with a single sustained event completed in the Southwest High-Grade Area in 2007 and one sustained event within the Central Area spanning from August 2010 through February 2011. Approximately 250,000 gallons of light non-aqueous phase liquids (LNAPL) were recovered during the events in 2007, 2009, and 2010 through early 2011. It should be noted that the majority of LNAPL (2.7 million gallons) was recovered during the first three years (1985 through 1987) of groundwater and LNAPL pumping, while approximately 900,000

gallons were recovered over the next two decades of continuous pumping (from 1988 through 2006). The volume of LNAPL recovered over the first three high-grade events is more than 25% of the volume recovered over the previous 19 years of continuous operation of the groundwater production wells and treatment systems, demonstrating that the near term remedy is functioning as intended.

In addition, focused operation of the horizontal soil vapor extraction (HSVE) system in accordance with groundwater triggers has resulted in extraction of approximately 275,000 pounds (22,000 gallons) of petroleum hydrocarbons from the smear zone beneath the community of Hooven, Ohio; with a rate of removal of 455 pounds per day of operation. Finally, biovent system operations continue to reduce residual LNAPL mass beneath Gulf Park. In some portions of the smear zone, aerobic conditions prevail in the vadose zone throughout the year and additional operation of the system will not enhance the rate of smear zone mass depletion beyond that of intrinsic processes. Where anaerobic conditions predominate in the vadose zone, additional operation of the biovent system will continue to enhance the rate of smear zone depletion.

Each of the additional monitoring locations, engineered controls, and remedial system components required to be installed as part of the final corrective measures and described within the *Remedy Implementation Plan (RIP) for Final Groundwater Remedy, Chevron Cincinnati Facility* (Trihydro 2007a) were installed including additional sentinel and point of compliance (POC) groundwater monitoring wells, rapid optical screening technology (ROST) monitoring transects, nested soil vapor wells, nested groundwater monitoring wells, pore water lysimeters, and groundwater production wells PROD_24 and PROD_25. River bank stabilization measures and performance monitoring networks were also installed along the Great Miami River on the former refinery and in Gulf Park.

DOES THE REMEDY REMAIN PROTECTIVE OF SENSITIVE RECEPTORS?

The vapor intrusion pathway has remained incomplete beneath Hooven and the Southwest Quad, even under worse case conditions when high-grade pumping is focused beneath Hooven exposing the lower reaches of the smear zone and the HSVE system is not operated in accordance with groundwater triggers. Concentrations of volatile petroleum hydrocarbons in the vadose zone (with the exception of a few detections within the deepest vapor probes situated in the smear zone) continue to remain below conservative risk based screening levels and there is not an increase in incremental risk for residents in Hooven, tenants in the former elementary school, or occupants of businesses associated with intrusion of volatile constituents from the former refinery. Occupants of current and future structures on the former refinery situated over the smear zone are and will be protected from intrusion of volatile constituents from the smear zone via mitigation measures including passive vapor barriers, and if necessary sub-slab depressurization or venting systems incorporated into the building design.

Dissolved phase monitoring conducted along the bank of the Great Miami River demonstrates that constituents of concern present in the smear zone are not migrating beneath the partial penetrating barrier wall. There have been low level detections of petroleum related constituents in the hyporheic and surface water samples collected since engineered controls were constructed. However, these detections have been associated with up-stream sources and concentrations remain below surface water screening levels that are protective of sensitive receptors in the river.

Finally, ROST and dissolved phase monitoring results continue to show that the smear zone limits and dissolved phase plume are stable and there has not been any redistribution of constituents following termination of continuous hydraulic controls following execution of the 2006 AOC. Localized changes in dissolved phase conditions have been observed in the Southwest Quad with constituents of concern including benzene, ethylbenzene, and xylenes reported in groundwater samples collected from sentinel and POC monitoring wells. These detections are attributable to alternate sources in the Southwest Quad (unrelated to the former refinery) when flow conditions are altered by periodic flooding and rapid re-equilibration of the water table.

ARE REMEDIAL END-POINTS VALID?

It was anticipated that a total of two to four sustained recovery events in each high-grade area would accomplish the goal of reducing the recoverable LNAPL in the lower reaches of the smear zone to a point where further engineered recovery is no longer productive, and should be discontinued. It was recognized that high-grade recovery may not be feasible every year, thus the time frame for high-grade recovery operations was projected to be as long as twelve years. Following five years of corrective measures implementation, the first of the primary end-point criterion (frequency of occurrence of LNAPL greater than 0.1-foot within wells) was met within the Southwest High-Grade Area, but not the Central Area. While the second primary criterion (change in hydrograph ranking) was not met in either high-grade area, there has been significant progress towards achieving this criterion within the Southwest Area since 2003 with a decrease in the ranking (and thus occurrence of LNAPL) within most of the monitoring wells, indicating an overall decrease in LNAPL saturations across the high-grade area. Additional high-grade pumping will be performed over the next five years within both areas, in accordance with groundwater elevation triggers.

It's anticipated that when the HSVE system is ready to be permanently shut down, the remaining hydrocarbon mass within the influence of the system would diminish to the point where continued operation does not result in reduction of soil vapor concentrations beyond those observed via aerobic biodegradation alone; this is currently observed in the vapor source concentration trends for nested soil vapor monitoring well VW-93. Operation of the HSVE system in accordance with the 2006 AOC and associated amendments will continue until conditions within the remainder of the smear zone beneath Hooven are similar to those observed near nested vapor monitoring well VW-93.

The long-term objective of the final groundwater corrective measures at the former Gulf Refinery has been established as the United States Environmental Protection Agency (USEPA) Maximum Cleanup Levels (MCLs). Decreasing trends have been observed in the LNAPL, vapor phase, and dissolved phase concentrations over time as a result of both engineered and intrinsic biodegradation processes. Hydrogeochemical indicators and fixed gases also demonstrate that natural attenuation is occurring within the saturated and vadose zones across the smear zone limits. It is expected that the long-term objective will be achieved at the margins first, and then will subsequently be met over time proceeding inward towards the center of the smear zone. Routine monitoring results collected over the first five years of corrective measures implementation are consistent with this expectation, indicating outside-in attenuation of petroleum hydrocarbons within the smear zone.

1.0 INTRODUCTION

Chevron is performing final groundwater corrective measures implementation and monitoring of the remedy performance at the former Gulf Refinery located east of the unincorporated town of Hooven, Ohio. The groundwater remedy was designed to be protective of human health and the environment, with the long-term objective of remediating petroleum hydrocarbons to meet cleanup objectives defined as USEPA MCLs. Achieving the long-term objective will take many years; therefore, the following interim objectives have been adopted for the groundwater remedy:

- Monitor soil vapor concentrations and prevent migration of volatile petroleum hydrocarbons into indoor air above risk based limits
- Measure the stability of LNAPL and dissolved phase petroleum hydrocarbons
- Remove recoverable LNAPL to agreed upon end-points
- Stabilize the bank of the Great Miami River on the main facility and in Gulf Park to prevent erosion of soils containing petroleum hydrocarbons

Groundwater remediation and monitoring efforts are being conducted in accordance with the 2006 AOC between Chevron and the USEPA (Docket No: RCRA-05-2007-0001). The primary components of the groundwater remedy specified in the 2006 AOC include:

- Re-establishment of natural hydraulic conditions beneath the facility, Hooven, and off-site properties to the southwest (commonly referred to as the Southwest Quad) through discontinuance of year round groundwater recovery
- Focused LNAPL removal during periods of seasonal low water table conditions through high-grade pumping over the first decade of the final remedy
- Combined operation of the HSVE system beneath Hooven with high-grade recovery according to groundwater triggers
- Continued seasonal operation of the Gulf Park biovent system during low water table conditions
- Engineered stabilization of the bank of the Great Miami River at the former refinery and Gulf Park to prevent erosion of soil containing petroleum hydrocarbons
- Long-term monitoring of natural source zone attenuation including dissolved and vapor phase biodegradation

A fundamental concept of the final groundwater remedy is the continued stability of the LNAPL and dissolved phase plumes. The majority of recoverable LNAPL has been removed from beneath the former refinery and off-site properties over the past two decades. This is especially true in the upper and middle reaches of the smear zone, where LNAPL saturations are low. High-grade recovery is intended to focus on remaining LNAPL removal within the lower reaches of the smear zone and core portions of the plume with the highest remaining LNAPL saturations. However, it is understood that the long-term remedy objective will be accomplished primarily through natural processes that drive petroleum hydrocarbon degradation and mass removal over time.

A detailed discussion of the objectives and activities to be conducted to achieve the groundwater remedy goals, are described in the documents titled, *RIP*, and *Operation, Maintenance, and Monitoring (OMM) Plan for Final Groundwater Remedy, Chevron Cincinnati Facility* (Trihydro 2007b).

1.1 SITE HISTORY

The former Gulf Oil refinery is located approximately 20 miles west of Cincinnati, Ohio, near the intersection of Ohio State Route 128 and US Highway 50. The surrounding land uses are residential, commercial, as well as undisturbed upland forest and riparian areas. The former refinery site occupies approximately 500 acres bordered on the north, east, and south by the Great Miami River. Commercial retail property is developed along State Route 128. Figure 1-1 shows the location of the former refinery and surrounding area.

In accordance with the site description included in the 2006 AOC, the former refinery includes a closed land treatment unit (LTU) located on a ridge northwest of the refinery property, a former loading dock on the Ohio River, as well as a products pipeline corridor between the refinery and the barge terminal. Two past pipeline releases are also described including one at "the Islands" located directly across the Great Miami River from the former refinery, and a second area referred to as Gulf Park (currently the Cleves Community Park), located in the Village of Cleves, Ohio.

Although the LTU is included within the facility definition, groundwater monitoring is conducted in accordance with the post-closure work plan approved by the Ohio Environmental Protection Agency (OEPA). Inspection, maintenance, and monitoring conducted at the LTU are reported to the OEPA on an annual basis.

Corrective measures at the Islands has been previously completed and reported to the USEPA and therefore no further remediation or monitoring is necessary on these properties. Assessment and remedial efforts of the former products pipeline corridor between the refinery and the barge terminal have been conducted through historical voluntary

remedial efforts. These include remediation completed at the former Barge Terminal and on-going remedial efforts at Gulf Park, which are further detailed herein.

1.1.1 OPERATIONAL HISTORY

Prior to 1931, a foundry and horse carriage manufacturing facility (Phoenix Manufacturing Company) operated at the southern portions of the property. The remaining parcels were likely utilized for agricultural purposes. Gulf Oil Corporation began property acquisition in 1930, and by 1931 had constructed a refinery on the property to refine crude oil into fuels and asphalt. The major products produced at the refinery included gasoline, jet fuel, diesel, home-heating fuels, asphalt, and sulfur. In 1985, Chevron acquired Gulf Oil Corporation and assumed operation of the refinery. Operations at the refinery were terminated in 1986.

A portion of the former refinery situated along State Route 128 and south of the former marketing terminal was leased to Elco, Inc. between 1965 and 2000. Elco, Inc. operated a lubrication oil additive manufacturing facility. Dravo Corporation also leased property along the southern portion of the former refinery. The property leased by Dravo Corporation served as the terminus of an inactive gravel conveyor system, which crossed over the Great Miami River.

1.1.2 SUMMARY OF INVESTIGATION ACTIVITIES

The former refinery has been subject to a number of investigations since 1982. Based on early assessment activities it was determined that:

- During the active operation of the refinery prior to 1980, some of the various wastes generated by operations were disposed in several solid waste management units (SWMUs) and areas of concern (AOCs), including tanks and impoundments. The typical refinery wastes generated included various heavy (high molecular weight) oily sludges, spent caustic, and leaded tank bottoms. Some of these wastes contained residual volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and metals such as lead, cadmium, chromium, and nickel. Other wastes such as spent caustic were considered to be hazardous as a result of elevated pH.
- Accidental spills and possibly pipe or tank leakage prior to the shutdown of the refinery in 1986 released both organic and inorganic constituents to soil and groundwater beneath the former refinery. The specific sources of the product releases are not known.

In 1985, an oily sheen was observed on the Great Miami River along the southeast portion of the property. In response, the water production well located on the Dravo Corporation sand and gravel quarry, adjacent to the refinery, was started and the LNAPL sheening on the river ceased. Two hydrocarbon recovery systems were subsequently installed

in 1985 (by the Gulf Oil Corporation) at the refinery and the Dravo Corporation quarry. Analyses of LNAPL samples collected from the recovery systems indicated a composition of approximately 80% leaded gasoline and 20% diesel fuel.

In May 1993, Chevron entered into the Administrative Order on Consent (1993 Consent Order) for the Facility with the USEPA. The 1993 Consent Order stipulated completion of a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and Corrective Measures Studies. Since execution of the 1993 Consent Order in 1993, Chevron has completed numerous assessments including:

- Phase I RFI to investigate groundwater and soil quality at the perimeter of the former refinery and determine the potential extent of off-site impacts. Phase I of the RFI included a screening ecological risk assessment to evaluate habitats at the former refinery, ecological receptors, exposure pathways, and constituents of potential concern.
- Phase II RFI to assess soil and groundwater quality within the former refinery limits. The Phase II RFI included completion of a facility-wide human health risk assessment and preliminary ecological risk assessment.
- Human health risk assessments completed in the off-site commercial properties located to the southwest of the Facility (commonly referred to as the Southwest Quad) and the community of Hooven.
- Risk based prioritization to evaluate surface and subsurface soil quality within the SWMUs and AOCs, and prioritize the areas requiring stabilization and additional assessment.
- Environmental indicator assessment to ensure that humans are not being exposed to unacceptable levels of refinery related constituents in soil and/or groundwater.
- Environmental indicator assessment to demonstrate that LNAPL and dissolved phase impacts are not continuing to migrate in groundwater.
- Corrective Measures Study and additional assessments to support final corrective measures for sludges, soils, and groundwater.

1.1.2.1 PHASE I AND PHASE II RFI

The RFI was completed during two separate investigations. The overall approach of the RFI was submitted to the USEPA within the *Project Management Plan for the RFI at the Chevron Cincinnati Facility* (Environmental Science & Engineering 1997). Phase I of the RFI placed priority on investigating conditions at the perimeter of the former refinery, and evaluating potential off-site impacts. Phase II of the RFI was focused upon soil and groundwater quality within the former refinery's boundaries. The overall objectives of the RFI were to:

1. Characterize potential pathways of constituent migration.
2. Characterize sources of refinery related constituents of concern.
3. Define the degree and extent of impacts to soil and groundwater.
4. Identify potential receptors.
5. Support the development of corrective measures options.

Phase I of the RFI included the installation and sampling of a perimeter and off-site groundwater monitoring wells, collection of bank soil and sediment samples along the west bank of the Great Miami River; and surface water sampling within the River. The results of the Phase I RFI were submitted in the *Technical Memorandum for the Phase I RFI at the Chevron Facility, Hooven, Ohio* (QST, et al. 1998). The *Screening Ecological Risk Assessment* (Ecology and Environment, Inc. 1998b) was submitted under separate cover to the USEPA in January 1998.

Phase II of the RFI included the collection of unbiased soil samples at the former refinery. The unbiased soil samples were collected using a sample grid approach for both surface and subsurface soil sampling activities. In addition, biased soil, sediment, groundwater, and surface water samples were collected to delineate the extent of impacts in vicinity of each of the SWMUs and AOCs. Finally, surface vapor flux testing was performed at various locations across the former refinery to evaluate the vapor intrusion pathway.

Results of the Phase II RFI were submitted to the USEPA in the *RCRA Facility Investigation Report for the Chevron Cincinnati Facility* (Environmental Science & Engineering 2000). Results of the facility wide human health and preliminary ecological risk assessments were submitted within the *Chevron Cincinnati Facility Phase II Facility-Wide Human Health and Ecological Risk Assessment* (Ecology and Environment, Inc. 2000). The results, conclusions, and recommendations submitted within the RFI were approved by the USEPA in 2000.

1.1.2.2 CORRECTIVE MEASURES STUDY FOR GROUNDWATER

The *Corrective Measures Study for Groundwater at the ChevronTexaco Cincinnati Facility* (*CMS for Groundwater*, URS 2002) was submitted to the USEPA in October of 2002. The *CMS for Groundwater* concluded the most viable option for meeting remedial goals for LNAPL and dissolved phase petroleum hydrocarbons is containment. Containment of LNAPL and dissolved phase impacts can be accomplished in a number of ways. The *CMS for Groundwater* specified that the alternative be optimized in order to determine the most proactive, efficient, and cost-effective method to maintain containment. In April 2003, Chevron submitted the *Conceptual Groundwater Remedy Report, ChevronTexaco Former Cincinnati Facility* (*Conceptual Groundwater Remedy Report*, ChevronTexaco

Cincinnati Groundwater Task Force 2003) that provided further or "optimized" recommendations for the interim and final remedies selected to achieve corrective action objectives. The preferred remedy proposed by Chevron included:

- Phasing out the interim program of continuous pumping and treatment of large volumes of groundwater year-round
- Conducting focused (high-grade) LNAPL recovery during seasonal low water table conditions
- Implementing institutional and engineered controls to reduce potential risks to human health or ecological exposure in consideration of anticipated future land use
- Establishing field based measures of success that will lead to eventual transition to a long-term monitored natural attenuation program for mitigation of residual impacts in groundwater that cannot practicably be removed via active groundwater and LNAPL recovery and treatment

The *Conceptual Groundwater Remedy Report* was submitted with the understanding that many aspects of the site conceptual model (SCM) required field based confirmation to define specific performance measures. The USEPA provided general and specific comments related to the *Conceptual Groundwater Remedy Report*, in correspondence dated July 13, 2004. Chevron responded to the USEPA's comments in correspondence dated December 10, 2004. Field based confirmation of the conceptual site model and additional assessment to support implementation of groundwater corrective measures was conducted between December 2004 and November 2006.

The USEPA provided a description of the proposed final groundwater remedy in the *Statement of Basis for Groundwater, Chevron Cincinnati Facility, Hooven, Ohio* issued in April 2006. Following a public meeting and comment period, USEPA issued a *Final Decision and Response to Comments Selection of Remedial Alternative for Groundwater for the Chevron Facility near Hooven, Ohio* on August 30, 2006. These two documents are the underlying technical basis, which in conjunction with the 2006 AOC, define the overall groundwater remedy components and goals.

1.2 SOILS CORRECTIVE MEASURES

Risk-based prioritization of the SWMUs and AOCs was conducted at the former refinery in 1997. Activities included collection and analysis of waste, surface soil, and subsurface soil samples. Surface soil, subsurface soil, and waste samples were collected from SWMU 1, SWMU 2, SWMU 3, SWMU 4, SWMU 7, SWMU 8, SWMU 9/13, SWMU 38, SWMU 39, AOC B, and at AST No. 227.

Three surface soil samples were collected from each of the SWMUs and AOCs included in the investigation. Two of the surface samples were collected from areas displaying visible evidence of waste. The third surface sample was collected from an area adjacent to the SWMU or AOC that did not display evidence of waste. The subsurface sampling depths for the SWMUs and AOCs were based on the results of subsurface field screening performed via Cone Penetrometer Testing (CPT) and ROST assessment. The CPT/ROST screening provided continuous characterization of stratigraphy and a vertical profile of wastes and impacted soils that assisted in the selection of sample intervals. The samples were analyzed for an abbreviated modified Skinner list, including selected VOCs, polycyclic aromatic hydrocarbons (PAHs), and metals. Results of the risk prioritization were submitted to the USEPA in June 1998 with the *Chevron Cincinnati Risk-Based Prioritization Report* (Ecology and Environment, Inc. 1998a).

1.2.1 INTERIM MEASURES

Although the results of the Risk-Based Prioritization Report did not indicate the existence of an unacceptable risk to human health or the environment, Chevron completed voluntary removal activities of several SWMUs and AOCs at the former refinery. SWMU 1, SWMU 2, SWMU 3, non-hazardous portions of SWMU 4, SWMU 9/13, SWMU 22, SWMU X, the majority of SWMU Y, AST Nos. 61/62 area, AST No. 63 area, and areas containing leaded tank bottoms and surficial lead impacts were removed via excavation and off-site disposal in concurrence with the RFI. Additionally, SWMU 11 and SWMU 14 were removed prior to execution of the 1993 Consent Order. Work plans and summary closure reports were submitted to the USEPA for these interim excavation and off-site disposal activities.

1.2.2 FINAL CORRECTIVE MEASURES

In September 2001, Chevron submitted the Corrective Measures Study for Sludges and Contaminated Soils at the Chevron Cincinnati Facility (CMS for Sludges and Contaminated Soils, URS 2001). The recommended remedy for addressing impacted soil and sludges in the remaining SWMUs and AOCs at the former refinery included excavation, stabilization, and disposal in an on-site Corrective Action Management Unit (CAMU). The USEPA was in the process of reviewing the CMS for Sludges and Contaminated Soils when on January 22, 2002, revisions to Title 40 of the Code of Federal Regulations Parts 260, 264, and 271 were revised in the Federal Register. The revisions, commonly referred to as the "CAMU Amendments" presented an opportunity for a new remedial alternative, which was not previously available to Chevron at the time of the original submittal of the CMS for Sludges and Contaminated Soils. This remedial alternative entailed the excavation and consolidation of impacted soils and sludges at an off-site RCRA Subtitle C Hazardous Waste Landfill. On February 5, 2001, Chevron requested that the USEPA discontinue review of the CMS for Sludges and Contaminated Soils in order to evaluate this newly available remedial option. In October 2002, Chevron re-submitted the CMS for Sludges and Contaminated Soils at the Chevron Cincinnati Facility (URS 2002b), based upon the Amendments to the "CAMU Rule."

In June 2003, USEPA issued the *Statement of Basis for Sludges and Contaminated Soils for ChevronTexaco Cincinnati Facility* (USEPA 2003). The USEPA approved the preferred remedy for addressing hazardous wastes present in the remaining SWMUs and AOCs at the former refinery. In response to public comments the USEPA issued the *RCRA Final Decision (Final Decision) and Response to Comment, Selection of Remedial Alternatives for Sludges and Contaminated Soils for ChevronTexaco Cincinnati Facility* (USEPA 2004a). In March 2004, the USEPA and Chevron entered into the *Performance Agreement for Sludges and Contaminated Soils* (USEPA 2004b).

In June 2004, the USEPA approved the Final Work Plan for Off-Site Consolidation of Hazardous Contaminated Soils and Sludges, ChevronTexaco Cincinnati Facility (Final Work Plan for Off-Site Consolidation of Hazardous Contaminated Soils and Sludges, Trihydro 2004). In December 2007, the implementation of the Performance Agreement for Sludges and Soils was discontinued. More than 570,000 cubic yards of sludges and impacted soils were removed in accordance with the Final Work Plan for Off-Site Consolidation of Hazardous Contaminated Soils and Sludges. There were several areas of the former refinery that required further action under the Performance Agreement for Sludges and Soils but could not be excavated due to the presence of groundwater remediation facilities including the biologically enhanced granular activated carbon treatment unit, storage tanks, piping, etc.

During discussions with the USEPA, it was decided that the final report for work completed under the *Performance Agreement for Sludges and Soils* would be submitted to the USEPA and considered complete. Any remaining SWMUs or AOCs will be left undisturbed until the groundwater remediation facilities are decommissioned and removed, in accordance with the 2006 AOC. Following decommissioning, any sludge or impacted soil in these areas will be subject to the guidelines of the *Final Work Plan for Off-Site Consolidation of Hazardous Contaminated Soils and Sludges*.

1.3 INTERIM GROUNDWATER CORRECTIVE MEASURES

Hydraulic containment measures were implemented to minimize migration of petroleum hydrocarbons off-site. The refinery ceased production in 1986 and the refinery infrastructure was subsequently dismantled. Interim measures initially focused on hydraulic control of LNAPL and dissolved phase petroleum hydrocarbons by extracting groundwater and creating inward hydraulic gradients. These measures were expanded to include soil vapor extraction and six-phase heating beneath the Islands; bioventing beneath Gulf Park; and operation of the HSVE system designed to remove hydrocarbons beneath State Route 128 and Hooven. Historical remediation activities completed at the former refinery are summarized in the subsections below.

1.3.1 HYDRAULIC CONTROL

Hydraulic control and recovery of petroleum hydrocarbons began in early 1985 using three of the refinery's groundwater production wells located in the interior portions of the site. Chevron installed five additional groundwater and LNAPL production wells (PROD_19 through PROD_23) at the western boundary of the former refinery, in a north-south transect along State Route 128 between September 1998 and August 2001 (Figure 1-2). These additional production wells were installed as an interim measure to control migration of hydrocarbons down-gradient of the facility, as well as beneath Hooven and Southwest Quad. Hydrocarbon recovery efforts were focused along the western portion of the site and extending beneath State Route 128, to improve recovery in this area where the LNAPL had a greater potential to be mobile and a higher fraction of volatile constituents compared to other areas of the facility. Groundwater extraction rates increased over the first 15 years in proportion to the number of production wells brought on-line, with the maximum rate of extraction occurring during the late 1990s. More than two million gallons of groundwater were removed each day in the late 1990s.

1.3.2 LNAPL RECOVERY

More than 3.6 million gallons of LNAPL were recovered via hydraulic recovery between 1985 and 2006. As shown on Figure 1-3, More than 2.7 million gallons were extracted from the subsurface over the first three years of pumping from three production wells. The remaining 0.9 million gallons were removed over the next 20 years from 11 production wells. The rate of recovery strongly diminished through time, indicating that the majority of the recoverable LNAPL within the influence of the production wells has been removed.

The remaining LNAPL is present in the pore spaces between soil particles within an area just above and below the groundwater table known as the smear zone. The thickness of the smear zone generally increases from inches at the plume periphery, to as much as 20 feet in locations of the production wells. The depth to the top of the smear zone varies across the site, from as little as 10 feet near the Great Miami River, to approximately 30 feet across most of the former process areas and tank farms, to about 60 feet under the town of Hooven.

1.3.3 HORIZONTAL SOIL VAPOR EXTRACTION

Chevron installed the HSVE system as an interim measure for reducing the hydrocarbon concentrations beneath Hooven (ERM 1999). Pilot testing to determine the effectiveness of soil vapor extraction technology beneath Hooven was conducted in June and November 1998. Based upon the results of the pilot testing and completion of a remedial options analysis in June 1999, it was determined that HSVE presented the best available technology for removing hydrocarbons and minimizing disruptions to residents. The HSVE system includes three horizontal vapor extraction wells, installed between 1999 and 2000, which extend approximately 800 feet from the western portion of the Chevron

property, underneath State Route 128, westward beneath Brotherhood Avenue, Hooven Avenue, and Ohio Street in Hooven. The horizontal vapor recovery wells were designed to remove soil vapors from approximately five feet above the previously observed 15-year maximum seasonal high water table elevation. The system commenced operation in November 1999 following installation of HSVE Line No. 1. Line No. 2 and Line No. 3 were installed in 2000 and brought online during the first quarter 2001. More than 400,000 pounds of organic carbon (approximately 52,000 gallons) of LNAPL were recovered using the three extractions lines between 1999 and 2006.

1.3.4 GULF PARK BIOVENT SYSTEM

A biovent system was installed in Gulf Park in 1996 and expanded in 2000 to enhance aerobic degradation of petroleum hydrocarbons present due to a historical release(s) from the pipelines that connected the former refinery with the loading terminal on the Ohio River. Bioventing stimulates intrinsic biodegradation of petroleum hydrocarbons in the smear zone by injecting air at low flow rates to provide sufficient oxygen (O_2) to sustain aerobic microbial activity. Airflow is injected at rates designed to maximize O_2 delivery to the subsurface while minimizing volatilization of hydrocarbon constituents, thus eliminating the necessity for vapor intrusion or ambient air pollution control measures.

1.4 FINAL GROUNDWATER CORRECTIVE MEASURES

The final corrective measures for groundwater entails two primary components. The near term (approximately first decade) will focus on engineered source removal from the LNAPL smear zone during naturally low water table conditions, which occurs during times of limited regional precipitation, generally in the late summer to fall months. Over the long term (subsequent 30 years) depletion of the remaining hydrocarbons within the smear zone will be accomplished through natural attenuation, referred to as NSZD. It is understood that NSZD processes will drive petroleum hydrocarbon degradation and mass removal over time until remedial objectives are achieved.

1.4.1 NEAR TERM FINAL CORRECTIVE MEASURES

The high-grade approach is based on observations during the more than 20 years of interim hydraulic control and LNAPL recovery performed at the former refinery. Measurable and recoverable LNAPL was only present during times of naturally low water table conditions. The Buried Valley Aquifer beneath the former refinery is highly productive and it is impractical to artificially lower the aquifer and expose the lower reaches of the smear zone during periods of moderate to high water table elevations. However, when the water table is naturally depressed, it is possible to induce LNAPL recoverability by pumping high volumes of groundwater to further draw down the water table and allow entrapped LNAPL in the lower reaches of the smear zone to be recovered.

High-grade recovery will focus on two areas at the former refinery based on (1) higher LNAPL saturations within the smear zone and (2) elevated mole fraction of petroleum related constituents measured within the LNAPL relative to other portions of the smear zone. The first high-grade area, referred to as the Southwest High-Grade Area, focuses on additional recovery beneath Hooven, the Southwest Quad, and southern limits of the former refinery. A number of groundwater production wells were historically operated within this high-grade area along the western boundary of the former refinery including wells PROD_19 and PROD_20. These two wells are primarily used for high-grade purposes within this area, along with one additional production well (PROD_24) installed in Hooven in 2007. The HSVE system although operating on independent groundwater trigger elevations also reduces LNAPL mass within the smear zone during high-grade recovery focused on this area. The second area, the Central High-Grade Area, will reduce LNAPL mass within the core of the smear zone where interim measures were not directly focused. One existing production well (PROD_12) was located within this high-grade area but was replaced with newly installed production well PROD_25 in 2010.

Ultimately, high-grade pumping within each of these two areas will reach practical end-points, which were detailed within the Proposed Criteria for Discontinuing High-Grade LNAPL Recovery under the Final Groundwater Remedy, Chevron Cincinnati Facility, Hooven, Ohio (Trihydro 2009e). Chevron expects that two to four sustained high-grade events under low water table conditions will be necessary within each high-grade area before these end-points are realized. Based on historical precipitation and fluid level data, this should occur in six to twelve years; after which, it will be evident if final end-points have been met.

1.4.2 LONG TERM FINAL CORRECTIVE MEASURES

The long-term remedy objectives will be accomplished primarily through natural processes that drive petroleum hydrocarbon degradation and removal over time. In general, NSZD occurs as constituents present in the smear zone partition to groundwater and soil vapor, where they are biodegraded via aerobic and anaerobic processes. Routine monitoring of dissolved phase, vapor phase, and LNAPL composition over the long-term remedy will demonstrate that NSZD processes are reducing concentrations to remedial end-points within the timeframe that is expected. A detailed description of the lines of evidence that will be considered over the course of the long-term remedy are provided in Section 3 and Appendix B herein.

1.4.3 CONSTRUCTION OF REMEDY COMPONENTS

While much of the necessary systems and infrastructure necessary for operation, maintenance, and monitoring of the final groundwater remedy was in place prior to finalizing the 2006 AOC, installation of additional monitoring

locations, engineered controls, and groundwater production wells were required as outlined within the *RIP*. Additional infrastructure installed over the first five years of the final groundwater corrective measures included:

- Additional sentinel and POC monitoring wells in the Southwest Quad
- Three ROST monitoring transects along the down-gradient limits of the smear zone
- Nested soil vapor monitoring wells at the grouped media locations near monitoring wells MW-18, MW-20, and MW-21, as well as one additional well near the down-gradient limits of the smear zone near monitoring well MW-139
- Four new nested groundwater monitoring wells at each of the grouped media locations: MW-18, MW-20, MW-21, and MW-93
- Four nested lysimeter pairs at each of the grouped media locations
- Groundwater production wells PROD_24 in the Southwest High-Grade Area and PROD_25 in the Central High-Grade Area
- River bank stabilization measures along the west bank of the Great Miami River on the former refinery
- River bank stabilization measures along the bank of the Great Miami River in Gulf Park
- Abandonment of dry wells used for storm water management in the Southwest Quad and construction of a combined storm water treatment sewer system

Details regarding installation of the monitoring networks and infrastructure necessary for the final groundwater corrective measures implementation were included within the routine semiannual reports submitted for the former refinery. A summary of construction activities for major infrastructure including groundwater production wells and riverbank stabilization measures are provided in subsequent sections.

1.4.3.1 PRODUCTION WELL PROD_24

Between October 8 and October 10, 2007, production well PROD_24 was installed by Jackson & Sons Drilling & Pump, Inc. using a bucket auger drilling methodology. Production well PROD_24 was installed in the central portions of Hooven approximately 250 feet east of monitoring well MW-96S. Coarse sand, gravels, cobbles, and boulders were encountered during installation of this well. Large boulders (as much as 3-feet thick) were encountered at 45 and 54 feet below ground surface (ft-bgs). A 38-inch boring was installed to a total depth of 90 ft-bgs and a 36-inch surface casing was set from 25 ft-bgs to the ground surface to facility advancement of the bucket auger during drilling.

Following completion of the boring to the total depth, an 18-inch continuous wrapped stainless steel screen (0.10-inch slot size) was set from the total boring depth to approximately 50 ft-bgs. Blank 18-inch steel casing was set from the top of the screen to approximately one foot above the ground surface. A No. 3 gravel pack was placed from the bottom of the screen interval to approximately 25 ft-bgs. A concrete-bentonite grout seal was placed above the gravel pack to the ground surface. In 2009, an inflatable packer was installed at approximately 75 ft-bgs to reduce LNAPL entrainment during operation of this well. A self-seeking LNAPL recovery system (Magnum Spill Buster™) was then installed above the packer.

1.4.3.2 PRODUCTION WELL PROD_25

HD Water Services installed production well PROD_25 between June 1 and July 1, 2010 using a cable tool drilling methodology. Production well PROD_25 was installed approximately 275 feet north of production well PROD_12. Clay, silt, coarse sand, gravels, and cobbles were encountered during installation of this well. The finer materials (clays and silts) were non-native fill within the upper 8 ft-bgs. A 36-inch boring was installed to a total depth of 80 ft-bgs with a 36-inch outer steel casing advanced to the total depth to keep the boring open during emplacement of the screen, gravel pack, and seal.

Following completion of the boring to the total depth, a 24-inch continuous wrapped stainless steel screen (0.10-inch slot size) was set from 70 ft-bgs to approximately 20 ft-bgs with a steel cased sump from 70 to 80 ft-bgs. Blank 24-inch steel casing was set from the top of the screen to approximately two feet above the ground surface. A No. 3 gravel pack was placed from the bottom of the screen interval to approximately 10 ft-bgs. A concrete-bentonite grout seal was placed above the gravel pack to the ground surface. A 36-inch surface casing with gravel tubes was left in place from 18 ft-bgs to the ground surface to allow for addition of sand pack as settling occurs.

The newly installed production well was developed between July 2 and July 16, 2010. Groundwater purged from the well during development was transmitted to the biologically enhanced GAC for treatment. A vertical high capacity turbine pump was installed within production well PROD_25 following development. The pump intake was set within the sump at approximately 77 ft-bgs. An inflatable packer was installed at 45 ft-bgs to reduce LNAPL entrainment and a self-seeking LNAPL recovery system (Magnum Spill Buster™) was installed above the packer.

1.4.3.3 RIVER BANK STABILIZATION MEASURES AT THE FORMER REFINERY

The bank stabilization and barrier construction activities were completed between September and December 2008 in general accordance *Remedial Measures Work Plan for Sheet Pile Barrier and Bank Stabilization along the Great*

Miami River, Chevron Cincinnati Facility (Trihydro 2008a). As-built drawings showing the riverbank stabilization measures and alignment of the sheet pile barrier wall is provided on Figure 1-4.

An approximate 1,800 linear-foot partially penetrating, steel sheet pile barrier wall was installed with piles driven from north to south. The sheet piles consisted of 2.5-foot wide by 30-foot tall Roll Form Group EZ88 steel piles. The piles were driven into the ground surface using a track-mounted RAM sheet pile driver to a top-of-pile target elevation of approximately 472 feet above mean sea level (ft-amsl) at the northern limits of the barrier sloping down to approximately 471 ft-amsl at the southern tie in of the wall. The sheet piles were delivered in seal-welded pairs with a water-swelling sealant applied to the non-welded joint interlocks.

A professionally licensed surveyor established control points throughout the project area and completed an as-built survey of the constructed sheet pile barrier wall. Each of the sheet piles were emplaced within +/- 4 inches of the target depth, with the vast majority driven within +/- 2 inches of the design elevation. Piling was driven without refusal except for one area near the southernmost tie-in. Piling in this area was relocated approximately six inches to the east and the remaining sections of the wall realigned accordingly to avoid large diameter glacial deposits (i.e., boulders) within the Buried Valley Aquifer.

As part of the river bank stabilization measures, contingency horizontal air sparge lines were installed along the inland portions of the barrier between the existing smear zone limits and the sheet pile wall. Figure 1-4 shows the location of the eight air sparge lines (five at the downstream segment and three at the upstream segment) installed along the reconstructed west bank. The sparge lines were emplaced along the two portions of the west bank where the smear zone was in close contact with the former river bank. Sparging will be performed using selected or all of the contingency lines if LNAPL or dissolved phase constituents from the smear zone are determined to be discharging beneath the wall and into the Great Miami River. These conditions have not been observed since installation of the barrier wall and stabilized river bank, and therefore the contingency air sparge system has remained idle.

Grading activities began following installation of the partially penetrating sheet pile wall and the air sparge piping to create a low-sloping bench along the west bank of the Great Miami River. The existing bank was re-contoured using primarily river gravel with some native soils (river silts) to the proposed grade. Flood-tolerant vegetation was planted to protect the newly formed bank from erosion. A riprap revetment system was constructed along the outboard portion of the sheet pile barrier to protect the partially penetrating wall from scouring during future flood events. Prior to positioning riprap, river gravel was placed outboard of the barrier at the angle of repose (i.e., the maximum angle of a stable slope).

Hydraulic modeling was completed to evaluate potential stresses on the barrier wall and stabilized riverbank during flood conditions within the Great Miami River. The model results indicated that during intervals of high flow, the flood control levee adjacent to former SWMU-10 may constrict the channel resulting in increased shear stress along the proposed barrier wall. Therefore, the height of the flood control levee was reduced north of the sheet pile wall to decrease shear stress and potential scour during flood events.

In addition, sediments were excavated from portions of the East Island Channel (channel located east of Islands No. 1 and No. 2 as described in the 2006 AOC) in order to reduce upstream flood elevations (i.e., achieve no rise to the modeled 100-year flood elevation) and further reduce potential shear stress along the partially penetrating sheet pile wall. Historically, flow through this channel had only occurred under high water conditions, hindered by sedimentation at the northern and southern limits of the channel.

In accordance with the Performance Monitoring Plan, Sheet Pile Barrier Along Great Miami River, Chevron Cincinnati Facility, Hooven, Ohio (Performance Monitoring Plan for Sheet Pile Barrier Along Great Miami River, Trihydro 2008b), a monitoring network was constructed between November 10 and December 29, 2008. The monitoring network is comprised of three monitoring transects along the northern, central, and southern portions of the barrier wall as illustrated on Figure 1-4. Each transect includes a groundwater monitoring nest (shallow, intermediate, and deep wells) situated inboard of the sheet pile wall and a groundwater monitoring nest located on the outboard side of the wall. In addition, a hyporheic/surface water monitoring well was also constructed outboard of the wall at each monitoring transect.

1.4.3.4 RIVER BANK STABILIZATION MEASURES AT GULF PARK

In order to isolate petroleum hydrocarbons present in the smear zone along the east bank of the Great Miami River in Gulf Park, a partially penetrating sheet pile barrier and river bank stabilization measures were installed along the northern portion of the smear zone during the second half of 2009 and along the southern portion of the smear zone on the neighboring property to the south during the second half of 2011. The sheet pile barrier placements were selected based on smear zone morphology with the objective of eliminating potential petroleum hydrocarbon flux towards the river. The river bank stabilization measures at Gulf Park were constructed in accordance with the *Remedial Measures Work Plan for Sheet Pile Barrier Construction and Bank Stabilization along the East Bank of the Great Miami River, Gulf Park, Cleves, Ohio* (Trihydro 2008c).

As shown on Figure 1-5, an approximate 300-linear foot wall was constructed along the northern portion of the smear zone while an approximate 250-linear foot wall was installed to the south. The barrier wall was constructed with 30-

foot-tall JZ-120 steel sheet piles. The piles were driven into the ground surface using a track-mounted sheet pile driver to a top-of-pile target elevation of approximately 465 ft-amsl. Similar to riverbank stabilization measures completed on the former refinery property, the existing riverbank in Gulf Park was re-contoured as a low-sloping bench and a riprap revetment system was constructed along the outboard portion of the sheet pile barrier to protect the partially penetrating wall from scouring during flood events.

Two monitoring wells were constructed near the center of the northern segment of the barrier wall in Gulf Park, with one well on the inboard and one on the outboard side of the wall (Figure 1-5). Monitoring wells to measure the effectiveness of the riverbank stabilization measures along the property to the south of the Park will be constructed between the fourth quarter 2011 and first quarter 2012.

1.4.4 INSTITUTIONAL CONTROLS

Institutional controls stipulating restrictions regarding the use of groundwater, as well as the types of use, subsurface disturbance, and construction methodologies were proposed as part of the draft environmental covenants for the Chevron Cincinnati Facility, as submitted to the USEPA in revised draft form on October 28, 2010 (Trihydro 2010b). Specifically, limitations set forth in theses covenants specify that no residential structures, daycare facilities, schools, nursing homes or other such structures will be constructed on any parcels within the former refinery or LTU. In addition, no commercial or industrial buildings shall be constructed with sub-grade features. Any buildings constructed on these parcels will require engineered controls, which will include an impermeable membrane in the building foundation at a minimum or a sub-slab depressurization or venting system, if necessary. At locations beyond the former refinery limits on property owned by Chevron, basements and other sub-grade structures will not be constructed where the depth to the top of the smear zone is less than approximately 30 ft-bgs, without a location and structure-specific analysis of necessary protective measures.

In accordance with the 2006 AOC, Chevron will exercise best efforts to install vapor barriers in buildings in the Southwest Quad, as a protective measure to limit the flux of vapors into commercial structures; despite the fact that the vapor intrusion pathway was demonstrated to be incomplete beneath these properties. The majority of redevelopment in the Southwest Quad occurred within the past 15 years, and Chevron has offered assistance and funding for incorporation of a vapor barrier in all structures built to date. Nearly all businesses have accepted and installed the vapor barriers. Chevron purchased additional property so that it owns most of the land remaining in the Southwest Quad that is located over the smear zone and has not already been developed. With these actions, Chevron is in a position to control future development to ensure that engineering controls are built into future design and construction plans.

As noted in Paragraph 16 of the 2006 AOC, Sections 5301.80 to 5301.92 of the Ohio Revised Code provides the legal mechanism for placing an enforceable, lasting use restriction on a property deed. Upon USEPA approval of the draft environmental covenants, Chevron will proceed to finalize the environmental covenants and deed restrictions for the parcels within the former refinery and the LTU.

1.4.5 MONITORING OVER THE FIRST FIVE YEARS OF GROUNDWATER CORRECTIVE MEASURES

One of the most important aspects of the final groundwater corrective measures program is routine monitoring to evaluate the progress towards meeting the interim and long term remedy objectives. The monitoring network has been established to meet multiple performance and compliance monitoring criteria including collection of data to support remedial system operation; confirmation of high-grade pumping and HSVE system effectiveness; determination of compliance at boundaries where sensitive receptors are present; and evaluation of natural attenuation mechanisms. Monitoring has been divided into the following activities:

- Fluid level gauging including continuous monitoring using pressure transducers as well as weekly, monthly and bimonthly manual measurements
- Groundwater sampling to demonstrate dissolved phase plume stability, protection of sensitive receptors, and efficacy of NSZD mechanisms within the saturated zone
- ROST monitoring to confirm stability of the LNAPL plume at the down-gradient limits of the smear zone
- LNAPL and soil core analysis to track petroleum hydrocarbon constituent depletion within the smear zone
- River monitoring to track potential releases of smear zone soils into surface water, along the west bank of the Great Miami River
- Vapor monitoring to track the vapor intrusion pathway beneath Hooven, evaluate natural attenuation mechanism in the vadose zone, and demonstrate depletion of vapor source concentrations

Table 1-1 presents a summary of routine monitoring performed between 2008 and June 2011, which is considered the reporting period for this first five year groundwater corrective measures implementation review. This includes monitoring performed since approval of the *RIP* and *OMM Plan* by the USEPA on November 15, 2007 and for which data has been received from the analytical laboratory and validated. Routine monitoring results including field forms, analytical reports, data validation reviews, as well as summary tables and figures have been provided with semiannual reports submitted to the USEPA and are not included herein.

1.5 REPORT OUTLINE

The overall purpose of this report is to provide a summary of the operations and monitoring conducted in accordance with the 2006 AOC, *RIP*, and *OMM Plan* over the first five years of implementing final corrective measures for groundwater. Specifically, this report will evaluate the (1) protectiveness of the final corrective measures for residents and commercial workers in Hooven and the Southwest Quad, and sensitive receptors within the Great Miami River, (2) progress towards achieving active remedial end-points including high-grade recovery, Hooven HSVE system, and Gulf Park biovent system operations, and (3) trends in dissolved phase, vapor phase, and smear zone constituents to determine if the remedy is progressing as expected. The remainder of this report is organized into the following sections:

- Section 2.0 – Describes the SCM for the former refinery and off-site parcels including the nature, extent, fate, and transport of petroleum hydrocarbons in the subsurface.
- Section 3.0 – Provides a summary of engineered removal measures (or near term measures) performed over the past five years of the remedy including progress towards remedial end-points and modifications to any of these active systems.
- Section 4.0 – Presents qualitative and quantitative lines of evidence supporting the efficacy of natural attenuation mechanisms to degrade petroleum hydrocarbons within the smear zone over the course of the remedy.
- Section 5.0 – Includes a summary of operations and routine monitoring conducted over the first five years of implementation of groundwater corrective measures at the Chevron Cincinnati Facility.

2.0 GROUNDWATER CONCEPTUAL MODEL

A conceptual model is a summary of the site-specific conditions affecting the distribution, mobility, and fate of chemicals in the environment that is used to assess and communicate the potential for human health and environmental risks. The SCM typically includes information about the source, pathways, chemical transport processes, and receptors. It can also include identification of background conditions and/or alternate sources of contaminants. This section describes the SCM for groundwater beneath the former refinery, as well as to the west and southwest. A detailed SCM for groundwater was presented in the *First 2008 Semiannual Monitoring Report, Chevron Cincinnati Facility, Hooven, Ohio* (*First 2008 Semiannual Monitoring Report*, Trihydro 2009a). A summary of the SCM is provided herein including updates made using assessment and routine monitoring results collected since 2008 (Trihydro 2011a, 2011b, 2010a, 2009b, 2009d). Figure 2-1 shows a diagrammatic SCM for the facility, Hooven, and Southwest Quad.

2.1 SETTING

The former refinery is situated in a glacial valley incised into Ordovician-age shale and partially filled with glacial outwash and fluvial deposits of the Great Miami River (Spieker and Durrell 1961, Spieker 1968, Watkins and Spieker 1971). The fluvio-glacial aquifer ranges from approximately 20 to 100 feet thick, is composed of dominantly coarse sediment, and is referred to as the Great Miami Buried Valley Aquifer. An upward fining sequence is present in areas along the riverbank and flood plain on the former refinery. In addition, a clayey-silt layer is exposed at the ground surface in the western portion of Hooven with a thickness of at least 10 feet along the western edge of town. This layer serves as an apparent aquiclude with runoff flowing eastward over the shallow aquiclude before descending towards the groundwater table and joining regional flow within the Buried Valley Aquifer.

The Buried Valley Aquifer pinches out beneath the western portions of Hooven (west of monitoring wells MW-113 and MW-129). Saturated sediments were not observed during installation of monitoring well MW-130 despite there being a high water table present when this well was installed in the spring of 2005. This soil boring was installed approximately two feet within the weathered portions of the Ordovician-age shale bedrock at a total depth of 65 ft-bgs. Monitoring well MW-130 is located approximately 325 feet west of well MW-129.

Groundwater within the Buried Valley Aquifer generally flows from north to south, although episodic flooding tends to result in redirection of the flow to the east for periods ranging from days to weeks dependent on the magnitude of the flood event. This redirection of flow can affect dissolved phase concentrations measured in the point of compliance and sentinel monitoring wells in the Southwest Quad. Dissolved phase constituents associated with alternate sources in

the Southwest Quad that are typically down- and cross-gradient, have been measured in groundwater samples collected from these wells following seasonal flooding events, when flow conditions are redirected.

A partially penetrating sheet pile wall was installed at the facility as part of the riverbank stabilization measures between September and December 2008. The partial penetrating wall does not affect horizontal flow conditions (i.e. flow direction primarily parallel to the river bank) within the Buried Valley Aquifer under ambient conditions. However, as designed, communication between groundwater and surface water has been dampened locally near the barrier wall during periods of increasing or decreasing discharge within the Great Miami River.

2.2 SOURCE

Refinery operations terminated in 1986, and the distribution of LNAPL stabilized as gravity and capillary forces approached equilibrium. Vertical smearing of the LNAPL occurred over time as a result of seasonal fluctuation of the water table, leaving some LNAPL within the pore spaces below and above the water table. The top and bottom of the "smear zone" are roughly coincident with the historical high and low groundwater elevation. Therefore, some smear zone is exposed above the water table, even during periods of seasonal high groundwater, although the maximum exposure of LNAPL occurs during low water table events. The thickness of the smear zone generally increases from inches at the plume periphery, to as much as 20 feet in locations of the production wells. The depth to the top of the smear zone varies across the site, from as little as 10 feet near the Great Miami River, to approximately 30 feet across most of the former process areas and tank farms, 40 feet beneath the Southwest Quad, and up to 60 feet under the town of Hooven.

An integral component of the near term remedy is that, LNAPL recoverability is a function of water table elevations (triggers) and those conditions and responses have changed through time. Field observations have shown that LNAPL is generally observed in monitoring wells when the water table is relatively low, exposing the bottom third of the smear zone. This nearly depleted smear zone condition is the result of more than two decades of engineered recovery that has removed approximately four million gallons of LNAPL from the smear zone. Approximately 70% of this volume was recovered during the first three years of operations. Measurable LNAPL is observed within groundwater monitoring wells during low water table conditions that exist less than 10% of the time, which is a considerable constraint for LNAPL recovery.

Soil core and ROST monitoring results collected across the smear zone show that petroleum hydrocarbon concentrations and saturations are highest in the bottom third of the smear zone. This is more pronounced along the smear zone limits as seen in soil cores collected in Hooven and routine ROST results from the Southwest Quad where

petroleum hydrocarbons are sorbed to soil or present in the dissolved phase within the upper and middle portions of the smear zone (i.e., residual LNAPL is no longer present), and LNAPL saturations are generally below 5% within the lower reaches of the smear zone. As previously described, the near term remedy (i.e., high-grade pumping coupled with HSVE operation) is designed to focus on LNAPL removal within the lowest reaches of the smear zone and core portions of the plume with the highest remaining LNAPL saturations.

Petroleum hydrocarbon liquids are a mixture of individual constituents from many families, including aliphatics, aromatics, paraffins, isoparaffins, olefins, and naphthalenes. Each constituent has somewhat different physical, chemical, and toxicological properties. Some of these constituents are sufficiently toxic to pose a potential human health risk via dermal contact, ingestion, and inhalation if present at sufficient concentration. In the area adjacent to the distribution of LNAPL, some hydrocarbons dissolve in groundwater and migrate as solutes in the aqueous phase. Volatilization from LNAPL or dissolved phase hydrocarbons can produce vapors in the unsaturated zone immediately above the water table.

2.3 PLUME STABILITY

As described in the previous section, the majority of recoverable LNAPL has been removed from beneath the former refinery and off-site properties with the highest remaining LNAPL saturations remaining in the lower reaches of the smear zone. The LNAPL and dissolved phase plume boundaries are generally coincident at the up-gradient and lateral edges of the smear zone (i.e., western limit in Hooven and eastern limit along the Great Miami River), where dissolved phase petroleum hydrocarbons are generally indicative of LNAPL within the smear zone. Whereas, in the primary flow direction towards the south, a dissolved phase "halo" extends approximately 100 to 200 feet down-gradient from the LNAPL plume boundary.

Dissolved phase plume stability is expected to continue over the long-term, however, it was anticipated that some re-distribution of dissolved phase hydrocarbons would occur at the down-gradient edge of the plume after discontinuance of hydraulic pumping that was performed as part of the interim measures for more than two decades. Dissolved phase plume stability was expected to become re-established during the first few years after pumping was discontinued.

Detections of dissolved phase benzene in samples collected from the sentinel well MW-35 and point of compliance well MW-133 were observed in 2008 and 2009. Dissolved phase benzene was not measured in any of the monthly groundwater samples collected from these two wells from September 2009 through the end of 2010. The detections of benzene in groundwater are not believed to be associated with re-distribution of the dissolved phase hydrocarbons associated with the former refinery at the southern limits of the plume. The benzene detected in these two wells was

likely derived from an alternate source in the Southwest Quad, as the measured dissolved phase concentrations did not follow trends that would be expected if constituents were migrating down-gradient from the smear zone limits to the point of compliance well. Subsequent detections of dissolved phase constituents within the sentinel and point of compliance network have been attributed to alternate sources in the Southwest Quad as a result of redirection of hydraulic gradients following seasonal flooding of the Great Miami River.

The primary driver for plume stability is believed to be active biodegradation along the boundaries of the smear zone (i.e., up- and down-gradient limits of the smear zone, lower reaches of the smear zone within the saturated zone, and upper contact of the smear zone within the unsaturated zone). Most petroleum hydrocarbons are readily degradable by soil microorganisms in the presence of O_2, a process referred to as aerobic biodegradation. Petroleum hydrocarbons are also degraded by soil microorganisms in the absence of O_2 via anaerobic respiration, but generally at a slower rate compared with aerobic degradation.

The pathway for migration of petroleum hydrocarbons in soil vapor into structures located in Hooven and the Southwest Quad is considered incomplete. Soils within the vadose zone to the west of the refinery are predominantly sand and gravel, which allow water to drain relatively freely; therefore, the pore-spaces are mostly air-filled, which provides a pathway for vapor migration. The migration of hydrocarbon vapors from the vapor source at depth is retarded by biological degradation where soil microbes metabolize hydrocarbon vapors as a source of energy. Beneath Hooven, where the vadose zone is nearly 60 feet thick, the hydrocarbon vapors are generally reduced through aerobic biodegradation, where O_2 in the atmosphere diffuses down into the unsaturated zone and is reduced along with the petroleum hydrocarbon vapors. Alternate sources are present in the vadose zone from surface releases of petroleum and non-petroleum related constituents in the Southwest Quad and Hooven. These releases affect the vertical profile of constituents of concern and fixed gases through utilization of O_2 and mixing of vapors within the shallow and intermediate portions of the vadose zone.

Microbiological degradation can also occur in the absence of O_2 within the vadose zone, where secondary oxidizers such as iron, manganese, sulfate, nitrates, and CO_2 are reduced, with the reduction of CO_2 resulting in the production of methane (CH_4). The CH_4 will subsequently diffuse upward and is generally degraded at shallower intervals where O_2 concentrations are sufficient. Anaerobic degradation is typically observed in the deeper intervals above the LNAPL and dissolved phase plume; however, anaerobic conditions can persist in the intermediate portions of the vadose zone during seasonally low water table conditions if alternate sources of petroleum hydrocarbons are present in the shallow subsurface and are utilizing available O_2.

Biodegradation is a primary driver not only for stability of vapor and dissolved phase petroleum hydrocarbons, but also for hydrocarbon mass reduction throughout the smear zone. Aerobic and anaerobic processes reduce petroleum hydrocarbon mass and concentrations in the dissolved and vapor phase. Whenever O_2 is available, aerobic biodegradation processes predominate. Aerobic degradation processes are the dominant mechanism for reductions in petroleum hydrocarbon concentrations in the plume periphery. Within the interior portions of the plume where atmospheric and dissolved O_2 is depleted, anaerobic biodegradation processes will tend to dominate. These anaerobic processes are expected to continue in portions of the smear zone where secondary oxidizers are available, given the relatively consistent supply of petroleum hydrocarbons (i.e., source of carbon) from the smear zone.

2.4 RECEPTOR

Receptors that have the potential to be affected by LNAPL and dissolved phase petroleum hydrocarbons include residents within Hooven, commercial workers in businesses situated in the Southwest Quad, sensitive ecological communities along the Great Miami River, visitors and workers employed in remedy support and redevelopment activities on the former refinery, and trespassers coming onto the facility property. As the groundwater beneath the facility, Hooven, or Southwest Quad is not used for drinking purposes or secondary uses (e.g., irrigation, bathing, etc.) ingestion and dermal contact with dissolved phase petroleum hydrocarbons associated with the former refinery will not occur. Administrative and engineering controls, as well as personal protective equipment, will be used as appropriate to prevent site workers and visitors from potential unacceptable levels of exposure to LNAPL or dissolved phase petroleum hydrocarbons during subsurface disturbance associated with future redevelopment on the former refinery. Bank stabilization measures along the Great Miami River prevent soil containing petroleum hydrocarbons from eroding into the river or the discharge of dissolved phase petroleum hydrocarbons to surface water.

With respect to vapor intrusion, the receptor would be any occupant of a building on the former refinery, in Hooven, or to the southwest if vapors coming from the smear zone or dissolve phase plume entered that building at concentrations that pose a potential health risk. If soil vapors diffuse within the "zone of influence" of a structure without degrading, they will become available to be transported into the structure via advection and convection through drains, cracks, utility entrances, sumps, or other permeable discontinuities in the building floor or basement walls. Wind load on the side of a building, barometric pressure changes, HVAC system operation, or temperature differences can all contribute to building depressurization that can drive advection. Most of these processes are reversible, so gases generally flow into and out of buildings under varying conditions. Atmospheric air also enters buildings through doors, windows, and small openings, and the rate of air exchange in buildings typically reduces soil vapor concentrations by a factor of 100 to 10,000 (Johnson 1999), depending on building design, construction, use, maintenance, soil conditions, weather conditions and other factors.

The vapor intrusion pathway in Hooven was demonstrated to be incomplete during the subsurface investigation completed in 2005, through characterization of the petroleum hydrocarbon source, soil vapor, and migration pathway (Trihydro and GeoSyntec 2005). In addition, the soil vapor data collected from the nested monitoring wells from 1997 to 1999 and following the 2005 investigation have also indicated vapors from the plume are not migrating from the smear zone to indoor air within the residences, businesses, or former elementary school at concentrations sufficient to pose an unacceptable excess health risk (Trihydro and GeoSyntec 2008). It should be noted that the Hooven Elementary School was closed prior to the start of the 2011-2012 academic year and converted into a community resource center. In portions of the Southwest Quad overlying the smear zone, commercial structures were constructed with a passive vapor barrier beneath the slab as a protective measure for inhibiting migration of vapors into the building, if present. Two independent investigations performed between 2008 and 2009 by the USEPA and Chevron confirmed that the vapor intrusion pathway is incomplete beneath Hooven and the Southwest Quad even under worst-case conditions (i.e., high-grade recovery exposing the lower portions of the smear zone without operation of the HSVE system), and there is not a health risk to any occupants within homes, businesses, or the former school associated with the smear zone or dissolved phase constituents beneath the community (Trihydro and GeoSyntec 2010).

2.5 ALTERNATE SOURCES

There are multiple potential alternate sources of LNAPL, vapor phase, and dissolved phase petroleum hydrocarbons within proximity of the former refinery. These include a former service station (currently a non-commercial automotive service center) located directly north of the facility, former operations at the Dravo Corporation sand and gravel quarry including diesel and gasoline underground storage tanks removed in 1991, the Kroger gasoline and diesel service station, underground storage tanks removed at the Hooven Elementary School and Hooven Fire Station, dry wells installed in the Southwest Quad, the Whitewater Reclamation (formerly Golsch) construction and demolition landfill, an asphalt production plant, a gravel quarry, railroad operations, surface releases associated with vehicles travelling on Ohio State Route 128 and United States Highway 50, surface releases from vehicles located in parking lots across the Southwest Quad, commercial businesses (e.g., automotive repair, long-haul trucking, and construction lay down yards) located within Hooven and the Southwest Quad, as well as local point sources associated with residential, municipal and commercial activities in the Southwest Quad and Hooven. In addition, each of the residences and other occupied structures in Hooven maintained an individual septic system to treat wastewater prior to extension of a municipal sanitary sewer system into the community in 2006. Several studies including DeWalle et al. (1985) and Conn and Seigrist (2009) have documented releases of volatile petroleum related constituents from septic systems.

Volatile petroleum hydrocarbons are ubiquitous in indoor and outdoor air from many sources, including industrial and commercial operations, automobiles, combustion sources (e.g., gasoline, fuel oil, natural gas, etc.), combustion byproducts (e.g., diesel, wood, coal, candles, etc.), water treatment chemicals and byproducts, a variety of different consumer products, small power tools, tobacco smoke, glues, household cleaners, carpeting, and furniture. Indoor air often contains measurable concentrations of volatile and semivolatile constituents from household activities, consumer products, building materials, furnishings, and outdoor air sources. Volatile petroleum and non-petroleum related constituents associated with ambient sources unrelated to the former refinery have been measured in outdoor air samples collected during routine monitoring in Hooven and on the former refinery since 2004. Residential and commercial areas can also have shallow releases of hydrocarbons to the subsurface from sources similar to those described above. Therefore, hydrocarbon vapors are present in the vadose zone and indoor air in Hooven and the Southwest Quad associated with alternate sources.

3.0 NEAR TERM REMEDY COMPONENTS

The active components of the groundwater remedy primarily consist of high-grade pumping, soil vapor extraction, and biovent system operation. Start up and shut down of the engineered remedial systems is based upon groundwater elevation triggers when the lower reaches of the smear zone are exposed during times of limited regional precipitation (i.e. drought-like conditions). These systems are designed to reduce LNAPL mass and saturations within the smear zone. This section provides a summary of engineered remedial systems operations conducted over the last five years including an assessment of system effectiveness and progress towards reaching operational end-points.

3.1 HIGH-GRADE RECOVERY SUMMARY

High-grade pumping was performed in 2007, 2009, and 2010. High-grade recovery that started in August 2010 extended through February 2011 due to higher trigger levels within the Central High-Grade Area and relatively low precipitation rates throughout the fall and winter months. In 2008, significant regional precipitation occurred during the summer and fall causing groundwater elevations to remain above trigger levels throughout the year.

Approximately 250,000 gallons of LNAPL were recovered during the seasonal recovery events in 2007, 2009, and 2010 through early-2011. It should be noted that the majority of LNAPL (2.7 million gallons) was removed during the first three years (1985 through 1987) of groundwater and LNAPL recovery operations, while approximately 900,000 gallons were removed over the next two decades of continuous pumping (from 1988 through 2006). The volume recovered over the past three high-grade events was more than 25% of the volume recovered over the previous 19 years of continuous operation of the groundwater production wells and treatment systems.

While multiple production wells were operated during each high-grade event, the preponderance of LNAPL was recovered from a single well during each event as follows:

Year	Primary Production Well	High-Grade Area	Days of Operation	LNAPL Recovered (gallons)
2007	PROD_19	Southwest	156	67,808
2009	PROD_20	Southwest	103	24,015
2010	PROD_25	Central	202	143,677

As described in Section 1.4.1, it is anticipated that two to four sustained high-grade events under low water table conditions will be necessary within each high-grade area before recovery end-points are realized. A single sustained high-grade event was achieved in the Southwest High-Grade Area in 2007 and one sustained event was completed within the Central Area in 2010.

3.1.1 LNAPL RECOVERY EFFECTIVENESS BY EVENT

Table 3-1 provides a summary of cumulative and daily LNAPL recovery rates, average groundwater extraction rates, as well as the LNAPL removal efficiency for the primary production wells used during the 2007, 2009, and 2010 high-grade recovery events. As shown in Table 3-1, the 2007 high-grade recovery activities in the Southwest Area exhibited a relatively high LNAPL removal efficiency at production well PROD_19, recovering approximately 163 gallons of LNAPL for every million gallons of groundwater pumped. The removal efficiency was 57 gallons of LNAPL per million gallons of water during the 2009 high-grade event using primarily production well PROD_20.

LNAPL recovery from newly installed production well PROD_25 in the Central High-Grade Area during the 2010 through early-2011 high-grade event resulted in the greatest efficiency; approximately 279 gallons of LNAPL was recovered for every million gallons of groundwater removed from the aquifer. The recovery efficiency from this well was more than 1.7 times greater than that obtained in 2007 and almost 5.0 times that obtained during the 2009 high-grade event. This is attributable to higher LNAPL saturations within the central portions of the smear zone combined with the ambient low water table conditions existing over an extended timeframe (approximately seven months). It is expected that the LNAPL removal efficiency will be reduced in each area following subsequent high-grade recovery events as LNAPL saturations are reduced within the lower reaches of the smear zone.

3.1.2 LNAPL RECOVERY RADIUS OF INFLUENCE

As a means to better understand the effectiveness of LNAPL recovery during a high-grade pumping event, an evaluation of the radius of influence (ROI) of LNAPL recovery was performed. The first part of this evaluation entailed assessing the ROI of LNAPL recovery from newly installed production well PROD_25 during high-grade pumping performed intermittently between August 2010 and February 2011. The ROI was estimated for steady state periods of recovery, as well as over the entire event using volumetric approximations. The second part of this evaluation involved estimation of LNAPL flux through the formation as derived from single well LNAPL tracer dilution tests. A LNAPL-soluble fluorescent tracer was used to measure the rate of LNAPL movement towards a production well, in this case production well PROD_25 during the end of the high-grade operations in February 2011. Specific methodologies, equations, and inputs relating to the volumetric and LNAPL tracer dilution testing are provided in Appendix A.

Results of the volumetric analysis indicate an overall ROI of approximately 300 to 470 feet for high-grade recovery conducted in production well PROD_25 between 2010 and 2011, with an average seepage velocity through the formation estimated between 14.7 and 36.2 feet/day. Results of the LNAPL tracer dilution testing indicate a range of seepage velocities between approximately 1 and 4 feet/day at monitoring well LTTMW-25 at the time tracer testing was conducted. This disparity in the seepage velocity estimates is likely attributable to the transient nature of LNAPL

recovery. The volumetric analysis considers the average LNAPL movement over the entire high-grade event; whereas, the LNAPL tracer dilution testing evaluates instantaneous LNAPL mobility over focused periods of time, which in this case was during the final weeks of the 2010 high-grade event as LNAPL recovery rates diminished in response to ambient rebound of the water table.

3.1.3 REVISED TRIGGER PUMPING ELEVATIONS

LNAPL recovery is undertaken during low water table conditions, based on historical trends and field observations during seasonal dry periods. LNAPL accumulates within wells and is recoverable as a function of water table elevations (triggers) as they relate to the smear zone. Maximal exposure of the smear zone occurs when the water table is drawn down below the previous minimum groundwater elevation. Thus, the minimum historical groundwater elevation within a well is used to establish targets for initiating high-grade recovery. With each successful high-grade event, the depth of maximum smear zone exposure will be lowered, thereby establishing new, lower triggers for starting high-grade recovery over subsequent events. The trigger for initiating high-grade recovery is determined via the following equation:

$$High\text{-}Grade\ Trigger = PT_i + s_{i,j}$$

Where:

PT_i = Pumping target at monitoring well location i; value is the historical minimum water table elevation in ft-amsl

$s_{i,j}$ = Expected drawdown at monitoring well location i caused by high-grade pumping at production well j

As noted by the subscripts in the above equation, pumping triggers are specific to the monitoring location and the production well. Trigger levels developed after the 2007, 2009, and 2010 high-grade events are presented on Table 3-2. After each high-grade event, new pumping triggers were calculated by analyzing the fluid level data from the preceding event. New triggers were established at locations where the water table was lowered to a new minimum elevation. If a new minimum was not achieved, triggers from the preceding year were carried forward. The next high-grade event will be conducted using the most recent trigger levels established for the Southwest and Central High-Grade Areas.

3.1.4 PROGRESS TOWARDS RECOVERY END-POINTS

Within the *Final Decision and Response to Comments, Selection of Remedial Alternative for Groundwater* the USEPA established that high grade pumping shall continue until the approach is no longer capable of efficiently recovering further LNAPL. The final remedy anticipated that a total of two to four high-grade recovery events (in each high-grade

area) would accomplish the goal of reducing the recoverable LNAPL in the lower reaches of the smear zone to a point where further engineered recovery is no longer productive, and should be discontinued. It was recognized that high-grade recovery may not be feasible every year, thus the time frame for high-grade recovery operations was projected to be as long as twelve years.

Because there was a limited set of high-grade operational data available at the time the 2006 AOC was developed, it was agreed that development of specific criteria for measuring and defining when effective end-points had been reached would be deferred until additional high-grade recovery efforts had been conducted. Evaluation of the data collected during the 2007 event, in conjunction with high-grade pilot testing conducted in 2005 and 2006, supported the additional evaluation of the behavior and characteristics of the residual LNAPL in the lower reaches of the smear zone. Using these data, Chevron provided USEPA a set of proposed criteria for discontinuing high-grade LNAPL recovery in the *Proposed Criteria for Discontinuing High-Grade LNAPL Recovery under the Final Groundwater Remedy*.

As summarized in Table 3-3, specific high-grade end-points include a set of primary and secondary criteria. The two primary end-point criteria are discussed below along with an evaluation of progress towards reaching these primary criteria within the two high-grade areas, based on data collected over the first five years of groundwater corrective measures implementation.

3.1.4.1 PERCENT OF IN-WELL LNAPL THICKNESSES GREATER THAN 0.10 FOOT

The first primary criterion involves the percent of fluid measurements greater than 0.10-foot of LNAPL as defined by the following:

1. During years in which high-grade pumping is performed, less than 20% of the monthly LNAPL thickness measurements within monitoring wells located in a high-grade area are greater than 0.10-foot throughout the year
2. During years in which high-grade pumping is not performed, less than 10% of the monthly LNAPL thickness measurements within monitoring wells located in a high-grade area are greater than 0.10-foot throughout the year

These conditions are to be applied over a multi-year period. For example, the first condition could be met during the final year of high-grade operations, and the second could be met during subsequent years. Alternatively, one or more years may transpire between high-grade events during which the second condition is met, and then the first could be met during a final year of high-grade operations. Once both of these conditions have been achieved, then this primary criterion will be considered to have been met.

To apply this criterion effectively, fluid level gauging should be performed at regular intervals that capture the temporal variability of hydraulic conditions throughout the year. Over the past five years some monitoring wells were gauged more frequently than others, particularly during high-grade pumping. As a result, fluid level data was normalized on a monthly basis. If multiple measurements were taken during a particular month, any LNAPL thickness greater than 0.10 foot was considered an exceedence for that month. The percentage of monthly measurements exceeding 0.10 foot was then calculated as: the number of monthly exceedences divided by the total number of months in which one or more fluid level gauging events were conducted. Calculating percentages in this manner minimizes the bias resulting from variability in the gauging frequency throughout the year.

A summary of the progress towards meeting this criterion within wells located in the Central and Southwest High-Grade Areas for 2007, 2008, 2009, and 2010 (through the end of high-grade operations in February 2011) is provided as Table 3-4. Results indicate that this criterion was not met during any of the past four years for the Central High-Grade Area. However, this end-point criterion was met for the three previous years for the Southwest High-Grade Area.

In order to justify discontinuing high-grade recovery at a particular area, both primary criteria and one of the three secondary criteria must be met. As the first criterion was not met for the Central Area, the second primary criterion evaluation was performed for the Southwest Area only, and is presented below.

3.1.4.2 HYDROGRAPH EVALUATION

The second primary criterion consists of a hydrograph evaluation at wells within the high-grade area in which the frequency of occurrence and thickness of LNAPL is assessed. The analysis method consists of ranking the hydrographs based on LNAPL thickness trends over time. The ranking system ranges from 0 to 3 and is structured as follows:

0 = No, or very little (less than 0.10 foot) LNAPL measurable in the well since 1988

1 = LNAPL occurs infrequently in the well (compared to the 1985 to 1988 period), and sometimes several years go by without a measurable thickness observed

2 = LNAPL occurs in the well during most years, typically only during low water table conditions or high-grade pumping

3 = LNAPL occurs in the well annually with or without high-grade pumping

Effectiveness of high-grade recovery can be evaluated through periodic re-ranking of the hydrographs for wells in the two areas. As the near term remedy progresses, LNAPL recovery should cause the hydrograph ranks to decrease. The end-point for high-grade recovery within each area is defined as:

1. Hydrograph rankings must be 0 or 1 for ten or more of the twelve monitoring wells in the Southwest High-Grade Area
2. Hydrograph rankings must be 0 or 1 in seven or more of the eight monitoring wells in the Central High-Grade Area

Hydrographs showing LNAPL thickness were created for each of the monitoring wells located in the Southwest Area (i.e., MW-20S, MW-24, MW-52, MW-81S, MW-92S, MW-93S, MW-96S, MW-98S, MW-99S, MW-112, MW-121, and MW-140) and are provided in Appendix C. Each hydrograph was ranked from 0 to 3 and the results tabulated on Table 3-5 alongside historical rankings. It should be noted that monitoring well MW-126 was abandoned in the summer of 2011 and well MW-127 was installed at the limits of the smear zone making it a poor indicator of changes to LNAPL saturations in the Southwest Area. Therefore, these two wells were not included in this evaluation. To maintain a total of twelve wells considered for this criterion for the Southwest High-Grade Area, monitoring wells MW-81S and MW-140 were amended to the hydrograph ranking list and will be used during subsequent end-point evaluations.

The hydrograph ranking evaluation for the Southwest High-Grade Area indicates that the second end-point criterion was not met for this area, with only six of twelve wells having a hydrograph ranking of 0 or 1. While the second primary criterion (change in hydrograph ranking) was not met in either high-grade area, there has been significant progress towards achieving this criterion within the Southwest Area since 2003 with a decrease in the ranking (and thus occurrence of LNAPL) within the majority of the monitoring wells, indicating an overall decrease in LNAPL saturations across this high-grade area.

3.2 HSVE SYSTEM OPERATIONS SUMMARY

The HSVE system is comprised of three six-inch diameter, Schedule 40 carbon steel pipes that extend from the western edge of the facility beneath State Route 128 continuing under Hooven, coincident with the distribution of refinery related hydrocarbons as shown on Figure 3-1. Line No. 1 extends westward beneath Hooven Avenue, Line No. 2 is located beneath Brotherhood Avenue curving to the south towards the former Hooven Elementary School, and Line No. 3 is located beneath Ohio Street. The well screens for each of the lines were installed approximately five feet above the 15 year maximum groundwater elevation at the time of installation (478 ft-amsl) for Line Nos. 1 and 2 and 475 ft-amsl for Line No. 3).

Pilot test, modeling, tracer test, and performance monitoring results indicate a ROI of the HSVE system of at least 125 and likely more than 450 feet from the extraction lines (Trihydro and GeoSyntec 2010). No structure in Hooven, situated over the distribution of petroleum hydrocarbons associated with releases from the former refinery, is more than 200 feet from one of the HSVE extraction lines.

The system commenced operation in November 1999 following installation of HSVE Line No. 1. Lines No. 2 and No. 3 were installed in 2000 and brought online during the first quarter 2001. Currently, operation of the HSVE occurs in accordance with the USEPA AOC amendment dated June 23, 2010, which states that the system will be operated upon completion of soil vapor monitoring in the 10-, 20-, 30, and 40-foot intervals in nested wells VW-96 and VW-99 once a groundwater elevation of 465 ft-amsl is reached in monitoring well MW-96. Seasonal operation of the HSVE system is terminated once groundwater elevations rebound above the trigger elevation in monitoring well MW-96.

3.2.1 HSVE SYSTEM EFFECTIVENESS

Table 3-6 presents the annual days of operation and total organic carbon removed beneath Hooven via operation of the HSVE system since November 1999. More than 594,000 pounds (approximately 74,000 gallons) of petroleum hydrocarbons have been removed from the smear zone beneath Hooven since 1999. The HSVE system was designed to remove volatile petroleum hydrocarbons at a high rate initially, with an expectation that the mass removal rate would gradually diminish as the volatile petroleum hydrocarbons within the smear zone were depleted, at which time the system would be operated intermittently and ultimately shut down. More than 40% of the mass recovered from the vadose zone occurred over the first year of operation. Since execution of the 2006 AOC, focused operation of the HSVE system according to groundwater triggers has resulted in extraction of approximately 275,000 pounds (22,000 gallons) of hydrocarbons from the smear zone beneath Hooven, with a rate of removal of 455 pounds per day of operation. During the previous six years of operation between 2000 and 2006, approximately 164,000 pounds (20,500 gallons) of hydrocarbons were recovered using the HSVE system, with a removal rate of less than 400 pounds per day.

Figure 3-2 presents the estimated hydrocarbons recovered beneath Hooven via operation of the HSVE system since November 1999, as well as the benzene and total volatile petroleum hydrocarbon (TVPH) concentrations in the influent. The concentrations of benzene and TVPH measured in the extracted vapor from HSVE Line No. 1 decreased dramatically from November 1999 through May 2000, and then increased from May 2000 through December 2000, while this line was continuously operated. Seasonal water table fluctuations strongly affect the mass removal rate of the HSVE system, with water levels typically highest in the late spring and lowest in the late fall. A similar trend was observed in 2001, although the concentrations in the fall 2001 were notably lower than the concentrations in the fall 2000. By the fall 2002, benzene and TVPH concentrations were approximately two orders of magnitude lower than

concentrations measured in November 1999 at system start up. A significant rebound in the influent concentrations in the influent samples has not been observed.

3.2.2 CATALYTIC SYSTEM OPERATION

With this overall reduction in influent concentrations, the petroleum hydrocarbon extraction rate has remained below 125 pounds per hour since 2007. As a result, on August 17, 2010, the treatment system for extracted vapors was converted from a thermal to a catalytic oxidizer. Installation and notification to OEPA was performed in accordance with Section C.1.e(2) of the *Air Pollution Permit-to-Install and Operate (PTIO) for source P010 Horizontal Soil Vapor Extraction System*. Following installation of catalysts, temperatures within the oxidizer have been significantly reduced from an average of 1,400 degrees Fahrenheit in thermal oxidation mode to 770 degrees Fahrenheit in catalytic mode. This reduction in operating temperature results in a significant reduction in natural gas usage while still maintaining effluent concentrations below permitted levels.

3.2.3 END-POINTS FOR OPERATION OF THE HSVE SYSTEM

It's anticipated that when the HSVE system is ready to be permanently shut down, the remaining hydrocarbon mass within the influence of the system would diminish to a level where continued operation does not result in reduction of soil vapor concentrations beyond those observed via aerobic biodegradation alone, as can be observed in the vapor source concentration trends for nested soil vapor monitoring well VW-93 (Figure 3-3). However, in some portions of Hooven, volatile petroleum hydrocarbon concentrations have persisted in the smear zone, despite operation of the HSVE system. This may be explained by alternate sources (i.e., not related to historical releases from the former refinery) of petroleum hydrocarbons identified in the vadose zone near these locations, as discussed in the *Hooven Vapor Site Conceptual Model Update, Chevron Cincinnati Facility, Hooven, Ohio* (*Hooven Vapor SCM Update*, Trihydro and GeoSyntec 2010) and Section 4.1.3 herein. Aerobic biodegradation of these alternate petroleum hydrocarbon sources in the shallower portions of the subsurface preferentially utilizes O_2. As such, O_2 transport to deeper depths where hydrocarbons from the former refinery are present at the water table is limited; therefore decreasing the rate of NSZD. This can be observed in the vapor source trends for wells VW-96 and VW-99 (Figures 3-4 and 3-5). In portions of Hooven where alternate sources of hydrocarbons are present at shallower depths, the HSVE system not only removes volatile petroleum hydrocarbons, but also advectively transports O_2 to the deepest portions of the vadose zone where it would otherwise not be present.

As shown on the vertical profiles of fixed gases and TVPH for wells VW-96 and VW-99 (Figures 3-6 and 3-7) collected in 2010 and early-2011, during operation of the HSVE system, O_2 concentrations remain at atmospheric levels from the ground surface to at least 40 ft-bgs. O_2 concentrations remain elevated and TVPH concentrations

remain reduced for several months following termination of seasonal HSVE system operations. An increase in TVPH concentrations and shift to anaerobic conditions is not observed in the deeper portions of the vadose zone beneath Hooven until the lower portions of the smear are re-exposed during the subsequent seasonal low groundwater event. Aerobic biodegradation, and not source removal via operation of the HSVE system, is the predominant mechanism degrading the volatile petroleum hydrocarbons present in the smear zone beneath Hooven. This may explain the difference in vapor source concentration trends observed in well VW-93 (Figure 3-3) compared to wells VW-96 and VW-99 (Figures 3-4 and 3-5), where alternate sources of petroleum hydrocarbons are present in Hooven.

3.3 GULF PARK BIOVENT SYSTEM

A former products transfer pipeline corridor, consisting of five 6-inch diameter lines that connected the former refinery with a loading terminal on the Ohio River, was located beneath the Gulf Park property. The pipelines carried three grades of gasoline, kerosene, aviation fuel, diesel, and fuel oil during use between 1930 and the mid-1980s. Petroleum hydrocarbons were identified in soil at Gulf Park in January 1993 at approximately 10 to 14 feet below grade. Several subsurface investigations to define the nature and extent of petroleum hydrocarbons in soil and groundwater were conducted between 1993 and 1994.

Based upon the findings of these investigations, a bioventing system was installed in the area that is now the westernmost soccer field at Gulf Park in 1996. It consisted of 14 air injection wells designed to deliver approximately 30 to 35 standard cubic feet per minute (scfm) to each injection well, and a blower. Valve controls for the air injection wells installed in the soccer field area were located in a nearby Valve Control Shed (VCS No. 1). Based on the demonstrated results of bioventing to reduce concentrations in soil and groundwater beneath the soccer field area, an expansion of the system was completed between August and October 2000. The expansion included installation of an additional 38 bioventing wells connected to a separate Valve Control Shed (VCS No. 2). Figure 3-8 shows the layout of the two bioventing systems installed at Gulf Park.

In order to isolate petroleum hydrocarbons present in the smear zone along the east bank of the Great Miami River in Gulf Park, a partially penetrating sheet pile barrier and river bank stabilization measures were installed along the northern portion of the smear zone during the second half of 2009 and along the southern portion of the smear zone on the neighboring property to the south during the second half of 2011. As shown on Figure 1-5, the sheet pile barrier placements were selected based on smear zone morphology, with the objective of eliminating potential petroleum hydrocarbon flux towards the river.

There are three lines of evidence considered herein to evaluate the performance of final corrective measures at Gulf Park. First, temporal and spatial trends in the dissolved phase constituents, as well as natural attenuation indicators will

be used to evaluate engineered and natural attenuation processes within the saturated zone. Second, soil quality analytical results from the shallow and deeper portions of the vadose zone will be used to define the nature and limits of the smear zone remaining beneath the Park. Third, fixed gas monitoring results from shallow vapor monitoring points will be used to evaluate the mechanisms and rate of attenuation within the vadose zone.

3.3.1 BIOVENT SYSTEM OPERATIONS SUMMARY

Bioventing stimulates intrinsic biodegradation of petroleum hydrocarbons in the vadose zone by injecting air at low flow rates to provide sufficient O_2 to sustain aerobic microbial activity. Airflow is injected at rates designed to maximize O_2 delivery to the subsurface while minimizing volatilization of hydrocarbon constituents, thus eliminating the necessity for vapor intrusion or ambient air pollution control measures.

Startup and shutdown criteria for the biovent system are related to groundwater trigger levels beneath Gulf Park. Historical soil vapor monitoring data indicate that higher respiration rates occur within the lower portions of the smear zone. However, this portion of the smear zone is only exposed during low water table conditions. The groundwater level is typically above the trigger level elevation from January through June and below the trigger level intermittently from July through December. The period of low water table conditions is considered the seasonal bioventing operation period. Figure 3-9 presents the hydrographs from the trigger monitoring wells for 2006 through 2011.

During operations, the biovent system control valves are periodically adjusted to deliver a target 35 standard cubic feet per minute (scfm) of atmospheric air to each biovent well. Table 3-7 provides a summary of days of operation, average flow rate, and cumulative air supplied across the vadose zone beneath Gulf Park since 2006. Based upon average flow rates measured at the biovent wells and recorded operation times, more than 2.2 billion standard cubic feet of air was injected into the vadose zone across the biovent system area beneath Gulf Park between 2006 and 2010.

3.3.2 GROUNDWATER MONITORING RESULTS

Groundwater samples were collected from the shallow monitoring wells (GPW-1S through GPW-5S, TH-1S, TH-2, and TH-3) and intermediate groundwater monitoring wells (GPW-1I, GPW-2I, GPW-3I and TH-1I) from 2006 through 2011 for analysis of the dissolved phase constituents of concern. Monitored natural attenuation parameters were also analyzed in groundwater samples collected from each of the shallow monitoring wells.

A comparison of total benzene, toluene, ethylbenzene, and xylenes (BTEX) versus time for groundwater samples collected from shallow monitoring wells GPW-1S through GPW-5S is shown on Figure 3-10. The last reported detection of any of these constituents in groundwater samples collected from these five wells occurred in June 2008.

The overall decrease in total BTEX concentrations observed in these wells is attributable to a combination of intrinsic biodegradation and biovent system operations.

The total dissolved phase BTEX concentration compared to the groundwater elevation over time for monitoring wells TH-1S and TH-2 is provided as Figures 3-11 and 3-12, respectively. An overall decreasing trend has been observed in dissolved phase BTEX concentrations measured in well TH-2. This decrease is attributed to both operation of the biovent system and NSZD. Whereas, concentrations of total BTEX measured in groundwater samples collected from well TH-1S appear to be more constant over time. Monitoring well TH-1S is located beyond the influence of the biovent system.

Figure 3-13 shows a summary of the concentration of total BTEX versus distance through the smear zone with a comparison to electron acceptors (nitrate and sulfate) and attenuation by-product (ferrous iron and CH_4) concentrations. Electron acceptors such as nitrate and sulfate are reduced as groundwater flows across the smear zone, and then rebound down-gradient of the smear zone limits. Conversely, biodegradation byproducts including ferrous iron and CH_4 increase within the smear zone and then rapidly decrease beyond the smear zone limits. It should be noted that iron reduction appears to be more dominant near well TH-1S while methanogenesis appears to be the dominant reduction-oxidation pathway in the saturated zone near well TH-2.

3.3.3 SOIL ANALYTICAL RESULTS

Soil samples were collected from 46 soil borings across Gulf Park between September 20 and October 6, 2010 to evaluate soil quality within the vadose zone following 15 years of biovent system operations. The locations of the soil borings installed across Gulf Park are shown on Figure 3-14. Typically, two samples were collected from each soil boring, one from the shallow portions of the vadose zone between 5 and 10 ft-bgs and the second from deeper portions of the vadose zone above the water table between 10 and 20 ft-bgs.

As expected, concentrations of VOCs including total BTEX (Figure 3-15) and SVOCs including total polycyclic aromatic hydrocarbons (PAHs, Figure 3-16) have been significantly reduced within the influence of the biovent system with the exception of one location along the northern limits of the system (boring GPSA-43). Air delivery has been obstructed within this portion of the biovent system, with only 7 to 8 scfm being delivered into the subsurface using biovent well BVW-3, compared to the design volume of 35 scfm within the remaining biovent wells.

At the western limits of the biovent system, concentrations of VOCs and SVOCs measured in soil samples increase, such as along the northern section of the barrier wall. Additionally, at two locations south of the biovent system, the first near well TH-1S and the second south of well TH-2, concentrations in soil samples were reported above 50 mg/kg

for total PAHs and above 100 mg/kg for total BTEX. These borings appear to be located beyond the influence of the biovent system and therefore concentrations of petroleum related constituents within the vadose zone have not been affected by operations of the system. This may explain elevated concentrations of dissolved phase constituents that have persisted in groundwater monitoring wells TH-1S and to a lesser degree well TH-2, over time.

3.3.4 SOIL VAPOR AND RESPIROMETRY RESULTS

Fixed gases were measured within selected nested vapor monitoring points including existing wells VP1-50S, VP1-50D, VP2-50S, VP2-50D, VP3-35S, VP3-35D VP4-25S, and VP4-25D, as well as newly installed points VP-8S, VP-8D, VP-9S, VP-9D, VP-10S, VP-10D, VP-11S, VP-11D, VP-12S, VP-12D, VP-13S, and VP-13D. The new vapor monitoring points were installed as part of a soil investigation performed in Gulf Park to assess remedial measures effectiveness during the second half of 2010. Measurement of fixed gases including O_2, CO_2, and CH_4 were performed using a Landtec GEM 2000® portable field instrument. These field measurements have been shown to have a nearly 1:1 correlation with laboratory measurements for O_2 and CO_2 as documented within the semiannual monitoring reports. Fixed gases were measured within selected existing and newly installed vapor monitoring points following temporary shut-down of the biovent system on October 11, 2010, with more frequent measurements collected during the early periods of system inactivity. Another round of fixed gas measurements was collected on November 11, 2010 after restarting the biovent system.

Tabulated and graphical results of field measurements are provided in Appendix E. Comparison of the fixed gas concentrations measured during system operation and following shutdown indicates that bioventing has a measurable impact on portions of the vadose zone situated within the smear zone. At each of the vapor monitoring points indicated above, a decreasing trend in O_2 concentration was observed during the period of system inactivity. For the majority of vapor points, this decrease in O_2 concentration was accompanied by an increase in CO_2 and a rebound (i.e., O_2 increased and CO_2 decreased) upon reactivation of the biovent system.

The rate of decline in O_2 concentration is proportional to the rate of subsurface microbial respiration, providing a quantitative indicator of the rate of hydrocarbon consumption by petrophyllic bacteria. O_2 consumption is the preferred measure of biodegradation because not all carbon from the degraded molecule is converted directly into carbon dioxide; some carbon will remain as degraded intermediates, some will be mineralized to CO_2, and some may go into solution as carbonate and bicarbonate.

O_2 utilization rates are determined from the slope of the percent O_2 versus time line. To quantify O_2 consumption, a linear best fit was performed on the O_2 concentration versus time data during the portion of time the system was

inactive. The slopes of these lines represent the percent decrease of O_2 per day. The biodegradation rate is expressed in terms of milligrams of hexane-equivalent per kilogram of soil per day and is estimated using the following equation.

$$K_{Bio} = \frac{-K_{O2} * V_{air} * D_{O2} * C}{100}$$

where:

K_{Bio} = biodegradation rate (milligram/kilogram-day)

K_{O2} = O_2 utilization rate (percent per day)

V_{air} = volume of air per mass of soil (liters per kilogram)

D_{O2} = density of O_2 gas (milligram/liter)

C = mass ratio of hydrocarbon to O_2 required for mineralization (1/3.5 for hexane)

An assumed porosity of 0.3, soil bulk density of 1,440 kilograms per cubic meter, and O_2 density of 1,330 milligrams per liter were used for subsequent calculations.

Results of the calculated biodegradation rate at each vapor monitoring point are summarized on Table 3-8. A review of these results indicates the highest respiration and hydrocarbon degradation rates occur at VP2-50S, VP2-50D, VP-8S, and VP-8D. The lowest hydrocarbon degradation rates were observed at monitoring points VP1-50S, VP1-50D, VP3-35S, VP3-35D, VP-10S, VP-10D, VP-11S, and VP-11D.

In addition to O_2 consumption rates, subsurface conditions prior to the seasonal start up of the biovent system were evaluated to determine if conditions were aerobic or anaerobic. Anaerobic conditions generally occur in the vadose zone when O_2 concentrations are below 1 to 2% (DeVaull et al. 1997). While pre-system startup data was not available for all vapor monitoring points, conditions at the following points were found to be aerobic immediately before seasonal activation of the biovent system either during the July 2009 or July 2010 fixed gas measurement events: VP1-25S, VP1-25D, VP1-50S, VP3-35S, and VP3-35D.

The vapor points exhibiting both low respiration rates and consistent aerobic conditions (despite system inactivity) are located within the southeast portion of the biovent system; therefore, air flow to biovent wells within the eastern half of the central and southern system lines will be discontinued to allow for enhancements to air delivery to alternate biovent wells as detailed below.

3.3.5 BIOVENT SYSTEM MODIFICATIONS

The overarching goal of biovent system modifications is to redirect air flow from areas in which biodegradation is currently not rate limited by diffusion of O_2 from the atmosphere to the smear zone into areas where aerobic degradation of petroleum hydrocarbons is rate limited by the availability of O_2. These modifications to the biovent system will include (1) constructing new biovent wells within portions of the smear zone that are currently outside the influence of the system and (2) increasing the rate of flow into existing biovent wells as discussed below.

3.3.5.1 PROPOSED BIOVENT SYSTEM EXPANSION

As discussed in Section 3.3.3, regions of elevated BTEX and PAH concentration were observed in soils within the vadose zone located to the south outside of the ROI of the current biovent system. Therefore, the 14 biovent wells lines that extend from VCS No.1 to the northeast beneath the soccer fields (where petroleum hydrocarbon concentrations have been reduced within the vadose and saturated zones; and additional operation of the biovent system no longer affects the rate of aerobic degradation) will be repurposed for air delivery to the 14 locations identified in Figure 3-16 (proposed biovent wells BVW-39 through BVW-52). Specifically, the PVC pipes adjacent to VCS No.1 will be exposed and cut, with the existing lines capped and abandoned. An approximately 2-ft-deep trench line will be created and new 3-inch-diameter, Schedule 40 PVC lines will be emplaced to deliver air to the 14 proposed biovent wells. A typical biovent well detail is provided as Figure 3-17. The existing balancing valves and flow meters within VCS No.1 will be used to monitor air flow to these new locations.

Additionally, the line that extends from biovent well BVW-3 will be exposed to determine if there are any obvious obstructions or breaks within the PVC line. If no obstruction or breaks are noted in the line, then this biovent well will be abandoned, re-drilled, and installed in proximity to soil boring GPSA-43 where petroleum hydrocarbon concentrations in soil remain elevated.

3.3.5.2 AUGMENTATION OF AIR DELIVERY RATES

Based on the results of respirometry testing, the southeast region of the biovent system appears to exhibit slow biodegradation rates and, based on O_2 measurements prior to system startup, does not appear to be rate limited by diffusion of O_2 through the subsurface. Therefore, balancing valves for the twelve biovent wells located on the eastern half of the central and southern pipe runs (including wells BVW-11, BVW-12, BVW-20, BVW-21, BVW-22, BVW-23, BVW-24, BVW-25, BVW-35, BVW-36, BVW-37, and BVW-38) will be closed, allowing for increased flow to the remaining 26 biovent wells. Balancing the additional flow between the remaining 26 biovent wells and 14 proposed wells will allow for an approximate 30% increase in air flow, augmenting the current nominal 35 scfm to approximately 45 scfm delivered to each well.

The expansion of the biovent system to the southern portions of the smear zone beneath the Park and augmentation of air flow to existing portions of the biovent system will allow enhanced removal of LNAPL where elevated concentrations of petroleum hydrocarbons persist in soil and groundwater.

4.0 LONG TERM REMEDY EVALUATION

Routine monitoring data collected since 2007 and reported on a semiannual basis demonstrate that intrinsic processes in the saturated and unsaturated zones are degrading petroleum hydrocarbons in the smear zone. NSZD processes generally reduce the mass and concentration of petroleum hydrocarbons to varying degrees of effectiveness depending on the nature and volume of hydrocarbon released as well as the physical, chemical, and biological characteristics of the saturated and vadose zone. These processes can be inferred from the routine monitoring results using qualitative and quantitative analyses. Qualitative analyses consider spatial trends in petroleum hydrocarbons and electron acceptors in groundwater and soil gas. Quantitative analyses include temporal analysis of petroleum hydrocarbon concentrations and NSZD rate estimates.

There are two general lines of evidence provided herein to support the efficacy of natural attenuation processes to degrade petroleum hydrocarbons at a rate that will achieve remedial goals for groundwater (i.e. USEPA MCLs) in a timeframe comparable to active remedial measures. The primary lines of evidence include evaluation of LNAPL, groundwater, and vapor data that demonstrate the stability of petroleum hydrocarbons in the smear zone and protectiveness of sensitive receptors (Section 4.1.1); as well as meaningful trends of decreasing constituent concentrations over time (Section 4.1.2). The secondary lines of evidence include evaluation of hydrogeochemical data that demonstrate indirectly that natural attenuation mechanisms are acting to transform hydrocarbon constituents, reduce concentrations, and inhibit mobility of the LNAPL, dissolved phase, and vapor phase impacts (Section 4.1.3).

The routine analytical results have been combined with measured rates of chemical transport within the vadose and saturated zones, as well as the smear zone morphology to provide an estimate of the rate of NSZD. This method is described in detail in the 2009 Interstate Technology and Regulatory Council (ITRC) document titled, *Evaluating Natural Source Zone Depletion at Sites with LNAPL*, based largely on the methodology described in Johnson et al. (2006a, 2006b). A summary of the results of the numeric modeling conducted to estimate NSZD rates in the vadose and saturated zones is provided in Section 4.2.

4.1 PLUME STABILITY AND PROTECTIVENESS OF SENSITIVE RECEPTORS

During execution of the final groundwater remedy at the site, Chevron must continue to demonstrate that the LNAPL and dissolved phase plumes are stable and that sensitive receptors remain protected (USEPA 1999). If the extent of the LNAPL, dissolved, or vapor phase petroleum hydrocarbons are determined to be mobile or impacting sensitive receptors above risk based limits, contingency measures would be employed as outlined in the *OMM Plan*.

4.1.1 LNAPL

As discussed in the *Update to Site Conceptual Model and Summary of Remedial Decision Basis* (Chevron Cincinnati Groundwater Task Force 2005) and outlined within the *First 2008 Semiannual Monitoring Report*, LNAPL within the smear zone is stable. This determination was made based on (1) the age of the release; (2) a decrease in LNAPL gradients, transmissivity, and saturations due to natural degradation and engineered recovery; (3) morphology of the smear zone with a "thicker" core, which thins at the lateral edges; (4) there having been no expansion of LNAPL beyond the originally defined limits of the smear zone; and (5) preferential depletion of petroleum related constituents within the LNAPL at the soil gas and groundwater interface (otherwise referred to as outside-in weathering of the plume).

4.1.1.1 ROST MONITORING RESULTS

Data collected since 2007 support that the smear zone is stable based on the laser induced fluorescence measurements in the three ROST monitoring transects (RT-1 through RT-3) installed perpendicular to the limits of the smear zone in the Southwest Quad, as shown in Figure 4-1. ROST technology was identified as the preferred tool for monitoring the potential for expansion of the smear zone at its down-gradient limits because it is designed to provide real-time analysis of the physical and chemical characteristics of the distribution of petroleum hydrocarbons to distinguish between soils containing LNAPL and those outside of the smear zone. Each ROST monitoring transect consists of an interior location (I) situated at the approximate lateral limit of the smear zone, an intermediate location (M) located 20-feet from the approximate lateral limit of the smear zone, and an outer location (O) installed 40-feet from the approximate lateral limit of the smear zone. ROST technology and installation methodology is presented in greater detail in the *RIP*.

ROST monitoring was completed on a semiannual basis within the three ROST transects since 2007. Variability in the relative response of the laser induced fluorescence has been observed between the monitoring events. The yellow-green laser used to conduct the ROST was calibrated prior to each event using a reference solution containing the spectrum of petroleum hydrocarbons that can be detected by the fluorescence system. The fluorescence data collected using the ROST is consistently normalized as a percentage of the intensities measured against the reference solution. The power output of the laser can change due to environmental conditions over time (i.e. temperature, humidity, etc.) and aging of the components of the system. Use of the standard normalizes the data collected during each event. While the laser induced fluorescence results are not directly comparable between events, the data that is collected during a given event across the depth profile are semi-quantitative in nature, as the fluorescence results have been referenced against the same standard using the same instrument.

4.1.1.2 FLUID LEVEL RESULTS

In addition to the laser induced fluorescence results demonstrating that there was not the presence of LNAPL within the middle or outer monitoring locations in each ROST transect, LNAPL was not measured in any of the sentinel or point of compliance monitoring wells installed in the Southwest Quad. Fluid level gauging within the performance monitoring network installed along the west bank of the Great Miami River also confirmed the stability of the smear zone along the restored river bank on the former refinery and in Gulf Park.

4.1.1.3 RESIDUAL LNAPL SATURATIONS IN SOIL CORES

Historical petrophysical tests on soil cores collected in the saturated portions of the smear zone indicate two-phase (water-oil) LNAPL residual saturation ranges from about 18 to 25%. Data collected from the facility show an exponential decrease in the ability of LNAPL to migrate at saturations below 20 to 25%. Field testing completed in the late 1990s indicates that the two-phase LNAPL saturations in the majority of the plume were below residual values (i.e., immobilized). Additionally, soil core samples were collected on the facility in November 2008 and soil saturations calculated using this data also demonstrated that LNAPL saturations within the upper, middle, and lower portions of the smear zone were below residual values.

Smear zone coring was completed in May 2009 in Hooven near monitoring wells MW-93 and MW-96 and the LNAPL saturations were estimated using the total petroleum hydrocarbon concentrations averaged for the soil cores collected at each location, soil bulk density, LNAPL density, and soil porosity. The analytical results for smear zone location SZ-93, as well as the upper and middle location at location SZ-96 indicate that petroleum hydrocarbons are sorbed to soil or present in the dissolved phase, and measurable LNAPL is no longer present. Average LNAPL saturations in the lower portion of the smear zone near monitoring well MW-96 was 5.6%. As with the saturations measured within the soil cores collected on the former refinery in November 2008, the LNAPL saturations in Hooven were below the residual values and the plume is considered immobile.

4.1.2 DISSOLVED PHASE

In general, dissolved phase constituents of concern (including benzene, toluene, ethylbenzene, xylene, chlorobenzene, dissolved arsenic, and dissolved lead) have not been measured within routine samples collected from the sentinel and point of compliance groundwater monitoring network nor along the outboard monitoring network along the Great Miami River since execution implementation of the *OMM Plan* in January 2008. Arsenic and lead have been sporadically detected in groundwater collected from monitoring wells located throughout the Southwest Quad and along the river bank over the more than two decades of monitoring and are generally indicative of background metals

measured in soils in Ohio as reported in the *Evaluation of Background Metal Concentrations in Ohio Soils* (Cox-Colvin & Associates, Inc. 1996) and the *Closure Plan Review Guidance for RCRA Facilities* (OEPA 1999).

4.1.2.1 SOUTHWEST QUAD

It should be noted that benzene was detected in the groundwater sample collected from sentinel well MW-35 and point of compliance well MW-133 at concentrations exceeding the USEPA MCL (0.005 mg/L) between November 2008 and August 2009. Benzene has not been measured above detection limits in samples collected from sentinel well MW-35 since April 2009 or in point of compliance well MW-133 since August 2009 as summarized on Table 4-1. In response to the detections, additional monitoring was performed within selected sentinel and point of compliance wells in the Southwest Quad, hydraulic controls were resumed using production wells PROD_15 and PROD_24, five monitoring wells were installed up-gradient of sentinel well MW-35, and the *Work Plan for Contingency Measures in the Southwest Quad, Chevron Cincinnati Facility, Hooven, Ohio* (Trihydro 2009c) was prepared. Multiple lines of evidence were used to demonstrate that the dissolved phase detections measured in wells MW-35 and MW-133 were attributable to a separate, non-refinery related source and not redistribution of dissolved phase constituents following termination of hydraulic controls beneath the Southwest Quad, including: (1) hydraulic analysis showing that no preferential pathways for groundwater flow were present prior to resuming continuous pumping using production wells PROD_15 and PROD_24, (2) the limited number of constituents measured in groundwater samples collected from these wells, with only benzene detected despite the smear zone having higher mole fractions of more soluble and less degradable hydrocarbons, and (3) a distribution of dissolved phase benzene across the Southwest Quad that is not consistent with the source being associated with the smear zone; whereby concentrations decreased in the down-gradient direction beyond the smear zone and then increased within the sentinel well MW-35 and POC well MW-133.

Furthermore, during groundwater monitoring performed in March and May 2011, low level detections (parts per billion range) of benzene, ethylbenzene, and xylene were reported in groundwater samples collected from sentinel wells MW-35 and MW-131 as well as POC well MW-120. The measured concentrations were all below the USEPA MCLs. Groundwater flow directions during these monitoring events were primarily from the west to the east, which is perpendicular to the typical flow direction, with some component of flow from the south to the north. There was an approximate 10-foot decrease in groundwater elevations observed across the Southwest Quad in the days preceding groundwater sample collection. This rapid reduction in the groundwater elevations and redirection of groundwater flow towards the east was attributed to a return to ambient conditions following flooding events in March and May 2011. Appendix D presents potentiometric surface maps and hydrographs showing the flow conditions in the Southwest Quad before and after collection of groundwater samples when these low levels of dissolved phase constituents of concern were detected in the samples from the sentinel and POC wells.

Groundwater samples collected during the March and May 2011 events were not measuring dissolved phase constituent flux from the smear zone, which is located to the north-northeast but instead were measuring groundwater conditions to the west, where the smear zone attributed to releases from the former Gulf refinery is not present. Other sources of petroleum hydrocarbons are present west of these monitoring wells. It is likely that dissolved phase benzene measured in sentinel well MW-35 and POC well MW-133 between November 2008 and August 2009 are also associated with flux from alternate sources when flow conditions were altered by periodic flooding and rapid re-equilibration of the water table. Based on monitoring performed in the Southwest Quad over the past five years it is reasonable to conclude that the dissolved phase plume is stable and there has not been redistribution of constituents following termination of continuous hydraulic control following execution of the 2006 AOC.

4.1.2.2 GREAT MIAMI RIVER BANK

As part of these bank stabilization measures, a barrier wall performance monitoring network was installed along the restored river bank in accordance with the *Performance Monitoring Plan for Sheet Pile Barrier Along Great Miami River*. This work plan specified measures to characterize baseline conditions and monitor performance of the partially penetrating sheet pile wall during implementation of the final corrective measures for groundwater. The performance of the sheet pile wall is monitored by observing the hydraulic gradients in groundwater and surface water, as well as evaluating groundwater, hyporheic water, and surface water quality over time.

The barrier monitoring network is comprised of three monitoring transects along the northern, central, and southern portions of the barrier wall as illustrated on Figure 1-4. Each transect includes a groundwater monitoring nest (shallow, intermediate, and deep wells) situated inboard of the sheet pile wall and a groundwater monitoring nest located on the outboard side of the wall. In addition, a hyporheic/surface water monitoring well was also constructed outboard of the wall at each monitoring transect. A description of the installation and construction details for the sheet pile wall, stabilization measures, and performance monitoring network is provided in the *Second 2008 Semiannual Monitoring Report, Chevron Cincinnati Facility, Hooven, Ohio* (Trihydro 2009b).

Dissolved phase analytical results indicate constituents of concern have been infrequently detected within the barrier monitoring network including:

- Low concentrations of benzene, ethylbenzene, and total xylenes reported predominantly below the method detection limit (MDL) in the surface and hyporheic water samples outboard of the barrier
- Dissolved phase toluene reported below the MDL for a single sample collected from wells MW-137S and MW-137I inboard of the barrier

- Dissolved phase arsenic was reported predominately below the MDL in samples collected from inboard wells MW-136S and MW-137S

In no case were constituents detected on both sides of the barrier wall during any of the quarterly or semiannual monitoring events performed since installation of the network indicating that there is not flux of petroleum related hydrocarbons from the smear zone into the river. Measured concentrations within the surface water and hyporheic water samples are attributable to other sources up-stream of the former refinery.

4.1.3 VAPOR PHASE

In order to evaluate protectiveness of human health from migration of deep soil vapors into structures located in Hooven and the Southwest Quad, the data from the nested wells is compared to conservative risk based screening levels. Screening levels are concentrations that are sufficiently low that any results below these can safely be considered to pose no significant risk. They are developed with consideration for uncertainty, and are designed to be overly protective; therefore, concentrations above the screening levels do not necessarily pose an unacceptable risk.

A screening level evaluation was not conducted for the buildings on the refinery as there are few buildings situated over the smear zone. Mitigation measures have been incorporated into those structures overlying the smear zone where there is the potential for volatile constituents to migrate into the structure. As described in Section 1.4.4, proposed environmental covenants for any parcels redeveloped on the former refinery would require mitigation measures including passive vapor barriers, and if necessary sub-slab depressurization or venting systems to be incorporated into the building design.

Table 4-2 provides the screening level evaluation for gasoline related constituents reported within the deep soil gas samples collected from the nested vapor wells in Hooven and the Southwest Quad between 2008 and February 2011. The residential indoor air screening levels (assuming a lifetime incremental cancer risk of 1E-5 for carcinogenic constituents and a Hazard Quotient of 1 for non-carcinogenic constituents) provided on the USEPA Regional Screening Level (RSL) tables (USEPA 2009a) were divided by semi-site specific attenuation factors from Figure 3a of the USEPA *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (*OSWER Draft VI Guidance*, USEPA 2002) to derive soil vapor screening levels (SVSLs). This approach for defining the SVSLs was developed in cooperation with USEPA Region V risk assessment staff and has been presented in previously submitted semiannual monitoring reports. Application of the attenuation factors from Figure 3a of the *OSWER Draft VI Guidance* is extremely conservative for this evaluation, since these do not account for attenuation due to aerobic biodegradation, which is the chief mechanism limiting vapor transport beneath Hooven.

The 2009 residential RSLs are used to define the SVSLs, as these were developed with updates to the toxicity data for inhalation of many petroleum and non-petroleum related constituents, and as such represent the most current understanding of the health effects of inhaling the petroleum related constituents discussed herein. In December 2009, the USEPA Office of Inspector General identified that the indoor air screening levels provided in the *OSWER Draft VI Guidance* were outdated and may impede evaluation of the vapor intrusion pathway (USEPA 2009b). In general, the RSLs are comparable or lower (more protective) than the screening levels provided within the *OSWER Draft VI Guidance*, with the exception of toluene, hexane, and 1,3-butadiene, which were higher. Four constituents (the alkylbenzenes [n-propyl-, n-butyl-, and sec-butyl-] and methylcyclohexane) had screening levels in the *OSWER Draft VI Guidance* for which the USEPA did not calculate RSLs, as the most recent toxicity data did not support inclusion of these constituents as an inhalation risk.

It is worth noting that screening levels were not provided in the *OSWER Draft VI Guidance* or included as part of the RSL tables for 2,2,4-trimethylpentane. 2,2,4-trimethylpentane is a component of gasoline and has been detected in soil gas samples collected from the vapor source above the smear zone since 2005. In July 2007, the USEPA summarized the available hazard and dose-response assessment information for 2,2,4-trimethylpentane in the document titled *Toxicological Review of 2,2,4-Trimethylpentane* (USEPA 2007). This report is intended as a thorough review of the scientific understanding regarding the toxicology of 2,2,4-trimethylpentane with the stated purpose of providing "scientific support and rationale for hazard and dose-response assessment in the Integrated Risk Information System pertaining to chronic exposure." In other words, it specifically addressed the task of developing defendable reference concentrations (rfCs) and reference doses (rfDs) for chronic exposure to 2,2,4-trimethylpentane. This report was prepared by independent toxicologists, and was subjected to peer review by both USEPA-internal and external toxicologists prior to finalization. The final version reflects an achieved common understanding among the multiple USEPA branches and concludes that there is insufficient data to develop defendable rfCs or rfDs for 2,2,4-trimethylpentane. As such, a screening evaluation for 2,2,4-trimethylpentane is not provided herein.

The screening level evaluation was applied to the deep soil vapor samples collected from 20 ft-bgs or greater in Hooven. The data collected from the shallow probes was not evaluated because vapor concentrations at depths less than 20 ft-bgs are attributable to alternate, surface derived sources of petroleum hydrocarbons. Based on Figure 3a of the *OSWER Draft VI Guidance*, an attenuation factor of 0.002 was applied to samples collected from depths of 20 ft-bgs, 0.001 was used to screen soil vapor data from greater than 20 ft-bgs to 35 ft-bgs, and an attenuation factor of 0.0007 was used to screen data greater than 35 ft-bgs. Note that the attenuation factors shown on Figure 3a of the *OSWER Draft VI Guidance* correspond to the depth below the foundation. For this evaluation the depth of the basement was conservatively assumed to be 5 ft-bgs; therefore, a sample depth of 20 ft-bgs corresponds to a depth of 15 feet, as shown on Figure 3a.

A similar screening level approach was applied for petroleum related vapors measured in nested vapor well VW-139, with the significant exception that structures within the Southwest Quad have a slab-on-grade foundation. The SVSLs for the Southwest Quad were calculated using the RSLs for residential air and semi-site specific attenuation factors from Figure 3a of the *OSWER Draft VI Guidance*. For depths between 5 and 10 ft-bgs an attenuation factor of 0.002 was used, for depths of greater than 10 ft-bgs to 30 ft-bgs an attenuation factor of 0.001 was used, and for depths greater than 30 ft-bgs an attenuation factor of 0.0007 was used. This is a conservative evaluation as ambient background concentrations were not accounted for in the shallow vapor samples collected from well VW-139 and there are no residences situated within the Southwest Quad.

There were no exceedences of the SVSLs in any of the samples collected from nested monitoring wells VW-93, VW-127, VW-128, and VW-129 during any of the monitoring events conducted between 2008 and 2011. There were only exceedences of the SVSLs in the detected results from nested soil vapor monitoring wells VW-96, VW-99, and VW-139. Detected concentrations of benzene, ethylbenzene, hexane, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene exceeded the depth-specific SVSL in a limited number of samples collected from the deepest intervals in these three wells. The deepest probes were installed within the upper limits of the smear zone at these locations.

The detection limits for several constituents including 1,2-dichloroethane, 1,2-dibromoethane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,3-butadiene, benzene, ethylbenzene, hexane, and naphthalene exceeded the depth-specific SVSL in intervals reported with non-detect results within nested wells VW-96, VW-99, VW-130, and VW-139 during several sampling event. Typically samples collected from other intervals within these nests were reported with non-detect results for these constituents below the SVSLs, which would indicate that the constituent concentrations were below conservative risk based levels within the vadose zone near these wells.

There were some cases where the non-detect reporting limits exceeded the respective SVSLs throughout the intermediate and deep portions of the vadose zone, typically in nested wells VW-96 and VW-99 during the monitoring events performed in 2009 under worse case conductions (i.e., high-grade pumping without operation of the HSVE system). Although the soil vapor results in these cases were not sufficient to determine that these constituents were not present above the SVSLs, the monitoring results combined with historical data provide some insight into the vapor intrusion pathway at these locations. First, for many of the constituents there were no detections of these constituents above their respective SVSLs, even in the deepest samples collected within the smear zone. In addition, data collected during previous monitoring events indicate that the vapor intrusion pathway was incomplete for these constituents. Finally, for constituents that were detected in the deepest sampling intervals above SVSLs, the analytical results strongly support that there are rapidly decreasing concentrations within shallower depths above the smear zone. The

data collected between 2008 and June 2011 continues to demonstrate that there is not a risk to residents in Hooven, tenants within the former elementary school, or occupants of businesses associated with intrusion of volatile constituents from the former refinery, even under worse case conditions.

4.2 CONSTITUENT TRENDS

It is expected that the data collected over the course of the remedy will show a meaningful trend of decreasing hydrocarbon mass and/or constituent concentrations over time. Analyses that may be used in evaluating the progress of the long term remedy include evaluation of temporal trends in constituent concentrations, comparisons of observed distributions with predictions, as well as comparison of calculated attenuation rates with those necessary to meet remedial goals within an expected time frame. These analyses can be complicated as a result of variation in the petroleum hydrocarbon distribution across the site, temporal fluctuations related to seasonal and longer term trends, heterogeneity in the vadose and saturated zones across the plume footprint, along with measurement variability. These complications necessitate the use of multiple lines of evidence and expanded monitoring networks to reduce uncertainty.

4.2.1 LNAPL AND SOIL CORE CONSTITUENT TRENDS

Figure 4-2 shows the mole fraction of benzene in LNAPL samples collected in 1997, 1999, 2005, and 2010 from four sets of wells (MW-1R/PROD_20, MW-58/PROD_12/PROD_25, PROD_15, and MW-96S) and the mole fraction of benzene in smear zone soil cores samples (SZ-18, SZ-20, SZ-21, SZ-58, SZ-96 and SZ-NTF1) collected in 2008 and 2009 on a logarithmic-linear scale. This figure also shows the decline in the average benzene mole fraction for all the LNAPL samples collected over this timeframe. The trends presented on this figure depict a first order degradation rate for benzene in the LNAPL since 1997.

As the LNAPL saturation and transmissivity continue to decrease across the smear zone over time, it may become infeasible to collect LNAPL samples for laboratory analysis. As a result, smear zone soil coring is being conducted to provide a means of measuring LNAPL composition, with the first coring events performed in 2008 and 2009. The benzene mole fractions estimated within the soil cores collected during these initial events were compared to the benzene mole fraction in LNAPL shown on Figure 4-2. There was general agreement between benzene mole fractions reported in the LNAPL samples collected in 2010 and smear zone soil cores collected in 2008 and 2009, with slightly higher concentrations estimated in the soil cores. This is likely a function of the conservative assumptions used in calculating benzene mole fraction in LNAPL from the soil core samples.

It is important to note that the total petroleum hydrocarbon concentrations measured in the soil core samples collected at boring SZ-93, as well as the top and middle samples collected at the locations SZ-96 were below 100 mg/kg. These low values are typically associated with petroleum hydrocarbons present in the dissolved phase, and sorbed to soil organic matter, rather than being present as LNAPL. The average total petroleum hydrocarbon concentration measured in bottom samples collected at location SZ-96 was 3,055 mg/kg. This corresponds to a LNAPL saturation of approximately 5.6% (API Interactive LNAPL Guide, version 2.0.4, 2004).

In the past, LNAPL has been observed to enter monitoring wells MW-93 and MW-96. Under equilibrium conditions, LNAPL presence in a monitoring well would correspond to LNAPL presence in the formation near the water table. Based on the total petroleum hydrocarbon results, LNAPL is only present at the base of the smear zone near monitoring well MW-96, and absent near monitoring well MW-93. This suggests that environmental dynamics, such as a natural attenuation, a fluctuating water table, high grade LNAPL recovery, and HSVE system operation, have acted to remove much of the subsurface LNAPL in these portions of Hooven. Future monitoring of the smear zone in Hooven will focus on the bottom sampling interval at location SZ-96, where LNAPL is still present. Smear zone soil coring and LNAPL sample collection will be conducted on five year intervals with the next event slated to occur between 2013 and 2015.

4.2.2 DISSOLVED PHASE CONSTITUENT TRENDS

It is useful to evaluate the dissolved phase constituent trends in two ways. First, dissolved phase constituent trends within individual groundwater monitoring wells can be used to assess spatial variability in engineered mass removal and intrinsic biodegradation processes across the smear zone footprint and identify areas that are not behaving as predicted. Trend analyses should be conducted in monitoring locations situated throughout the distribution of petroleum hydrocarbons to assess the range of dominant intrinsic processes acting on the plume. Temporal trends in individual wells may also indicate changes in climatic, hydrogeochemical, hydrocarbon release, site reuse, or other conditions unrelated to attenuation processes and need to be evaluated in the context of other lines of evidence.

Second, groundwater quality trends can be averaged within areas of the smear zone (i.e., up-gradient, interior, down-gradient) to assess overall trends in natural attenuation processes. These area averages are less sensitive to variations within individual wells that can sometimes complicate temporal analyses and provide an understanding of natural attenuation processes affecting the smear zone as a whole. For discussion purposes, there are two areas up-gradient of the smear zone, one to the north of the facility property and the second to the west along the Buried Valley Aquifer-bedrock interface in Hooven.

Individual well and area wide trend analyses performed using data collected from monitoring wells across the smear zone during previous semiannual monitoring events have demonstrated a first order degradation rate for benzene associated with both natural attenuation and engineered mass removal, with preferential depletion along the smear zone margins (i.e., outside-in weathering). Historically, groundwater samples are collected from a set of interior and supplemental groundwater monitoring wells (MW-17, MW-22, MW-81S, MW-93S, L-1RR, L-3R, MW-21, MW-38, MW-64, MW-99S, MW-85S, and MW-115S) for completing these temporal analyses.

4.2.2.1 TRENDS WITHIN INDIVIDUAL MONITORING WELLS

Historically, groundwater samples have not been collected from the interior plume monitoring wells due to the presence of LNAPL during sampling. For the purpose of this analysis, trends are inferred for wells that have viable groundwater data from at least three monitoring events spanning three separate years. Of the ten interior plume wells, six monitoring wells (MW-10, MW-18R, MW-20S, MW-58S, MW-88, and MW-96S) do not have data that meet these criteria. Many of these wells have been sampled for at least three consecutive years but due to water table elevations, some of the data was excluded based on potential dilution during high water table elevations or potential for LNAPL during low water table elevations. Constituent of concern concentrations reported in the samples collected from interior monitoring well MW-85D were all reported below the remedial goals, which is expected as this well is screened in the deeper portions of the Buried Valley Aquifer, well below the vertical distribution of dissolved phase petroleum hydrocarbons. Dissolved phase trends for the four remaining interior plume monitoring wells (MW-17, MW-22, MW-81S and MW-93S) are provided on Figures 4-3 through 4-6. Monitoring well MW-17 is located in the interior of the smear zone, where dissolved phase benzene concentrations continue to be measured at concentrations above remedial goals. There is a slight decreasing trend in benzene concentrations over time. This decreasing trend may become more pronounced over time as the smear zone up-gradient of well MW-17 becomes depleted and attenuation continues from the "outside-in." Monitoring well MW-22 is located north of well MW-17, closer to the up-gradient edge of the smear zone, and accordingly shows a stronger decreasing trend in benzene concentrations over time. Monitoring well MW-81S is situated in the southwest limit of Hooven adjacent to State Route 128 and MW-93S is located in the central portion of Hooven adjacent to the former elementary school. Dissolved phase constituent concentrations in these two wells show a clear decreasing trend between 1996 and 2011. This trend is likely pronounced by groundwater and LNAPL recovery as well as HSVE system operations.

Of the nine supplemental groundwater monitoring wells (L-1RR, L-3R, MW-21, MW-33, MW-38, MW-51, MW-64, MW-80, and MW-99), wells L-1RR, L-3R, MW-21, MW-33, MW-38, MW-64, and MW-99S had sufficient data (i.e., results from at least three monitoring events spanning more than three years) to complete trend analysis. Many of these wells have been sampled for at least three consecutive years but due to water table elevations, some of the data was

excluded based on potential dilution during high water table elevations or LNAPL entrainment in samples collected during low water table elevations. The dissolved phase results for the constituents of concern reported in samples collected from well MW-33 have remained below MCLs over time.

As presented on Figures 4-7 through 4-10, dissolved phase benzene concentrations reported in supplemental monitoring wells L-1RR, L-3R, MW-21, and MW-38 showed a first order degradation rate over time. These wells are generally located outside of the footprint of engineered remedial measures at the facility; therefore these decreasing trends are indicative of natural attenuation processes. The rate of decline in benzene concentrations is greater in well MW-21 compared to monitoring wells L-1RR, L-3R and MW-38, as this well is located along the up-gradient edge of the smear zone.

The dissolved phase benzene concentrations reported in samples collected from monitoring wells MW-64 (Figure 4-11) and MW-99S (Figure 4-12) also show decreasing trends over time. These two monitoring wells are located on the eastern and western edge of the smear zone, respectively, and also demonstrate preferential depletion of benzene along the smear zone margins (i.e., outside-in weathering). Moreover, dissolved phase trends observed in monitoring well MW-99 reflect mass loss through engineered recovery like the other wells situated in Hooven.

Temporal analysis of the dissolved phase results can also be conducted for two additional monitoring wells (MW-85S and MW-115S) located within the distribution of hydrocarbons at the facility, as these wells have a sufficient monitoring history with concentrations above remedial goals. MW-115S (Figure 4-13) is located outside the influence of historical remedial efforts in the Southwest Quad. Dissolved phase benzene shows a decreasing trend over time within samples collected from this well, which can be considered indicative of natural attenuation processes.

Monitoring well MW-85S (Figure 4-14) has historically shown a decreasing trend, which was slightly reversed with inclusion of the result from the groundwater sample collected during the first half of 2010. It is possible that installation of the partially penetrating barrier wall along the west bank of the Great Miami River in 2008 has subsequently limited the transport of electron acceptors such as dissolved O_2 to this portion of the smear zone along the river. Future groundwater monitoring will help resolve short term and long term dissolved phase benzene trends in this well and other monitoring wells installed along the west bank of the river within the smear zone.

The average first order degradation rate estimated using the dissolved phase analytical results from eleven monitoring wells (L-1RR, L-3R, MW-17, MW-21, MW-38, MW-22, MW-64, MW-81S, MW-93S, MW-99S, and MW-115S) was approximately 6.91 x 10-4 per year. As additional dissolved phase data is collected, it will be possible to make meaningful decisions regarding the temporal trends across the distribution of hydrocarbons. Attenuation rates will be

compared over time within individual wells installed across the plume and progress towards meeting the remedial goals will be further considered.

4.2.2.2 AVERAGE TRENDS ACROSS SMEAR ZONE

The average dissolved phase constituent and total petroleum hydrocarbon concentrations are indicative of ongoing NSZD processes, with preferential LNAPL depletion at the smear zone boundaries. Other than the detections discussed in Section 4.1.2, dissolved phase benzene was not detected in samples collected from monitoring wells up-gradient and down-gradient of the smear zone. This indicates that attenuation processes such as dispersion, sorption, and biodegradation reduce the dissolved phase concentration, reduce mobility of the plume, and/or transform constituents of concern as groundwater exits the smear zone.

The average dissolved phase benzene concentration trends for selected monitoring wells located in the up-gradient (MW-21 and MW-22), interior (L-1RR, L-3R, MW-17, and MW-18R), and down-gradient (MW-48S, MW-94S, and MW-115S) portions of the smear zone are presented on Figure 4-15. Dissolved phase concentrations reported during monitoring conducted in 2002, 2004, 2008, 2009, 2010, and 2011 are averaged for the up-gradient, interior, and down-gradient wells. Irrespective of the well locations, there is a decreasing trend in the dissolved phase benzene concentration reported between 2002 and 2011, indicative of benzene depletion from the smear zone. These decreasing trends are more pronounced at the margins of the smear zone compared to the interior portion of the plume. At its margins, the smear zone is thinner and LNAPL saturations are lower.

As the up-gradient portion of the smear zone is depleted of petroleum hydrocarbons, the benzene removal rates from the interior portion of the smear zone will increase as outside-in weathering continues. It is anticipated that the dissolved phase benzene concentrations reported in monitoring wells L-1RR and MW-17 will show trends similar to those currently observed in wells MW-21 and MW-22. This may then be followed by a similar transition in the dissolved phase benzene trends observed in monitoring wells L-3R and MW-18R. Over time, benzene concentrations in groundwater will continue to decrease across the smear zone, eventually reaching remedial goals (i.e., USEPA MCLs).

4.2.3 VAPOR PHASE CONSTITUENT TRENDS

As with temporal analysis of the dissolved constituents of concern, soil vapor results from samples collected directly above the LNAPL smear zone (i.e., vapor source) should be considered as a line of evidence to demonstrate the effectiveness of natural attenuation mechanisms to degrade the smear zone over time. Vapor source trend analyses will be conducted using data collected from soil vapor monitoring wells installed across the distribution of petroleum

hydrocarbons to assess the rate of attenuation in various portions of the plume. The trends observed in the vapor source should be evaluated in the context of the other lines of evidence to identify secondary causes of variation such as seasonal fluid level fluctuations or longer term cyclical events such as droughts.

Monitoring wells VW-93, VW-96, and VW-99 have a sufficient monitoring history to complete temporal analyses and are located over the smear zone. Figures 3-3 through 3-5 show the concentration of benzene and TVPH reported in the vapor source in nested wells VW-93, VW-96, and VW-99 over the past 14 years. A first order degradation rate is observed in the vapor source concentration since 1997, with a two to five order of magnitude decrease in benzene and total petroleum hydrocarbon concentrations. This decrease in concentrations is partially attributable to operation of groundwater, LNAPL, and soil vapor recovery systems in Hooven beginning in 1999.

Reduction in the TVPH and benzene concentrations has been more significant in well VW-93 compared to wells VW-96 and VW-99. As shown on Table 3-6, Line No. 2 (the closest extraction line to nested vapor well VW-93) has been run less than half of the number of days of Lines No. 1 and No. 3 (closest extractions lines near wells VW-96 and VW-99 respectively). This may be an indication that operation of the HSVE system alone does not fully account for the reduction of petroleum related constituents in the smear zone beneath Hooven. Alternate sources of petroleum hydrocarbons have not been observed in the soil vapor profiles from well VW-93; therefore O_2 transport and aerobic biodegradation is not limited within the deeper portions of the vadose zone near this well.

There was a significant increase in the TVPH concentrations in the vapor source (i.e., deepest sample) reported in wells VW-96 and VW-99 between September 2008 and October 2009 associated with extended shutdown of the HSVE system for more than 22 months during the USEPA investigation of the vapor intrusion pathway beneath Hooven. This trend was magnified during the September/October 2009 event by operation of the high-grade system. Induced depression of the water table during high-grade operation exposed the deepest portions of the smear zone containing the highest mole fraction of volatile petroleum hydrocarbons (Trihydro 2009b). This trend was reversed again with operation of the HSVE system during 2009 and 2010.

4.3 HYDROGEOCHEMICAL INDICATORS OF NATURAL ATTENUATION

Characterization of geochemical variations in the vadose and saturated zones provides evidence of the types of biodegradation processes that are thought to be attenuating petroleum hydrocarbons in the smear zone. Many of the processes attenuating hydrocarbons in the smear zone cannot be measured directly (e.g., biological transformation of constituents). However, the processes may cause changes in geochemical parameters, leaving an observable "footprint" that can be related qualitatively and quantitatively to the natural attenuation processes (National Research

Council 2000). In general, naturally occurring inorganic geochemical species serve as electron acceptors and are reduced during microbial degradation (i.e., oxidation) of petroleum hydrocarbons.

4.3.1 DISSOLVED PHASE CONSTITUENTS

During microbial degradation of petroleum impacts, dissolved O_2 concentrations steadily decrease until anaerobic conditions prevail. Once anaerobic conditions exist and multiple potential electron acceptors (i.e., oxidizers) are available, microorganisms preferentially use the electron acceptor that is thermodynamically most favorable. In other words, petrophyllic bacteria that utilize the electron acceptor that offers the most energy during consumption of the petroleum hydrocarbon source will proliferate over other bacteria until they exhaust that electron acceptor and then another bacteria that uses the next most favorable electron acceptor (based on availability in groundwater) thrives. The general order of preference for anaerobic hydrocarbon biodegradation based on the Gibb's energy of the reaction is:

- Denitrification (reduction of nitrate), with the eventual production of molecular nitrogen
- Reduction of manganese from Mn4+ to Mn2+
- Reduction of ferric iron (Fe3+) to ferrous iron (Fe2+)
- Sulfate reduction, with eventual production of sulfide
- Reduction of CO_2 and generation of CH_4

These microbial processes generally segregate into distinct zones dominated by O_2, nitrate, ferric iron, sulfate, and CO_2 reduction. Furthermore, given the different electron acceptors consumed and final by-products, it is theoretically possible to differentiate the "zones" of microbial processes across the smear zone. When applied at a field scale this differentiation of microbial zones must be framed in a general terms which accommodate uncertainties, as several of the by-products of microbial metabolism (such as ferric iron, hydrogen sulfide, and CH_4) are readily transported down-gradient.

A summary of the hydrogeochemical indicator concentrations versus distance for monitoring performed since 2008 is displayed on Figure 4-16. Select hydrogeochemical concentrations are compared to the dissolved phase benzene concentrations through the centerline of the smear zone. Iron and sulfate reduction primarily occurs within 2,000 feet down-gradient of the smear zone boundary where available electron receptors are fully reduced. There is a rapid increase in benzene, CH_4, and dissolved iron concentrations with an associated decrease in sulfate. Methanogenesis is then the dominant process degrading hydrocarbons through the central portions of the smear zone. These trends reverse toward the down-gradient edge of the smear zone. The concentration versus distance plots further support that outside-in weathering of the smear zone is occurring.

4.3.2 HYDROGEOCHEMICAL FLUX WITH RAINWATER INFILTRATE

Two soil moisture lysimeters were constructed at the grouped media locations near wells MW-18, MW-20, MW-21, and MW-93 in September 2008, in accordance with details presented in the *RIP*. The lysimeters are used to measure the contribution of hydrogeochemical flux into the upper limits of the saturated zone. The lysimeter analytical results are presented in Table 4-2.

The concentrations of electron acceptors measured in the infiltrate collected from lysimeter L-21S (northernmost location) and lysimeter L-18S (central portion of the smear zone) were generally low or not detected. Reduced byproducts including dissolved manganese and CH_4 were elevated within the samples collected from these locations. This is an indication of ongoing attenuation of petroleum hydrocarbons, and subsequent partitioning of CH_4 and volatile petroleum hydrocarbons from soil vapor to pore water within the vadose zone.

In the southern portions of the smear zone, the pore water generally contains higher levels of electron acceptors with elevated sulfate and nitrate concentrations measured in lysimeter L-20S and elevated O_2, nitrate, and sulfate measured in lysimeter L-93S. Reduced by-products were reported at relatively low concentrations in the infiltrate samples collected from these two lysimeters. Based on these results it appears that there is a higher flux of electron acceptors into the saturated portions of the smear zone along the southern portion of the site.

Precipitation and subsequent infiltration comprise an important component of the aquifer budget. Much of this infiltrating water contains electron acceptors that are used by microorganisms in the smear zone to destroy hydrocarbons. The lysimeter data are useful in understanding this process, as demonstrated by an analysis of the assimilative capacity. A summary bar graph of pore water assimilative capacity over time is presented in Figure 4-17. The assimilative capacity is estimated by summing the concentrations of electron acceptors and subtracting reduction-oxidation byproducts, scaled to stoichiometric coefficients for attenuation of hydrocarbons. As shown on this figure, pore water in the northern and central portion of the smear zone (as evaluated using lysimeters L-21S and L-18S) has a low or negative assimilative capacity, indicating that precipitation infiltrate at these locations does not have the potential to further degrade hydrocarbons within the saturated zone. On the other hand, the assimilative capacity of infiltrate in the southern portions of the smear zone (assessed using lysimeters L-20S and L-93S) is much higher.

4.3.3 VAPOR PHASE CONSTITUENTS

Aerobic degradation of hydrocarbon vapor occurs (often in a relatively thin zone) where the concentrations of O_2 and volatile constituents in the soil vapor are optimal for the growth of petrophyllic bacteria. Aerobic degradation has the potential to reduce soil gas concentrations by several orders of magnitude, as long as the supply of O_2 is not rate

limiting (Roggemans et al. 2001). CO_2 is produced as a result of aerobic biodegradation of hydrocarbons. The expected vertical profiles of O_2 and CO_2 concentrations in the presence of aerobic biodegradation tend to be mirror images. Depth profiles of petroleum related constituent and O_2 concentrations provide qualitative evidence of the occurrence of aerobic biodegradation in the vadose zone.

- For cases where there is little or no hydrocarbon source at depth, the hydrocarbon vapor profiles will show results at or near the reporting limit (i.e., background or non-detectable concentrations) from the deepest to the shallowest portions of the vadose zone. The concentration of O_2 will be nearly constant (approaching atmospheric levels) throughout the unsaturated zone.
- Where there is a significant hydrocarbon source at depth and aerobic biodegradation of volatile constituents, the hydrocarbon vapor profile will show a decrease in hydrocarbon concentration with increasing distance above the plume that is more rapid than that expected due to diffusion alone. The petroleum hydrocarbon concentration profile will show three distinct zones. The first zone is from the source to a depth where active aerobic biodegradation is not occurring. This zone is representative of anoxic conditions where diffusion is the primary transport mechanism and hydrocarbon vapor concentrations decrease in a linear profile, if at all. The second portion of the profile represents the active zone of aerobic biodegradation (which can be relatively thin compared to the thickness of the unsaturated zone), where there is rapid attenuation of hydrocarbon concentrations coinciding with consumption of O_2 (Johnson et al. 1999). It is not uncommon to see O_2 concentrations decrease from atmospheric levels (20.9%) to 1-2% (DeVaull et al. 1997). In the third zone (above the biologically active layer) hydrocarbon concentrations are typically very low or not detectable and there is generally elevated O_2. These profiles may vary if there are significant stratigraphic layers of different geologic materials, but this is not the case beneath the former refinery or Hooven.
- For cases where there is a release of petroleum hydrocarbons at or near the ground surface that is unrelated to historical releases from the former refinery (referred to herein as an alternate source) that has migrated into the unsaturated zone, the vertical profiles will be different than the case of a single source at the bottom of the unsaturated zone. If the alternate source is minor, O_2 depletion may only be a few percent below atmospheric levels and vapor concentrations may be reduced to non-detectable or background levels within a few feet of the alternate source. However, where the alternate source is more significant, O_2 concentrations may be fully consumed and aerobic degradation may be limited, in which case, hydrocarbon vapors would be more persistent and migrate by diffusion to shallower and deeper portions of the vadose zone. Consumption of O_2 by an alternate source would also limit the supply of O_2 to deeper portions of the vadose zone, thereby reducing the effectiveness of aerobic biodegradation in deeper portions of the vadose zone where the vapor source is present. If this occurs, vapors from the source at depth diffusing upward and those associated with the alternate source diffusing

downward may comingle at intermediate depths. Depending on the composition of the alternate source (i.e., petroleum versus non-petroleum) it may be difficult to distinguish whether the vapors are derived from shallow or deep sources. Additionally, the presence of alternate sources and preferential depletion of O_2 at shallow depths in the vadose zone may allow migration of vapors from the source at depth to shallower portions of the vadose zone than would otherwise occur if the alternate source was not present.

Petroleum hydrocarbon constituent and O_2 profiles were created for selected nested vapor wells for monitoring events between 2008 and 2011, as described in the subsections below. The vertical soil vapor profiles were grouped into three general categories, based on the location of the nested vapor monitoring wells:

1. Overlying LNAPL, including nested wells VW-93 (Figure 4-18), VW-96 (Figure 3-6), VW-99 (Figure 3-7), and VW-139 (Figure 4-19)
2. Overlying dissolved phase petroleum hydrocarbons, as represented by nested well VW-128 (Figure 4-20)
3. Background areas outside the LNAPL and dissolved phase hydrocarbons, as represented by nested well VW-129 (Figure 4-21)

Profiles were constructed for TVPH, which is a mixture of hydrocarbon constituents whose composition can vary significantly both spatially (across depth intervals in each nest) and temporally (across sample events). TVPH was estimated by summing the mass of the detected volatile petroleum related hydrocarbon constituents shown in Table 4-2. For constituents that were reported as "non-detect", half the detection limit was used as a surrogate in the estimation of the TVPH concentration. CH_4 was not included in calculation of the TVPH values.

4.3.3.1 NESTED WELLS OVERLYING LNAPL

Profiles from nested wells VW-96 and VW-99 from the April 2008, September 2008, and August 2010 monitoring events generally show a rapid decrease in TVPH concentrations from the source to depths between 30 and 45 ft-bgs. Consumption of O_2 is noted throughout the vertical profile during these events, indicating that aerobic degradation is the primary mechanism for these reductions. An increase in vapor concentrations is observed in the TVPH profile above 30 ft-bgs in well VW-96 during monitoring in April and September 2008 and in well VW-99 during the September 2008 and December 2010 events. Increasing concentration trends above the 30 foot interval and shallower are not consistent with vapor diffusion from a single vapor source at the water table. Diffusion occurs as a result of a concentration gradient and results in movement of chemicals from areas of high concentration to areas of low concentration. The reverse concentration gradient above 30 ft-bgs is consistent with the presence of an alternate source of petroleum hydrocarbons that may have migrated downward into the vadose zone from a release at or near ground

surface. The contribution of volatile constituents associated with these alternate sources within the shallow and intermediate portions of the vadose zone have also been observed during previous monitoring conducted between 1997 and 2007 (Trihydro and GeoSyntec 2010).

In December 2008 and September/October 2009, TVPH concentrations decrease from the source in the smear zone to shallower depths; however, the reduction in concentrations is less dramatic than has been observed during other events. The fixed gas data for these events show that O_2 is being consumed at shallower depths in the vadose zone. The profiles for data collected in December 2009 and September/October 2009 from these two wells show that alternate sources are being aerobically degraded, resulting in a consumption of O_2 in the upper portions of the vadose zone which in turn limits diffusion into deeper portions of the unsaturated zone. This reduces the rate and extent of aerobic biodegradation of the source at depth. The hydrocarbon profiles show a shift over time from a clear distinction between the source at depth and the alternate sources present in the shallow and intermediate portions of the vadose zone, to a comingling of vapor constituents from the two sources.

Per requirement of the USEPA, the HSVE system was not operated in accordance with triggers established in the *OMM Plan* between December 2007 and October 2009. Operation of the HSVE system advectively transports O_2 into the deeper portions of the vadose, enhancing the rate of aerobic biodegradation. Therefore, in a case where O_2 is being consumed during aerobic biodegradation of alternate sources, operation of the HSVE system becomes more important in enhancing attenuation of the source at depth. At times when O_2 is being depleted within the intermediate portions of the vadose zone, operating the HSVE system increases the efficacy of aerobic degradation of the smear zone vapor source. It should be noted that after start up of the HSVE system (September 2010 through February 2011 monitoring events), TVPH concentrations within both of these wells were primarily composed of non-detect results and O_2 concentrations were comparable to atmospheric levels throughout the vadose zone, irrespective of which line of the HSVE system was operating.

In comparison, the vapor profile for nested well VW-139, situated above the smear zone in the Southwest Quad, provides a prototypical example of aerobic biodegradation of hydrocarbon constituents in the vadose zone without the influence of alternate sources. O_2 is able to diffuse into deeper portions of the vadose zone resulting in significant reduction of hydrocarbon concentrations by 30 ft-bgs. It is important to note that the vadose zone is only approximately 40 feet thick beneath the Southwest Quad, compared to 55-60 feet near nested wells VW-96 and VW-99 in Hooven. Even with the thinner vadose zone, concentrations are reduced to non-detect or background levels within 10 feet above the smear zone. If alternate sources were not present near nested vapor wells VW-96 and VW-99, the profiles from these locations would be expected to be similar to those observed at nested well VW-139.

The profiles for data collected between 2008 and 2011 for nested well VW-93 are consistent with those from a limited hydrocarbon source (i.e., concentrations near background or not detected throughout the profile). These results are similar with previous sampling events. It is worth noting that historically the concentrations of TVPH measured above the smear zone in this well were similar to those measured in wells VW-96 and VW-99. These data support that the vapor source concentrations have decreased dramatically due to the combined effects of aerobic biodegradation and corrective measures system operation and that LNAPL is no longer present near this well.

4.3.3.2 NESTED WELLS OVERLYING DISSOLVED HYDROCARBONS

Nested vapor monitoring well VW-128 is located over the dissolved phase hydrocarbon plume but outside the area of residual LNAPL present in the smear zone. The TVPH profiles for this well are consistent with cases where there is a limited hydrocarbon source at depth. During some of the monitoring events there is an increase in TVPH concentrations at shallow depths that is attributable to sources near the ground surface. Generally, the concentrations observed in the shallow portions of the vadose zone are similar in areas over dissolved phase hydrocarbons and those outside of the distribution of petroleum hydrocarbons associated with releases from the refinery elsewhere in Hooven.

4.3.3.3 NESTED WELLS OUTSIDE OF LNAPL AND DISSOLVED PHASE HYDROCARBONS

Vertical profiles of TVPH and fixed gases for nested vapor well VW-129 located outside the area of petroleum hydrocarbons associated with the former refinery show that there were not any reported detections of TVPH within the deepest monitoring interval during any of the monitoring events conducted at this well. The vapor profiles for this well are consistent with there being no source present at depth. It is worth noting that several non-petroleum related hydrocarbons including dichlorodifluoromethane and trichlorofluoromethane are measured throughout the vertical profile within this background monitoring well and the other background nested well in Hooven (VW-130). Dichlorodifluoromethane and trichlorofluoromethane were historically used in freon refrigerants and are ubiquitous in the environment. Freon use decreased in the 1980's after federal regulatory agencies banned their use because of their detrimental effects on the ozone layer. Freons are commonly detected at elevated concentrations beneath landfills due to improper disposal practices.

4.4 NATURAL SMEAR ZONE DEPLETION

The rate of NSZD was estimated using the routine monitoring results collected between 2008 and 2011, as described in Appendix B. The data was considered over an extended timeframe to adjust for spatial and temporal variations within the vadose and saturated zones. NSZD rates are calculated as the rate of total petroleum hydrocarbon mass loss over

time. It is not possible to estimate biodegradation rates for individual constituents using the method described herein because the stoichiometric coefficients for each electron acceptor are not constituent specific.

To estimate NSZD for the Chevron Cincinnati facility, the smear zone was divided into four control volumes of roughly square lateral dimensions. These control volumes were selected to provide some discretization of hydrologically different portions of the smear zone as follows:

- CV21 – is the up-gradient portion of the smear zone encompassing the northern tank farm and marketing terminal.
- CV18 – is the "core" of the smear zone. The majority of the process units, southern tank farm, sludge pits, and historical process waste disposal areas were located within this control volume.
- CV20 – during operation of the refinery many of the support/administrative functions and associated structures were located within this control volume. The majority of the community of Hooven overlying the smear zone is also situated within this control volume. Finally, the horseshoe factory, which pre-dated the refinery, was situated within the limits of this control volume. It should be noted that groundwater flowing into this control volume is from both the up-gradient smear zone and also from the Buried Valley Aquifer-Ordovician age bedrock contact to the southwest (referred to as the Hooven area herein).
- CV93 – this control volume includes the off-site commercial area southwest of the refinery (referred to as the Southwest Quad) and several former gravel pits located on and off-site that were subsequently converted to landfills. Similar to control volume CV20, this control volume primarily receives groundwater from the up-gradient portions of the smear zone with a contribution from the Hooven area.

4.4.1 SATURATED ZONE

The estimated NSZD rate in the saturated zone ranges from approximately 1,700 pounds per year (lb/yr) in control volume CV18 to approximately 5,300 lb/yr in control volume CV93, with a total of approximately 15,000 lb/yr across the entire smear zone. The two primary pathways for NSZD within the saturated zone are methanogenesis and sulfate reduction. This indicates that biodegradation of smear zone hydrocarbons in the saturated zone largely occurs under anaerobic conditions. This is to be expected for a LNAPL smear zone with a high oxidant demand that would quickly use the available O_2. On a control volume by control volume basis, methanogenesis is relatively steady, but sulfate reduction is an important process in control volumes CV20 and CV93. This increase in sulfate reduction in the two down-gradient control volumes is due primarily to the presence of this electron acceptor in groundwater that originates from the Buried Valley Aquifer-bedrock contact in Hooven. When this water enters the smear zone, it provides sulfate-rich groundwater and increases the rate of biodegradation. Put another way, the higher estimated NSZD rates in control

volumes CV20 and CV93 are due primarily to the input of sulfate into the smear zone from groundwater originating in the Hooven area.

Other electron acceptors including O_2, nitrate, manganese, and iron provide a minor contribution to NSZD rates, at less than 10% of the total for all four electron acceptors combined. The highest NSZD rates for these electron acceptors are observed in control volume CV93, where the dissolved phase plume is generally reduced to concentrations below the remedial goals. While these electron acceptors may play a relatively minor role in the total mass loss from the smear zone, they are important in maintaining a stable dissolved phase groundwater plume down-gradient of the smear zone beneath the Southwest Quad.

4.4.2 VADOSE ZONE

The estimated NSZD rate in the vadose zone ranges from approximately 2,000 lb/yr in control volume CV93 to approximately 42,400 lb/yr in control volume CV18. The total estimated NSZD in the vadose zone for all four control volumes is approximately 82,100 lb/yr. Each of these control volumes have approximately equal surface areas (i.e., the same size flux planes for vapor transport); therefore, any differences in mass loss rates by control volume can be attributed largely to the source strength. TVPH concentrations measured throughout the vadose zone within control volume CV18 are much higher than those observed in control volume CV93, consistent with the higher source zone concentrations measured in control volume CV18. This may be related to the location of each control volume within the smear zone. The majority of historical refining and waste disposal activities were performed in control volume CV18 while much of the land in control volume CV93 is located off-site and was only recently developed for commercial purposes. In addition, nested well VW-93 is located within the zone of influence of the HSVE and high-grade systems, and the smear zone has been depleted over the past 25 years via engineered recovery. Corrective measures focused in control volume CV18 began in 2010. The higher NSZD rates within the vadose zone in control volume CV18 occurs despite the thinner smear zone and lower rates of diffusion within the finer grained deposits.

The relative importance of aerobic versus anaerobic biodegradation in the vadose zone also varies by control volume. Anaerobic biodegradation (i.e., methanogenesis) is the dominant biodegradation pathway in control volume CV18. In control volumes CV21 and CV20, mass losses from aerobic and anaerobic biodegradation processes are similar in magnitude.

4.5 SUMMARY OF LINES OF EVIDENCE OF NATURAL ATTENUATION

Performance monitoring for any corrective measure is necessary to demonstrate that the remedial action is progressing as anticipated and will meet remedial goals while ensuring that sensitive receptors remain protected. The USEPA has

established additional performance monitoring criteria for remedies incorporating intrinsic natural attenuation processes for degradation of residual impacts (USEPA 1999, USEPA 2004c). Performance monitoring programs in these cases must be designed to:

1. Demonstrate that natural attenuation is occurring according to expectations
2. Detect changes in environmental conditions (e.g., hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of any of the natural attenuation processes
3. Identify any potentially toxic and/or mobile transformation products (such as CH_4 generated within the vadose zone via methanogenesis)
4. Verify that the LNAPL or dissolved phase plume is not expanding down-gradient
5. Verify no unacceptable impact to down-gradient receptors
6. Detect new releases of petroleum or non-petroleum related constituents to the environment that could impact the effectiveness of the natural attenuation remedy

Each of these performance monitoring criteria have been achieved over the first five years of the groundwater corrective measures implementation based upon the qualitative and quantitative lines of evidence used to demonstrate the stability of petroleum hydrocarbons in the smear zone, protectiveness of sensitive receptors, transformation of petroleum hydrocarbon constituents via intrinsic processes, as well as decreasing petroleum hydrocarbon constituent concentrations and mass over time. Many of the lines of evidence provided represent a baseline understanding of the processes acting to attenuate the smear zone for comparison during future five year reviews.

5.0 SUMMARY

This first *Five Year Groundwater Corrective Measures Implementation Review* demonstrates that the groundwater remedy at the Chevron Cincinnati Facility is continuing to reduce hydrocarbon mass and saturations throughout the smear zone through engineered measures and intrinsic processes. Remedial system construction, operations, and monitoring were completed in accordance with the 2006 AOC, *RIP*, and *OMM Plan*. Specifically, the following was completed over the first five years of the final remedy:

- While much of the needed infrastructure for the groundwater corrective measures was in place, additional monitoring locations, engineered controls, and remedial system components as outlined within the *RIP* were installed including additional sentinel and POC groundwater monitoring wells, ROST monitoring transects, nested soil vapor wells, nested groundwater monitoring wells, pore water lysimeters, groundwater production wells PROD_24 and PROD_25, as well as river bank stabilization measures along the Great Miami River on the former refinery and in Gulf Park.
- Three high-grade recovery events have been performed since November 2006, with a single sustained high-grade event completed in the Southwest High-Grade Area in 2007 and one sustained event within the Central Area in 2010. Approximately 250,000 gallons of LNAPL were recovered during the events in 2007, 2009, and 2010 through early 2011. LNAPL recovery efficiency has been greatly improved through high-grade pumping compared to the previous two decades of LNAPL recovery via year-round pump and treat operations at the former refinery.
- It was anticipated that a total of two to four sustained recovery events in each high-grade area would accomplish the goal of reducing the recoverable LNAPL in the lower reaches of the smear zone to a point where further engineered recovery is no longer productive, and should be discontinued. It was recognized that high-grade recovery may not be feasible every year, thus the time frame for high-grade recovery operations was projected to be as long as twelve years. Primary and secondary criteria for determining when high-grade recovery should be discontinued was provided in the *Proposed Criteria for Discontinuing High-Grade LNAPL Recovery under the Final Groundwater Remedy*. Following five years of corrective measures implementation, the first of the primary end-point criterion (frequency of occurrence of LNAPL greater than 0.1-foot within wells) was met within the Southwest High-Grade Area, but not the Central Area. The second primary criterion (change in hydrograph ranking) was not met in either high-grade area; although there has been significant progress towards achieving this criterion within the Southwest Area since 2003 with a decrease in the ranking (and thus occurrence of LNAPL) within most of the monitoring wells, indicating an overall decrease in LNAPL saturations across the Southwest High-Grade Area.

- Since execution of the 2006 AOC, focused operation of the HSVE system in accordance with groundwater triggers has resulted in extraction of approximately 275,000 pounds (22,000 gallons) of hydrocarbons from the smear zone beneath Hooven, with a rate of removal of 455 pounds per day of operation. During the previous six years of operation between 2000 and 2006, approximately 164,000 pounds (20,500 gallons) of hydrocarbons were recovered using the HSVE system, with a removal rate of less than 400 pounds per day. It's anticipated that when the HSVE system is ready to be permanently shut down, the remaining hydrocarbon mass within the influence of the system would diminish to the point where continued operation does not result in reduction of soil vapor concentrations beyond those observed via aerobic biodegradation alone, as can be observed in the vapor source concentration trends for nested soil vapor monitoring well VW-93 (Figure 3-3).
- Biovent system operations continue to reduce residual LNAPL mass beneath Gulf Park. In some portions of the smear zone, aerobic conditions prevail in the vadose zone throughout the year and additional operation of the system will not enhance the rate of smear zone mass depletion beyond that of intrinsic processes. Expansion of the biovent system to the southern portions of the smear zone beneath the Park will allow enhanced removal of LNAPL, where elevated concentrations of petroleum hydrocarbon persist in soil and groundwater.

The USEPA has established performance monitoring criteria for remedies incorporating intrinsic natural attenuation processes (USEPA 1999, USEPA 2004c). These performance monitoring criteria have been used to evaluate the progress of the final groundwater remedy at the Chevron Cincinnati Facility and demonstrate the following:

- The vapor intrusion pathway has remained incomplete beneath Hooven and the Southwest Quad, even under worse case conditions when high-grade pumping is focused beneath Hooven exposing the lower reaches of the smear zone and the HSVE system is not operated in accordance with groundwater triggers. As described in the *Hooven Vapor SCM Update*, alternate sources in the shallow and intermediate portions of the vadose zone beneath portions of Hooven can deplete O_2 before it is able to diffuse to the smear zone in the absence of HSVE system operations. This can result in comingling of volatile constituents and CH_4 from the two sources throughout the vertical profile. Irrespective, concentrations of volatile petroleum hydrocarbons in the vadose zone (with the exception of a few detections within the deepest vapor probes situated in the smear zone) continue to remain below conservative risk based screening levels and there is not an increase in incremental risk for residents in Hooven, tenants within the former elementary school, or occupants of businesses associated with intrusion of volatile constituents from the former refinery.
- ROST and dissolved phase monitoring results verify that the LNAPL and dissolved phase constituents were stable beneath the Southwest Quad and on the facility. Localized changes in dissolved phase conditions have been observed in the Southwest Quad with benzene reported in groundwater samples collected from sentinel monitoring well MW-35 and point of compliance well MW-133 during monitoring in 2008 and 2009. These detections are

likely associated with alternate sources when flow conditions are altered by periodic flooding and rapid re-equilibration of the water table. Based on monitoring performed in the Southwest Quad over the past five years it is concluded that the smear zone limits and dissolved phase plume are stable and there has not been any redistribution of constituents following termination of continuous hydraulic control following execution of the 2006 AOC.

- Dissolved phase monitoring conducted along the west bank of the Great Miami River showed that constituents of concern present in the smear zone are not migrating beneath the partial penetrating barrier wall. The surface water screening standards were not exceeded in any of the hyporheic or surface water samples collected since engineered controls were constructed and sensitive receptors within the river remain protected.
- LNAPL samples collected in 1997, 1999, 2005, and 2010 from four locations across the smear zone demonstrate first order degradation of petroleum hydrocarbon concentrations including benzene over time. As the LNAPL saturation and transmissivity continue to decrease across the smear zone over time, it may become infeasible to collect LNAPL samples for laboratory analysis. As a result, smear zone soil coring is being conducted to provide a means of measuring LNAPL composition, with the first coring events performed in 2008 and 2009. Soil coring performed in Hooven indicates that LNAPL saturations have been significantly reduced over time. LNAPL is only present at the base of the smear zone near monitoring well MW-96, and is no longer observed near monitoring well MW-93.
- Vapor phase natural attenuation indicators continue to demonstrate that intrinsic biodegradation is occurring within the vadose zone above the smear zone. First order degradation is observed in the vapor source beneath Hooven since 1997, with a two to five order of magnitude decrease in benzene and total petroleum hydrocarbon concentrations. This decrease in concentrations is attributable to a combination of NSZD as well as operation of groundwater, LNAPL, and soil vapor recovery systems in Hooven beginning in 1999. It should be noted that reduction in volatile petroleum-related constituent concentrations has been more significant in well VW-93 compared to wells VW-96 and VW-99, despite the fact that the extraction line closest to well VW-93 has been run less than half of the number of days as the extraction lines nearest wells VW-96 and VW-99. Additionally, alternate sources of petroleum hydrocarbons have not been observed in the soil vapor profiles from well VW-93; therefore O_2 transport and aerobic biodegradation is not limited within the deeper portions of the vadose zone near this well.
- Individual well and area wide trend analyses performed using data collected from the groundwater monitoring wells across the smear zone also demonstrate first order degradation of benzene associated with both natural attenuation and engineered mass removal. Decreasing dissolved phase constituent trends are more pronounced at the margins of the smear zone compared to the interior portion of the plume. At its margins, the smear zone is

thinner and LNAPL saturations are lower. In addition, groundwater enriched in electron acceptors intercepts the smear zone north of the facility and again to the southeast of the Buried Valley Aquifer-bedrock interface in Hooven creating a situation whereby petroleum hydrocarbons including benzene are attenuated more quickly along the margins than within the interior of the smear zone. These observations are consistent with the expectation of outside-in attenuation of petroleum hydrocarbons within the smear zone.

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TABLES

TABLE 1-1. ROUTINE MONITORING SCHEDULE
FIVE YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Monitoring Type	2008												2009												2010												2011					
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Groundwater Monitoring within Perimeter Wells				X							X					X						X							X					X							X	
Groundwater Monitoring within Sentinel Wells	X1			X			X1				X			X1		X			X1			X							X					X							X	
Groundwater Monitoring within POC Wells	X1			X			X1				X			X1		X			X1			X							X					X							X	
Groundwater Monitoring within Interior Plume				X							X					X						X							X												X	
Groundwater Monitoring within Nested Wells												X																														X	
Lysimeter Monitoring																	X							X					X							X							X
Groundwater Monitoring within Supplemental Southwest Quad Wells															X	X			X			X				X			X			X							X			
Groundwater Monitoring from Select Southwest Quad Wells														X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X		X	
ROST/UVOST Monitoring						X						X						X						X						X						X						X
Surface Water Sampling				X																																						
Groundwater Monitoring from Barrier Wells (COC)															X			X			X			X			X		X				X		X							X
Groundwater Monitoring from Barrier Wells (MNA)																		X						X					X						X							
LNAPL/Soil Core Analysis											X						X																X			X						
Groundwater Monitoring in Gulf Park (COCs)							X											X											X													
Groundwater Monitoring in Gulf Park (MNA)																		X											X													
Soil Vapor Monitoring from Nested Wells				X					X			X									X											X										
Soil Vapor Monitoring of Select Intervals within VW-96 and VW-99																																X	X	X	X	X	X	X				
HSVE Influent and Effluent Vapor Monitoring																						X	X	X								X	X	X	X	X	X	X				

Notes:
X - monitoring performed during the indicated month
X1 - monitoring performed in newly installed Southwest Quad wells

TABLE 3-1. LNAPL RECOVERY EFFICIENCY COMPARISON
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Production Well	High-Grade Recovery Area	High-Grade Pumping Start Date	High-Grade Pumping End Date	Cumulative LNAPL Recovered (gallons)	Average Daily LNAPL Recovery Rate (gpd)	Average Daily Groundwater Extraction Rate (gpd)	LNAPL Removal Efficiency (gallons / mega-gallon)
PROD_19	Southwest	7/11/07	12/14/07	67,808	435	2,667,720	163
PROD_20	Southwest	8/19/09	11/30/09	24,015	233	4,108,065	57
PROD_25	Central	8/10/10	2/28/11	143,677	855	3,060,094	279

NOTES:

gpd - gallons per day

gpm - gallons per minute

LNAPL Removal Efficiency - gallons of LNAPL recovered per million gallons of groundwater extracted.

TABLE 3-2. HIGH-GRADE TRIGGER LEVELS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

SOUTHWEST HIGH-GRADE AREA TRIGGER LEVELS AFTER 2009 HIGH-GRADE EVENT

Monitoring Well	Historical Low Groundwater Elevation (ft-amsl)	Date of Historical Low Groundwater Elevation	Drawdown 2005 Production Well PROD_20 (feet)	Drawdown 2006 Production Well PROD_19 (feet)	Drawdown 2007 Production Well PROD_19 (feet)	Drawdown 2009 Production Well PROD_20 (feet)	Initial High-Grade Trigger[1] (ft-amsl)	Revised Pumping Trigger (ft-amsl)[1]
MW-20S	458.20	10/16/2009	3.60	4.20	4.21	5.24	464.80	463.44
MW-93S	460.66	10/16/2009	3.90	1.30	2.47	2.55	466.20	464.56
MW-96S	459.38	10/16/2009	3.60	2.40	3.47	3.21	465.90	462.98
MW-99S	459.09	10/1/2007	3.40	3.50	3.59	2.31	465.50	462.68

CENTRAL HIGH-GRADE AREA TRIGGER LEVELS AFTER 2010 HIGH-GRADE EVENT

Monitoring Well	Historical Low Groundwater Elevation (ft-amsl)	Date of Historical Low Groundwater Elevation	Maximum Drawdown PROD_25 (feet)	Revised Pumping Trigger (ft-amsl)[2]
MW-18R	463.41	11/22/1999	4.84	468.25
MW-40	463.40	9/24/1999	4.66	468.06
MW-56	462.56	9/24/1999	4.58	467.14
MW-57	463.00	11/22/1999	3.98	466.98
MW-79	463.54	11/22/1999	5.17	468.71

NOTES:

[1] - Initial high-grade trigger described in the *Remedy Implementation Plan for Final Groundwater Remedy, Chevron Cincinnati Facility* (Trihydro 2007a) and *Operations, Maintenance and Monitoring Plan for Final Groundwater Remedy, Chevron Cincinnati Facility* (Trihydro 2007b)

[2] - Pumping Trigger based on historic low groundwater elevation plus maximum observed drawdown (corrected for ambient groundwater conditions) during the 2010 high grade period.

ft-amsl - feet above mean sea level

TABLE 3-3. SUMMARY OF PROPOSED HIGH-GRADE RECOVERY END-POINTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

End-Point No.	High-Grade Recovery End-Point	Conditions
Primary Criteria - Both 1 and 2 must be met		
1	Percent of Wells in High-Grade Area with Greater than 0.1-foot of LNAPL	Less than 10% of measurements of wells within High-Grade Area exhibit greater than 0.1-foot LNAPL under non-pumping condition and less than 20% of measurements of wells greater than 0.1-foot during high-grade pumping, based on monthly measurements throughout the year
2	Hydrograph Evaluation	10 of 12 wells in the Southwest High-Grade Area, and 7 of 8 wells in the Central Area transitioned to Type 1 or 0 hydrograph
Secondary Criteria - One of 3 through 5 must be met		
3	Groundwater versus LNAPL Recovery Ratio	Over a full high-grade season, groundwater/LNAPL recovery ratio exceeds 40,000:1
4	Carbon Dioxide versus LNAPL Recovery Ratio	Over a full high-grade season, carbon dioxide produced/gallons LNAPL recovered ratio exceeds 75:1
5	Smear Zone Natural Depletion versus Engineered Recovery Ratio	During a high grade year, smear zone natural depletion/engineered LNAPL recovery ratio exceeds 1:1

NOTE:

Given uncertainty regarding the practicality of achieving some of the above proposed criteria, high-grade recovery operations will be considered complete when metrics one and two, and either three, four or five have been met within a High-Grade Area

TABLE 3-4. PERCENTAGE OF MEASUREMENTS WITH LNAPL THICKNESS GREATER THAN 0.10 FOOT
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

		2007 - HG			2008 - No HG			2009 - No Central HG			2010 - HG		
	Location	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage
Central High-Grade Area	L-7	0	10	0.0%	0	6	0.0%	0	8	0.0%	0	11	0.0%
	MW-18R	2	8	25.0%	0	6	0.0%	0	9	0.0%	5	11	45.5%
	MW-19	6	8	75.0%	5	9	55.6%	0	6	0.0%	4	10	40.0%
	MW-40	1	8	12.5%	0	9	0.0%	0	6	0.0%	4	11	36.4%
	MW-56	0	8	0.0%	0	9	0.0%	0	6	0.0%	4	11	36.4%
	MW-57	2	8	25.0%	0	9	0.0%	0	6	0.0%	4	10	40.0%
	MW-58S	7	8	87.5%	6	9	66.7%	6	8	75.0%	8	11	72.7%
	MW-79	0	6	0.0%	0	6	0.0%	0	6	0.0%	6	11	54.5%
	Total	18	64	28.1%	11	63	17.5%	6	55	10.9%	35	86	40.7%
	End-point Criterion Pass/Fail?			FAIL (>20%)			FAIL (>10%)			FAIL (>10%)			FAIL (>20%)

		2007 - HG			2008 - No HG			2009 - HG			2010 - HG		
	Location	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage	# Months with Measurement >0.1 foot	# Months with Measurement(s)	Percentage
Southwest High-Grade Area	MW-20S	6	12	50.0%	2	12	16.7%	4	12	33.3%	5	13	38.5%
	MW-24	1	6	16.7%	0	6	0.0%	1	6	16.7%	0	10	0.0%
	MW-52	0	6	0.0%	0	6	0.0%	0	6	0.0%	0	7	0.0%
	MW-81S	4	10	40.0%	0	5	0.0%	2	11	18.2%	0	11	0.0%
	MW-92S	2	6	33.3%	0	3	0.0%	2	8	25.0%	0	7	0.0%
	MW-93S	0	10	0.0%	0	5	0.0%	0	11	0.0%	0	13	0.0%
	MW-96S	6	10	60.0%	4	12	33.3%	5	12	41.7%	4	13	30.8%
	MW-98S	0	9	0.0%	0	6	0.0%	0	6	0.0%	0	9	0.0%
	MW-99S	6	10	60.0%	1	6	16.7%	5	9	55.6%	5	11	45.5%
	MW-112	2	12	16.7%	0	12	0.0%	0	12	0.0%	0	13	0.0%
	MW-121	5	7	71.4%	0	5	0.0%	0	9	0.0%	1	7	14.3%
	MW-140	NA	NA	NA	NA	NA	NA	3	8	37.5%	2	9	22.2%
	Total	32	98	32.7%	7	78	9.0%	22	110	20.0%	17	123	13.8%
	End-point Criterion Pass/Fail?			FAIL (>20%)			PASS (<10%)			PASS (<20%)			PASS (<20%)

NOTE:

Pass or fail determinations for the end-point criterion involves the percent of fluid measurements greater than 0.10-foot of LNAPL as defined by the following:

1. During years in which high-grade pumping is performed, "PASS" indicates less than 20% of the monthly LNAPL thickness measurements within monitoring wells located in a high-grade area are greater than 0.10-foot throughout the year
2. During years in which high-grade pumping is not performed, "PASS" indicates less than 10% of the monthly LNAPL thickness measurements within monitoring wells located in a high-grade area are greater than 0.10-foot throughout the year

TABLE 3-5. HYDROGRAPH RANKINGS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

	Location	Hydrograph Rank Conceptual Groundwater Remedy Report, July 2003	Hydrograph Rank 2008	Hydrograph Rank 2010
Southwest High-Grade Area	MW-20S	3	2	2
	MW-24	2	1	1
	MW-52	1	0	0
	MW-81S	NA	NA	2
	MW-92S	3	1	1
	MW-93S	3	0	0
	MW-96S	3	2	3
	MW-98S	2	0	0
	MW-99S	3	2	2
	MW-112	1	1	0
	MW-121	3	2	2
	MW-126	3	2	NA
	MW-140	NA	NA	2
	Total End-Point Criterion Pass/Fail?	2 of 12 FAIL (<10 of 12)	6 of 12 FAIL (<10 of 12)	6 of 12 FAIL (<10 of 12)

NOTE:

Pass or fail determinations for the end-point criterion involves periodic re-ranking of the hydrographs for monitoring wells within a high-grade area. For the Southwest Area, hydrograph rankings must be 0 or 1 for ten or more of the twelve groundwater monitoring wells for this criterion to reach a "PASS" determination

TABLE 3-6. SUMMARY OF HSVE OPERATION AND PETROLEUM HYDROCARBONS RECOVERED
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Year	Days of Operation			Cumulative Days of Operation[1]	Petroleum Hydrocarbons Recovered (lbs)	Average Mass Removal Rate (lbs/day)
	Line No. 1	Line No. 2	Line No. 3			
1999	38	0	0	38	120,000	3,158
2000	218	0	0	218	135,000	619
2001	30	29	198	253	42,500	168
2002	27	20	87	122	58,000	475
2003	0	0	9	9	2,200	244
2004	0	44	0	44	22,200	505
2005	33	42	40	55	14,500	264
2006	1	3	34	35	24,300	694
2007	70	17	85	164	78,850	481
2008	0	0	0	0	0	0
2009	23	43	28	63	34,000	540
2010	50	25	112	183	62,990	344
Total	490	223	593	1,184	594,540	502

NOTES:

[1] - Multiple lines may be operated simultaneously during HSVE system operation. The cumulative days of operation represents the number of days the system was operating and not the total operation summed from operation of each individual line

lbs - pounds

lbs/day - pounds per day

TABLE 3-7. SUMMARY OF GULF PARK BIOVENT SYSTEM OPERATIONS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Year	Average Flow Across Biovent Lines (scfm)	Days of Operation	Minutes of Operation	Cumulative Air Injected into Subsurface (scf)
2006	1,600	102	147,130	244,999,014
2007	1,770	172	247,700	441,528,885
2008	1,814	145	209,140	397,443,140
2009	1,866	234	337,030	629,795,739
2010	1,886	188	271,275	515,106,697
Total	1,787	842	1,212,275	2,228,873,475

NOTES:

scfm - standard cubic feet per minute

scf - standard cubic feet

TABLE 3-8. SUMMARY OF GULF PARK BIOVENT SYSTEM RESPIROMETRY TESTING
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Vapor Well	Oxygen Depletion Rate (% per day)	Biodegradation Rate (mg/kg-day)
VP1-50S	0.212	0.17
VP1-50D	0.207	0.16
VP2-50S	3.969	3.14
VP2-50D	2.766	2.19
VP3-35S	0.140	0.11
VP3-35D	0.270	0.21
VP4-25S	0.525	0.42
VP4-25D	0.533	0.42
VP-8S	1.430	1.13
VP-8D	5.837	4.62
VP-9S	0.299	0.24
VP-9D	0.309	0.24
VP-10S	0.121	0.10
VP-10D	0.265	0.21
VP-11S	0.177	0.14
VP-11D	0.246	0.19
VP-12S	0.446	0.35
VP-12D	0.636	0.50
VP-13S	0.911	0.72
VP-13D	0.943	0.75
VP-14S	0.370	0.29
VP-14D	0.532	0.42

Notes:

% - percent

mg/kg - milligrams per kilogram

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-26R	11/25/08	0.003 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	0.0008 J	ND(0.01)	ND(0.0069)
	3/27/09	0.007	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	11/12/09	ND(0.0005)	ND(0.0008) J	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/11/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	10/21/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	5/18/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012) J
MW-35	11/19/08	0.13	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
Dup	11/19/08	0.13	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	2/17/09	0.021	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/3/09	0.021	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
Dup	4/3/09	0.021	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/28/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	5/27/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	6/29/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	7/21/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	8/11/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	9/14/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	10/12/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
Dup	10/12/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	11/17/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	12/11/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	1/12/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	2/23/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	3/29/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	4/21/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/4/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
Dup	5/4/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	6/15/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	7/14/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-35	8/25/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	9/28/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	10/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	3/22/11	ND(0.00051)	ND(0.00051)	0.0012	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
	5/11/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
MW-37	11/18/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/2/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	10/20/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.003 JB	ND(0.0069)
	5/5/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0086 J	ND(0.0069)
	10/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	5/16/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
	6/2/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
Dup	6/2/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
MW-94S	12/8/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
Dup	12/8/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/2/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	5/6/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0166J/ND(0.0166)U*	ND(0.0069)
	10/19/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	5/17/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
MW-115S	12/9/08	ND(0.0005)	ND(0.0008)	0.0008 J	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/3/09	0.009	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	10/12/09	0.0008 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0109 J	ND(0.0069)
	5/5/10	0.011	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0185 J	ND(0.0069)
	10/20/10	0.003 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0142 J	ND(0.0069)
	5/11/11	0.01	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	0.011 JB	ND(0.0012)

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-120	11/18/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/1/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	10/7/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	3/29/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
Dup	3/29/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	4/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/5/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	6/14/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
Dup	6/14/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	7/13/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	8/24/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	9/29/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	10/19/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	3/22/11	ND(0.00051)	ND(0.00051)	0.0016	ND(0.00048)	0.0014	ND(0.00024)	ND(0.0012)
	5/17/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
MW-131	11/21/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0155 J	0.0225
	2/18/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0144 J	ND(0.0069)
	4/2/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	7/23/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.01 J	ND(0.0069)
	10/20/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0266/ND(0.0266)U*	ND(0.0069)
	5/6/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0252 JB	ND(0.0069)
Dup	5/6/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0174J/ND(0.0174)U*	ND(0.0069)
	10/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0147 J	ND(0.0069)
	5/16/11	0.0078	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
	6/1/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	0.02 JB	ND(0.0012)
	11/17/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	2/19/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	3/30/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
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CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-132	7/20/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
Dup	7/20/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	10/5/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/5/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
Dup	5/5/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	10/19/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	5/17/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
MW-133	11/18/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	2/17/09	0.003 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/1/09	0.11	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/28/09	0.036	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	5/26/09	0.032	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	6/29/09	0.11	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	7/21/09	0.051	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	8/11/09	0.031	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	9/14/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	10/8/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	11/17/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	12/11/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	1/12/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	2/23/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	3/29/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	4/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/4/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	6/14/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	7/13/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
Dup	7/13/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	8/24/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	9/27/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-133	10/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
Dup	10/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	3/22/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
	5/17/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
MW-134	11/17/08	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	2/19/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	3/30/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	7/20/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	10/5/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/5/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0104 J	ND(0.0069)
	10/19/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	5/17/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
MW-138	3/31/09	0.005 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.01)	ND(0.0069)
	4/28/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	5/28/09	0.002 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	6/29/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	7/21/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	8/12/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	9/15/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	10/7/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	11/18/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	12/14/09	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	1/13/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	2/23/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	3/30/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	4/21/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/4/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	6/14/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-138	7/14/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	8/25/10	0.001 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	9/28/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	10/20/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	3/23/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
	5/18/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012) J
MW-139	3/31/09	0.15	ND(0.0008)	ND(0.0008)	0.005 J	0.005 J	0.0122 J	ND(0.0069)
	4/28/09	0.019	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	4/28/09	0.098	ND(0.0008)	ND(0.0008)	0.003 J	0.003 J	--	--
	5/28/09	0.085	ND(0.0008)	ND(0.0008)	0.003 J	0.003 J	--	--
	6/30/09	0.11	ND(0.0008)	0.0009 J	0.005 J	0.004 J	0.0126 J	ND(0.0069)
	7/21/09	0.12	ND(0.0008)	0.001 J	0.006	0.005 J	0.0175 J	ND(0.0069)
	8/12/09	0.12	ND(0.0008)	ND(0.0008)	0.006	0.005 J	0.0164 J	ND(0.0069)
	9/15/09	0.048	ND(0.0008)	ND(0.0008)	0.002 J	0.0009 J	0.0097 J	ND(0.0069)
	10/7/09	0.017	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0131 J	ND(0.0069)
	11/18/09	0.002 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	12/14/09	0.004 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	1/13/10	0.0009 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	--	--
	2/24/10	ND(0.0005)	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0095 J	ND(0.0069)
	3/30/10	0.004 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	4/21/10	0.007	ND(0.0008)	0.001 J	ND(0.0007)	ND(0.0008)	ND(0.0072)	ND(0.0069)
	5/4/10	0.009	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0117 J	ND(0.0069)
	6/14/10	0.002 J	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	ND(0.0098)	ND(0.0069)
	7/14/10	0.026	ND(0.0008)	0.003 J	0.002 J	0.004 J	0.0104 J	ND(0.0069)
	8/25/10	0.05	ND(0.0008)	ND(0.0008)	0.003 J	0.003 J	0.0177 J	ND(0.0069)
	9/28/10	0.023	ND(0.0008)	ND(0.0008)	0.001 J	0.001 J	0.0242	ND(0.0069)
Dup	9/28/10	0.024	ND(0.0008)	ND(0.0008)	0.001 J	0.001 J	0.0241	ND(0.0069)
	10/20/10	0.009	ND(0.0008)	ND(0.0008)	ND(0.0007)	ND(0.0008)	0.0212	ND(0.0069)

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-139	3/23/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
Dup	3/23/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	ND(0.0012)
	5/18/11	0.013	ND(0.00051)	0.0031	0.0017	0.0037	0.01 J	0.0085 J
MW-140	3/27/09	0.35	ND(0.002)	0.43	0.041	0.55	ND(0.01)	ND(0.0069)
	7/10/09	33 J	ND(2) J	2000 J	30 J	--	--	--
	6/15/10	0.12	ND(0.0008)	0.013	0.004 J	0.033	ND(0.0098)	ND(0.0069)
	3/23/11	0.033	ND(0.00051)	0.016	0.0054	0.024	0.007	ND(0.0012) J
MW-141	4/1/09	0.51	ND(0.002)	0.06	0.013	0.039	ND(0.01)	ND(0.0069)
Dup	4/1/09	0.52	ND(0.002)	0.062	0.013	0.042	ND(0.01)	ND(0.0069)
	7/23/09	0.4	ND(0.0008)	0.017	0.011	0.016	ND(0.0072)	ND(0.0069)
	10/13/09	0.29	ND(0.0008)	0.045	0.01	0.032	0.0131 J	ND(0.0069)
	2/24/10	0.19	ND(0.0008)	0.014	0.006	0.015	ND(0.0072)	ND(0.0069)
Dup	2/24/10	0.18	ND(0.0008)	0.014	0.006	0.015	ND(0.0072)	ND(0.0069)
	5/5/10	0.14	ND(0.0008)	0.019	0.008	0.024	0.0094 J	ND(0.0069)
	8/26/10	0.13	ND(0.002)	0.009 J	0.005 J	0.008 J	ND(0.0098)	ND(0.0069)
	3/23/11	0.0071	ND(0.00051)	ND(0.00068)	ND(0.00048)	0.0018	ND(0.00024)	ND(0.0012) J
	5/19/11	ND(0.00051)	ND(0.00051)	ND(0.00068)	ND(0.00048)	ND(0.00073)	ND(0.00024)	0.0072 J
MW-142	3/31/09	0.13	ND(0.002)	0.39	0.028	0.35	0.0166 J	ND(0.0069)
	5/28/09	0.12	ND(0.0008)	0.53	0.025	0.31	--	--
	6/30/09	0.31	ND(0.0008)	0.023	0.014	0.056	0.0212	ND(0.0069)
	7/23/09	0.27	ND(0.0008)	0.045	0.015	0.061	0.0254	ND(0.0069)
	8/12/09	0.21	ND(0.002)	0.31	0.022	0.21	0.0172 J	ND(0.0069)
	9/15/09	0.15	ND(0.0008)	0.15	0.019	0.13	0.0219	ND(0.0069)
	10/13/09	0.11	ND(0.0008)	0.19	0.021	0.17	0.0211	ND(0.0069)
	11/18/09	0.043	ND(0.002)	0.052	0.011 JB	0.058	--	--
	12/14/09	0.035	ND(0.0008)	0.12	0.013	0.13	--	--

TABLE 4-1. SOUTHWEST QUAD DISSOLVED PHASE ANALYTICAL RESULTS SUMMARY (NOVEMBER 2008 TO JUNE 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Benzene (mg/L)	Chlorobenzene (mg/L)	Ethylbenzene (mg/L)	Toluene (mg/L)	Xylenes, Total (mg/L)	Arsenic, Dissolved (mg/L)	Lead, Dissolved (mg/L)
MW-142	1/13/10	0.084	ND(0.002)	0.023	0.006 J	0.027	--	--
Dup	1/13/10	0.085	ND(0.002)	0.023	0.006 J	0.027	--	--
	2/24/10	0.09	ND(0.0008)	0.2	0.017	0.11	0.0211	ND(0.0069)
	3/30/10	0.066	ND(0.0008)	0.039	0.009	0.042	0.0194 J	ND(0.0069)
	4/20/10	0.13	ND(0.0008)	0.061	0.014	0.073	0.0267	ND(0.0069)
Dup	4/20/10	0.13	ND(0.0008)	0.061	0.013	0.074	0.0249	ND(0.0069)
	5/4/10	0.12	ND(0.002)	0.18	0.016	0.15	0.0203	ND(0.0069)
	6/15/10	0.16	ND(0.0008)	0.036	0.013	0.062	0.0192 J	ND(0.0069)
	7/13/10	0.16	ND(0.0008)	0.037	0.011	0.061	0.023	ND(0.0069)
	8/26/10	0.1	ND(0.002)	0.004 J	0.008 J	0.031	0.0211	ND(0.0069)
Dup	8/26/10	0.1	ND(0.002)	0.004 J	0.008 J	0.031	0.0201	ND(0.0069)
	9/28/10	0.11	ND(0.0008)	0.024	0.012	0.047	0.0212	ND(0.0069)
	10/20/10	0.15	ND(0.0008)	0.072	0.014	0.07	0.0226	ND(0.0069)
Dup	10/20/10	0.16	ND(0.0008)	0.074	0.015	0.073	0.0243	ND(0.0069)
	3/23/11	0.02	ND(0.00051)	0.052	0.0053	0.033	0.012	ND(0.0012)
	5/18/11	0.067	ND(0.00051)	0.11	0.0098	0.048	0.013	0.012 J
Dup	5/18/11	0.067	ND(0.00051)	0.11	0.0098	0.047	0.014	0.012 J

NOTES:

The method detection limit was used as the reporting limit.

-- - Not analyzed

Dup - Duplicate sample

J - Estimated concentration

JB - Estimated concentration due to detection of analyte within the method blank.

mg/L - milligram per liter

ND - Not detected at the indicated laboratory reporting limit or the method detection limit.

* - The first result represents the laboratory reported concentration. The second result was evaluated to be undetected at the reported concentration during validation due to detection of the analyte within the method blank.

TABLE 4-2. SCREENING EVALUATION FOR NESTED SOIL VAPOR RESULTS, GASOLINE RELATED CONSTITUENTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Nested Vapor Monitoring Well	Date	Depth	Dilution Factor	n-Butyl-benzene mg/m^3	sec-Butyl-benzene mg/m^3	Isopropyl-benzene mg/m^3	n-Propyl-benzene mg/m^3	1,2-Dichloro-ethane mg/m^3	1,2-Dibromo-ethane mg/m^3	MTBE mg/m^3	Naphthalene mg/m^3	Benzene mg/m^3	Toluene mg/m^3	Ethyl-benzene mg/m^3	m,p-Xylene mg/m^3	o-Xylene mg/m^3	Cyclo-hexane mg/m^3	Hexane mg/m^3	Heptane mg/m^3	Styrene mg/m^3	2,2,4-Trimethyl-pentane mg/m^3	1,3,5-Trimethyl-benzene mg/m^3	1,2,4-Trimethyl-benzene mg/m^3	1,3-Butadiene mg/m^3	4-Ethyl-toluene mg/m^3	Butane mg/m^3	Isopentane mg/m^3	Methyl cyclohexane mg/m^3
VW-93	Apr 2008	20	2.58	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052) J	ND(0.0099)	ND(0.0046)	ND(0.027) J	ND(0.0041)	0.011 J	ND(0.0056)	0.012 J	ND(0.0056)	ND(0.0044)	ND(0.0045) J	ND(0.0053) J	ND(0.0055)	ND(0.006)	ND(0.0063)	ND(0.0063)	ND(0.0028)	ND(0.0063)	--	--	--
		20 Dup	2.58	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052) J	ND(0.0099)	ND(0.0046)	ND(0.027) J	ND(0.0041)	ND(0.0049) J	ND(0.0056)	ND(0.0056) J	ND(0.0056)	ND(0.0044)	ND(0.0045) J	ND(0.0053) J	ND(0.0055)	ND(0.006)	ND(0.0063)	ND(0.0063)	ND(0.0028)	ND(0.0063)	--	--	--
		25	2.33	ND(0.026)	ND(0.026)	ND(0.0057) J	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024) J	ND(0.0037)	ND(0.0044)	ND(0.005) J	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048) J	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	--	--	--
		30	2.42	ND(0.026)	ND(0.026)	ND(0.0059) J	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025) J	ND(0.0039)	ND(0.0046)	ND(0.0052) J	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005) J	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	--	--	--
		35	2.29	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024) J	ND(0.0036)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.0039)	ND(0.004)	ND(0.0047) J	ND(0.0049)	ND(0.0053)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	--	--	--
		40	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026) J	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052) J	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	--	--	--
		45	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049) J	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	--	--	--
		50	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026) J	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	0.02	ND(0.0051) J	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	--	--	--
		55	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026) J	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052) J	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	--	--	--
	Sep 2008	20	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026)	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		20 Dup	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.014)	ND(0.02)
		25	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	0.0047 JB	0.011	ND(0.0048)	0.0062	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		30	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
		35	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	0.006 JB	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	0.041	ND(0.019)
		40	2.29	ND(0.025)	ND(0.025)	0.0061	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	0.046	ND(0.0036)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0053)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		45	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.014)	ND(0.02)
		50	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)
		55	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)
		60	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
	Dec 2008	20	2.02	ND(0.022)	ND(0.022)	ND(0.005)	0.0059 J	ND(0.0041)	ND(0.0078)	ND(0.0036)	ND(0.021)	ND(0.0032)	0.16	0.035	0.15	0.059	ND(0.0035)	ND(0.0036)	0.0074	ND(0.0043)	ND(0.0047)	0.0067	0.014	ND(0.0022)	0.021	ND(0.0096)	ND(0.012)	ND(0.016)
		25	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022)	0.0056	0.043	0.012	0.052	0.022	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0044)	ND(0.0049)	0.0067	0.021	ND(0.0023)	0.02	ND(0.0099)	ND(0.012)	ND(0.017)
		30	2.13	ND(0.023)	ND(0.023)	ND(0.0052)	ND(0.0052)	ND(0.0043)	ND(0.0082)	ND(0.0038)	ND(0.022)	ND(0.0034)	ND(0.004)	ND(0.0046)	ND(0.0046)	ND(0.0046)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0045)	ND(0.005)	ND(0.0052)	ND(0.0052)	ND(0.0024)	ND(0.0052)	ND(0.01)	ND(0.012)	ND(0.017)
		35	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		40	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	0.11	0.0057	0.031	0.0076	0.029	0.035	ND(0.0036)	ND(0.0037)	ND(0.0043)	0.013	ND(0.0049)	ND(0.0051)	0.018	ND(0.0023)	0.014	ND(0.0099)	ND(0.012)	ND(0.017)
		45	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		50	2.13	ND(0.023)	ND(0.023)	ND(0.0052)	ND(0.0052)	ND(0.0043)	ND(0.0082)	ND(0.0038)	ND(0.022)	0.0043	ND(0.004)	ND(0.0046)	ND(0.0046)	ND(0.0046)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0045)	ND(0.005)	ND(0.0052)	ND(0.0052)	ND(0.0024)	ND(0.0052)	ND(0.01)	ND(0.012)	ND(0.017)
		55	2.02	ND(0.022)	ND(0.022)	ND(0.005)	ND(0.005)	ND(0.0041)	ND(0.0078)	ND(0.0036)	ND(0.021)	ND(0.0032)	ND(0.0038)	ND(0.0044)	ND(0.0044)	ND(0.0044)	ND(0.0035)	ND(0.0036)	0.0042	ND(0.0043)	ND(0.0047)	ND(0.005)	ND(0.005)	ND(0.0022)	ND(0.005)	ND(0.0096)	ND(0.012)	ND(0.016)
		55 Dup	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		60	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022)	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0044)	ND(0.0049)	ND(0.0051)	ND(0.0051)	ND(0.0023)	ND(0.0051)	ND(0.0099)	ND(0.012)	ND(0.017)
	Sep/Oct 2009	20	2.31	ND(0.025)	ND(0.025)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.0089)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.018)
		25	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		30	2.41	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0092)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	ND(0.011)	ND(0.014)	ND(0.019)
		35	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		40	2.37	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0051)	ND(0.0051)	ND(0.0051)	ND(0.0041)	ND(0.0042)	ND(0.0048)	ND(0.005)	ND(0.0055)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
		45	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025)	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	ND(0.012)	ND(0.014)	ND(0.019)
		50	2.44	0.027 J	ND(0.027)	ND(0.006)	0.0078 J	ND(0.0049)	ND(0.0094)	ND(0.0044)	ND(0.026)	0.008 J	0.079 J	0.026 J	0.11 J	0.048 J	ND(0.0042)	ND(0.0043)	0.0052 J	ND(0.0052)	ND(0.0057)	0.022 J	0.065 J	ND(0.0027)	0.052 J	ND(0.012)	ND(0.014)	ND(0.02)
		50 Dup	2.44	ND(0.027)	ND(0.027)	0.014 J	0.037 J	ND(0.0049)	ND(0.0094)	ND(0.0044)	ND(0.026)	ND(0.0039)	0.38 J	0.12 J	0.57 J	0.25 J	ND(0.0042)	ND(0.0043)	0.022 J	ND(0.0052)	ND(0.0057)	0.062 J	0.14 J	ND(0.0027)	0.15 J	ND(0.012)	ND(0.014)	0.045 J
		55	2.44	ND(0.027)	ND(0.027)	ND(0.006)	ND(0.006)	ND(0.0049)	ND(0.0094)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0053)	ND(0.0053)	ND(0.0053)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0057)	ND(0.006)	ND(0.006)	ND(0.0027)	ND(0.006)	ND(0.012)	ND(0.014)	ND(0.02)
		60	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025)	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	ND(0.012)	ND(0.014)	ND(0.019)
	Aug 2010	20	2.48	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0045)	ND(0.026) J	ND(0.004)	ND(0.0047)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0043)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.015)	ND(0.02)
		30	2.64	ND(0.029)	ND(0.029)	ND(0.0065)	ND(0.0065)	ND(0.0053)	ND(0.01)	ND(0.0048)	ND(0.028) J	ND(0.0042)	ND(0.005)	ND(0.0057)	ND(0.0057)	ND(0.0057)	ND(0.0045)	ND(0.0046)	ND(0.0054)	ND(0.0056)	ND(0.0062)	ND(0.0065)	ND(0.0065)	ND(0.0029)	ND(0.0065)	ND(0.012)	ND(0.016)	ND(0.021)
		40	2.89	ND(0.032)	ND(0.032)	ND(0.0071)	ND(0.0071)	ND(0.0058)	ND(0.011)	ND(0.0052)	ND(0.03) J	ND(0.0046)	ND(0.0054)	ND(0.0063)	0.012	0.0063	ND(0.005)	ND(0.0051)	ND(0.0059)	ND(0.0062)	ND(0.0068)	ND(0.0071)	0.0084	ND(0.0032)	ND(0.0071)	ND(0.014)	ND(0.017)	ND(0.023)
		50	2.46	ND(0.027)	ND(0.027)	ND(0.006)	ND(0.006)	ND(0.005)	ND(0.0094)	ND(0.0044)	ND(0.026) J	ND(0.0039)	ND(0.0046)	ND(0.0053)	ND(0.0053)	ND(0.0053)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0057)	ND(0.006)	ND(0.006)	ND(0.0027)	ND(0.006)	ND(0.012)	ND(0.014)	ND(0.02)
		50 DUP	2.39	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0048)	ND(0.0092)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0026)	ND(0.0059)	ND(0.011)	ND(0.014)	ND(0.019)
		60	2.48	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0045)	ND(0.026) J	ND(0.004)	ND(0.0047)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0043)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.015)	ND(0.02)

TABLE 4-2. SCREENING EVALUATION FOR NESTED SOIL VAPOR RESULTS, GASOLINE RELATED CONSTITUENTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Nested Vapor Monitoring Well	Date	Depth	Dilution Factor	n-Butyl-benzene mg/m^3	sec-Butyl-benzene mg/m^3	Isopropyl-benzene mg/m^3	n-Propyl-benzene mg/m^3	1,2-Dichloro-ethane mg/m^3	1,2-Dibromo-ethane mg/m^3	MTBE mg/m^3	Naphthalene mg/m^3	Benzene mg/m^3	Toluene mg/m^3	Ethyl-benzene mg/m^3	m,p-Xylene mg/m^3	o-Xylene mg/m^3	Cyclo-hexane mg/m^3	Hexane mg/m^3	Heptane mg/m^3	Styrene mg/m^3	2,2,4-Trimethyl-pentane mg/m^3	1,3,5-Trimethyl-benzene mg/m^3	1,2,4-Trimethyl-benzene mg/m^3	1,3-Butadiene mg/m^3	4-Ethyl-toluene mg/m^3	Butane mg/m^3	Isopentane mg/m^3	Methyl cyclohexane mg/m^3
VW-96	Apr 2008	20	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025) J	0.047	0.13	0.028	0.039	0.019	ND(0.0042)	0.0063	0.0078 J	ND(0.0052)	0.0094	ND(0.0059)	0.0067	ND(0.0027)	ND(0.0059)	--	--	--
		25	2.09	ND(0.023)	ND(0.023)	ND(0.0051) J	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022) J	ND(0.0033)	ND(0.0039)	ND(0.0045) J	0.0074	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043) J	ND(0.0044)	ND(0.0049)	ND(0.0051)	0.0087	ND(0.0023)	0.0061	--	--	--
		30	2.02	ND(0.022)	ND(0.022)	ND(0.005) J	ND(0.005)	ND(0.0041)	ND(0.0078)	ND(0.0036)	ND(0.021) J	ND(0.0032)	ND(0.0038)	ND(0.0044) J	ND(0.0044)	ND(0.0044)	ND(0.0035)	ND(0.0036)	ND(0.0041) J	ND(0.0043)	0.014	ND(0.005)	ND(0.005)	ND(0.0022)	ND(0.005)	--	--	--
		35	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005) J	ND(0.0095)	ND(0.0044)	ND(0.026) J	ND(0.0039)	ND(0.0046)	ND(0.0054)	0.011	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051) J	ND(0.0053)	ND(0.0058)	0.016	0.0076	ND(0.0027)	0.0069	--	--	--
		40	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023) J	ND(0.0034)	0.012	ND(0.0047)	ND(0.0047)	ND(0.0047)	0.005	0.055	ND(0.0044) J	ND(0.0046)	ND(0.005)	0.014	ND(0.0053)	ND(0.0024)	ND(0.0053)	--	--	--
		45	2.29	ND(0.025)	ND(0.025)	ND(0.0056)	0.028	ND(0.0046) J	ND(0.0088)	ND(0.0041)	ND(0.024) J	0.004	0.028	0.053	0.078	0.061	ND(0.0039)	ND(0.004)	ND(0.0047) J	ND(0.0049)	0.012	0.089	0.17	ND(0.0025)	0.11	--	--	--
		50	2.64	ND(0.029)	ND(0.029)	ND(0.0065)	ND(0.0065)	ND(0.0053) J	ND(0.01)	ND(0.0048)	ND(0.028) J	ND(0.0042)	ND(0.005)	ND(0.0057)	0.0076	ND(0.0057)	ND(0.0045)	ND(0.0046)	ND(0.0054) J	ND(0.0056)	0.033	0.054	0.068	ND(0.0029)	0.012	--	--	--
		55	129	ND(1.4)	ND(1.4)	ND(0.32)	ND(0.32)	ND(0.26)	**ND(0.5)**	ND(0.23)	**ND(1.4) J**	1.1 J	ND(0.24)	ND(0.28)	ND(0.28)	ND(0.28)	1.9 J	1.1 J	0.62 J	ND(0.27)	160 J	ND(0.32)	0.44 J	ND(0.14)	ND(0.32)	--	--	--
	Sep 2008	20	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	0.042	0.16	0.045	ND(0.0042)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	0.0092	0.01	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.014)	ND(0.02)
		25	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	0.028	ND(0.0039)	0.028	0.0063	0.05	0.022	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	0.0068	0.017	0.052	ND(0.0027)	0.029	ND(0.012)	ND(0.014)	ND(0.019)
		30	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026)	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052)	ND(0.0054)	0.0075	0.016	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		35	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	0.015	ND(0.0058)	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
		40	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	0.019	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.014)	ND(0.02)
		45	2.58	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052)	ND(0.0099)	ND(0.0046)	ND(0.027)	ND(0.0041)	ND(0.0049)	ND(0.0056)	ND(0.0056)	ND(0.0056)	ND(0.0044)	ND(0.0045)	ND(0.0053)	ND(0.0055)	ND(0.006)	0.0099	0.0088	ND(0.0028)	ND(0.0063)	ND(0.012)	ND(0.015)	ND(0.021)
		50	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	0.0083 JB	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	0.034	ND(0.0049)	ND(0.0051)	0.13	0.037	0.02	ND(0.0026)	ND(0.0058)	0.02 JB	0.022	ND(0.019)
		55	84.3	ND(9.2)	ND(9.2)	ND(2.1)	ND(2.1)	**ND(1.7)**	**ND(3.2)**	ND(1.5)	**ND(8.8)**	ND(1.3)	ND(1.6)	ND(1.8)	ND(1.8)	ND(1.8)	90	120	39	ND(1.8)	640	ND(2.1)	ND(2.1)	ND(0.93)	ND(2.1)	21	230	150
		60	2.42	ND(26)	ND(26)	16	32	**ND(4.9)**	**ND(9.3)**	ND(4.4)	**ND(25)**	**23**	ND(4.6)	**62**	88	ND(5.2)	740	**1700**	780	ND(5.2)	2500	**12**	**75**	**ND(2.7)**	25	100	1400	1600
	Dec 2008	20	7.47	ND(0.82)	ND(0.82)	ND(0.18)	ND(0.18)	ND(0.15)	**ND(0.29)**	ND(0.13)	**ND(0.78)**	ND(0.12)	ND(0.14)	ND(0.16)	ND(0.16)	ND(0.16)	ND(0.13)	ND(0.13)	ND(0.15)	ND(0.16)	110	ND(0.18)	ND(0.18)	ND(0.083)	ND(0.18)	3.1	14	ND(0.6)
		25	8.2	ND(0.9)	ND(0.9)	ND(0.2)	ND(0.2)	ND(0.16)	**ND(0.32)**	ND(0.15)	**ND(0.86)**	ND(0.13)	ND(0.15)	ND(0.18)	ND(0.18)	ND(0.18)	ND(0.14)	ND(0.14)	ND(0.17)	ND(0.17)	170	ND(0.2)	ND(0.2)	ND(0.091)	ND(0.2)	6.8	28	ND(0.66)
		30	17.4	ND(1.9)	ND(1.9)	ND(0.43)	ND(0.43)	ND(0.35)	**ND(0.67)**	ND(0.31)	**ND(1.8)**	ND(0.28)	ND(0.33)	ND(0.38)	ND(0.38)	ND(0.38)	ND(0.3)	0.31	ND(0.36)	ND(0.37)	220	ND(0.43)	ND(0.43)	ND(0.19)	ND(0.43)	11	41	ND(1.4)
		35	18.3	ND(2)	ND(2)	ND(0.45)	ND(0.45)	ND(0.37)	**ND(0.7)**	ND(0.33)	**ND(1.9)**	ND(0.29)	ND(0.34)	ND(0.4)	ND(0.4)	ND(0.4)	ND(0.31)	ND(0.32)	ND(0.37)	ND(0.39)	230	ND(0.45)	ND(0.45)	ND(0.2)	ND(0.45)	9.8	44	ND(1.5)
		40	23.3	ND(2.6)	ND(2.6)	ND(0.57)	ND(0.57)	ND(0.47)	**ND(0.9)**	ND(0.42)	**ND(2.4)**	ND(0.37)	ND(0.44)	ND(0.5)	ND(0.5)	ND(0.5)	ND(0.4)	0.7	ND(0.48)	ND(0.5)	420	ND(0.57)	ND(0.57)	ND(0.26)	ND(0.57)	16	85	ND(1.9)
		45	34.6	ND(3.8)	ND(3.8)	ND(0.85)	ND(0.85)	ND(0.7)	**ND(1.3)**	ND(0.62)	**ND(3.6)**	ND(0.55)	ND(0.65)	ND(0.75)	ND(0.75)	ND(0.75)	5.9	9.3	ND(0.71)	ND(0.74)	580	ND(0.85)	ND(0.85)	ND(0.38)	ND(0.85)	21	130	8.1
		50	106	ND(12)	ND(12)	ND(2.6)	ND(2.6)	**ND(2.1)**	**ND(4.1)**	ND(1.9)	**ND(11)**	ND(1.7)	ND(2)	ND(2.3)	ND(2.3)	ND(2.3)	72	82	21	ND(2.2)	1200	ND(2.6)	ND(2.6)	**ND(1.2)**	ND(2.6)	38	360	170
		50 Dup	108	ND(12)	ND(12)	ND(2.6)	ND(2.6)	**ND(2.2)**	**ND(4.1)**	ND(1.9)	**ND(11)**	ND(1.7)	ND(2)	ND(2.3)	ND(2.3)	ND(2.3)	73	84	20	ND(2.3)	1200	ND(2.6)	ND(2.6)	**ND(1.2)**	ND(2.6)	41	360	160
		55	104	ND(11)	ND(11)	ND(2.6)	ND(2.6)	**ND(2.1)**	**ND(4)**	ND(1.9)	**ND(11)**	ND(1.7)	ND(2)	ND(2.2)	ND(2.2)	ND(2.2)	150	180	75	ND(2.2)	1200	ND(2.6)	ND(2.6)	**ND(1.2)**	ND(2.6)	46	440	340
		60	220	ND(24)	ND(24)	15	29	**ND(4.4)**	**ND(8.4)**	ND(4)	**ND(23)**	**22**	ND(4.1)	13	51	ND(4.8)	560	**1100**	890	ND(4.7)	2600	6.7	**50**	**ND(2.4)**	18	56	570	1600
	Mar 2009	20	2.64	ND(0.29)	ND(0.29)	ND(0.065)	ND(0.065)	ND(0.053)	**ND(0.1)**	ND(0.048)	ND(0.28)	ND(0.042)	ND(0.05)	ND(0.057)	ND(0.057)	ND(0.057)	ND(0.045)	ND(0.046)	ND(0.054)	ND(0.056)	26	ND(0.065)	ND(0.065)	ND(0.029)	ND(0.065)	ND(0.12)	ND(0.16)	ND(0.21)
		25	24.2	ND(2.6)	ND(2.6)	ND(0.59)	ND(0.59)	ND(0.49)	**ND(0.93)**	ND(0.44)	**ND(2.5)**	ND(0.39)	ND(0.46)	ND(0.52)	ND(0.52)	ND(0.52)	ND(0.42)	ND(0.43)	ND(0.5)	ND(0.52)	520	ND(0.59)	ND(0.59)	ND(0.27)	ND(0.59)	ND(1.2)	ND(1.4)	ND(1.9)
		30	48.4	ND(5.3)	ND(5.3)	ND(1.2)	ND(1.2)	**ND(0.98)**	**ND(1.8)**	ND(0.87)	**ND(5.1)**	ND(0.77)	ND(0.91)	ND(1)	ND(1)	ND(1)	ND(0.83)	ND(0.85)	ND(0.99)	ND(1)	660	ND(1.2)	ND(1.2)	ND(0.54)	ND(1.2)	5	16	ND(3.9)
		35	86.2	ND(9.5)	ND(9.5)	ND(2.1)	ND(2.1)	**ND(1.7)**	**ND(3.3)**	ND(1.6)	**ND(9)**	ND(1.4)	ND(1.6)	ND(1.9)	ND(1.9)	ND(1.9)	ND(1.5)	ND(1.5)	ND(1.8)	ND(1.8)	900	ND(2.1)	ND(2.1)	**ND(0.95)**	ND(2.1)	9.4	60	ND(6.9)
		40	44	ND(4.8)	ND(4.8)	ND(1.1)	ND(1.1)	ND(0.89)	**ND(1.7)**	ND(0.79)	**ND(4.6)**	ND(0.7)	ND(0.83)	ND(0.96)	ND(0.96)	ND(0.96)	3.4	ND(0.78)	ND(0.9)	ND(0.94)	940	ND(1.1)	ND(1.1)	ND(0.49)	ND(1.1)	19	200	ND(3.5)
		45	74.7	ND(8.2)	ND(8.2)	ND(1.8)	ND(1.8)	**ND(1.5)**	**ND(2.9)**	ND(1.3)	**ND(7.8)**	ND(1.2)	ND(1.4)	ND(1.6)	ND(1.6)	ND(1.6)	28	4.6	ND(1.5)	ND(1.6)	1100	ND(1.8)	ND(1.8)	ND(0.83)	ND(1.8)	29	350	49
		50	77.7	ND(8.5)	ND(8.5)	ND(1.9)	ND(1.9)	**ND(1.6)**	**ND(3)**	ND(1.4)	**ND(8.1)**	1.8	ND(1.5)	ND(1.7)	ND(1.7)	ND(1.7)	130	30	3.8	ND(1.6)	1300	ND(1.9)	ND(1.9)	ND(0.86)	ND(1.9)	64	920	280
		55	92	ND(10)	ND(10)	ND(2.3)	ND(2.3)	**ND(1.9)**	**ND(3.5)**	ND(1.6)	**ND(9.6)**	1.5	ND(1.7)	ND(2)	ND(2)	ND(2)	170	51	15	ND(2)	1200	ND(2.3)	ND(2.3)	ND(1)	ND(2.3)	67	940	340
	Sep/Oct 2009	20	238	ND(26)	ND(26)	ND(5.8)	ND(5.8)	**ND(4.8)**	**ND(9.1)**	ND(4.3)	**ND(25)**	**ND(3.8)**	ND(4.5)	**ND(5.2)**	ND(5.2)	ND(5.2)	ND(4.1)	ND(4.2)	ND(4.9)	ND(5.1)	750	**ND(5.8)**	**ND(5.8)**	**ND(2.6)**	ND(5.8)	14	82	ND(19)
		25	276	ND(30)	ND(30)	ND(6.8)	ND(6.8)	**ND(5.6)**	**ND(11)**	ND(5)	**ND(29)**	**ND(4.4)**	ND(5.2)	ND(6)	ND(6)	ND(6)	ND(4.8)	ND(4.9)	ND(5.6)	ND(5.9)	1200	**ND(6.8)**	ND(6.8)	**ND(3)**	ND(6.8)	37	300	ND(22)
		30	448	ND(49)	ND(49)	ND(11)	ND(11)	**ND(9.1)**	**ND(17)**	ND(8.1)	**ND(47)**	**ND(7.2)**	ND(8.4)	ND(9.7)	ND(9.7)	ND(9.7)	15	9.4	ND(9.2)	ND(9.5)	1300	**ND(11)**	**ND(11)**	**ND(5)**	ND(11)	98	890	ND(36)
		35	432	ND(47)	ND(47)	ND(11)	ND(11)	**ND(8.7)**	**ND(16)**	ND(7.8)	**ND(45)**	**ND(6.9)**	ND(8.1)	ND(9.4)	ND(9.4)	ND(9.4)	34	17	ND(8.8)	ND(9.2)	1400	**ND(11)**	**ND(11)**	**ND(4.8)**	ND(11)	130	1200	44
		35 Dup	432	ND(47)	ND(47)	ND(11)	ND(11)	**ND(8.7)**	**ND(16)**	ND(7.8)	**ND(45)**	**ND(6.9)**	ND(8.1)	ND(9.4)	ND(9.4)	ND(9.4)	31	16	ND(8.8)	ND(9.2)	1300	**ND(11)**	**ND(11)**	**ND(4.8)**	ND(11)	120	1100	42
		40	710	ND(78)	ND(78)	ND(17)	ND(17)	**ND(14)**	**ND(27)**	ND(13)	**ND(74)**	**ND(11)**	ND(13)	**ND(15)**	ND(15)	ND(15)	68	38	ND(14)	ND(15)	1200	**ND(17)**	**ND(17)**	**ND(7.8)**	ND(17)	130	1200	93
		45	611	ND(67)	ND(67)	ND(15)	ND(15)	**ND(12)**	**ND(23)**	ND(11)	**ND(64)**	**ND(9.8)**	ND(12)	ND(13)	ND(13)	ND(13)	180	120	ND(12)	ND(13)	1700	**ND(15)**	**ND(15)**	**ND(6.8)**	ND(15)	190	1800	340
		50	763	ND(84)	ND(84)	ND(19)	ND(19)	**ND(15)**	**ND(29)**	ND(14)	**ND(80)**	**ND(12)**	ND(14)	**ND(16)**	ND(16)	ND(16)	220	180	22	ND(16)	1200	**ND(19)**	**ND(19)**	**ND(8.4)**	ND(19)	170	1600	400
		55	763	ND(84)	ND(84)	ND(19)	ND(19)	**ND(15)**	**ND(29)**	ND(14)	**ND(80)**	**ND(12)**	ND(14)	**ND(16)**	ND(16)	ND(16)	310	360	90	ND(16)	1500	**ND(19)**	**ND(19)**	**ND(8.4)**	ND(19)	210	1900	600
		60	763	ND(84)	ND(84)	ND(19)	32	**ND(15)**	**ND(29)**	ND(14)	**ND(80)**	**50**	ND(14)	**35**	ND(16)	ND(16)	590	900	450	ND(16)	2200	**ND(19)**	**ND(19)**	**ND(8.4)**	ND(19)	220	2200	1500

TABLE 4-2. SCREENING EVALUATION FOR NESTED SOIL VAPOR RESULTS, GASOLINE RELATED CONSTITUENTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Nested Vapor Monitoring Well	Date	Depth	Dilution Factor	n-Butyl-benzene mg/m³	sec-Butyl-benzene mg/m³	Isopropyl-benzene mg/m³	n-Propyl-benzene mg/m³	1,2-Dichloro-ethane mg/m³	1,2-Dibromo-ethane mg/m³	MTBE mg/m³	Naphthalene mg/m³	Benzene mg/m³	Toluene mg/m³	Ethyl-benzene mg/m³	m,p-Xylene mg/m³	o-Xylene mg/m³	Cyclo-hexane mg/m³	Hexane mg/m³	Heptane mg/m³	Styrene mg/m³	2,2,4-Trimethyl-pentane mg/m³	1,3,5-Trimethyl-benzene mg/m³	1,2,4-Trimethyl-benzene mg/m³	1,3-Butadiene mg/m³	4-Ethyl-toluene mg/m³	Butane mg/m³	Isopentane mg/m³	Methyl cyclohexane mg/m³
VW-96	Aug 2010	20	2.46	ND(0.027)	ND(0.027)	ND(0.006)	ND(0.006)	ND(0.005)	ND(0.0094)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0053)	ND(0.0053)	ND(0.0053)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0057)	ND(0.006)	ND(0.006)	ND(0.0027)	ND(0.006)	ND(0.012)	ND(0.014)	ND(0.02)
		30	2.39	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0048)	ND(0.0092)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	0.0072	ND(0.0059)	ND(0.0026)	ND(0.0059)	ND(0.011)	ND(0.014)	ND(0.019)
		40	2.52	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0045)	ND(0.026) J	ND(0.004)	ND(0.0047)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0043)	ND(0.0044)	ND(0.0052)	ND(0.0054)	0.011	0.012	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		50	2.23	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0048)	ND(0.0048)	ND(0.0048)	0.012	ND(0.0039)	ND(0.0046)	ND(0.0047)	0.026	0.032	0.012	ND(0.0025)	ND(0.0055)	ND(0.011)	0.047	0.023
		60	64.2	ND(7)	ND(7)	ND(1.6)	1.7	ND(1.3)	**ND(2.5)**	ND(1.2)	**ND(6.7)**	**11 J**	ND(1.2)	**7.7**	10	ND(1.4)	200	310	140	ND(1.4)	1100	2.6	2.8	ND(0.71)	ND(1.6)	34	590	560
	Sep 2010	20	2.44	ND(0.027)	ND(0.027)	ND(0.006)	ND(0.006)	ND(0.0049)	ND(0.0094)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0053)	ND(0.0053)	ND(0.0053)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0057)	ND(0.006)	ND(0.006)	ND(0.0027)	ND(0.006)	ND(0.012)	ND(0.014)	ND(0.02)
		30	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	0.028	ND(0.011)	ND(0.014)	ND(0.018)
		40	2.52	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0045)	ND(0.026)	ND(0.004)	ND(0.0047)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0043)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	0.0086	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
	Oct 2010	20	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024) J	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	0.006	ND(0.0057) J	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)
		30	2.58	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052)	ND(0.0099)	ND(0.0046)	ND(0.027) J	ND(0.0041)	ND(0.0049)	ND(0.0056)	ND(0.0056)	ND(0.0056)	ND(0.0044)	ND(0.0045)	ND(0.0053)	ND(0.0055)	ND(0.006)	0.007	ND(0.0063) J	ND(0.0028)	ND(0.0063)	ND(0.012)	ND(0.015)	ND(0.021)
		40	2.29	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024) J	ND(0.0036)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0053)	0.013	ND(0.0056) J	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
	Nov 2010	20	2.52	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0045)	ND(0.026)	ND(0.004)	ND(0.0047)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0043)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		30	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	0.009	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		40	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	0.008	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		40 DUP	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	0.009	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
	Dec 2010	20	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		30	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		40	4.32	ND(0.047)	ND(0.047)	ND(0.011)	ND(0.011)	ND(0.0087)	ND(0.016)	ND(0.0078)	ND(0.045)	ND(0.0069)	ND(0.0081)	ND(0.0094)	ND(0.0094)	ND(0.0094)	ND(0.0074)	ND(0.0076)	ND(0.0088)	ND(0.0092)	ND(0.01)	ND(0.011)	ND(0.011)	ND(0.0048)	ND(0.011)	ND(0.02)	ND(0.025)	ND(0.035)
	Jan 2011	20	2.23	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0047)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		30	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022)	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0044)	ND(0.0049)	0.007	ND(0.0051)	ND(0.0023)	ND(0.0051)	ND(0.0099)	ND(0.012)	ND(0.017)
		40	2.28	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0036)	ND(0.0043)	ND(0.0049)	ND(0.005)	ND(0.005)	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0048)	ND(0.0053)	0.01	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.013)	ND(0.018)
	Feb 2011	20	2.12	ND(0.023)	ND(0.023)	ND(0.0052)	ND(0.0052)	ND(0.0043)	ND(0.0081)	ND(0.0038)	ND(0.022)	ND(0.0034)	ND(0.004)	ND(0.0046)	ND(0.0046)	ND(0.0046)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0045)	0.011	ND(0.0052)	ND(0.0052)	ND(0.0023)	ND(0.0052)	ND(0.01)	ND(0.012)	ND(0.017)
		30	2.26	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0087)	ND(0.0041)	ND(0.024)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0039)	ND(0.004)	ND(0.0046)	ND(0.0048)	ND(0.0053)	0.006	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.013)	ND(0.018)
		40	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	0.014	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
VW-99	Apr 2008	20	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023) J	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046) J	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	--	--	--
		25	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049) J	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	--	--	--
		30	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026) J	ND(0.004)	0.0049	ND(0.0055)	0.006	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052) J	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	--	--	--
		35	22.9	ND(0.25)	ND(0.25)	ND(0.056)	ND(0.056)	ND(0.046)	**ND(0.088)**	ND(0.041)	ND(0.24) J	ND(0.036)	ND(0.043)	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.039)	ND(0.04)	ND(0.047) J	ND(0.049)	8.7	ND(0.056)	ND(0.056)	ND(0.025)	ND(0.056)	--	--	--
		40	22.4	ND(0.24)	ND(0.24)	ND(0.055)	ND(0.055)	ND(0.045)	**ND(0.086)**	ND(0.04)	ND(0.23) J	ND(0.036)	ND(0.042)	ND(0.049)	ND(0.049)	ND(0.049)	ND(0.038)	ND(0.039)	ND(0.046) J	ND(0.048)	16	ND(0.055)	ND(0.055)	ND(0.025)	ND(0.055)	--	--	--
		45	46.6	ND(0.51)	ND(0.51)	ND(0.11)	ND(0.11)	ND(0.094)	**ND(0.18)**	ND(0.084)	ND(0.49) J	ND(0.074)	ND(0.088)	ND(0.1)	ND(0.1)	ND(0.1)	ND(0.08)	ND(0.082)	ND(0.095) J	ND(0.099)	36	ND(0.11)	ND(0.11)	ND(0.052)	ND(0.11)	--	--	--
		50	110	ND(1.2)	ND(1.2)	ND(0.27)	ND(0.27)	ND(0.22) J	**ND(0.42)**	ND(0.2)	**ND(1.2) J**	ND(0.18)	ND(0.21)	ND(0.24)	ND(0.24)	ND(0.24)	ND(0.19)	ND(0.19)	ND(0.22) J	ND(0.23)	56 J	ND(0.27)	ND(0.27)	ND(0.12)	ND(0.27)	--	--	--
		50 Dup	110	ND(1.2)	ND(1.2)	ND(0.27)	ND(0.27)	ND(0.22)	**ND(0.42)**	ND(0.2)	**ND(1.2) J**	ND(0.18)	ND(0.21)	ND(0.24)	ND(0.24)	ND(0.24)	ND(0.19)	0.23	ND(0.22) J	ND(0.23)	96	ND(0.27)	ND(0.27) J	ND(0.12)	ND(0.27)	--	--	--
	Sep 2008	20	2.58	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052)	ND(0.0099)	ND(0.0046)	ND(0.027)	ND(0.0041)	ND(0.0049)	ND(0.0056)	ND(0.0056)	ND(0.0056)	ND(0.0044)	ND(0.0045)	ND(0.0053)	ND(0.0055)	ND(0.006)	ND(0.0063)	ND(0.0063)	ND(0.0028)	ND(0.0063)	ND(0.012)	ND(0.015)	ND(0.021)
		25	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		30	2.13	ND(0.023)	ND(0.023)	ND(0.0052)	ND(0.0052)	ND(0.0043)	ND(0.0082)	ND(0.0038)	ND(0.022)	0.023	ND(0.004)	ND(0.0046)	ND(0.0046)	ND(0.0046)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0045)	ND(0.005)	ND(0.0052)	ND(0.0052)	ND(0.0024)	ND(0.0052)	ND(0.01)	ND(0.012)	ND(0.017)
		35	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045) J	ND(0.0052)	ND(0.0052) J	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0058) J	0.0076 J	ND(0.0026)	ND(0.0058) J	ND(0.011)	ND(0.014)	ND(0.019)
		35 Dup	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	0.013 J	ND(0.0052)	0.021 J	0.0085	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	0.0059 J	0.02 J	ND(0.0026)	0.015 J	ND(0.011)	ND(0.014)	ND(0.019)
		40	2.29	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	0.058	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0036)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0049)	0.026	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		45	3.73	ND(0.41)	ND(0.41)	ND(0.092)	ND(0.092)	ND(0.075)	**ND(0.14)**	ND(0.067)	ND(0.39)	ND(0.06)	ND(0.07)	ND(0.081)	ND(0.081)	ND(0.081)	ND(0.064)	ND(0.066)	ND(0.076)	ND(0.079)	49	ND(0.092)	ND(0.092)	ND(0.041)	ND(0.092)	0.85	3.6	ND(0.3)
		50	16	ND(1.8)	ND(1.8)	ND(0.39)	ND(0.39)	ND(0.32)	**ND(0.61)**	ND(0.29)	**ND(1.7)**	ND(0.26)	ND(0.3)	ND(0.35)	ND(0.35)	ND(0.35)	13	8.8	ND(0.33)	ND(0.34)	200	ND(0.39)	ND(0.39)	ND(0.18)	ND(0.39)	14	140	15
		55	74.7	ND(8.2)	ND(8.2)	ND(1.8)	ND(1.8)	**ND(1.5)**	**ND(2.9)**	ND(1.3)	**ND(7.8)**	ND(1.2)	ND(1.4)	ND(1.6)	ND(1.6)	ND(1.6)	130	210	44	ND(1.6)	560	ND(1.8)	ND(1.8)	ND(0.83)	ND(1.8)	50	670	200
		55 Dup	74.4	ND(8.2)	ND(8.2)	ND(1.8)	ND(1.8)	**ND(1.5)**	**ND(2.9)**	ND(1.3)	**ND(7.8)**	ND(1.2)	ND(1.4)	ND(1.6)	ND(1.6)	ND(1.6)	130	200	44	ND(1.6)	550	ND(1.8)	ND(1.8)	ND(0.83)	ND(1.8)	48.000	630.000	200.000
		60	2.29	ND(0.025)	ND(0.025)	0.027	0.06	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0036)	0.006 JB	0.007	0.021	0.03	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0053)	0.056	0.15	ND(0.0025)	0.18	ND(0.011)	ND(0.014)	ND(0.018)

TABLE 4-2. SCREENING EVALUATION FOR NESTED SOIL VAPOR RESULTS, GASOLINE RELATED CONSTITUENTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Nested Vapor Monitoring Well	Date	Depth	Dilution Factor	n-Butyl-benzene mg/m³	sec-Butyl-benzene mg/m³	Isopropyl-benzene mg/m³	n-Propyl-benzene mg/m³	1,2-Dichloro-ethane mg/m³	1,2-Dibromo-ethane mg/m³	MTBE mg/m³	Naphthalene mg/m³	Benzene mg/m³	Toluene mg/m³	Ethyl-benzene mg/m³	m,p-Xylene mg/m³	o-Xylene mg/m³	Cyclo-hexane mg/m³	Hexane mg/m³	Heptane mg/m³	Styrene mg/m³	2,2,4-Trimethyl-pentane mg/m³	1,3,5-Trimethyl-benzene mg/m³	1,2,4-Trimethyl-benzene mg/m³	1,3-Butadiene mg/m³	4-Ethyl-toluene mg/m³	Butane mg/m³	Isopentane mg/m³	Methyl cyclohexane mg/m³
VW-99	Dec 2008	20	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022)	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0044)	ND(0.0049)	ND(0.0051)	ND(0.0051)	ND(0.0023)	ND(0.0051)	ND(0.0099)	ND(0.012)	ND(0.017)
		25	3.44	ND(0.38)	ND(0.38)	ND(0.084)	ND(0.084)	ND(0.07)	**ND(0.13)**	ND(0.062)	ND(0.36)	ND(0.055)	ND(0.065)	ND(0.075)	ND(0.075)	ND(0.075)	ND(0.059)	0.066 J	ND(0.07)	ND(0.073)	49 J	ND(0.084)	ND(0.084)	ND(0.038)	ND(0.084)	0.78 J	6.9 J	ND(0.28)
		30	42.6	ND(4.7)	ND(4.7)	ND(1)	ND(1)	ND(0.86)	**ND(1.6)**	ND(0.77)	**ND(4.5)**	ND(0.68)	ND(0.8)	ND(0.92)	ND(0.92)	ND(0.92)	ND(0.73)	2.2	ND(0.87)	ND(0.91)	430	ND(1)	ND(1)	ND(0.47)	ND(1)	9.4	65	7.3
		35	30.8	ND(3.4)	ND(3.4)	ND(0.76)	ND(0.76)	ND(0.62)	**ND(1.2)**	ND(0.56)	**ND(3.2)**	ND(0.49)	ND(0.58)	ND(0.67)	ND(0.67)	ND(0.67)	ND(0.53)	1.3 J	ND(0.63)	ND(0.66)	380 J	ND(0.76)	ND(0.76)	ND(0.34)	ND(0.76)	8.7 J	53 J	4.6 J
		40	27.7	ND(3)	ND(3)	ND(0.68)	ND(0.68)	ND(0.56)	**ND(1.1)**	ND(0.5)	**ND(2.9)**	ND(0.44)	ND(0.52)	ND(0.6)	ND(0.6)	ND(0.6)	9.9	10	ND(0.57)	ND(0.59)	490	ND(0.68)	ND(0.68)	ND(0.31)	ND(0.68)	15	160	9
		45	34.2	ND(3.8)	ND(3.8)	ND(0.84)	ND(0.84)	ND(0.69)	**ND(1.3)**	ND(0.62)	**ND(3.6)**	0.67	ND(0.64)	ND(0.74)	0.99	ND(0.74)	40	56	5.8	ND(0.73)	660	ND(0.84)	ND(0.84)	ND(0.38)	ND(0.84)	23	380	58
		50	52.2	ND(5.7)	ND(5.7)	ND(1.3)	ND(1.3)	ND(1)	**ND(2)**	ND(0.94)	**ND(5.5)**	1.0	ND(0.98)	ND(1.1)	ND(1.1)	ND(1.1)	120	160	38	ND(1.1)	870	ND(1.3)	ND(1.3)	ND(0.58)	ND(1.3)	22	550	220
		55	109	ND(12)	ND(12)	ND(2.7)	ND(2.7)	**ND(2.2)**	**ND(4.2)**	ND(2)	**ND(11)**	1.8 J	ND(2)	3.7 J	4.6 J	ND(2.4)	220 J	420 J	140 J	ND(2.3)	1000 J	ND(2.7)	ND(2.7)	**ND(1.2)**	ND(2.7)	100 J	750 J	520 J
		55 Dup	205	ND(22)	ND(22)	ND(5)	ND(5)	**ND(4.1)**	**ND(7.9)**	ND(3.7)	**ND(21)**	ND(3.3)	ND(3.9)	7.1 J	5.8	ND(4.4)	270	490	180 J	ND(4.4)	1300 J	ND(5)	ND(5)	**ND(2.3)**	ND(5)	59 J	810	660
		60	51.2	49	5.5	5.4	2.8	ND(1)	**ND(2)**	ND(0.92)	**ND(5.4)**	1.3	1.4	**23**	93	3.4	180	320	170	ND(1.1)	870	**77**	**74**	ND(0.57)	41	19	390	680
	Sep/Oct 2009	20	388	ND(42)	ND(42)	ND(9.5)	ND(9.5)	**ND(7.8)**	**ND(15)**	ND(7)	**ND(41)**	**ND(6.2)**	ND(7.3)	**ND(8.4)**	ND(8.4)	ND(8.4)	170	34	ND(8)	ND(8.3)	920	**ND(9.5)**	**ND(9.5)**	**ND(4.3)**	ND(9.5)	30	670	280
		25	164	ND(18)	ND(18)	ND(4)	ND(4)	**ND(3.3)**	**ND(6.3)**	ND(3)	**ND(17)**	ND(2.6)	ND(3.1)	ND(3.6)	ND(3.6)	ND(3.6)	98	25	ND(3.4)	ND(3.5)	740	ND(4)	ND(4)	**ND(1.8)**	ND(4)	20	460	170
		30	242	ND(26)	ND(26)	ND(5.9)	ND(5.9)	**ND(4.9)**	**ND(9.3)**	ND(4.4)	**ND(25)**	**ND(3.9)**	ND(4.6)	ND(5.2)	ND(5.2)	ND(5.2)	120	31	ND(5)	ND(5.2)	1000	ND(5.9)	ND(5.9)	**ND(2.7)**	ND(5.9)	30	600	230
		30 Dup	253	ND(28)	ND(28)	ND(6.2)	ND(6.2)	**ND(5.1)**	**ND(9.7)**	ND(4.6)	**ND(26)**	**ND(4)**	ND(4.8)	ND(5.5)	ND(5.5)	ND(5.5)	120	30	ND(5.2)	ND(5.4)	1100	ND(6.2)	ND(6.2)	**ND(2.8)**	ND(6.2)	31	610	240
		35	373	ND(41)	ND(41)	ND(9.2)	ND(9.2)	**ND(7.5)**	**ND(14)**	ND(6.7)	**ND(39)**	**ND(6)**	ND(7)	ND(8.1)	ND(8.1)	ND(8.1)	80	23	ND(7.6)	ND(7.9)	840	**ND(9.2)**	**ND(9.2)**	**ND(4.1)**	ND(9.2)	27	580	110
		40	397	ND(44)	ND(44)	ND(9.8)	ND(9.8)	**ND(8)**	**ND(15)**	ND(7.2)	**ND(42)**	**ND(6.3)**	ND(7.5)	ND(8.6)	ND(8.6)	ND(8.6)	140	83	12	ND(8.4)	910	**ND(9.8)**	ND(9.8)	**ND(4.4)**	ND(9.8)	30	740	260
		45	388	ND(42)	ND(42)	ND(9.5)	ND(9.5)	**ND(7.8)**	**ND(15)**	ND(7)	**ND(41)**	**ND(6.2)**	ND(7.3)	ND(8.4)	ND(8.4)	ND(8.4)	180	120	22	ND(8.3)	1000	**ND(9.5)**	ND(9.5)	**ND(4.3)**	ND(9.5)	38	910	360
		50	560	ND(61)	ND(61)	ND(14)	ND(14)	**ND(11)**	**ND(22)**	ND(10)	**ND(59)**	**ND(8.9)**	ND(10)	ND(12)	ND(12)	ND(12)	300	390	110	ND(12)	1300	**ND(14)**	**ND(14)**	**ND(6.2)**	ND(14)	44	1200	710
		55	672	ND(74)	ND(74)	ND(16)	ND(16)	**ND(14)**	**ND(26)**	ND(12)	**ND(70)**	**ND(11)**	ND(13)	ND(14)	ND(14)	ND(14)	400	660	220	ND(14)	1400	**ND(16)**	**ND(16)**	**ND(7.4)**	ND(16)	52	1400	920
		60	166	ND(18)	ND(18)	ND(4.1)	ND(4.1)	**ND(3.4)**	**ND(6.4)**	ND(3)	**ND(17)**	ND(2.6)	ND(3.1)	ND(3.6)	ND(3.6)	ND(3.6)	120	140	43	ND(3.5)	370	5.4	ND(4.1)	**ND(1.8)**	ND(4.1)	14	390	300
	Aug 2010	20	2.5	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0096)	ND(0.0045)	ND(0.026) J	ND(0.004)	ND(0.0047)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0043)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0028)	ND(0.0061)	ND(0.012)	ND(0.015)	ND(0.02)
		30	2.46	ND(0.027)	ND(0.027)	ND(0.006)	ND(0.006)	ND(0.005)	ND(0.0094)	ND(0.0044)	ND(0.026) J	ND(0.0039)	0.0063	ND(0.0053)	ND(0.0053)	ND(0.0053)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0057)	ND(0.006)	ND(0.006)	ND(0.0027)	ND(0.006)	ND(0.012)	0.014	ND(0.02)
		40	9.43	ND(1)	ND(1)	ND(0.23)	ND(0.23)	ND(0.19)	**ND(0.36)**	ND(0.17)	ND(0.99)	ND(0.15)	ND(0.18)	ND(0.2)	ND(0.2)	ND(0.2)	ND(0.16)	ND(0.17)	ND(0.19)	ND(0.2)	150	ND(0.23)	ND(0.23)	ND(0.1)	ND(0.23)	0.58	1.3	ND(0.76)
		50	132	ND(14)	ND(14)	ND(3.2)	ND(3.2)	**ND(2.7)**	**ND(5.1)**	ND(2.4)	**ND(14)**	ND(2.1)	ND(2.5)	ND(2.9)	ND(2.9)	ND(2.9)	18	13	ND(2.7)	ND(2.8)	520	ND(3.2)	ND(3.2)	**ND(1.5)**	ND(3.2)	ND(6.3)	59	19
		55	176	ND(19)	ND(19)	ND(4.3)	ND(4.3)	**ND(3.6)**	**ND(6.8)**	ND(3.2)	**ND(18)**	ND(2.8)	ND(3.3)	ND(3.8)	ND(3.8)	ND(3.8)	120	98	45	ND(3.7)	990	ND(4.3)	ND(4.3)	**ND(1.9)**	ND(4.3)	10	190	310
		55 DUP	54.6	ND(6)	ND(6)	ND(1.3)	ND(1.3)	ND(1.1)	**ND(2.1)**	ND(0.98)	**ND(5.7) J**	1.2 J	ND(1)	ND(1.2)	ND(1.2)	ND(1.2)	110	88	39	ND(1.2)	850	ND(1.3)	ND(1.3)	ND(0.6)	ND(1.3)	9	160 J	280
	Sep 2010	20	2.57	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052)	ND(0.0099)	ND(0.0046)	ND(0.027)	ND(0.0041)	ND(0.0048)	ND(0.0056)	ND(0.0056)	ND(0.0056)	ND(0.0044)	0.006	ND(0.0053)	ND(0.0055)	ND(0.006)	ND(0.0063)	ND(0.0063)	ND(0.0028)	ND(0.0063)	ND(0.012)	ND(0.015)	ND(0.021)
		30	2.37	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0051)	ND(0.0051)	ND(0.0051)	ND(0.0041)	ND(0.0042)	ND(0.0048)	ND(0.005)	ND(0.0055)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
		30 DUP	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)
		40	2.37	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0051)	ND(0.0051)	ND(0.0051)	ND(0.0041)	ND(0.0042)	ND(0.0048)	ND(0.005)	ND(0.0055)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
	Oct 2010	20	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	0.035	ND(0.0058)	ND(0.0058) J	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
		30	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023) J	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055) J	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		40	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026) J	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061) J	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.014)	ND(0.02)
		40 DUP	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023) J	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054) J	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
	Nov 2010	20	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		30	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	0.007	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		40	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
	Dec 2010	20	2.12	ND(0.023)	ND(0.023)	ND(0.0052)	ND(0.0052)	ND(0.0043)	ND(0.0081)	ND(0.0038)	ND(0.022)	ND(0.0034)	ND(0.004)	ND(0.0046)	ND(0.0046)	ND(0.0046)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0045)	ND(0.005)	ND(0.0052)	ND(0.0052)	ND(0.0023)	ND(0.0052)	ND(0.01)	ND(0.012)	ND(0.017)
		30	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022)	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0044)	ND(0.0049)	ND(0.0051)	ND(0.0051)	ND(0.0023)	ND(0.0051)	ND(0.0099)	ND(0.012)	ND(0.017)
		30 DUP	2.06	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.0079)	ND(0.0037)	ND(0.022)	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0035)	ND(0.0036)	ND(0.0042)	ND(0.0044)	ND(0.0048)	ND(0.0051)	ND(0.0051)	ND(0.0023)	ND(0.0051)	ND(0.0098)	ND(0.012)	ND(0.016)
		40	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
	Jan 2011	20	2.18	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.0039)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0038)	ND(0.0038)	ND(0.0045)	ND(0.0046)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		30	2.15	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.022)	ND(0.0034)	ND(0.004)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		30 DUP	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		40	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
	Feb 2011	20	2.18	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.0039)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0038)	ND(0.0038)	ND(0.0045)	ND(0.0046)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		30	2.1	ND(0.023)	ND(0.023)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0081)	ND(0.0038)	ND(0.022)	ND(0.0034)	0.006	ND(0.0046)	ND(0.0046)	ND(0.0046)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0045)	ND(0.0049)	ND(0.0052)	ND(0.0052)	ND(0.0023)	ND(0.0052)	ND(0.01)	ND(0.012)	ND(0.017)
		30 DUP	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022)	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0044)	ND(0.0049)	ND(0.0051)	ND(0.0051)	ND(0.0023)	ND(0.0051)	ND(0.0099)	ND(0.012)	ND(0.017)
		40	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)

TABLE 4-2. SCREENING EVALUATION FOR NESTED SOIL VAPOR RESULTS, GASOLINE RELATED CONSTITUENTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Nested Vapor Monitoring Well	Date	Depth	Dilution Factor	n-Butyl-benzene mg/m^3	sec-Butyl-benzene mg/m^3	Isopropyl-benzene mg/m^3	n-Propyl-benzene mg/m^3	1,2-Dichloro-ethane mg/m^3	1,2-Dibromo-ethane mg/m^3	MTBE mg/m^3	Naphthalene mg/m^3	Benzene mg/m^3	Toluene mg/m^3	Ethyl-benzene mg/m^3	m,p-Xylene mg/m^3	o-Xylene mg/m^3	Cyclo-hexane mg/m^3	Hexane mg/m^3	Heptane mg/m^3	Styrene mg/m^3	2,2,4-Trimethyl-pentane mg/m^3	1,3,5-Trimethyl-benzene mg/m^3	1,2,4-Trimethyl-benzene mg/m^3	1,3-Butadiene mg/m^3	4-Ethyl-toluene mg/m^3	Butane mg/m^3	Isopentane mg/m^3	Methyl cyclohexane mg/m^3
VW-127	Apr 2008	20	2.64	ND(0.029)	ND(0.029)	ND(0.0065)	ND(0.0065)	ND(0.0053) J	ND(0.01)	ND(0.0048)	ND(0.028) J	ND(0.0042)	ND(0.005)	ND(0.0057)	ND(0.0057)	ND(0.0057)	ND(0.0045)	ND(0.0046)	ND(0.0054) J	ND(0.0056)	ND(0.0062)	ND(0.0065)	ND(0.0065)	ND(0.0029)	ND(0.0065)	--	--	--
		30	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048) J	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	0.0087 J	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	--	--	--
		40	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049) J	ND(0.0093)	ND(0.0044)	ND(0.025) J	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005) J	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	--	--	--
		50	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047) J	ND(0.009)	ND(0.0042)	ND(0.024) J	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	0.0053	ND(0.0041)	ND(0.0048) J	ND(0.005)	0.0085	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	--	--	--
	Sep 2008	20	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.014)	ND(0.02)
		30	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		40	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)
		50	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	0.0038	ND(0.0041)	0.0049	0.037	0.011	0.0064	0.0046 JB	0.0072	ND(0.0047)	0.0085	0.0097	0.024	ND(0.0024) J	0.016	ND(0.01)	ND(0.013)	0.018
	Dec 2008	20	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)
		30	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	0.026	0.036	0.012	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	0.029	ND(0.017)
		40	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022)	ND(0.0033)	ND(0.0039)	ND(0.0045)	0.031 U	0.013 U	ND(0.0036)	ND(0.0037)	ND(0.0043)	ND(0.0044)	ND(0.0049)	0.0081 U	0.029 U	ND(0.0023)	0.02 U	ND(0.0099)	ND(0.012)	ND(0.017)
		40 Dup	2.05	ND(0.022)	ND(0.022)	ND(0.005)	ND(0.005)	ND(0.0041)	ND(0.0079)	ND(0.0037)	ND(0.021)	ND(0.0033)	ND(0.0039)	ND(0.0044)	ND(0.0044)	ND(0.0044)	ND(0.0035)	ND(0.0036)	ND(0.0042)	ND(0.0044)	ND(0.0048)	ND(0.005)	ND(0.005)	ND(0.0023)	ND(0.005)	ND(0.0097)	ND(0.012)	ND(0.016)
		50	2.05	ND(0.022)	ND(0.022)	ND(0.005)	ND(0.005)	ND(0.0041)	ND(0.0079)	ND(0.0037)	ND(0.021)	ND(0.0033)	ND(0.0039)	ND(0.0044)	ND(0.0044)	ND(0.0044)	ND(0.0035)	ND(0.0036)	ND(0.0042)	ND(0.0044)	ND(0.0048)	ND(0.005)	ND(0.005)	ND(0.0023)	ND(0.005)	ND(0.0097)	ND(0.012)	ND(0.016)
	Sep/Oct 2009	20	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		30	2.29	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0036)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0053)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		40	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025)	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	ND(0.012)	ND(0.014)	ND(0.019)
		40 Dup	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025)	0.0046	ND(0.0046)	0.0095	0.021 J	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0056)	ND(0.0059)	0.013 J	ND(0.0027)	0.0091	ND(0.012)	ND(0.014)	ND(0.019)
		50	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	ND(0.011)	ND(0.014)	ND(0.019)
VW-128	Apr 2008	20	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049) J	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	--	--	--
		30	2.02	ND(0.022)	ND(0.022)	ND(0.005)	ND(0.005)	ND(0.0041)	ND(0.0078)	ND(0.0036)	ND(0.021) J	ND(0.0032)	0.013	ND(0.0044)	ND(0.0044)	ND(0.0044)	ND(0.0035)	0.0089	ND(0.0041) J	ND(0.0043)	ND(0.0047)	ND(0.005)	ND(0.005)	ND(0.0022)	ND(0.005)	--	--	--
		40	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	0.029 J	ND(0.0038)	0.02	0.0089	0.044	0.018	ND(0.0041)	ND(0.0042)	ND(0.0049) J	ND(0.0051)	ND(0.0056)	0.0088	0.034	ND(0.0026)	0.02	--	--	--
		50	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022) J	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043) J	ND(0.0044)	ND(0.0049)	ND(0.0051)	ND(0.0051)	ND(0.0023)	ND(0.0051)	--	--	--
		50 Dup	2.09	ND(0.023)	ND(0.023)	ND(0.0051)	ND(0.0051)	ND(0.0042)	ND(0.008)	ND(0.0038)	ND(0.022) J	ND(0.0033)	ND(0.0039)	ND(0.0045)	ND(0.0045)	ND(0.0045)	ND(0.0036)	ND(0.0037)	ND(0.0043) J	ND(0.0044)	ND(0.0049)	ND(0.0051)	ND(0.0051)	ND(0.0023)	ND(0.0051)	--	--	--
	Sep 2008	20	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		30	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		40	2.29	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0036)	0.0095 JB	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.0039)	0.005 JB	ND(0.0047)	ND(0.0049)	ND(0.0053)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		50	2.33	ND(0.026)	ND(0.026)	0.032	0.16	ND(0.0047)	ND(0.009)	ND(0.0042)	0.058	0.05	0.7	0.18	0.74	0.34	0.02	0.014	0.067	ND(0.005)	ND(0.0054)	0.22	1 .0	ND(0.0026)	0.7	ND(0.011)	ND(0.014)	0.092
	Dec 2008	20	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		30	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		40	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0049)	ND(0.0049)	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		50	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
	Sep/Oct 2009	20	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	0.0054	ND(0.0048)	0.0068	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	0.0079	ND(0.0024)	0.0056	0.014	ND(0.013)	ND(0.018)
		30	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		40	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		50	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
	Aug 2010	20	2.57	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052)	ND(0.0099)	ND(0.0046)	ND(0.027) J	ND(0.0041)	ND(0.0048)	ND(0.0056)	ND(0.0056)	ND(0.0056)	ND(0.0044)	ND(0.0045)	ND(0.0053)	ND(0.0055)	ND(0.006)	ND(0.0063)	ND(0.0063)	ND(0.0028)	ND(0.0063)	ND(0.012)	ND(0.015)	ND(0.021)
		30	2.94	ND(0.032)	ND(0.032)	ND(0.0072)	ND(0.0072)	ND(0.0059)	ND(0.011)	ND(0.0053)	ND(0.031) J	ND(0.0047)	ND(0.0055)	ND(0.0064)	ND(0.0064)	ND(0.0064)	ND(0.005)	ND(0.0052)	ND(0.006)	ND(0.0063)	ND(0.0069)	ND(0.0072)	ND(0.0072)	ND(0.0032)	ND(0.0072)	ND(0.014)	ND(0.017)	ND(0.024)
		40	2.57	ND(0.028)	ND(0.028)	ND(0.0063)	ND(0.0063)	ND(0.0052)	ND(0.0099)	ND(0.0046)	ND(0.027) J	ND(0.0041)	ND(0.0048)	ND(0.0056)	ND(0.0056)	ND(0.0056)	ND(0.0044)	ND(0.0045)	ND(0.0053)	ND(0.0055)	ND(0.006)	ND(0.0063)	ND(0.0063)	ND(0.0028)	ND(0.0063)	ND(0.012)	ND(0.015)	ND(0.021)
		50	2.76	ND(0.03)	ND(0.03)	ND(0.0068)	ND(0.0068)	ND(0.0056)	ND(0.011)	ND(0.005)	ND(0.029) J	ND(0.0044)	ND(0.0052)	ND(0.006)	ND(0.006)	ND(0.006)	ND(0.0048)	ND(0.0049)	ND(0.0056)	ND(0.0059)	ND(0.0064)	ND(0.0068)	ND(0.0068)	ND(0.003)	ND(0.0068)	ND(0.013)	ND(0.016)	ND(0.022)
		50 DUP	2.66	ND(0.029)	ND(0.029)	ND(0.0065)	ND(0.0065)	ND(0.0054)	ND(0.01)	ND(0.0048)	ND(0.028) J	ND(0.0042)	ND(0.005)	ND(0.0058)	ND(0.0058)	ND(0.0058)	ND(0.0046)	ND(0.0047)	ND(0.0054)	ND(0.0057)	ND(0.0062)	ND(0.0065)	ND(0.0065)	ND(0.0029)	ND(0.0065)	ND(0.013)	ND(0.016)	ND(0.021)

TABLE 4-2. SCREENING EVALUATION FOR NESTED SOIL VAPOR RESULTS, GASOLINE RELATED CONSTITUENTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Nested Vapor Monitoring Well	Date	Depth	Dilution Factor	n-Butyl-benzene mg/m³	sec-Butyl-benzene mg/m³	Isopropyl-benzene mg/m³	n-Propyl-benzene mg/m³	1,2-Dichloro-ethane mg/m³	1,2-Dibromo-ethane mg/m³	MTBE mg/m³	Naphthalene mg/m³	Benzene mg/m³	Toluene mg/m³	Ethyl-benzene mg/m³	m,p-Xylene mg/m³	o-Xylene mg/m³	Cyclo-hexane mg/m³	Hexane mg/m³	Heptane mg/m³	Styrene mg/m³	2,2,4-Trimethyl-pentane mg/m³	1,3,5-Trimethyl-benzene mg/m³	1,2,4-Trimethyl-benzene mg/m³	1,3-Butadiene mg/m³	4-Ethyl-toluene mg/m³	Butane mg/m³	Isopentane mg/m³	Methyl cyclohexane mg/m³
VW-129	Apr 2008	20	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024) J	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048) J	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	--	--	--
		30	2.24	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023) J	ND(0.0036)	0.0051	ND(0.0049)	0.0052	ND(0.0049)	ND(0.0038)	ND(0.0039)	ND(0.0046) J	ND(0.0048)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	--	--	--
		40	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049) J	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	--	--	--
		50	2.47	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026) J	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051) J	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	--	--	--
	Sep 2008	20	2.47	ND(0.027)	ND(0.027) J	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0044)	ND(0.026) J	ND(0.0039)	ND(0.0046)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0042)	ND(0.0044)	ND(0.0051)	ND(0.0053)	0.014 J	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.014)	ND(0.02)
		20 Dup	2.42	ND(0.026)	ND(0.026) J	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025) J	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0056) J	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	ND(0.012)	ND(0.014)	ND(0.019)
		30	2.38	ND(0.026)	ND(0.026) J	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	0.007 JB	0.0078	0.0085	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0058)	0.0087	ND(0.0026)	0.0087	ND(0.011)	ND(0.014)	ND(0.019)
		40	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		50	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026)	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		50 Dup	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026)	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
	Dec 2008	20	2.13	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.012)	ND(0.017)
		30	2.2	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.018)
		40	2.29	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.011)	ND(0.014)	ND(0.018)
		50	2.09	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.0099)	ND(0.012)	ND(0.017)
	Sep/Oct 2009	20	2.39	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0048)	ND(0.0092)	ND(0.0043)	ND(0.025)	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0026)	ND(0.0059)	ND(0.011)	ND(0.014)	ND(0.019)
		30	2.64	ND(0.029)	ND(0.029)	ND(0.0065)	ND(0.0065)	ND(0.0053)	ND(0.01)	ND(0.0048)	ND(0.028)	ND(0.0042)	ND(0.005)	ND(0.0057)	ND(0.0057)	ND(0.0057)	ND(0.0045)	ND(0.0046)	ND(0.0054)	ND(0.0056)	ND(0.0062)	ND(0.0065)	ND(0.0065)	ND(0.0029)	ND(0.0065)	ND(0.012)	ND(0.016)	ND(0.021)
		40	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025)	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	ND(0.012)	ND(0.014)	ND(0.019)
		50	2.48	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0045)	ND(0.026)	ND(0.004)	ND(0.0047)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0043)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.015)	ND(0.02)
		50 Dup	2.44	ND(0.027)	ND(0.027)	ND(0.006)	ND(0.006)	ND(0.0049)	ND(0.0094)	ND(0.0044)	ND(0.026)	ND(0.0039)	ND(0.0046)	ND(0.0053)	ND(0.0053)	ND(0.0053)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0057)	ND(0.006)	ND(0.006)	ND(0.0027)	ND(0.006)	ND(0.012)	ND(0.014)	ND(0.02)
	Aug 2010	20	2.7	ND(0.03)	ND(0.03)	ND(0.0066)	ND(0.0066)	ND(0.0055)	ND(0.01)	ND(0.0049)	ND(0.028) J	ND(0.0043)	ND(0.0051)	ND(0.0059)	ND(0.0059)	ND(0.0059)	ND(0.0046)	ND(0.0048)	ND(0.0055)	ND(0.0058)	ND(0.0063)	ND(0.0066)	ND(0.0066)	ND(0.003)	ND(0.0066)	ND(0.013)	ND(0.016)	ND(0.022)
		30	2.52	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0045)	ND(0.026) J	ND(0.004)	ND(0.0047)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0043)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		40	2.46	ND(0.027)	ND(0.027)	ND(0.006)	ND(0.006)	ND(0.005)	ND(0.0094)	ND(0.0044)	ND(0.026) J	ND(0.0039)	ND(0.0046)	ND(0.0053)	ND(0.0053)	ND(0.0053)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0057)	ND(0.006)	ND(0.006)	ND(0.0027)	ND(0.006)	ND(0.012)	ND(0.014)	ND(0.02)
		50	2.48	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0045)	ND(0.026) J	ND(0.004)	ND(0.0047)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0043)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.015)	ND(0.02)
		50 DUP	2.48	ND(0.027)	ND(0.027)	ND(0.0061)	ND(0.0061)	ND(0.005)	ND(0.0095)	ND(0.0045)	ND(0.026) J	ND(0.004)	ND(0.0047)	ND(0.0054)	ND(0.0054)	ND(0.0054)	ND(0.0043)	ND(0.0044)	ND(0.0051)	ND(0.0053)	ND(0.0058)	ND(0.0061)	ND(0.0061)	ND(0.0027)	ND(0.0061)	ND(0.012)	ND(0.015)	ND(0.02)
VW-130	Apr 2008	20	2.33	ND(0.026) J	ND(0.026) J	ND(0.0057) J	ND(0.0057) J	ND(0.0047) J	ND(0.009) J	ND(0.0042) J	ND(0.024) J	ND(0.0037) J	ND(0.0044) J	ND(0.005) J	ND(0.005) J	ND(0.005) J	ND(0.004) J	0.039 J	ND(0.0048) J	ND(0.005) J	ND(0.0054) J	ND(0.0057) J	ND(0.0057) J	ND(0.0026) J	ND(0.0057) J	--	--	--
		30	77.7	ND(0.85) J	ND(0.85) J	ND(0.19) J	ND(0.19) J	ND(0.16) J	**ND(0.3) J**	ND(0.14) J	**ND(0.81) J**	ND(0.12) J	ND(0.15) J	ND(0.17) J	ND(0.17) J	ND(0.17) J	ND(0.13) J	ND(0.14) J	ND(0.16) J	ND(0.16) J	ND(0.18) J	ND(0.19) J	ND(0.19) J	ND(0.086) J	ND(0.19) J	--	--	--
		40	2.38	ND(0.026)	ND(0.026)	ND(0.0058)	ND(0.0058)	ND(0.0048)	ND(0.0091)	ND(0.0043)	ND(0.025) J	ND(0.0038)	ND(0.0045)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	0.01 J	0.0088 J	ND(0.0051)	ND(0.0056)	ND(0.0058)	ND(0.0058)	ND(0.0026)	ND(0.0058)	--	--	--
		40 Dup	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025) J	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043) J	ND(0.005) J	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	--	--	--
	Sep 2008	20	2.2	ND(0.024)	ND(0.024)	ND(0.0054)	ND(0.0054)	ND(0.0044)	ND(0.0084)	ND(0.004)	ND(0.023)	ND(0.0035)	ND(0.0041)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0045)	ND(0.0047)	ND(0.0051)	ND(0.0054)	ND(0.0054)	ND(0.0024)	ND(0.0054)	ND(0.01)	ND(0.013)	ND(0.018)
		30	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	0.015 JB	ND(0.014)	ND(0.019)
		40	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026)	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		40 Dup	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026)	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
	Dec 2008	20	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	ND(0.0034)	0.01	ND(0.0047)	0.017	0.0084	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	0.0069	0.029	ND(0.0024)	0.014	ND(0.01)	ND(0.013)	ND(0.017)
		30	2.05	ND(0.022)	ND(0.022)	ND(0.005)	ND(0.005)	ND(0.0041)	ND(0.0079)	ND(0.0037)	ND(0.021)	ND(0.0033)	ND(0.0039)	ND(0.0044)	ND(0.0044)	ND(0.0044)	ND(0.0035)	ND(0.0036)	ND(0.0042)	ND(0.0044)	ND(0.0048)	ND(0.005)	ND(0.005)	ND(0.0023)	ND(0.005)	ND(0.0097)	ND(0.012)	ND(0.016)
		40	2.53	ND(0.028)	ND(0.028)	ND(0.0062)	ND(0.0062)	ND(0.0051)	ND(0.0097)	ND(0.0046)	ND(0.026)	ND(0.004)	ND(0.0048)	ND(0.0055)	ND(0.0055)	ND(0.0055)	ND(0.0044)	ND(0.0044)	ND(0.0052)	ND(0.0054)	ND(0.0059)	ND(0.0062)	ND(0.0062)	ND(0.0028)	ND(0.0062)	ND(0.012)	ND(0.015)	ND(0.02)
		40 Dup	2.42	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0049)	ND(0.0093)	ND(0.0044)	ND(0.025)	ND(0.0039)	ND(0.0046)	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0042)	ND(0.0043)	ND(0.005)	ND(0.0052)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0027)	ND(0.0059)	ND(0.012)	ND(0.014)	ND(0.019)
	Sep/Oct 2009	20	2.39	ND(0.026)	ND(0.026)	ND(0.0059)	ND(0.0059)	ND(0.0048)	ND(0.0092)	ND(0.0043)	ND(0.025)	ND(0.0038)	0.0076	ND(0.0052)	ND(0.0052)	ND(0.0052)	ND(0.0041)	ND(0.0042)	ND(0.0049)	ND(0.0051)	ND(0.0056)	ND(0.0059)	ND(0.0059)	ND(0.0026)	ND(0.0059)	0.018	ND(0.014)	ND(0.019)
		30	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	ND(0.0037)	0.0077	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	0.015	ND(0.019)
		40	2.68	ND(0.029)	ND(0.029)	ND(0.0066)	ND(0.0066)	ND(0.0054)	ND(0.01)	ND(0.0048)	ND(0.028)	ND(0.0043)	ND(0.005)	ND(0.0058)	ND(0.0058)	ND(0.0058)	ND(0.0046)	ND(0.0047)	ND(0.0055)	ND(0.0057)	ND(0.0062)	ND(0.0066)	ND(0.0066)	ND(0.003)	ND(0.0066)	ND(0.013)	ND(0.016)	ND(0.022)
		40 Dup	2.71	ND(0.03)	ND(0.03)	ND(0.0067)	ND(0.0067)	ND(0.0055)	ND(0.01)	ND(0.0049)	ND(0.028)	ND(0.0043)	ND(0.0051)	ND(0.0059)	ND(0.0059)	ND(0.0059)	ND(0.0047)	ND(0.0048)	ND(0.0056)	ND(0.0058)	ND(0.0063)	ND(0.0067)	ND(0.0067)	ND(0.003)	ND(0.0067)	ND(0.013)	ND(0.016)	ND(0.022)

TABLE 4-2. SCREENING EVALUATION FOR NESTED SOIL VAPOR RESULTS, GASOLINE RELATED CONSTITUENTS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Nested Vapor Monitoring Well	Date	Depth	Dilution Factor	n-Butyl-benzene mg/m^3	sec-Butyl-benzene mg/m^3	Isopropyl-benzene mg/m^3	n-Propyl-benzene mg/m^3	1,2-Dichloro-ethane mg/m^3	1,2-Dibromo-ethane mg/m^3	MTBE mg/m^3	Naphthalene mg/m^3	Benzene mg/m^3	Toluene mg/m^3	Ethyl-benzene mg/m^3	m,p-Xylene mg/m^3	o-Xylene mg/m^3	Cyclo-hexane mg/m^3	Hexane mg/m^3	Heptane mg/m^3	Styrene mg/m^3	2,2,4-Trimethyl-pentane mg/m^3	1,3,5-Trimethyl-benzene mg/m^3	1,2,4-Trimethyl-benzene mg/m^3	1,3-Butadiene mg/m^3	4-Ethyl-toluene mg/m^3	Butane mg/m^3	Isopentane mg/m^3	Methyl cyclohexane mg/m^3
VW-139	Jul 2009	5	3.95	ND(0.043)	ND(0.043)	ND(0.0097)	ND(0.0097)	ND(0.008)	ND(0.015)	ND(0.0071)	ND(0.041)	0.0011 J	ND(0.0074)	0.0038 J	0.0017 J	ND(0.0086)	ND(0.0068)	ND(0.007)	ND(0.0081)	ND(0.0084)	ND(0.0092)	ND(0.0097)	ND(0.0097)	ND(0.0044)	ND(0.0097)	ND(0.019)	ND(0.023)	ND(0.032)
		10	2.29	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	0.0088	0.02	0.0042 J	0.02	0.0095	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0053)	ND(0.0056)	0.012	ND(0.0025)	0.0061	ND(0.011)	ND(0.014)	ND(0.018)
		15	2.33	ND(0.026)	ND(0.026)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.009)	ND(0.0042)	ND(0.024)	0.0005 J	0.0009 J	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0048)	ND(0.005)	ND(0.0054)	ND(0.0057)	ND(0.0057)	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.019)
		20	4.76	ND(0.052)	ND(0.052)	ND(0.012)	ND(0.012)	ND(0.0096)	ND(0.018)	ND(0.0086)	ND(0.05)	0.003 J	0.005 J	0.0022 J	0.0031 J	ND(0.01)	ND(0.0082)	ND(0.0084)	ND(0.0098)	ND(0.01)	ND(0.011)	ND(0.012)	ND(0.012)	ND(0.0053)	ND(0.012)	ND(0.023)	ND(0.028)	ND(0.038)
		30	4.66	ND(0.051)	ND(0.051)	ND(0.011)	ND(0.011)	ND(0.0094)	ND(0.018)	ND(0.0084)	ND(0.049)	ND(0.0074)	ND(0.0088)	ND(0.01)	ND(0.01)	ND(0.01)	ND(0.008)	ND(0.0082)	ND(0.0095)	ND(0.0099)	ND(0.011)	ND(0.011)	ND(0.011)	ND(0.0052)	ND(0.011)	ND(0.022)	ND(0.028)	ND(0.037)
	Sep/Oct 2009	5	2.23	ND(0.024)	ND(0.024)	ND(0.0055)	ND(0.0055)	ND(0.0045)	ND(0.0086)	ND(0.004)	ND(0.023)	ND(0.0036)	ND(0.0042)	ND(0.0048)	ND(0.0048)	ND(0.0048)	ND(0.0038)	ND(0.0039)	ND(0.0046)	ND(0.0047)	ND(0.0052)	ND(0.0055)	ND(0.0055)	ND(0.0025)	ND(0.0055)	ND(0.011)	ND(0.013)	ND(0.018)
		10	2.3	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0037)	ND(0.0043)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.004)	ND(0.0047)	ND(0.0049)	ND(0.0054)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.014)	ND(0.018)
		15	2.28	ND(0.025)	ND(0.025)	ND(0.0056)	ND(0.0056)	ND(0.0046)	ND(0.0088)	ND(0.0041)	ND(0.024)	ND(0.0036)	ND(0.0043)	ND(0.0049)	0.005 J	ND(0.005)	ND(0.0039)	ND(0.004)	ND(0.0047)	ND(0.0048)	ND(0.0053)	ND(0.0056)	ND(0.0056)	ND(0.0025)	ND(0.0056)	ND(0.011)	ND(0.013)	ND(0.018)
		20	2.16	ND(0.024)	ND(0.024)	ND(0.0053)	ND(0.0053)	ND(0.0044)	ND(0.0083)	ND(0.0039)	ND(0.023)	0.0057	ND(0.0041)	ND(0.0047)	ND(0.0047)	ND(0.0047)	ND(0.0037)	ND(0.0038)	ND(0.0044)	ND(0.0046)	ND(0.005)	ND(0.0053)	ND(0.0053)	ND(0.0024)	ND(0.0053)	ND(0.01)	ND(0.013)	ND(0.017)
		30	2.31	ND(0.025)	ND(0.025)	ND(0.0057)	ND(0.0057)	ND(0.0047)	ND(0.0089)	ND(0.0042)	ND(0.024)	ND(0.0037)	ND(0.0044)	ND(0.005)	ND(0.005)	ND(0.005)	ND(0.004)	ND(0.0041)	ND(0.0047)	ND(0.0049)	0.0084	ND(0.0057)	0.0062	ND(0.0026)	ND(0.0057)	ND(0.011)	ND(0.014)	ND(0.018)
		40	632	ND(69)	ND(69)	ND(16)	ND(16)	**ND(13)**	**ND(24)**	ND(11)	**ND(66)**	**ND(10)**	ND(12)	ND(14)	24 J	ND(14)	440	320	260 J	ND(13)	2400	**ND(16)**	**ND(16)**	**ND(7)**	ND(16)	34	1200	780
		40 Dup	625	ND(69)	ND(69)	ND(15)	ND(15)	**ND(13)**	**ND(24)**	ND(11)	**ND(66)**	**ND(10)**	ND(12)	14 J	31 J	ND(14)	510	370	310 J	ND(13)	2800	**ND(15)**	**22**	**ND(6.9)**	ND(15)	38	1400	920
USEPA RSL for Depths of 20 ft-bgs				NA	NA	210	NA	0.47	0.021	47	0.36	1.6	2600	4.9	365	365	3150	365	NA	500	NA	3.2	3.7	0.41	NA	NA	NA	NA
USEPA RSL for Depths Greater than 20 ft-bgs to 35 ft-bgs				NA	NA	420	NA	0.94	0.041	94	0.72	3.1	5200	9.7	730	730	6300	730	NA	1000	NA	6.3	7.3	0.81	NA	NA	NA	NA
USEPA RSL for Depths Greater than 35 ft-bgs				NA	NA	600	NA	1.3	0.059	134	1.0	4.4	7429	14	1043	1043	9000	1043	NA	1429	NA	9.0	10.4	1.16	NA	NA	NA	NA

NOTES:

Screening levels for Hooven calculated using the Regional Screening Levels for Residential Air and semi-site specific attenuation factors from Figure 3a of the *OSWER Draft VI Guidance*. For depths of 20 ft-bgs an attenuation factor of 0.002 was used, for depths of greater than 20 ft-bgs to 35 ft-bgs an attenuation factor of 0.001 was used, and for depths greater than 35 ft-bgs an attenuation factor of 0.0007 was used.

Screening levels for the Southwest Quad calculated using the Regional Screening Levels for residential air and semi-site specific attenuation factors from Figure 3a of the *OSWER Draft VI Guidance*. For depths between 5 and 10 ft-bgs an attenuation factor of 0.002 was used, for depths of greater than 10 ft-bgs to 30 ft-bgs an attenuation factor of 0.001 was used, and for depths greater than 30 ft-bgs an attenuation factor of 0.0007 was used.

BOLD - reported value is above the adjusted USEPA April 2009 RSL screening standard at the specified depth

Dup - Blind Duplicate Sample

J – estimated concentration

mg/m^3 - milligram per cubic meter

MTBE - methyl tert butyl ether

NA - Not Available

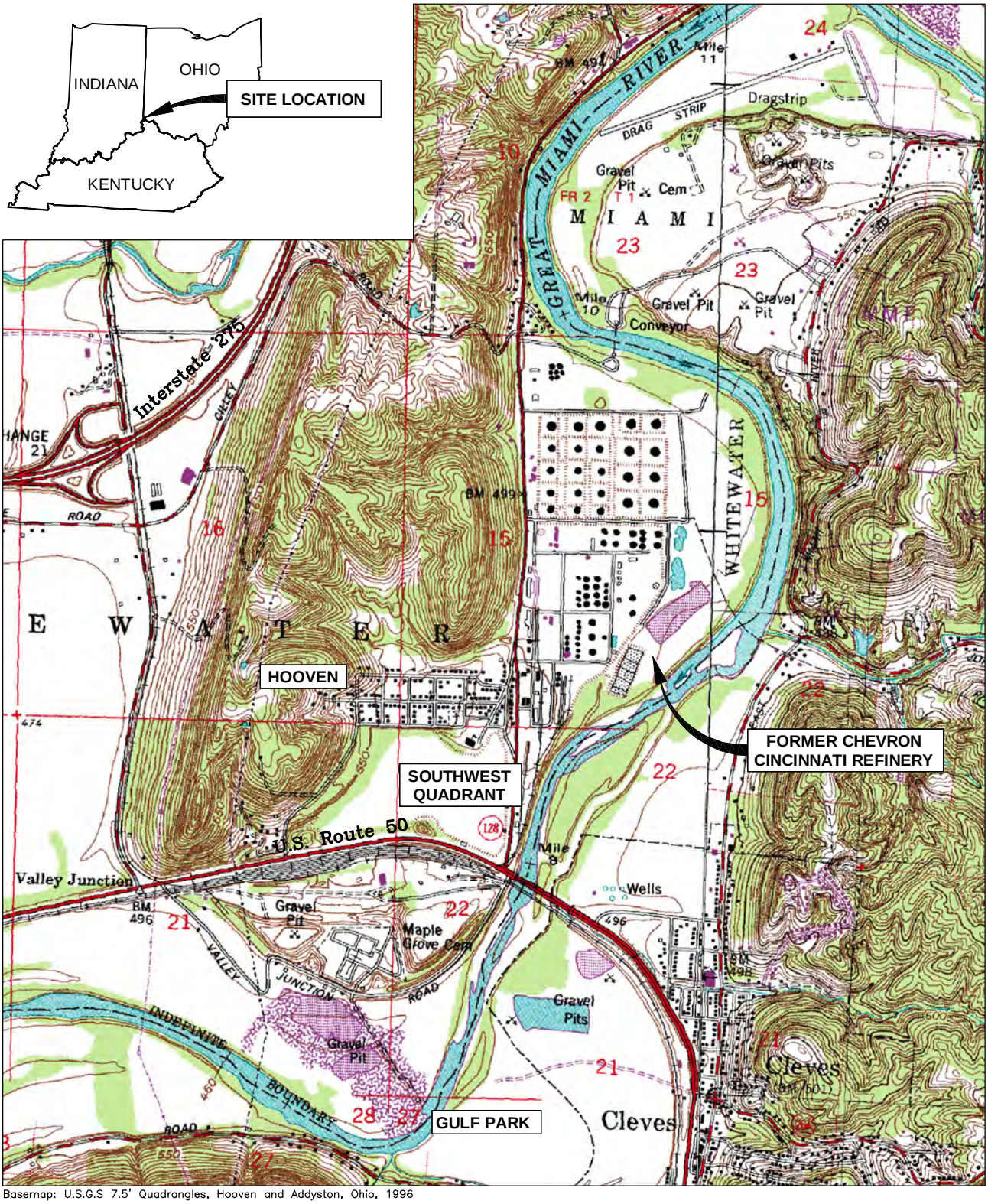
ND - Not detected

TABLE 4-3. LYSIMETER ANALYTICAL RESULTS SUMMARY
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Location ID	Date Sampled	Dissolved Oxygen[1] (mg/L)	ORP[1]	Methane (mg/L)	Manganese Total (mg/L)	Manganese Dissolved (mg/L)	Iron Total (mg/L)	Nitrogen Nitrate (mg/L)	Sulfate (mg/L)	Iron Dissolved (mg/L)	Assimilative Capacity (mg hydrocarbon/L)
L-18S	5/14/09	4.2	189	1.9	0.362	0.357	0.319	ND(0.25)	1.8 J	ND(0.0522)	-0.500
	12/09/09	2.8	148	1.4	0.257	0.26	1.36	ND(0.25)	ND(1.5)	ND(0.0522)	-0.231
	6/03/10	2.0	45	2.7	0.256	0.259	2.38	ND(0.25)	ND(1.5)	ND(0.0522)	-2.268
	12/20/10	1.0	23	2.4	0.134	0.131	8.39	ND(0.25)	ND(1.5)	ND(0.0522)	-1.842
	6/16/11	2.0	-24	3.0	1.1	1.0	12	ND(0.0045)	ND(0.02)	7.2	-3.096
L-20S	5/14/09	2.6	208	ND(0.014)U	0.637	0.66	0.268	ND(0.25)	156	ND(0.0522)	15.000
	12/09/09	4.0	164	ND(0.01)	0.0978	0.0089	1	10.7	169	ND(0.0522)	35.290
	6/03/10	2.0	86	0.011 J	1.99	1.92	1.15	ND(0.25)	59.6	ND(0.0522)	11.734
	12/20/10	2.0	116	ND(0.005)	0.0518	0.0181	0.351	2.5	126 J	ND(0.0522)	24.981
	6/16/11	2.8	142	0.0024	0.13	0.11	ND(0.00097)	5.0	46	ND(0.00097)	10.490
L-21S	5/14/09	3.0	211	0.27	0.197	0.187	1.21	ND(0.25)	1.6 J	ND(0.0522)	0.900
	12/09/09	5.0	189	0.34	0.155	0.157	0.41	ND(0.25)	ND(1.5)	ND(0.0522)	1.581
	6/03/10	6.0	67	2.2	0.148	0.145	1.02	ND(0.25)	ND(1.5)	ND(0.0522)	-0.548
	12/20/10	3.0	82	0.95	0.12	0.117	3.87	ND(0.25)	ND(1.5)	ND(0.0522)	0.334
	6/16/11	2.0	69	0.74	0.17	0.17	1.8	ND(0.0045)	ND(0.02)	ND(0.00097)	-0.246
L-93S	5/14/09	6.0	173	ND(0.005)	0.0039 J	0.0034 J	ND(0.0522)	14.4	124	ND(0.0522)	19.800
	12/09/09	6.0	84	ND(0.01)	0.0034 J	0.0035 J	ND(0.0522)	1.3	155	ND(0.0522)	31.424
	6/03/10	6.0	101	ND(0.005)	0.0036 J	0.0014 J	0.0813 J	14.6	45.5	ND(0.0522)	13.155
	12/20/10	6.0	116	ND(0.005)	0.0041 J	0.0034 J	0.106 J	25.3	32.9 J	ND(0.0522)	12.785
	6/16/11	2.8	72	ND(0.00083)	ND(0.00023)	ND(0.00023)	ND(0.00097)	15	60	ND(0.00097)	15.062

NOTES:
[1] - ORP and DO measured in the field using titration kits
The method detection limit was used as the reporting limit.
J - Estimated concentration
mg/L - milligram per liter
mg hydrocarbon/L - milligrams of petroleum hydrocarbons per liter
ND - Not detected at the indicated laboratory reporting limit or the method detection limit.
ND(0.014)U - The result was evaluated to be undetected at the reported concentration during validation due to detection of the analyte within the method blank

FIGURES



Basemap: U.S.G.S 7.5' Quadrangles, Hooven and Addyston, Ohio, 1996

N

0 2,000'

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FIGURE 1-1

SITE LOCATION MAP

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: MM	Scale: 1" = 2,000'	Date: 11/4/11	File: 500USGSSITE201111

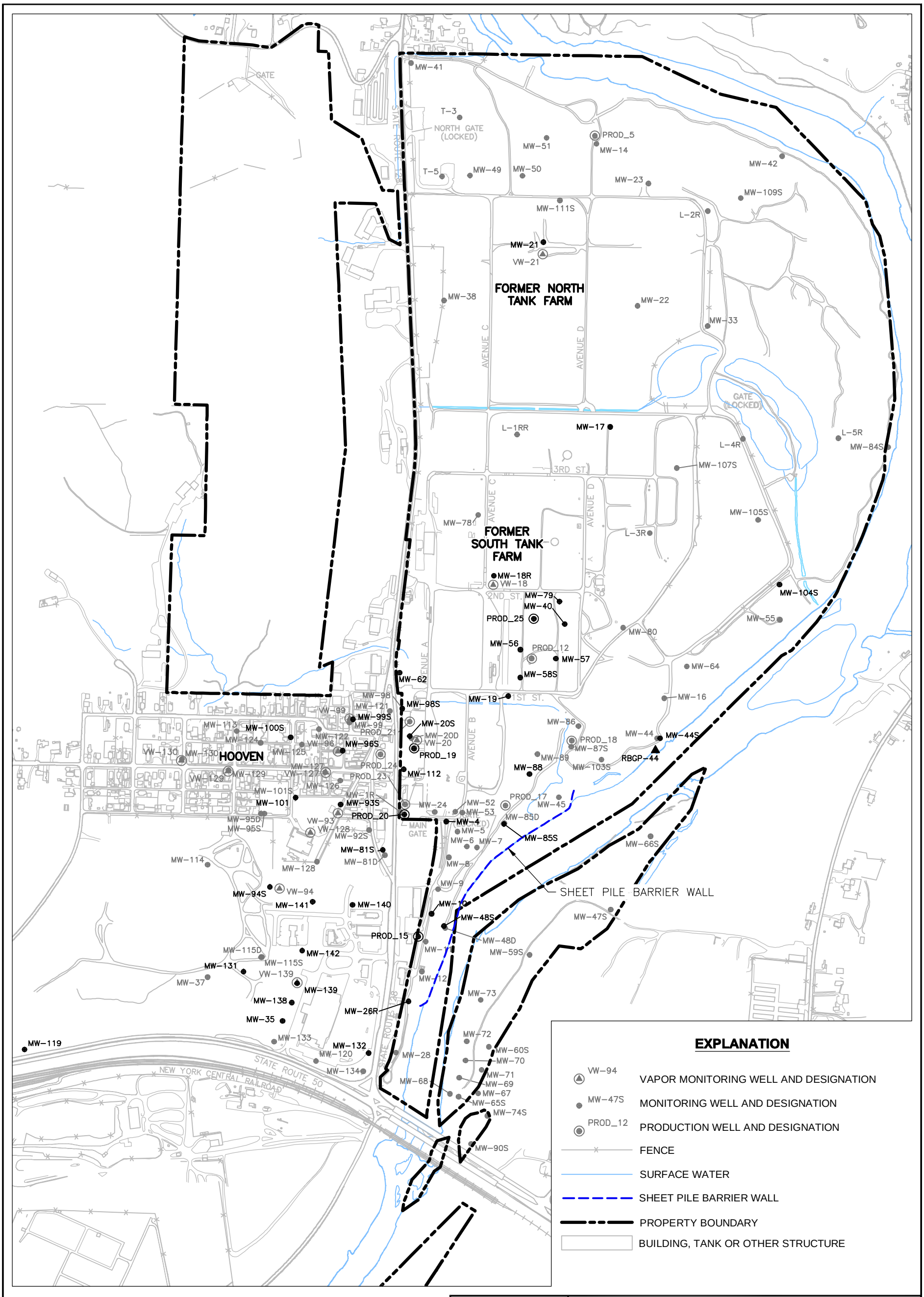

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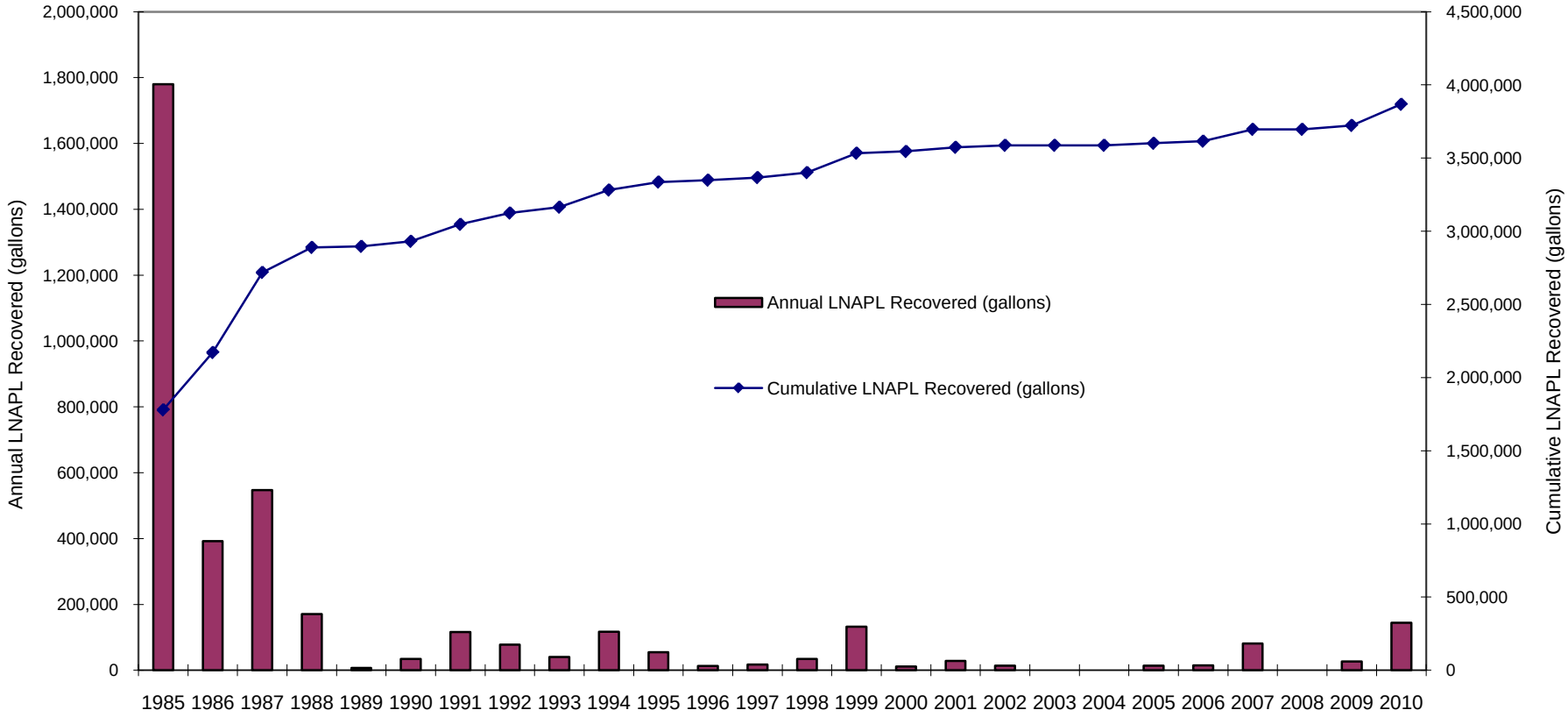
FIGURE 1-2

SITE MONITORING WELL NETWORK

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: MM	Scale: 1" = 650'	Date: 11/4/11	File: 500TRANMONWELLS201111

FIGURE 1-3. ANNUAL LNAPL RECOVERED VIA GROUNDWATER TREATMENT SYSTEMS
FIVE YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



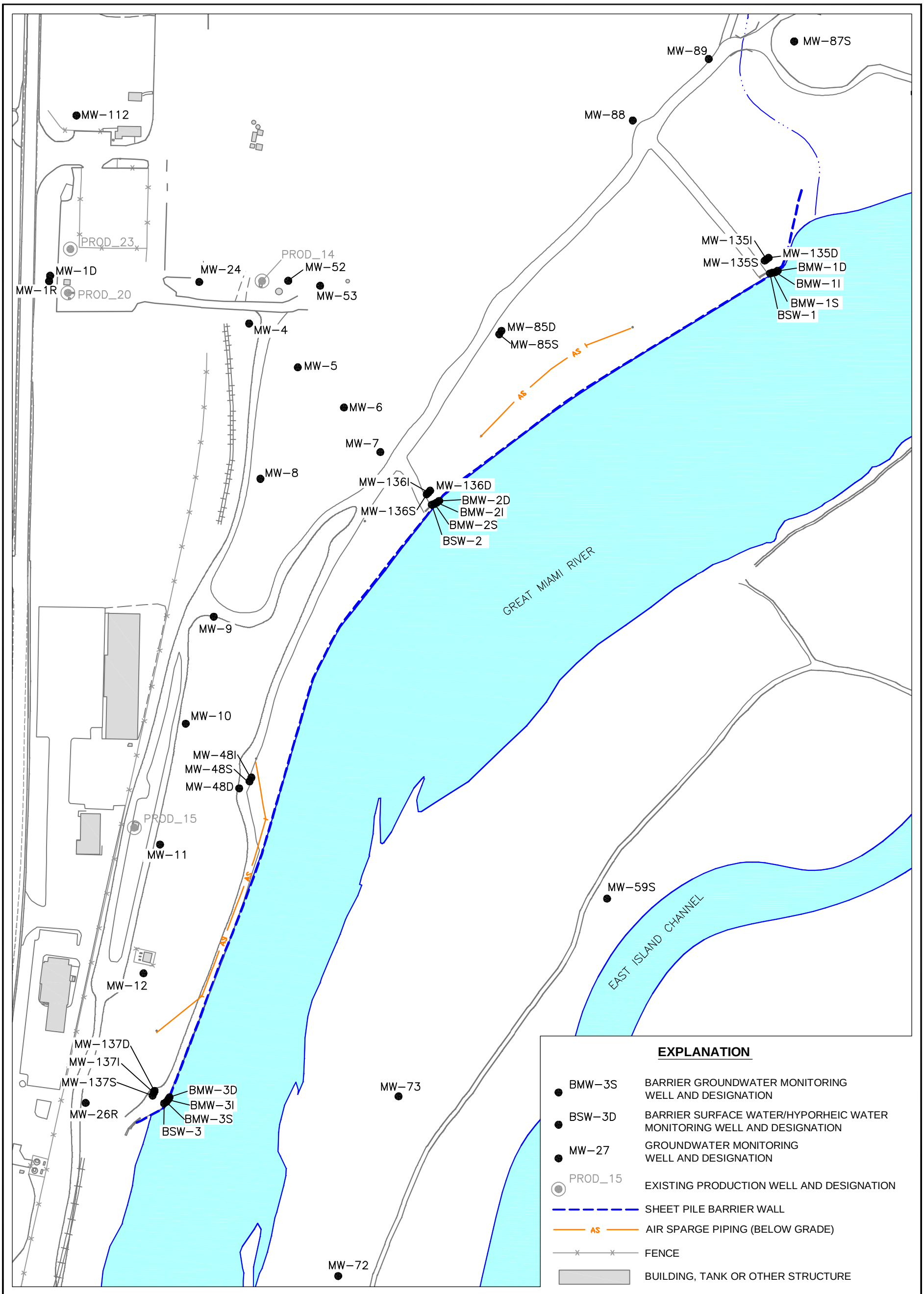


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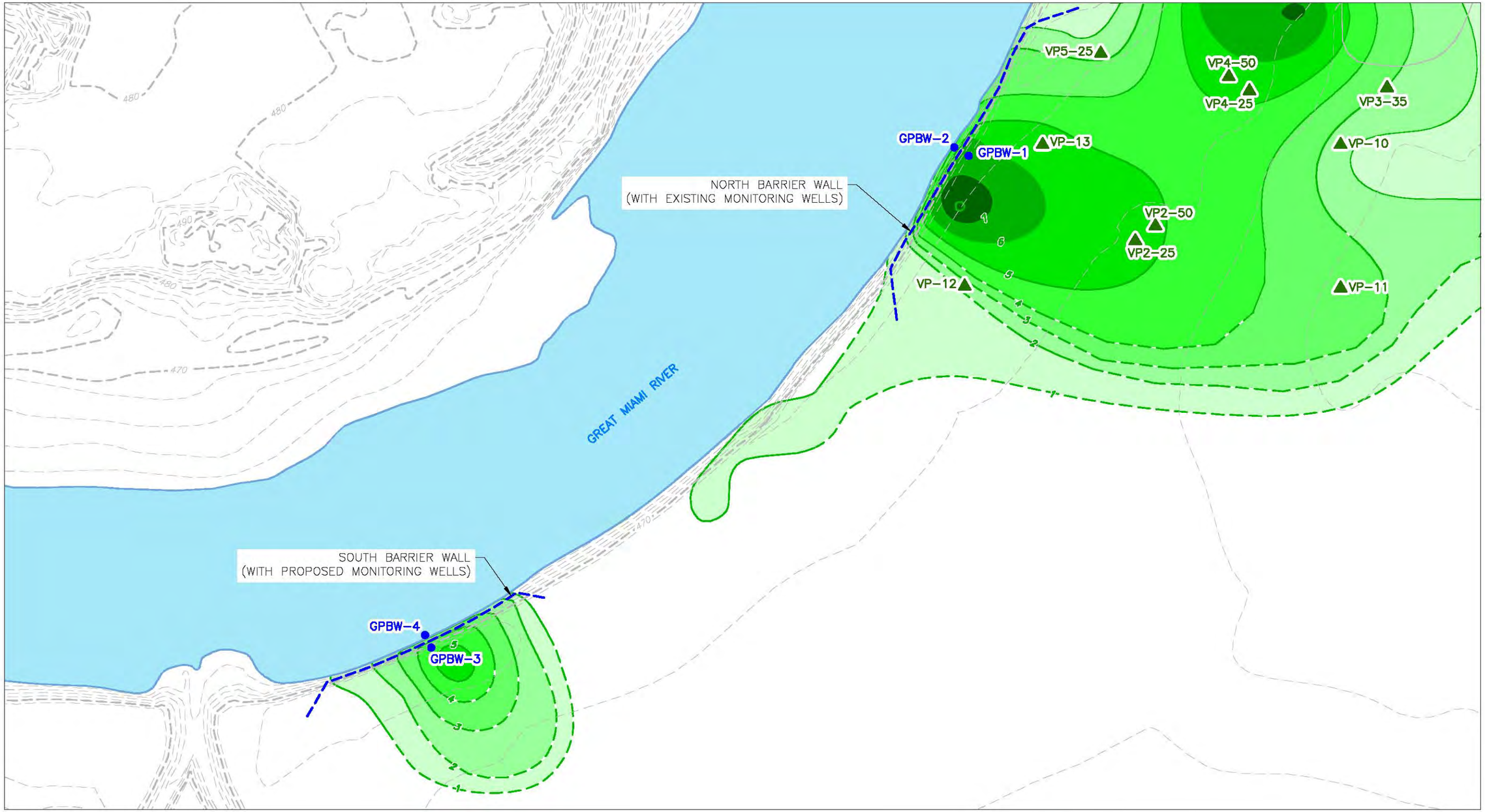
FIGURE 1-4

BARRIER PERFORMANCE AIR SPARGE AND MONITORING WELL NETWORK

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: JGP	Scale: 1" = 150'	Date:5/23/11	File: 500ASBUILTMONNET-201111



EXPLANATION

- GPBW–3 — GROUNDWATER MONITORING WELL AND DESIGNATION
- VP2–25 — SOIL VAPOR MONITORING POINT AND DESIGNATION
- SHEET PILE BARRIER WALL
- LINE OF EQUAL LNAPL THICKNESS (INTERVAL 1 FOOT, DASHED WHERE INFERRED)
- 480 — GENERAL TOPOGRAPHIC CONTOUR (FT AMSL, INTERVAL 2 FEET, DASHED WHERE INFERRED)
- FT AMSL — FEET ABOVE MEAN SEA LEVEL

N

0 100'

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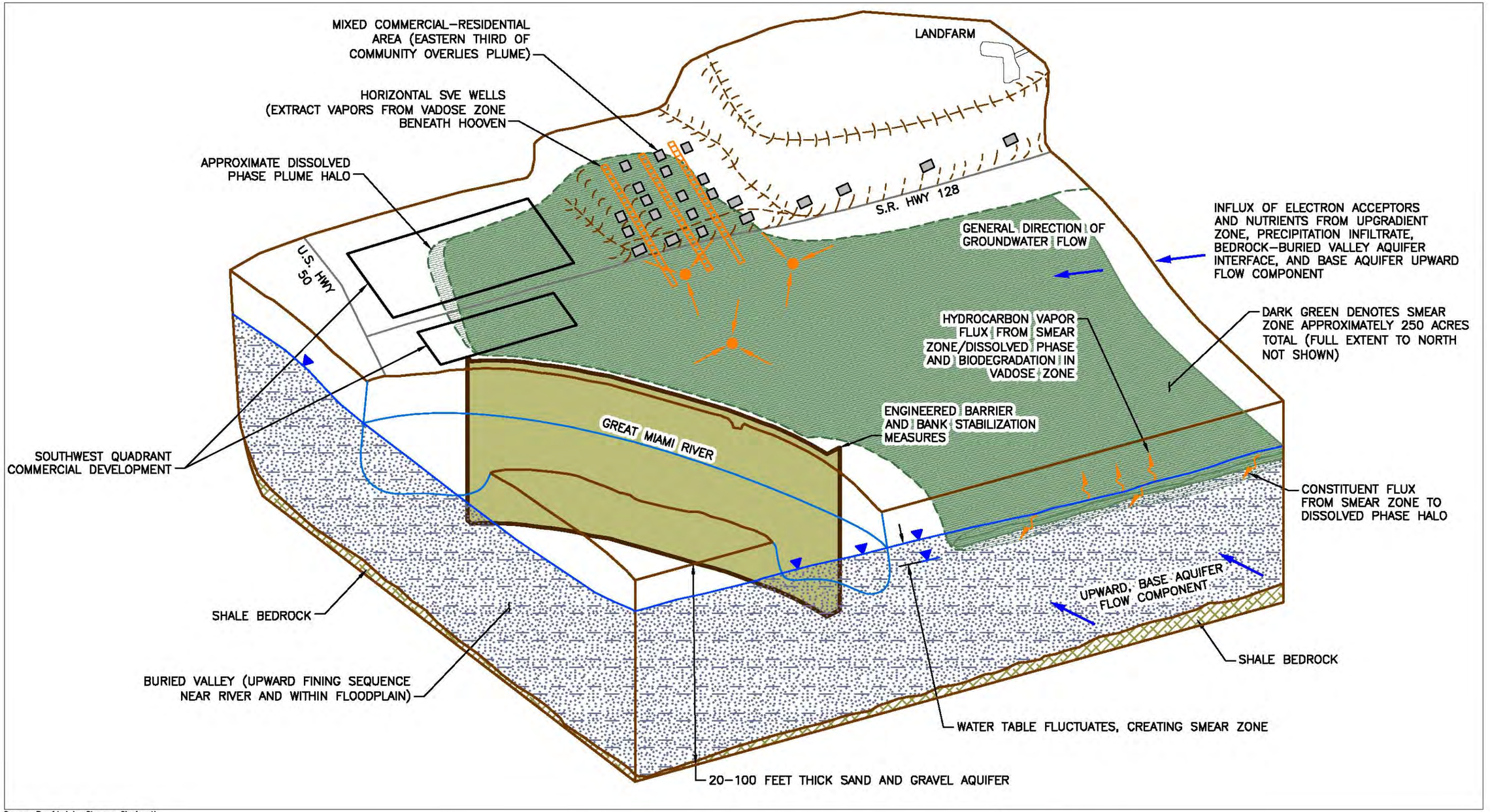
FIGURE 1-5

GULF PARK PROTECTIVE MEASURES AND MONITORING NETWORK

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: PM	Scale: 1"=100'	Date: 11/4/11	File: 500GP_EXTENT201111



Source: Provided by Chevron Cincinnati.

EXPLANATION

- HIGH-GRADE PUMPING TARGETED AREAS WITH HIGHEST RESIDUAL LNAPL SATURATION.
- WATER LEVEL
- DISSOLVED PHASE PLUME EXTENT
- SMEAR ZONE EXTENT

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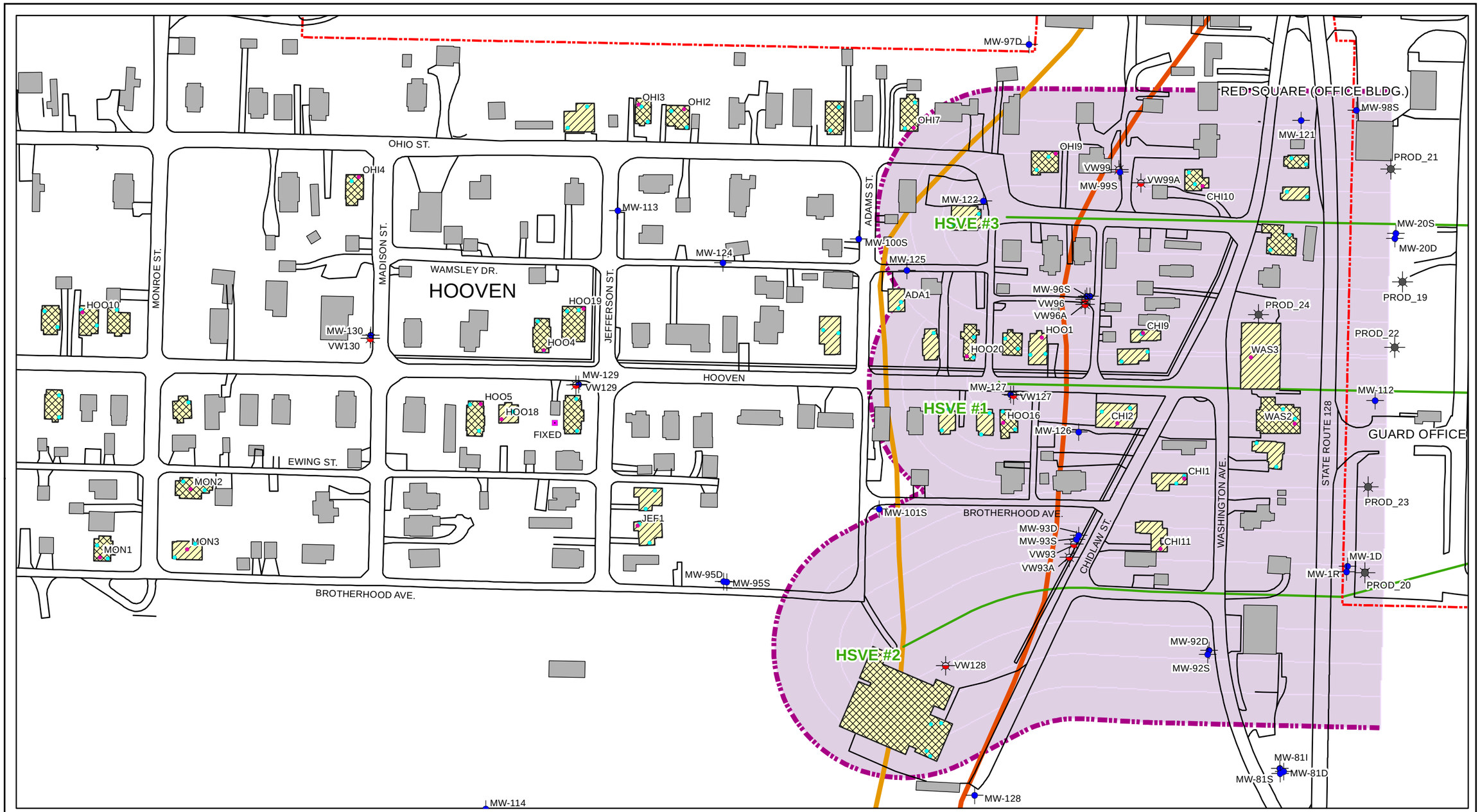
FIGURE 2-1

GROUNDWATER CONCEPTUAL SITE MODEL

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: MM	Scale: NONE	Date: 11/4/11	File: 500GWCONCMODEL-201111



EXPLANATION

- GROUNDWATER MONITORING WELL
- NESTED DEEP SOIL VAPOR MONITORING WELL
- PRODUCTION WELL
- HSVE LINES
- 200-FOOT INFLUENCE OF HSVE SYSTEM
- ESTIMATED EXTENT OF LNAPL PLUME
- ESTIMATED EXTENT OF DISSOLVED-PHASE PLUME
- CHEVRON PROPERTY BOUNDARY

N

0 150'

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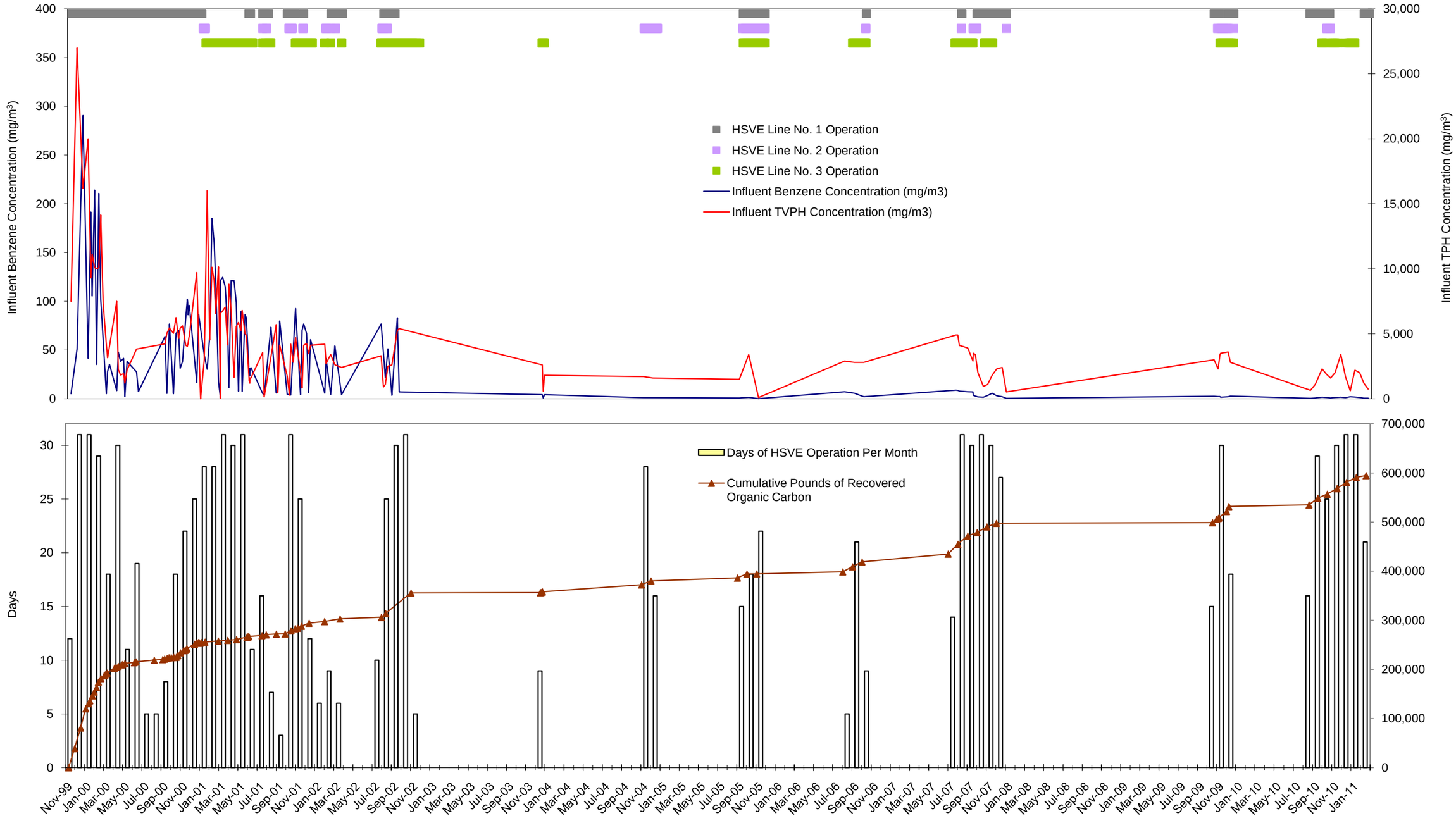
FIGURE 3-1

SITE LOCATION MAP INCLUDING 200-FOOT INFLUENCE OF HSVE SYSTEM

FIVE-YEAR CORRECTIVE MEASURES IMPLEMENTATION REVIEW CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

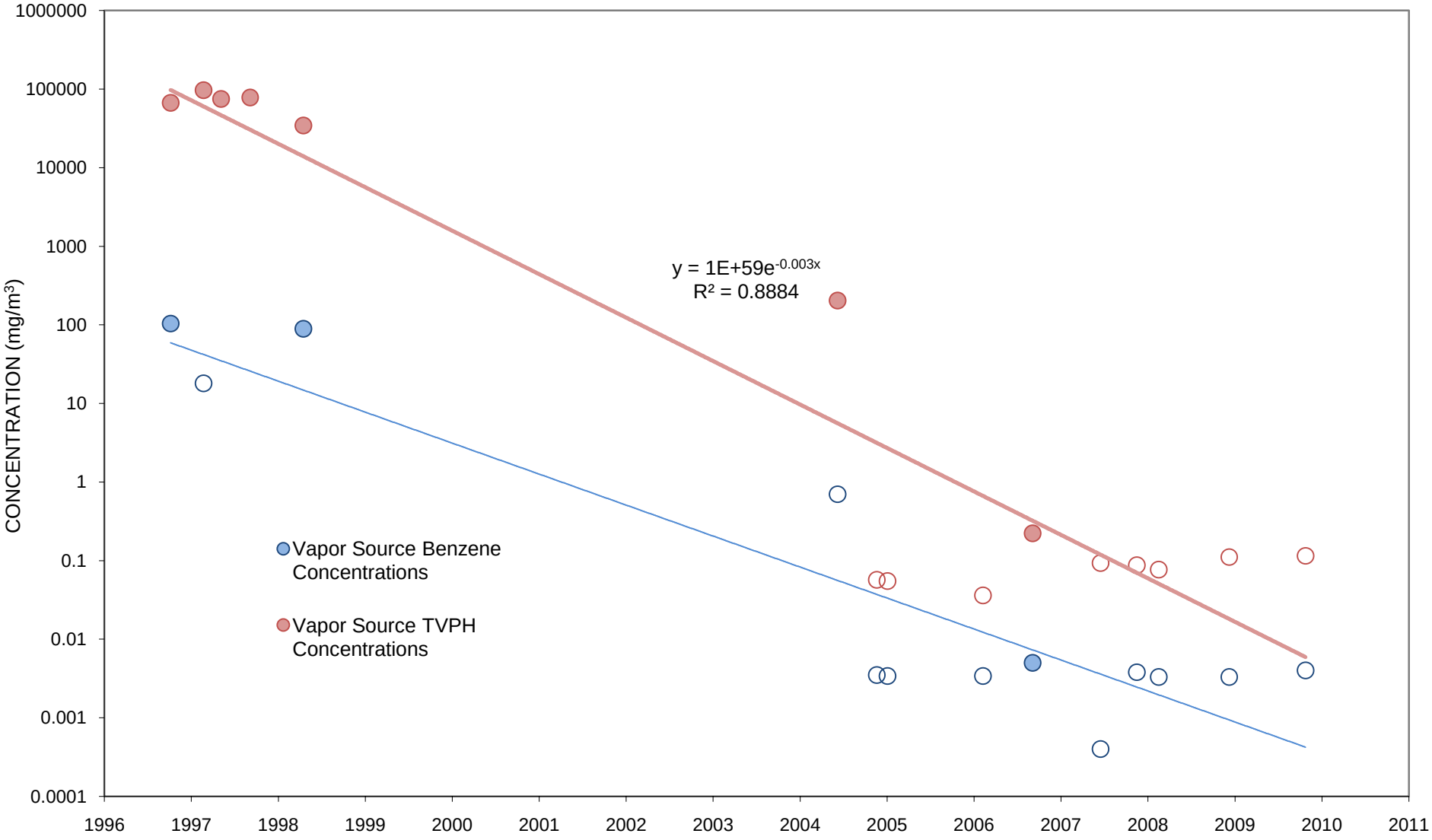
Drawn By: AS	Checked By: PM	Scale: 1" = 150'	Date: 2/15/10	File:201002_Figure_1.mxd

FIGURE 3-2. HSVE OPERATION, INFLUENT CONCENTRATION, AND CUMULATIVE POUNDS OF RECOVERED PETROLEUM HYDROCARBONS
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



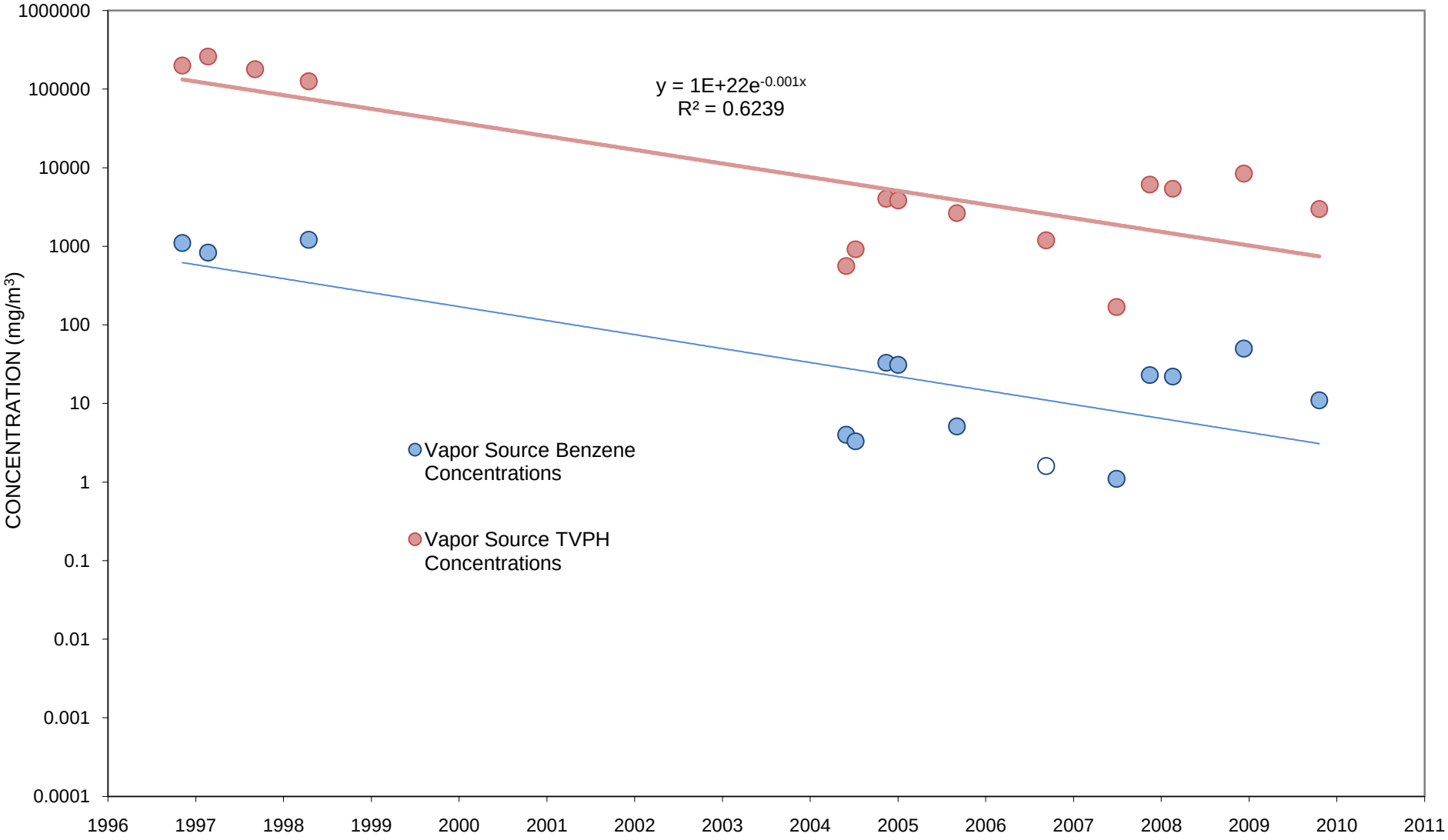
201111_HSVE-MassRemovalEstimates_FIG-3-2.xlsx

FIGURE 3-3. VAPOR SOURCE CONCENTRATIONS, NESTED VAPOR MONITORING WELL VW-93
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



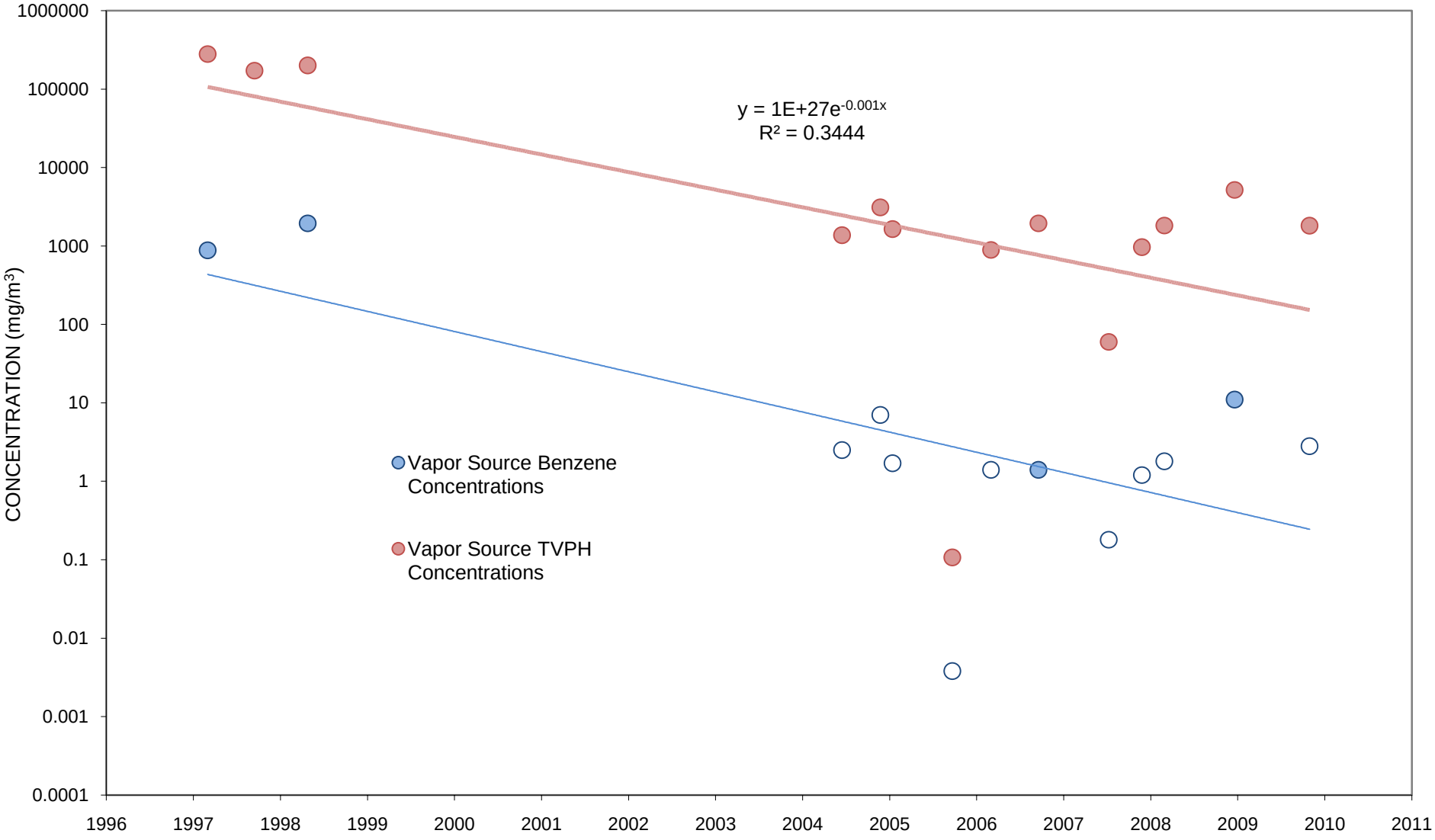
EXPLANATION
OPEN SYMBOL DESIGNATES A NON-DETECT VALUE

FIGURE 3-4. VAPOR SOURCE CONCENTRATIONS, NESTED VAPOR MONITORING WELL VW-96
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION
OPEN SYMBOL DESIGNATES A NON-DETECT VALUE

FIGURE 3-5. VAPOR SOURCE CONCENTRATIONS, NESTED VAPOR MONITORING WELL VW-99
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION
OPEN SYMBOL DESIGNATES A NON-DETECT VALUE

FIGURE 3-6. TVPH AND FIXED GAS PROFILES, NESTED VAPOR MONITORING WELL VW-96
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

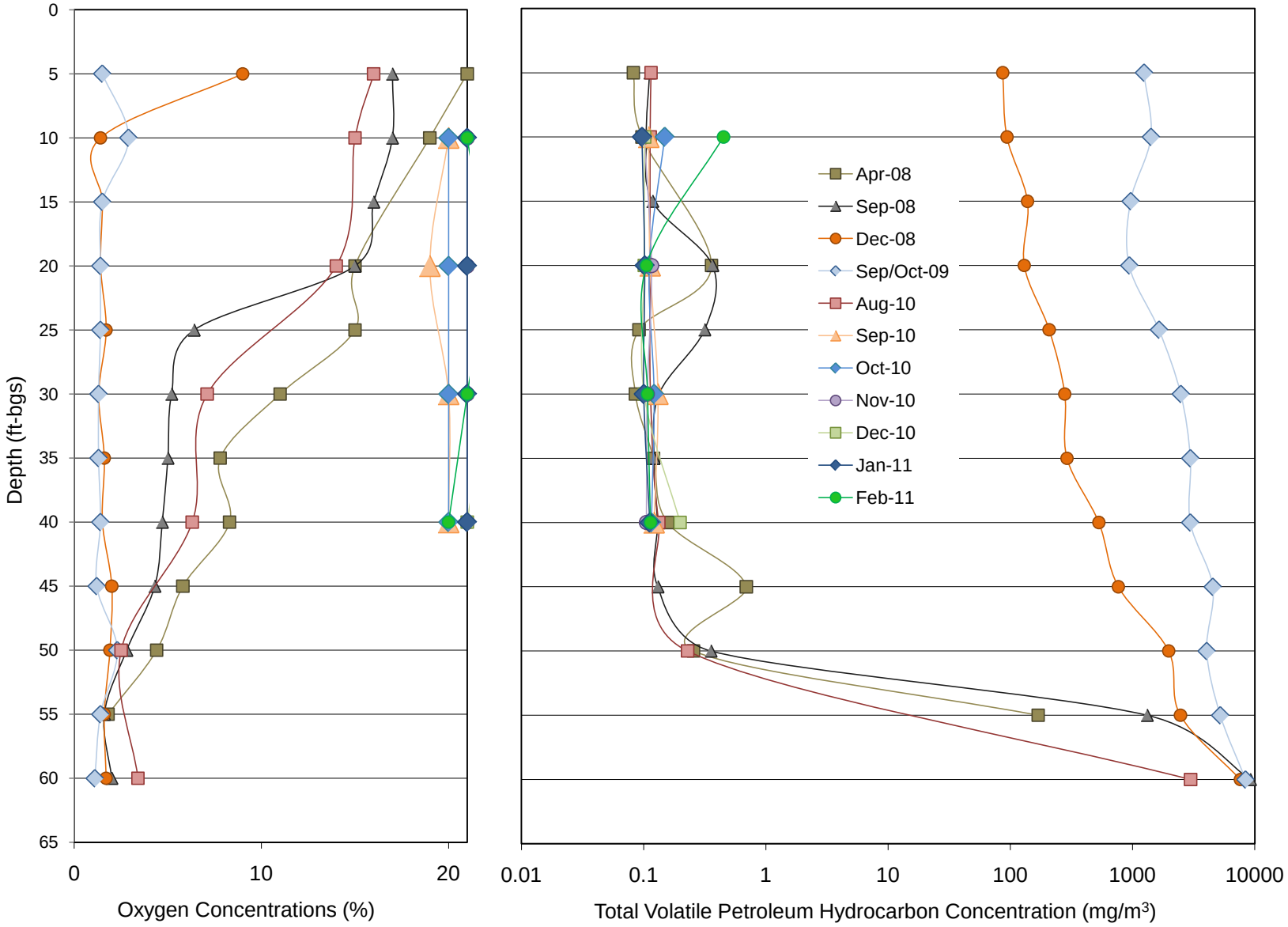
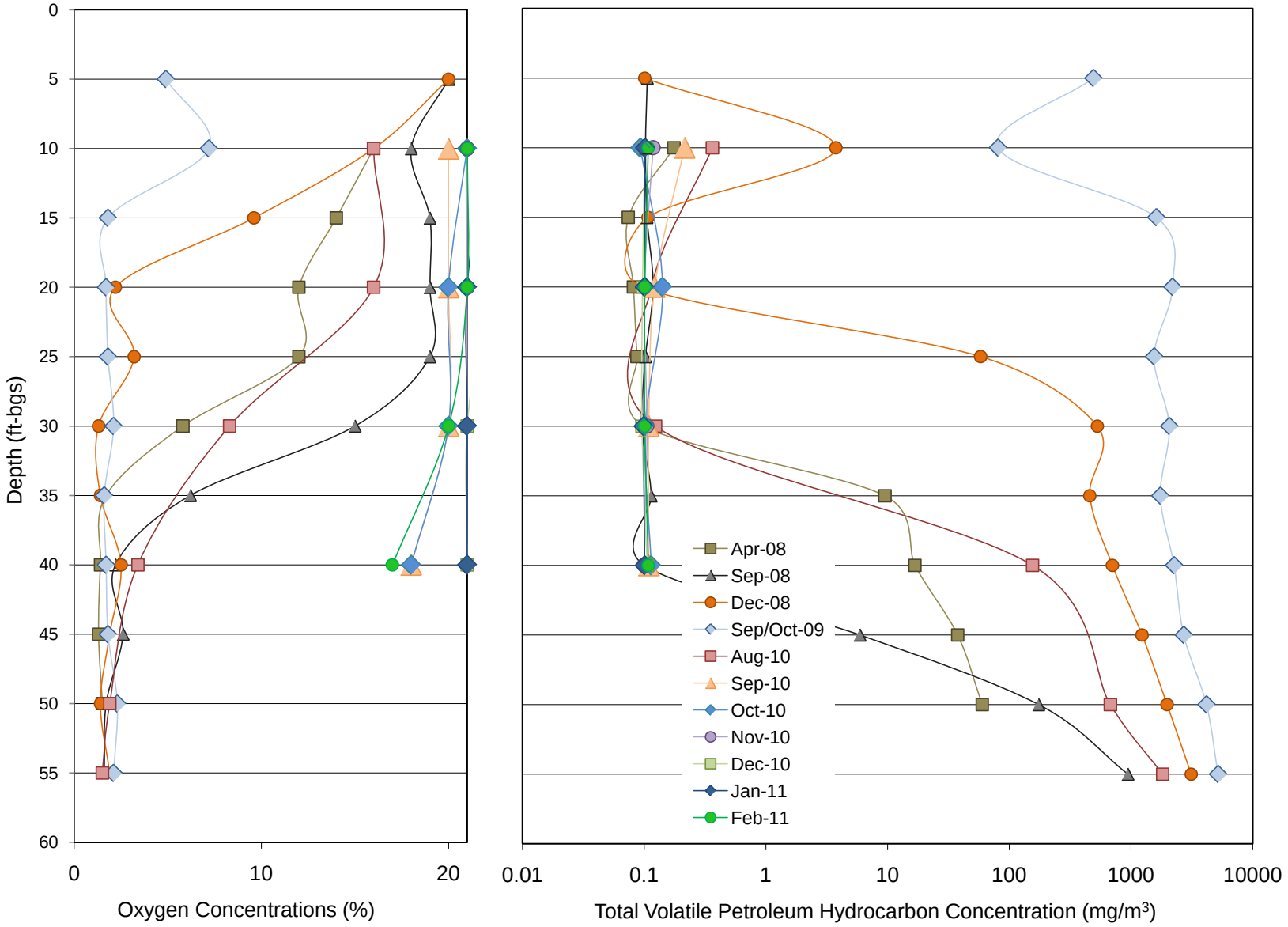
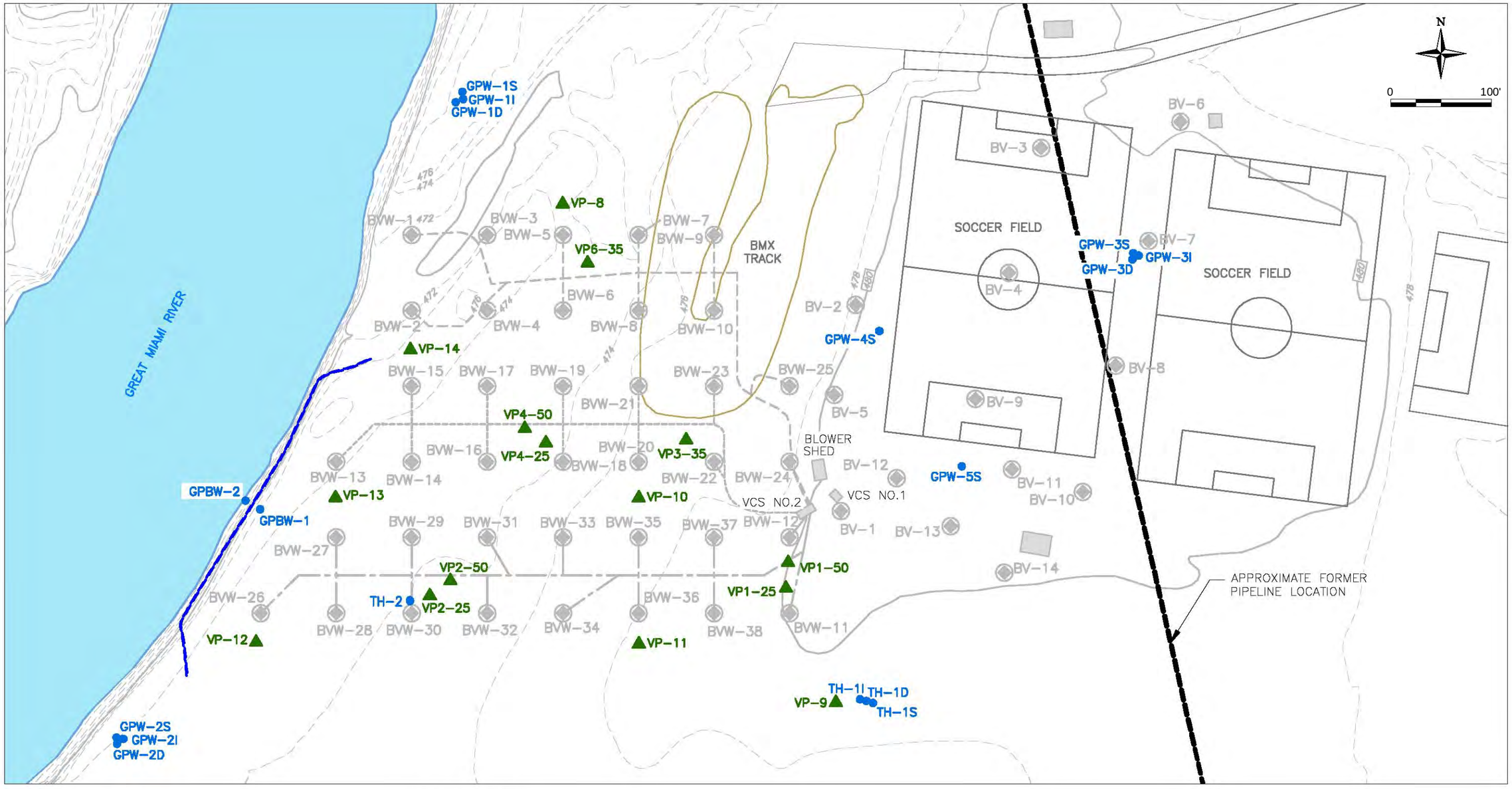


FIGURE 3-7. TVPH AND FIXED GAS PROFILES, NESTED VAPOR MONITORING WELL VW-99
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO





EXPLANATION

- GPW-2D — GROUNDWATER MONITORING WELL AND DESIGNATION
- VP2-25 — SOIL VAPOR MONITORING POINT AND DESIGNATION
- BVW-26 — BIOVENT WELL AND DESIGNATION
- EXPANDED BIOVENTING SYSTEM PIPE RUN #1
- EXPANDED BIOVENTING SYSTEM PIPE RUN #2
- EXPANDED BIOVENTING SYSTEM PIPE RUN #3
- SHEET PILE BARRIER WALL
- 480 — GENERAL TOPOGRAPHIC CONTOUR (FT-AMSL, INTERVAL 2 FEET, DASHED WHERE INFERRED)
- BUILDING, TANK OR OTHER STRUCTURE
- ROAD
- VCS — VALVE CONTROL SHED
- FT AMSL — FEET ABOVE MEAN SEA LEVEL

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FIGURE 3-8

GULF PARK BIOVENT SYSTEMS LAYOUT

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: MM	Scale: 1"=100'	Date: 11/4/11	File: 500GP_LAYOUT201111

FIGURE 3-9. GULF PARK HYDROGRAPHS AND TRIGGER LEVELS FOR WELLS TH-2 AND GPW-5S (2006 THROUGH 2011)
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

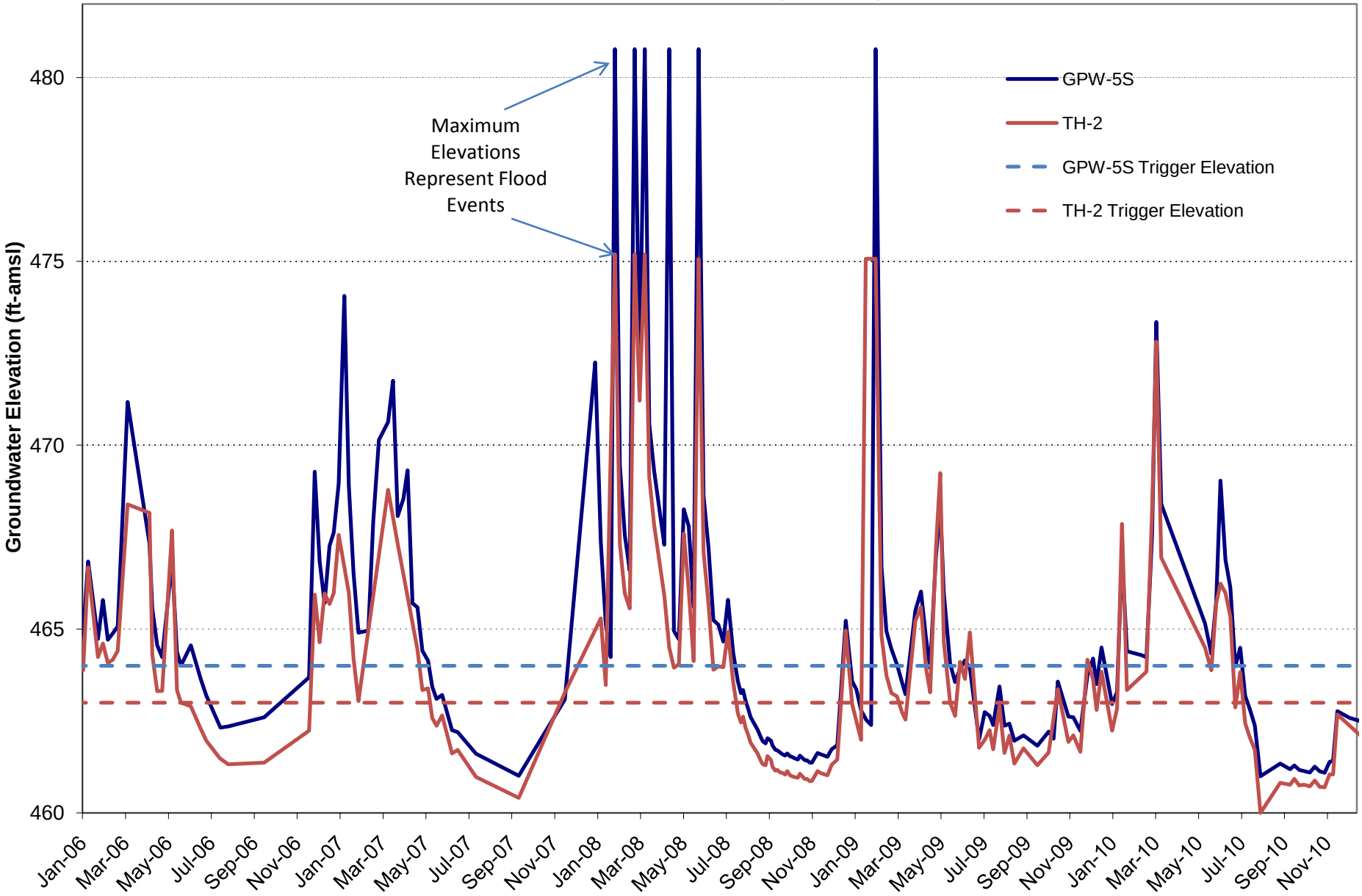


FIGURE 3-10. TOTAL BTEX CONCENTRATION VERSUS TIME FOR GULF PARK WELLS GPW-1S, GPW-2S, GPW-3S, GPW-4S, and GPW-5S
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

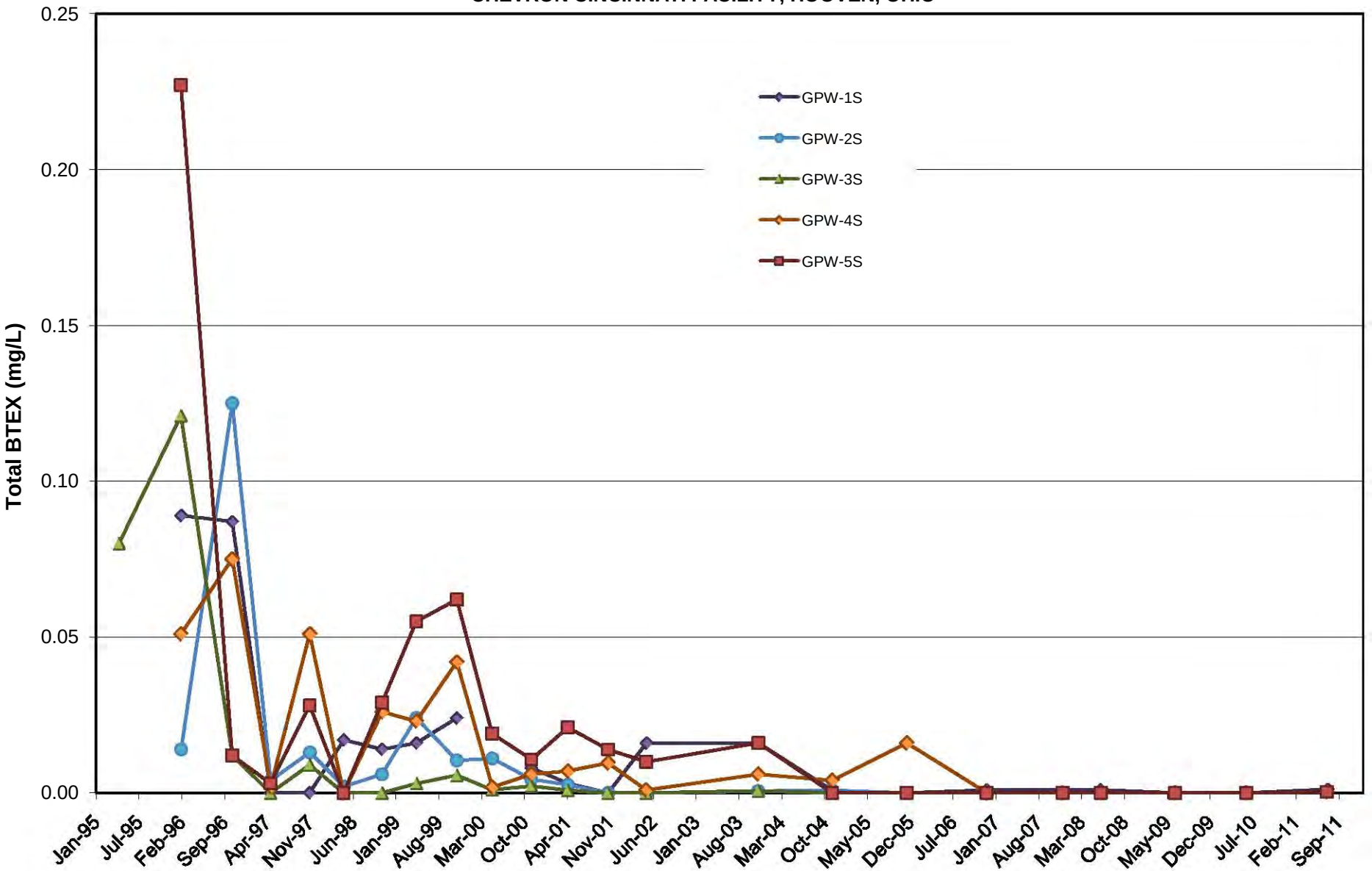


FIGURE 3-11. TOTAL BTEX CONCENTRATION VERSUS TIME FOR GULF PARK WELL TH-1S
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

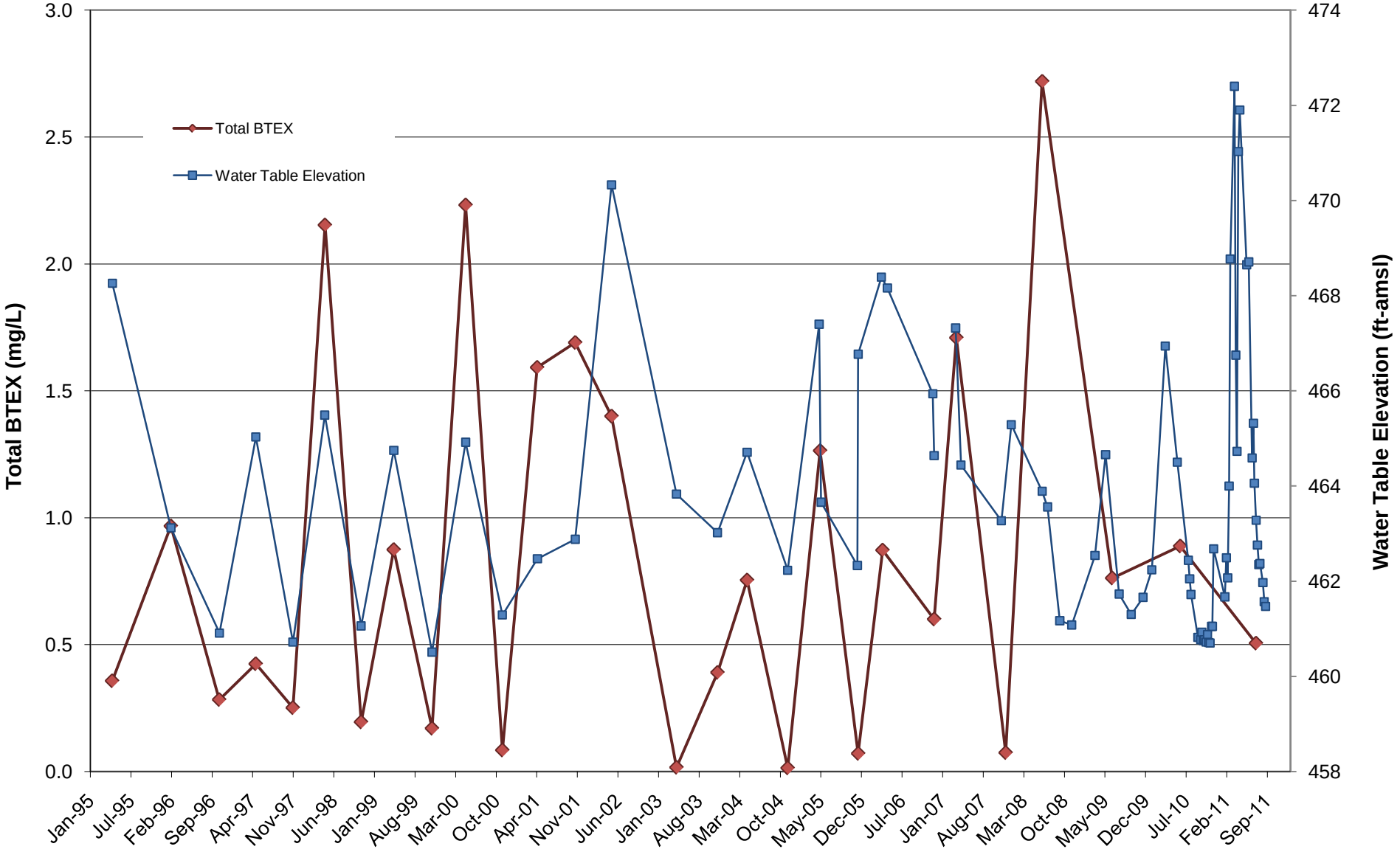


FIGURE 3-12. TOTAL BTEX CONCENTRATION VERSUS TIME FOR GULF PARK WELL TH-2
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

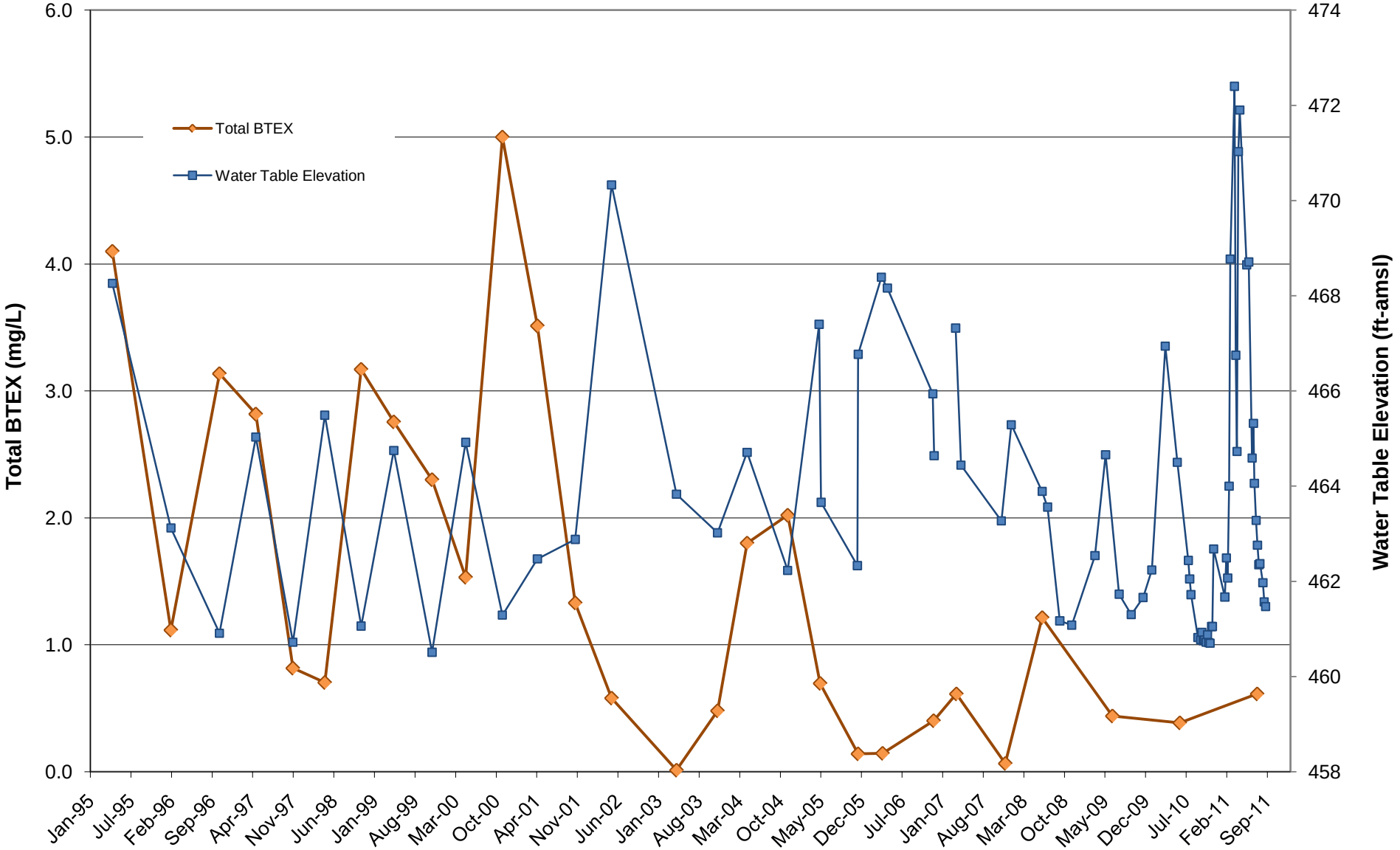
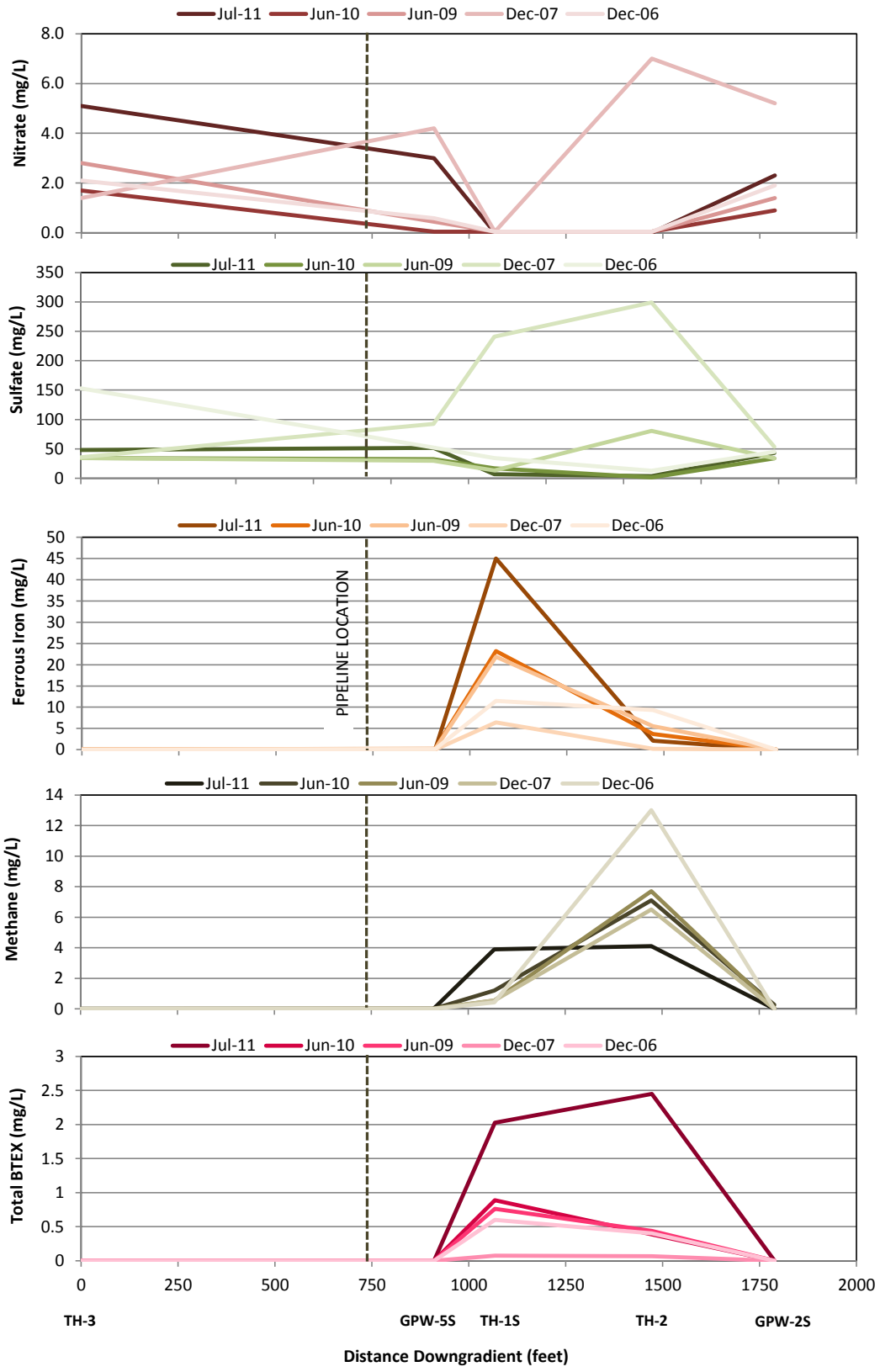
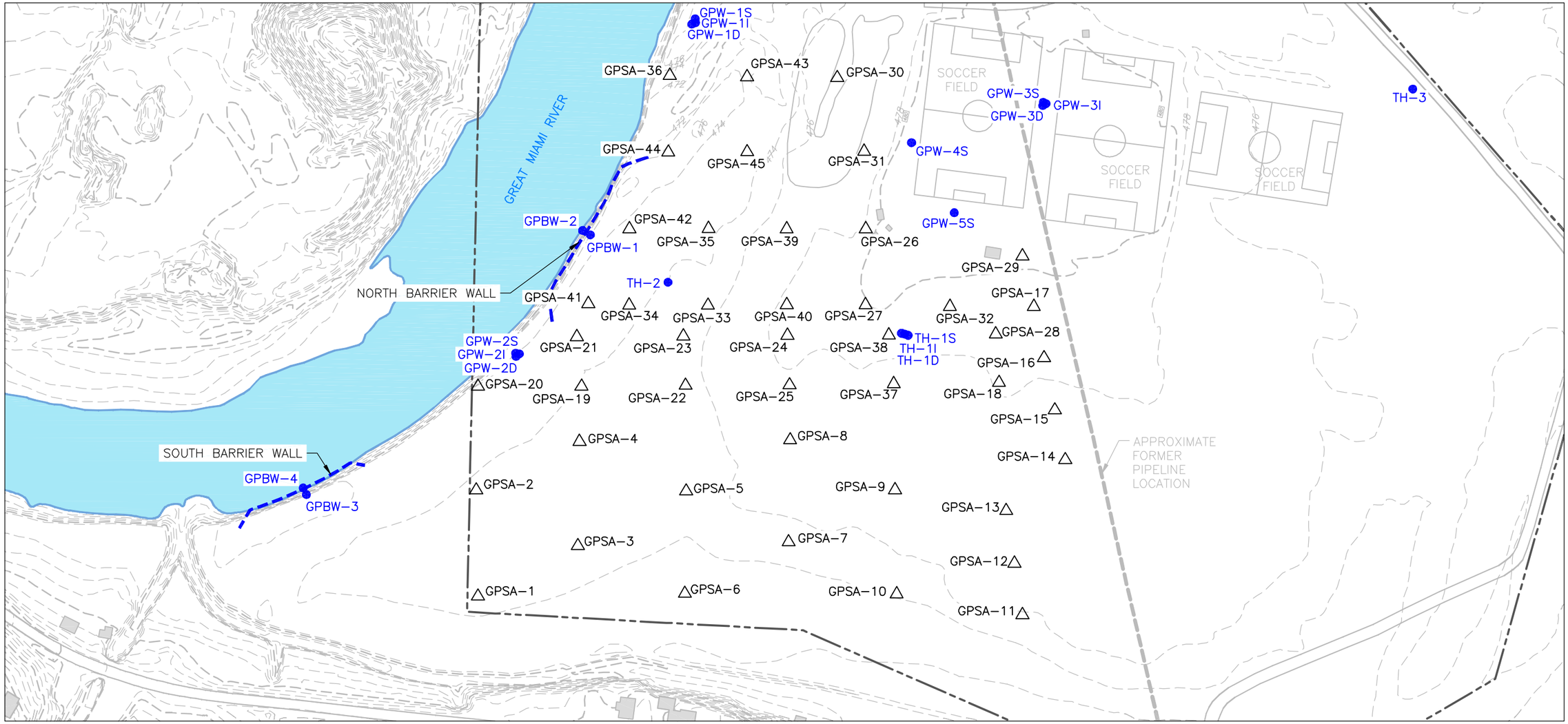


FIGURE 3-13. TOTAL BTEX AND HYDROGEOCHECMICAL SUMMARY VERSUS DISTANCE AT GULF PARK
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO





EXPLANATION

GPW-2D	GROUNDWATER MONITORING WELL AND DESIGNATION
GPRB-10	SOIL BORING AND DESIGNATION
	PROPERTY BOUNDARY
	SHEET PILE BARRIER WALL
	ROAD
474	EXISTING TOPOGRAPHIC CONTOUR (FT AMSL, INTERVAL = 2 FEET)
	BUILDING, TANK OR OTHER STRUCTURE
VCS	VALVE CONTROL SHED
FT AMSL	FEET ABOVE MEAN SEA LEVEL
mg/kg	MILLIGRAMS PER KILOGRAM

N

0 200'

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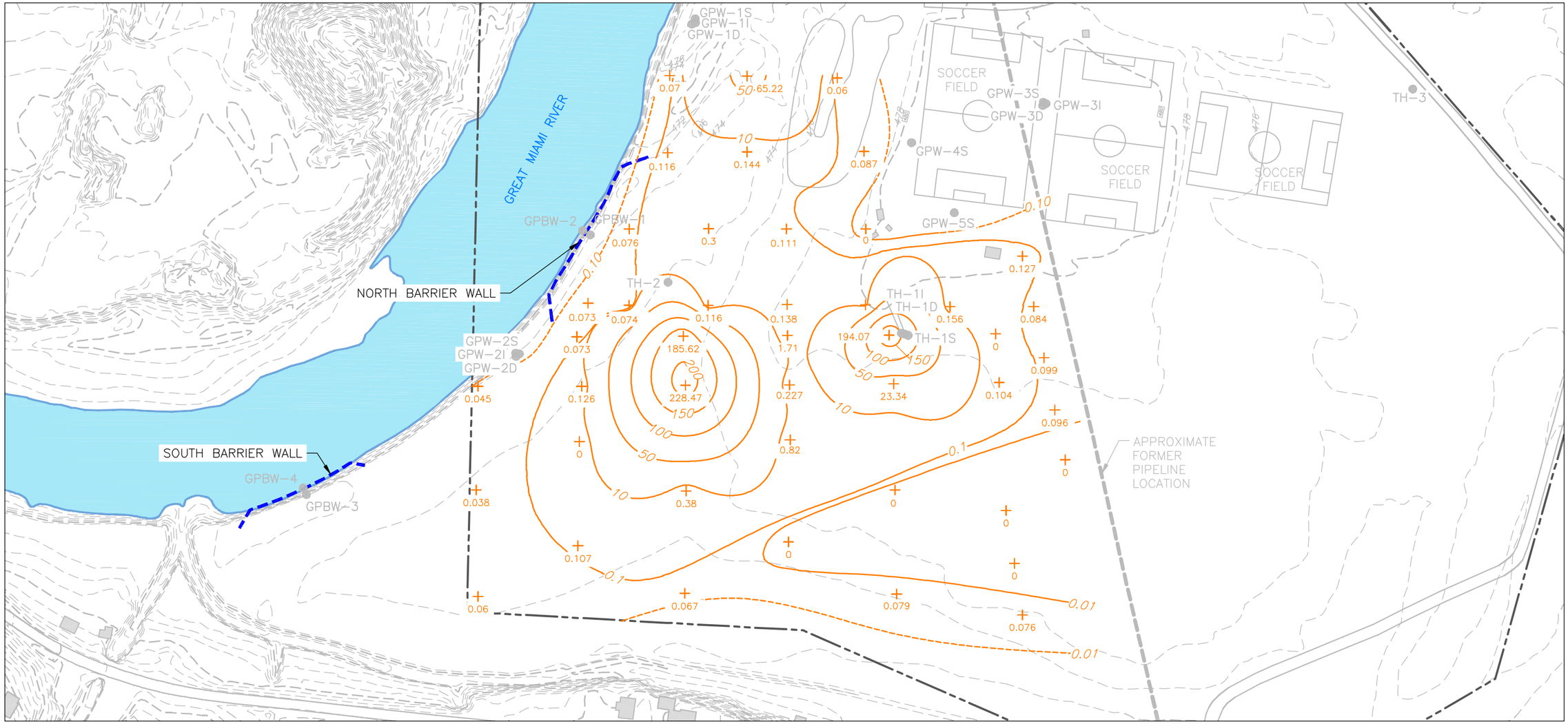
FIGURE 3-14

GULF PARK SOIL BORING LOCATIONS

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: PM	Scale: 1"=200'	Date: 11/14/11	File: 500GP-SOILBORINGLAYOUT201111



EXPLANATION

0.06	SOIL BORING LOCATION SHOWING TOTAL BTEX CONCENTRATION IN mg/kg	474	EXISTING TOPOGRAPHIC CONTOUR (FT AMSL, INTERVAL = 2 FEET)
GPW-2D	GROUNDWATER MONITORING WELL AND DESIGNATION		BUILDING, TANK OR OTHER STRUCTURE
20	BTEX ISOCONCENTRATION CONTOUR (DASHED WHERE INFERRED)	VCS	VALVE CONTROL SHED
	PROPERTY BOUNDARY	FT AMSL	FEET ABOVE MEAN SEA LEVEL
	SHEET PILE BARRIER WALL	mg/kg	MILLIGRAMS PER KILOGRAM
	ROAD		

N

0 200'

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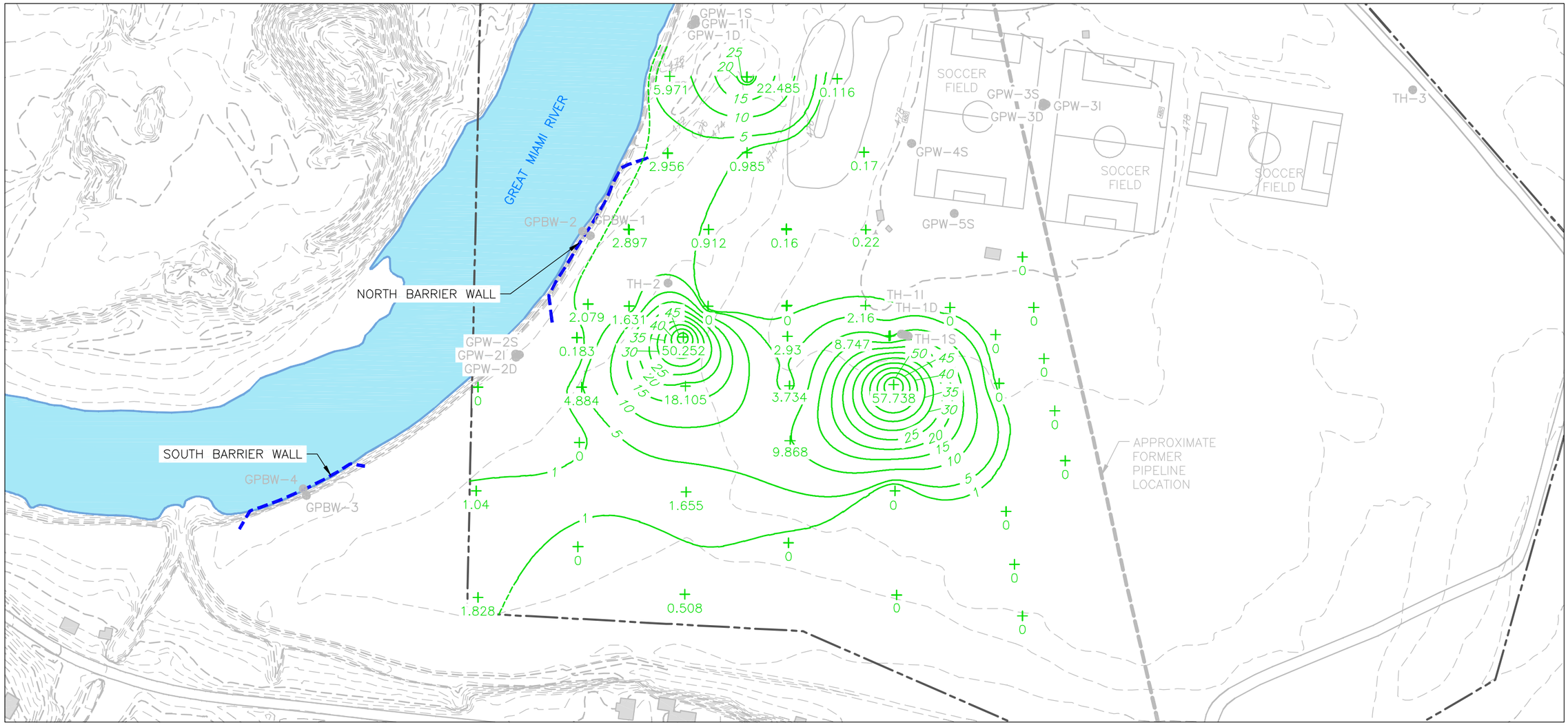
FIGURE 3-15

TOTAL BTEX DISTRIBUTION IN SOIL AT GULF PARK

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: PM	Scale: 1"=200'	Date: 11/14/11	File: 500GP_BTEX-LINEAR-201111



EXPLANATION

0.06 — SOIL BORING LOCATION SHOWING TOTAL PAH CONCENTRATION IN mg/kg	474 — EXISTING TOPOGRAPHIC CONTOUR (FT AMSL, INTERVAL = 2 FEET)
GPW-2D — GROUNDWATER MONITORING WELL AND DESIGNATION	BUILDING, TANK OR OTHER STRUCTURE
0 — PAH ISOCONCENTRATION CONTOUR (DASHED WHERE INFERRED)	VCS — VALVE CONTROL SHED
PROPERTY BOUNDARY	FT AMSL — FEET ABOVE MEAN SEA LEVEL
SHEET PILE BARRIER WALL	mg/kg — MILLIGRAMS PER KILOGRAM
ROAD	

N

0 200'

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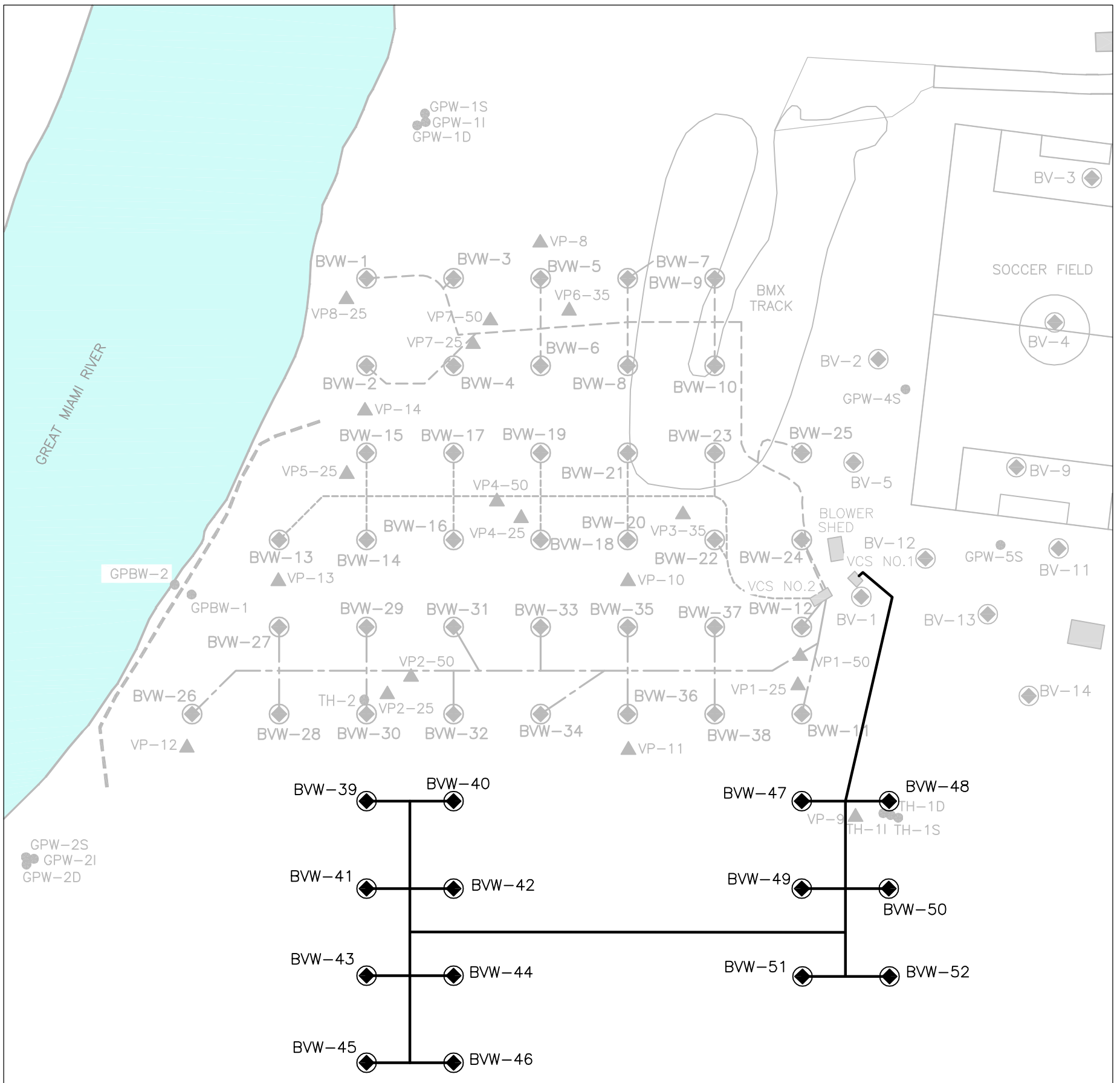
FIGURE 3-16

TOTAL PAH DISTRIBUTION IN SOIL AT GULF PARK

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: JGP	Scale: 1"=200'	Date: 6/8/11	File: 500GP_PAH-LINEAR-201111



EXPLANATION

- BVW–39 PROPOSED BIOVENT WELL AND DESIGNATION
- BVW–26 BIOVENT WELL AND DESIGNATION
- GPW–2D GROUNDWATER MONITORING WELL AND DESIGNATION
- VP2–25 SOIL VAPOR MONITORING POINT AND DESIGNATION
- PROPOSED EXPANDED BIOVENTING SYSTEM PIPE RUN #4
- EXPANDED BIOVENTING SYSTEM PIPE RUN #1
- EXPANDED BIOVENTING SYSTEM PIPE RUN #2
- EXPANDED BIOVENTING SYSTEM PIPE RUN #3
- SHEET PILE BARRIER WALL
- BUILDING, TANK OR OTHER STRUCTURE
- ROAD
- VCS VALVE CONTROL SHED

N

0 100'

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FIGURE 3-17

PROPOSED GULF PARK BIOVENT SYSTEM EXPANSION

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: JP	Scale: 1" = 100'	Date: 11/11/11	File: 500GP_LAYOUTALT201111

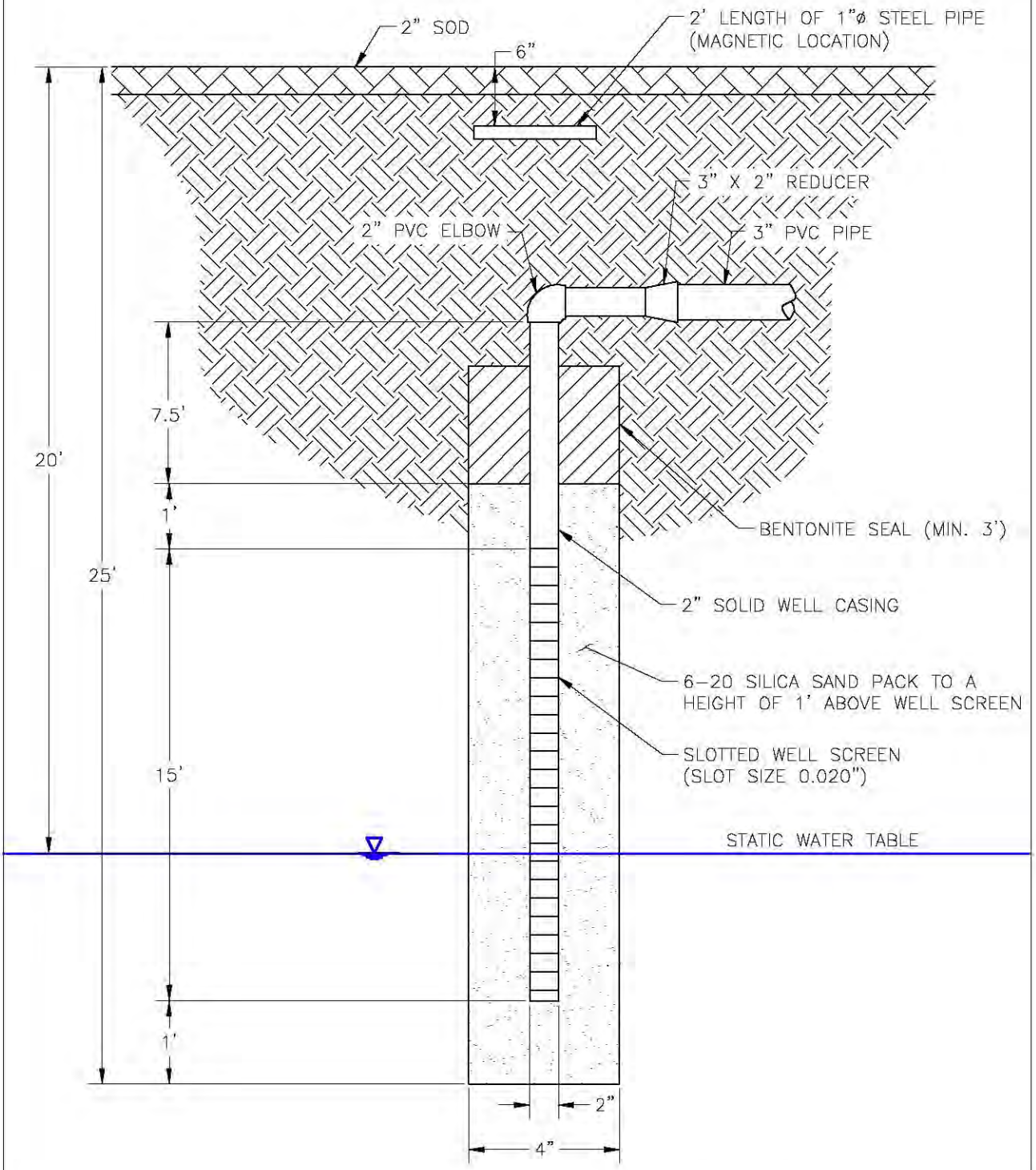

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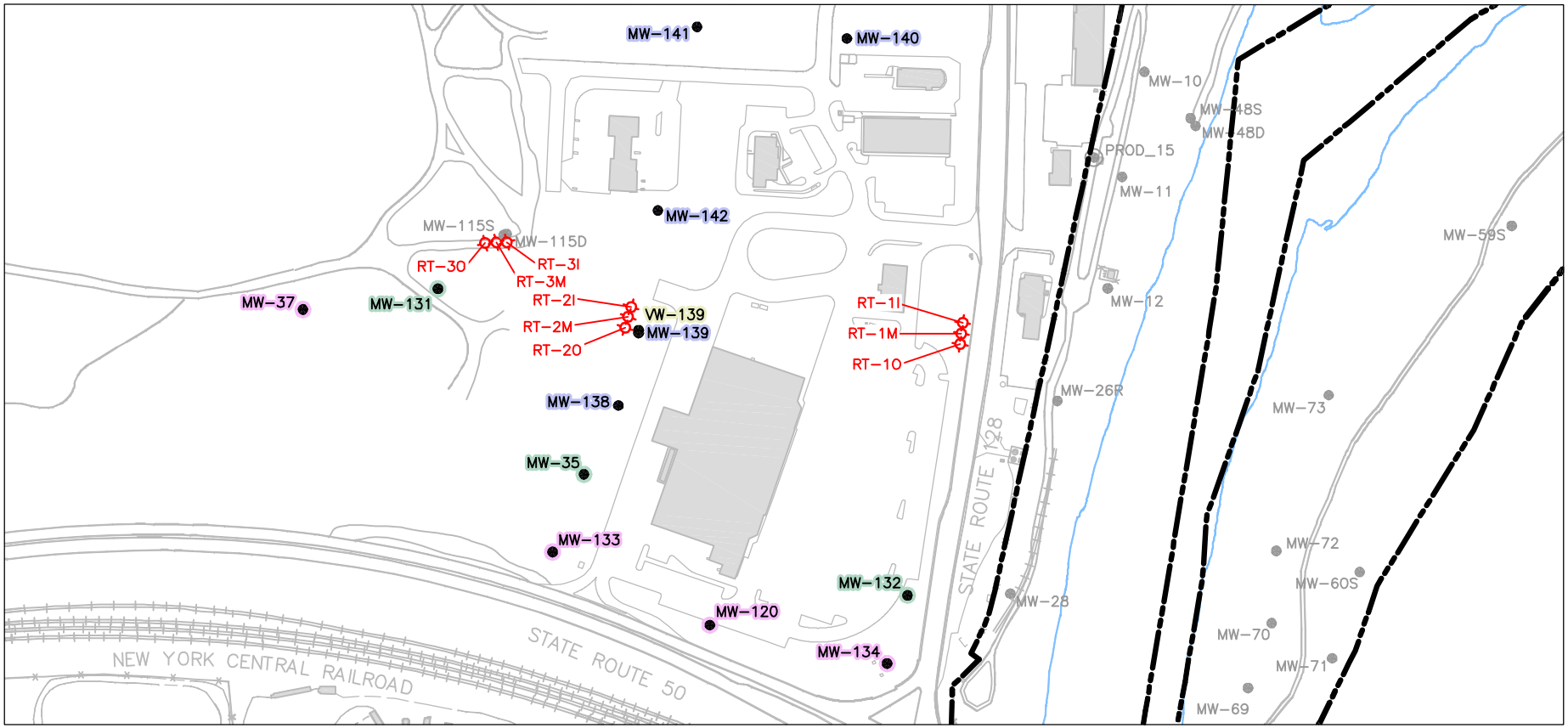
FIGURE 3-18

GULF PARK
TYPICAL BIOVENT WELL DETAIL

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: JP	Scale: NONE	Date: 11/11/11	File: 500BIOVENTWELL201111



EXPLANATION

- RT-20 / RT-2M / RT-2I — PERMANENT ROST TRANSECT AND DESIGNATION (I-INNER, M-MIDDLE, O-OUTER)
- MW-138 — MONITORING WELL AND DESIGNATION (INSTALLED MARCH 2009)
- MW-35 — SENTINEL MONITORING WELL AND DESIGNATION
- MW-37 — POINT OF COMPLIANCE MONITORING WELL AND DESIGNATION
- VW-139 — NESTED VAPOR WELL AND DESIGNATION
- MW-47S — MONITORING WELL AND DESIGNATION
- PROD_12 — PRODUCTION WELL AND DESIGNATION
- SURFACE WATER
- PROPERTY BOUNDARY
- BUILDING, TANK OR OTHER STRUCTURE

N

0 300'

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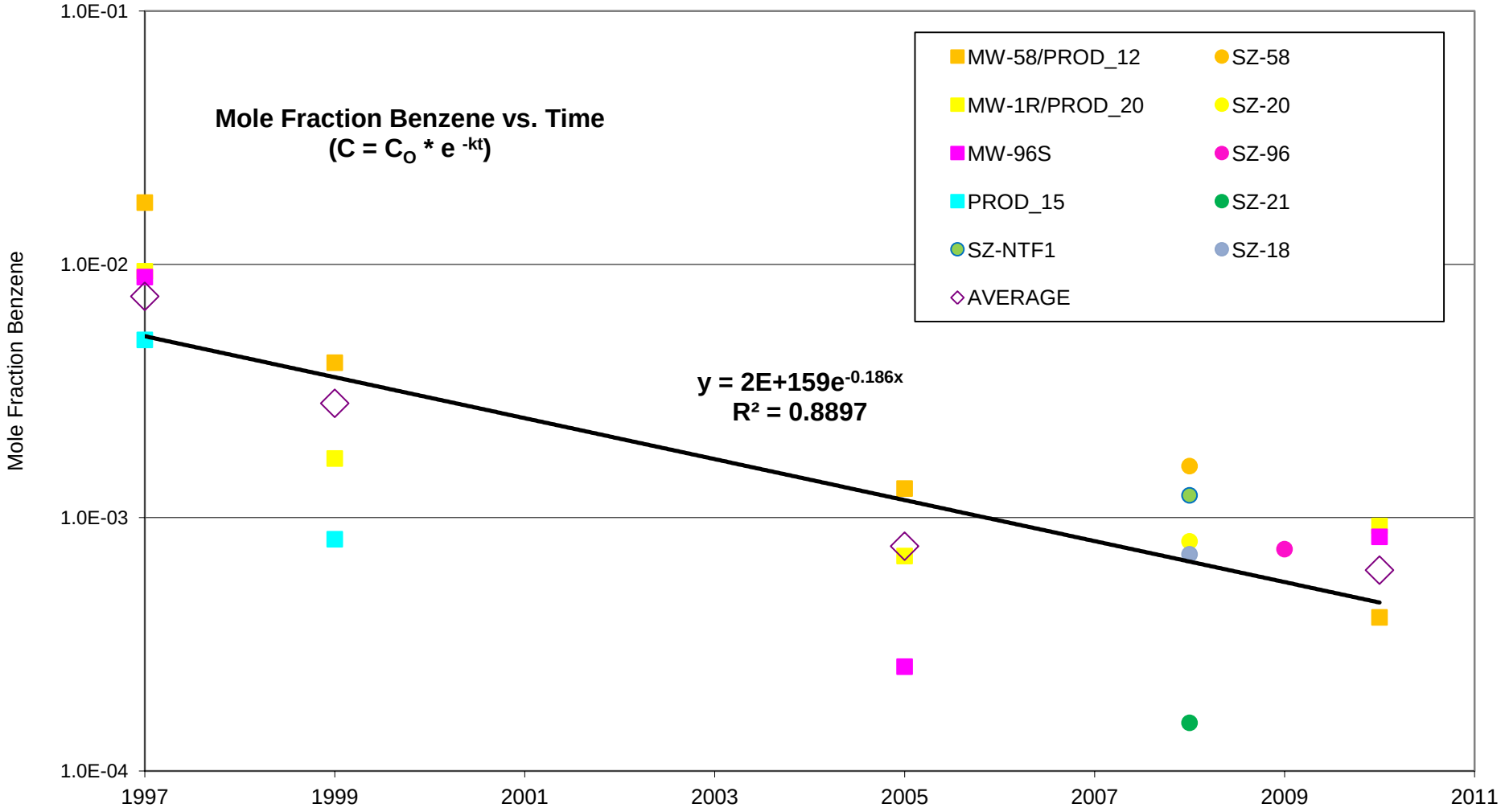
FIGURE 4-1

SENTINEL, POINT OF COMPLIANCE, AND ROST MONITORING NETWORK

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: MM	Scale: 1"=300'	Date: 11/4/11	File: 500ROST-TRANSECTS201111

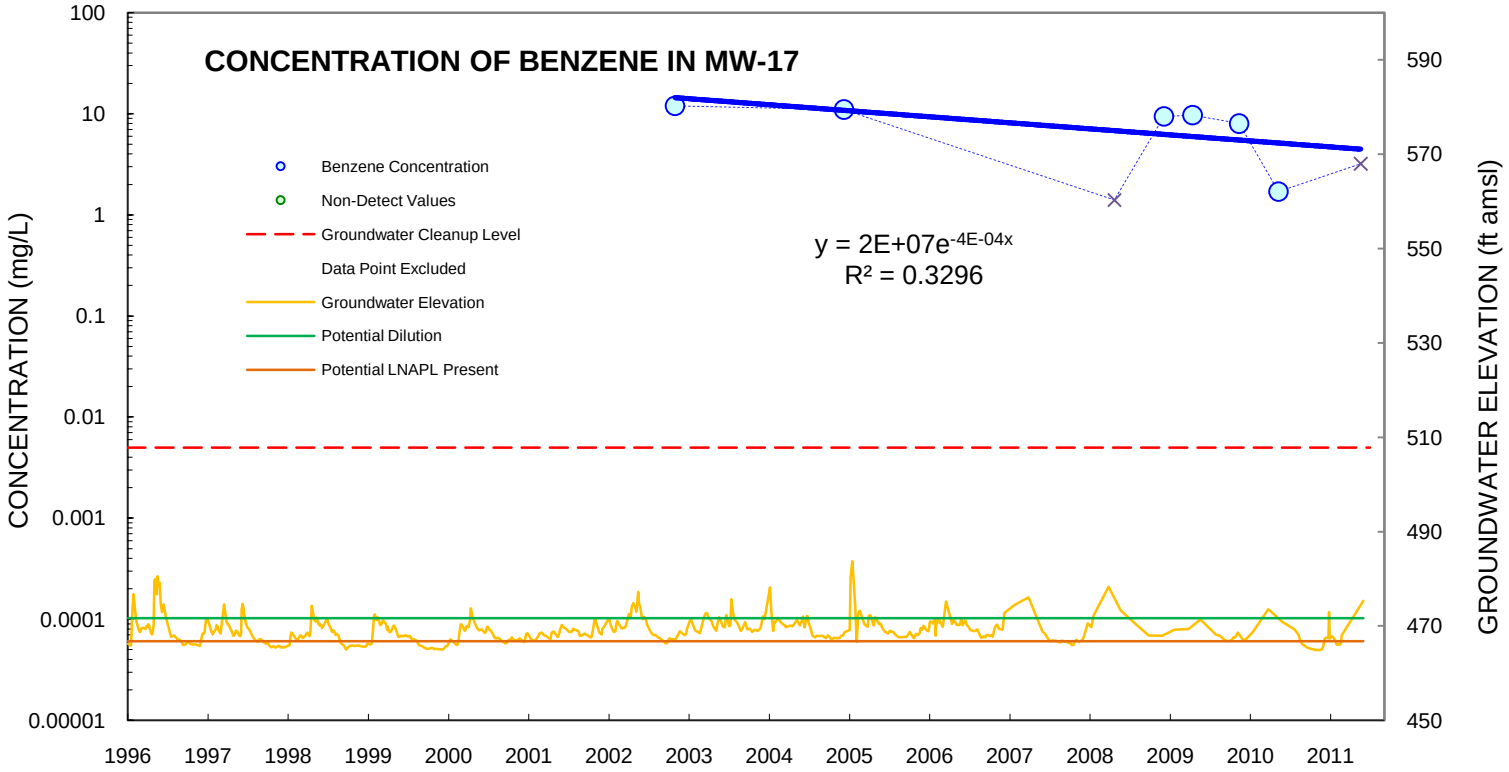
FIGURE 4-2. BENZENE MOLE FRACTION VERSUS TIME IN LNAPL AND SOIL CORE SAMPLES
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

1. SZ DESIGNATION INDICATES SMEAR ZONE SOIL CORES COLLECTED IN 2008 AND 2009 WHERE MOLE FRACTION BENZENE ARE AVERAGED FOR EACH OF THE SAMPLES COLLECTED FROM THE MIDDLE OF THE SMEAR ZONE AT EACH LOCATION.
2. MOLE FRACTION BENZENE FOR ALL OTHER EVENTS CALCULATED USING LNAPL ANALYTICAL RESULTS

FIGURE 4-3. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-17
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

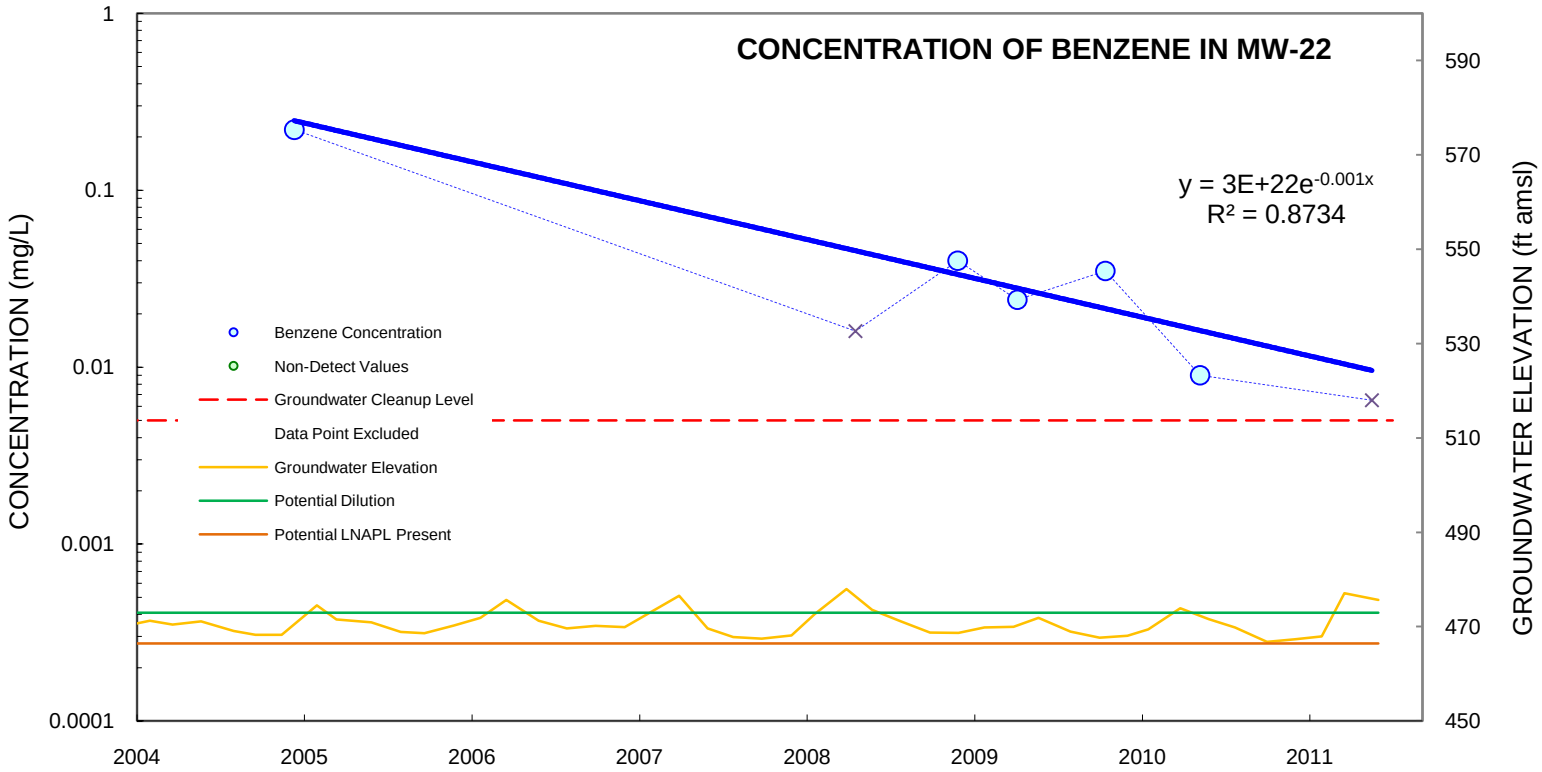
LNAPL.

ONE DATA POINT EXCLUDED (4/23/08)

FT AMSL - FEET ABOVE MEAN SEA LEVEL

mg/L - MILLIGRAMS PER LITER

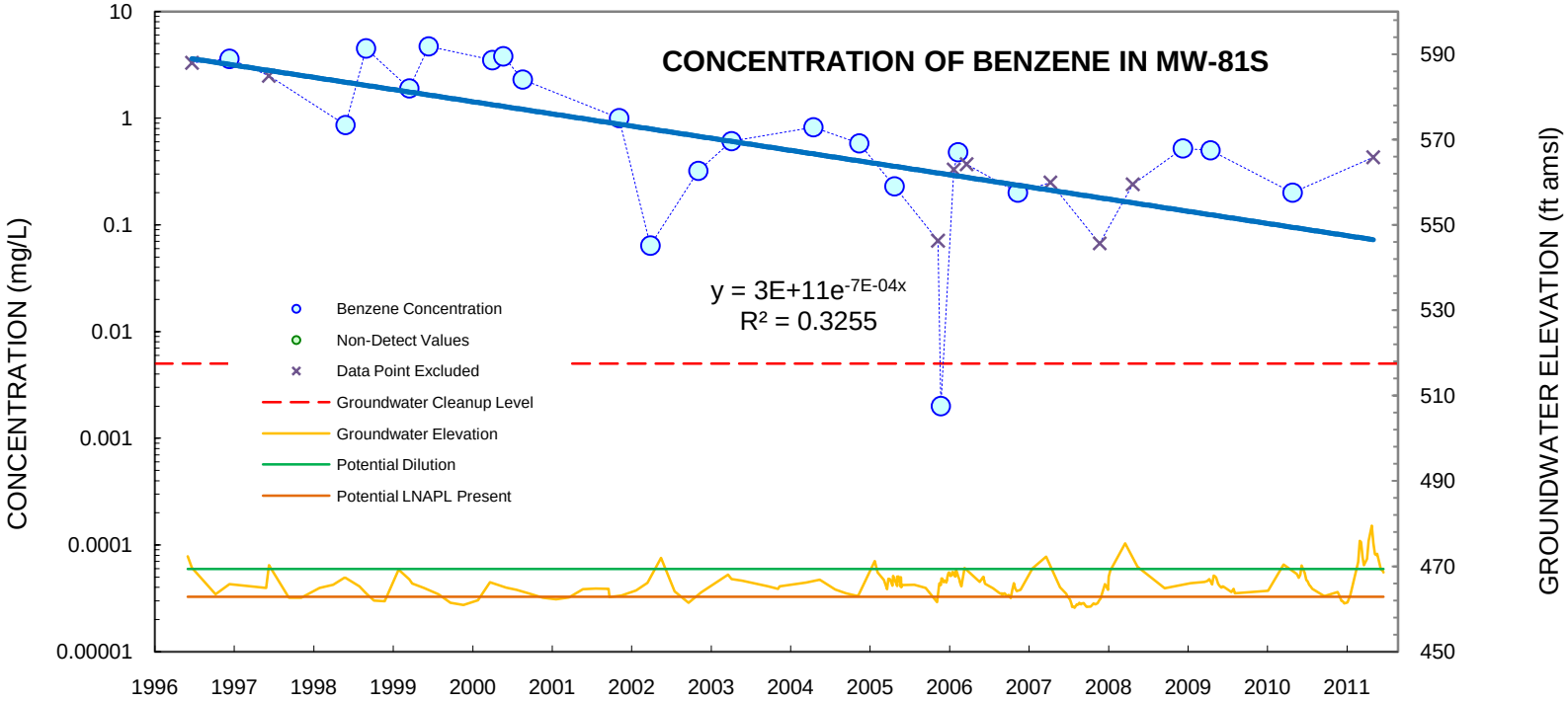
FIGURE 4-4. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-22
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
TWO DATA POINTS EXCLUDED (4/16/08 and 5/16/11)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

FIGURE 4-5. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-81S
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.

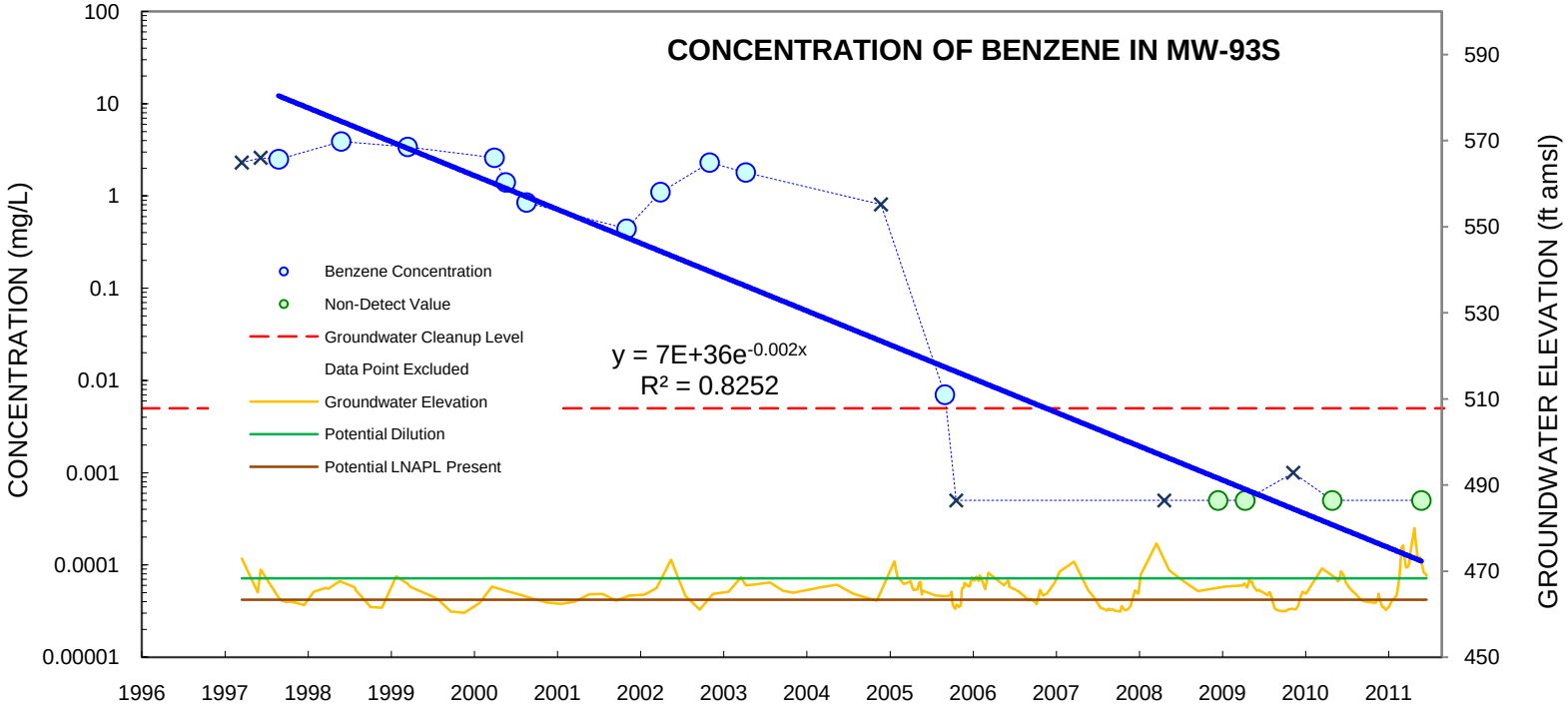
NO ANALYTICAL DATA AVAILABLE FOR FALL 2009 BECAUSE LNAPL WAS PRESENT IN THE WELL.

EIGHT DATA POINTS EXCLUDED (6/20/96, 6/9/97, 4/1/02, 11/15/05, 11/28/05, 12/29/05, 4/30/08, 5/12/11)

FT AMSL - FEET ABOVE MEAN SEA LEVEL

mg/L - MILLIGRAMS PER LITER

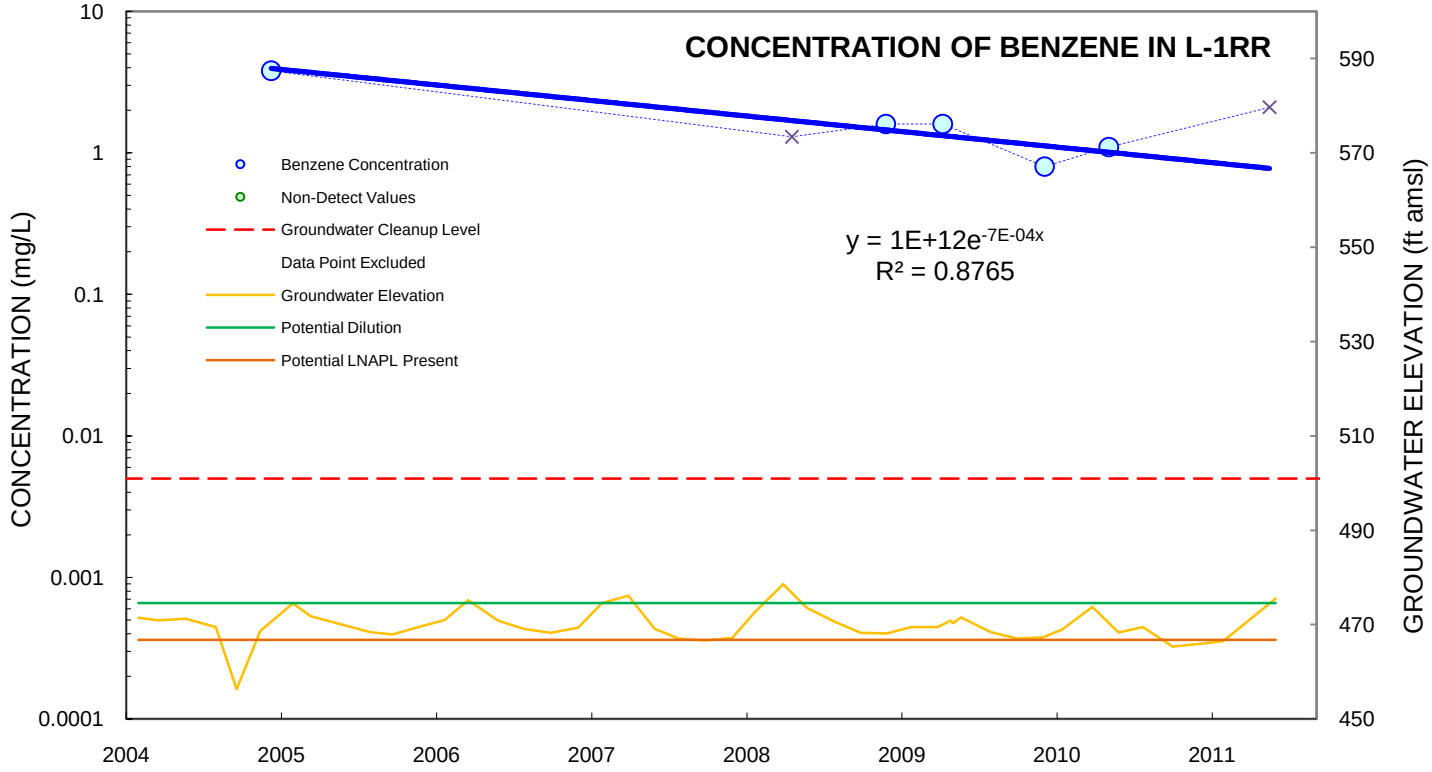
FIGURE 4-6. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-93S
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
FIVE DATA POINTS EXCLUDED (3/18/97, 6/9/97, 11/30/04, 10/27/05, 4/30/08, AND 11/19/09)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

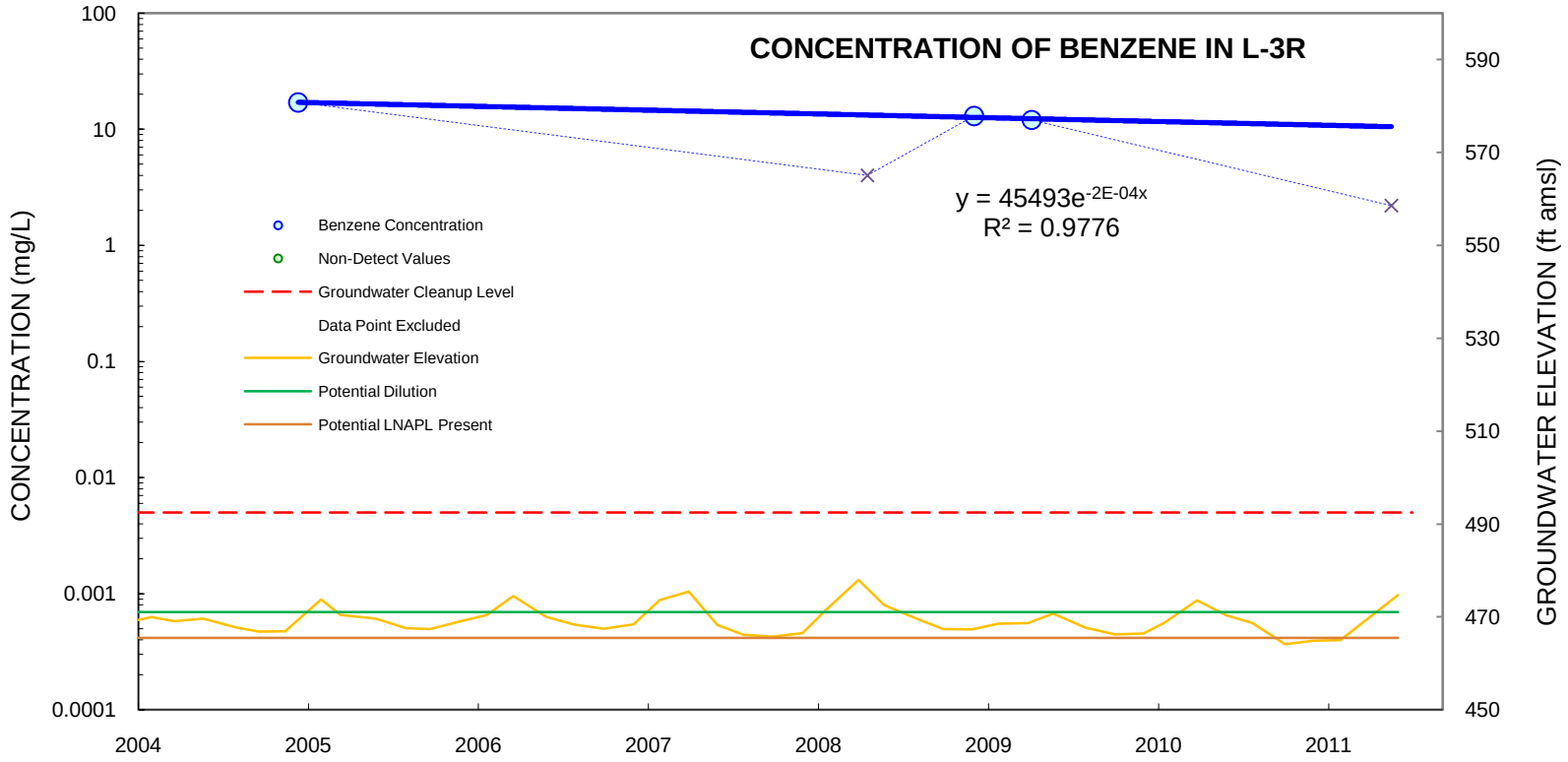
FIGURE 4-7. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL L-1RR
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION.
TWO DATA POINTS EXCLUDED (4/17/08 and 5/16/11)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

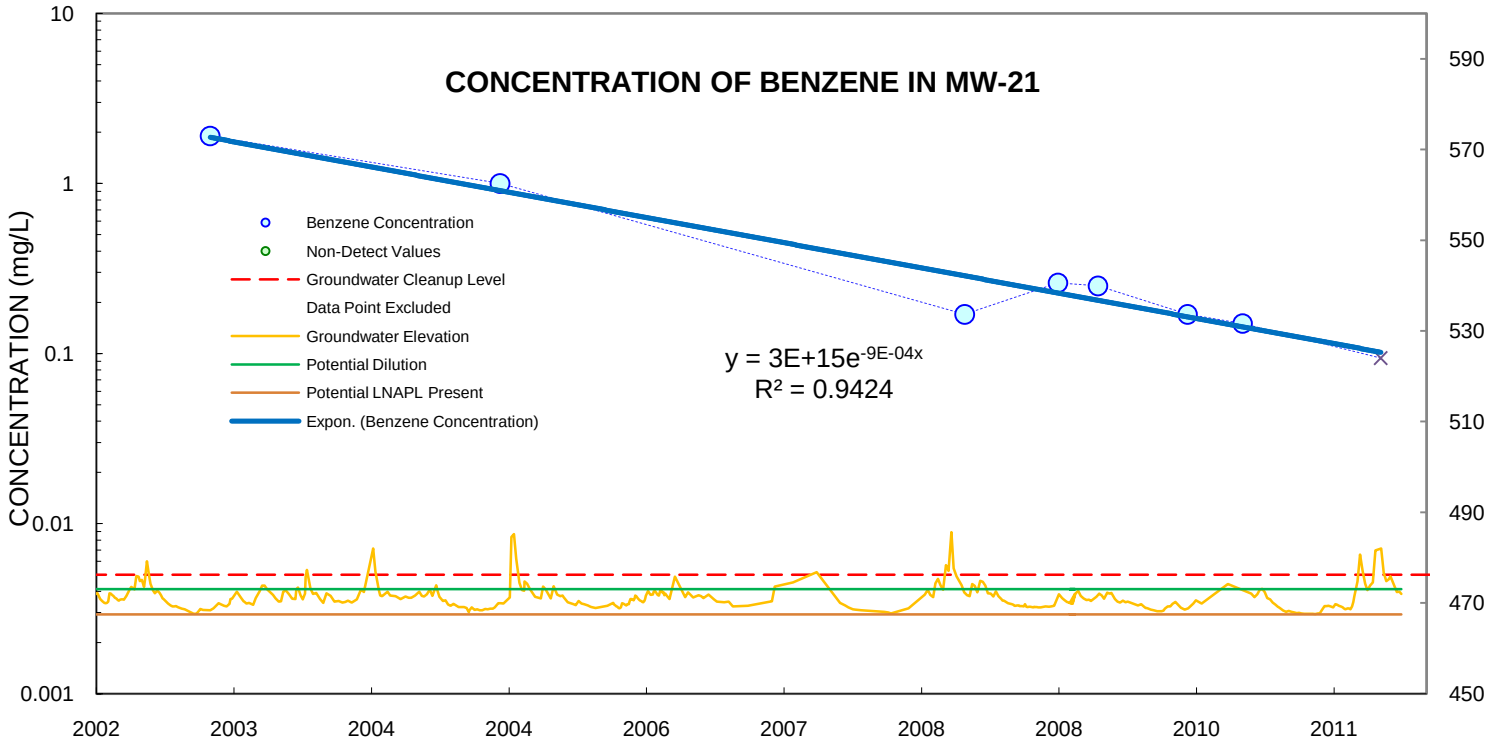
FIGURE 4-8. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL L-3R
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
NO ANALYTICAL DATA AVAILABLE FOR FALL 2009 OR SPRING 2010 DUE TO LNAPL PRESENCE IN WELL.
TWO DATA POINTS EXCLUDED (4/16/08 and 5/16/11)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

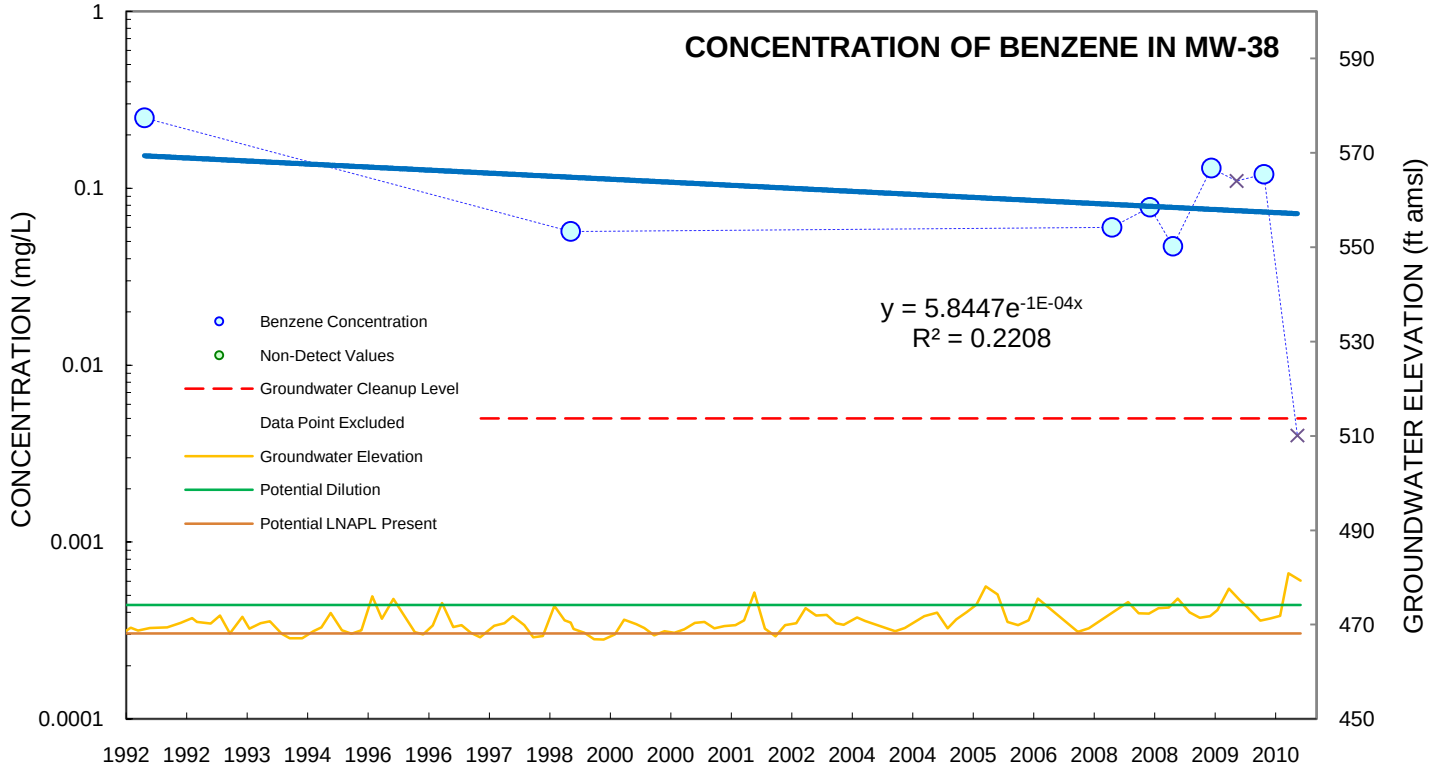
FIGURE 4-9. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-21
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
ONE DATA POINT EXCLUDED (5/5/11)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

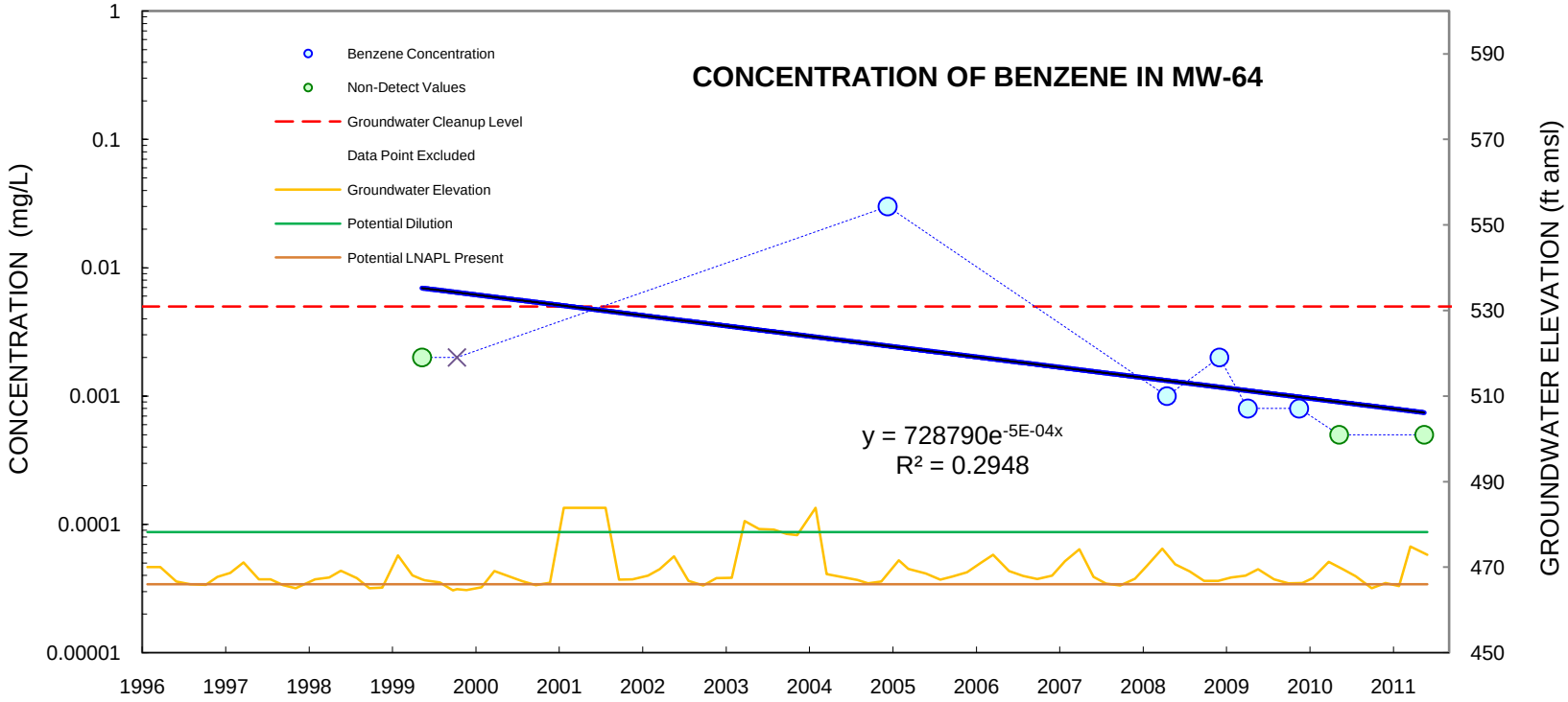
FIGURE 4-10. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-38
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
TWO DATA POINTS EXCLUDED (5/10/10 and 5/11/11)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

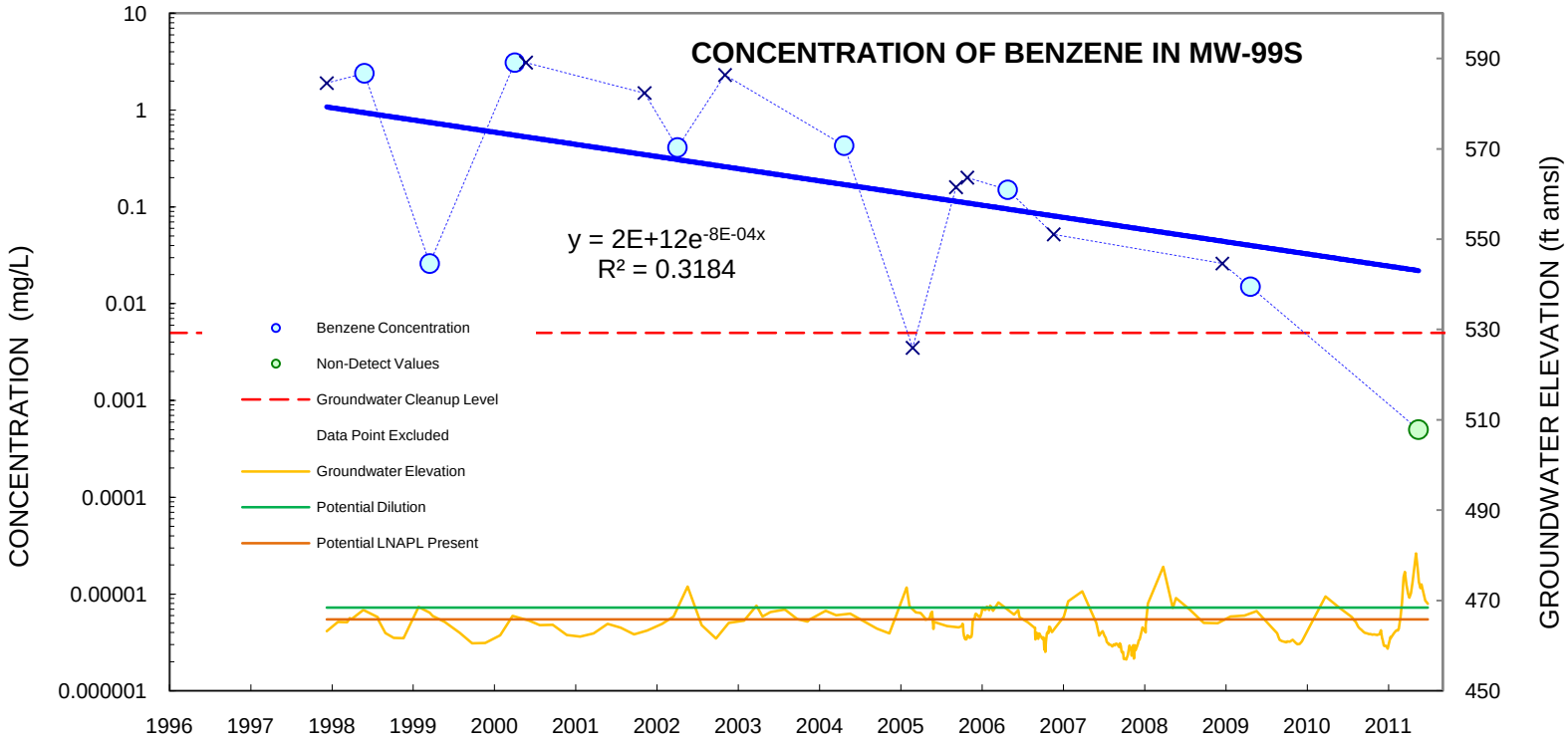
FIGURE 4-11. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-64
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
ONE DATA POINT EXCLUDED (10/12/99)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

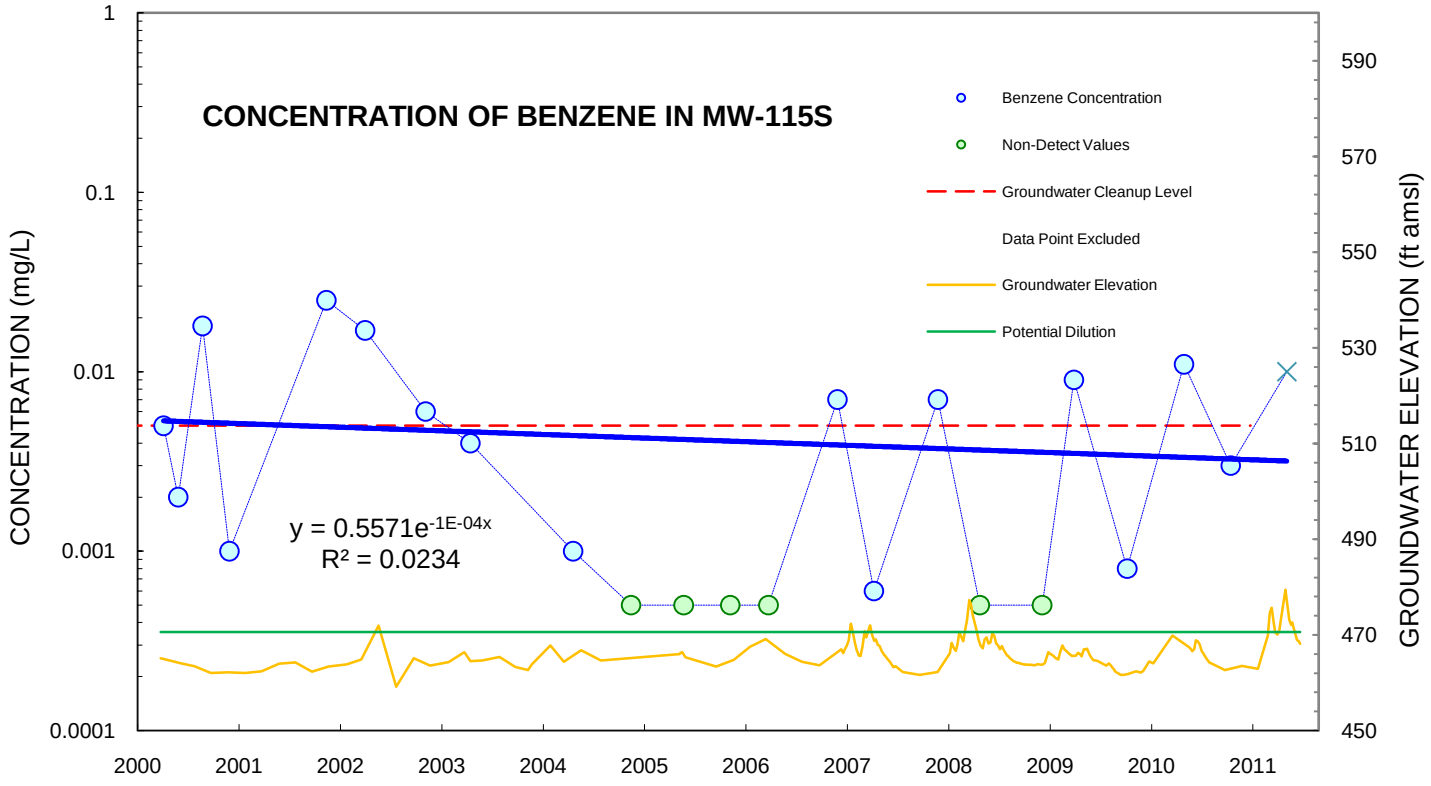
FIGURE 4-12. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-99S
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION:

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
NINE DATA POINTS EXCLUDED (12/10/97, 4/3/00, 5/23/00, 11/7/01, 11/4/02, 2/24/05, 9/7/05, 10/28/05, and 11/20/06).
WELL NOT SAMPLED IN SPRING 2010 DUE TO LNAPL PRESENCE IN WELL.
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

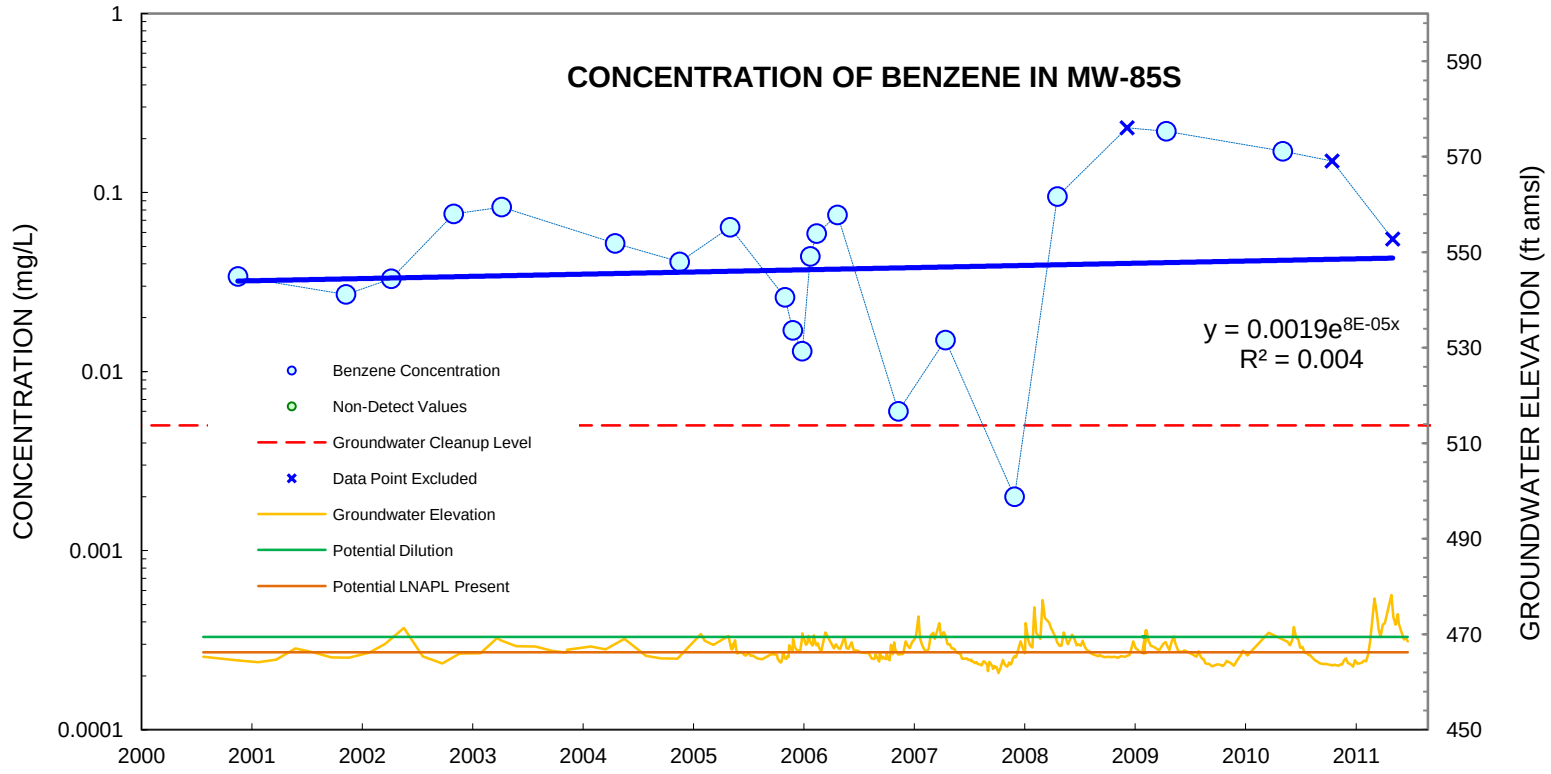
FIGURE 4-13. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-115S
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



EXPLANATION

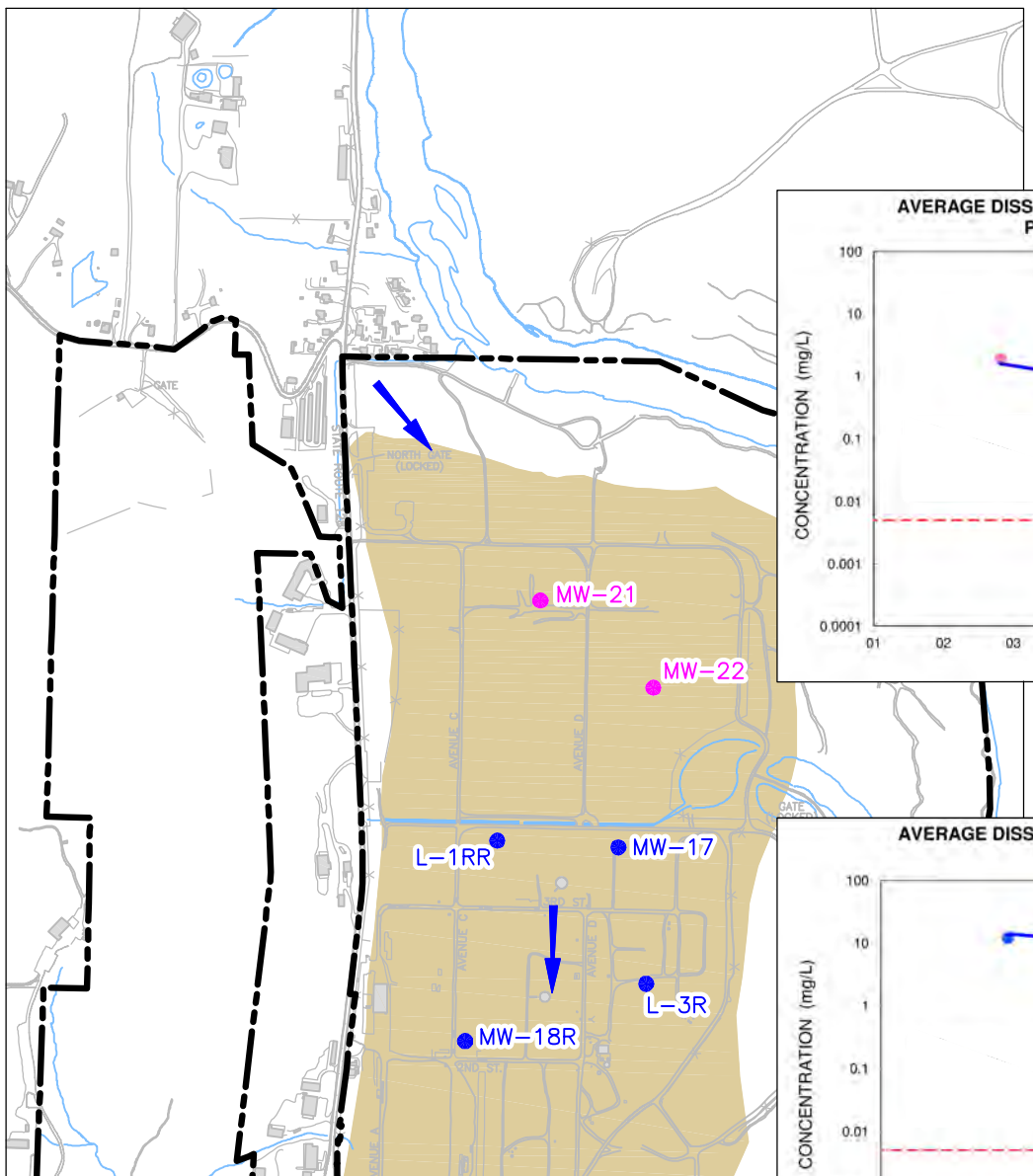
WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION.
ONE DATA POINTS EXCLUDED (5/11/11)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER

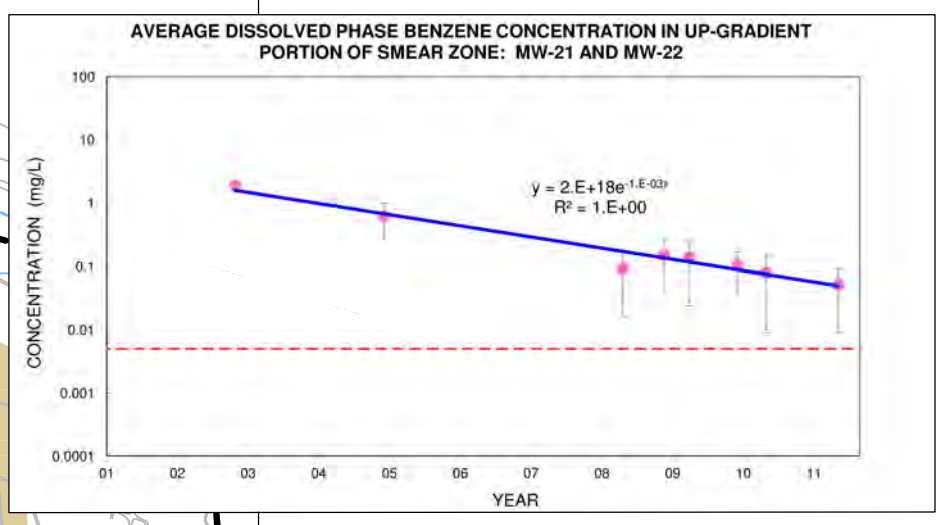
FIGURE 4-14. GROUNDWATER CONSTITUENT CONCENTRATIONS VERSUS TIME, MONITORING WELL MW-85S
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

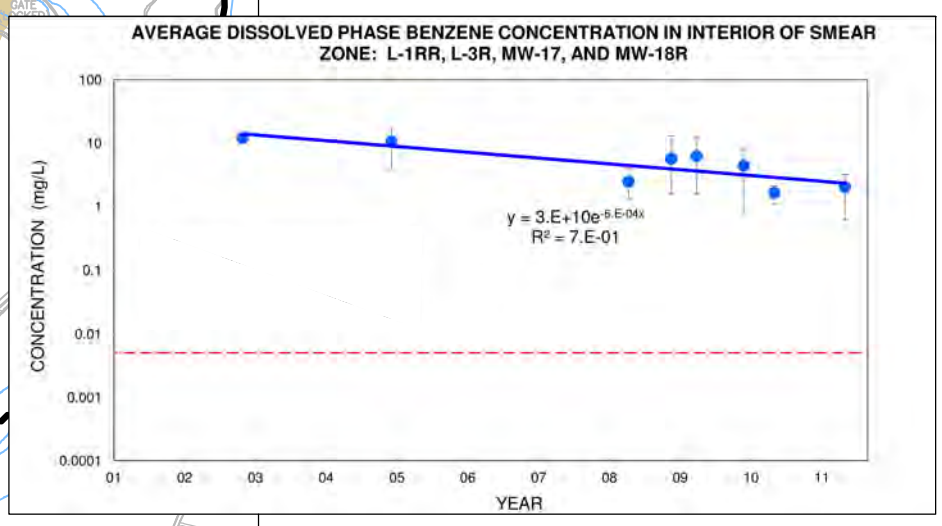


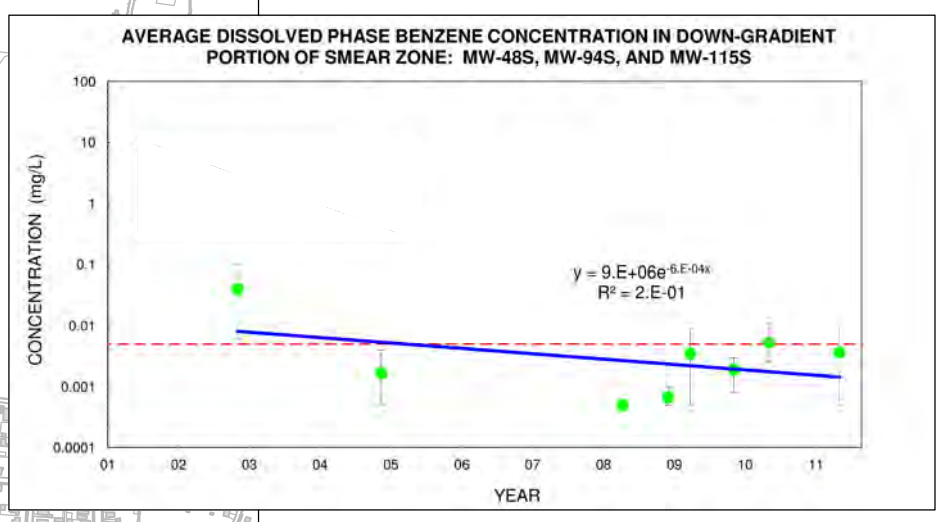
EXPLANATION

WATER LEVELS PRESENTED FOR POSSIBLE EXCLUSION OF DATA POINTS BASED ON POTENTIAL DILUTION OR PRESENCE OF LNAPL.
THREE DATA POINTS EXCLUDED (12/11/08, 10/21/10, and 5/10/11)
FT AMSL - FEET ABOVE MEAN SEA LEVEL
mg/L - MILLIGRAMS PER LITER









EXPLANATION

- MW–22 — UPGRADIENT MONITORING WELL AND DESIGNATION
- MW–17 — INTERIOR MONITORING WELL AND DESIGNATION
- MW–48S — DOWNGRADIENT MONITORING WELL AND DESIGNATION
- PROPERTY BOUNDARY
- FENCE
- STREAM
- GROUNDWATER CLEANUP LEVEL
- GENERAL GROUNDWATER FLOW DIRECTION
- BUILDING, TANK OR OTHER STRUCTURE
- SMEAR ZONE

NOTES:

1. ERROR BARS REPRESENT MINIMUM AND MAXIMUM CONCENTRATIONS MEASURED DURING SAMPLING EVENT.
2. NON-DETECT CONCENTRATIONS SET TO REPORTING LIMIT FOR AVERAGING.
3. SAMPLING EVENTS DISPLAYED: FALL 2002, FALL 2004, SPRING 2008, FALL 2008, SPRING 2009, FALL 2009, AND SPRING 2010.

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FIGURE 4-15

AVERAGE DISSOLVED PHASE BENZENE TRENDS ACROSS THE SMEAR ZONE

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: REP	Checked By: MM	Scale: AS SHOWN	Date: 11/2/11	File: 500SPATIO201111

FIGURE 4-16. DISSOLVED PHASE BENZENE AND HYDROGROCHEMICAL SUMMARY VERSUS DISTANCE
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

FIGURE 4-17. PORE WATER ASSIMILATIVE CAPACITY OVER TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

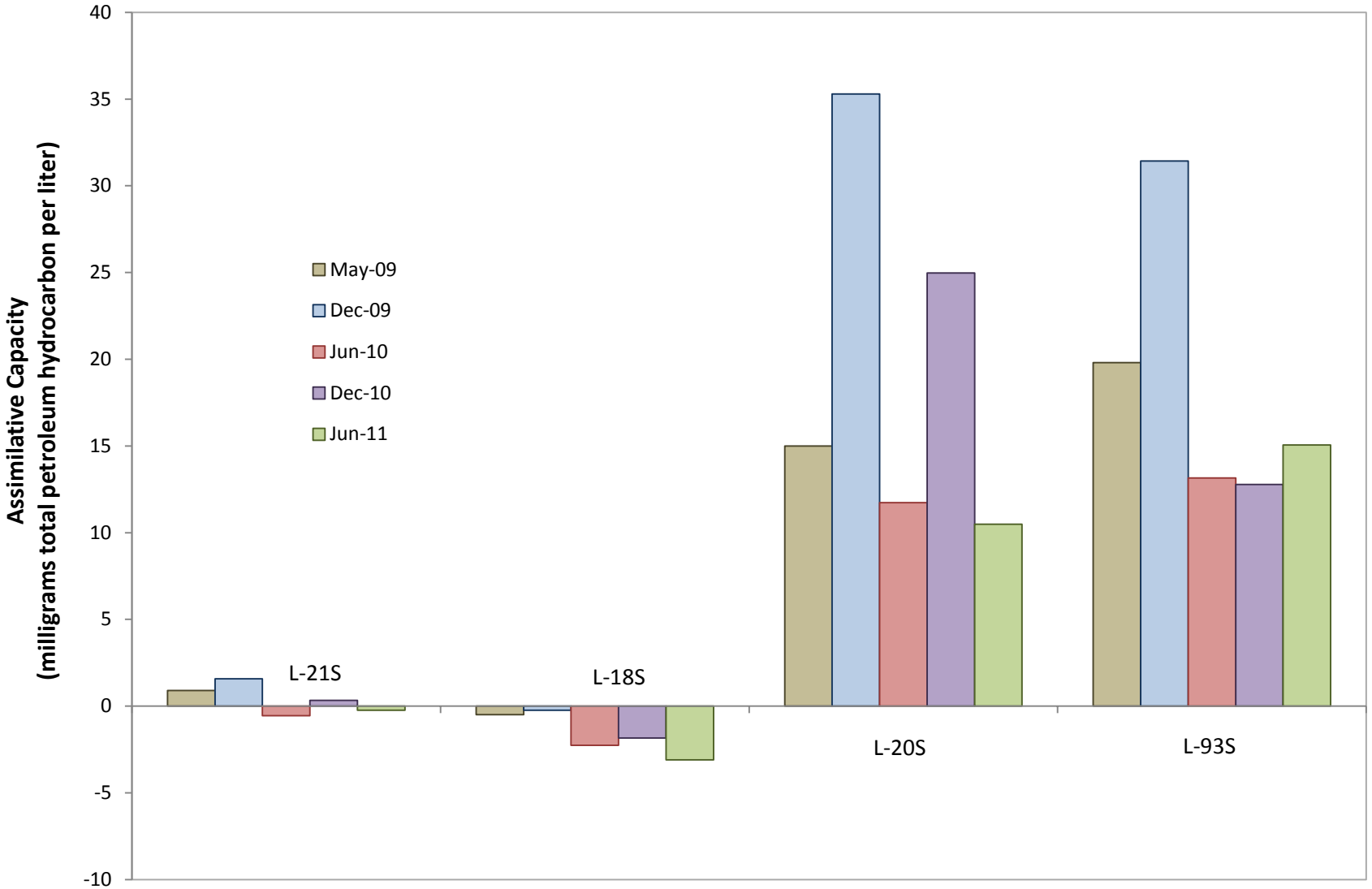


FIGURE 4-18. TVPH AND FIXED GAS PROFILES, NESTED VAPOR MONITORING WELL VW-93
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

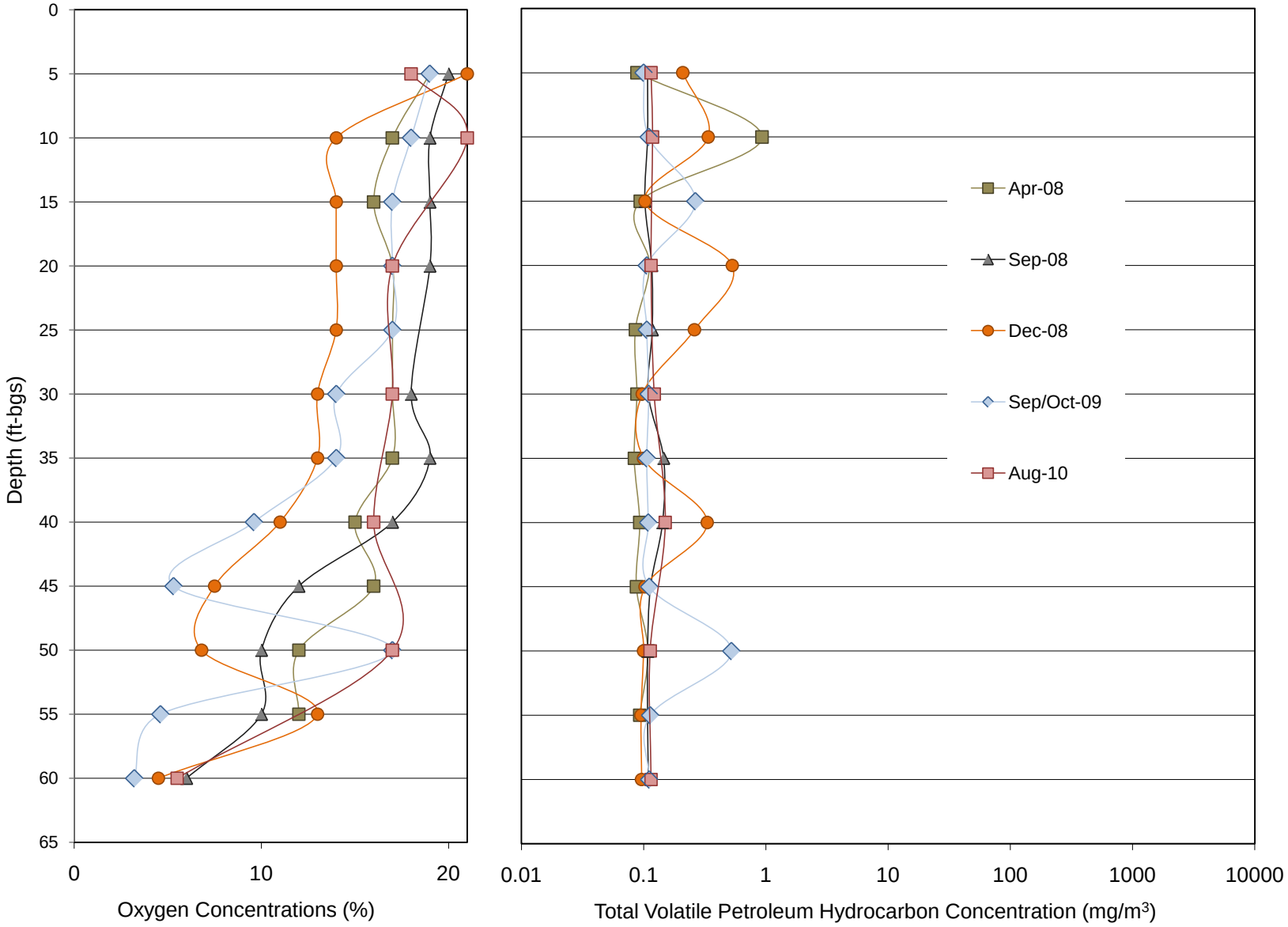


FIGURE 4-19. TVPH AND FIXED GAS PROFILES, NESTED VAPOR MONITORING WELL VW-139
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

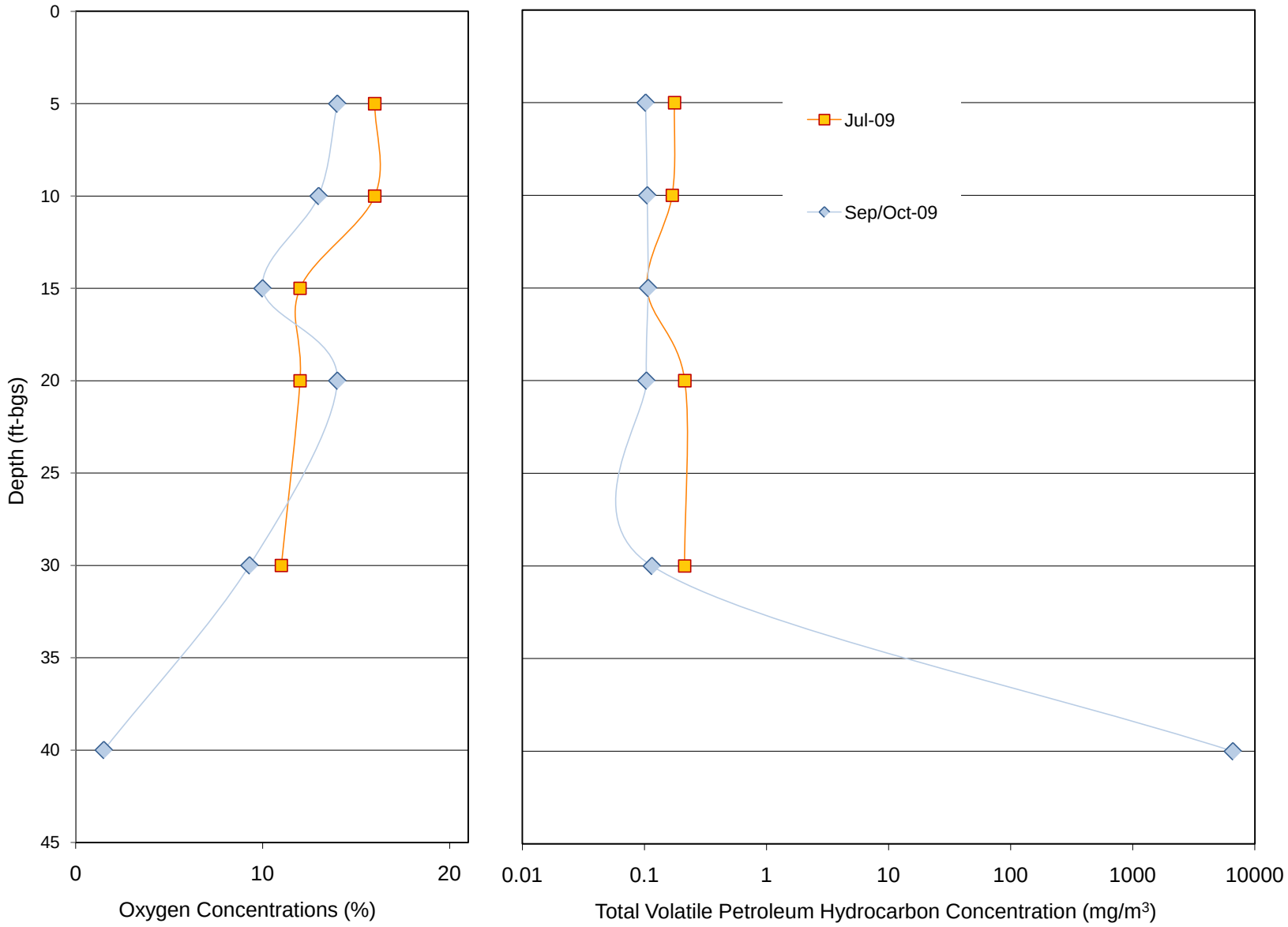


FIGURE 4-20. TVPH AND FIXED GAS PROFILES, NESTED VAPOR MONITORING WELL VW-128
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

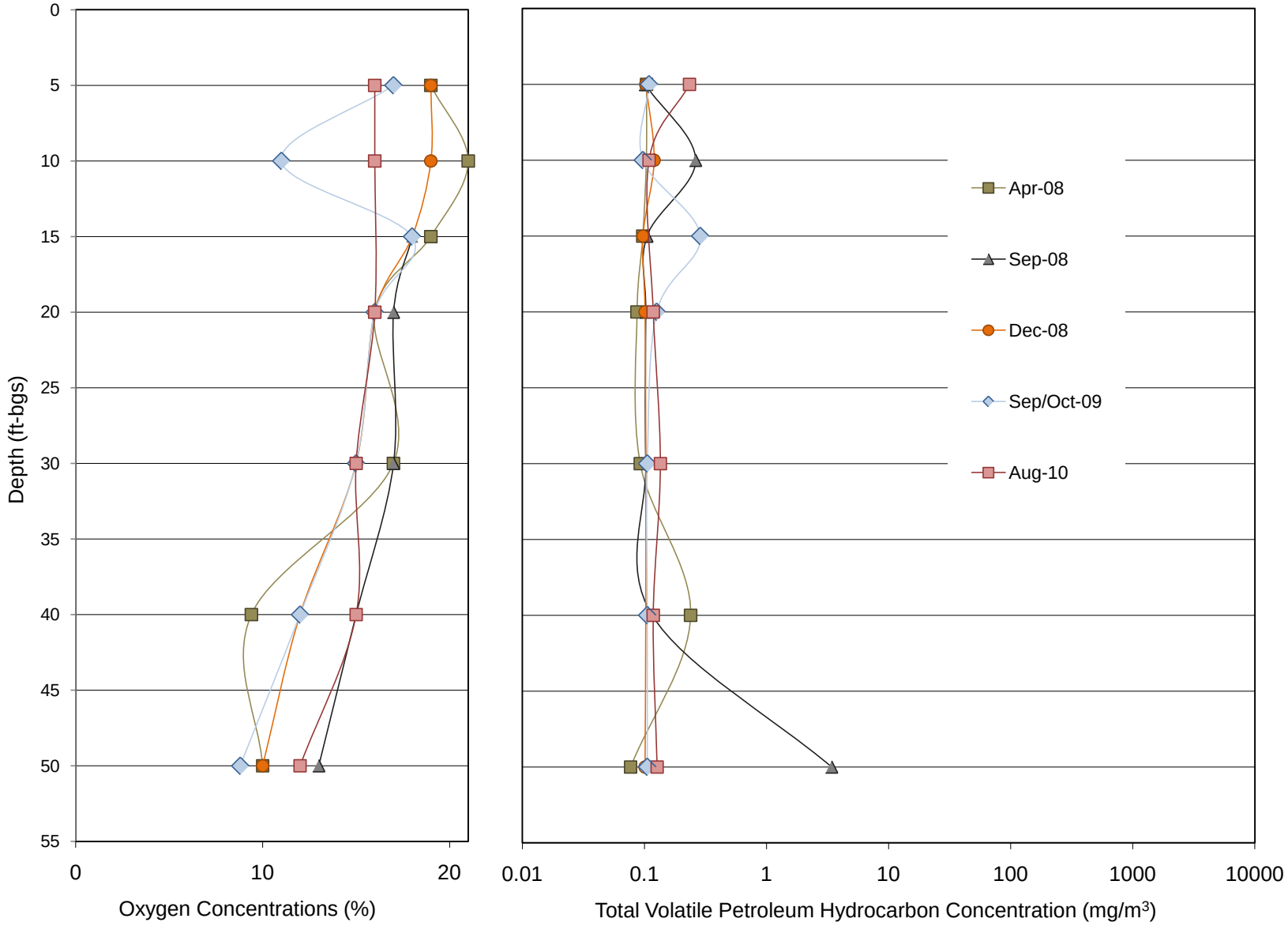
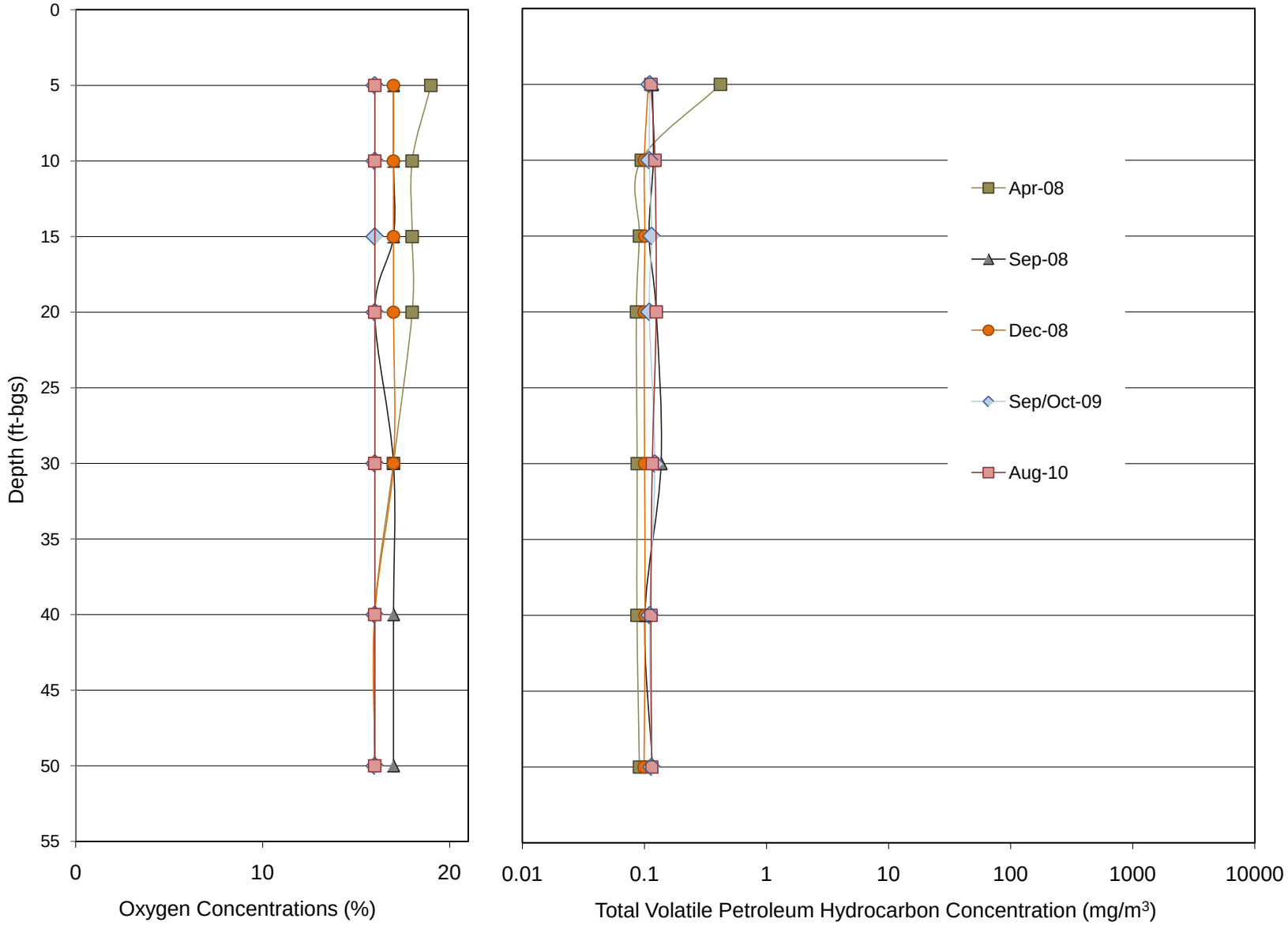


FIGURE 4-21. TVPH AND FIXED GAS PROFILES, NESTED VAPOR MONITORING WELL VW-129
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



APPENDIX A

LNAPL TRACER TESTING AND VOLUMETRIC ANALYSES

APPENDIX A

RADIUS OF INFLUENCE OF HIGH-GRADE RECOVERY

AND LNAPL TRACER TEST RESULTS

November 29, 2011

Project No.: 500-018-014

PREPARED BY: Trihydro Corporation

1252 Commerce Drive, Laramie, WY 82070

SUBMITTED BY: Chevron Environmental Management Company

Chevron Cincinnati Facility, 5000 State Route 128, Cleves, Ohio 45002

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1.0 INTRODUCTION

The high-grade pumping component of the groundwater remedy focuses on seasonal removal of light non-aqueous phase liquid (LNAPL) from the lower reaches of the smear zone where the LNAPL saturations remain the greatest. The purposes of high-grade recovery are to (1) further reduce LNAPL mobility at the lowest ambient water table conditions and (2) remove additional LNAPL mass from the smear zone. LNAPL recovery is undertaken during low water table conditions, based on historical trends and field observations during seasonal dry periods. LNAPL appears in wells and is recoverable as a function of water table elevations (triggers) as they relate to the smear zone. The water table must be low enough to expose the approximate bottom third of the smear zone before LNAPL can be recovered. The goal of high-grade pumping is to use focused groundwater extraction to maximally expose the smear zone and recover LNAPL during periods of low water table conditions. Maximal exposure of the smear zone occurs when the water table is drawn down below the previous minimum groundwater elevation. Thus, the minimum historical groundwater elevation within a well is used to establish targets for initiating high-grade recovery. With each successful high-grade event, the depth of maximum smear zone exposure will be lowered, thereby establishing new, lower triggers for starting high-grade recovery over subsequent events.

1.1 PURPOSE

The purpose of this evaluation is to better understand the effectiveness of LNAPL recovery during a high-grade pumping event. The first part of this evaluation entails evaluation of the radius of influence (ROI) of LNAPL recovery from newly installed production well PROD_25 during high-grade pumping performed intermittently between August 2010 and February 2011. The ROI is estimated for steady state periods of recovery, as well as over the entire event using volumetric approximations. The second part of this evaluation involves estimation of LNAPL flux through the formation derived from single well LNAPL tracer dilution tests. A fluorescent tracer that was soluble within the LNAPL was used to measure the rate of LNAPL movement towards a production well, in this case production well PROD_25 during the end of the high-grade recovery event in early 2011. The LNAPL flux estimated using the volumetric analysis is compared to the estimate of the LNAPL flux through the formation derived from the tracer dilution tests to evaluate agreement between these estimates and gauge the reasonableness of the ROI derived via volumetric analyses.

2.0 LNAPL TRACER TESTING METHODOLOGY

The premise of single-well tracer dilution testing is that the rate at which the concentration of a tracer decreases in a well is proportional to the flux of fluid passing through the well and adjacent formation (Smith et. al 2011). Such testing does not resolve the direction of LNAPL movement; however, this can be determined from the local water table surface. In the case of a single active LNAPL recovery well for which the monitoring well is within the pumping cone of depression, LNAPL can be assumed to flow radially toward the production well. Procedurally, single-well intermittent mixing tracer dilution testing involves:

1. Introducing a uniformly distributed soluble tracer into LNAPL within a well at time t_0
2. Measuring the tracer concentration in the LNAPL at t_0
3. Allowing a period of time Δt to pass during which no active mixing occurs
4. At time $t_0 + \Delta t$, remixing the tracer in the well
5. Re-measuring the tracer concentration in the well
6. Estimating a vertically averaged LNAPL flux passing through the well and adjacent formation, based on stepwise changes in tracer concentration over time

This section provides a description of the single well LNAPL dilution tracer testing conducted at the Chevron Cincinnati Facility.

2.1 INSTALLATION OF TEMPORARY TEST WELLS NEAR PRODUCTION WELL PROD_25

On July 13, 2010, prior to starting high-grade recovery, three temporary monitoring wells (LTTMW-25, LTTMW-50, and LTTMW-100) were installed approximately 25, 50, and 100 feet from production well PROD_25. A 3.25-inch diameter soil boring was continuously cored using a 5-foot continuous sampler at each proposed monitoring well location using an AMS 9630 Power Probe. The soil borings were installed to 45 feet below ground surface, a depth corresponding to the lower limits of the smear zone.

An aliquot of the soil from each 5-foot interval was placed in a re-sealable plastic bag and the headspace was monitored for total organic vapors using a MiniRae 2000 photoionization detector (PID). The PID was calibrated daily, in accordance with the manufacturer's guidelines, to a factory-prepared 100 parts per million isobutylene standard. Each sample was allowed to equilibrate to ambient temperature before screening for total organic vapors.

The soil core was inspected by a professional geologist and a lithologic log prepared in general accordance with American Society of Testing and Materials (ASTM) standards. Additional information, such as odors, discoloration, artificial/non-native debris, and observations pertaining to potential petroleum hydrocarbon impacts were noted on the lithology logs.

After advancement of each soil boring to the total depth, a groundwater monitoring well was installed using ten feet of two-inch diameter, 0.010-inch factory-slotted polyvinyl chloride (PVC) screen inserted through the direct push rod. PVC flush-threaded blank casing was installed from the top of the screened interval to approximately three feet above ground surface. Sand and gravel within the formation were allowed to collapse within the borehole to a depth of approximately two feet above the top of the screened interval. An annular seal consisting of hydrated benseal granular bentonite was placed above the filter pack to ground surface. A four-inch Schedule 40 PVC casing was placed over the monitoring wells to act as a protective casing for the temporary monitoring well.

Following installation, the top of casing at each well was surveyed relative to nearby monitoring wells using a level and stadia rod. The northing and easting were surveyed using a Trimble Asset GPS unit relative to the state plane coordinate system. The horizontal accuracy for the temporary tracer test monitoring wells was established as +/- 3 feet and the vertical accuracy was +/- 0.5 feet, which was determined acceptable for temporary monitoring locations. The well designation and measuring point were clearly labeled on each well.

2.2 LNAPL TRACER TESTING METHODOLOGY

LNAPL tracer testing was first attempted using several monitoring wells located at various radial distances from production well PROD_25 between early-October and late-November 2010. Early testing was focused on: (1) determining a methodology that was repeatable, (2) resolving performance issues with the field equipment, (3) estimating the frequency of measurements, and (4) identifying which monitoring wells should be the focus of future tracer testing. This early testing did not yield results that supported further analysis. These early-tests were conducted using groundwater monitoring wells L-1R, LTTMW-25, LTTMW-50, LTTMW-100, and MW-57. Subsequent testing in February 2011, focused primarily on monitoring well LTTMW-25 with additional tests conducted in wells LTTMW-100 and MW-57.

The fluid levels within each monitoring well were gauged using a Solonist interface probe accurate to 0.01-feet. The measurements were completed from the pre-marked (surveyed) measuring point on the well casing. The exposed portion of the tape and the probe were decontaminated before performing measurements at each monitoring well.

Once LNAPL of adequate thickness (generally greater than 0.1-feet) was confirmed to be present through fluid level gauging activities, a ½-inch diameter Schedule 80 chlorinated polyvinyl chloride (CPVC) casing was inserted into the monitoring well, through the LNAPL, to the total depth of the well. The ½-inch CPVC casing effectively isolated a portion of LNAPL that would be used to measure the background fluorescence throughout the dilution tracer test. The background fluorescence of the LNAPL was then measured using an Ocean Optics, Inc. S2000 temperature-regulated UV-VIS spectrometer equipped with a 470 nanometer light source. The 470 nanometer light was transmitted into the LNAPL present within the background CPVC casing (referred to as the "in-well background standard") using an Ocean Optics, Inc. six around one fiber optic cable. Six of the fibers transmitted the 470 nanometer light into the LNAPL and the seventh fiber transmitted the induced fluorescence signal back to the spectrometer. The intensity of induced fluorescence was measured between 540 and 550 nanometers.

After setting the in-well background standard and measuring the relative fluorescence, an aliquot of LNAPL, typically less than 100 milliliters (mL), was withdrawn from the monitoring well using a hydrophilic bailer and transferred into a 250 mL wide mouth container. Approximately 10 mL of soluble tracer was then mixed into the aliquot of LNAPL withdrawn from the monitoring well. The soluble tracer was Bright Solutions, Inc. BSL 715, which is typically used as a dye to detect oil leaks in engines. When excited with the 470 nanometer light-source, BSL 715 has fluorescence peaks centered at 545 and 580 nanometers. The tracer spiked LNAPL was then injected back into the monitoring well using a 100 mL syringe, ¼-inch Nylaflo tubing, and a ¼-inch stainless steel probe. The tracer was fully mixed with the LNAPL in the monitoring well by slowly injecting air using a manual pump through the ¼-inch Nylaflo tubing and stainless steel probe. The intensity of induced fluorescence of the tracer spiked LNAPL within the monitoring well was then measured between 540 and 550 nanometer wavelengths using the fiber optic cable and spectrometer. The intensity of fluorescence measured in the spiked LNAPL was confirmed to be approximately two times that measured within the in-well background standard. If not, an additional aliquot of LNAPL was removed from the well and spiked with soluble tracer following the same procedure.

Once the induced fluorescence of the tracer spiked LNAPL was measured at twice that of background, a second ½-inch diameter Schedule 80 chlorinated polyvinyl chloride (CPVC) casing was inserted into the monitoring well, through the tracer spiked LNAPL, to the total depth of the well. This ½-inch CPVC casing effectively isolated a portion of tracer spiked LNAPL that would be used to measure the maximum fluorescence of the tracer spiked LNAPL throughout the duration of dilution tracer testing. The relative fluorescence of the LNAPL within this standard would only decrease as a function of volatilization, sorption, and dissolution, but not as a result of dilution due to flux of the LNAPL out of the monitoring well. The in-well background standard was labeled C_0 on the CPVC casing and the in-well tracer spiked standard was labeled C_{100}.

The induced fluorescence of the tracer spiked LNAPL within the monitoring well (C_{well}), in-well background standard (C_0), and in-well tracer spiked standard (C_{100}) were then measured and recorded as time t_0. The tracer in the monitoring well and the two standards were then intermittently remixed at intervals of Δt. The induced florescence was re-measured using the fiber optic cable and spectrometer within the two standards as well as the monitoring well and recorded at time $t_0 + \Delta t$. These measurements were repeated between five and ten times until at least 20% of the LNAPL soluble tracer was displaced from the temporary tracer test monitoring well.

The induced fluorescence measurements recorded from the two standards were used to correct (1) background fluorescence from the LNAPL (not related to the tracer) induced by the 470 nanometer light source and (2) variations in the sensitivity of the spectrometer and fiber optic cable during each measurement. The fluorescence intensity measurements will vary naturally in the field in response to the temperature of the spectrometer and attributes of the fiber optic cable such as orientation. The intensity of fluorescence within the monitoring well, at each time interval, was corrected using the background and maximum tracer spiked standards in the following manner:

$$\frac{C_{T_{t_0+\Delta t}}}{C_{T_{t_0}}} = \frac{\frac{I_{TW_{t+\Delta t}} - I_{C0_{t+\Delta t}}}{I_{C100_{t+\Delta t}} - I_{C0_{t+\Delta t}}}}{\frac{I_{TW_t} - I_{C0_t}}{I_{C100_t} - I_{C0_t}}}$$

where:

$\frac{C_{T_{t_0+\Delta t}}}{C_{T_{t_0}}}$ = ratio of LNAPL tracer concentration at time Δt relative to the start of the test t_0 (unitless)

$I_{TW_{t+\Delta t}}$ = tracer fluorescence intensity within test well at time Δt after start of test (%)

$I_{C0_{t+\Delta t}}$ = in-well background tracer fluorescence intensity at time Δt after start of test (%)

$I_{C100_{t+\Delta t}}$ = in-well spiked tracer fluorescence intensity at time Δt after start of test (%)

I_{TW_t} = tracer fluorescence within test well at the start of test (%)

I_{C0_t} = in-well background tracer fluorescence intensity at start of test (%)

I_{C100_t} = in-well spiked tracer fluorescence intensity at start of test (%)

3.0 DATA EVALUATION

This section describes the analyses used to estimate the LNAPL flux through the formation as well as the ROI of high-grade recovery performed using production well PROD_25 based on a volumetric assessment of the recovered LNAPL. The LNAPL flux estimated using the volumetric analysis is compared to the estimate of the LNAPL flux through the formation derived from the LNAPL tracer dilution tests performed within monitoring well LTTMW-25. The assumptions and limitations of the analyses are also discussed herein.

3.1 VOLUMETRIC ANALYSES AND INPUTS

During 2010 and 2011, recovery within the Central High-Grade Area was performed during two discrete timeframes (Figure 1). High-grade pumping began on August 10, 2010 when groundwater trigger elevations were first reached. High-grade operations subsequently focused on the use of several production wells in the Southwest and Central Areas over the course of the event as follows:

- PROD_25 – August 10, 2010 to December 2, 2010
- PROD_19 and PROD_24 – December 3, 2010 to January 7, 2011
- PROD_20 and PROD_25 – January 7, 2011 to January 19, 2011
- PROD _25 – January 19, 2011 to February 28, 2011

The volumetric analysis described herein considered the two operating periods for high-grade recovery performed using production well PROD_25 separately (i.e., pumping in 2010 and 2011 evaluated uniquely) and then recovery totals for the entire high-grade event were combined. Results of the volumetric analyses including an estimate of the area of influence and LNAPL flux for the three cases are described in the following sub-sections.

3.1.1 LNAPL THICKNESS IN FORMATION AS A FUNCTION OF LNAPL THICKNESS IN WELL

As the LNAPL thickness within the formation ($b_{formation}$) is an input into all subsequent volumetric and tracer dilution analyses, it is derived first. The relationship between the LNAPL thickness within a test well (b_{well}) and the formation is as follows (McWhorter and Nelson 1980):

$$b_{formation} = b_{well} - b_{LNAPL\ heel} + b_{air\ heel}$$

where:

$$b_{air\ heel} = \frac{1.34 * cm * \rho_w * \sigma_{ao}}{\sigma_{aw} * \rho_{LNAPL} * \left(\frac{K_w * sec}{cm}\right)^{0.43}}$$

and:

$$b_{LNAPL\ heel} = \frac{1.34 * cm * \rho_w * \sigma_{aw}}{\sigma_{aw} * (\rho_w - \rho_{LNAPL}) * \left(\frac{K_w * sec}{cm}\right)^{0.43}}$$

and:

ρ_w = density of water (grams/centimeter^3)
ρ_o = density of oil (grams/centimeter ^{3})
σ_{ow} = oil-water interfacial tension (dyne/centimeter)
σ_{aw} = air-water interfacial tension (dyne/centimeter)
σ_{ao} = air-oil interfacial tension (dyne/centimeter)
K_w = hydraulic conductivity (centimeter/second)

Inputs and results for the two recovery periods and the combined total over the high-grade event are provided in Table 1, using the recorded LNAPL thickness measured in monitoring well LTTMW-25 during high grade recovery. Overall, $b_{formation}$ is approximately 0.08 feet less than b_{well}. This adjustment has been made in subsequent equations involving LNAPL thickness within the formation.

3.1.2 RADIUS OF INFLUENCE FOR HIGH GRADE RECOVERY

As a means to assess the radial influence of high grade recovery (i.e., the lateral extent to which LNAPL may be drawn toward, and potentially captured at, the recovery well), a volumetric analysis was performed following the method described by Sale (2011a and 2011b). This analysis assumes a slug of LNAPL recovered during a period of active recovery emanated from a thin cylinder of thickness $b_{formation}$ and radial distance (defined as the ROI). While actual recovery occurs in a heterogeneous soil matrix with an irregular LNAPL distribution, a volumetric analysis of this sort provides an estimate of the ROI of LNAPL recovery during a high-grade event. The ROI is calculated as follows:

$$ROI = \sqrt{\frac{V_{LNAPL}}{\pi * b_{formation} * \phi * S_{LNAPL}}}$$

where:

V_{LNAPL} = volume of LNAPL recovered (feet^3)
$b_{formation}$ = LNAPL thickness (feet)
ϕ = soil porosity (unitless)
S_{LNAPL} = LNAPL saturation (unitless)

As previously described, during the 2010 through 2011 high-grade event, recovery from production well PROD_25 was conducted over two discrete time periods. As shown on Figure 1, the majority of LNAPL (96,746 gallons) was recovered during the first steady state period, which extended from September 27, 2010 to November 15, 2010 representing a total of 49 days. A lesser LNAPL volume (10,759 gallons) was recovered during the second steady state period, which extended from February 4, 2011 to February 18, 2011. Input parameters and the resulting range for the ROI estimates for the individual steady state periods, as well as the period of total recovery (i.e., including periods before and after steady state recovery) are provided in Table 2. It should be noted that due to uncertainty and heterogeneity of LNAPL saturations within the smear zone, a range of saturation values were used to calculate the ROI with a maximum saturation of 24.7% based on values reported on Table A-2 of the *Conceptual Groundwater Remedy Report* (ChevronTexaco Groundwater Task Force 2003) and a minimum value of 10%, which represents the upper range of two phase saturations reported within Section 3 of the *Chevron Cincinnati Facility Site Characterization Method Selection* (Radian International and Duke Engineering & Services 1999). The range of ROI estimates for the first recovery period performed in 2010 (229 to 360 feet) was nearly twice as large as that estimated for the second recovery period in 2011 (121 to 190 feet). This result is consistent with the shorter timeframe and smaller volume of LNAPL recovered during the second period. An overall ROI of approximately 300 to 470 feet was calculated for high-grade recovery conducted in production well PROD_25 between 2010 and 2011, using an average LNAPL formation thickness observed throughout the event.

3.1.3 SEEPAGE VELOCITY AS A FUNCTION OF RADIUS FROM PRODUCTION WELL

The average seepage velocity (v_{LNAPL}) at monitoring well LTTMW-25 was calculated for the two individual and then the combined recovery periods using the same input parameters as for the ROI estimation (Table 2). Average seepage velocity is calculated as follows:

$$v_{LNAPL} = \frac{Q_{LNAPL}}{2 * \pi * r_{tw} * b_{formation} * \phi * S_{LNAPL}}$$

where:

Q_{LNAPL} = the volumetric recovery rate of LNAPL at the production well (feet^3/day)
r_{tw} = radial distance from the monitoring well to the recovery well (feet)
$b_{formation}$ = formation LNAPL thickness (feet)
ϕ = soil porosity (unitless)
S_{LNAPL} = LNAPL saturation (unitless)

A range of LNAPL seepage velocities between approximately 20 and 50 feet/day was calculated for the first and second recovery periods, respectively. An average seepage velocity through the formation was estimated between 14.7

and 36.2 feet/day over the entire recovery event. The seepage velocity was estimated for a monitoring well situated 25 feet from the production well for direct comparison to results from the LNAPL tracer testing conducted in well LTTMW-25. The seepage velocity is inversely proportional to the radial distance from the production well.

3.2 LNAPL TRACER TESTING

The LNAPL flux through the test well LTTMW-25 was estimated based on the single well tracer dilution testing conducted between February 7 and 11, 2011, during the second high-grade recovery period using production well PROD_25. LNAPL flux through the test well was subsequently converted to seepage velocity through the formation and compared to that predicted by the volumetric analyses described in Section 3.1.3. Tracer testing results recorded from the other temporary and permanent monitoring wells could not be used for this analysis due to irregularities with the fluorescence measurements associated with the spectrometer, fiber optic cable, and mixing of the tracer within the well between measurements.

3.2.1 CALCULATION OF VERTICALLY AVERAGED LNAPL FLUX

Tables 3a and 3b contain the raw tracer intensity versus time data for LTTMW-25 (hourly and daily data) as well as multiple analyses used to calculate the vertically averaged LNAPL flux (q_{wL}) through the test well. The core equation used (equation 13 from Smith et al. 2011) for each analysis is:

$$\frac{C_{T_{t_0+\Delta t}}}{C_{T_{t_0}}} = \frac{2 * acos\left(\frac{q_{wL} * \Delta t}{2 * r_{well}}\right) - sin\left[2 * acos\left(\frac{q_{wL} * \Delta t}{2 * r_{well}}\right)\right]}{\pi}$$

where:

$\frac{C_{T_{t_0+\Delta t}}}{C_{T_{t_0}}}$ = ratio of LNAPL tracer concentration at time Δt relative to start of test (unitless)

Δt = time step (day)

q_{wL} = vertically averaged LNAPL flux (feet/day)

r_{well} = interior radius of test well (feet)

While multiple approaches were evaluated in order to estimate $q_{wL,}$ as shown on Tables 3a and 3b, a graphical straight-line solution was found to be the most appropriate. This solution consists of plotting the normalized intensity (C/C_0) values versus time and creating a straight line fit through the data. The left-hand side of the above equation ($C_{Tto+\Delta t}$ / C_{Tto}) was taken as the projected straight regression line (y = m ∗ x + b) at the final time step. Here, Δt is also equal to the total elapsed time. This is also the method preferred by Mahler et al. 2011.

Results of the analyses are summarized on Table 4. The following is a discussion of key values in the results summary table referenced by (Row Number). Row (2) indicates the LNAPL flux through the test well (q_{wL}) as calculated using the graphical approach described above. The average LNAPL thickness (b_{well}) observed in the test well at the time of the LNAPL tracer measurements is provided in Row (3). In Row (4), the LNAPL well thickness is converted to an average formation thickness ($b_{formation}$) using the methodology previously discussed in Section 3.1.1.

3.2.1.1 LIMITATIONS IN LNAPL TRACER TESTS

Similar straight-line fit analyses were performed for LNAPL tracer dilution data collected from monitoring wells LTTMW-100 (daily and hourly data) and LTTMW-57 (daily data). Upon review, these data sets were excluded from subsequent analysis either due to a limited data set (2 or 3 measurements collected during testing at wells LTTMW-100 daily and LTTMW-57 daily), which did not provide adequate support to a straight-line fit; or the data was biased toward early time data (LTTMW-100 hourly), which reduces the certainty of the straight-line fit analysis as well. The vertically averaged LNAPL flux predicted by the daily and hourly data from LTTMW-25 (21.1 and 20.9 feet/year, respectively) are consistent with one another (within 1%) providing a high degree of confidence in these measurements.

3.2.2 CORRECTION TO AVERAGE LNAPL FLUX WITHIN THE FORMATION

The average formation LNAPL flux (5) is calculated as follows:

$$q_{fL_{ave}} = \frac{q_{wL_{ave}} * b_{well}}{\alpha * b_{formation}}$$

where:

q_{fLave} = average formation LNAPL flux (feet/year)
q_{wLave} = average well LNAPL flux (feet/year)
b_{well} = well LNAPL thickness (feet)
$b_{formation}$ = formation LNAPL thickness (feet)
α = convergence factor (unitless)

The convergence factor (α) accounts for the nature of LNAPL flow into a groundwater well as a function of the open area of the screen. As indicated by Sale et al. 2007, an α of 0.79 was empirically derived for a 0.010-inch Schedule 40 PVC screen similar to that used to construct the temporary tracer test monitoring wells at the Chevron Cincinnati Facility.

The total LNAPL flow at the test well radius (6) is calculated as the test well LNAPL flux (5) multiplied by the radial LNAPL flux boundary ($2 * \pi * r_{tw} * b_{formation}$) (4).

The average LNAPL seepage velocity is then defined as:

$$v_{LNAPL} = \frac{q_{Lf}}{\phi * S_{LNAPL}}$$

where:

v_{LNAPL} = seepage velocity of LNAPL (feet/day)
q_{Lf} = vertically averaged LNAPL flux within the formation at the test well (feet/day)
ϕ = soil porosity (unitless)
S_{LNAPL} = LNAPL saturation (unitless)

Results of the LNAPL tracer dilution testing indicate a range of seepage velocities between approximately 1 and 4 feet per day at monitoring well LTTMW-25 at the time tracer testing was conducted.

3.2.3 COMPARISON OF LNAPL TRACER AND VOLUMETRIC ANALYSES SEEPAGE VELOCITIES

The volumetric analysis estimate for average seepage velocity is more than an order-of-magnitude greater than that estimated via tracer dilution testing performed in monitoring well LTTMW-25. One possible explanation for these differences in the estimated LNAPL flux through the formation has to do with the transient nature of LNAPL recovery. As shown on Figure 2, a graph of LNAPL recovery over time during the second recovery period at production PROD_25 appears as a rough bell shaped distribution. This is a function of the depression and then rebound of the water table due to engineered recovery and then ambient conditions. The volumetric analyses estimate a seepage velocity based on the average LNAPL recovered through time; whereas, the tracer test results provide a snapshot of the seepage velocity at a single point in time. Although the tracer testing was conducted during the latter half of the second recovery period, there is some lag time before the LNAPL observed passing through a test well (at a particular velocity) arrives at the recovery well. Preliminary estimates indicate this lag time may be between one and two weeks, putting the arrival time of the LNAPL observed within monitoring well LTTMW-25 during the tracer dilution tests at the tail end of the recovery period. Since the daily LNAPL recovery was trending downward at the time of the LNAPL tracer testing, it is expected that the instantaneous LNAPL seepage velocity was also trending downward as well and is therefore expected to be less than the average value observed over the recovery period.

4.0 REFERENCES

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TABLES

TABLE 1. LNAPL FORMATION THICKNESS AS A FUNCTION OF WELL THICKNESS
CALCULATION INPUTS AND RESULTS
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Parameter	Symbol	Value
Inputs		
Density of Water (g/cm^3)	ρ_w	1.00
Density of Oil (g/cm^3)[1]	ρ_o	0.80
Oil-Water Interfacial Tension (dyne/cm)[2]	σ_{ow}	13.6
Air-Water Interfacial Tension (dyne/cm)	σ_{aw}	65.0
Air-Oil Interfacial Tension (dyne/cm)[2]	σ_{ao}	24.7
Hydraulic Conductivity of Water (cm/sec)[3]	K_w	0.073
Intermediates		
LNAPL Heel Thickness (ft)	$b_{LNAPL\ heel}$	0.14
Air Heel Thickness (ft)	$b_{air\ heel}$	0.06
Results		
First *Steady State* Recovery Period (9/27/10 - 11/15/10)		
LNAPL Thickness in Well (ft)	b_{well}	1.38
LNAPL Thickness in Formation (ft)	$b_{formation}$	1.30
Second *Steady State* Recovery Period (2/4/11 - 2/18/11)		
LNAPL Thickness in Well (ft)	b_{well}	0.60
LNAPL Thickness in Formation (ft)	$b_{formation}$	0.52
Period of *Total* LNAPL Recovery (8/30/10 - 11/29/10 and 1/31/11 - 2/28/11)		
LNAPL Thickness in Well (ft)	b_{well}	1.22
LNAPL Thickness in Formation (ft)	$b_{formation}$	1.14

Notes:

[1] - Based on API testing for PROD_25 LNAPL Sample collected 12/20/10.

[2] - Conceptual Groundwater Remedy Report, Draft Revision 0, Page A8 of Appendix A. ChevronTexaco Groundwater Task Force. July 2003.

[3] - Average of Table 3-6 values. Chevron Cincinnati Facility Site Characterization Method Selection, Page 79 of Volume 1. Radian Int. and Duke Engineering & Services. February 1999.

TABLE 2. RADIUS OF INFLUENCE AND SEEPAGE VELOCITY CALCULATION INPUT PARAMETERS AND RESULTS
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Parameter	Symbol	First Steady State Recovery Period (9/27/10 - 11/15/10)	Second Steady State Recovery Period (2/4/11 - 2/18/11)	Period of Total LNAPL Recovery (8/30/10 - 11/29/10 and 1/31/11 - 2/28/11)
Inputs				
Distance from PROD_25 (ft)	r	25.4	25.4	25.4
Volume LNAPL Recovery (gal)	V_{LNAPL}	96,746	10,759	143,677
Recovery Time Period (days)		49	14	119
Average LNAPL Recovery Rate (gpd)	Q_{LNAPL}	1,974	769	1,207
Average LNAPL Thickness in LTTMW-25 (ft)	b_{well}	1.38	0.60	1.22
Average LNAPL Thickness in Formation (ft)	$b_{formation}$	1.30	0.52	1.14
Porosity[1]	ϕ	0.245	0.245	0.245
Saturation (High End)[1]	S	0.247	0.247	0.247
Saturation (Low End)[2]	S	0.100	0.100	0.100
Results				
Min. Radius of Influence (ft)	ROI	229	121	298
Max. Radius of Influence (ft)	ROI	360	190	468
Min. LNAPL Seepage Velocity at LTTMW-25 (ft/day)	v_{LNAPL}	21.0	20.5	14.7
Max. LNAPL Seepage Velocity at LTTMW-25 (ft/day)	v_{LNAPL}	51.9	50.5	36.2

Notes:

[1] - Conceptual Groundwater Remedy Report, Draft Revision 0. Table A-2, Page A7 of Appendix A. ChevronTexaco Groundwater Task Force. July 2003.

[2] - Upper range of two phase saturations reported within Section 3 of the Chevron Cincinnati Facility Site Characterization Method Selection, Volume 1. Radian Int. and Duke Engineering & Services. February 1999.

TABLE 3a. LTTMW-25 DAILY LNAPL TRACER DILUTION TEST FLUX CALCULATION WORKSHEET
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Well Name	LTTMW-25
Setup Date	2/7/2011

Radius	0.0833	ft
$2*r_w$	0.1667	ft
Tracer addition	10	mL

Inputs							
Time	Elapsed t (days)	Δ t	t - t_o	C0 (intensity)	C100 (intensity)	Well (intensity)	WS Normal
2/7/11 11:48	0.00	0.00	0.00	72,502	146,472	147,388	1.01
2/7/11 14:05	0.10	0.10	0.10	63,820	129,533	132,660	1.05
2/8/11 9:48	0.92	0.82	0.92	68,896	141,508	113,695	0.62
2/8/11 15:11	1.14	0.22	1.14	59,628	123,618	101,372	0.65
2/9/11 11:40	1.99	0.85	1.99	73,413	148,154	98,683	0.34
2/9/11 15:58	2.17	0.18	2.17	56,979	120,419	82,286	0.40
2/10/11 10:10	2.93	0.76	2.93	70,251	142,021	90,675	0.28

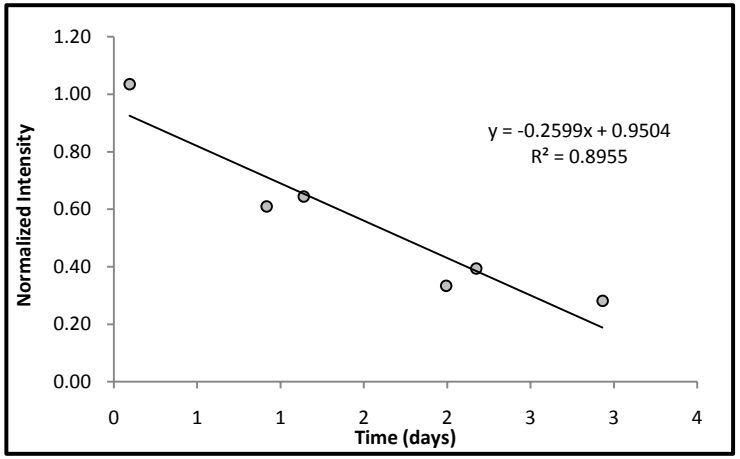
$$\frac{C_{T_{t+\Delta t}}}{C_{T_t}} = \frac{\dfrac{I_{Test\_Well_{t+\Delta t}} - I_{Co_{t+\Delta t}}}{I_{C100_{t+\Delta t}} - I_{Co_{t+\Delta t}}}}{\dfrac{I_{Test\_Well_t} - I_{Co_t}}{I_{C100_t} - I_{Co_t}}} \qquad (22)$$

TABLE 3a. LTTMW-25 DAILY LNAPL TRACER DILUTION TEST FLUX CALCULATION WORKSHEET
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

$$\frac{C_{T_{t_o+\Delta t}}}{C_{T_{t_o}}} = \frac{2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right) - \sin\left[2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right)\right]}{\pi} \quad \text{for } q_{wL}\Delta t \le 2r_w \qquad (13).$$

LHS RHS

Well LNAPL Flux Calcs (Note: Use Goal Seek to set LHS = RHS by altering $q_{wL}\Delta t$)									
Sequential Step Approach					Steps Relative to t_o				
LHS (13) Cto+Δt	RHS (13)	$q_{wL}\Delta t$	q_{wL} (ft/day)	q_{wL} (ft/year)	LHS (13) Cto+Δt	RHS (13)	$q_{wL}\Delta t$	q_{wL} (ft/day)	q_{wL} (ft/year)
1.035	1.035	-0.005	-0.048	-18	1.035	1.035	-0.005	-0.048	-18
0.589	0.589	0.055	0.067	24	0.609	0.609	0.05	0.057	21
1.057	1.057	-0.007	-0.033	-12	0.644	0.644	0.05	0.041	15
0.518	0.519	0.065	0.076	28	0.334	0.334	0.09	0.046	17
1.180	1.180	-0.024	-0.131	-48	0.394	0.394	0.08	0.038	14
0.713	0.713	0.038	0.050	18.2	0.281	0.281	0.10	0.034	13
		Average:	-0.003	-1.2			Average:	0.028	10.3
		Average (Positive Flux Data Only):	0.06	23			Average (Positive Flux Data Only):	0.028	15.8



Well LNAPL Flux Graphical Average Approach				
LHS (13) Cto+Δt / Cto	RHS (13)	$q_{wL}\Delta t$	q_{wL} (ft/day)	(2) q_{wL} (ft/year)
0.188	0.188	0.117	0.040	**14.5**

$$\frac{C_{T_{t_o+\Delta t}}}{C_{T_{t_o}}} = \frac{2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right) - \sin\left[2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right)\right]}{\pi} \quad \text{for } q_{wL}\Delta t \le 2r_w$$

TABLE 3a. LTTMW-25 DAILY LNAPL TRACER DILUTION TEST FLUX CALCULATION WORKSHEET
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

LTTMW-25 LNAPL Thickness Data During LNAPL Tracer Test			
Date	Depth to LNAPL (ft)	Depth to Groundwater (ft)	LNAPL Thickness (ft)
2/7/11	35.66	36.26	0.60
2/8/11	35.68	36.32	0.64
2/9/11	35.66	36.27	0.61
2/10/11	35.69	36.30	0.61
		(3) b_{well} (ft):	**0.62**
		(4) $b_{formation}$ (ft):	**0.54**

Results			
(5) Total LNAPL Flux through Formation (ft/year) (α=0.79)	(6) Total LNAPL Flow at Test Well Radius (gpd)	(7) Average LNAPL Seepage Velocity (ft/day) (n=0.245 S=0.247)	(8) Average LNAPL Seepage Velocity (ft/day)
21.1	**37.0**	**0.96**	**4.14**

$$q_{fL\,ave} = \frac{q_{wL\,ave}}{\alpha}\frac{b_{wL}}{b_{fL}}$$

$$v_{LNAPL} = q_{Lf} / nS_{LNAPL}$$

TABLE 3b. LTTMW-25 HOURLY LNAPL TRACER DILUTION TEST FLUX CALCULATION WORKSHEET
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Well Name	LTTMW-25
Setup Date	2/10/2011

Radius	0.0833	ft
$2*r_w$	0.1667	ft
Tracer addition	10	mL

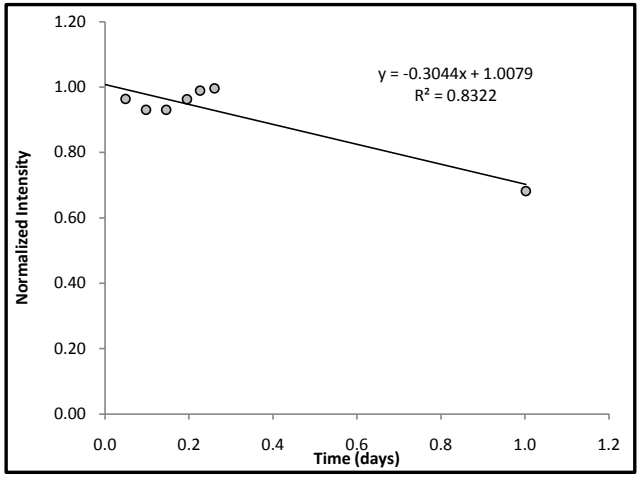
Inputs							
Time	Elapsed t (days)	Δ t	$t - t_o$	C0 (intensity)	C100 (intensity)	Well (intensity)	WS Normal
2/10/11 10:50	0.00	0.00	0.00	63,684	133,028	154,137	1.30
2/10/11 12:01	0.05	0.05	0.05	63,730	134,869	153,157	1.26
2/10/11 13:10	0.10	0.05	0.10	68,502	141,276	156,835	1.21
2/10/11 14:20	0.15	0.05	0.15	64,009	130,701	144,936	1.21
2/10/11 15:32	0.20	0.05	0.20	64,361	128,561	144,949	1.26
2/10/11 16:16	0.23	0.03	0.23	64,407	127,250	145,457	1.29
2/10/11 17:06	0.26	0.03	0.26	61,258	121,365	139,362	1.30
2/11/11 10:54	1.00	0.74	1.00	68,497	130,317	123,511	0.89

TABLE 3b. LTTMW-25 HOURLY LNAPL TRACER DILUTION TEST FLUX CALCULATION WORKSHEET
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

$$\frac{C_{T_{o}+\Delta t}}{C_{T_{o}}} = \frac{2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right) - \sin\left[2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right)\right]}{\pi} \quad \text{for } q_{wL}\Delta t \le 2r_w \qquad (13).$$

LHS RHS

Well LNAPL Flux Calcs (Note: Use Goal Seek to set LHS = RHS by altering $q_{wL}\Delta t$)									
Sequential Step Approach					Steps Relative to t_o				
LHS (13) Cto+Δt / Cto	RHS (13)	$q_{wL}\Delta t$	q_{wL} (ft/day)	q_{wL} (ft/year)	LHS (13) Cto+Δt / Cto	RHS (13)	$q_{wL}\Delta t$	q_{wL} (ft/day)	q_{wL} (ft/year)
0.964	0.964	0.0047	0.096	35	0.964	0.964	0.0047	0.096	35
0.966	0.966	0.0045	0.092	34	0.931	0.931	0.0090	0.093	34
1.000	1.000	0.0000	0.0000	0.0000	0.930	0.930	0.0092	0.063	23
1.034	1.034	-0.0045	-0.0891	-32.5088	0.962	0.962	0.0050	0.025	9
1.027	1.027	-0.0035	-0.1157	-42.2441	0.989	0.989	0.0014	0.006	2.3
1.008	1.008	-0.0010	-0.0302	-11.0148	0.996	0.996	0.0005	0.002	0.7
0.685	0.685	0.0417	0.056	21	0.682	0.682	0.0421	0.042	15
		Average (All Data):	0.0014	0.5			Average (All Data):	0.047	17
		Average (Positive Flux Data Only):	0.06	22			Average (Positive Flux Data Only):	0.07	27



Well LNAPL Flux Graphical Average Approach				
LHS (13) Cto+Δt / Cto	RHS (13)	$q_{wL}\Delta t$	q_{wL} (ft/day)	q_{wL} (ft/year)
0.703	0.703	0.0392	0.039	**14.3**

$$\frac{C_{T_{o}+\Delta t}}{C_{T_{o}}} = \frac{2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right) - \sin\left[2a\cos\left(\frac{q_{wL}\Delta t}{2r_w}\right)\right]}{\pi} \quad \text{for } q_{wL}\Delta t \le 2r_w$$

TABLE 3b. LTTMW-25 HOURLY LNAPL TRACER DILUTION TEST FLUX CALCULATION WORKSHEET
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

LTTMW-25 LNAPL Thickness Data During LNAPL Tracer Test			
Date	Depth to LNAPL (ft)	Depth to Groundwater (ft)	LNAPL Thickness (ft)
2/10/11	35.69	36.30	0.61
2/11/11	35.72	36.30	0.58
		(3) b_{well} (ft):	**0.59**
		(4) $b_{formation}$ (ft):	**0.51**

Results			
(5) Total LNAPL Flux through Formation (ft/year) (α=0.79)	(6) Total LNAPL Flow at Test Well Radius (gpd)	(7) Average LNAPL Seepage Velocity (ft/day)	(8) Average LNAPL Seepage Velocity (ft/day)
20.9	**35.2**	**0.95**	**3.94**

$$q_{fL\,ave} = \frac{q_{wL\,ave}}{\alpha}\frac{b_{wL}}{b_{fL}}$$

$$v_{LNAPL} = q_{Lf} / nS_{LNAPL}$$

TABLE 4. LTTMW-25 LNAPL TRACER DILUTION TEST RESULTS SUMMARY
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

	Parameter	LTTMW-25 (Daily)	LTTMW-25 (Hourly)
(1)	Radius (ft)	25.4	25.4
(2)	Average LNAPL Flux through the Test Well (ft/yr)	14.5	14.3
(3)	Test Well LNAPL Thickness (ft)	0.62	0.59
(4)	LNAPL Thickness in Formation	0.54	0.51
(5)	Average Formation LNAPL Flux using Well Thickness (ft/yr) (α=0.79, adjusted for $b_{well}/b_{formation}$)	21.1	20.9
(6)	Total LNAPL Flow at Test Well Radius (gpd)	37.0	35.2
(7)	Average LNAPL Seepage Velocity (Minimum) (ft/day; Porosity[1] = 0.245; Saturation[1] = 0.247)	0.96	0.95
(8)	Average LNAPL Seepage Velocity (Maximum) (ft/day; Porosity[1] = 0.245; Saturation[2] = 0.100)	4.14	3.94

Notes:

[1] - Conceptual Groundwater Remedy Report, Draft Revision 0. Table A-2, Page A7 of Appendix A. ChevronTexaco Groundwater Task Force. July 2003.

2 - Upper range of two phase saturations reported within Section 3 of the Chevron Cincinnati Facility Site Characterization Method Selection, Volume 1. Radian Int. and Duke Engineering & Services. February 1999.

FIGURES

FIGURE 1. LNAPL RECOVERY, DRAWDOWN, AND FLUID LEVEL SUMMARY (2010 THROUGH 2011 HIGH-GRADE EVENT)
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

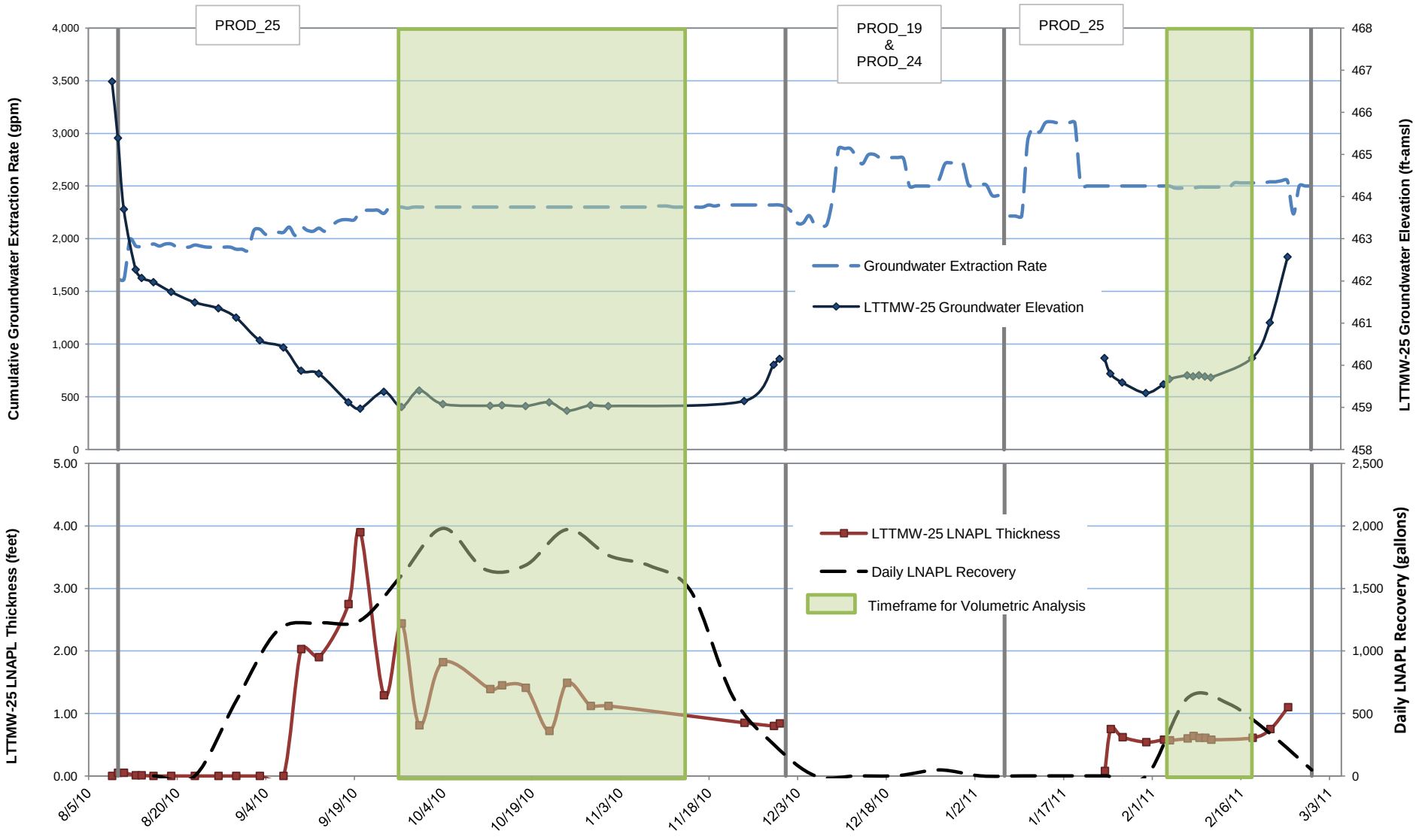
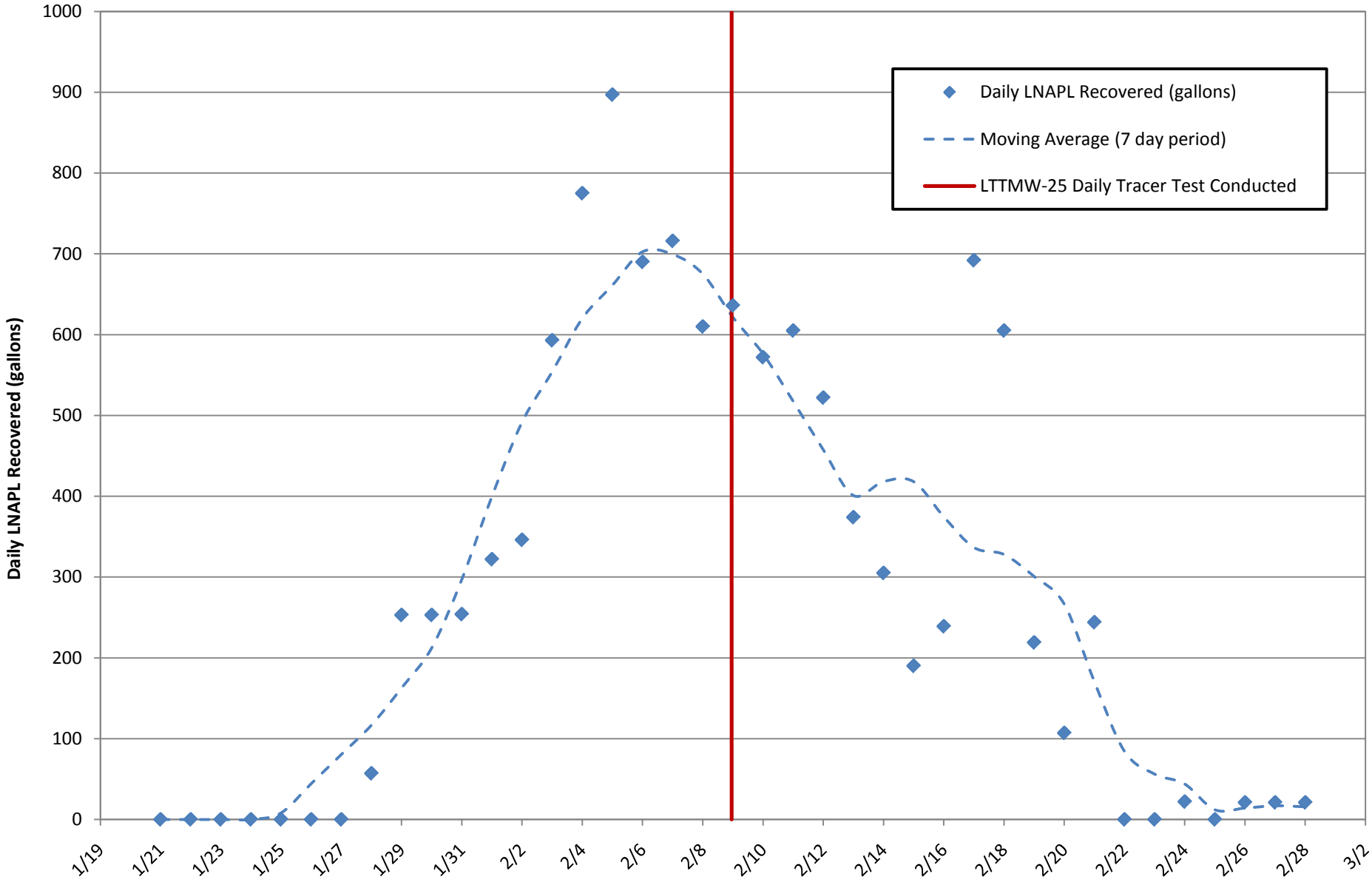


FIGURE 2. PRODUCTION WELL PROD_25 DAILY LNAPL RECOVERY VERSUS TIME
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



201111_CincyLNAPL-TracerFlux_FIG-2.xlsx

APPENDIX B

SOURCE ZONE NATURAL ATTENUATION EVALUATION

APPENDIX B

NATURAL SMEAR ZONE DEPLETION SUMMARY

CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

November 29, 2011

Project No.: 500-018-014

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1.0 INTRODUCTION

Routine monitoring results to support implementation of the final corrective measures at the Chevron Cincinnati Facility provide multiple lines of evidence demonstrating natural attenuation processes are acting to remove petroleum hydrocarbons from the light non-aqueous phase liquid (LNAPL) smear zone over time. These individual lines of evidence are presented on a semiannual basis within the routine groundwater monitoring reports and summarized within the *Five Year Groundwater Corrective Measures Implementation Review* (*5-Year Groundwater CMI Review*, Trihydro 2011).

The purpose of this evaluation is to integrate routine analytical results with measured rates of chemical transport within the vadose and saturated zones to provide an estimate of the rate of natural source zone depletion (NSZD). This method is described in detail in the 2009 Interstate Technology & Regulatory Council (ITRC) document titled, *Evaluating Natural Source Zone Depletion at Sites with LNAPL*, based largely on the methodology described in Johnson et al. (2006a, 2006b). This method allows for estimation of NSZD rates in the saturated zone and vadose zone attributable to specific reduction-oxidation (redox) processes.

This appendix details the inputs (Section 2) and results (Section 3) of the numerical model used for estimating NSZD rates at the Chevron Cincinnati Facility. This evaluation considers data collected between 2008 and 2011 following approval of the *Operation, Maintenance, and Monitoring (OMM) Plan for Final Groundwater Remedy, Chevron Cincinnati Facility* (Trihydro 2007b). The data is considered over this extended timeframe to adjust for spatial and temporal variations within the vadose and saturated zones. The rates of NSZD will be estimated and compared to the rates provided herein on five year intervals and included in future *Groundwater CMI Reviews*. In addition, the rates of NSZD will be compared to those achieved via high-grade pumping and used as one of the endpoints for discontinuing engineered recovery within portions of the smear zone.

2.0 INPUTS FOR NSZD RATES

To estimate NSZD for the Chevron Cincinnati facility, the smear zone was divided into four control volumes of roughly square lateral dimensions. These control volumes were selected to provide some discretization of hydrologically different portions of the smear zone. The control volumes are shown on Figure 1, and each has sufficient data for estimating NSZD rates and processes. The control volumes are as follows:

- CV21 – is the up-gradient portion of the smear zone encompassing the northern tank farm and marketing terminal. Groundwater generally absent of petroleum hydrocarbons enters the northern limits of the smear zone within this control volume.
- CV18 – is the "core" of the smear zone. The majority of the process units, southern tank farm, sludge pits, and historical process waste disposal areas were located within this control volume.
- CV20 – during operation of the refinery many of the support/administrative functions and associated structures were located within this control volume. The majority of the community of Hooven overlying the smear zone is also situated within this control volume. Finally, the horseshoe factory, which pre-dated the refinery, was situated within the limits of this control volume. It should be noted that groundwater flows into this control volume is from both the up-gradient smear zone and also from the Buried Valley Aquifer-Ordovician age bedrock contact to the southwest (referred to as the Hooven area herein).
- CV93 – this control volume includes the off-site commercial area southwest of the refinery (referred to as the Southwest Quad) and several former gravel pits located on and off-site that were subsequently converted to landfills. Similar to control volume CV20, this control volume primarily receives groundwater from the up-gradient portions of the smear zone with a contribution from the Hooven area.

The sources for input parameters for the NSZD estimates are listed in Table 1. Routine monitoring data associated with the final remedy was supplemented with historical information about site hydrogeology and smear zone morphology. Several of these inputs are described in more detail below.

2.1 SATURATED ZONE INPUTS

The hydrogeochemical data collected on an approximate semiannual basis from 2008 to 2011 were used to estimate oxidation of electron receptors within the saturated zone in each control volume. Figure 2 provides a summary of the inputs for estimating natural depletion rates within the saturated zone including the average, minimum, and maximum concentrations for each well, grouped by control volume.

Outlying data points identified on Figure 2 were determined by first computing the inter-quartile range for each constituent measured within groundwater samples collected from a monitoring well over time, and identifying results that were more than 1.5 times outside of the inter-quartile range. These outlying results were then further scrutinized based on site knowledge to determine if the data should be excluded from further analysis as it was not representative of conditions within the control volume.

The spatial trends in hydrogeochemical data are one of the lines of evidence demonstrating natural attenuation of petroleum hydrocarbons within the smear zone. As shown on Figure 2, the measured concentrations of electron acceptors (nitrate and sulfate) are high in groundwater collected from up-gradient monitoring wells relative to those collected within the smear zone. Conversely, biodegradation byproducts (manganese, ferrous iron, and methane) are generally lower up-gradient of the smear zone and become enriched within the smear zone. These trends are an indication that multiple electron acceptors were oxidized within the saturated portions of the smear zone reducing the mass of the LNAPL source.

For each control volume, representative input values for each parameter were chosen by examination of Figure 2. The representative input values are summarized in Table 2. This table also lists input values for the rainwater infiltrate measured in samples collected from the pore water lysimeters installed within each control volume. Rainwater infiltrate can provide a flux of electron acceptors into the saturated portion of the smear zone. Where possible, the mean value for all available hydrogeochemical data collected from monitoring wells located in a control volume was used when estimating NSZD within the saturated zone. To lessen the impact of extreme measurements, median values were sometimes selected. If greater than 60% of the available measurements were non-detects, half the detection limit was used as the input value.

2.2 VADOSE ZONE INPUTS

To estimate NSZD in the vapor phase, it was necessary to calculate soil gas concentration gradients at each nested soil vapor monitoring well within a control volume, and to measure the average vapor diffusion coefficient across this gradient interval. The routine monitoring data collected from 2008 to 2011 were sufficient to estimate both parameters in each of the control volumes with some exceptions as discussed herein.

2.2.1 VAPOR DIFFUSION COEFFICIENT ESTIMATES

The vapor diffusion coefficient (VDC) is defined as the “ease” at which vapors can move through the vadose zone soils. The VDC is a function of both the soil type and the moisture content of vadose zone soils. Soil vapors are transported more easily through soils with a high VDC. There are two primary approaches for estimating the VDC of

vadose zone soils. The first method involves mathematical approximation of the VDC based on the physical properties of the soil. One example of a mathematical solution for estimating the VDC is the Millington-Quirk (1960) equation, which relates the VDC to the soil porosity and moisture content. The second approach includes in-situ estimation of the VDC through tracer gas injection and recovery within a single soil gas probe. A tracer test method was described by Johnson et al. (1998) using sulfur hexafluoride or helium as a tracer gas.

Estimation of the VDC using the Johnson et. al. methodology was performed in each of the nested wells across the smear between 2008 and 2011. The method involves injection of 300 milliliters of ultra high purity grade helium into the vapor point with an airtight syringe followed by injection of a known volume of ambient air. The volume of ambient air injected into each vapor point is equal to the volume of ambient air present in the tubing between the ball valve at the top of the interval and the soil vapor probe at depth, such that the helium is displaced into the formation around the vapor probe.

An instantaneous sample was collected by purging the same volume of ambient air that was injected into the vapor point using the airtight syringe. After purging, 300 milliliters of soil gas were sampled into a 1-liter Tedlar bag and the instantaneous helium concentration was measured. This helium concentration was recorded as the "time zero" concentration. The vapor probe and line were then flushed with more than 10-liters of ambient air. This procedure was subsequently repeated and helium concentrations recorded over two successive time intervals (approximately 30 and 60 minutes) following injection of the tracer gas.

To estimate the vapor diffusion coefficient across each gradient interval, helium tracer testing results were vertically averaged at each vapor well and then scaled to free air diffusivities of the relevant gases (oxygen, methane, and total volatile petroleum hydrocarbons). The VDC estimated via helium tracer testing in monitoring wells VW-21, VW-18, VW-20, and VW-93 is displayed on Figure 3.

2.2.2 SOIL GAS CONCENTRATION GRADIENTS

To calculate soil gas concentration gradients, the fixed gas (oxygen, carbon dioxide, and methane) profiles for vapor wells VW-21, VW-18, VW-20, and VW-93 were inspected (Figure 4). These wells were selected because they are located above the smear zone and were sampled multiple times during the past three years (monitoring performed in the Spring 2008, Fall 2008, and Summer 2011). It should be noted that only data collected from nested monitoring well VW-93 that was not affected by operations of the horizontal soil vapor extraction (HSVE) system situated beneath Hooven was used in estimating concentration gradients within the vadose zone within this control volume.

Soil vapor monitoring results from wells VW-96 and VW-99 were not considered in estimating NSZD depletion rates in control volume CV20. Alternate sources of hydrocarbon vapors are known to affect the vertical profile at these locations by consuming oxygen within shallow and intermediate portions of the vadose zone before they are able to diffuse to the smear zone. Inclusion of the vapor monitoring results from these two wells, during periods when fixed gas profiles are not affected by operation of the HSVE system, may be considered in future NSZD estimates if determined appropriate. Finally, data collected from nested vapor monitoring well VW-139 located at the southern limits of the smear zone in control volume CV93 were not considered, as there was only a single monitoring event with appropriate data for estimating NSZD within the vadose zone. Data collected from nested vapor well VW-139 may also be used in the future to estimate NSZD rates as additional monitoring is performed.

As shown on Figure 4, the vertical profiles of fixed gases at monitoring wells VW-20 and VW-93 generally show decreasing oxygen concentrations with depth, indicative of aerobic biodegradation of petroleum related hydrocarbons and/or methane within the vadose zone. Whereas, at nested vapor wells VW-18 and VW-21 oxygen concentrations are generally reduced and methane concentrations are elevated throughout the vertical profile. This is profile is an indication of anaerobic biodegradation of petroleum hydrocarbons.

A mathematical "flux plane" (see Johnson 2006a for a description) was set near the smear zone for each vapor well, as shown on Figure 4. The vapor point just above this flux plane was set as the bottom of the interval for estimation of the concentration gradient, and the atmospheric concentration at ground surface was set as the top of the interval. The "bottom" or source zone concentrations within the deepest probe were calculated by averaging the measured concentrations of oxygen, methane, and total volatile petroleum hydrocarbons during the Spring 2008, Fall 2008, and Summer 2011 monitoring events. These average values are listed in Table 3.

It should be noted that the vapor profile for nested vapor well VW-18 shows high methane concentrations across all three sample events. This coupled with the low vapor diffusion coefficients (Figure 3) and relatively thin vadose zone (only 20-feet at this location) could be an indication that diffusion of oxygen into the subsurface is rate limited. The flux plane for this well was set close to the smear zone (15 feet below ground surface) to incorporate the low vapor diffusion coefficients and limit the potential for overestimating the flux via a small gradient interval. However, given the persistence of methane throughout the vadose zone it is also possible that shallow sources associated with historical releases from the process areas in this portion of the refinery may be contributing to volatile hydrocarbon and methane concentrations. If this is true, then the estimates of NSZD within this control volume over-predict smear zone losses. Regardless, the NSZD estimates for this well are expected to be a reasonable estimate of hydrocarbon mass loss and additional evaluation of alternate sources near this well will be considered as part of future estimates.

3.0 DATA EVALUATION

Depletion of the LNAPL smear zone is attributable to partitioning processes and subsequent biodegradation under natural conditions. For the saturated zone, the mechanism is partitioning of soluble hydrocarbons from LNAPL to groundwater, with subsequent consumption of the dissolved phase hydrocarbons by microbes. For the vapor phase, the mechanism is partitioning of volatile hydrocarbons to soil gas, with subsequent consumption of the vapor phase hydrocarbons by microbes. As described in the previous sections, NSZD estimates presented herein are based on averaging of the 2008 to 2011 routine monitoring data, to account for spatial and temporal variations in the input parameters.

3.1 SATURATED ZONE LOSSES

The rate of dissolved phase biodegradation in each control volume is dependent on the concentration of electron acceptors available for microorganisms. Some of these electron acceptors, such as oxygen, nitrate, and sulfate, can be measured in groundwater in oxidized form (i.e., prior to being oxidized). Other electron acceptors, such as manganese and iron, can be observed in reduced form (i.e., after being reduced). Methane is the reduction product when carbon dioxide is used as an electron acceptor (methanogenesis). From Johnson et al. (2006), dissolved phase biodegradation rates can be estimated using hydrogeochemical concentrations across the smear zone as follows:

$$R_{bio-sat\,(estimate)} = \begin{aligned} & WHq_U\{(S_O C_{O,U}) + (S_N C_{N,U}) + (S_S C_{S,U}) - (S_I C_{I,U}) - (S_{Mn} C_{Mn,U}) - (S_M C_{M,U})\} + \\ & WLq_R\{(S_O C_{O,R}) + (S_N C_{N,R}) + (S_S C_{S,R}) - (S_I C_{I,R}) - (S_{Mn} C_{Mn,R}) - (S_M C_{M,R})\} - \\ & WHq_D\{(S_O C_{O,D}) + (S_N C_{N,D}) + (S_S C_{S,D}) - (S_I C_{I,D}) - (S_{Mn} C_{Mn,D}) - (S_M C_{M,D})\} \end{aligned}$$

Where:

$R_{bio-sat}$ (estimate)	= biodegradation mass loss rate (kg/s)
W	= width of smear zone (ft)
L	= length of source zone (ft)
H	= height of source zone (ft)
q_U	= specific discharge, up-gradient (ft/day)
q_R	= specific discharge, rainwater infiltrate (ft/day)
q_D	= specific discharge, down-gradient (ft/day)
C_U	= dissolved concentrations at the up-gradient source zone control volume boundary (kg/ft^3-H_2O)
C_R	= dissolved concentrations in rainwater infiltrate (kg/ft^3-H_2O)
C_D	= dissolved concentrations at the down-gradient control volume boundary (kg/ft^3-H_2O)
S	= stoichiometric coefficients for total petroleum hydrocarbons (kg-TPH/kg-constituent)

Subscripts for hydrogeochemical constituents:

O	= oxygen
N	= nitrogen
I	= iron
Mn	= manganese
M	= methane
S	= sulfate

Together, the three main terms in the equation quantify dissolved phase biodegradation in a control volume. The first term (with U subscripts) quantifies the flux of hydrogeochemicals into the control volume from up-gradient, the second term (with R subscripts) quantifies the flux of hydrogeochemicals into the upper plane of the smear zone through rainwater infiltrate, and the third term (with D subscripts) quantifies hydrogeochemical flux down-gradient of each control volume.

The biodegradation rates are calculated as mass loss rates of total petroleum hydrocarbons. It is not possible to estimate biodegradation rates for individual constituents using the method described herein because the stoichiometric coefficients for each electron acceptor are not constituent specific. The NSZD estimates for the saturated zone are reported as total petroleum hydrocarbons removed from the smear zone in pounds per year (lb/yr), and are presented on Table 4 as well as Figure 5. Figure 5A shows the NSZD rate by control volume, and Figures 5B, 5C, and 5D segregate these rates into specific redox pathways within the saturated zone.

The estimated NSZD rate in the saturated zone ranges from approximately 1,700 lb/yr in control volume CV18 to approximately 5,300 lb/yr in control volume CV93, with a total of approximately 15,000 lb/yr across the entire smear zone. The two primary pathways for NSZD within the saturated zone are methanogenesis and sulfate reduction. This indicates that biodegradation of smear zone hydrocarbons in the saturated zone largely occurs under anaerobic conditions. This is to be expected for a LNAPL smear zone with a high oxidant demand that would quickly use the available oxygen. On a control volume by control volume basis, methanogenesis is relatively steady, but sulfate reduction is an important process in control volumes CV20 and CV93. This increase in sulfate reduction in the two down-gradient control volumes is due primarily to the presence of this electron acceptor in groundwater that originates from the Buried Valley Aquifer-bedrock contact in Hooven. When this water enters the smear zone, it provides sulfate-rich groundwater and increases the rate of biodegradation in the saturated zone. Put another way, the higher estimated NSZD rates in control volumes CV20 and CV93 are due primarily to the input of sulfate to the smear zone from the Hooven.

Other electron acceptors including oxygen, nitrate, manganese, and iron provide a minor contribution to the NSZD rates, at less than 10% of the total for all four electron acceptors combined. The highest NSZD rates for these electron acceptors are observed in control volume CV93, where the dissolved phase plume is generally reduced to concentrations below the remedial goals (i.e. United States Environmental Protection Agency Maximum Contaminant Levels). While these electron acceptors may play a relatively minor role in the total mass loss from the smear zone, they are important in maintaining a stable dissolved phase groundwater plume down-gradient of the smear zone beneath the Southwest Quad.

3.2 VADOSE ZONE LOSSES

Petroleum hydrocarbons within the smear zone will volatilize and migrate upward via diffusion. As these volatile constituents diffuse upward, they are consumed aerobically and an aerobically by microorganisms in the vadose zone, resulting in attenuation of petroleum hydrocarbons. The rate of vapor attenuation is proportional to the concentration gradients of petroleum hydrocarbons, oxygen, and methane in soil gas, as well as the effective vapor diffusion coefficient for each of these gases. From Johnson et al. (2006):

$$R_{vapor} = \iint_{WL} \left\{ -D_{HC}\left(\frac{\partial C_{HC}}{\partial z}\right) - S_{CH4}D_{CH4}\left(\frac{\partial C_{CH4}}{\partial z}\right) + S_O D_O\left(\frac{\partial C_O}{\partial z}\right) \right\} dxdy$$

where:

R_{vapor} = mass loss rate resulting from vapor transport-associated processes (kg/day)
D_{HC} = effective vapor diffusion coefficient for hydrocarbon vapors
D_{CH4} = effective vapor diffusion coefficient for methane
D_O = effective vapor diffusion coefficient for oxygen
S_{CH4} = stoichiometric coefficient for anaerobic conversion of hydrocarbons to methane
S_O = stoichiometric coefficient for aerobic oxidation of hydrocarbons and methane
dC_{HC}/dz = gradient of hydrocarbon vapors with depth
dC_{CH4}/dz = gradient of methane with depth
dC_O/dz = gradient of oxygen with depth

The three main terms in the equation above are based on the different transport processes associated with vapor attenuation. The first term (with HC subscripts) quantifies the flux of volatile petroleum hydrocarbons from the smear zone. The second term (with CH4 subscripts) quantifies the anaerobic biodegradation of hydrocarbons, which produces methane. The third term (with O subscripts) quantifies the aerobic biodegradation of hydrocarbons and methane, which consumes oxygen.

Johnson et al. (2006) simplify the equation above to only include the third term (with the O subscripts) for situations where a control plane can be placed just above the depth where methane, oxygen, and other hydrocarbon concentrations go to zero. However, this situation is not manifested for many of the vapor profiles at the Chevron Cincinnati Facility. At most locations, at least two, and sometimes three of these gases are present at all depths. Therefore, the equation cannot be simplified to remove the first two terms in the equation.

The NSZD estimates for the vadose zone are presented on Figure 6 and summarized on Table 4. Figure 6A shows the estimated NSZD rate by control volume and Figure 6B segregates these rates into the aerobic and anaerobic reduction pathways. The estimated NSZD rate in the vadose zone ranges from approximately 2,000 lb/yr in control volume CV93 to approximately 42,400 lb/yr in control volume CV18. The total estimated NSZD rate in the vadose zone for all four control volumes is approximately 82,100 lb/yr.

Each of these control volumes have approximately equal surface areas (i.e., the same size flux planes for vapor transport); therefore, any differences in mass loss rates by control volume can be attributed largely to the source strength. Volatile petroleum hydrocarbon concentrations measured throughout the vadose zone within control volume CV18 are much higher than those observed in control volume CV93, consistent with the higher source zone concentrations measured in control volume CV18. This may be related to the location of each control volume within the smear zone. The majority of historical refining and waste disposal activities were performed in control volume CV18 while much of the land in control volume CV93 is located off-site and was only recently developed for commercial purposes In addition, nested well VW-93 is located within the zone of influence of the HSVE and high-grade systems, and the smear zone has been depleted over the past 25 years via engineered recovery. Corrective measures focused in control volume CV18 began in 2010. The higher NSZD rates within the vadose zone in control volume CV18 occurs despite the thinner smear zone and lower rates of diffusion within the finer grained deposits.

The relative importance of aerobic versus anaerobic biodegradation in the vadose zone also varies by control volume. Anaerobic biodegradation (i.e., methanogenesis) is the dominant biodegradation pathway in control volume CV18. In control volumes CV21 and CV20, mass losses from aerobic and anaerobic biodegradation processes are similar in magnitude. This is related to the vapor profiles (Figure 4) that show a zone of elevated methane near the smear zone (anaerobic biodegradation) and higher oxygen concentrations near the ground surface (aerobic biodegradation). Note that the stoichiometric conversion coefficient used in these estimates accounts for both destruction of methane and petroleum hydrocarbons to avoid over-estimating vapor phase losses. In control volume CV93, aerobic degradation is the dominant attenuation process within the vadose zone.

3.3 NSZD SUMMARY

Figure 7 compares estimated saturated zone and vadose zone NSZD rates for each control volume. In the two up-gradient control volumes (CV21 and C18), vadose zone NSZD rates are far greater than saturated zone loss rates. This can be attributed in part to limited saturated zone electron acceptor supply within the saturated zone coupled with high vapor fluxes attributed to higher source zone concentrations. Over time it is expected that mass loss rates in control volumes CV21 and CV18 will become more similar in chemical composition to the down-gradient control volumes as additional mass is lost via engineered recovery and natural attenuation processes.

Estimated vadose zone NSZD rates in control volumes CV20 and CV93 are low relative to the two up-gradient control volumes, so much so that in control volume CV93 the mass loss rates in the saturated zone are approximately twice that measured in the vadose zone. As previously described, the relatively high magnitude of saturated zone losses results from an influx of sulfate with recharge water entering the smear zone from Hooven. While overall the estimated NSZD rates in control volumes CV20 and CV93 are lower than the up-gradient control volumes, the hydrocarbon losses are important in maintaining a stable dissolved phase plume at the smear zone limits beneath the Southwest Quad.

In summary, the estimated NSZD rates presented herein provide a strong line of evidence that natural attenuation is acting to remove hydrocarbons from the LNAPL smear zone. The NSZD rates indicate that hydrocarbon losses from both the saturated zone and vadose zone are important, and that the relative importance of each of these varies for different portions of the smear zone. These NSZD processes are expected to continue into the future, with "core" portions of the smear zone becoming similar to those currently observed at the smear zone limits. Continued monitoring will track these changes to the smear zone, and will identify transitions in NSZD rates and mechanisms (e.g., aerobic versus anaerobic biodegradation) over time.

One of the secondary criteria for identifying when high-grade operations have reached a productive end point is when LNAPL recovered via pumping during a high-grade season (defined as groundwater elevations remaining below trigger elevations for two or more months) becomes less than that lost via natural attenuation mechanisms over that year. During four of the first five years of the final corrective measures implementation for groundwater, engineered recovery rates exceeded the NSZD depletion rates. During 2008, the high-grade system was not operated and therefore there were no losses via engineered recovery. The rate of recovery of LNAPL via high-grade pumping will decrease over time as the recoverable fraction of LNAPL is removed from the lower portions of the smear zone during each subsequent high-grade event and ultimately NSZD rates will exceed the engineered rates of recovery.

4.0 REFERENCES

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TABLES

TABLE 1. SUMMARY OF INPUT PARAMETERS FOR NSZD CALCULATIONS
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Input Parameter	Units	Value	Source
Analytical Input Parameters			
MNA Parameters - Groundwater	mg/L	CV specific	2008 - 2011 semiannual groundwater sampling results
Fixed Gas and Total Volatile Petroleum Hydrocarbons in Vapor	$\mu g/m^3$	CV specific	Spring 2008, Fall 2008, and Summer 2011 nested vapor well sampling results
Hydrogeology Input Parameters			
Hydraulic Conductivity (K)	ft/day	CV specific	Previous site hydrogeology studies
Hydraulic Gradient (i_h)	ft/ft	CV specific	Site gauging data for 2008 - 2011, with data corresponding to high grade pumping filtered out
Rainwater infiltration	ft/day	Site-specific	Previous site and regional hydrogeology studies
Width of Source Zone (W_{source})	ft	CV specific	Historical ROST and soil boring data
Saturated Height of Source Zone (H_{source})	ft	CV specific	Historical ROST and soil boring data, along with site gauging data
Length of Source Zone (L_{source})	ft	CV specific	Historical ROST and soil boring data
Vapor Diffusion Coefficient (VDC)	m^2/sec	CV specific	Spring 2008, Fall 2008, Spring 2009 and Summer 2011 helium tracer testing at nested vapor wells

Notes:
CV - Control Volume
ft - feet
ft/day - feet per day
ft/ft - feet per feet
m^2/sec - meter squared per second
$\mu g/m^3$ - microgram per cubic meter
mg/l - milligram per liter

TABLE 2. SATURATED ZONE INPUT PARAMETERS
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Sampling Location	Oxygen Concentration C_O (mg/L)	Nitrate Concentration C_N (mg/L)	Sulfate Concentration C_S (mg/L)	Iron (II) Concentration C_I (mg/L)	Manganese (II) Concentration C_{Mn} (mg/L)	Methane Concentration C_M (mg/L)
Control Volume 21						
Upgradient Groundwater	0.03	0.66	57.00	0.012	0.224	0.005[a]
Downgradient Groundwater	0.00	0.02[a]	2.10[b]	10.46[c]	0.402[c]	14.00[b]
Recharge Water	3.80[c]	0.125[a]	0.75[a]	1.21[e]	0.157	0.74
Control Volume 18						
Upgradient Groundwater	0.00	0.02[a]	2.10[b]	10.46[c]	0.402[c]	14.00[b]
Downgradient Groundwater	0.05	0.02[a]	5.91[c]	15.62[c,d]	0.263[c]	15.00[b]
Recharge Water	2.40[c]	0.125[a]	0.75[a]	4.89[c,e]	0.260	2.40
Control Volume 20						
Upgradient CV Groundwater	0.05	0.02[a]	5.91[c]	15.62[c,d]	0.263[c]	15.00[b]
Upgradient Hooven Groundwater	3.53	5.75	61.57[c]	0.025	0.001	0.011
Downgradient Groundwater	0.00	0.02[a]	10.43[c,d]	14.00[c,d]	0.635[b]	10.62[c]
Recharge Water	2.60	3.74[c]	111.3[c]	0.59[c,e]	0.204[c,d]	0.005[a]
Control Volume 93						
Upgradient Groundwater	0.00	0.02[a]	10.43[c,d]	14.00[c,d]	0.635[b]	10.62[c]
Upgradient Hooven Groundwater	3.53	7.90	83.20	0.010	0.001	0.005[a]
Downgradient Groundwater	1.39	0.02[a]	11.02[c,d]	9.06[c,d]	0.892[c]	7.18[c]
Recharge Water	6.00	14.6	83.50[c]	0.081[e]	0.003	0.005[a]

Notes:

mg/L - milligram per liter

Values listed above are the mean value of measurements taken between 2008 and 2011, unless otherwise noted:

[a] - if >60% of measurements were non-detects, the input value is half the detection limit

[b] - median of all measurements at all wells in control volume (used to reject outliers, see d)

[c] - mean of all measurements at all wells in control volume (half detection limit used for non-detects)

[d] - rejected one or more outliers (data value outside the interquartile range by more than 1.5 times the value of the range)

[e] - iron concentrations in recharge water are Total Iron, not Iron (II)

TABLE 3. VADOSE ZONE INPUT PARAMETERS
CHEVRON CINCINNATI FACILITY, HOOVEN OHIO

VW-18 (15 ft-bgs)

ID	Spring 2008 (%)	Summer 2008 (%)	Fall 2011 (%)
O2	1.6	1.2	1.2
CH4	21	37	32
TVPH	NA	NA	NA

Spring 2008 (µg/m^3)	Summer 2008 (µg/m^3)	Fall 2011 (µg/m^3)	Average (µg/m^3)
21,333,333	16,000,000	16,000,000	17,777,778
140,000,000	246,666,667	213,333,333	200,000,000
6,219,500	8,644,000	9,754,500	8,206,000

VW-20 (25 ft-bgs)

ID	Spring 2008 (%)	Summer 2008 (%)	Fall 2011 (%)
O2	5.8	1.6	1.5
CH4	0.00125	6.7	11
TVPH	NA	NA	NA

Spring 2008 (µg/m^3)	Summer 2008 (µg/m^3)	Fall 2011 (µg/m^3)	Average (µg/m^3)
77,333,333	21,333,333	20,000,000	39,555,556
8,333	44,666,667	73,333,333	39,336,111
6,466	1,996,450	2,108,600	1,370,505

VW-21 (15 ft-bgs)

ID	Spring 2008 (%)	Summer 2008 (%)	Fall 2011 (%)
O2	1.5	1.4	1.5
CH4	4.4	10	8.1
TVPH	NA	NA	NA

Spring 2008 (µg/m^3)	Summer 2008 (µg/m^3)	Fall 2011 (µg/m^3)	Average (µg/m^3)
20,000,000	18,666,667	20,000,000	19,555,556
29,333,333	66,666,667	54,000,000	50,000,000
4,361,000	4,888,850	--	4,624,925

VW-93 (50 ft-bgs)

ID	Spring 2008 (%)	Summer 2008 (%)	Fall 2011 (%)
O2	12	10	18
CH4	0.000125	0.000115	0.000115
TVPH	NA	NA	NA

Spring 2008 (µg/m^3)	Summer 2008 (µg/m^3)	Fall 2011 (µg/m^3)	Average (µg/m^3)
160,000,000	133,333,333	240,000,000	177,777,778
833	767	767	789
109	86	84	93

Notes:
O2 - oxygen
CH4 - methane
CO2 - carbon dioxide
TVPH - total volatile petroleum hydrocarbons
ft-bgs - feet below ground surface
µg/m^3 - micrograms per cubic meter

TABLE 4. ESTIMATED NSZD RATES FOR SATURATED ZONE AND VADOSE ZONE
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

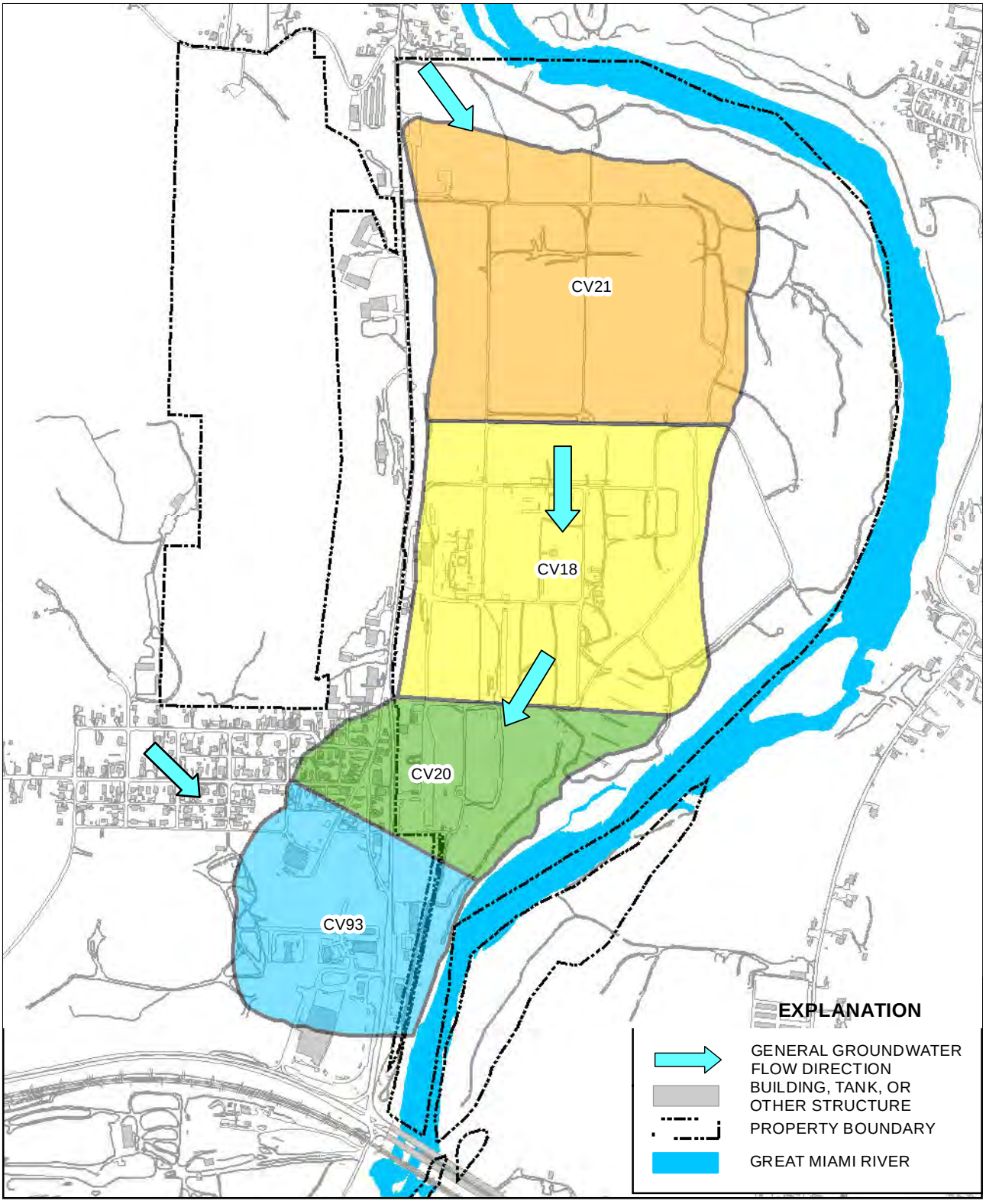
Control Volume	Saturated Zone Estimated Annual TPH Loss (lb/yr)	Vadose Zone Estimated Annual TPH Loss (lb/yr)
CV21	2,806	23,510
CV18	1,708	42,403
CV20	5,179	14,147
CV93	5,270	2,024
Total	14,963	82,084

Notes:

lb/yr - pounds per year

TPH - total petroleum hydrocarbons

FIGURES



N

0 1,000'

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FIGURE 1

SMEAR ZONE CONTROL VOLUMES FOR NATURAL SOURCE ZONE DEPLETION ESTIMATES

CHEVRON CINCINNATI FACILITY
HOOVEN, OHIO

Drawn By: BLM	Checked By: PM	Scale: 1" = 1000'	Date: 09/19/11	File: 201110_CV.mxd

FIGURE 2. DISSOLVED PHASE ELECTRON ACCEPTORS AND BYPRODUCTS
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

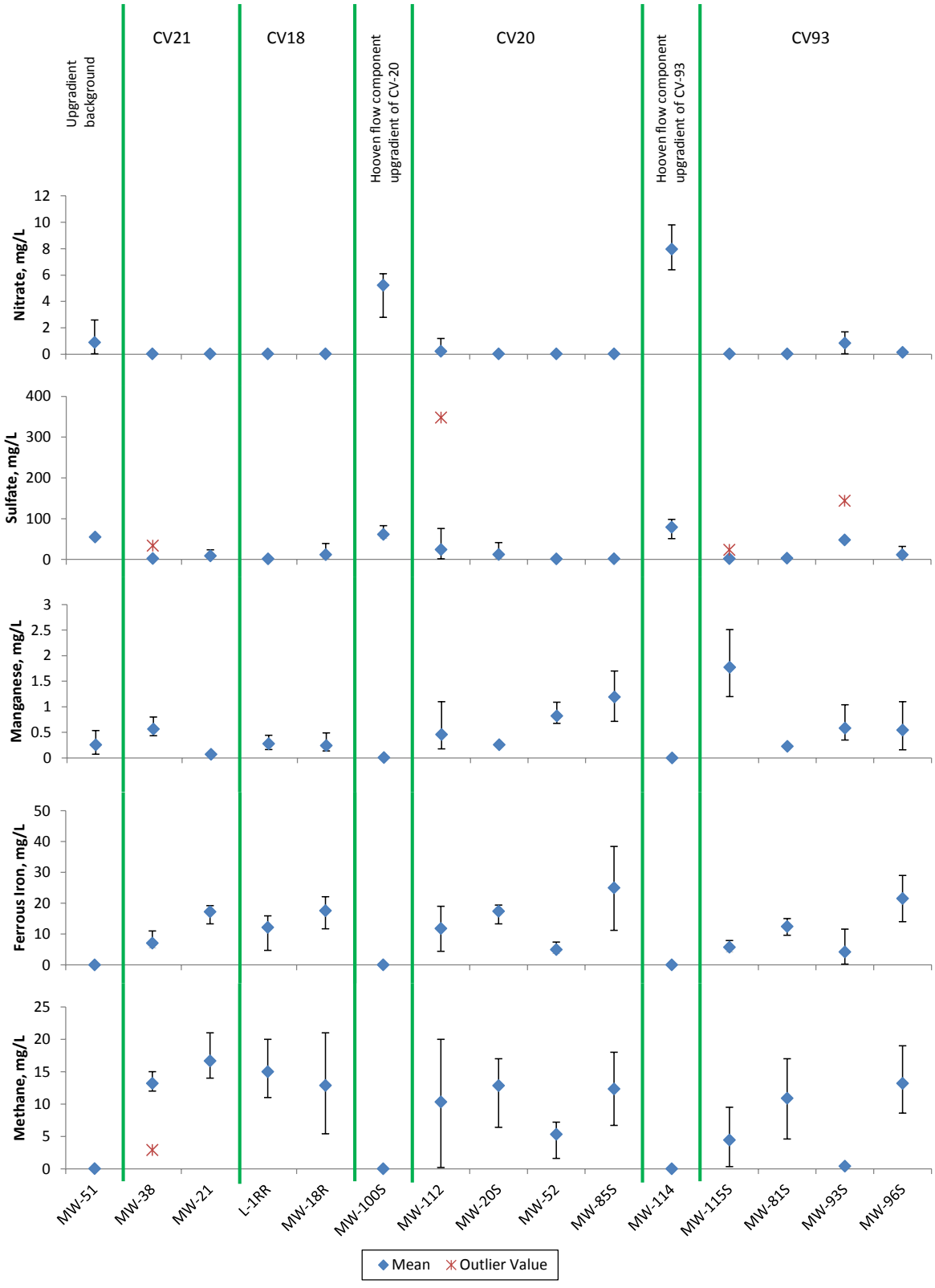
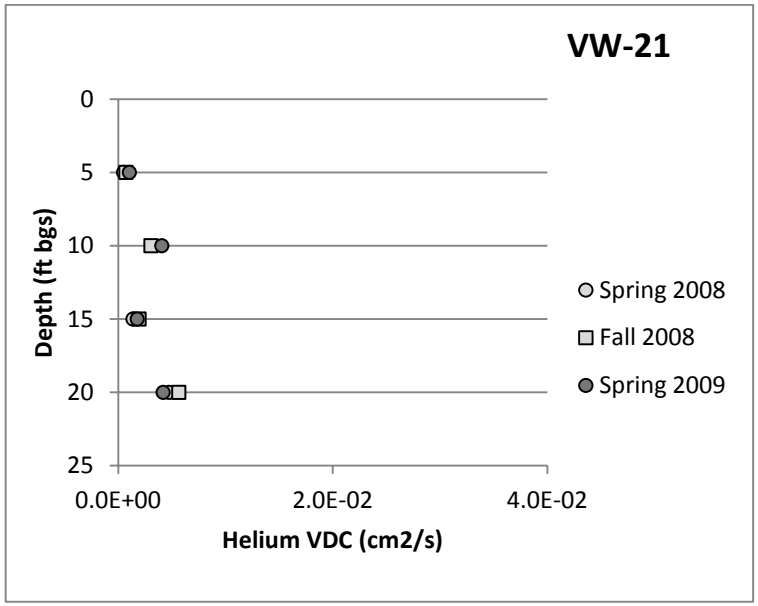
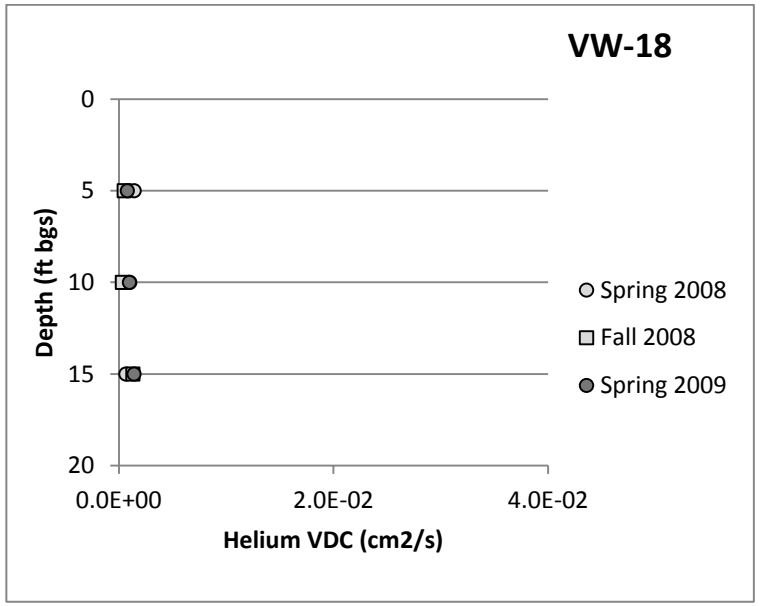
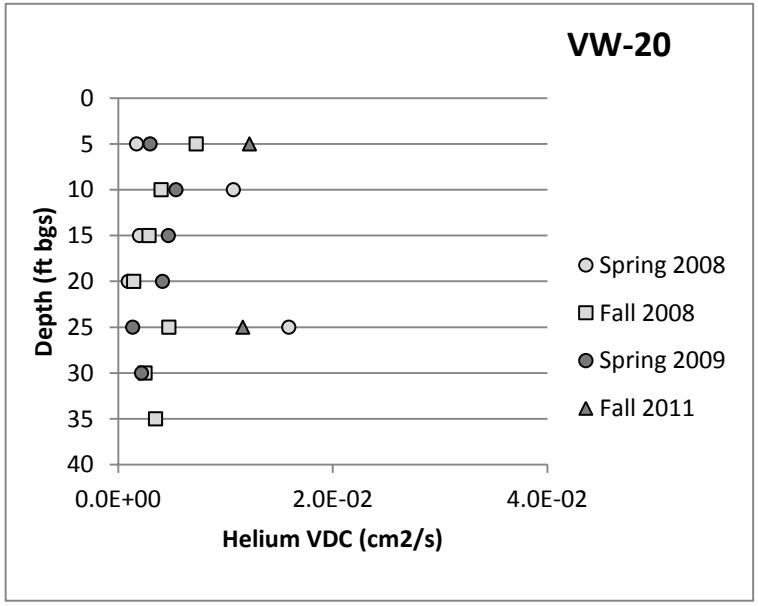


FIGURE 3. VAPOR DIFFUSION COEFFICIENTS MEASURED WITH HELIUM TRACER TESTING
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO







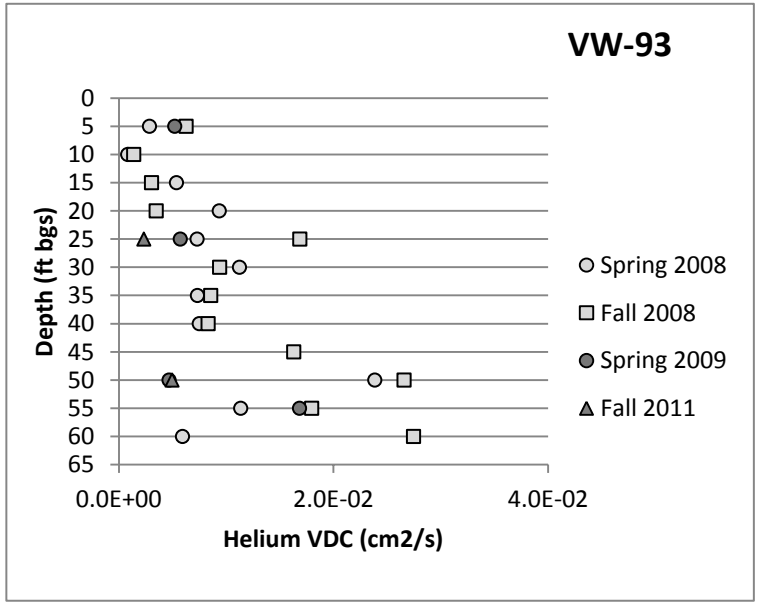


FIGURE 4. FIXED GAS PROFILES FOR NESTED VAPOR MONITORING WELLS
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

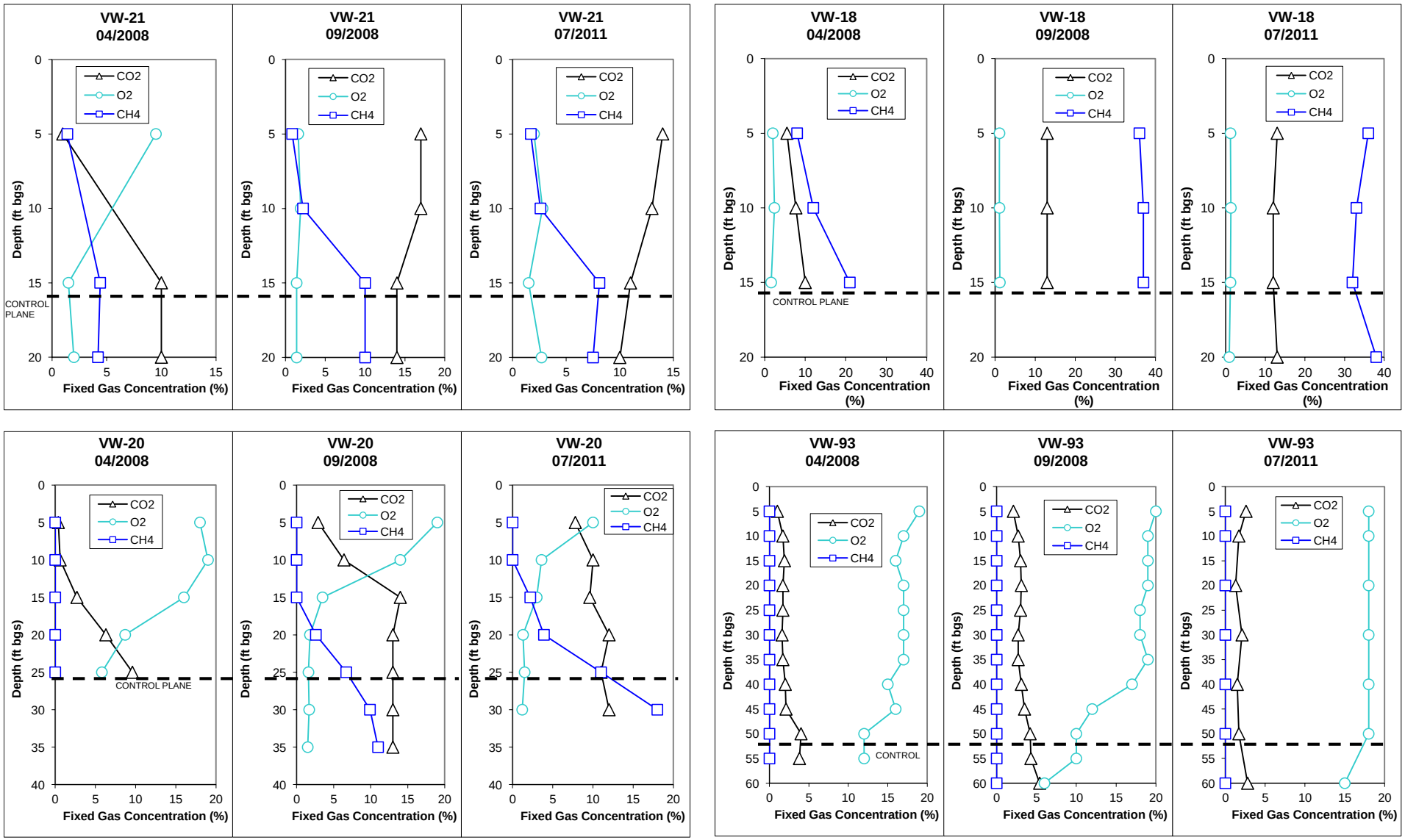
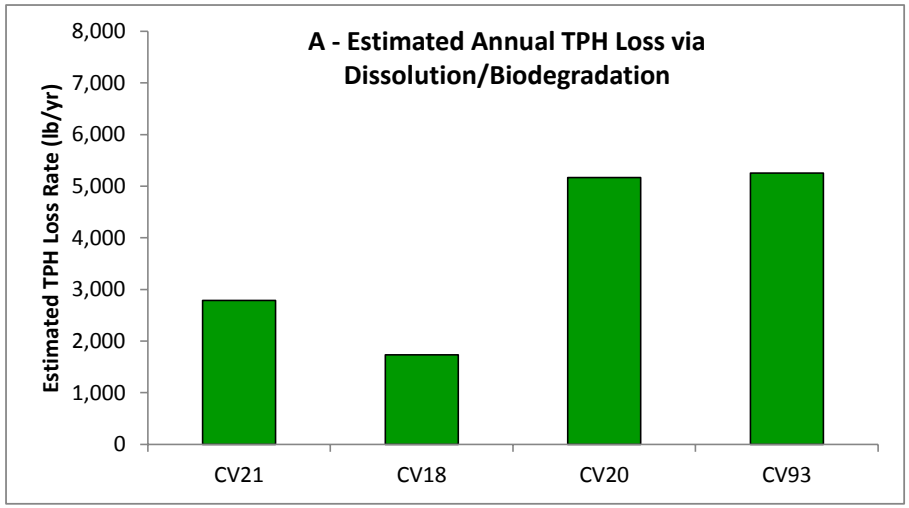
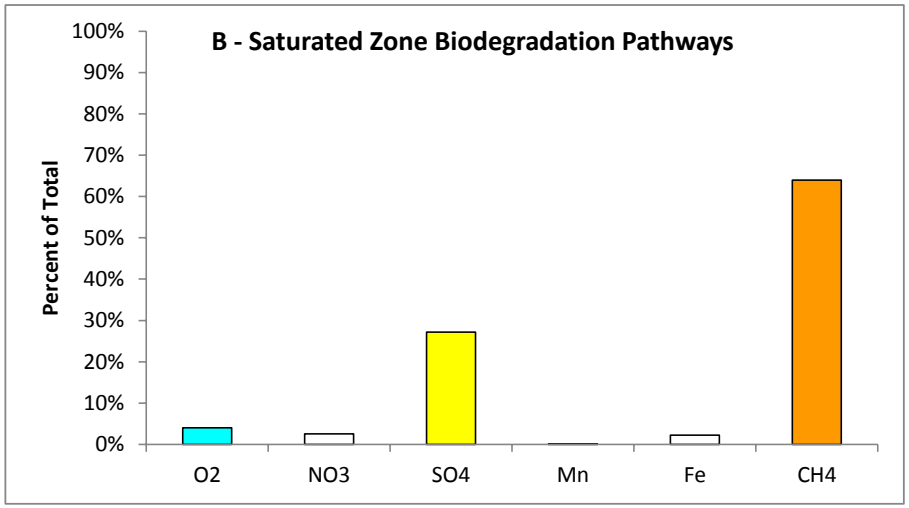
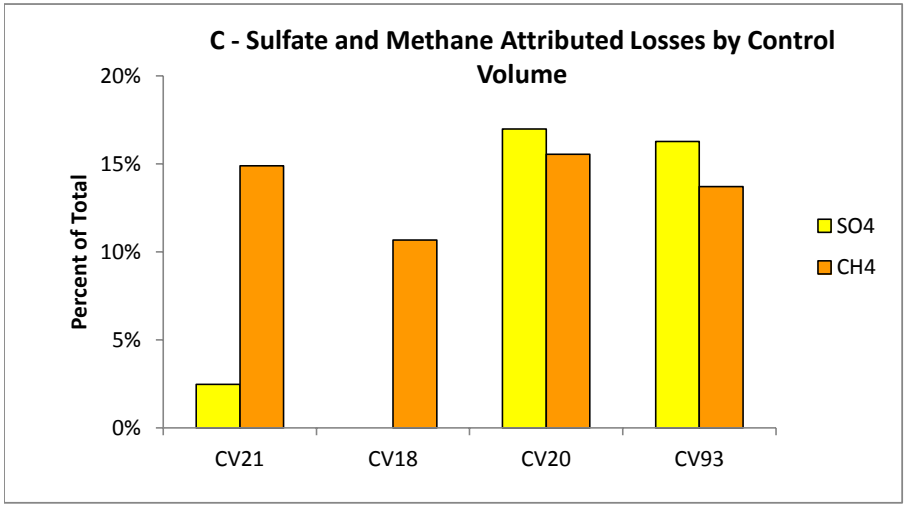
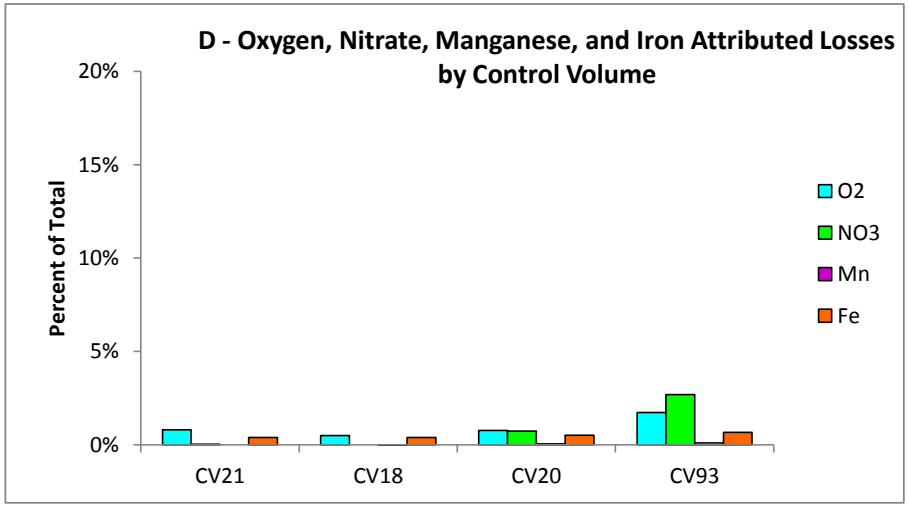


FIGURE 5. NSZD ESTIMATES FOR THE SATURATED ZONE
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



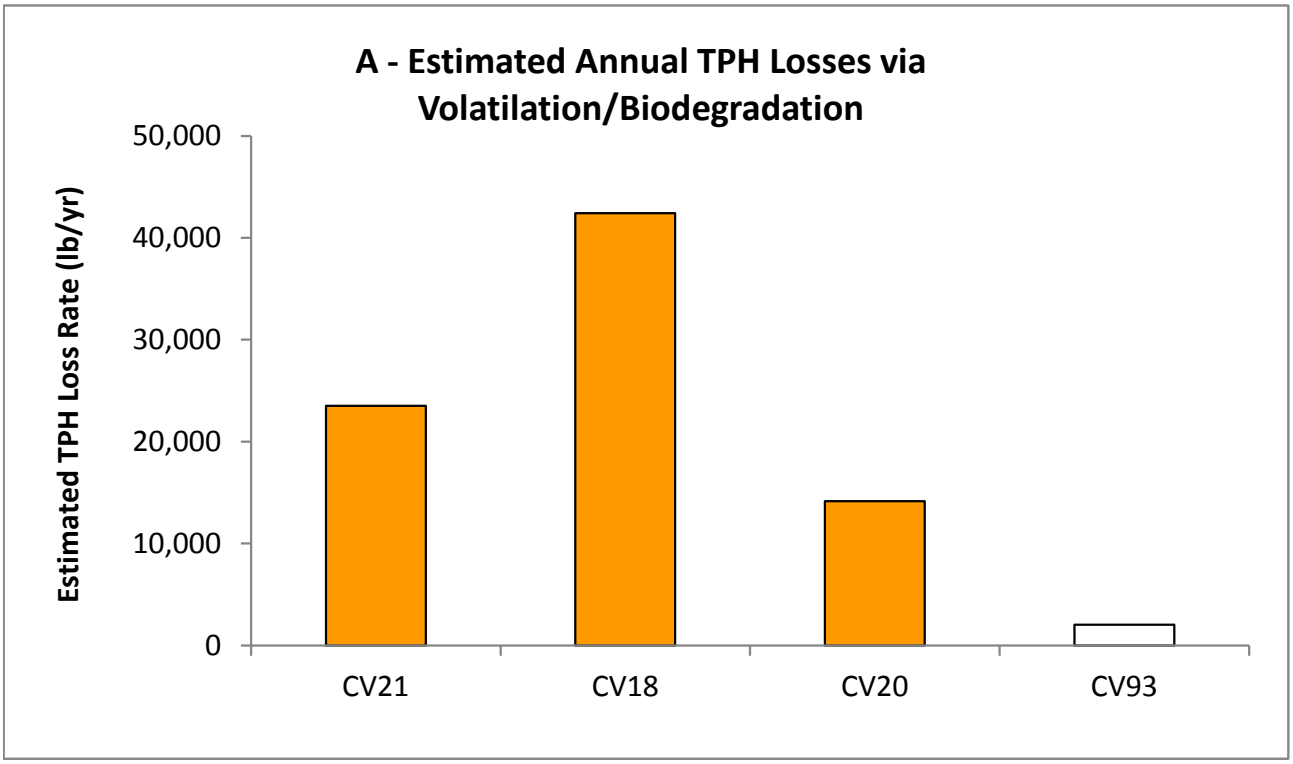






O2 - smear zone losses attributed to oxygen reduction (i.e., aerobic biodegradation)
NO3 - smear zone losses attributed to nitrate reduction
SO4 - smear zone losses attributed to sulfate reduction
Mn - smear zone losses attributed to manganese reduction
Fe - smear zone losses attributed to iron reduction
CH4 - smear zone losses attributed to methanogenesis

FIGURE 6. NSZD ESTIMATES FOR VADOSE ZONE
CHEVRON CINCINNATI FACILITY



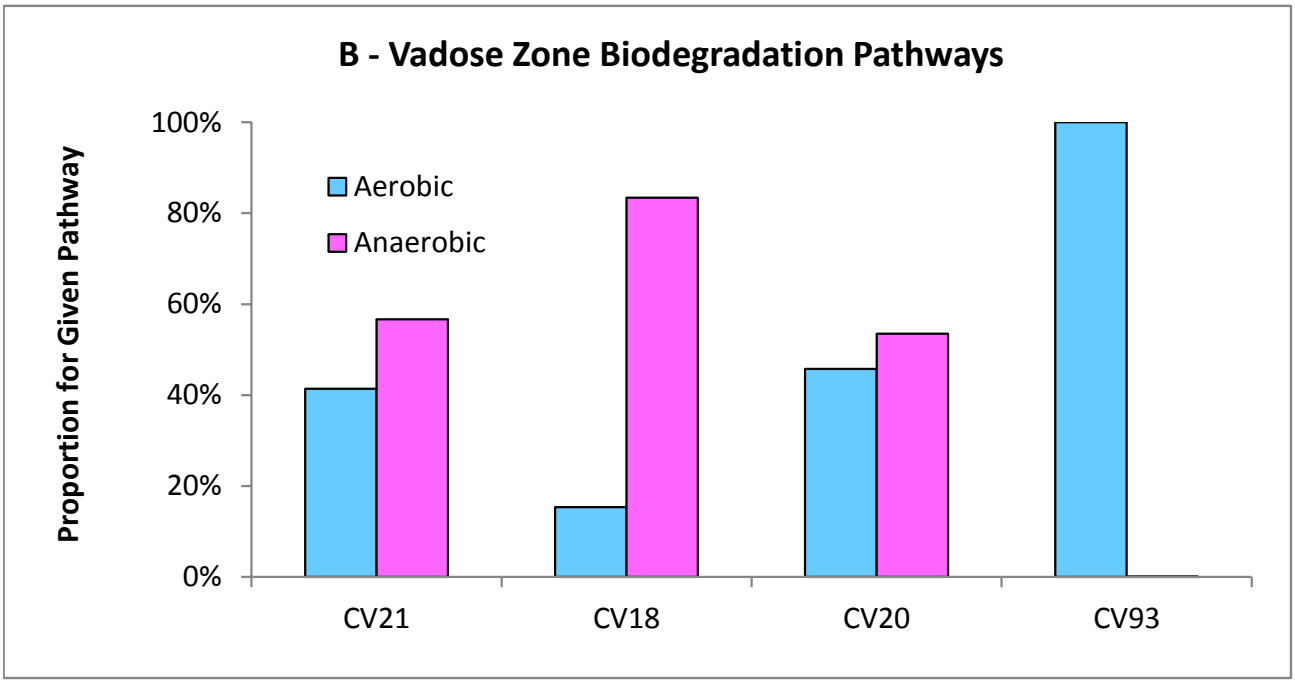
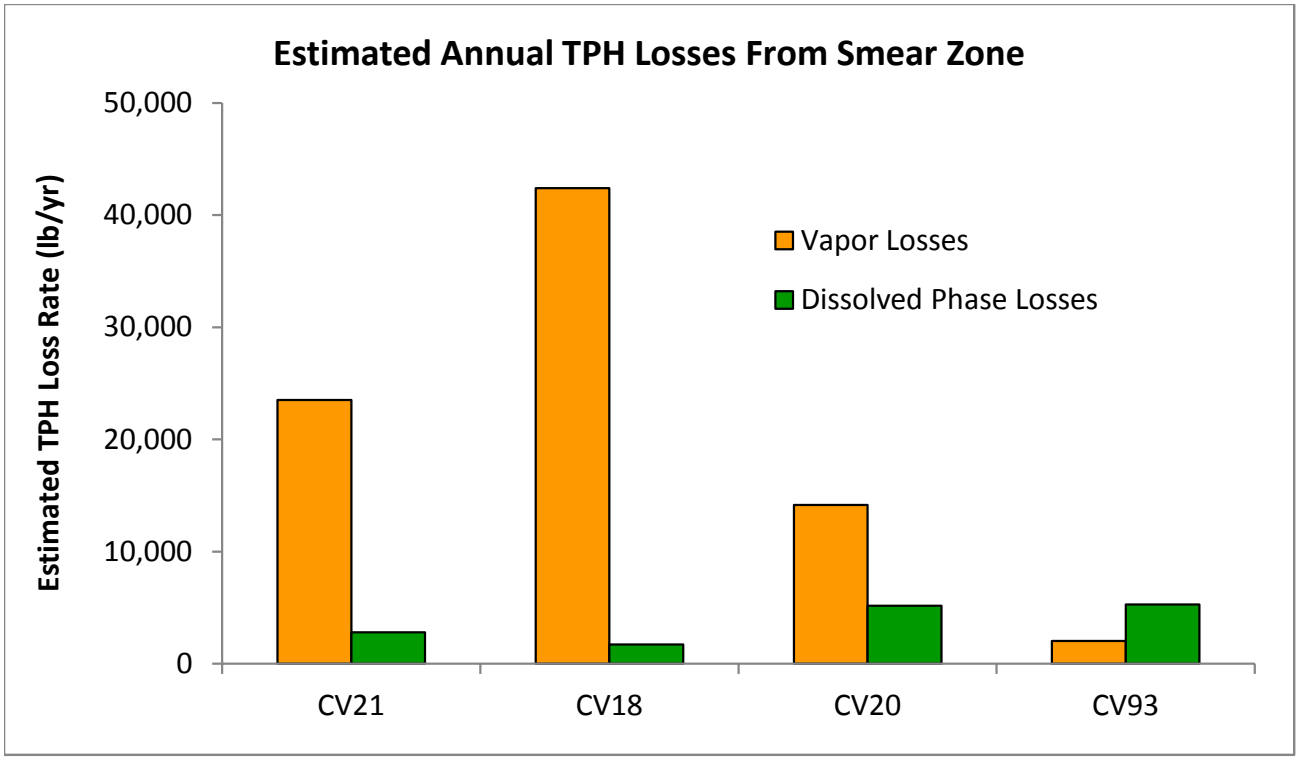


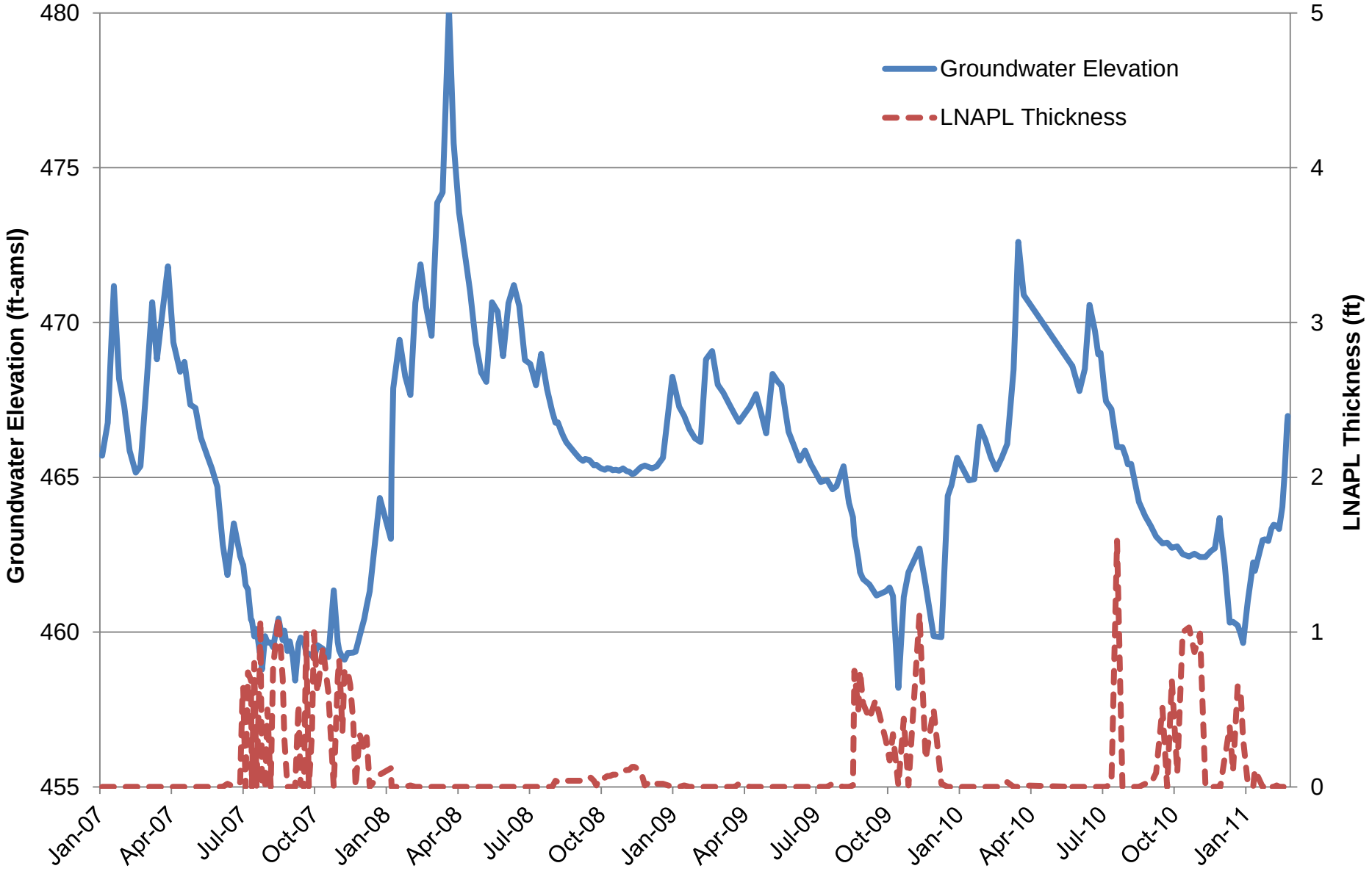
FIGURE 7. COMPARISON OF NSZD RATES FOR VADOSE ZONE AND SATURATED ZONE
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



APPENDIX C

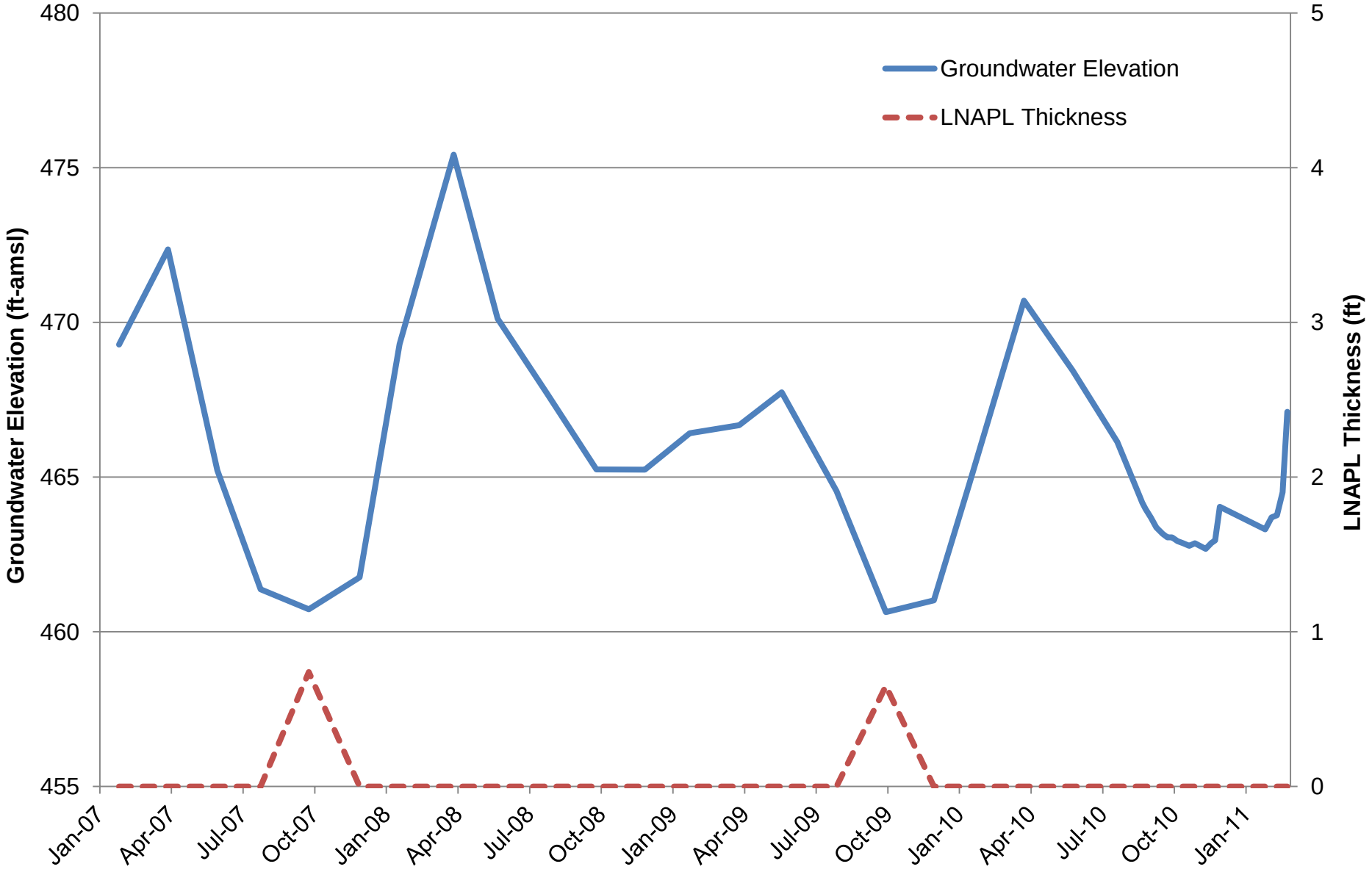
HYDROGRAPHS FOR HIGH-GRADE RECOVERY END-POINT EVALUATION

FIGURE C-1. MW-20S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



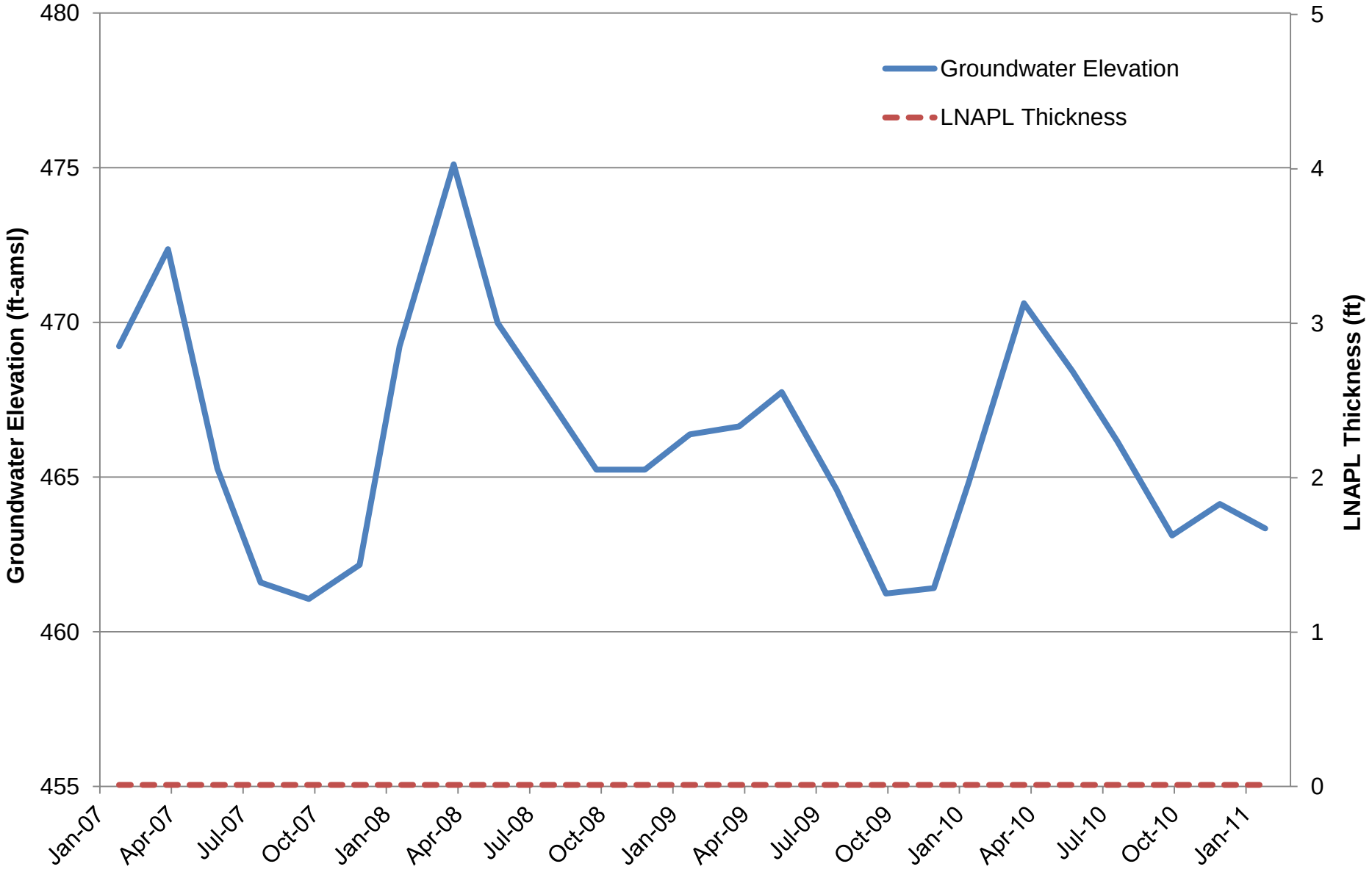
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-2. MW-24 HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



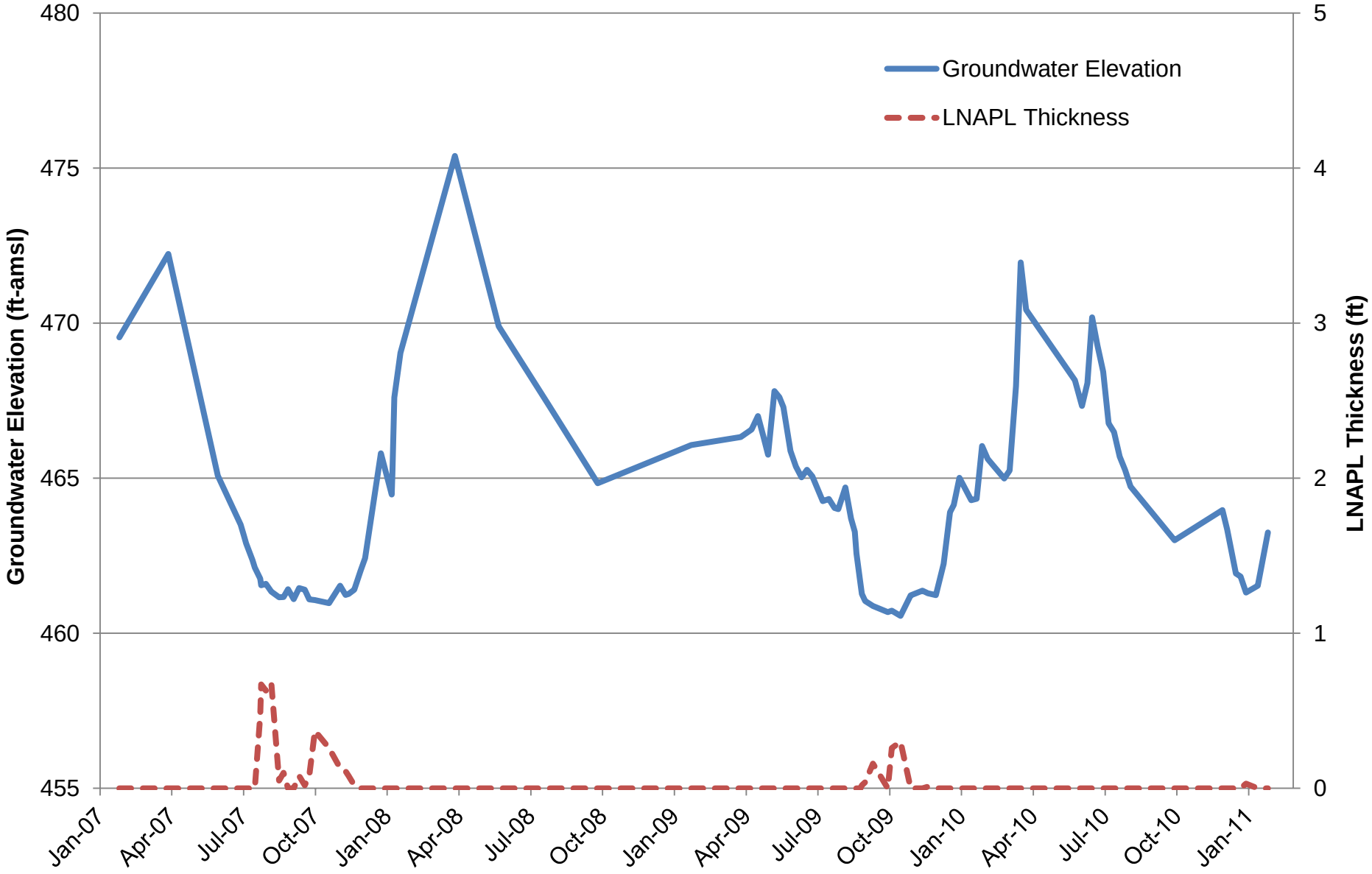
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-3. MW-52 HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



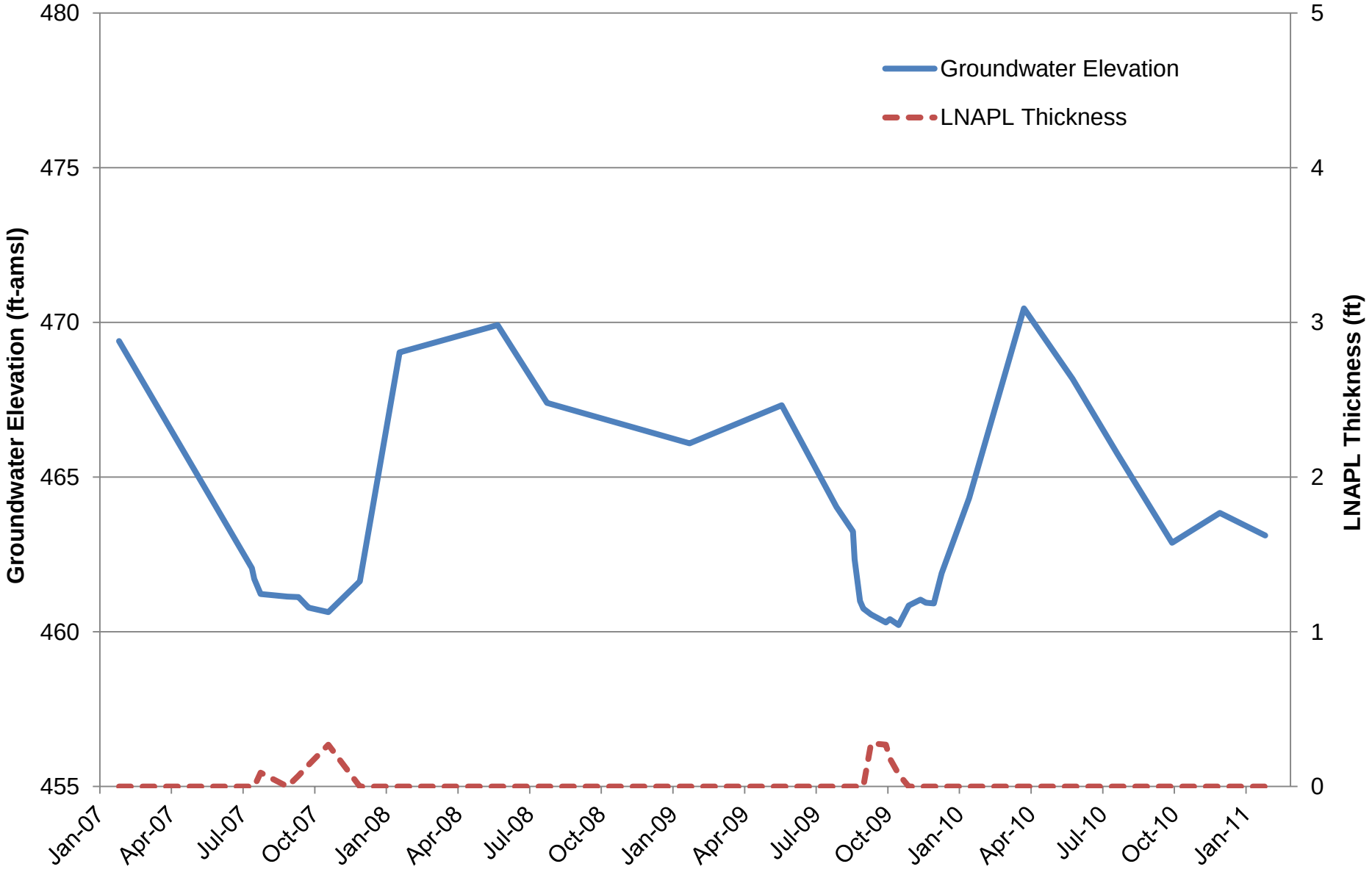
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-4. MW-81S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



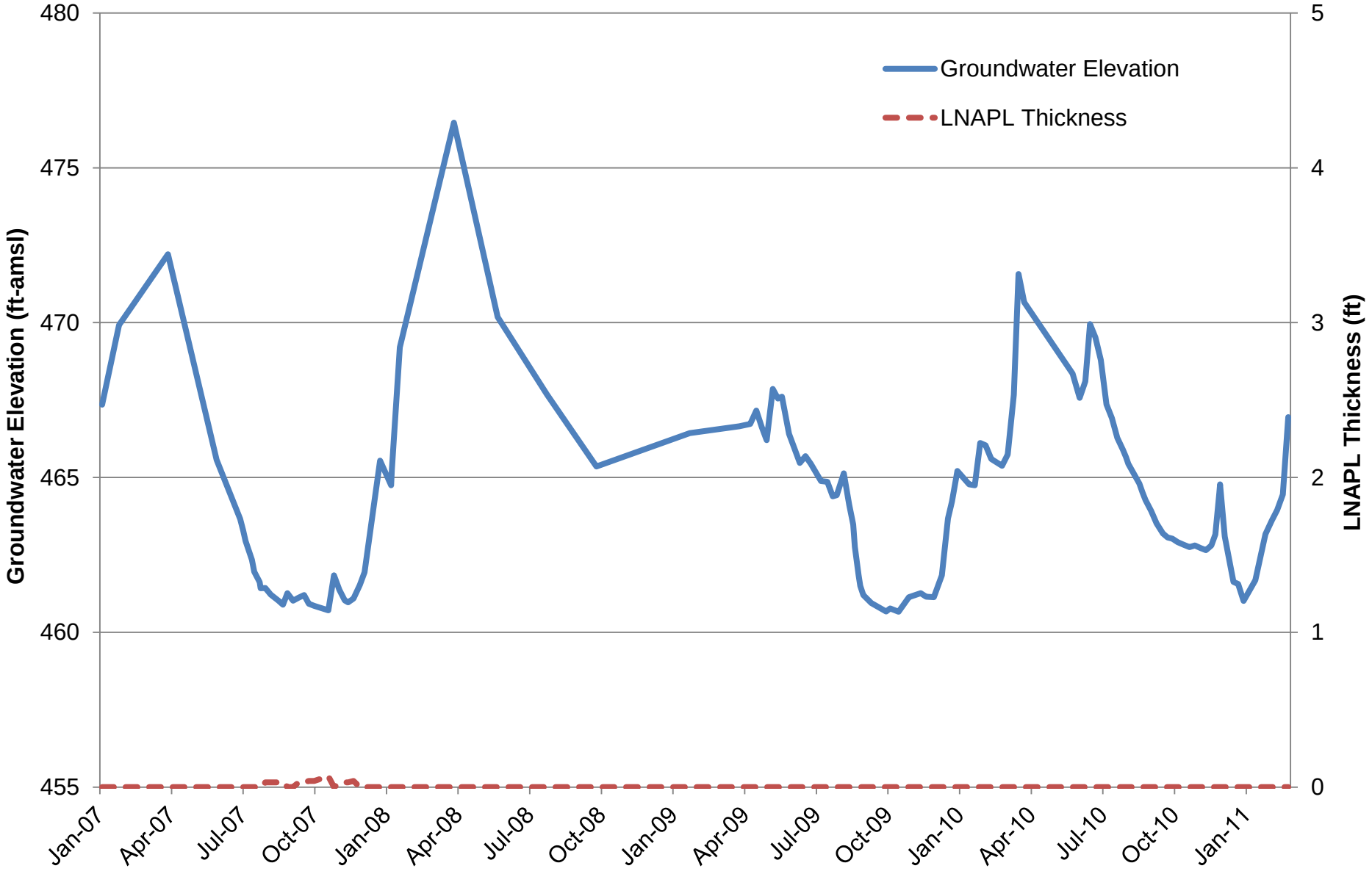
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-5. MW-92S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



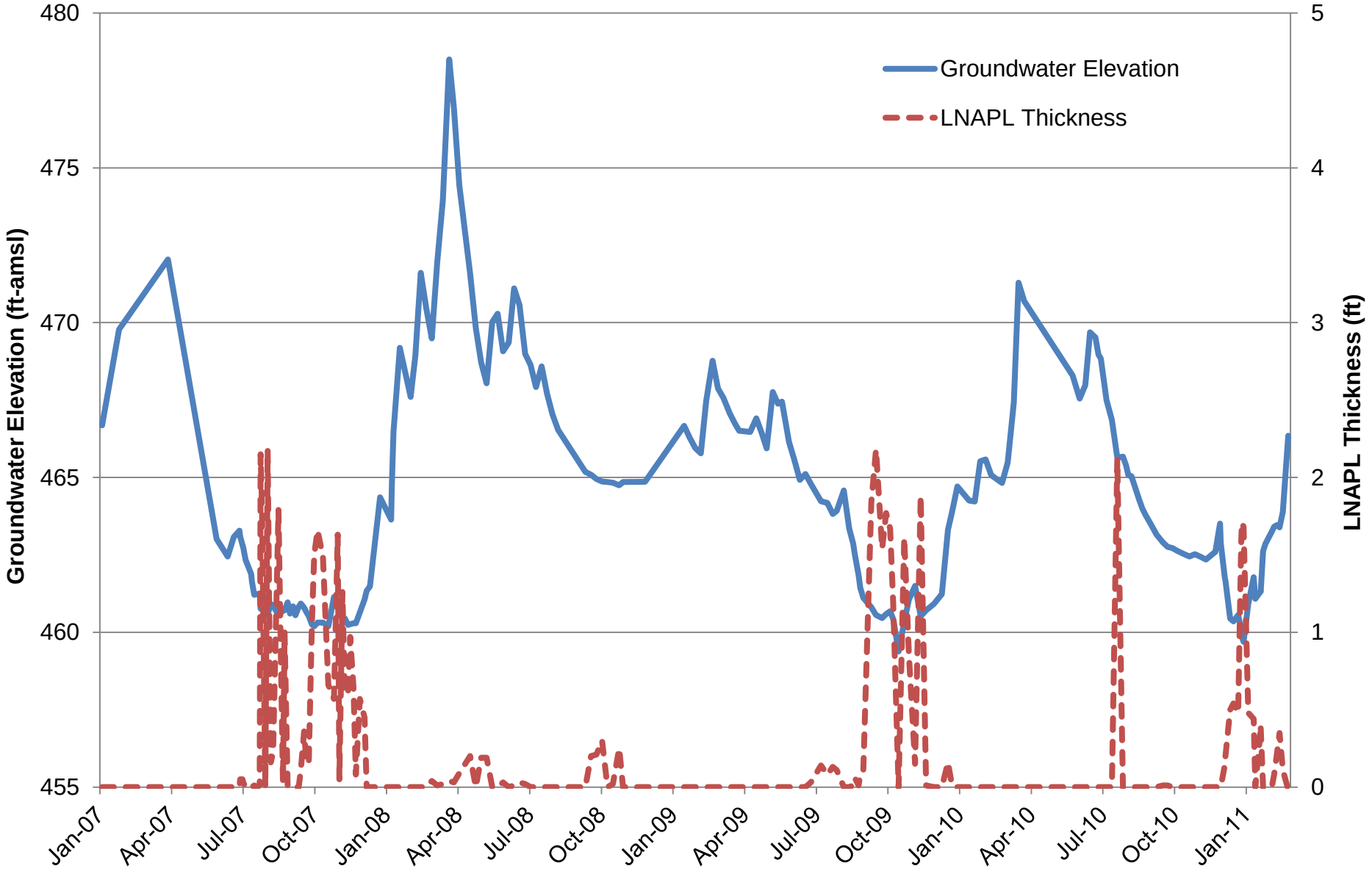
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-6. MW-93S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



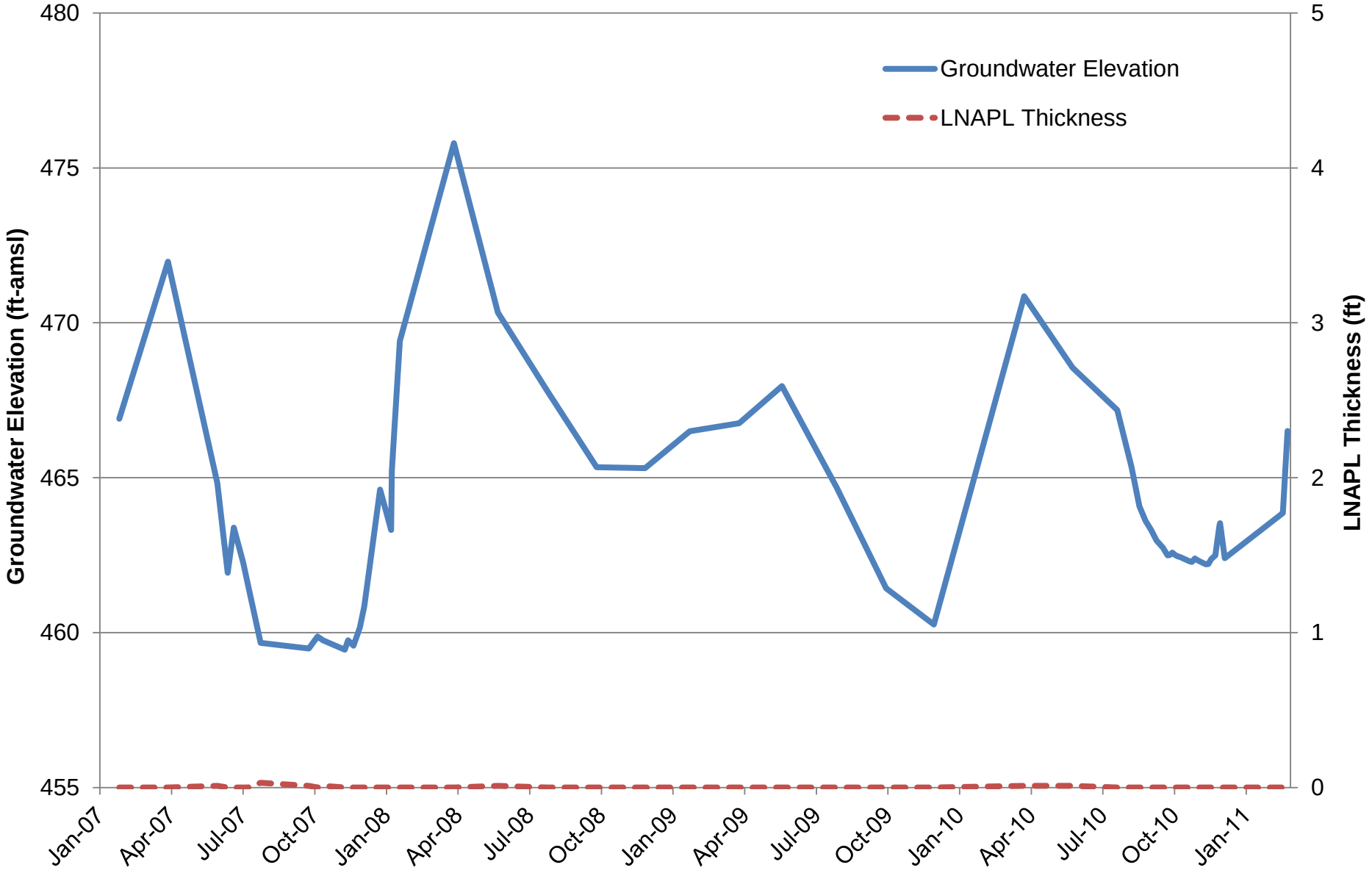
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-7. MW-96S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



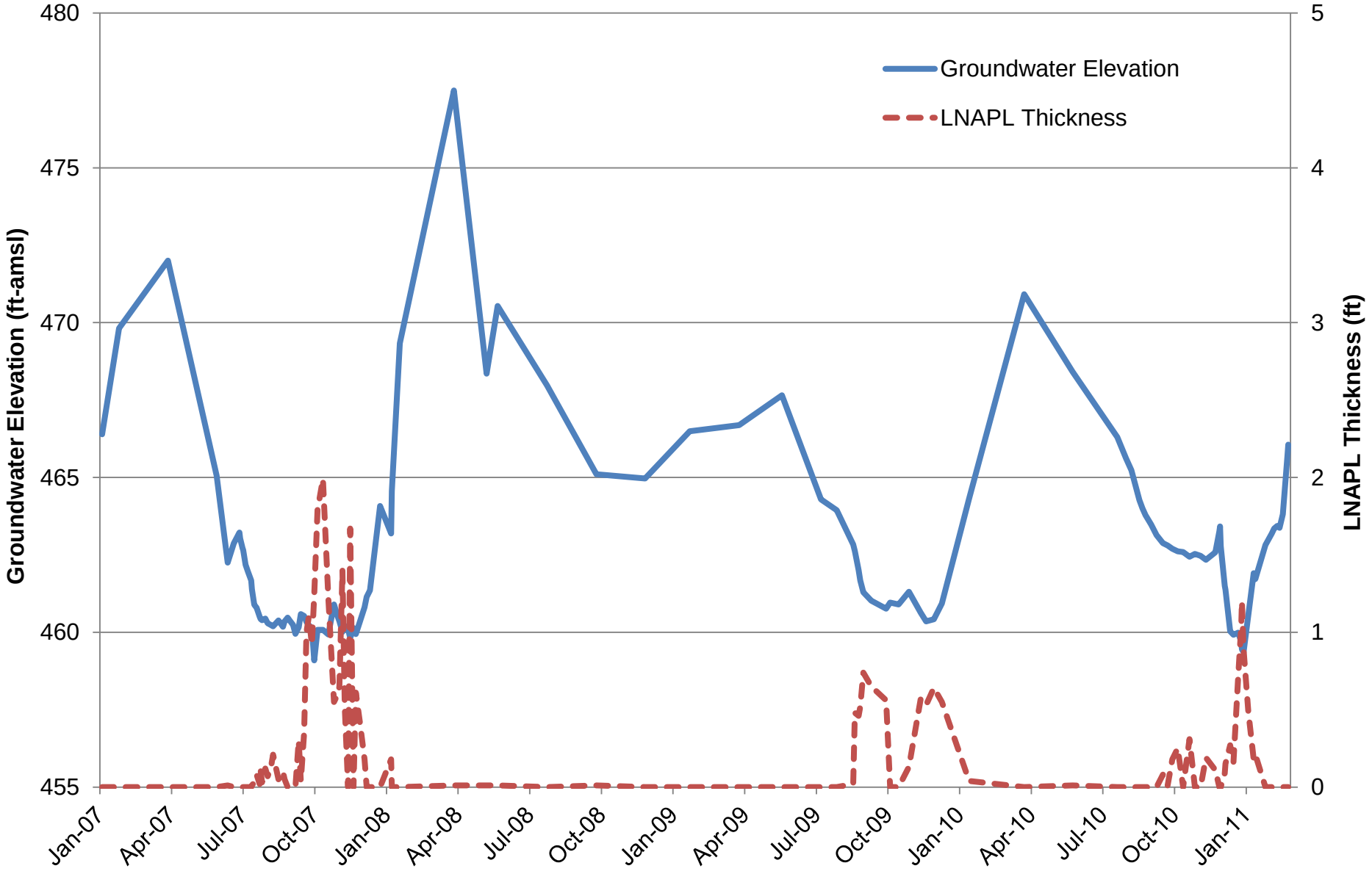
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-8. MW-98S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



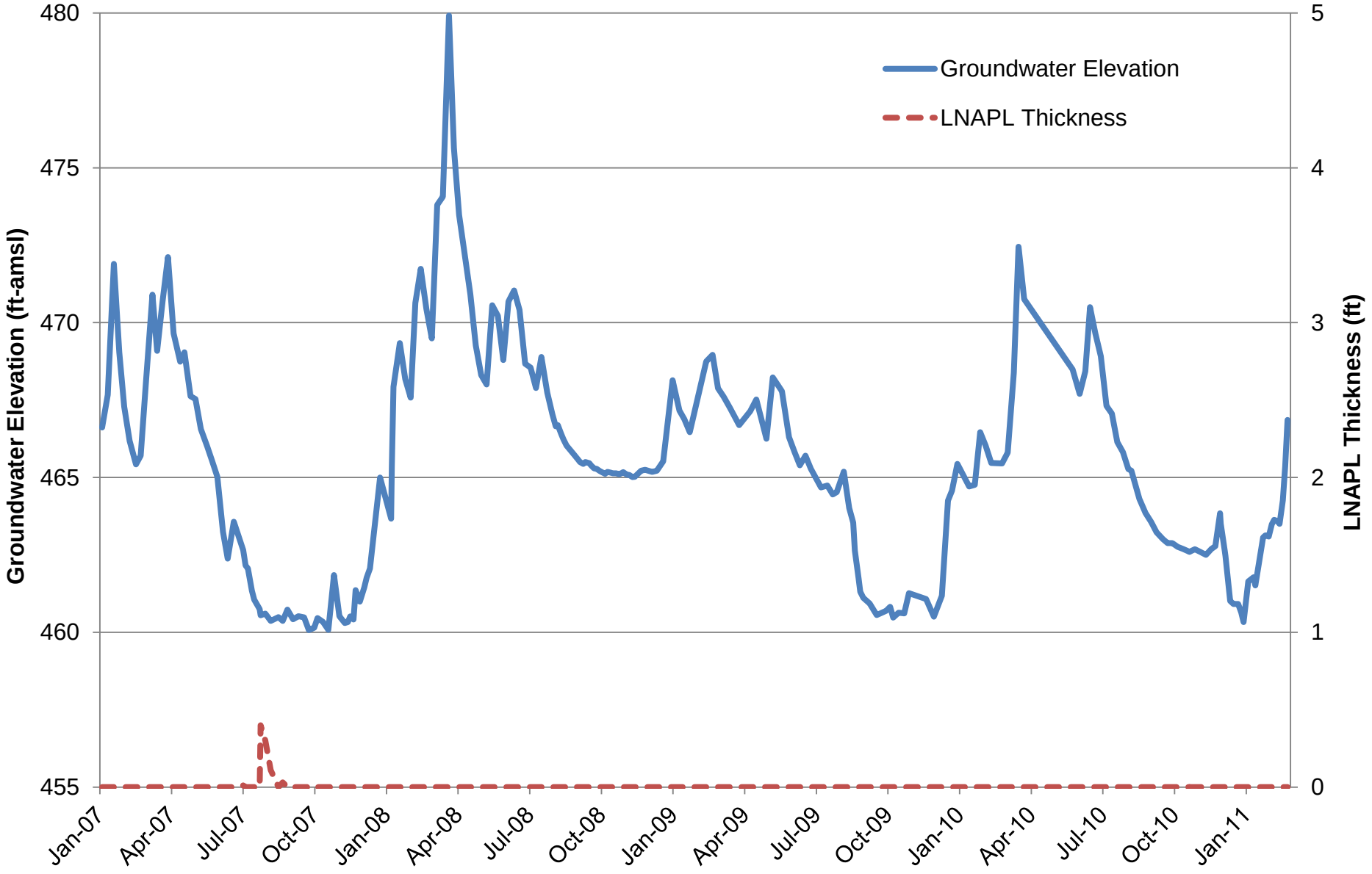
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-9. MW-99S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



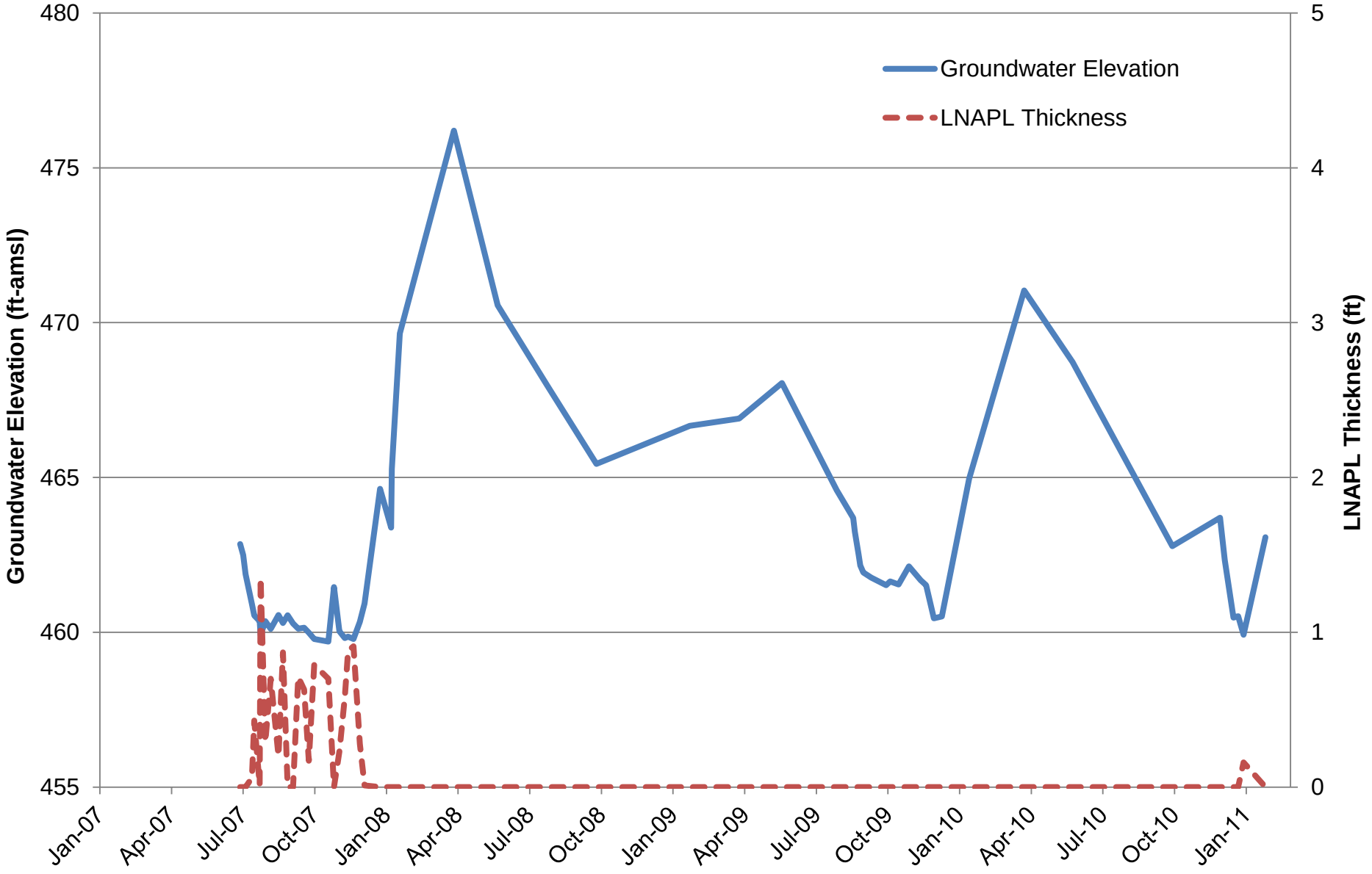
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-10. MW-112 HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



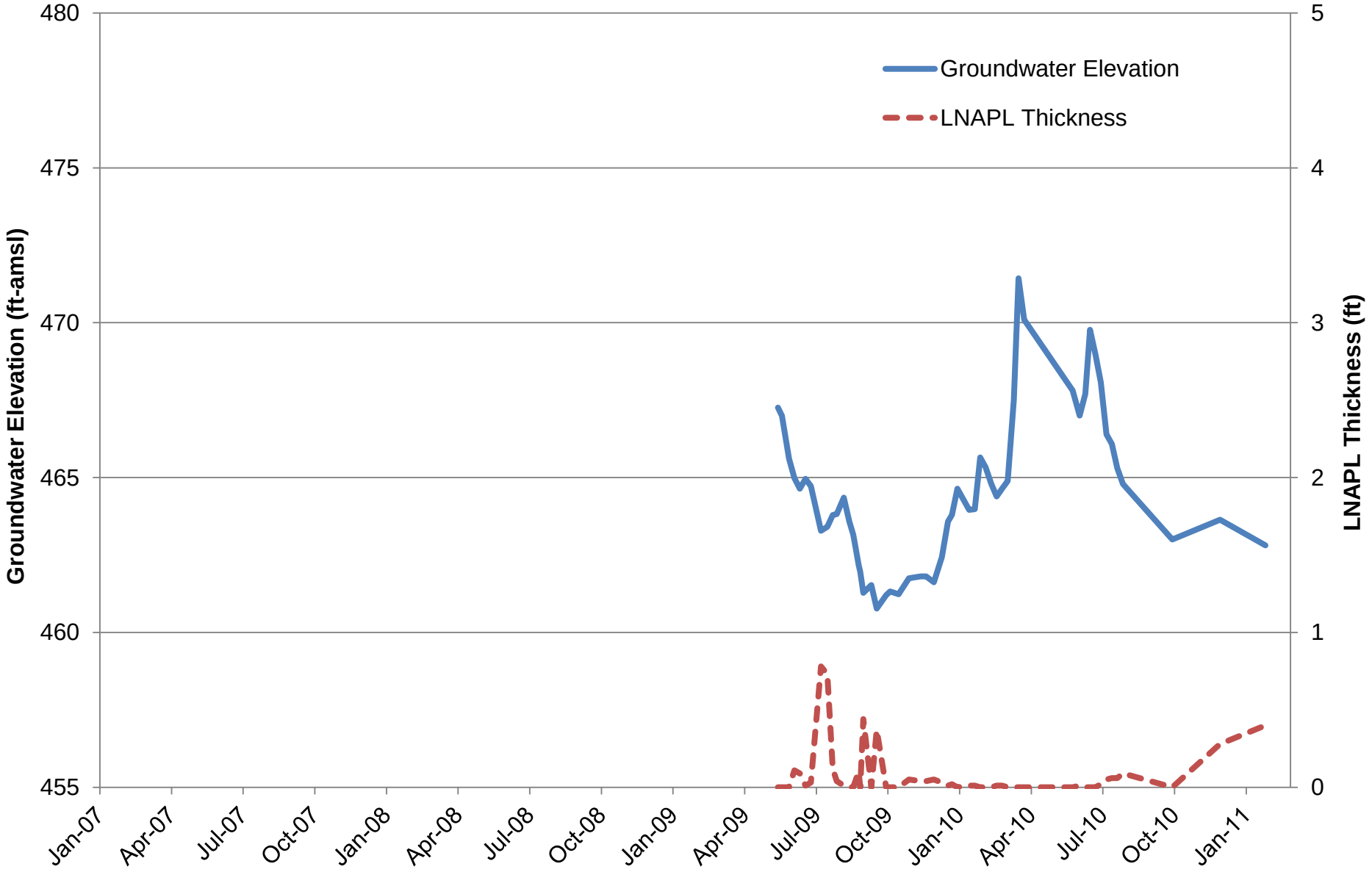
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-11. MW-121 HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



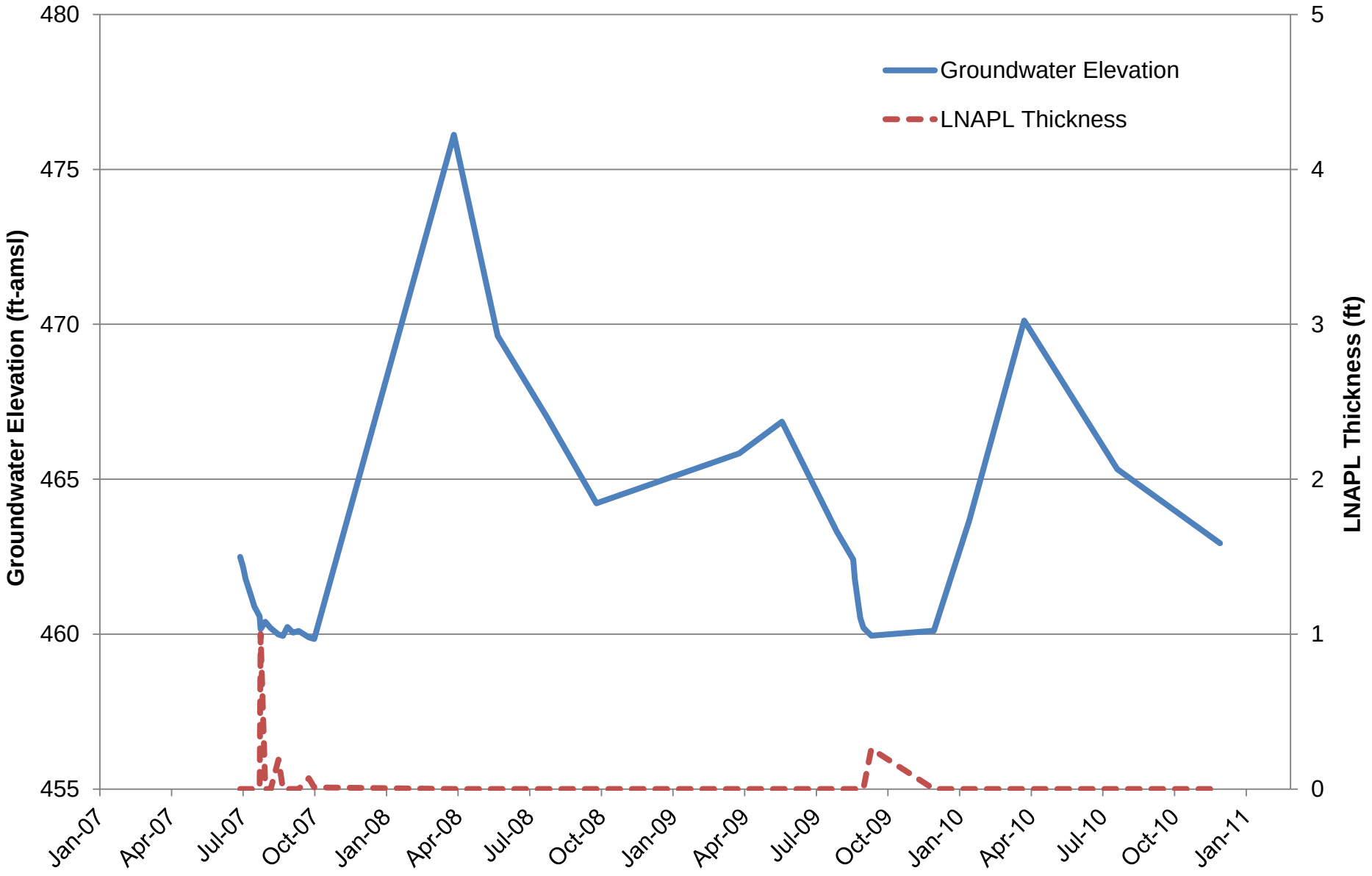
HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-12. MW-140S HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



HighGradeEndpointsCriteria1and2.xlsx

FIGURE C-13. MW-126 HYDROGRAPH
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



HighGradeEndpointsCriteria1and2.xlsx

APPENDIX D

2011 SOUTHWEST QUADRANT HYDRAULIC ANALYSES

MW-99S
476.32'

MW-100S
476.18'

MW-96S
476.11'

PROD_24
475.95'

MW-20S
475.81'

MW-112
475.77'

MW-101S
476.04'

MW-93S
476.01'

476.0

475.0

MW-85S
474.48'

474.0

MW-81S
475.68'

MW-128
475.69'

MW-94S
475.8'

MW-141
475.65'

MW-140
475.53'

MW-48S
474.6'

PROD_15
474.67'

MW-142
475.54'

MW-115S
475.66'

MW-131 *
476.05'

MW-37
475.61'

MW-12
474.22'

MW-139
475.48'

MW-26R
473.5'

MW-138
475.42'

MW-35
475.55'

MW-133
476.04'

MW-132
473.87'

MW-120
474.86'

MW-134
473.91'

EXPLANATION

EQUIPOTENTIAL CONTOUR LINE
Elevation In Feet Above Mean Sea Level
Contour Interval is 0.2 feet

BARRIER WALL

NOTE: * GROUNDWATER ELEVATION WAS NOT USED DUE TO A CHANGE IN TOP-OF-CASING ELEVATION.

N

0 250'

Trihydro CORPORATION
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Laramie, WY 82070
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FIGURE D-1

**POTENTIOMETRIC SURFACE MAP
MARCH 18, 2011**

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW, CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: BR	Checked By: MM	Scale: 1" = 250'	Date: 4/8/11	File: Mar_18_2011_Potsurface_Rpt.mxd

MW-99S
473.42'

MW-100S
474.47'

MW-96S
473.06'

MW-20S
472.25'

PROD_24
472.43'

MW-112
472.23'

MW-101S
473.51'

MW-93S
472.73'

MW-85S
471.03'

MW-81S
472.14'

MW-128
472.51'

MW-94S
473'

MW-141
472.5'

MW-140
472.05'

MW-48S
470.87'

PROD_15
470.9'

MW-142
472.28'

MW-115S
472.65'

MW-131*
473.36'

MW-37
473'

MW-12
470.29'

MW-139
472.06'

MW-138
471.89'

MW-26R
469.46'

MW-35
471.95'

MW-133
472.35'

MW-132
469.28'

MW-120
470.51'

MW-134
469.16'

474.0

473.0

472.0

471.0

470.0

EXPLANATION

EQUIPOTENTIAL CONTOUR LINE
Elevation In Feet Above Mean Sea Level
Contour Interval is 0.2 feet

BARRIER WALL

NOTE: * GROUNDWATER ELEVATION WAS NOT USED DUE TO A CHANGE IN TOP-OF-CASING ELEVATION.

N

0 250'

Trihydro CORPORATION
1252 Commerce Drive
Laramie, WY 82070
www.trihydro.com
(P) 307/745.7474 (F) 307/745.7729

FIGURE D-2

**POTENTIOMETRIC SURFACE MAP
MARCH 25, 2011**

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW, CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: BR	Checked By: MM	Scale: 1" = 250'	Date: 4/8/11	File: Mar_25_2011_Potsurface_Rpt.mxd

MW-99S
471.51'

MW-100S
472.42'

MW-96S
471.21'

PROD_24
470.62'

MW-20S
470.48'

MW-112
470.44'

MW-101S
471.5'

MW-93S
470.87'

MW-85S
469.42'

MW-81S
470.29'

MW-128
470.53'

MW-94S
470.91'

MW-141
470.43'

MW-140
470.13'

MW-48S
469.05'

PROD_15
469.05'

MW-142
470.25'

MW-115S
470.56'

MW-131*
471.36'

MW-37
470.79'

MW-12
468.44'

MW-139
470.03'

MW-26R
467.67'

MW-138
469.88'

MW-35
469.89'

MW-133
470.25'

MW-132
467.47'

MW-120
468.53'

MW-134
467.33'

472.0

471.0

470.0

469.0

468.0

EXPLANATION

EQUIPOTENTIAL CONTOUR LINE
Elevation In Feet Above Mean Sea Level
Contour Interval is 0.2 feet

BARRIER WALL

NOTE: * GROUNDWATER ELEVATION WAS NOT USED DUE TO A CHANGE IN TOP-OF-CASING ELEVATION.

N

0 250'

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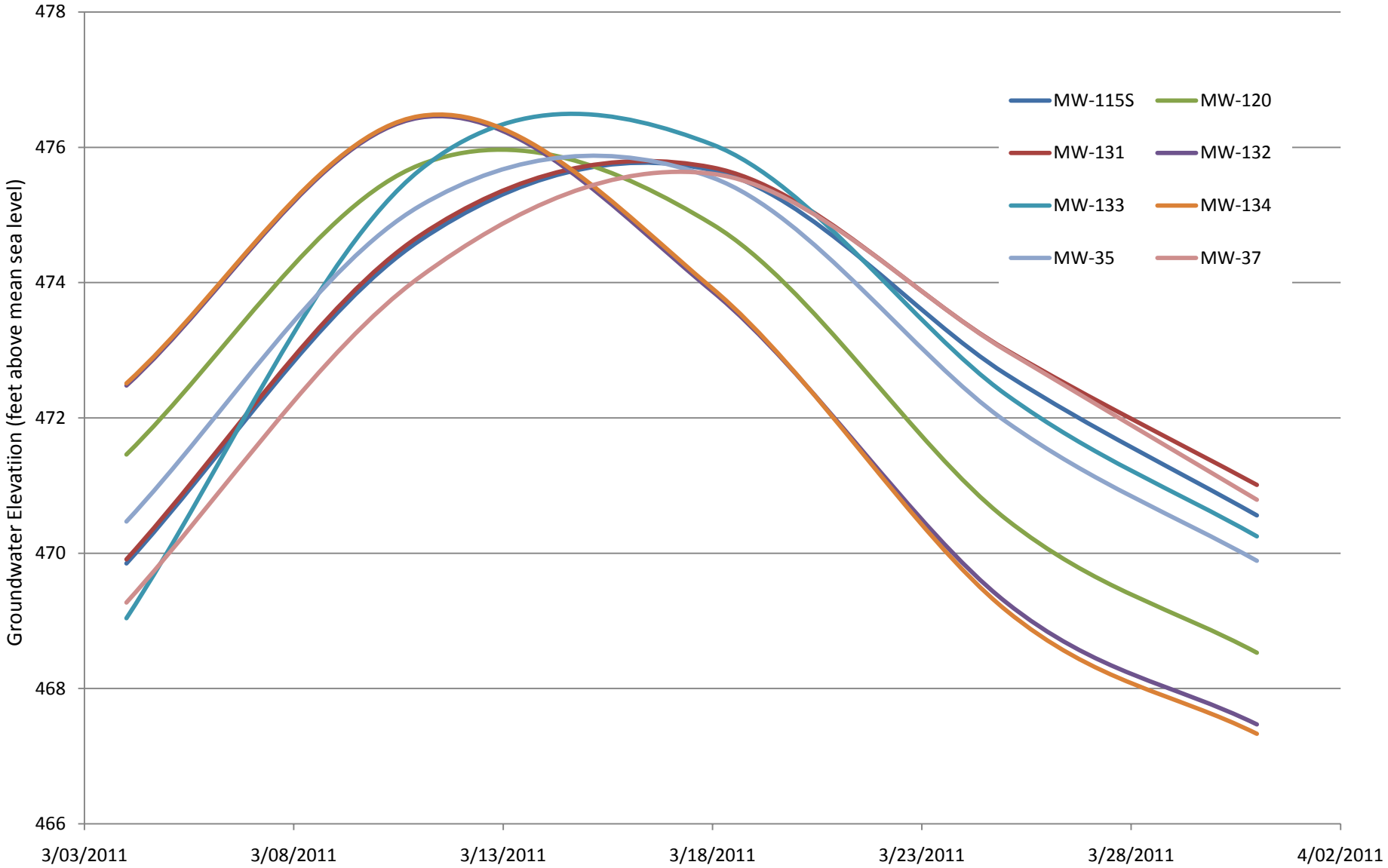
FIGURE D-3

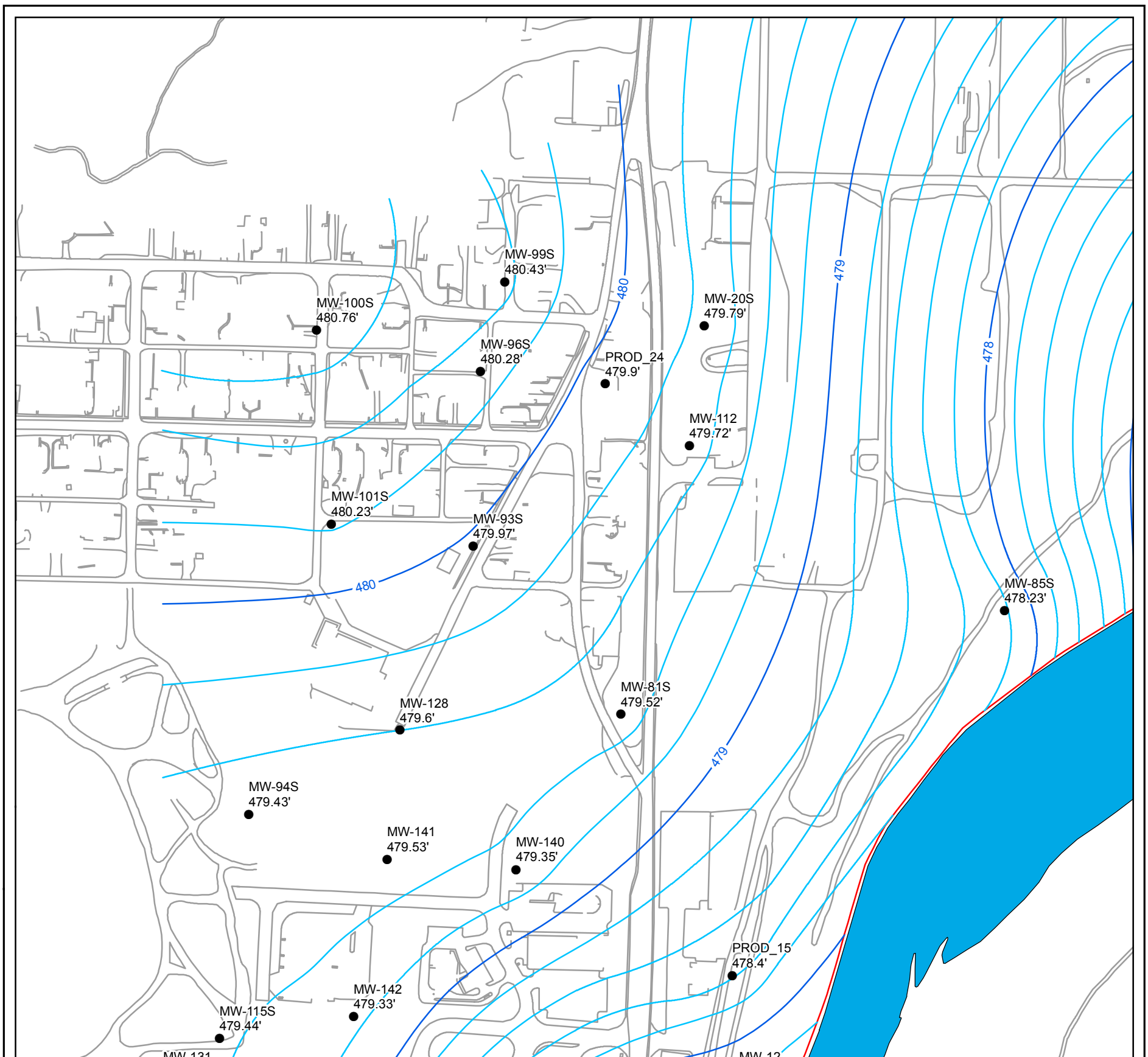
**POTENTIOMETRIC SURFACE MAP
MARCH 31, 2011**

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW, CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: BR	Checked By: MM	Scale: 1" = 250'	Date: 4/8/11	File: Mar_31_2011_Potsurface_Rpt.mxd

FIGURE D-4. HYDROGRAPHS FOR SELECTED MONITORING WELLS IN THE SOUTHWEST QUAD
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO





EXPLANATION

EQUIPOTENTIAL CONTOUR LINE
Elevation In Feet Above Mean Sea Level
Contour Interval is 0.2 feet

BARRIER WALL

N

0 250'

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Laramie, WY 82070
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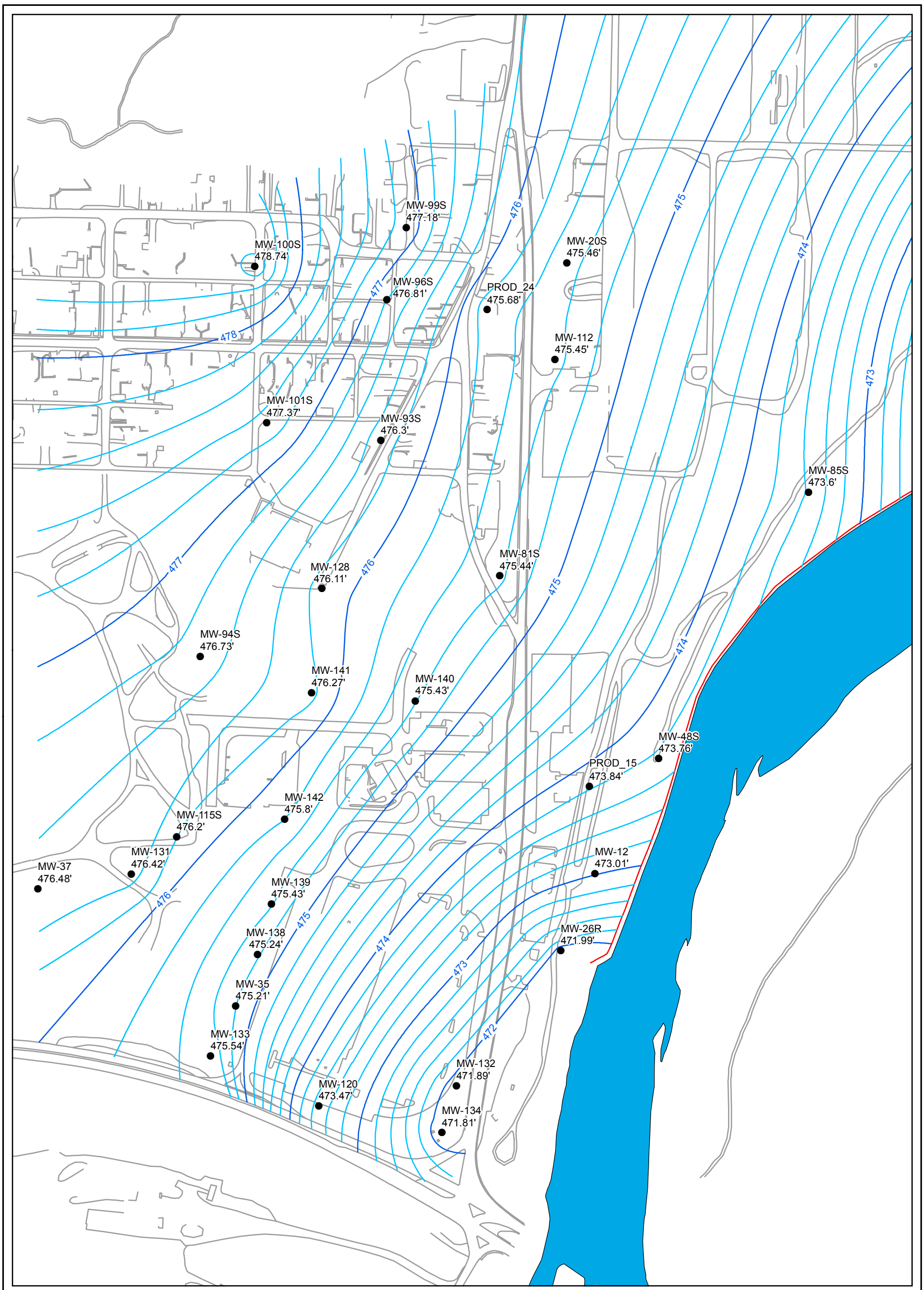
FIGURE D-5

POTENTIOMETRIC SURFACE MAP
MAY 6, 2011

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW, CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: BR	Checked By: MM	Scale: 1" = 250'	Date: 6/1/11	File: May_6_2011_Potsurface_Rpt.mxd



EXPLANATION

EQUIPOTENTIAL CONTOUR LINE
Elevation In Feet Above Mean Sea Level
Contour Interval is 0.2 feet

BARRIER WALL

N

0 250'

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Laramie, WY 82070
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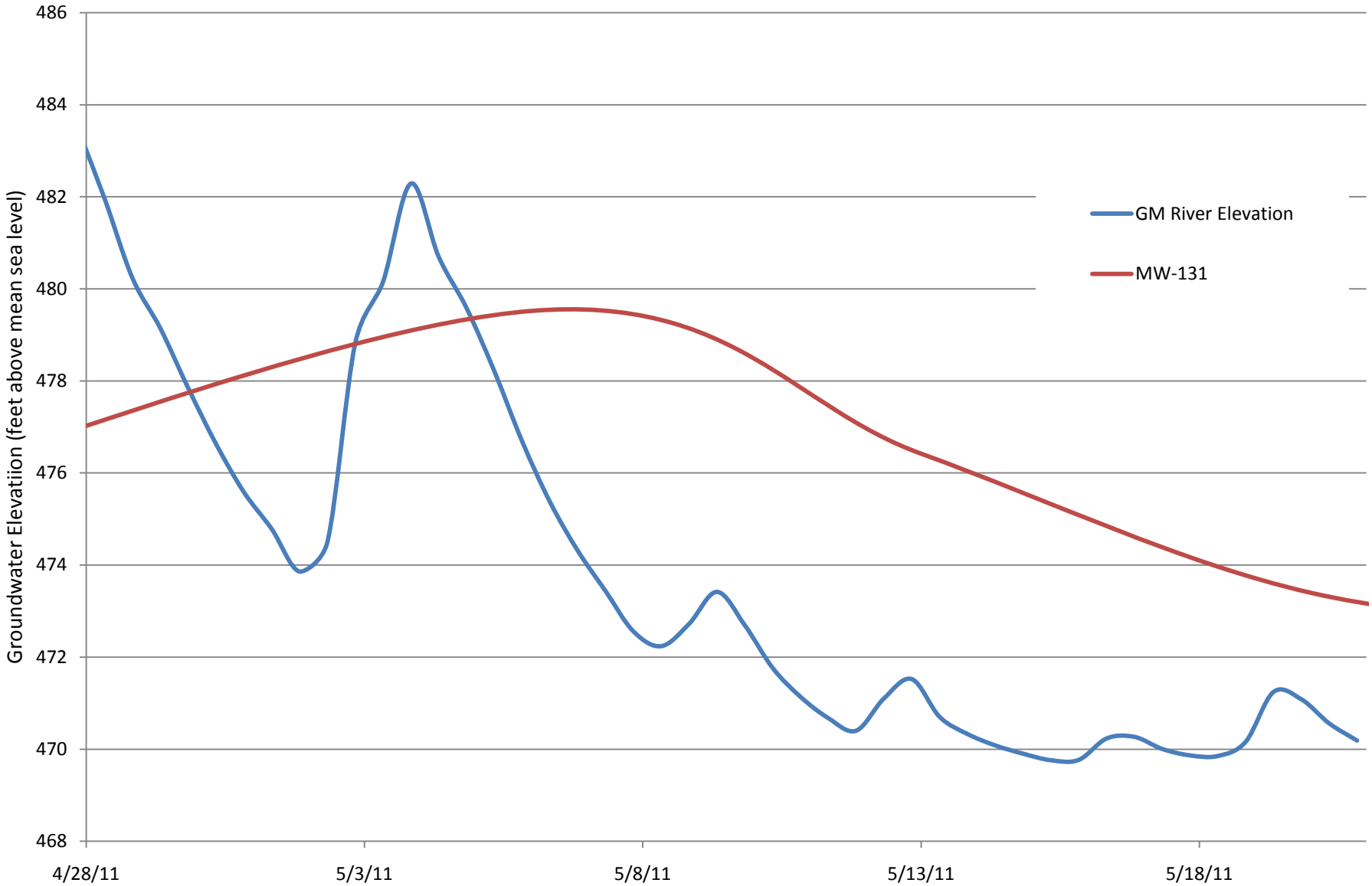
FIGURE D-6

**POTENTIOMETRIC SURFACE MAP
MAY 13, 2011**

FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW, CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Drawn By: BR	Checked By: MM	Scale: 1" = 250'	Date: 6/1/11	File: May_13_2011_Potsurface_Rpt.mxd

FIGURE D-7. HYDROGRAPHS FOR THE GREAT MIAMI RIVER AND MW-131
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO



APPENDIX E

GULF PARK BIOVENT SYSTEM RESPIROMETRY RESULTS

TABLE E-1. SOIL VAPOR FIELD SCREENING RESULTS FOR GULF PARK
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Vapor Well	Date/Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
VP1-50S	3/4/10 10:55	20.9	0.0	0.0
	7/27/10 13:15	14.0	0.4	0.0
	10/13/10 10:37	21.2	0.0	0.0
	10/13/10 15:08	20.8	0.0	0.0
	10/14/10 10:00	20.7	0.1	0.0
	10/14/10 14:22	19.9	0.1	0.0
	10/15/10 11:44	19.9	0.1	0.0
	10/18/10 10:34	20.0	0.2	0.0
	10/20/10 14:48	19.2	0.2	0.0
	10/25/10 9:35	18.2	0.3	0.0
	11/1/10 9:55	20.6	0.0	0.0
VP1-50D	10/13/10 10:40	11.9	3.6	0.3
	10/13/10 15:10	11.8	3.4	0.3
	10/14/10 10:07	11.2	4.0	0.2
	10/14/10 14:20	10.6	3.9	0.2
	10/15/10 11:41	10.4	4.1	5.0
	10/18/10 10:37	10.3	4.3	0.3
	10/20/10 14:46	10.3	4.3	0.2
	10/25/10 9:34	8.9	4.6	0.4
	11/1/10 9:58	13.4	4.6	0.3
VP2-50S	3/4/10 11:45	16.3	0.5	0.0
	7/27/10 14:40	0.4	9.3	3.1
	10/13/10 10:55	18.8	1.7	0.0
	10/13/10 14:40	18.9	1.1	0.0
	10/14/10 9:43	16.4	2.2	1.3
	10/14/10 13:57	14.7	2.4	1.3
	10/15/10 11:14	8.4	2.7	0.0
	10/18/10 10:04	0.0	3.0	0.1
	11/1/10 10:02	18.3	2.6	0.0
VP2-50D	10/13/10 11:00	19.2	1.4	1.3
	10/13/10 14:42	18.5	1.4	1.7
	10/14/10 9:46	14.6	2.3	0.0
	10/14/10 13:55	12.9	2.1	0.0
	10/15/10 11:17	12.5	3.1	17.0
	10/18/10 10:07	4.8	5.4	1.2
	11/1/10 10:10	19.0	1.5	0.9

TABLE E-1. SOIL VAPOR FIELD SCREENING RESULTS FOR GULF PARK
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Vapor Well	Date/Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
VP3-35S	3/4/10 10:30	20.9	0.0	0.0
	7/27/10 14:45	11.4	0.3	0.0
	10/13/10 10:30	20.1	1.0	0.0
	10/13/10 15:17	21.1	0.0	0.0
	10/14/10 10:16	20.8	0.1	0.0
	10/14/10 14:27	20.1	0.1	0.0
	10/15/10 11:46	20.2	0.1	0.0
	10/18/10 10:43	20.0	0.2	0.0
	10/20/10 14:39	19.6	0.2	0.1
	10/25/10 9:41	18.9	0.2	0.0
	11/1/10 10:17	20.5	0.0	0.0
VP3-35D	10/13/10 10:32	21.2	0.0	0.0
	10/13/10 15:15	20.1	0.8	0.0
	10/14/10 10:14	19.7	1.0	0.0
	10/14/10 14:25	18.9	1.0	0.0
	10/15/10 11:49	18.9	1.1	0.0
	10/18/10 10:43	18.6	1.2	0.0
	10/20/10 14:41	18.1	1.3	0.1
	10/25/10 9:40	17.0	1.5	0.0
	11/1/10 10:15	19.5	1.1	0.0
VP4-25S	3/4/10 10:24	20.7	0.1	0.0
	7/27/10 14:47	0.5	0.5	0.0
	10/13/10 10:20	21.2	0.1	0.0
	10/13/10 14:57	20.7	0.0	0.0
	10/14/10 9:52	20.8	0.1	0.0
	10/14/10 14:00	19.5	0.1	0.0
	10/15/10 11:23	19.5	0.1	0.0
	10/18/10 10:10	18.2	0.2	0.0
	10/20/10 14:56	17.0	0.2	0.1
	10/25/10 9:48	14.6	0.2	0.0
	11/1/10 10:30	20.7	0.6	0.0
VP4-25D	10/13/10 10:22	21.2	0.1	0.0
	10/13/10 14:55	20.7	0.1	0.0
	10/14/10 9:50	20.8	0.1	0.0
	10/14/10 14:02	19.6	0.1	0.0
	10/15/10 11:20	19.5	0.1	0.0
	10/18/10 10:13	18.3	0.2	0.0
	10/20/10 14:59	17.0	0.2	0.2
	10/25/10 9:47	14.5	0.4	0.0
	11/1/10 10:25	20.8	0.0	0.0

TABLE E-1. SOIL VAPOR FIELD SCREENING RESULTS FOR GULF PARK
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Vapor Well	Date/Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
VP-8S	10/13/10 9:00	2.9	13.1	23.9
	10/13/10 14:12	2.3	13.1	23.0
	10/14/10 9:22	2.0	13.7	21.0
	10/14/10 13:35	0.0	16.2	25.1
	10/15/10 10:53	0.0	14.7	100.0
	10/20/10 15:56	0.1	15.2	15.2
	11/1/10 10:47	0.0	16.9	24.5
VP-8D	10/13/10 9:05	11.0	6.5	13.0
	10/13/10 14:10	11.3	5.0	12.6
	10/14/10 9:28	8.6	6.7	28.8
	10/14/10 13:33	1.8	8.9	59.5
	10/15/10 10:50	0.0	9.6	100.0
	10/20/10 15:58	0.1	10.9	100.0
	11/1/10 10:43	0.0	15.0	100.0
VP-9S	10/13/10 9:10	21.2	0.1	0.0
	10/13/10 14:52	20.8	0.0	0.1
	10/14/10 9:57	21.0	0.1	0.0
	10/14/10 14:07	19.7	0.1	0.0
	10/15/10 11:28	19.8	0.1	0.0
	10/18/10 10:19	19.2	0.1	0.0
	10/20/10 14:52	18.4	0.1	0.1
	10/25/10 9:53	17.4	0.1	0.0
	11/1/10 11:00	21.0	0.0	0.0
VP-9D	10/13/10 9:15	21.2	0.1	0.0
	10/13/10 14:50	20.7	0.0	0.0
	10/14/10 9:55	21.0	0.1	0.0
	10/14/10 14:05	19.7	0.1	0.0
	10/15/10 11:26	19.9	0.1	0.0
	10/18/10 10:16	19.4	0.1	0.0
	10/20/10 14:51	18.4	0.1	0.1
	10/25/10 9:52	17.2	0.2	0.0
	11/1/10 10:58	21.0	0.0	0.0
VP-10S	10/13/10 9:20	20.6	0.7	0.0
	10/13/10 15:02	20.5	0.5	0.0
	10/14/10 10:02	20.8	0.5	0.0
	10/14/10 14:12	19.8	0.5	0.0
	10/15/10 11:33	20.0	0.5	0.0
	10/18/10 10:25	20.2	0.4	0.0
	10/20/10 15:11	19.8	0.4	0.1
	10/25/10 9:45	18.9	0.4	0.0
	11/1/10 11:09	20.5	0.7	0.0

TABLE E-1. SOIL VAPOR FIELD SCREENING RESULTS FOR GULF PARK
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Vapor Well	Date/Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
VP-10D	10/13/10 9:25	20.3	1.0	0.2
	10/13/10 15:00	20.1	0.7	0.2
	10/14/10 10:00	20.3	0.8	0.1
	10/14/10 14:10	19.3	0.8	0.1
	10/15/10 11:31	19.2	0.8	0.0
	10/18/10 10:22	18.8	0.9	0.0
	10/20/10 15:12	18.1	0.8	0.1
	10/25/10 9:47	17.0	1.1	0.0
	11/1/10 11:07	20.3	0.9	0.1
VP-11S	10/13/10 9:30	21.3	0.1	0.0
	10/13/10 15:07	21.2	0.0	0.0
	10/14/10 10:07	21.1	0.1	0.0
	10/14/10 14:17	20.2	0.0	0.0
	10/15/10 11:38	20.3	0.1	0.0
	10/18/10 10:31	20.2	0.1	0.0
	10/20/10 16:05	20.5	0.0	0.1
	10/25/10 9:30	18.6	0.1	0.0
	11/1/10 11:16	21.0	0.0	0.0
VP-11D	10/13/10 9:35	21.3	0.1	0.0
	10/13/10 15:05	21.1	0.0	0.0
	10/14/10 10:05	20.9	0.1	0.0
	10/14/10 14:15	19.9	0.1	0.0
	10/15/10 11:36	19.8	0.1	0.0
	10/18/10 10:28	19.6	0.2	0.0
	10/20/10 16:06	19.8	0.2	0.0
	10/25/10 9:29	17.7	0.5	0.0
	11/1/10 11:14	21.0	0.0	0.0
VP-12S	10/13/10 9:40	18.8	0.0	0.0
	10/13/10 14:32	14.5	0.1	0.0
	10/14/10 9:39	12.8	0.1	0.0
	10/14/10 13:52	14.2	0.1	0.0
	10/15/10 11:11	14.7	0.1	0.0
	10/18/10 10:00	12.6	0.1	0.0
	10/20/10 15:48	14.8	0.2	0.1
	10/25/10 9:25	9.3	0.1	0.0
	11/1/10 11:25	18.2	0.4	0.0

TABLE E-1. SOIL VAPOR FIELD SCREENING RESULTS FOR GULF PARK
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Vapor Well	Date/Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
VP-12D	10/13/10 9:45	21.3	0.1	0.0
	10/13/10 14:30	20.7	0.1	0.0
	10/14/10 9:37	20.9	0.1	0.0
	10/14/10 13:49	19.6	0.1	0.0
	10/15/10 11:08	19.4	0.1	0.0
	10/18/10 9:57	18.1	0.2	0.0
	10/20/10 15:49	17.1	0.2	0.1
	10/25/10 9:24	13.0	0.4	0.0
	11/1/10 11:23	21.0	0.0	0.0
VP-13S	10/13/10 9:50	16.2	1.8	0.0
	10/13/10 14:27	16.4	1.2	0.0
	10/14/10 9:33	15.6	2.7	0.0
	10/14/10 13:46	15.2	2.9	0.0
	10/15/10 11:05	14.4	2.7	0.0
	10/18/10 9:54	11.8	2.9	0.0
	10/20/10 15:38	9.9	2.2	0.1
	10/25/10 9:21	5.4	2.7	0.0
	11/1/10 11:37	17.7	2.5	0.0
VP-13D	10/13/10 9:53	20.5	0.1	0.0
	10/13/10 14:25	20.4	0.0	0.0
	10/14/10 9:30	8.8	0.4	0.0
	10/14/10 13:43	11.4	0.4	0.0
	10/15/10 11:02	12.4	0.4	0.0
	10/18/10 9:51	9.5	0.6	0.0
	10/20/10 15:36	9.7	0.6	0.1
	10/25/10 9:21	5.3	1.3	0.0
	11/1/10 11:33	20.2	0.2	0.0
VP-14S	10/13/10 9:56	21.2	0.1	0.0
	10/13/10 14:22	20.6	0.1	0.1
	10/14/10 9:27	20.6	0.2	0.0
	10/14/10 13:41	19.8	0.2	0.0
	10/15/10 10:59	19.5	0.2	0.0
	10/18/10 9:48	18.9	0.2	0.0
	10/20/10 15:42	18.3	0.2	0.0
	10/25/10 9:15	16.2	0.3	0.0
	11/1/10 11:44	21.0	0.0	0.0

TABLE E-1. SOIL VAPOR FIELD SCREENING RESULTS FOR GULF PARK
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

Vapor Well	Date/Time	Oxygen (%)	Carbon Dioxide (%)	Methane (%)
VP-14D	10/13/10 10:00	21.2	0.1	0.0
	10/13/10 14:20	20.5	0.1	0.0
	10/14/10 9:25	20.2	0.1	0.0
	10/14/10 13:39	19.5	0.1	0.0
	10/15/10 10:56	18.7	0.1	0.0
	10/18/10 9:45	17.8	0.2	0.0
	10/20/10 15:43	16.9	0.2	0.0
	10/25/10 9:16	14.2	0.4	0.0
	11/1/10 11:42	21.0	0.0	0.0

NOTES:
% - percent

FIGURE E-1: GULF PARK VAPOR MONITORING POINT VP1-50S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

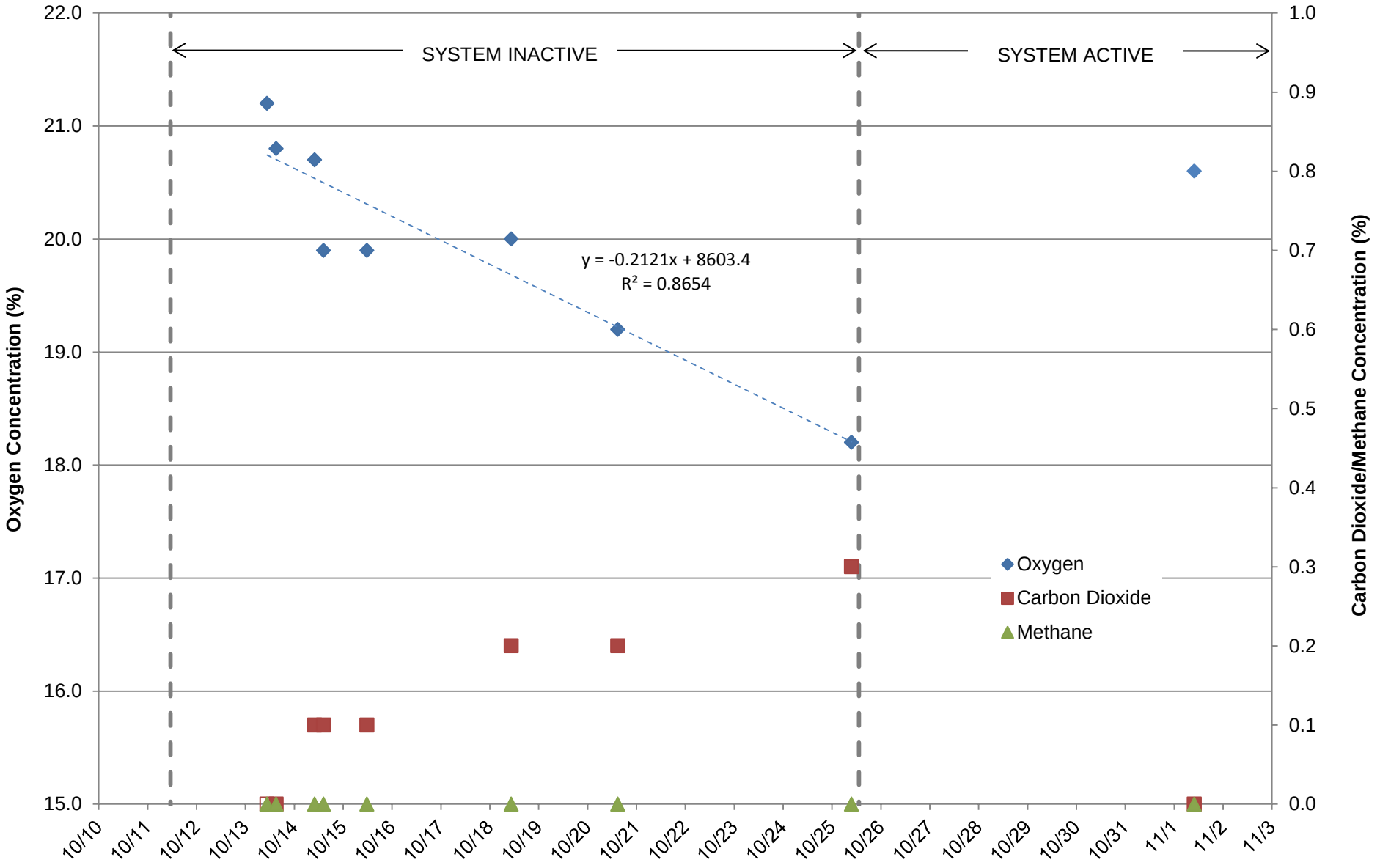


FIGURE E-2: GULF PARK VAPOR MONITORING POINT VP1-50D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

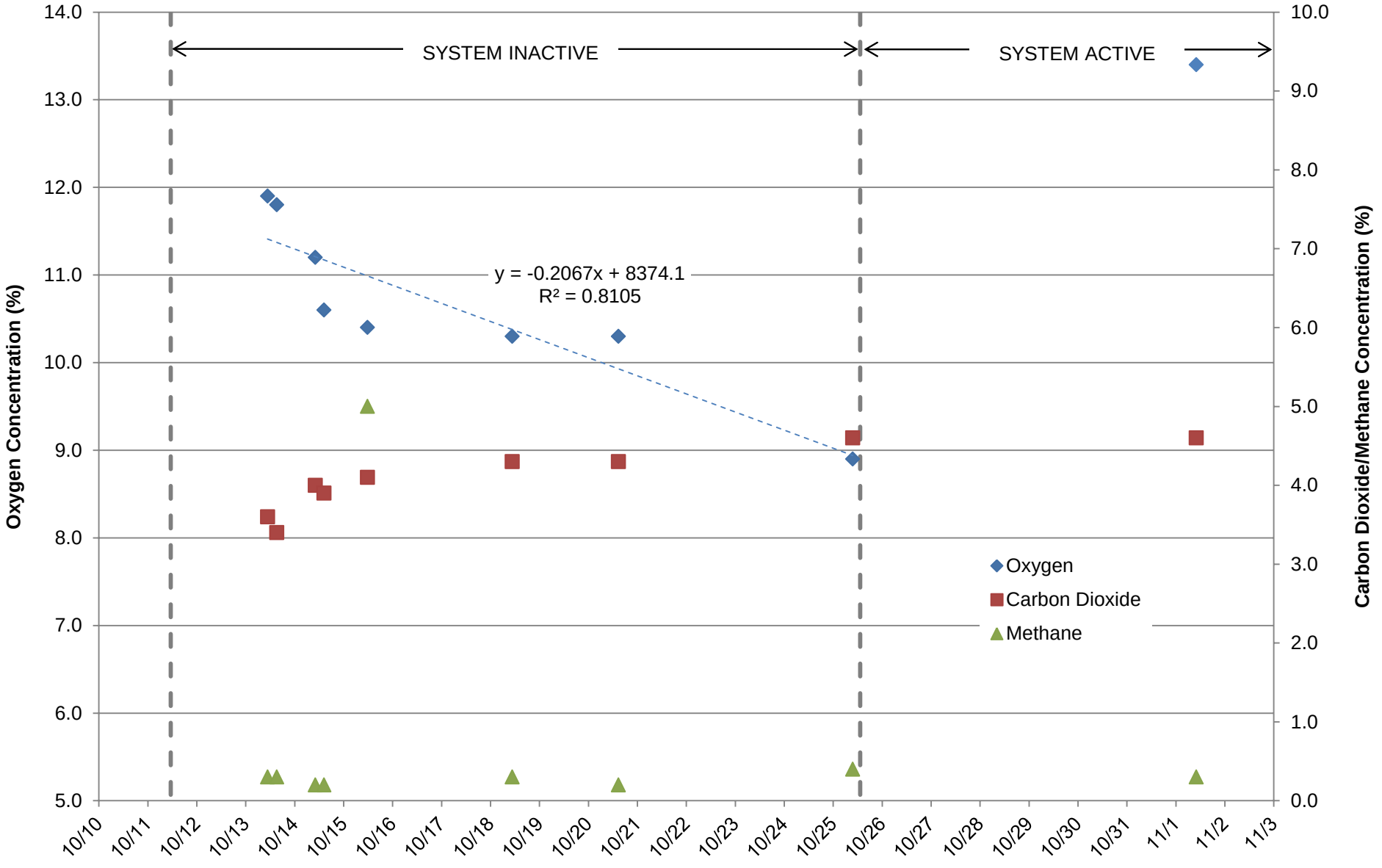


FIGURE E-3: GULF PARK VAPOR MONITORING POINT VP2-50S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

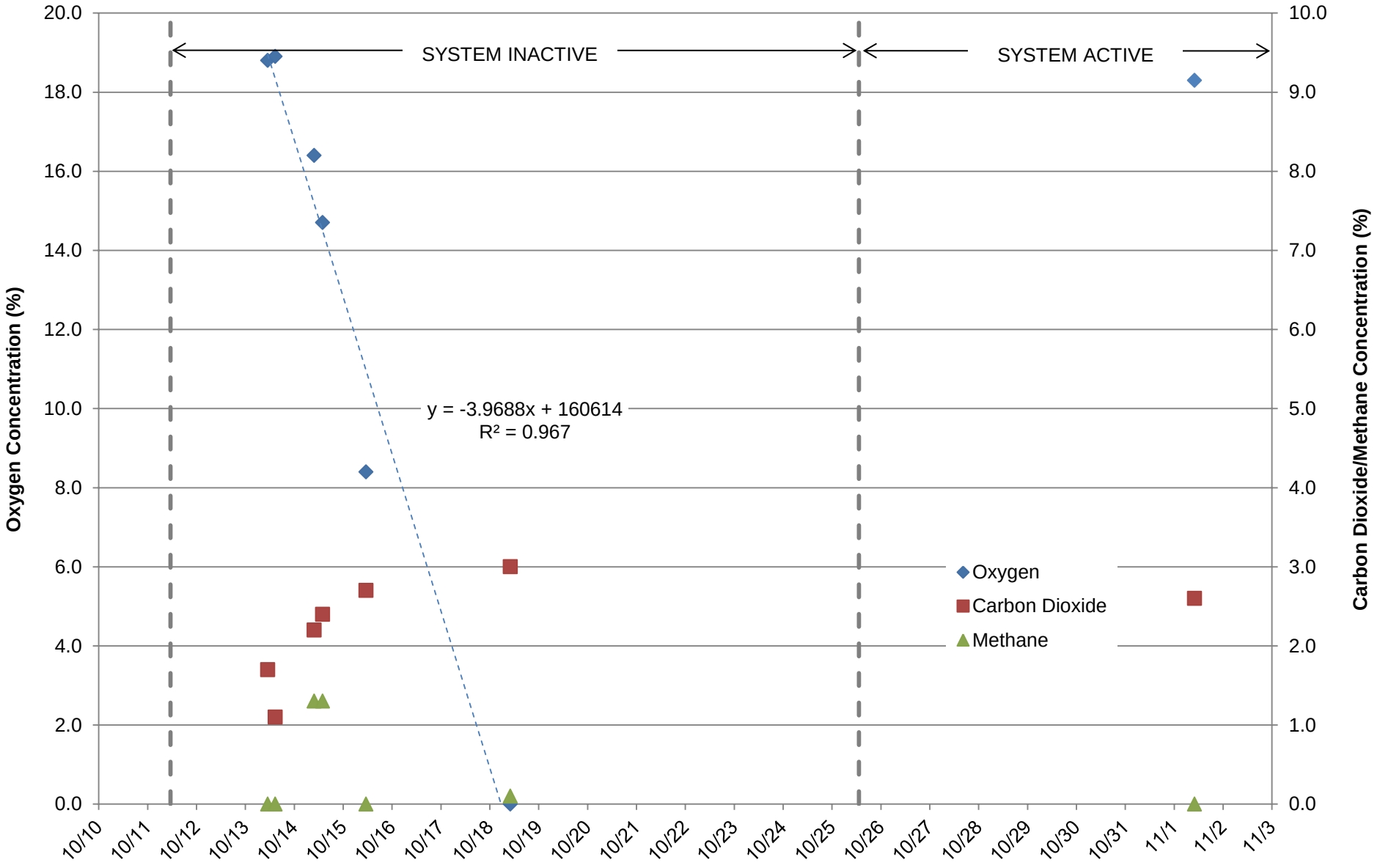


FIGURE E-4: GULF PARK VAPOR MONITORING POINT VP2-50D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

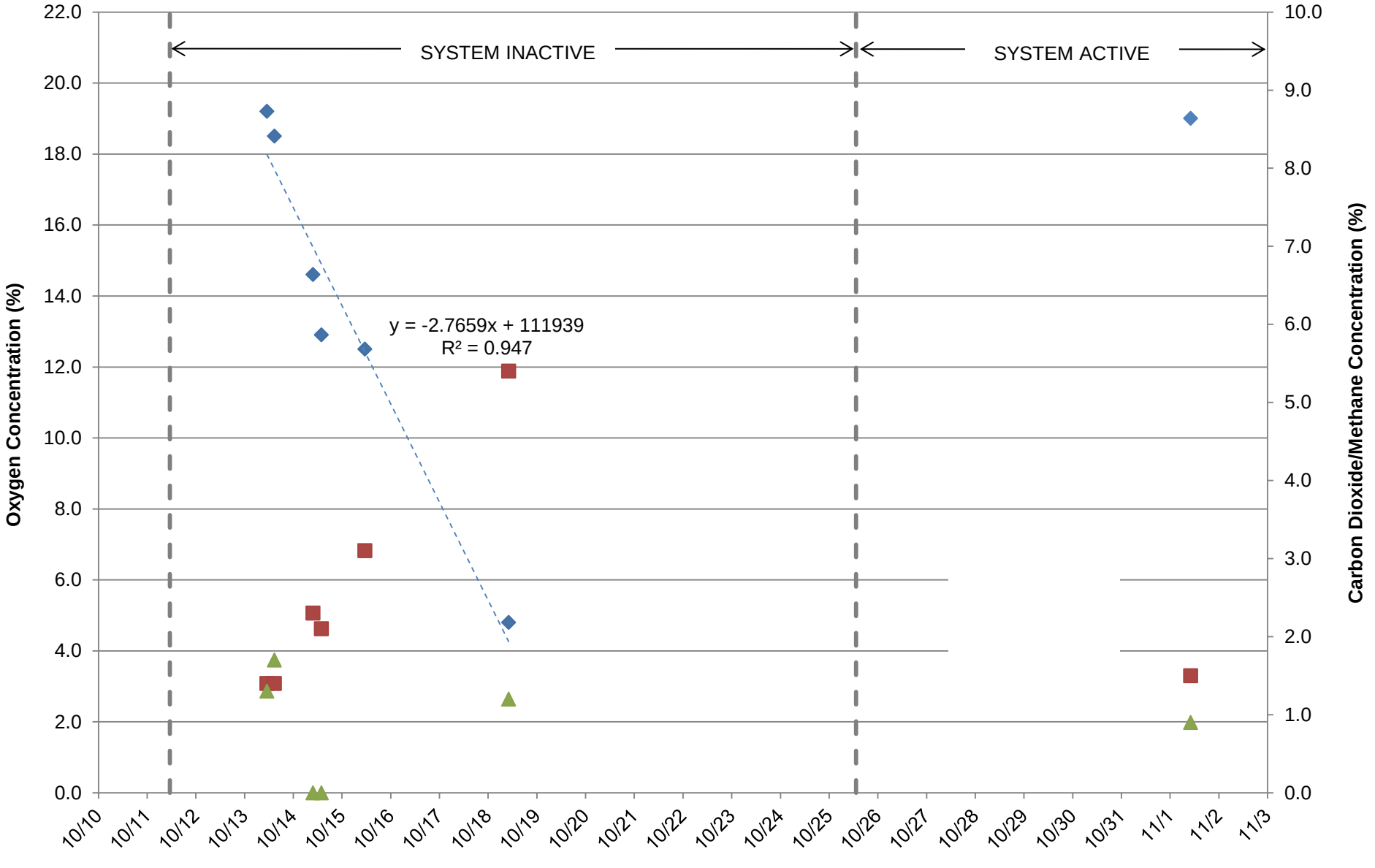


FIGURE E-5: GULF PARK VAPOR MONITORING POINT VP3-35S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

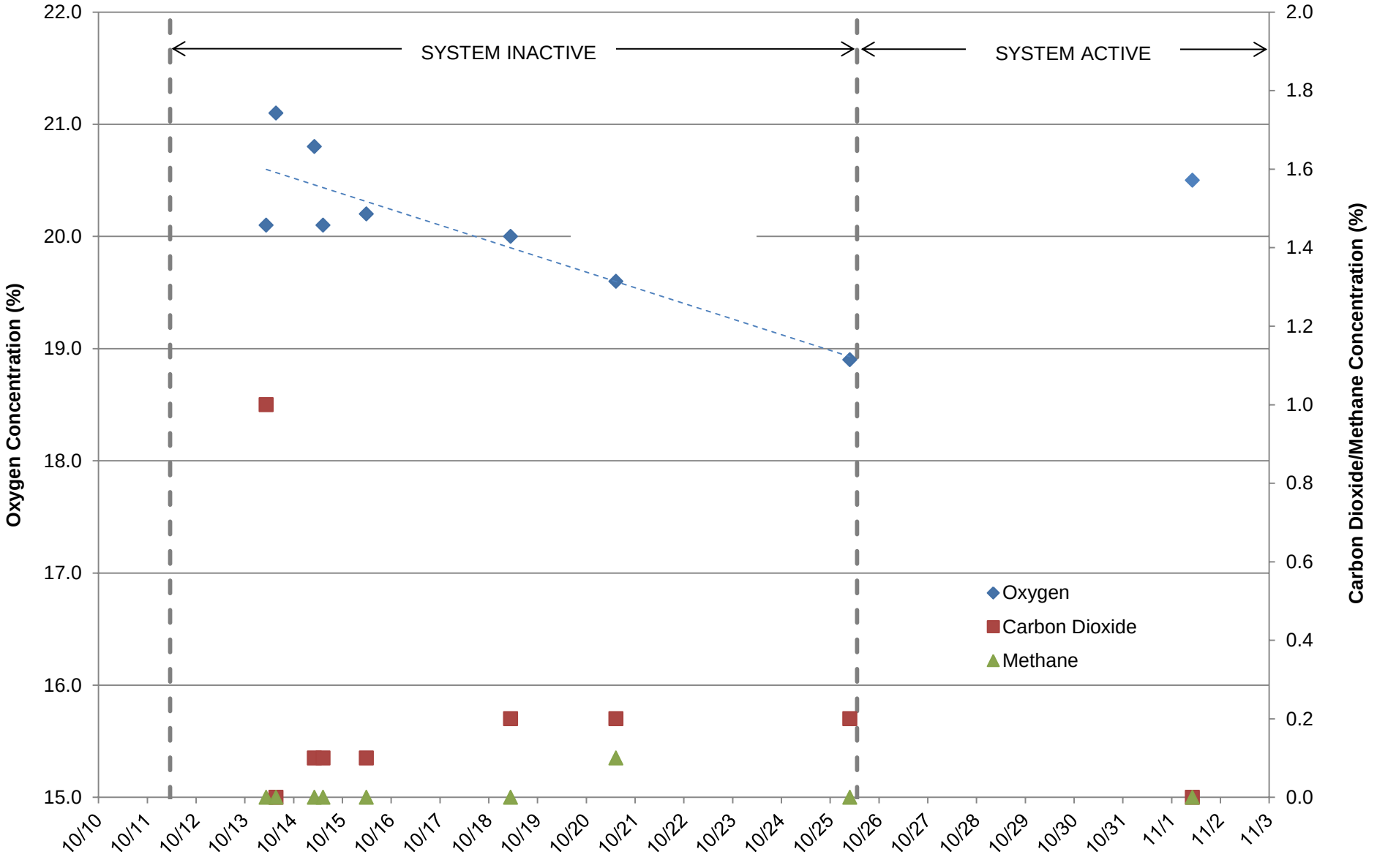


FIGURE E-6: GULF PARK VAPOR MONITORING POINT VP3-35D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

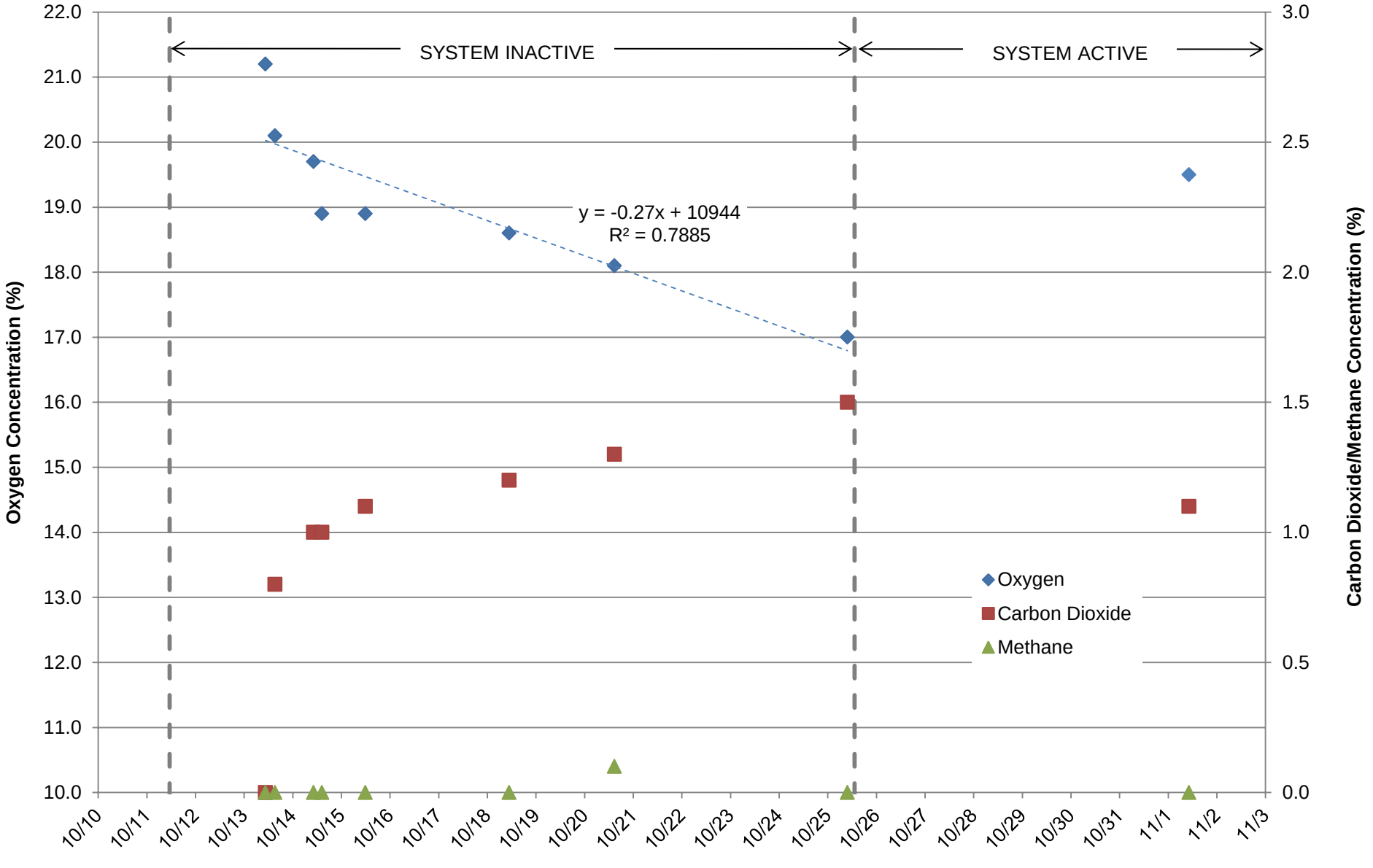


FIGURE E-7: GULF PARK VAPOR MONITORING POINT VP4-25S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

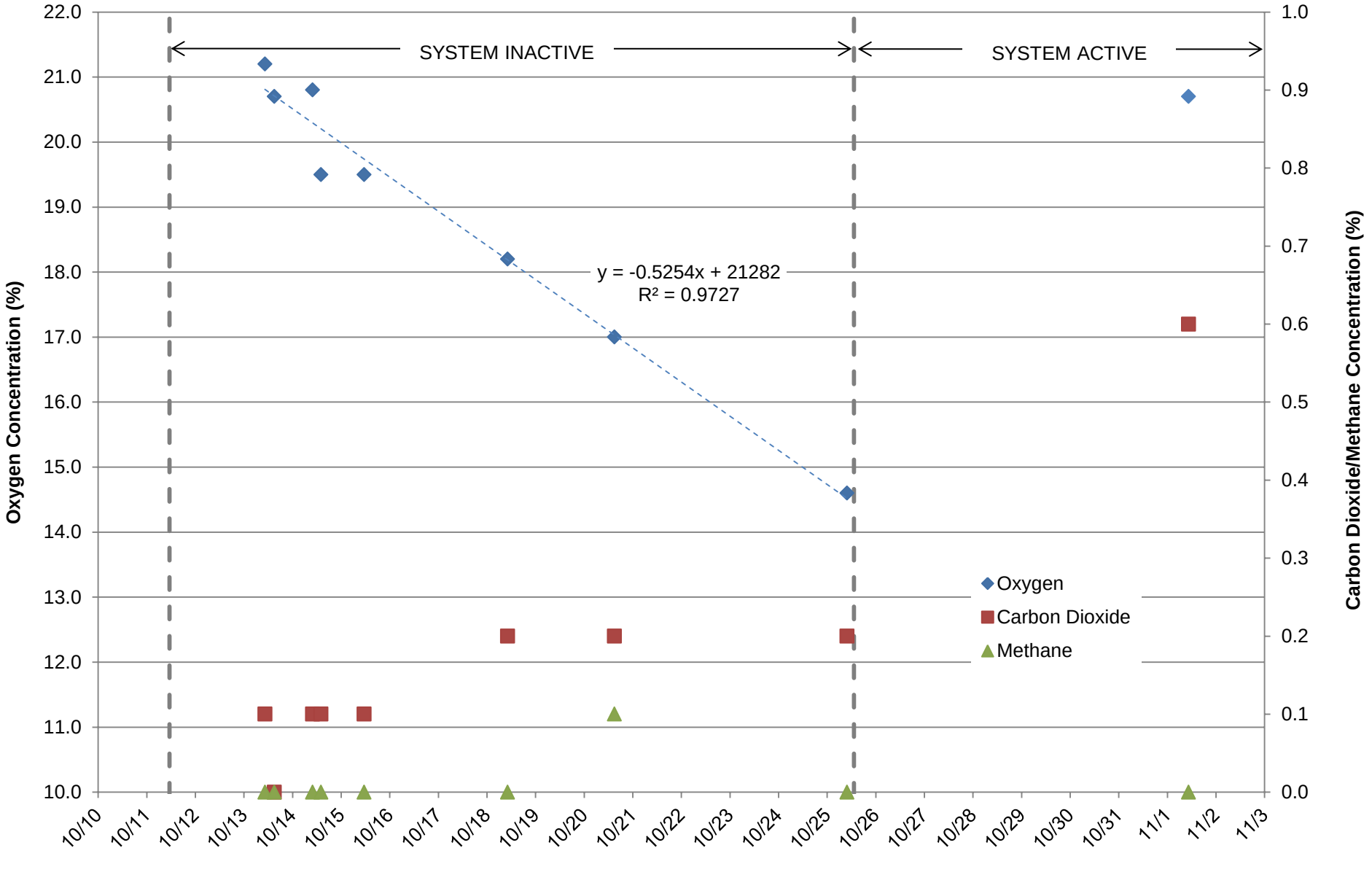


FIGURE E-8: GULF PARK VAPOR MONITORING POINT VP4-25D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

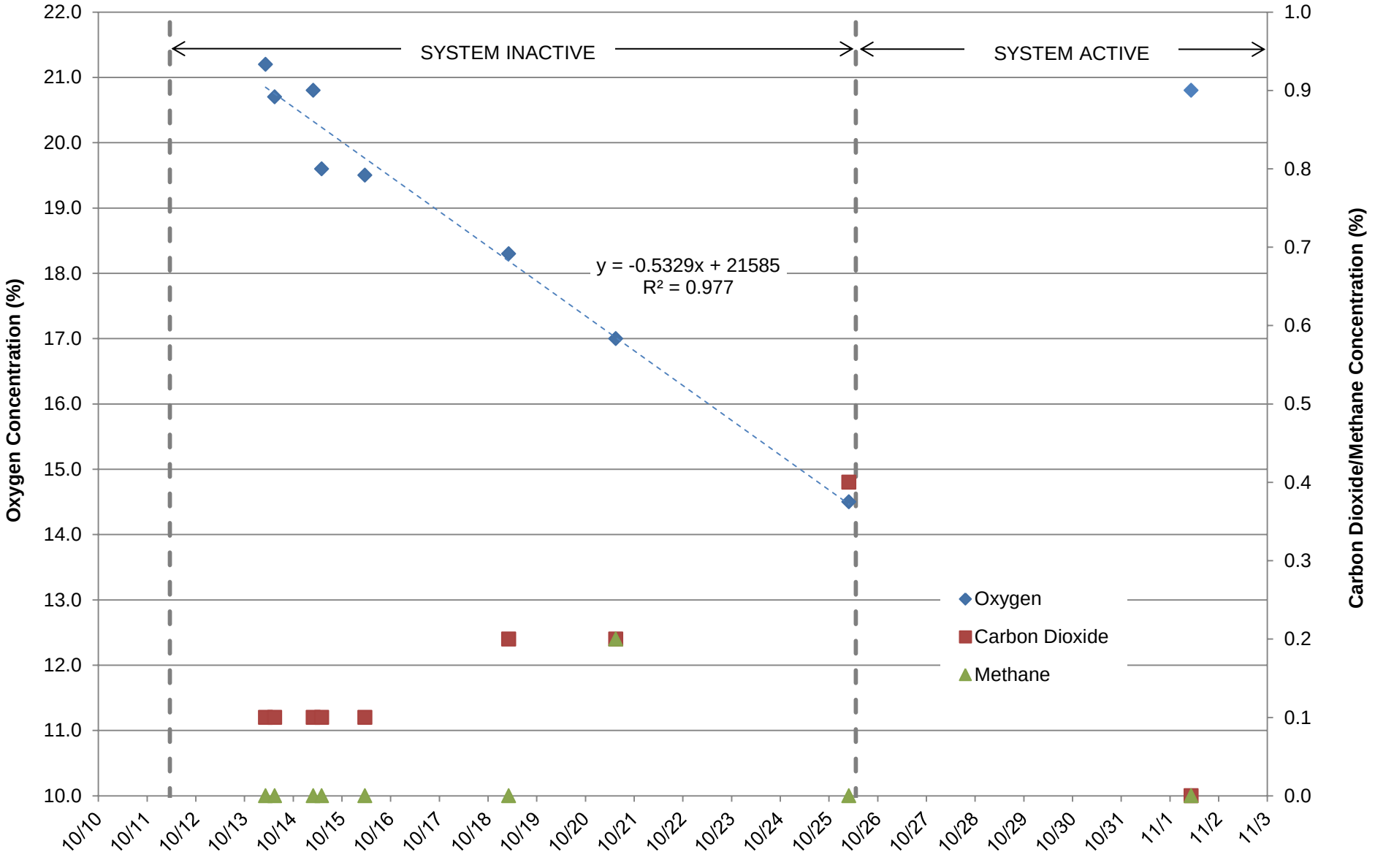


FIGURE E-9: GULF PARK VAPOR MONITORING POINT VP-8S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

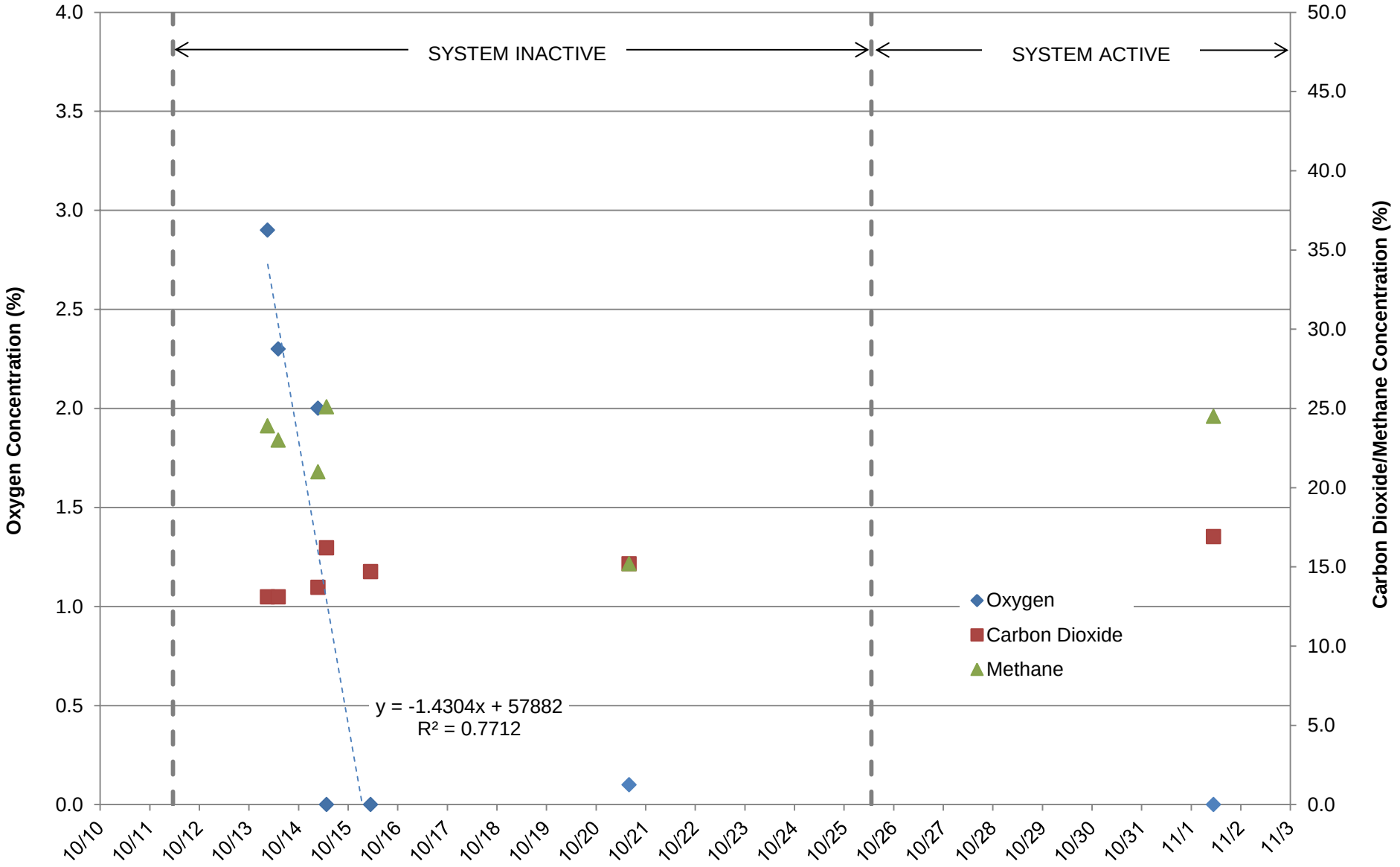


FIGURE E-10: GULF PARK VAPOR MONITORING POINT VP-8D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

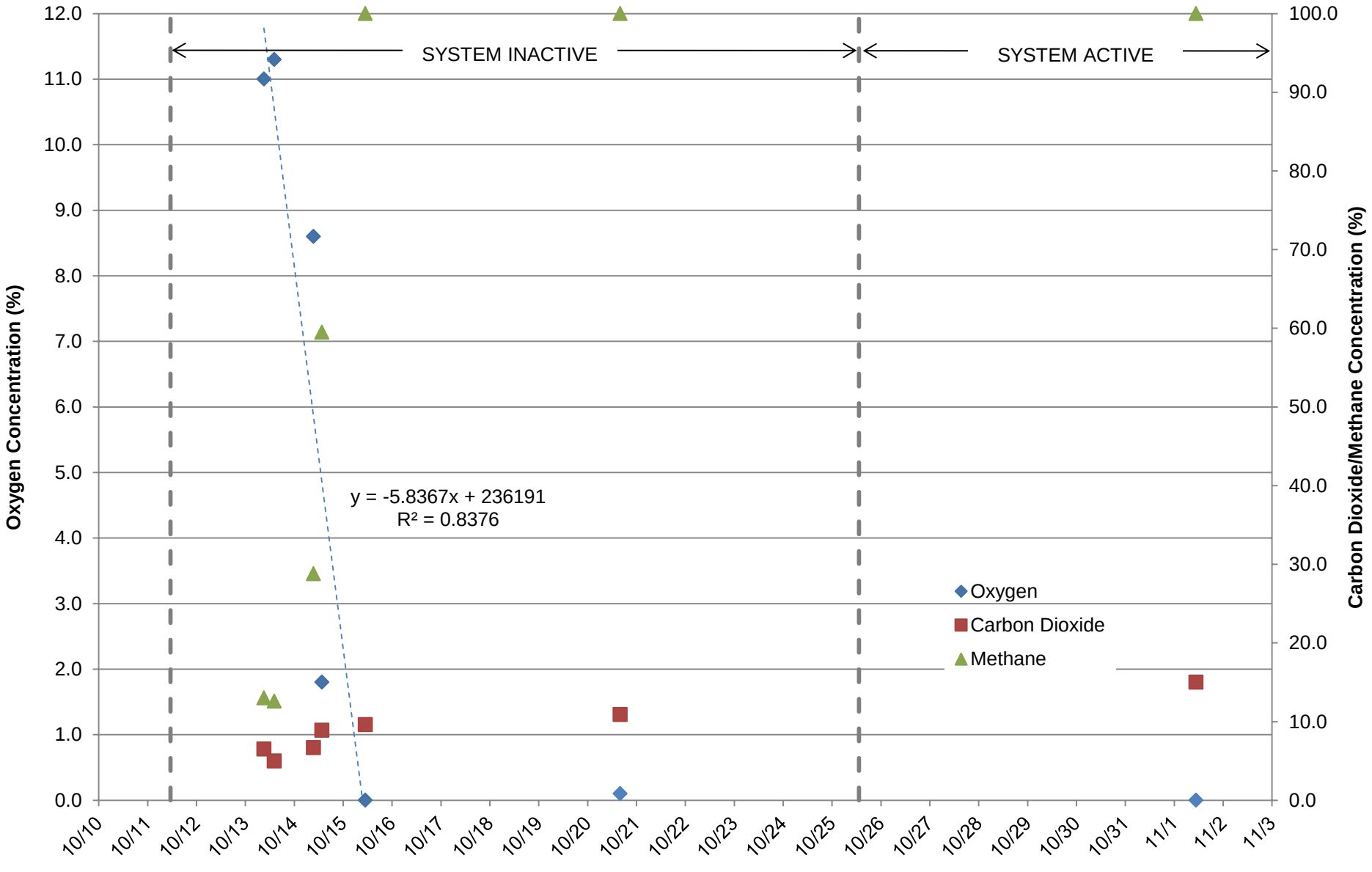


FIGURE E-11: GULF PARK VAPOR MONITORING POINT VP-9S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

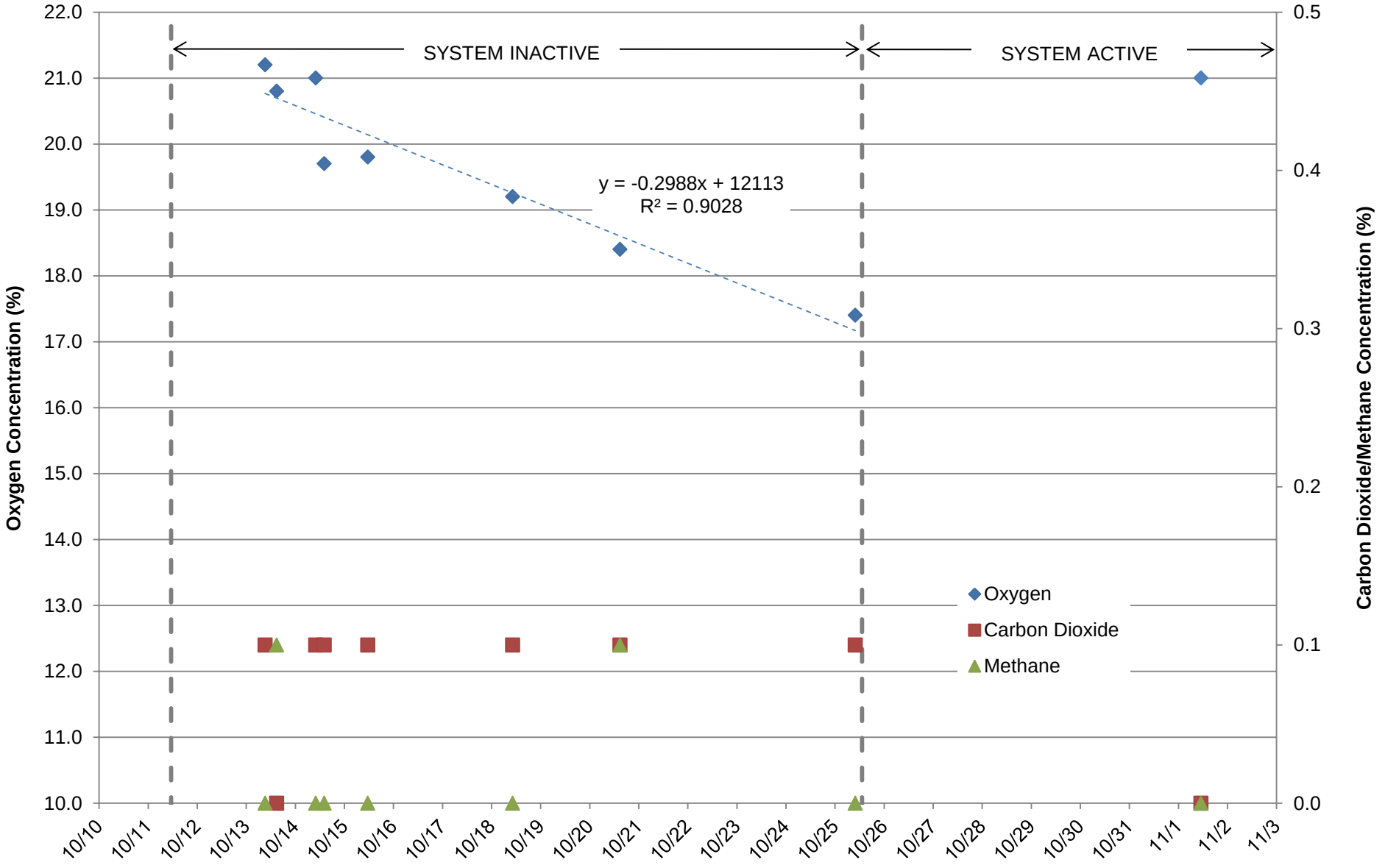


FIGURE E-12: GULF PARK VAPOR MONITORING POINT VP-9D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

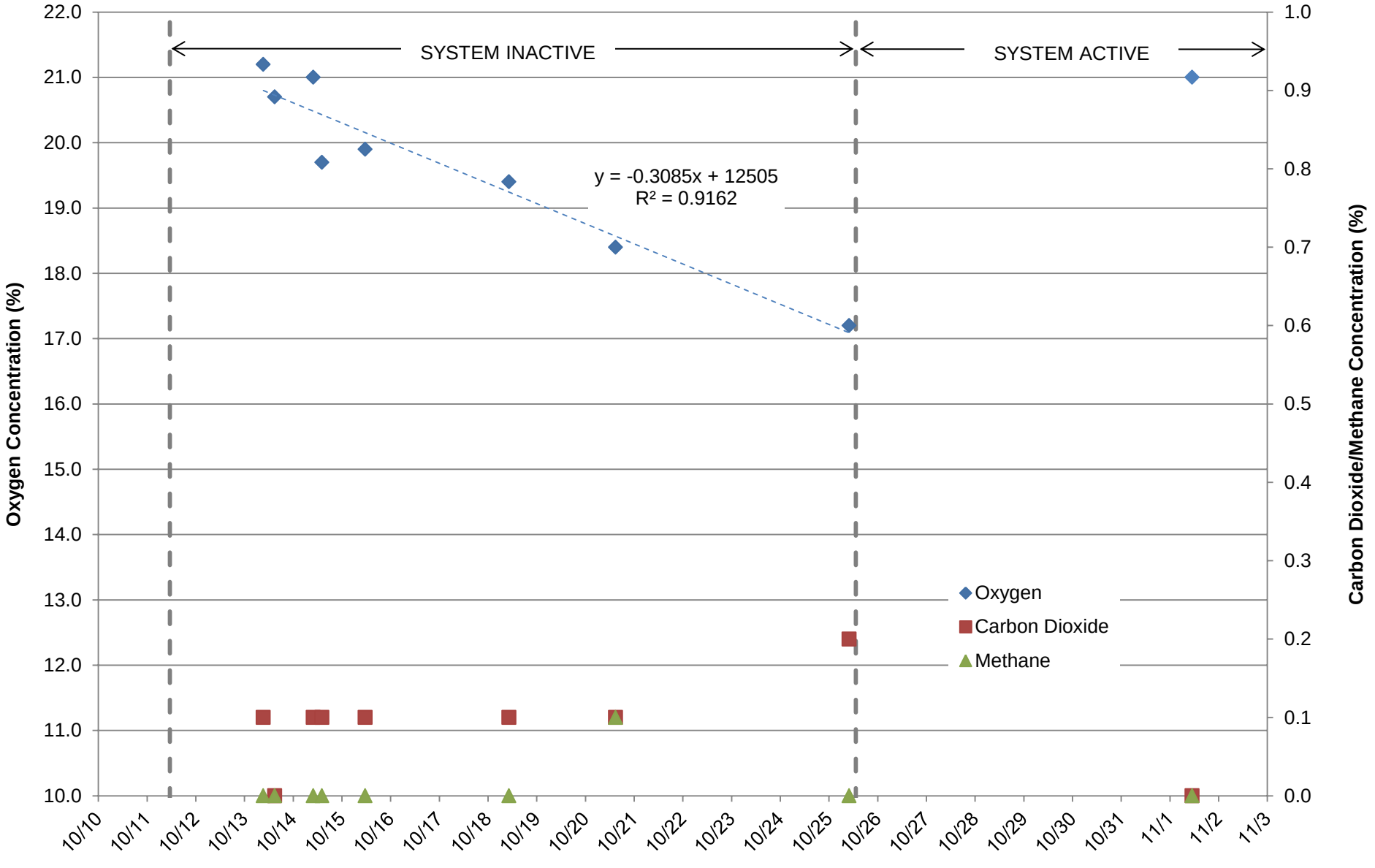


FIGURE E-13: GULF PARK VAPOR MONITORING POINT VP-10S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

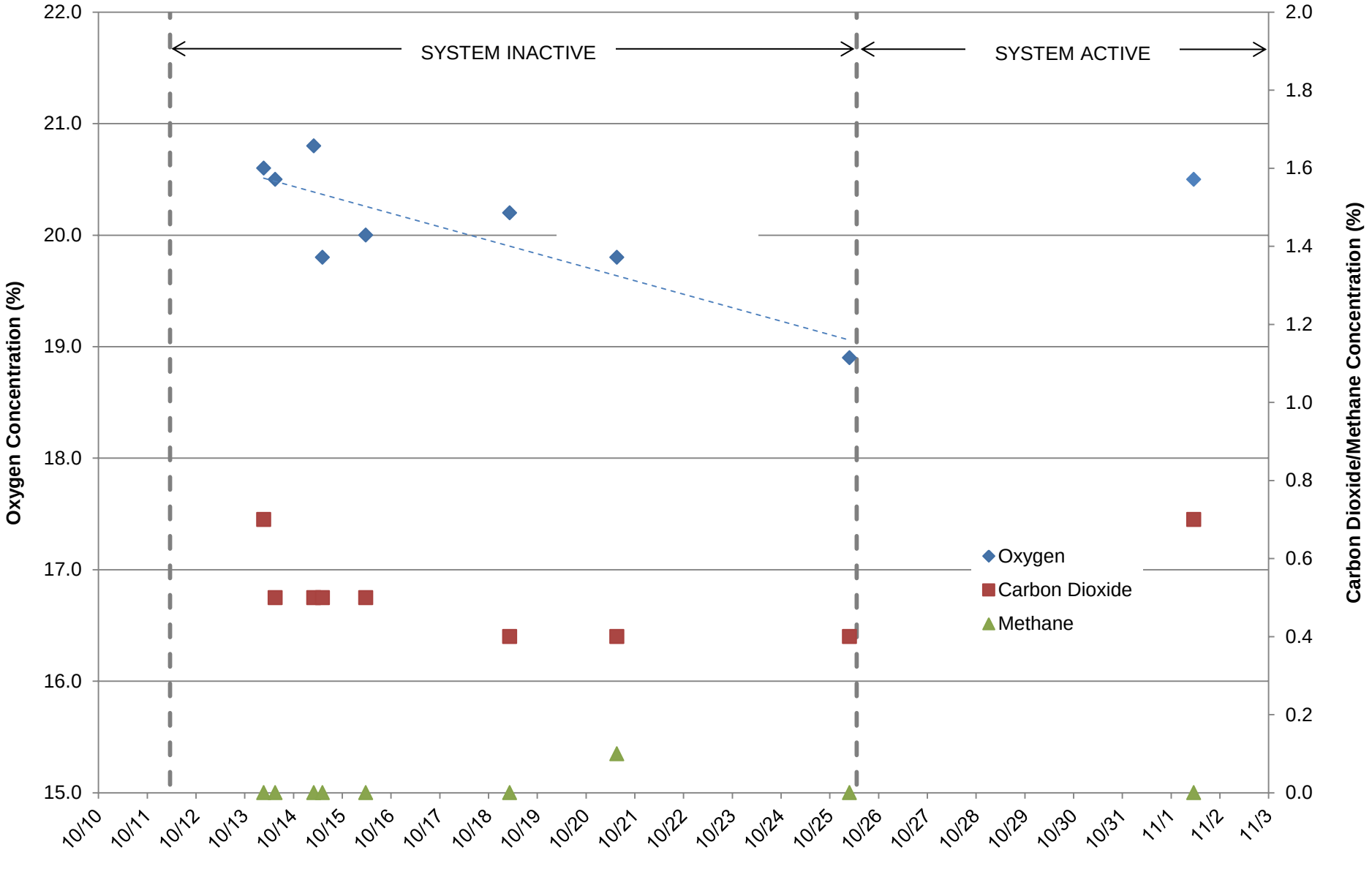


FIGURE E-14: GULF PARK VAPOR MONITORING POINT VP-10D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

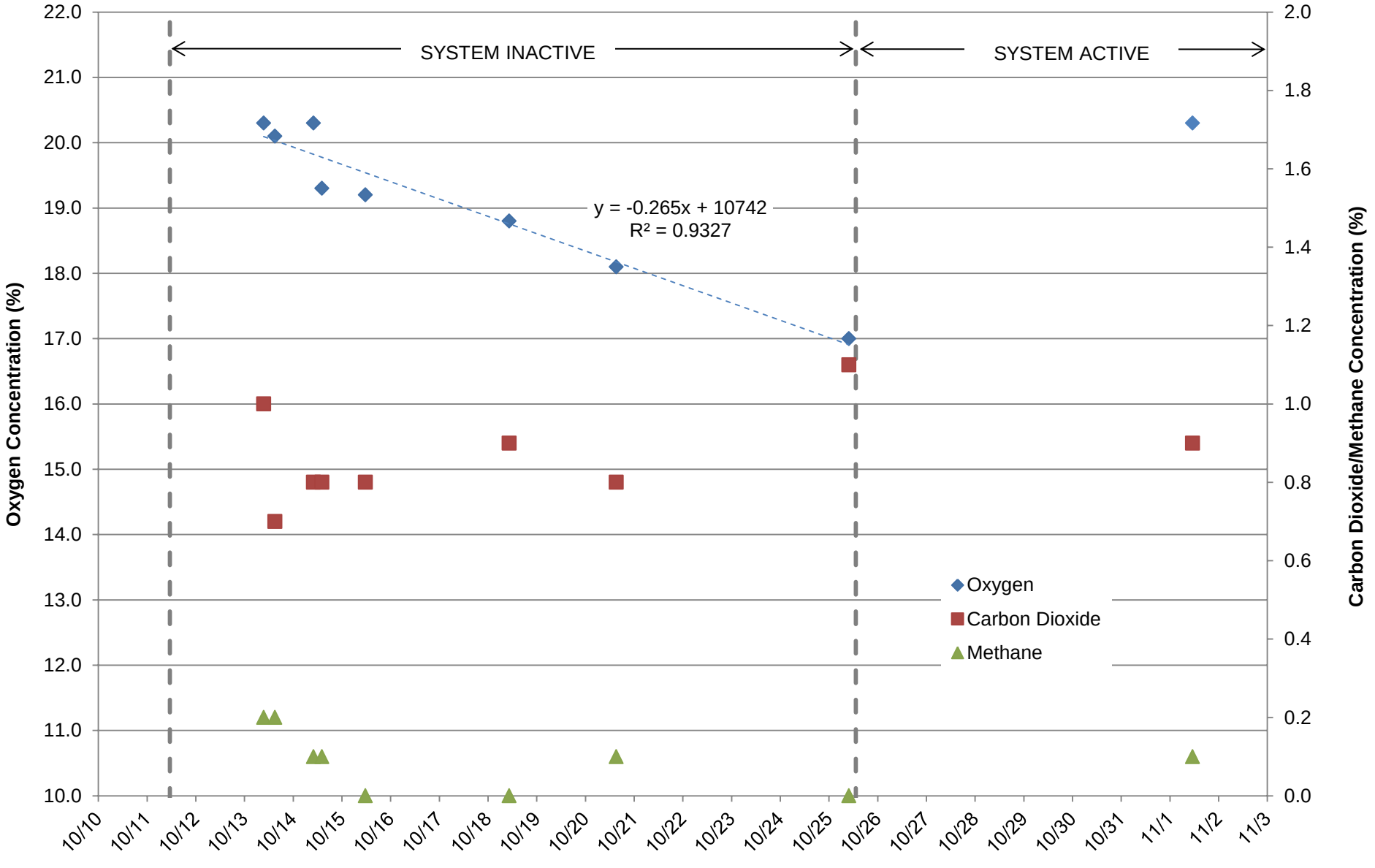


FIGURE E-15: GULF PARK VAPOR MONITORING POINT VP-11S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

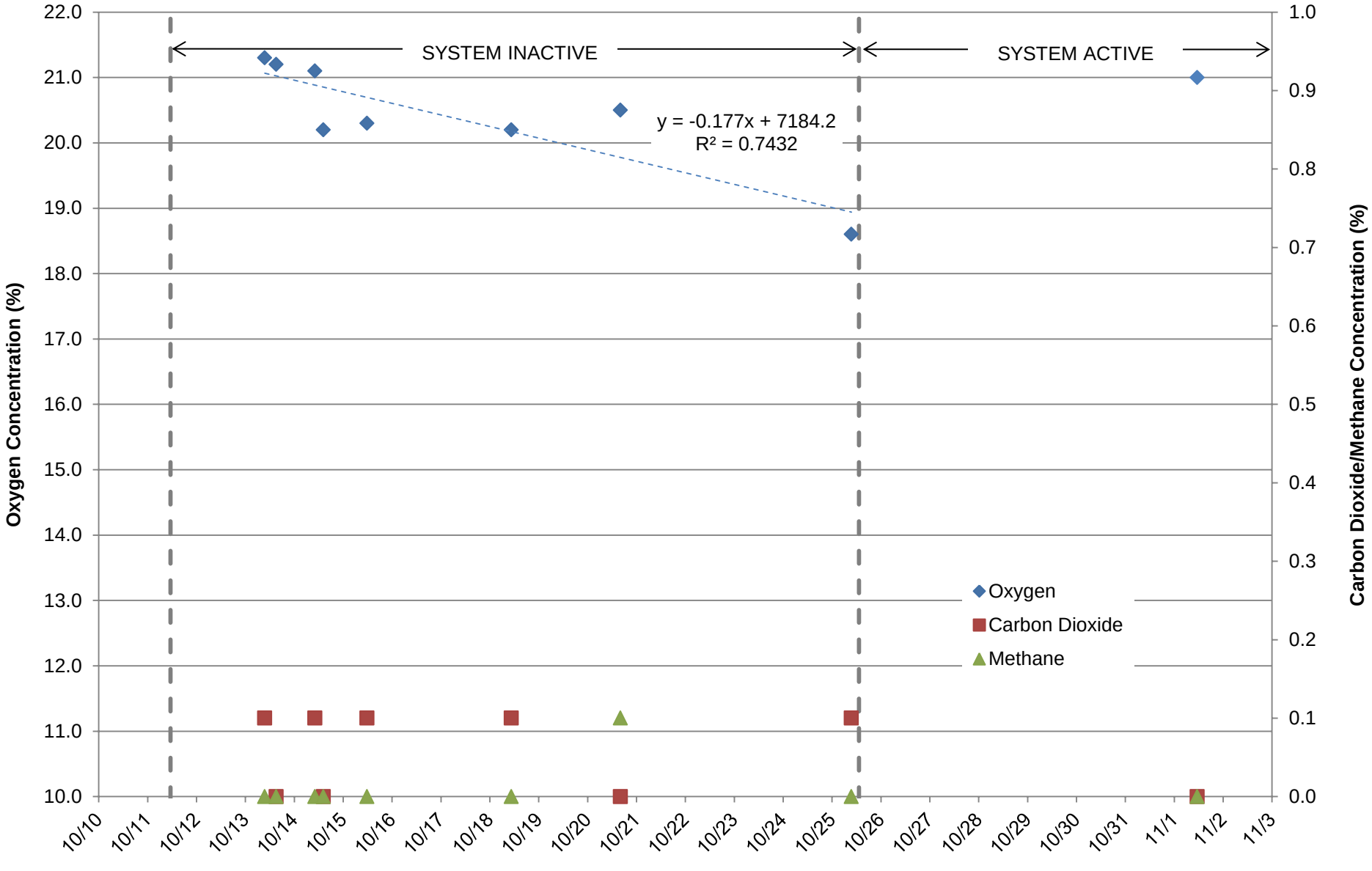


FIGURE E-16: GULF PARK VAPOR MONITORING POINT VP-11D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

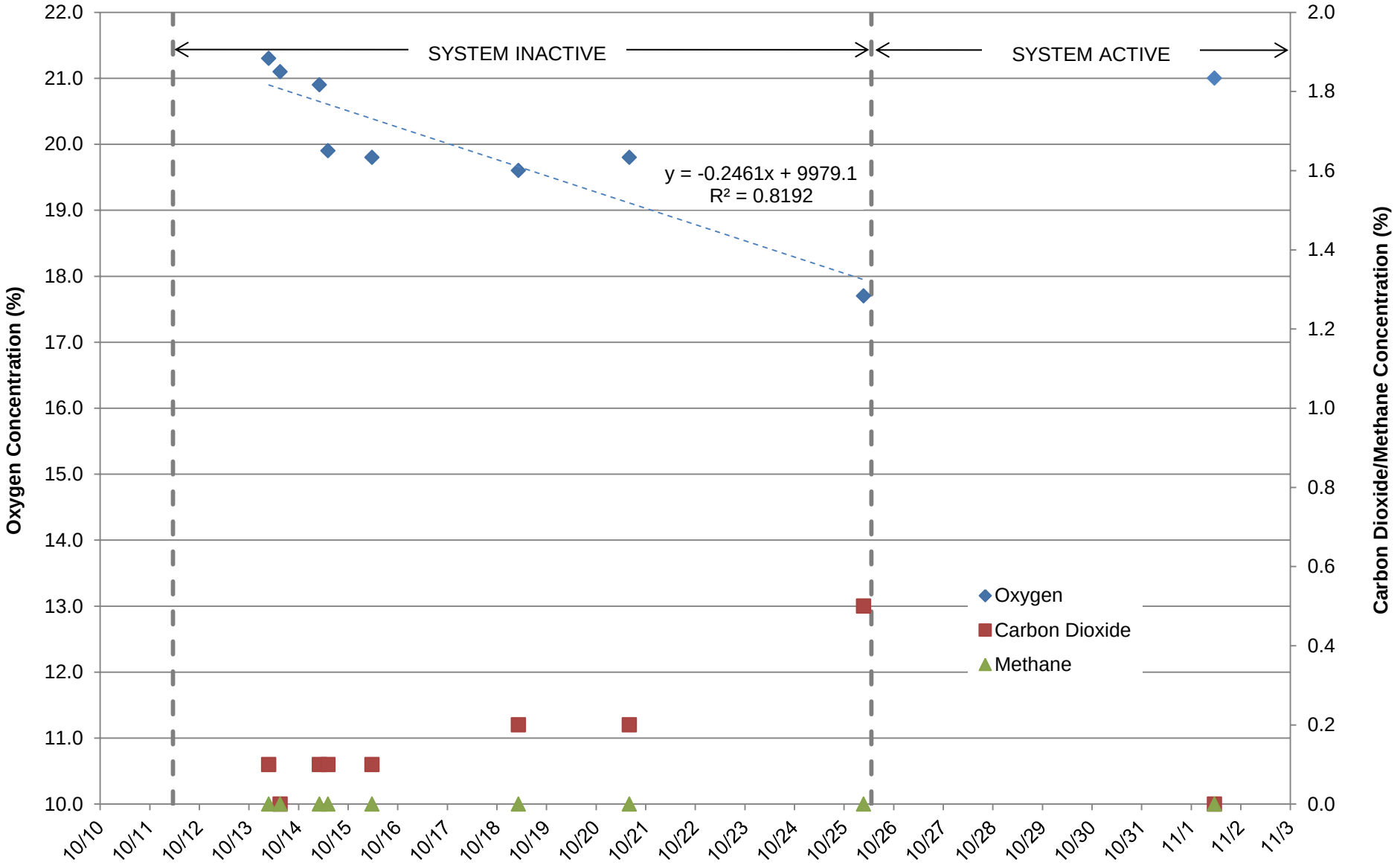


FIGURE E-17: GULF PARK VAPOR MONITORING POINT VP-12S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

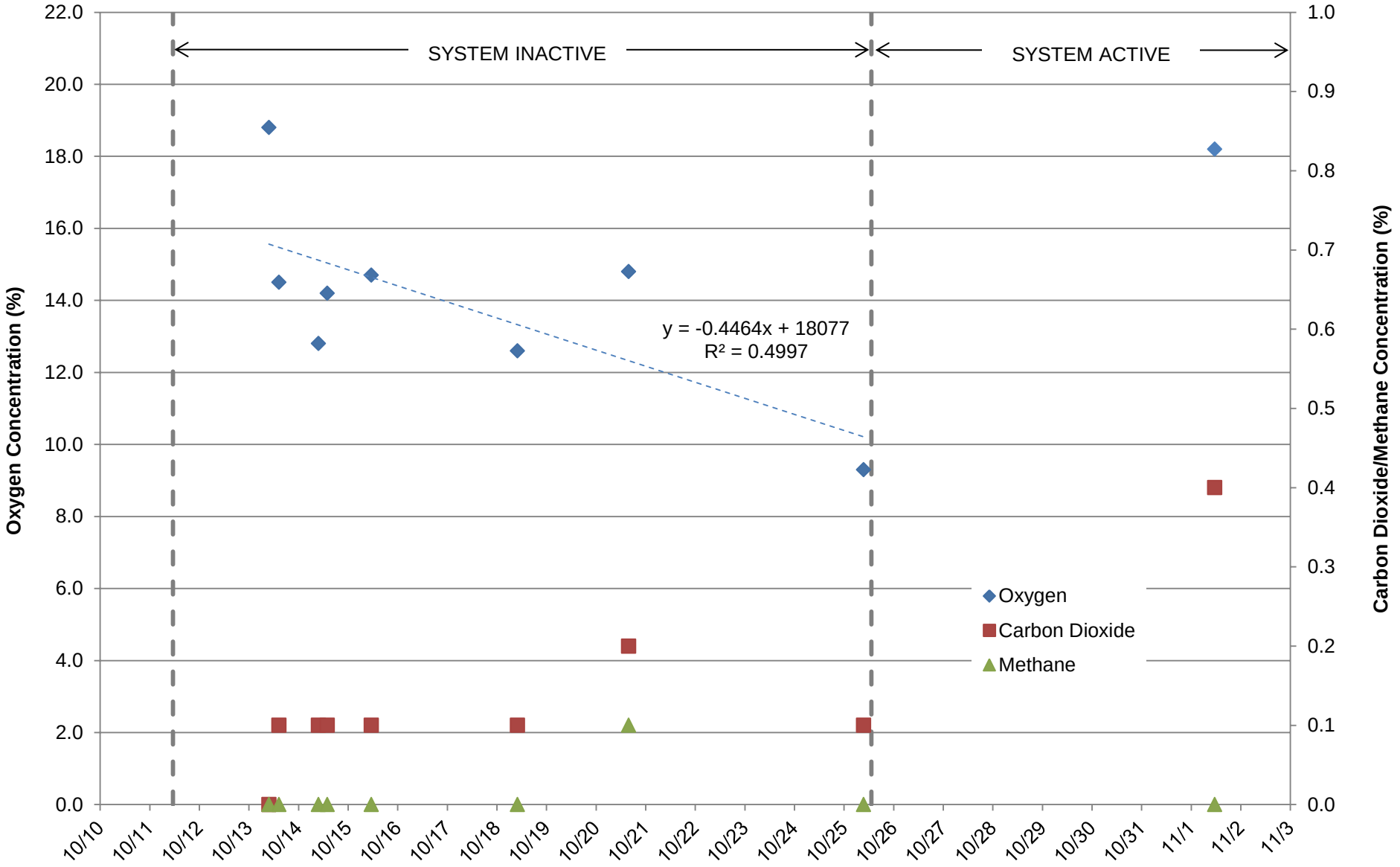


FIGURE E-18: GULF PARK VAPOR MONITORING POINT VP-12D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

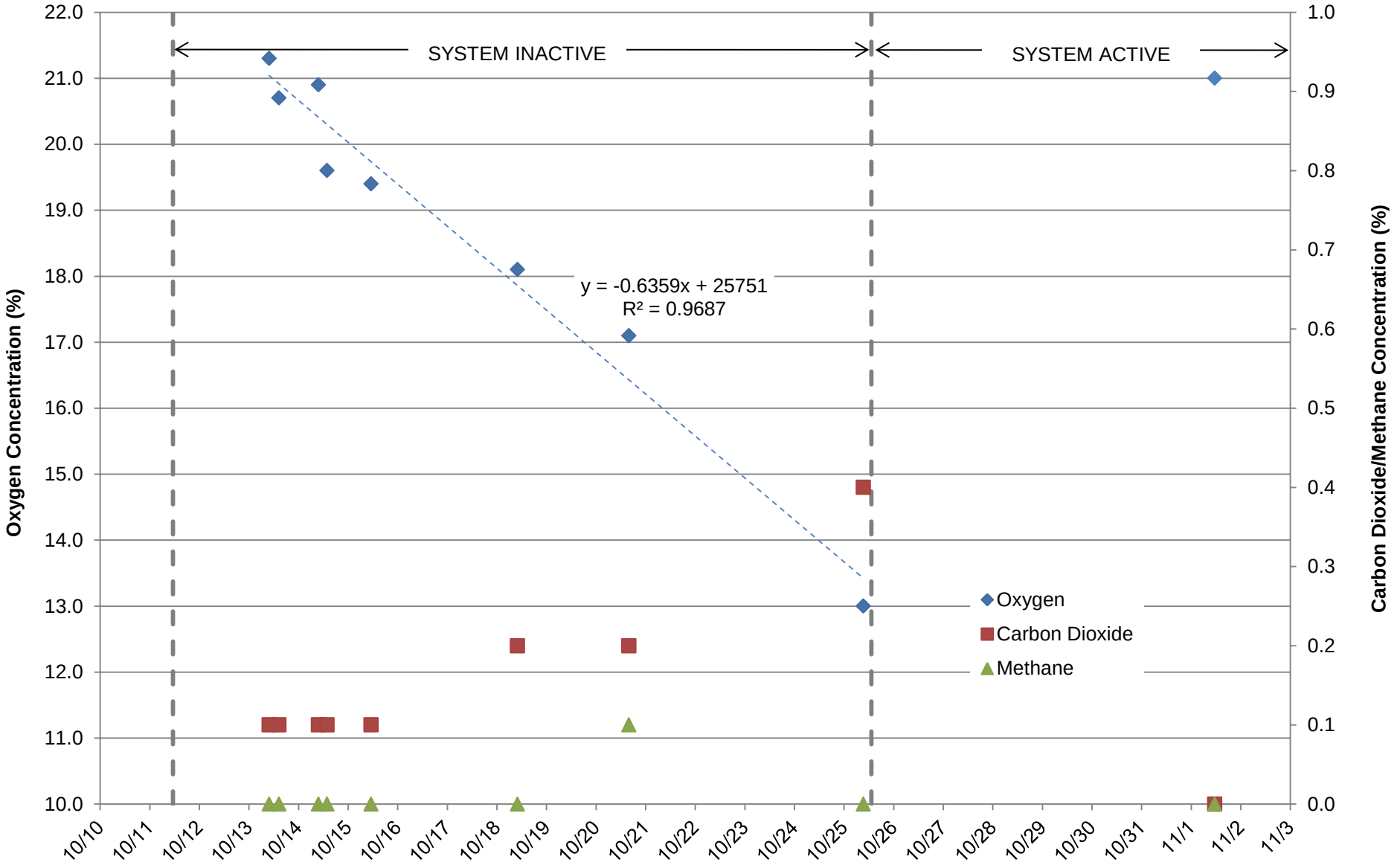


FIGURE E-19: GULF PARK VAPOR MONITORING POINT VP-13S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

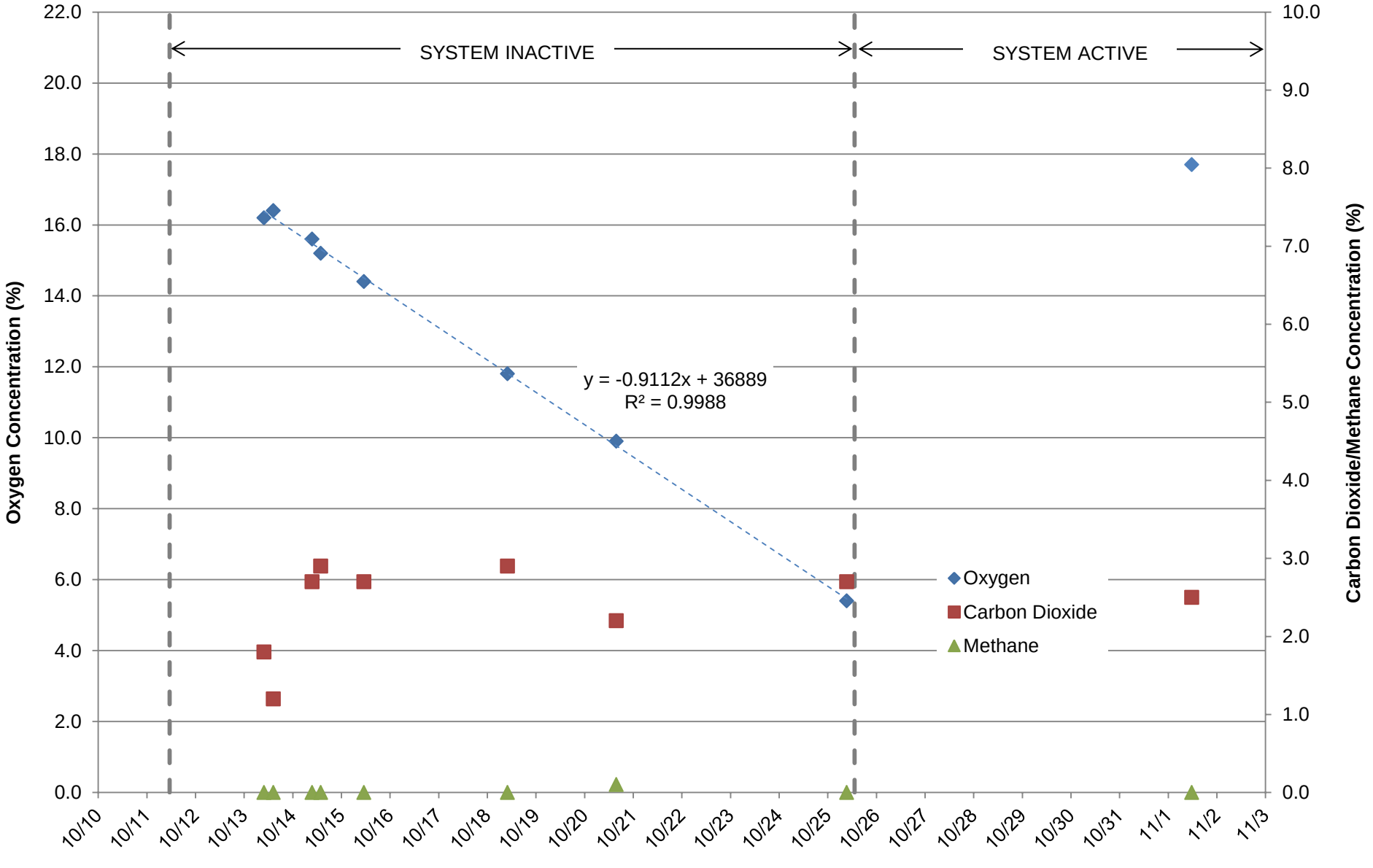


FIGURE E-20: GULF PARK VAPOR MONITORING POINT VP-13D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

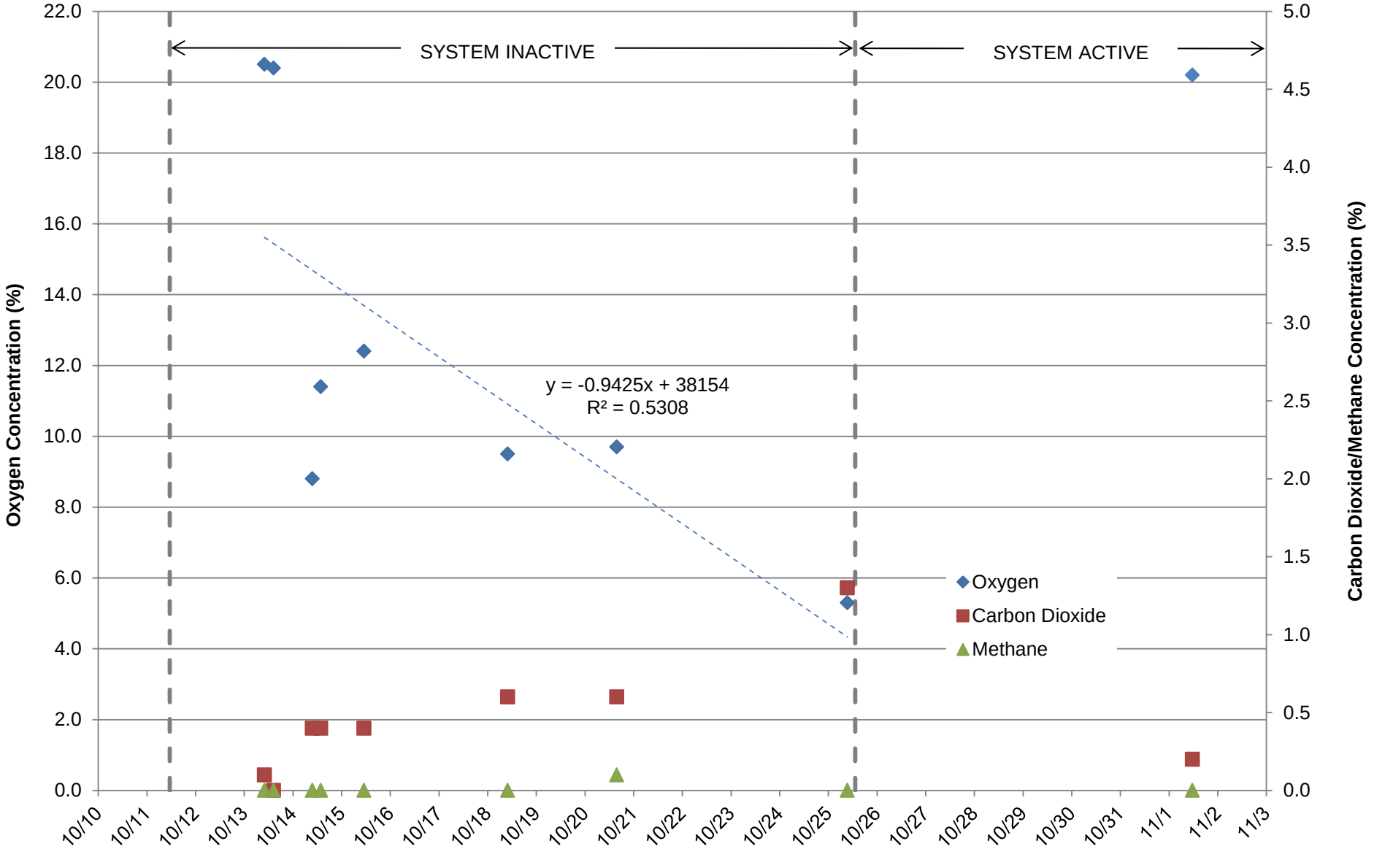


FIGURE E-21: GULF PARK VAPOR MONITORING POINT VP-14S FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO

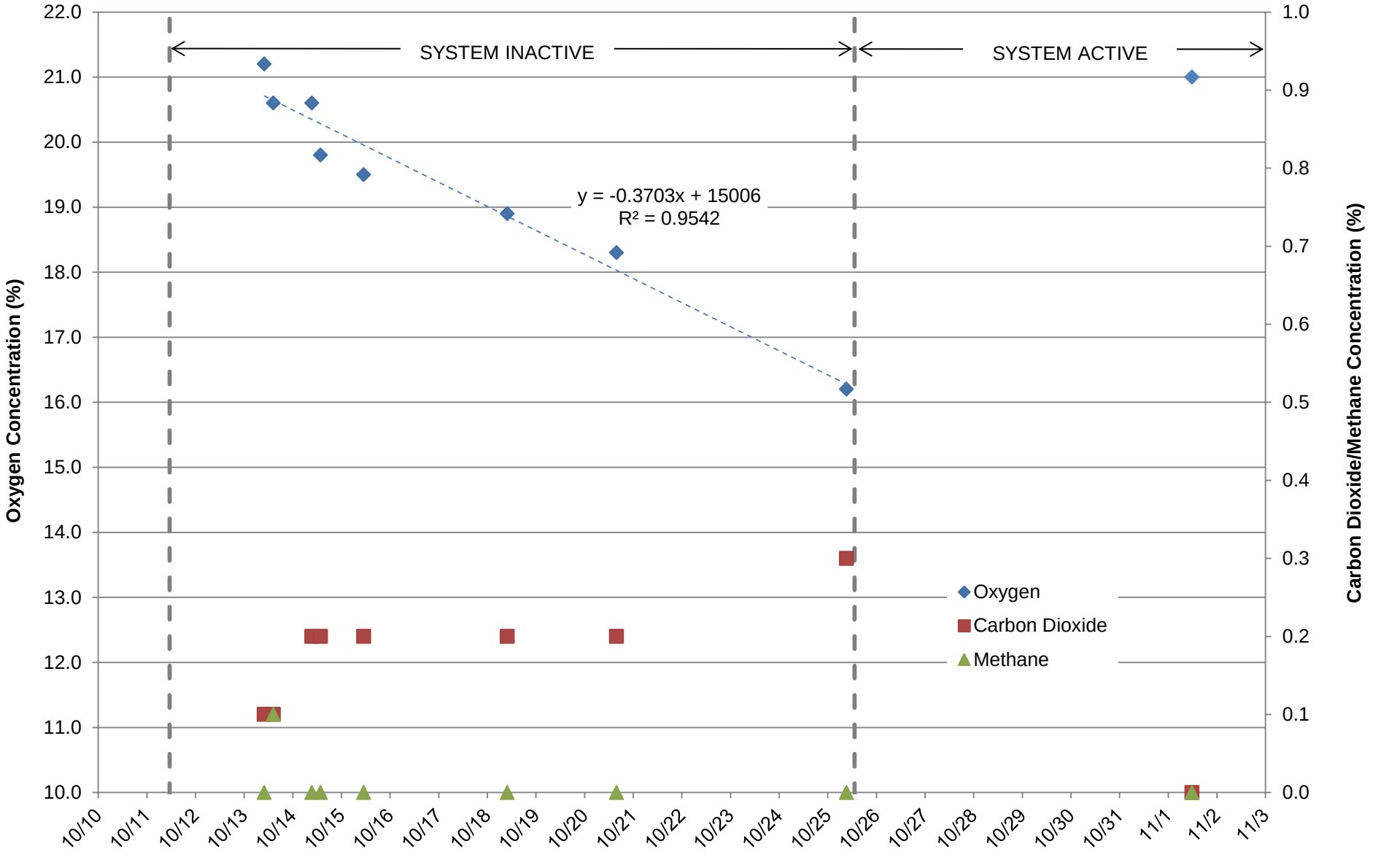


FIGURE E-22: GULF PARK VAPOR MONITORING POINT VP-14D FIXED GAS COMPOSITION VERSUS TIME
FIVE-YEAR GROUNDWATER CORRECTIVE MEASURES IMPLEMENTATION REVIEW
CHEVRON CINCINNATI FACILITY, HOOVEN, OHIO