November 8, 2011

Mr. David Burke
Mr. Ayman Ghobrial
Environmental Cleanup
Pennsylvania Department of Environmental Protection
2 East Main Street
Norristown, Pennsylvania 19401

**RE: Response Letter/Addendum to Agency Comments**
**Site Characterization/Remedial Investigation Report AOI 10**
**Sunoco, Inc.**
**Philadelphia Refinery**
**Philadelphia, Pennsylvania**

Dear Mr. Burke and Mr. Ghobrial:

The purpose of this letter is to provide responses to comments received by the Pennsylvania Department of Environmental Protection (PADEP) regarding the Site Characterization Report/Remedial Investigation Report (SCR/RIR) for AOI 10, dated June 29, 2011, prepared by Langan Engineering and Environmental Services, Inc. (Langan) on behalf of Sunoco Inc. (R&M) (Sunoco). Comments from the PADEP were received in a correspondence dated August 18, 2011. This response letter along with the attachments is meant to serve as an Addendum to the AOI 10 SCR/RIR.

Each comment provided by PADEP is noted below along with a response. Additional information for certain responses is included in the attachments to this letter.

**PADEP Comments/Conditions**

1. ***Following the requirements of Pennsylvania's Land Recycling Program/Technical Guidance Manual, the SWLOAD model must be utilized for all contaminants of concern to evaluate the mass loading of contaminants to surface water and ultimately to determine compliance with surface water quality criteria using PENTOXSD. Results from evaluating the migration of contaminants from groundwater to Lands Creek must be submitted as an addendum to the RIR and reviewed by the Department (DEP) prior to approving the report.***

**Response**

As described in the SCR/RIR, fate and transport calculations were completed for groundwater in AOI 10 to evaluate potential migration pathways/potential impacts to receptors. Eight monitoring wells (W-1, W-12, W-23, W-28, W-31, W-32, W-33, and W-34) in AOI 10 exhibited concentrations of groundwater constituents of concern (COCs) above their respective PADEP non-residential, used-aquifer (TDS<2,500) statewide health groundwater medium-specific concentrations (MSCs). The results from these monitoring wells were modeled using the PADEP's Quick Domenico (QD) model to determine whether COC concentrations could potentially reach the AOI 10 boundary. The modeling results indicate concentrations above the non-residential groundwater MSCs in monitoring wells W-1, W-12, W-23, W-28, W-31, W-32, and W-34 are not predicted to migrate beyond the AOI 10 boundary, with the exception of one well, W-33, which contains a concentration of benzene that has the potential to reach Lands Creek above the non-residential groundwater MSC. The QD-predicted benzene concentration at the Lands Creek boundary of 53 micrograms per liter (ug/L) is below the 25 Pa. Code Chapter 93 fish and aquatic life surface water quality criteria for benzene; however, to further assess the potential groundwater to surface water impact from benzene in well W-33, the PADEP's SWLOAD model was run for benzene. The input parameters for SWLOAD were the same as the input parameters used in the QD model. The edge criterion in SWLOAD is 5 ug/L which is the non-residential groundwater MSC for benzene. The distance between well W-33 and Lands Creek is 90 feet.

The SWLOAD model for W-33 predicted a benzene concentration of 51 ug/L along the centerline of the plume at the point of discharge to Lands Creek. This concentration is consistent with the QD-predicted concentration at this point. The SWLOAD model predicted the mass loading from benzene to Lands Creek to be 267 milligrams per day (mg/day). Because the predicted benzene concentration at the discharge point is above the edge criterion, the SWLOAD model suggests PENTOXSD is needed. PENTOXSD modeling was not completed because Lands Creek is an inland channel connected to the Schuylkill River and does not exhibit flow. An earthen berm is located between Lands Creek and the Schuylkill River further preventing any flow in the creek. Based on the ecological screening evaluation completed at AOI 10 and the sediment analytical results, an ecological risk assessment will be completed for Lands Creek. A copy of the revised fate and transport appendix for the SCR/RIR is included as Attachment A to this addendum.

2. ***Information regarding the API Model that was used to evaluate the distribution and the volume of the LNAPL was not included with the report.***

**Response**

As part of the Current Conditions Report and Comprehensive Remedial Plan (CCR) dated June 30, 2004 prepared for the Sunoco Philadelphia Refinery, light non-aqueous phase liquid (LNAPL) modeling was performed using the American Petroleum Institute (API) Model. A copy of the revised LNAPL Appendix from the AOI 10 SCR/RIR and the LNAPL modeling procedures, input parameters, and results are included as Attachment B to this addendum. During groundwater gauging activities for the CCR, LNAPL was identified in W-8 with a thickness of 0.01 feet and in W-14 with a thickness of 0.01 feet. A LNAPL sample was collected from W-8 and submitted to Torkelson Laboratories (Torkelson) of Tulsa, Oklahoma as part of the CCR site characterization activities. Torkelson identified the LNAPL in W-8 as a weathered residual oil. Based on the API modeling performed for the CCR, it was determined that the residual oil in W-8 was stable and immobile with a specific volume of $4.88e^{-10}$ feet and a seepage velocity of $2.45e^{-16}$ centimeters per second (cm/sec).

As discussed in the AOI 10 SCR/RIR, LNAPL was identified in W-8 (0.51 feet), W-14 (0.11 feet), and W-18 (0.01 feet). LNAPL samples were collected from all three monitoring wells and submitted to Torkelson for LNAPL typing analysis as part of the site characterization activities for the AOI 10 SCR/RIR. A summary of the LNAPL typing analysis is included in Attachment B. The quantity of sample submitted for W-18 was not sufficient for Torkelson to run LNAPL analysis but it appeared to be similar to the other LNAPL samples collected at W-14 and W-18. Based on the LNAPL characterization performed by Torkelson, the LNAPL types present in monitoring wells W-8 and W-14 consisted mainly of weathered residual oil, and is assumed to weathered residual oil in W-18. As part of this response letter, the API Model was updated to include the new LNAPL thickness value for W-8, W-14, and W-18. The input and output parameters of the updated API Model and seepage velocity calculations is presented in Attachment B as Tables B-1 through B-3, respectively of this response letter. In summary the updated LNAPL modeling outputs for W-8, W-14, and W-18 are as follows:

| Well ID | API Model Calculated LNAPL Specific Volumes (feet) | Calculated LNAPL Seepage Velocity (cm/sec) |
|---|---|---|
| W-8 | $4.41e^{-4}$ | $7.03e^{-10}$ |
| W-14 | $3.13e^{-6}$ | $4.84e^{-12}$ |
| W-18 | $2.13e^{-9}$ | $2.87e^{-15}$ |

Revised figures depicting the results of the LNAPL modeling are included in Attachment B as Figure B-1 - LNAPL Specific Volume and Figure B-2 - LNAPL Mobility Value.

Based on the LNAPL type (weathered residual oil) and the updated API Model output results, the weathered residual oil found in monitoring wells W-8, W-14, and W-18 is stable and immobile. Attachment B includes all of the information used to evaluate the distribution and volume of LNAPL in AOI 10.

3. ***The 1994 CCR indicates that site characterization activities were proposed in a "Corrective Measures Study Work Plan," dated April 1999. This document is not referenced in the SCR/RIR, so it is not clear whether the proposals in the 1999 document have been followed up. It would be useful if this were clarified.***

**Response**

As summarized in the AOI 10 Work Plan submitted to the PADEP and EPA on February 14, 2011, a number of RCRA corrective action investigations/reports were completed for AOI 10 between 1986 and 1997. The Corrective Measures Study (CMS) Work Plan was prepared in April 1997 by ENSR Consulting and Engineering on behalf of Sunoco, not in April of 1999 which was an incorrect reference in the CCR. In preparation of the AOI 10 Work Plan, theses RCRA investigations, reports, and correspondence, including the 1997 CMS Work Plan, were reviewed to develop the site characterization activities carried out in AOI 10.

The 1997 CMS Work Plan stated that, based on the RFI data, there were no further data gaps to initiate CMS activities at the CAMU. However, the 1997 CMS Work Plan laid out objectives for the CAMU to assure that there is no unacceptable exposure to waste on the ground surface and that potential exposures to subsurface materials are controlled or eliminated. The 1997 CMS Work Plan included potential alternative corrective measures such as institutional controls or covering, that could be implemented as result of the CMS.

Between 1997 and 1999, correspondence was exchanged between Sunoco and EPA regarding proposed revisions to the 1997 CMS Work Plan. In February of 1999, as a final response to the EPA's comments to the 1997 CMS Work Plan, Sunoco recommended that all soil data (surface and subsurface) be screened against PA Act 2 non-residential soil MSCs and any constituent above its respective soil MSC be considered a constituent of potential concern (COPC). Subsequent correspondence between Sunoco and EPA concluded that areas with COPC concentrations above the PA Act 2 non-residential soil MSCs would be further investigated. To develop the scope of work in the 2011 AOI 10 Work Plan for Site Characterization, the historic RFI data from both inside and outside of the CAMU were screened against current PA Act 2 MSCs. Results of this screening process were used to develop the COC list and sampling locations for characterization activities at the CAMU. Any area that had historic soil concentrations above the current PA Act 2 non-residential soil MSCs was further investigated during the AOI 10 site characterization activities though soil borings and sampling. In addition, the extent of the waste materials in the CAMU was delineated through borings.

Based on the recent site characterization activities and results, limited shallow soil samples were identified above their respective non-residential soil MSCs. The plan for these areas will include delineation and remediation to be addressed in the combined Ecological Risk Assessment and Cleanup Plan for AOI 10 as further described in the response to Comment 4 below.

4. ***The total cumulative risk for exposure to carcinogens is 3.65E-04, greater than the acceptable risk of 1.0E-04. The RIR proposes that the cumulative risk for exposure to carcinogens will be re-evaluated after addressing the areas with lead and benzo (a) pyrene that show concentrations above the calculated site-specific values. Additional remediation may be requested should the total cumulative risk not meet the Risk Target of 1.0E-04.***

**Response**

Sunoco acknowledges that remediation of locations with lead and benzo(a)pyrene above the calculated site specific values may not be enough to reduce the total cumulative risk of exposure to carcinogens below the acceptable risk level of $1.0e^{-04}$. Therefore, additional locations with higher detections of these compounds may also be selected for remediation with the goal to reduce the total cumulative risk to below $1.0e^{-4}$. These areas will be addressed by Sunoco through implementation of a remedy that will be presented in a combined Ecological Risk Assessment and Cleanup Plan for AOI 10.

5. ***Based on the ecological screening performed, and due to the presence of contaminated sediments along Lands Creek, the RIR proposes additional ecological evaluation. Results will be documented in the Cleanup Plan.***

**Response**

Sunoco and Langan will complete an ecological evaluation of Lands Creek in accordance with Act 2. The results of the ecological evaluation will be presented in a combined Ecological Risk Assessment and Cleanup Plan for AOI 10.

6. ***It is noted that the Pennsylvania Natural Heritage Inventory has indicated the possible presence of threatened or endangered species. Lands Creek is a tidal waterway, and probably has associated wetlands (although the presence of wetlands is not documented in the SC/RIR). It is possible that Exceptional Value Wetlands are present. (Exceptional Value Wetlands are defined in PA Code Title 25, Chapter 105, Section 105-17.)***

**Response**

A natural resources figure is presented in Attachment C of this response letter. The floodway and flood hazard areas depicted on the map were derived from the Digital Flood Insurance Rate Map Database (DFIRM) for Pennsylvania, by the federal Emergency Management Agency (FEMA) 2005. The wetlands depicted, which are all located off-site of AOI 10, were obtained from the National Wetlands Inventory (NWI) for Pennsylvania by the U.S. Fish and Wildlife Service (USFWS) published in September 25, 2009. Based on the current FEMA and NWI mapping databases, as shown on the figure presented in Attachment C, there are no known mapped wetlands within AOI 10. Therefore, the presence of exceptional value wetlands is highly unlikely, however as part of the ecological risk assessment (as described in Response No. 5 above), AOI 10 will be further evaluated for the presence of such wetlands.

7. ***Because of the likelihood of future development activity nearby, natural resources such as Lands Creek take on a particular significance as potential loci for targeted restoration, or creation of wetlands. Wetland creation opportunities may be sought by developers of projects who have mitigation obligations pursuant to the regulations that protect wetlands from destruction. Although Sunoco has no obligation to offer their property to others for the purpose of mitigation, DEP wishes to make sure that Sunoco is aware of this factor, which could play a role***

***in Sunoco's decision-making regarding the future disposition of the property at AOI-10.***

**<u>Response</u>**

Sunoco is aware and appreciates the PADEP's mention of this opportunity.

We hope this response letter and report addendum adequately addresses the department's comments. Should you have any questions regarding these items, or have further comments, please contact Jim Oppenheim of Sunoco at 610.833.3444.

Sincerely,
**Langan Engineering and Environmental Services, Inc.**

Dennis Webster
Project Manager

Jason Hanna
Senior Project Manager

Colleen Costello, P.G.
Senior Principal

Attachments:

A – Revised Appendix G from AOI 10 SCR/RIR - Fate and Transport Analysis
B – Revised Appendix F from AOI 10 SCR/RIR - LNAPL Modeling Procedures & Results
C – AOI 10 Existing Natural Resources Plan

cc: Steve O'Neil, PADEP
Hon Lee, US EPA
James Oppenheim, Sunoco, Inc
Tiffani Doerr, Aquaterra
Jennifer Menges, Stantec

# ATTACHMENT A

Revised Appendix G from AOI 10 SCR/RIR –

Fate and Transport Analysis

**ATTACHMENT A**
**REVISED APPENDIX G FROM THE JUNE 29, 2011 AOI 10 SCR/RIR**
**FATE AND TRANSPORT MODELING PROCEDURES**
**AOI 10: SUNOCO PHILADELPHIA REFINERY**
**PHILADELPHIA, PENNSYLVNIA**

## QUICK DOMENICO MODELING

## A.1 INTRODUCTION

Fate and transport calculations were completed for groundwater in Area of Interest (AOI) 10 to evaluate potential migration pathways/potential impacts to receptors. Eight wells (W-1, W-12, W-23, W-28, W-31, W-32, W-33, and W-34) in AOI 10 exhibited concentrations of groundwater compounds of concern (COCs) above their respective MSCs. The COCs above the MSCs include benzene, chrysene, naphthalene and lead. The COCs that were above the MSCs in these wells were modeled using the analytical results from the April 2011 groundwater sampling event, and the Quick Domenico Version 2 (QD) spreadsheet model developed by Pennsylvania Department of Environmental Protection (PADEP). Site-specific data was used to complete the fate and transport calculations, when available.

## A.2 MODEL OVERVIEW

The QD Model is a Microsoft Excel spreadsheet application based on the analytical contaminant transport equation developed by P.A. Domenico in *"An Analytical Model For Multidimensional Transport of a Decaying Contaminant Species,"* Journal of Hydrology, 91 (1987), pp. 49-58. The QD model calculates contaminant concentrations at any down-gradient location after a specified interval of time. The model incorporates the processes of advection, first order decay, retardation, and dispersion to describe fate and transport of compounds. In addition, the QD model displays the results as a two dimensional chart to facilitate interpretation of the results.

## A.3 MODEL LIMITATIONS

Limitations of the QD model include:

- Groundwater flow is assumed to be steady state, and one-dimensional;
- Aquifer properties are assumed to be reasonably uniform;
- Applicable only to unconsolidated aquifers;
- Intended for use primarily with dissolved organic compounds;

- Does not account for the transformation of parent compounds into daughter products as the result of biodegradation;
- Compounds are considered individually, and are assumed to not react with each other; and
- The contaminant source is limited to a single and continuous source concentration.

## A.4 MODEL INPUT PARAMTERS

In preparation of the June 2011 SCR/RIR, input values for the QD model were compiled from available site-specific data. When no site-specific data was available, estimated input values from the PADEP spreadsheet "Number Please! 2011" which is based on PA Code, Chapter 250, Appendix A, Table 5, or other acceptable literature sources, were utilized. The input parameters are discussed in detail in the following sections and are summarized in the input/output tables for each model (Tables A.1 through A.8). An Excel spreadsheet interface was used to construct the QD simulations. This interface allowed the simulation of all relevant compounds at each well location to be constructed and saved in a single electronic file.

### A.4.1 Source Concentration

Results of the April 2011 groundwater sampling indicated that three organic compounds (benzene, chrysene and naphthalene) and one metal (lead) were detected above their respective groundwater MSCs in shallow wells (W-1, W-12, W-23, W-28, W-31, W-32, W-33, and W-34). The potential for these compounds to migrate offsite (beyond property boundary or discharge to the Schuylkill River) was evaluated through the use of the QD model.

### A.4.2 Distance to Location of Concern (x)

Distance to the Location of Concern (distance) for the current simulations is the distance required for each COCs concentration to fall below its respective MSC under steady-state plume conditions. The distance is iteratively entered using the Excel "Solver" Add-on in the QD model until the location where the COC concentration falls below the MSC is identified. This step is performed using a large simulation time of 1 x $10^{99}$ days to ensure that the plume has reached steady-state.

### A.4.3 Dispersivity

Dispersivity is the tendency of a dissolved plume to "spread out" as it moves down-gradient.

- Longitudinal dispersivity ($A_X$) occurs in the direction parallel to groundwater flow;
- Transverse dispersivity ($A_Y$) occurs in the same plane as longitudinal dispersivity but perpendicular to the direction of groundwater flow; and
- Vertical dispersivity ($A_Z$) occurs in the upward direction, normal to the plane in which longitudinal and transverse dispersivity occur (Vertical dispersivity is usually negligible and is typically omitted from most QD analyses).

Dispersivity estimates are difficult to quantify and are commonly estimated from the following relationships:

1. $A_X$ = X/10 (where, X is the distance a contaminant has traveled by advective transport)
2. $A_Y = A_X/10$
3. $A_Z = A_X/20$ to $A_X/100$ (generally, it is recommended that $A_Z$ be a very small number (0.001) unless vertical monitoring can reliably justify a larger number. Additionally, a value of 0.0001 is suggested for uncalibrated or conceptual applications).

As stated above the value for $A_Y$ was estimated to be 10 percent of $A_X$. A value of 0.001 was used as a value for $A_Z$. A longitudinal dispersivity of 200 feet was assumed which is also the longitudianal dispersivity used in the CCR.

### A.4.4 Lambda

Lambda is the first order decay constant. It is determined by dividing 0.693 by the half-life of the compound. The value can typically be estimated for shrinking plumes by evaluating at concentrations versus time or distance. Lambda can also sometimes be estimated for stable plumes by evaluating concentration versus time using the methodology outlined in Buscheck and Alcantar (1995). Important considerations to estimating Lambda from site data include:

1. Are the measured concentrations along the centerline of the plume?
2. Are the measured concentrations the result of the single source area?
3. Are there no remedial systems and/or activities that effected the migration of the plume during the time interval of evaluation?

If the answer is yes to these questions, then the methodologies outlined in Buscheck and Alcantar may be utilized to estimate a site-specific lambda from site data.

Based on review of the available site data, the criteria necessary to calculate a site-specific lambda could not be met; therefore, a default value for lambda (when appropriate and available) was obtained from the PADEP spreadsheet "Number Please! 2011" which is based on PA Code, Chapter 250, Appendix A, Table 5. For the lead simulation, the lambda value was set to zero.

### A.4.5 Source Dimensions

Source width is the maximum width of the area measured perpendicular to the direction of groundwater flow. Source thickness is the thickness of the contaminated soils below the water table that contribute contamination to groundwater. In addition to the saturated zone, fluctuation in groundwater elevation may create a smear zone in the unsaturated portion of an aquifer. As an estimate of the thickness of the smear zone, average fluctuation can be used. An assumed source width of 100 ft was used for wells in AOI 10. An assumed source thicknesses of 60 feet (ft) was used for wells in AOI 10. This thickness is the average saturated thickness of the upper unconfined aquifer based on cross sections DD-DD' and EE-EE.'

### A.4.6 Hydraulic Conductivity (K)

The hydraulic conductivity of a geologic material is a measure of its ability to transmit water. A hydraulic conductivity of 4.64 ft/d was used in the AOI 10 QD simulations. This value was the average hydraulic conductivity of the fill/alluvium at the site, obtained from the CCR. The wells that were modeled are screened in the fill/alluvium.

### A.4.7 Hydraulic Gradient

Hydraulic gradient is the change in hydraulic head relative to the distance between head measurement locations. The hydraulic gradient is measured parallel to the direction of ground water flow assuming horizontal flow and a uniform gradient. Using the groundwater elevations collected in April 2011, the hydraulic gradient value was estimated between W-31 and W-16 and is 0.0046. This hydraulic gradient was used as a conservatively high estimation for all eight QD simulations.

### A.4.8 Porosity (n)

Porosity is measured as the ratio of the volume of void space in a geologic material to the total volume of material. A porosity of 0.35 was used in the fate and transport modeling and is based on historical geotechnical analysis of site alluvial sediments.

### A.4.9 Soil Bulk Density ($p_b$)

Soil bulk density is the dry weight of a sample divided by the total volume of the sample in an undisturbed state. Soil bulk density can either be determined by a laboratory or by the equation

$$p_b = 2.65 * (1- n).$$

Soil bulk density value used in the fate and transport modeling was 1.72 gm/cm$^3$ which is based on historical geotechnical analysis.

### A.4.10 Organic Carbon Partition Coefficient (KOC)

The organic carbon partition coefficient is chemical specific and was taken from the PADEP EP spreadsheet "Number Please! 2011" which is based on PA Code, Chapter 250, Appendix A, Table 5. Koc is chemical specific and can be found in the QD model input-out tables.

### A.4.11 Fraction Organic Carbon (foc)

The fraction of organic carbon is the organic carbon content of a soil. A laboratory using ASTM methods can determine this value. Samples for organic carbon are taken from the same soil horizon in which the contaminant occurs, but outside of the impacted area. Since no site specific fraction of organic carbon data was available for the site, the fate and transport modeling used the model-recommended default concentration of 0.005, which is a conservative value based on the description of site soils.

### A.4.12 Time (t)

'Time zero' is the point at which contamination was introduced into the aquifer. Time since 'time zero' is measured in days. The final simulation time of $1 \times 10^{99}$ days was used to ensure that a steady-state plume was simulated.

## A.5 QD OUTPUT DATA AND RESULTS

A spreadsheet for each well, for which a QD simulation was performed, is included in this appendix. The inputs for each model are summarized in Tables A.1 through A.8 and the model spreadsheets are provided for each well. Table A.9 is a summary of the QD modeling results. This table summarizes the QD-model predicted distance for each COC to reach its Act 2 non-residential groundwater MSC. The table also compares this predicted distance to the downgradient point of compliance distance.

The modeling results indicate concentrations above the groundwater MSCs in shallow wells W-1, W-12, W-23, W-28, W-31, W-32, and W-34 are not predicted to migrate beyond the AOI 10 boundary, with the exception of one well, W-33, which contains a concentration of benzene that has the potential to reach Lands Creek. The QD-predicted benzene concentration at the Lands Creek boundary (53 ug/L) is below the 25 Pa. Code Chapter 93 fish and aquatic life surface water quality criteria for benzene; however, to further assess the potential groundwater to surface water impact from benzene in well W-33, the PADEP's SWLOAD model was run for benzene. This model is discussed in the following section.

**SWLOAD MODELING**

## A.6 INTRODUCTION

Based on the results of the QD modeling described above, a SWLOAD model was prepared for benzene in well W-33.

## A.7 SW LOAD MODEL OVERVIEW

The SWLOAD model is Microsoft Excel spreadsheet applications based on the analytical contaminant transport equation developed by P.A. Domenico in *"An Analytical Model For Multidimensional Transport of a Decaying Contaminant Species,"* Journal of Hydrology, 91 (1987), pp. 49-58. The SWLOAD model calculates groundwater contaminant concentrations just before discharge to surface water and the volume of groundwater discharged to surface water. SWLOAD incorporates the processes of advection, first order decay, retardation, and dispersion to describe fate and transport of compounds.

## A.8 MODEL LIMITATIONS

Limitations of the SWLOAD models include:

- Groundwater flow is assumed to be steady state, and one-dimensional;
- Aquifer properties are assumed to be reasonably uniform;
- Applicable only to unconsolidated aquifers;
- Intended for use primarily with dissolved organic compounds;
- Does not account for the transformation of parent compounds into daughter products as the result of biodegradation;
- Compounds are considered individually, and are assumed to not react with each other; and
- The contaminant source is limited to a single and continuous source concentration.

## A.9 MODEL INPUT PARAMTERS

The input parameters of the SWLOAD model for W-33 are the same parameters used in the QD model described above.

### A.9.1 Edge Criterion

The maximum predicted groundwater concentration adjacent to a surface water body is compared to the edge criterion. For benzene, the edge criterion entered into the SWLOAD model is 5 ug/L, benzene's Act 2 non-residential groundwater MSC. If the maximum predicted plume concentration exceeds the edge criterion, then the model suggests whether additional evaluation using PENTOXSD is necessary.

### A.9.2 Distance to Stream

The distance between well W-33 and Lands Creek is 90 feet.

## A.10 SWLOAD RESULTS

A copy of the SWLOAD model spreadsheet for well W-33 is included at the end of this appendix. The SWLOAD model for W-33 predicted a benzene concentration of 51 ug/L along the centerline of the plume at the point of discharge to Lands Creek. This concentration is consistent with the QD-predicted concentration at this point. The SWLOAD model predicted the mass loading from benzene to Lands Creek to be 267 mg/day. Because the predicted benzene concentration at the discharge point is above the edge criterion, the SWLOAD model suggests PENTOXSD is needed. PENTOXSD modeling was not completed because Lands Creek is an inland channel connected to the Schuylkill River and does not exhibit flow. An earthen berm is located between Lands Creek and the Schuylkill River further preventing any flow in the creek. Sunoco plans to conduct additional ecological assessment activities at Lands Creek.

# QD SIMULATIONS

**Table A.1**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

| | |
|---|---|
| Project | 2574601 - Sunoco Philadelphia Refinery |
| Prepared by | Terrance Stanley |
| Date Prepared | 11/1/2011 |

| Generic Input Parameters | | | | Data Source |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-01** | |
| Sample Date | | | 4/27/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| Chemical Specific Input Parameters | | | | Data Source |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | benzene | |
| Source Concentration (mg/L) | | mg/L | 0.0200 | 4/27/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.001 | PADEP Number Please! 2011 |
| KOC | | | 58 | PADEP Number Please! 2011 |

**Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)**

| Contaminant | Starting Concentration (mg/L) | GW MSC[1] Non-Residential (mg/L) | Predicted Concentration (mg/L) | Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot) |
|---|---|---|---|---|
| Sim 1 - benzene | 0.0200 | 0.005 | 0.005 | **80** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 11/1/2011 Prepared by: Terrance Stanley
Contaminant: benzene

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

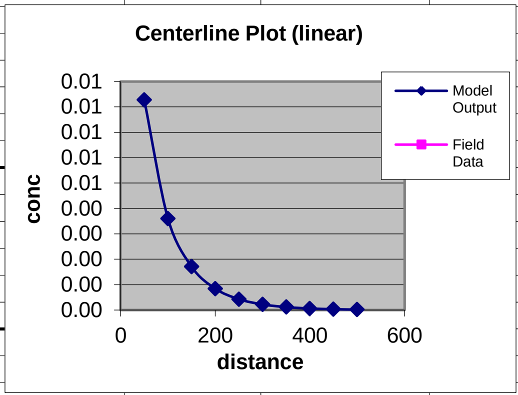
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.0009589 | 100 | 60 | 1E+99 |

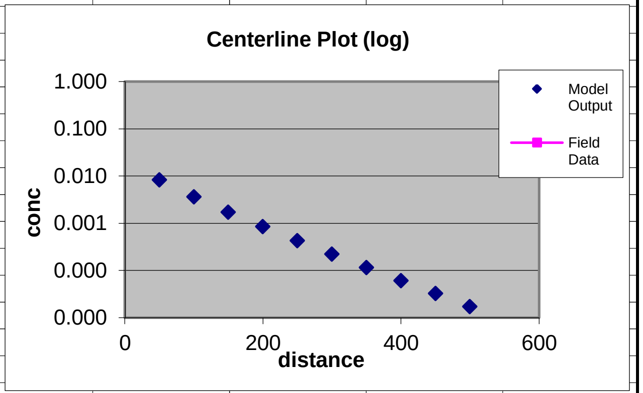
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density ($g/cm^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214286 | 0.025124628 |

## Point Concentration

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 79.52845346 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 79.52845346 | 0 | 0 |
| at | 1E+99 | days = | 0.005 mg/l |




AREAL CALCULATION
MODEL DOMAIN
Length (ft) 500
Width (ft) 100

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.005 | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.008 | 0.004 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.005 | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Field Data: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Centerline Concentration | | | | | | | |
| | Distance from Source | | | | | | | |

Table A.1 W-01 QD2 Model
SIM 1

**Table A.2**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

| | |
|---|---|
| Project | 2574601 - Sunoco Philadelphia Refinery |
| Prepared by | Terrance Stanley |
| Date Prepared | 11/1/2011 |

| **Generic Input Parameters** | | | | **Data Source** |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-12** | |
| Sample Date | | | 4/26/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| **Chemical Specific Input Parameters** | | | | **Data Source** |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | benzene | |
| Source Concentration (mg/L) | | mg/L | 0.0080 | 4/26/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.001 | PADEP Number Please! 2011 |
| KOC | | | 58 | PADEP Number Please! 2011 |

| **Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)** | | | | |
|---|---|---|---|---|
| **Contaminant** | **Starting Concentration (mg/L)** | **GW MSC[1] Non-Residential (mg/L)** | **Predicted Concentration (mg/L)** | **Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot)** |
| Sim 1 - benzene | 0.0080 | 0.005 | 0.005 | **28** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

| | | | |
|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley |
| | | Contaminant: | benzene |

NEW QUICK_DOMENICO.XLS

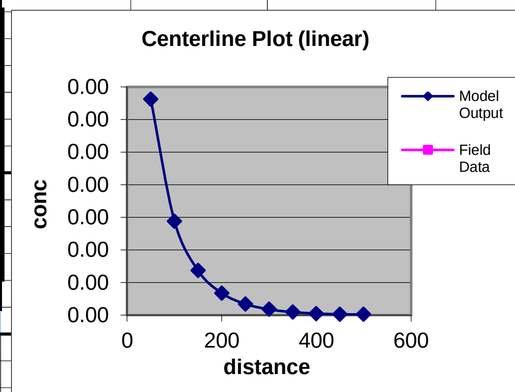
SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

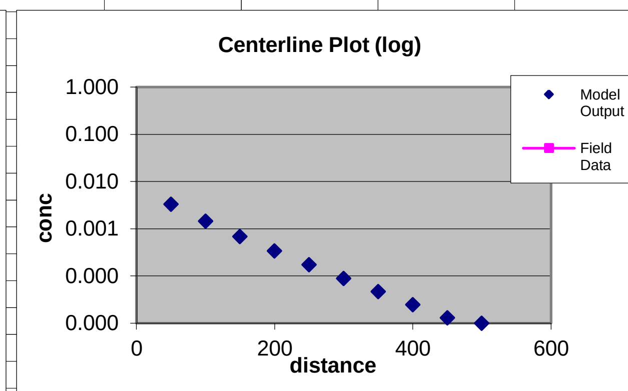
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.0009589 | 100 | 60 | 1E+99 |

| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density ($g/cm^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214286 | 0.025124628 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) | |
|---|---|---|---|
| 28.18057593 | 0 | 0 | |
| | x(ft) | y(ft) | z(ft) |
| Conc. At | 28.18057593 | 0 | 0 |
| at | 1E+99 | days = | **0.005** mg/l |




AREAL CALCULATION MODEL DOMAIN

| | |
|---|---|
| Length (ft) | 500 |
| Width (ft) | 100 |

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Field Data:** | **Centerline C Concentration** | | | | | | | |
| | **Distance from Source** | | | | | | | |

Table A.2 W-12 QD2 Model
SIM 1

**Table A.3**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

| | |
|---|---|
| Project | 2574601 - Sunoco Philadelphia Refinery |
| Prepared by | Terrance Stanley |
| Date Prepared | 11/1/2011 |

| **Generic Input Parameters** | | | | **Data Source** |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-23** | |
| Sample Date | | | 4/27/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| **Chemical Specific Input Parameters** | | | | **Data Source** |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | benzene | |
| Source Concentration (mg/L) | | mg/L | 0.0120 | 4/27/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.001 | PADEP Number Please! 2011 |
| KOC | | | 58 | PADEP Number Please! 2011 |

| **Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)** | | | | |
|---|---|---|---|---|
| **Contaminant** | **Starting Concentration (mg/L)** | **GW MSC[1] Non-Residential (mg/L)** | **Predicted Concentration (mg/L)** | **Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot)** |
| Sim 1 - benzene | 0.0120 | 0.005 | 0.005 | **50** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

| | | | |
|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley |
| | | Contaminant: | benzene |

NEW QUICK_DOMENICO.XLS

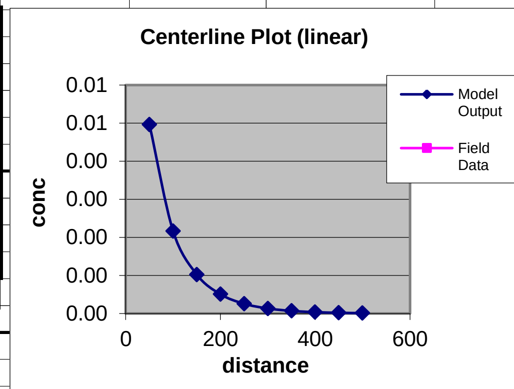
SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

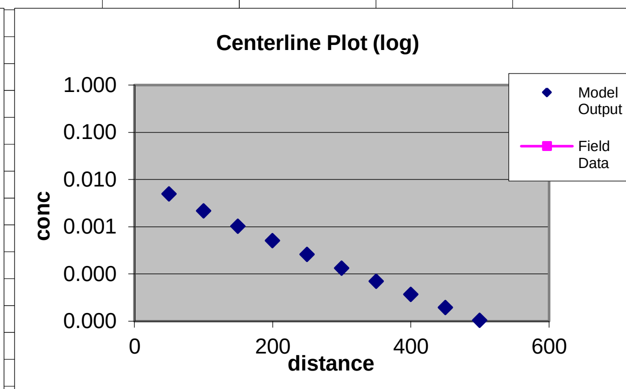
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.0009589 | 100 | 60 | 1E+99 |

| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm³) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214286 | 0.025124628 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) | |
|---|---|---|---|
| 49.70922802 | 0 | 0 | |
| | x(ft) | y(ft) | z(ft) |
| Conc. At | 49.70922802 | 0 | 0 |
| at | 1E+99 | days = | 0.005 mg/l |




| AREAL MODEL | CALCULATION DOMAIN |
|---|---|
| Length (ft) | 500 |
| Width (ft) | 100 |

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.003 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.005 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.003 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Field Data: | Centerline C Concentration | | | | | | | |
| | Distance from Source | | | | | | | |

Table A.3 W-23 QD2 Model
SIM 1

**Table A.4**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

| | |
|---|---|
| Project | 2574601 - Sunoco Philadelphia Refinery |
| Prepared by | Terrance Stanley |
| Date Prepared | 11/1/2011 |

| Generic Input Parameters | | | | Data Source |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-28** | |
| Sample Date | | | 4/27/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| Chemical Specific Input Parameters | | | | Data Source |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | chrysene | |
| Source Concentration (mg/L) | | mg/L | 0.0020 | 4/27/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.000 | PADEP Number Please! 2011 |
| KOC | | | 490000 | PADEP Number Please! 2011 |

**Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)**

| Contaminant | Starting Concentration (mg/L) | GW MSC[1] Non-Residential (mg/L) | Predicted Concentration (mg/L) | Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot) |
|---|---|---|---|---|
| Sim 1 - chrysene | 0.0020 | 0.002 | 0.002 | **<1** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

| | | | |
|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley |
| | | Contaminant: | chrysene |

NEW QUICK_DOMENICO.XLS

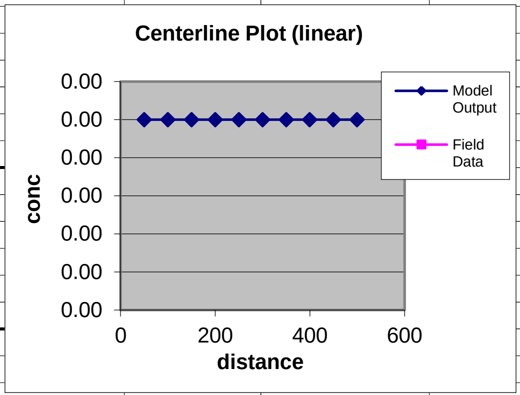
SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

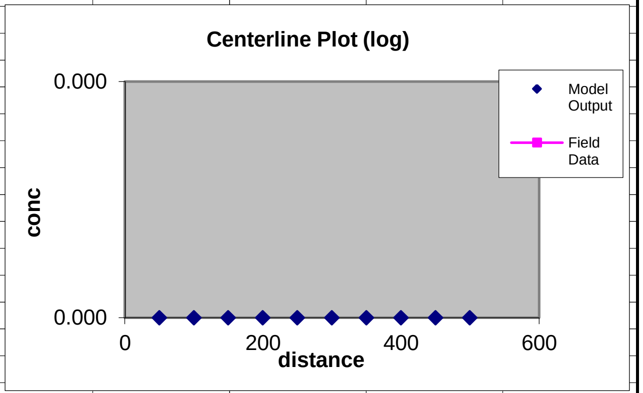
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.00035616 | 100 | 60 | 1E+99 |

| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density ($g/cm^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 490000 | 5.00E-03 | 12058.5 | 5.05725E-06 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) | |
|---|---|---|---|
| <1 | 0 | 0 | |
| | x(ft) | y(ft) | z(ft) |
| Conc. At | <1 | 0 | 0 |
| at | 1E+99 | days = | #VALUE! mg/l |




| AREAL MODEL | CALCULATION DOMAIN |
|---|---|
| Length (ft) | 500 |
| Width (ft) | 100 |

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Field Data: | Centerline C Concentration | | | | | | | |
| | Distance from Source | | | | | | | |

Table A.4 W-28 QD2 Model
SIM 1

**Table A.5**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

Project 2574601 - Sunoco Philadelphia Refinery
Prepared by Terrance Stanley
Date Prepared 11/1/2011

| Generic Input Parameters | | | | Data Source |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-31** | |
| Sample Date | | | 4/26/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium based on site-wide slug testing |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| Chemical Specific Input Parameters | | | | Data Source |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | benzene | |
| Source Concentration (mg/L) | | mg/L | 0.0100 | 4/26/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.001 | PADEP Number Please! 2011 |
| KOC | | | 58 | PADEP Number Please! 2011 |
| **Sim 2** | | | | |
| Contaminant | | | chrysene | |
| Source Concentration (mg/L) | | mg/L | 0.0040 | 4/26/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.000 | PADEP Number Please! 2011 |
| KOC | | | 490000 | PADEP Number Please! 2011 |
| **Sim 3** | | | | |
| Contaminant | | | lead | |
| Source Concentration (mg/L) | | mg/L | 0.0060 | 4/26/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.000 | PADEP Number Please! 2011 |
| KOC | | | 0.000 | PADEP Number Please! 2011 |

| Output (Distance from Source Where Concentration Equals Respective Ground Water MSC) | | | | |
|---|---|---|---|---|
| **Contaminant** | **Starting Concentration (mg/L)** | **GW MSC[1] Non-Residential (mg/L)** | **Predicted Concentration (mg/L)** | **Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot)** |
| Sim 1 - benzene | 0.0100 | 0.005 | 0.005 | **40** |
| Sim 2 - chrysene | 0.0040 | 0.002 | 0.002 | **1** |
| Sim 3 - lead | 0.0060 | 0.005 | 0.005 | **32** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

| | | | |
|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley |
| | | Contaminant: | **benzene** |

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

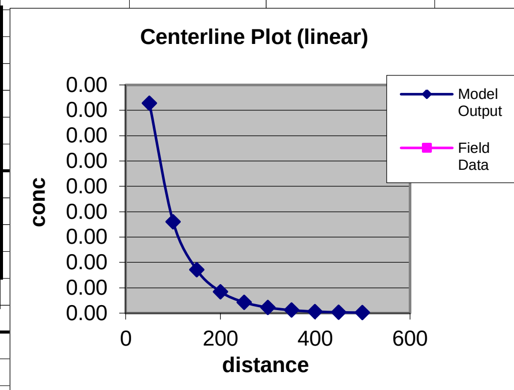
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.0009589 | 100 | 60 | 1E+99 |

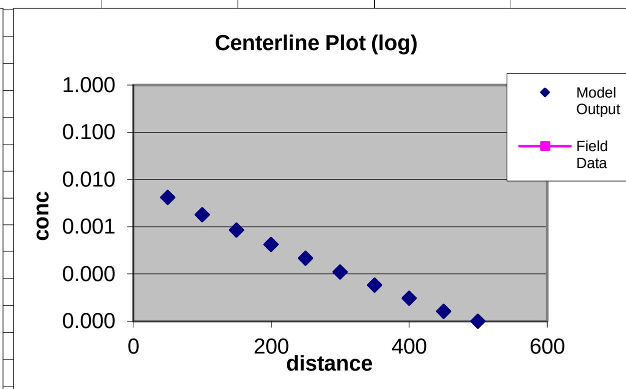
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm$^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214286 | 0.025124628 |

## Point Concentration

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 39.81038943 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 39.81038943 | 0 | 0 |
| at | 1E+99 | days = | **0.005** mg/l |




| AREAL MODEL | CALCULATION DOMAIN |
|---|---|
| Length (ft) | 500 |
| Width (ft) | 100 |

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| *100* | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *50* | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *0* | 0.004 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *-50* | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *-100* | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Field Data:** | **Centerline C Concentration** | | | | | | | |
| | **Distance from Source** | | | | | | | |

Table A.5 W-31 QD2 Model
SIM 1

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

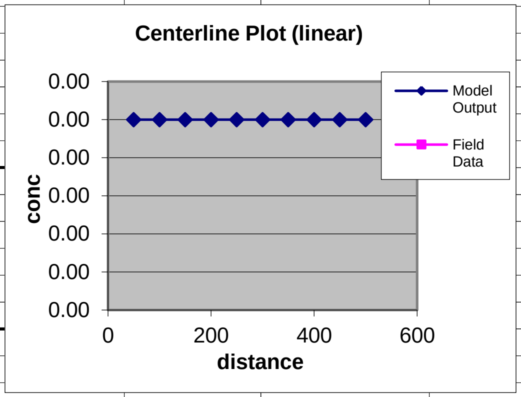
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | | | | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley | | | | |
| | | Contaminant: | chrysene | | | | |
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.00035616 | 100 | 60 | 1E+99 |
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm³) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 490000 | 5.00E-03 | 12058.5 | 5.05725E-06 |

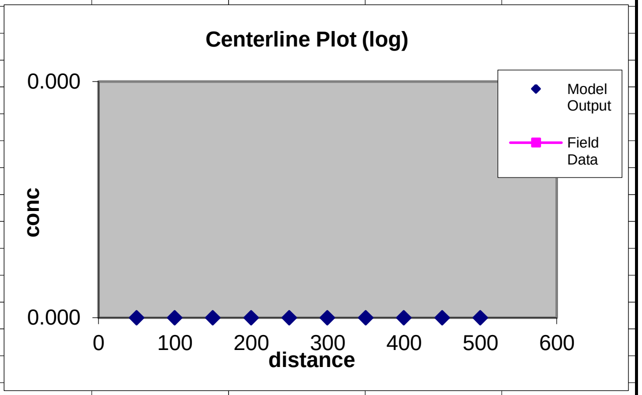
NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

**Point Concentration**

| x(ft) | y(ft) | z(ft) | |
|---|---|---|---|
| 1.180890581 | 0 | 0 | |
| | x(ft) | y(ft) | z(ft) |
| Conc. At | 1.180890581 | 0 | 0 |
| at | 1E+99 | days = | **0.002** mg/l |




AREAL CALCULATION
MODEL DOMAIN

| | |
|---|---|
| Length (ft) | 500 |
| Width (ft) | 100 |

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Field Data:** | **Centerline C Concentration** | | | | | | |
| | **Distance from Source** | | | | | | |

Table A.5 W-31 QD2 Model
SIM 2

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

| | | | |
|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley |
| | | Contaminant: | lead |

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

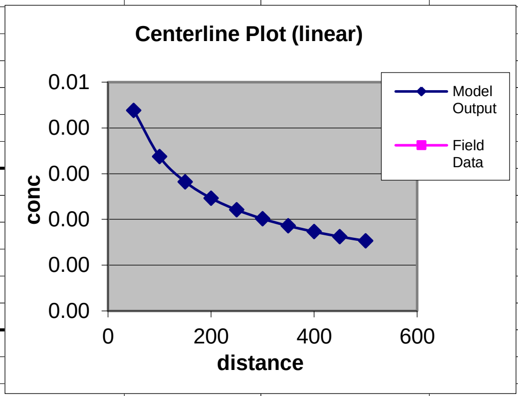
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.00001 | 100 | 60 | 1E+99 |

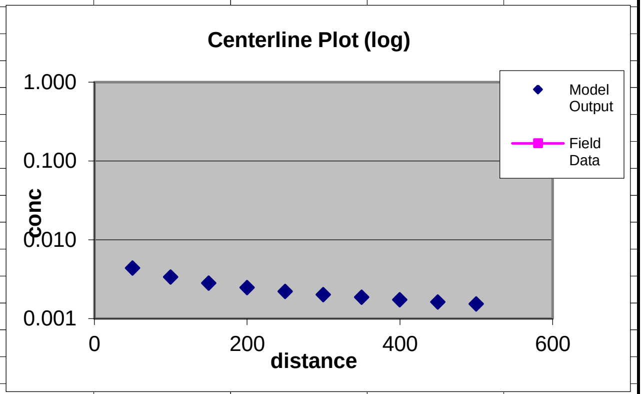
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density ($g/cm^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 0.00001 | 5.00E-03 | 1.000000246 | 0.060982842 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 32.06690731 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 32.06690731 | 0 | 0 |
| at | 1E+99 | days = | **0.005** mg/l |




**AREAL CALCULATION MODEL DOMAIN**

Length (ft) 500
Width (ft) 100

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| 50 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 |
| 0 | 0.004 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| -50 | 0.003 | 0.003 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 |
| -100 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

**Field Data:** Centerline C Concentration
Distance from Source

Table A.5 W-31 QD2 Model
SIM 3

**Table A.6**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

| | |
|---|---|
| Project | 2574601 - Sunoco Philadelphia Refinery |
| Prepared by | Terrance Stanley |
| Date Prepared | 11/1/2011 |

| Generic Input Parameters | | | | Data Source |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-32** | |
| Sample Date | | | 4/27/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| Chemical Specific Input Parameters | | | | Data Source |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | benzene | |
| Source Concentration (mg/L) | | mg/L | 0.0560 | 4/27/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.001 | PADEP Number Please! 2011 |
| KOC | | | 58 | PADEP Number Please! 2011 |
| **Sim 2** | | | | |
| Contaminant | | | chrysene | |
| Source Concentration (mg/L) | | mg/L | 0.0040 | 4/27/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.000 | PADEP Number Please! 2011 |
| KOC | | | 490000 | PADEP Number Please! 2011 |

**Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)**

| Contaminant | Starting Concentration (mg/L) | GW MSC[1] Non-Residential (mg/L) | Predicted Concentration (mg/L) | Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot) |
|---|---|---|---|---|
| Sim 1 - benzene | 0.0560 | 0.005 | 0.005 | **147** |
| Sim 2 - chrysene | 0.0040 | 0.002 | 0.002 | **1** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

| | | | |
|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley |
| | | Contaminant: | benzene |

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

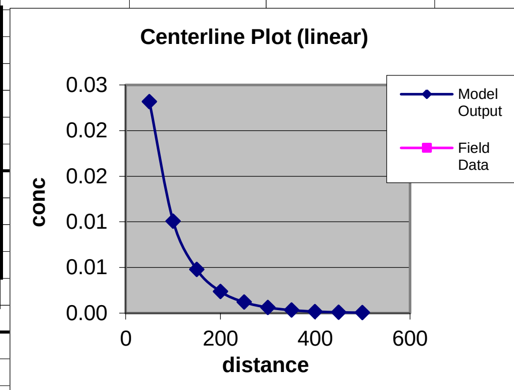
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.0009589 | 100 | 60 | 1E+99 |

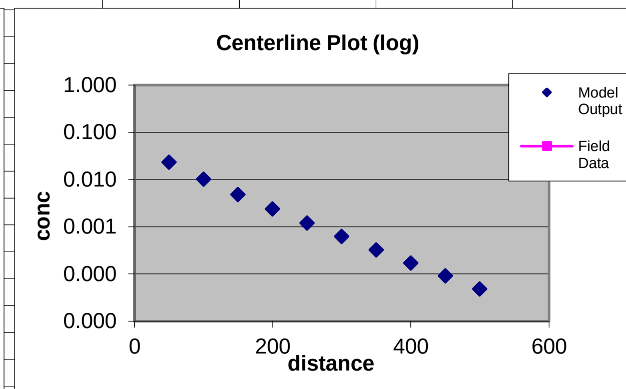
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm³) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214286 | 0.025124628 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 146.9739737 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 146.9739737 | 0 | 0 |
| at | 1E+99 | days = | **0.005** mg/l |




| AREAL MODEL | CALCULATION DOMAIN |
|---|---|
| Length (ft) | 500 |
| Width (ft) | 100 |

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.004 | 0.004 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.015 | 0.008 | 0.004 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.023 | 0.010 | 0.005 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.015 | 0.008 | 0.004 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.004 | 0.004 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Field Data: | Centerline C Concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distance from Source | | | | | | | |

Table A.6 W-32 QD2 Model
SIM 1

## ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

| | | | |
|---|---|---|---|
| Project: | 2574601 - Sunoco Philadelphia Refinery | | |
| Date: | 11/1/2011 | Prepared by: | Terrance Stanley |
| | | Contaminant: | chrysene |

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

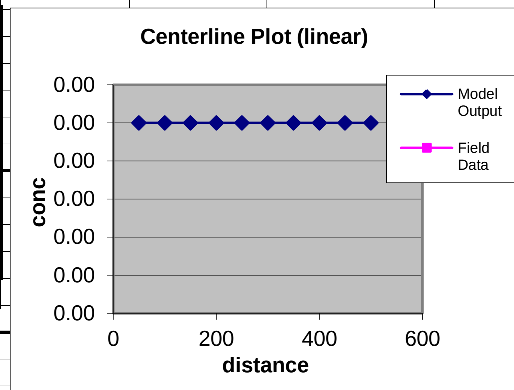
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.00035616 | 100 | 60 | 1E+99 |

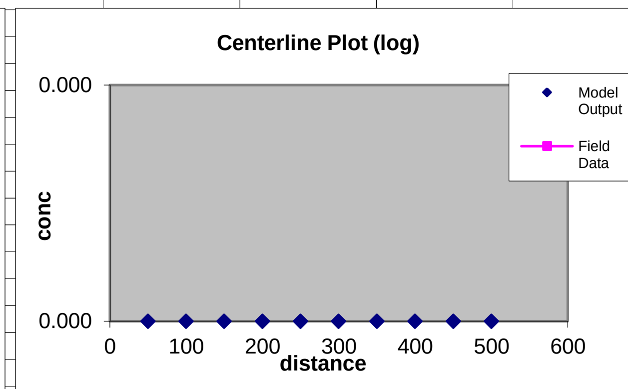
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm$^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 490000 | 5.00E-03 | 12058.5 | 5.05725E-06 |

### Point Concentration

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 1.1822598 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 1.1822598 | 0 | 0 |
| at | 1E+99 | days = | **0.002** mg/l |




| AREAL | CALCULATION |
|---|---|
| MODEL | DOMAIN |
| Length (ft) | 500 |
| Width (ft) | 100 |

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Field Data: | Centerline C Concentration | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Distance from Source | | | | | | | |

Table A.6 W-32 QD2 Model
SIM 2

**Table A.7**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

Project 2574601 - Sunoco Philadelphia Refinery
Prepared by Terrance Stanley
Date Prepared 11/1/2011

| **Generic Input Parameters** | | | | **Data Source** |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-33** | |
| Sample Date | | | 4/27/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| **Chemical Specific Input Parameters** | | | | **Data Source** |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | benzene | |
| Source Concentration (mg/L) | | mg/L | 0.2500 | 4/24/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.001 | PADEP Number Please! 2011 |
| KOC | | | 58 | PADEP Number Please! 2011 |
| **Sim 2** | | | | |
| Contaminant | | | chrysene | |
| Source Concentration (mg/L) | | mg/L | 0.0060 | 40657.0000 |
| Lambda (per day) | | $day^{-1}$ | 0.000 | PADEP Number Please! 2011 |
| KOC | | | 490000 | PADEP Number Please! 2011 |
| **Sim 3** | | | | |
| Contaminant | | | naphthalene | |
| Source Concentration (mg/L) | | mg/L | 0.3300 | 40657.0000 |
| Lambda (per day) | | $day^{-1}$ | 0.003 | PADEP Number Please! 2011 |
| KOC | | | 950 | PADEP Number Please! 2011 |

| **Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)** | | | | |
|---|---|---|---|---|
| **Contaminant** | **Starting Concentration (mg/L)** | **GW MSC[1] Non-Residential (mg/L)** | **Predicted Concentration (mg/L)** | **Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot)** |
| Sim 1 - benzene | 0.2500 | 0.005 | 0.005 | **255** |
| Sim 2 - chrysene | 0.0060 | 0.002 | 0.002 | **2** |
| Sim 3 - naphthalene | 0.3300 | 0.100 | 0.100 | **16** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 11/1/2011 Prepared by: Terrance Stanley
Contaminant: **benzene**

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF
"AN ANALYTICAL MODEL FOR
MULTIDIMENSIONAL TRANSPORT OF A
DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation

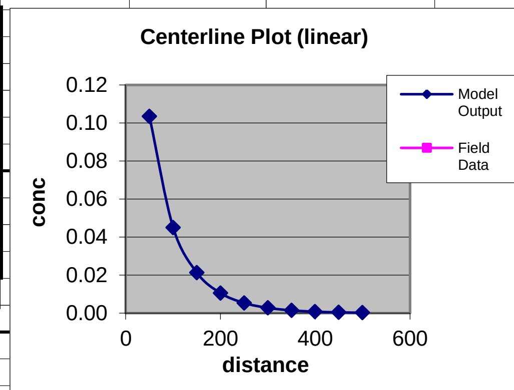
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.0009589 | 100 | 60 | 1E+99 |

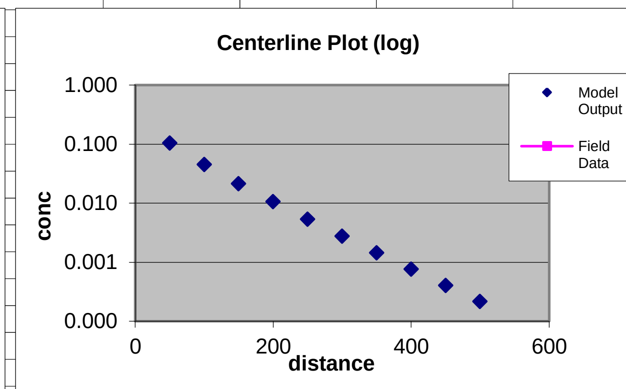
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density ($g/cm^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214286 | 0.025124628 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 255.2108561 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 255.2108561 | 0 | 0 |
| at | 1E+99 | days = | **0.005** mg/l |




**AREAL MODEL** **CALCULATION DOMAIN**
Length (ft) 500
Width (ft) 100

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.018 | 0.016 | 0.010 | 0.006 | 0.003 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 |
| 50 | 0.068 | 0.035 | 0.018 | 0.009 | 0.005 | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 |
| 0 | 0.103 | 0.045 | 0.021 | 0.011 | 0.005 | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 |
| -50 | 0.068 | 0.035 | 0.018 | 0.009 | 0.005 | 0.003 | 0.001 | 0.001 | 0.000 | 0.000 |
| -100 | 0.018 | 0.016 | 0.010 | 0.006 | 0.003 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 |

**Field Data:** **Centerline C Concentration**
**Distance from Source**

Table A.7 W-33 QD2 Model
SIM 1

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

Project: 2574601 - Sunoco Philadelphia Refinery

Date: 11/1/2011 Prepared by: Terrance Stanley

Contaminant: chrysene

| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.00035616 | 100 | 60 | 1E+99 |

| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm³) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 490000 | 5.00E-03 | 12058.5 | 5.05725E-06 |

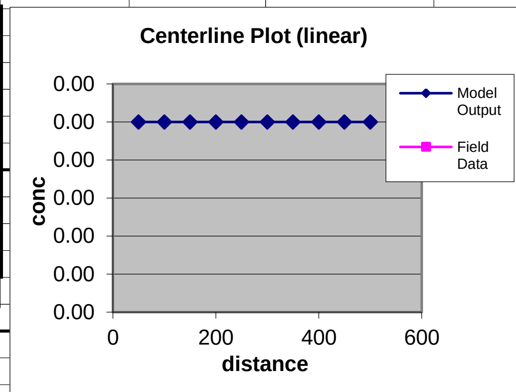
NEW QUICK_DOMENICO.XLS

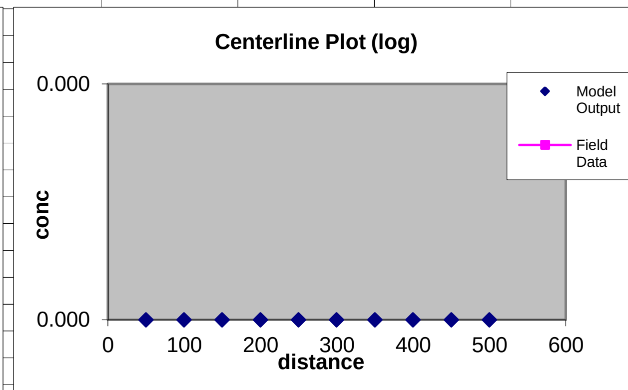
SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

## Point Concentration

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 1.868027573 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 1.868027573 | 0 | 0 |
| at | 1E+99 | days = | **0.002** mg/l |




AREAL CALCULATION

MODEL DOMAIN

Length (ft) 500

Width (ft) 100

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

| Field Data: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Centerline Concentration | | | | | | | | |
| Distance from Source | | | | | | | | |

Table A.7 W-33 QD2 Model SIM 2

**ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL**

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 11/1/2011 Prepared by: Terrance Stanley
Contaminant: naphthalene

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

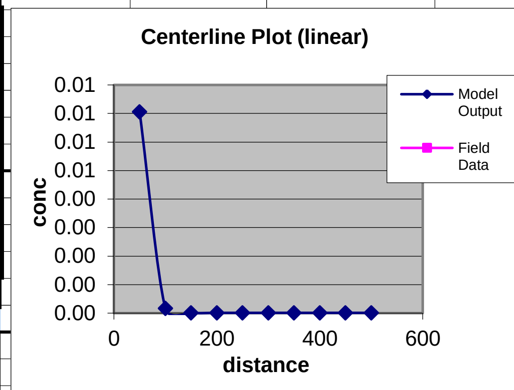
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.00268493 | 100 | 60 | 1E+99 |

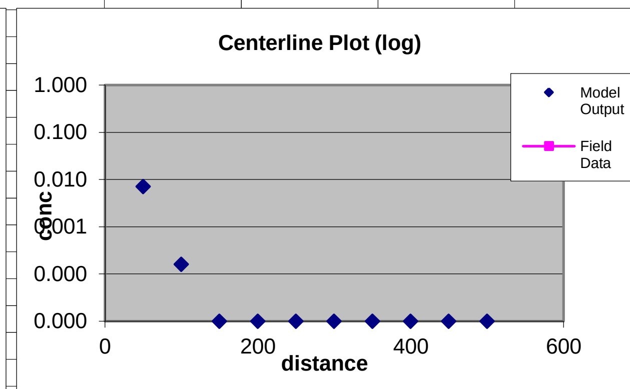
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm³) | KOC | Frac. Org. Carb. | Retardation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 950 | 5.00E-03 | 24.37678571 | 0.002501678 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 16.1517264 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 16.1517264 | 0 | 0 |
| at | 1E+99 | days = | **0.100** mg/l |




AREAL CALCULATION
MODEL DOMAIN
Length (ft) 500
Width (ft) 100

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Field Data:** Centerline C Concentration
Distance from Source

Table A.7 W-33 QD2 Model
SIM 3

**Table A.8**
**Quick Domenico**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

| | |
|---|---|
| Project | 2574601 - Sunoco Philadelphia Refinery |
| Prepared by | Terrance Stanley |
| Date Prepared | 11/1/2011 |

| Generic Input Parameters | | | | Data Source |
|---|---|---|---|---|
| Source Identification (or Well ID) | | | **W-34** | |
| Sample Date | | | 4/27/2011 | |
| Source Width | | ft | 100 | Delineated LNAPL (100' default if no plume is present) |
| Source Thickness | | ft | 60 | Estimated from cross-sections DD-DD' & EE-EE' |
| Longitudinal Dispersivity | $A_x$ | ft | 200 | From CCR QD Simulations |
| Transverse Dispersivity | $A_y$ | ft | 20.0 | Quick Domenico User's Manual |
| Vertical Dispersivity | $A_z$ | ft | 0.0001 | Quick Domenico User's Manual |
| Hydraulic Conductivty | k | ft/day | 4.64 | Alluvium |
| Hydraulic Gradient | | ft/ft | 0.0046 | W-31/W-16 April 2011 |
| Porosity | | decimal fraction | 0.35 | Site soil analyses |
| Soil Bulk Density | $p_b$ | g/cm3 | 1.7225 | ACT 2 TGM Default |
| Fraction of Organic Carbon | $f_{OC}$ | decimal fraction | 0.005 | ACT 2 TGM Default |
| Time | | days | 1.00E+99 | Steady-State Conditions |

| Chemical Specific Input Parameters | | | | Data Source |
|---|---|---|---|---|
| **Sim 1** | | | | |
| Contaminant | | | benzene | |
| Source Concentration (mg/L) | | mg/L | 0.0120 | 4/27/2011 |
| Lambda (per day) | | $day^{-1}$ | 0.001 | PADEP Number Please! 2011 |
| KOC | | | 58 | PADEP Number Please! 2011 |

**Output (Distance from Source Where Concentration Equals Respective Ground Water MSC)**

| Contaminant | Starting Concentration (mg/L) | GW MSC[1] Non-Residential (mg/L) | Predicted Concentration (mg/L) | Predicted Distance to Meet Non-Residential GW MSC (Rounded Upward to the Nearest foot) |
|---|---|---|---|---|
| Sim 1 - benzene | 0.0120 | 0.005 | 0.005 | **50** |

[1] ACT 2 TGM, Appendix A, Table 1 MSC for a Non-residential Used Aquifer with Total Dissolved Solids less than or equal to 2500.

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: 2574601 - Sunoco Philadelphia Refinery
Date: 11/1/2011 Prepared by: Terrance Stanley
Contaminant: benzene

NEW QUICK_DOMENICO.XLS

SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES" P.A. Domenico (1987) Modified to Include Retardation

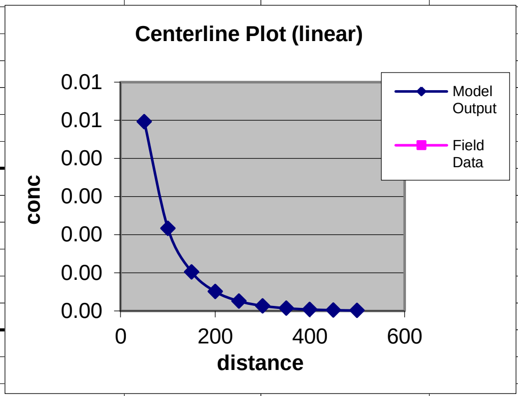
| SOURCE CONC (MG/L) | Ax (ft) | Ay (ft) | Az (ft) >=.001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) |
|---|---|---|---|---|---|---|---|
| 0 | 2.00E+02 | 2.00E+01 | 1.00E-04 | 0.0009589 | 100 | 60 | 1E+99 |

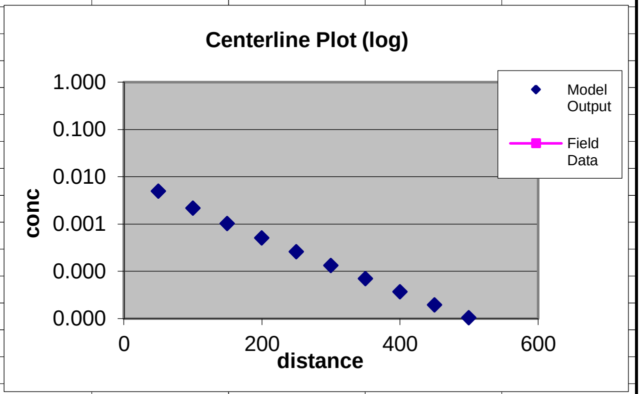
| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density ($g/cm^3$) | KOC | Frac. Org. Carb. | Retardation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214286 | 0.025124628 |

**Point Concentration**

| x(ft) | y(ft) | z(ft) |
|---|---|---|
| 49.70922802 | 0 | 0 |

| | x(ft) | y(ft) | z(ft) |
|---|---|---|---|
| Conc. At | 49.70922802 | 0 | 0 |
| at | 1E+99 | days = | 0.005 mg/l |




AREAL MODEL / CALCULATION DOMAIN
Length (ft) 500
Width (ft) 100

| | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 | 0.003 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0 | 0.005 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -50 | 0.003 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| -100 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Field Data:** Centerline C Concentration
Distance from Source

Table A.8 W-34 QD2 Model
SIM 1

# QD SUMMARY TABLE

**Table A.9**
**Fate and Transport Model Input and Output AOI 10**
**Sunoco Philadelphia Refinery**
**Philadelphia, Pennsylvania**

| Well ID | Compound | Starting Concentration | Final Concentration (Screening Value) | Predicted Distance to Achieve Screening Value | Estimated Distance to AOI 10 Boundary |
|---|---|---|---|---|---|
| | | ug/l | ug/l | ft | ft |
| W-1 | benzene | 20 | 5 | 80 | 90 |
| W-12 | benzene | 8 | 5 | 28 | 105 |
| W-23 | benzene | 12 | 5 | 50 | 98 |
| W-28 | chrysene | 2 | 1.9 | <1 | 180 |
| W-31 | benzene | 10 | 5 | 40 | 270 |
| | chrysene | 4 | 1.9 | 1 | |
| | lead | 6 | 5 | 32 | |
| W-32 | benzene | 56 | 5 | 147 | 170 |
| | chrysene | 4 | 1.9 | 1 | |
| W-33 | benzene | 250 | 5 | **255** | 90 |
| | chrysene | 6 | 1.9 | 2 | |
| | napthalene | 330 | 100 | 16 | |
| W-34 | benzene | 12 | 5 | 50 | 130 |

Note:
[grey shading] = indicates predicted distance is greater than distance to property boundary

# SWLOAD SIMULATION

**METHOD FOR ESTIMATNG FLOW, AVERAGE CONCENTRATION AND MASS LOADING TO SURFACE WATER FROM GROUNDWATER**

Project: SWLOAD5B
Date: **9/21/2011**
Contaminant: **Benzene**
Prepared by: **DH**

PA DEPARTMENT
OF ENVIRONMENTAL PROTECTION
SWLOAD5B.XLS
A METHOD FOR ESTIMATING
COMTAMINANT LOADING TO SURFACE
WATER
based on
P.A. Domenico (1987)
Modified to Include Retardation

| SOURCE CONC (units) mg/l | Ax (ft) >.0001 | Ay (ft) >.0001 | Az (ft) >=.0001 | LAMBDA day-1 | SOURCE WIDTH (ft) | SOURCE THICKNESS (ft) | Time (days) |
|---|---|---|---|---|---|---|---|
| 0.25 | 200 | 20 | 1.00E-04 | 0.001 | 100 | 60 | 1.00E+99 |

| Hydraulic Cond (ft/day) | Hydraulic Gradient (ft/ft) | Porosity (dec. frac.) | Soil Bulk Density (g/cm$^3$) | KOC | Frac. Org. Carb. | Retard-ation (R) | V (=K*i/n*R) (ft/day) |
|---|---|---|---|---|---|---|---|
| 4.64E+00 | 0.0046 | 0.35 | 1.7225 | 58 | 5.00E-03 | 2.427214 | 0.0251246 |

| | | | -144 | -115.2 | -86.4 | -57.6 | -28.8 | 0 | 28.8 | 57.6 | 86.4 | 115.2 | 144 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Edge Criterion (mg/l)** | **0.005** | 0 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| **Higest modeled conc.** | **0.05134** | -6 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| | | -12 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| **SURFACE WATER LOADING GRID** | | -18 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| **Distance to Stream (ft)** | **90** | -24 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| **Plume View Width (ft)** | **288** | -30 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| **Plume View Depth (ft)** | **60** | -36 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| | | -42 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| | | -48 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| **PENTOX NEEDED** | | -54 | 0.005 | 0.0116968 | 0.022466 | 0.0356263 | 0.0468713 | 0.0513379 | 0.0468713 | 0.0356263 | 0.0224664 | 0.011697 | 0.005 |
| | | -60 | 0.0025 | 0.0058484 | 0.011233 | 0.0178131 | 0.0234356 | 0.025669 | 0.0234356 | 0.0178131 | 0.0112332 | 0.005848 | 0.0025 |

**Average Groundwater Concentration** 0.02557 mg/l

**Plume Flow** 0.00426 cfs 0.00275 MGD

**Mass Loading to Stream** 267.08 mg/day

# ATTACHMENT B

Revised Appendix F from AOI 10 SCR/RIR –

LNAPL Modeling Procedures and Results

**ATTACHMENT B**
**REVISED APPENDIX F FROM THE JUNE 29, 2011 AOI 10 SCR/RIR**
**LNAPL MODELING PROCEDURES**
**AOI 10: SUNOCO PHILADELPHIA REFINERY**
**PHILADELPHIA, PENNSYLVANIA**

## B.1 INTRODUCTION AND OVERVIEW

Models which assess volume, mobility, and recoverability of light non-aqueous phase liquid (LNAPL) contamination have progressed beyond simply extrapolating LNAPL monitoring well thicknesses into the surrounding geologic materials. Instead, these models incorporate the physical properties of groundwater, LNAPL, and soil, in conjunction with an improved understanding of how fluids interact with each other and the surrounding geologic materials, and provide better estimates of LNAPL volume, mobility, and recoverability. These scientific improvements have allowed more realistic endpoints to be set during the remediation process.

For the LNAPL modeling at the Sunoco Refinery in Philadelphia, PA (the Facility), Langan utilized the American Petroleum Institute (API) Publication Number 4682, "Free-Product Recovery of Petroleum Hydrocarbon Liquids," dated June 1999, as a guide for assessing LNAPL volume, mobility, and recoverability. The parameters discussed in subsequent sections are presented in API Publication 4682 as the significant variables and parameters needed to evaluate the nature and extent of free LNAPL. An updated version of the API model found in the API publication "API Interactive LNAPL Guide," version 2.0.4, dated July 2004, was used. These parameters, the RETC model, and the API model were utilized to estimate the specific volume and mobility of LNAPL at the Facility.

## B.2 INPUT PARAMETERS

Where applicable, input parameters for the RETC and the API models were derived from the analyses of site-specific media. Representative values obtained from the API's LNAPL and Environmental Canada's Reference Database were used for the remaining input parameters. Table B-1 of this attachment summarizes the LNAPL modeling input parameters used for this phase of the project. The individual input parameters used for the LNAPL models are described in detail below.

## B.3 FLUID PROPERTIES

The fluids of concern in LNAPL modeling are LNAPL, groundwater, and air. Key physical properties of these fluids are density ($\rho$), interfacial tension ($\sigma$) and viscosity ($\mu$). Chromatographic and mass spectroscopic hydrocarbon LNAPL characterization analyses were conducted on collected LNAPL samples in an attempt to identify and categorize LNAPLs on site.

### B.3.1 Fluid Density and Specific Gravity

Fluid density, $\rho$, is the mass of fluid per unit volume. Specific gravity, $\rho_r$, is the relative density of LNAPL with respect to the density of water. The density of LNAPL is related to its specific gravity through the following relationship:

$$\rho_r = \rho_o/\rho_w \qquad \text{(F.1)}$$

where $\rho_o$ and $\rho_w$ are the LNAPL and water densities, respectively.

Density estimates for LNAPL samples collected from wells within the Facility were determined from LNAPL and groundwater density data. If a density value was not available for the LNAPL in a particular monitoring well, a value was assigned based on the physical characteristics of the LNAPL observed in neighboring wells.

### B.3.2 LNAPL Viscosity

Viscosity is the measure of friction between molecules within a given fluid. The dynamic (or absolute) viscosity, $\mu$, is defined as the ratio of the shear stress to the strain rate for a Newtonian fluid (Newtonian fluids have constant viscosity and flow immediately on the application of a force). The kinematic viscosity ($\nu$) is the ratio of the dynamic viscosity to the density of a fluid.

If a kinematic viscosity value was not available for the LNAPL within a monitoring well, a value was assigned based on the physical characteristics of the LNAPL in relation to neighboring monitor wells, or a representative viscocity value was selected from the

API or Environmental Canada Database chosen based upon other LNAPL physical characteristics.

## B.4 FORMATION PHYSICAL PROPERTIES

Where available, site-specific geologic and hydrogeologic data were obtained from site soil boring investigations, monitoring and recovery wells installation and sampling activities, and aquifer characteristic testing. All remaining physical property input values were obtained from reference literature.

Variations in soil type were noted from boring log descriptions. For the purpose of determining modeling parameters, generalizations of the geologic characteristics were made based on the occurrence and distribution of soil types within the LNAPL wetted screen interval of monitoring wells. Consistent with the API guidance publication, the geologic parameters of interest include: soil texture, porosity, bulk density, fluid saturation, capillary pressure relationships, and total organic carbon (TOC). These parameters are discussed in detail below.

### B.4.1 Formation Texture

One of the most important parameters in determining the properties of porous media is the size range of particles in a soil, which is referred to as soil texture. Grain size is closely related to soil texture, and a grain size distribution gives the relative percentage of grain sizes within a formation.

Where available, historic site-specific grain size distribution data were used to describe the relative percentage of grain size within the various geologic units at the Facility. Regions with similar grain size distributions were grouped together, and representative values were selected. Soil within the historic maximum LNAPL wetted interval was used for this selection. Note, however, that in any given boring log, the soil type spanning the LNAPL wetted interval may actually include a range of soil types. In addition to the grain size analyses, the soil Atterberg Limits were referenced for select soil types. The Atterberg limits were used to correlate and characterize the fine-grained soil (i.e., silt and clay) in conjunction with the grain size distribution analyses.

### B.4.2 Porosity

The ratio of the volume of void space in a soil to the total volume is defined as the porosity (n), which is usually written as a fraction or a percent of void space. Generally, wider variations in particle sizes result in smaller porosity values, as the void space between the larger particles are filled by smaller particles. The effective porosity (or kinematic porosity) refers to the volume of interconnected pore spaces through which fluids can flow.

### B.4.3 Bulk Density

Bulk density is a measure of the weight of the soil per unit volume, usually given on an oven-dry (110° C) basis. Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil. Most mineral soils have bulk densities between 1.0 and 2.0.

### B.4.4 Fluid Saturation

According to the API guidance documents, the void space of a natural porous medium affected by an LNAPL release is filled with water, air and LNAPL. The fraction of the pore space of a representative volume of material that is occupied by a particular fluid is called the fluid saturation. The fluid saturation of each phase can range from 0 to 1, and the sum of the three phases must equal 1.

### B.4.5 Capillary Pressure Relationships

According to the API guidance document, molecules located near the interface between two fluids (i.e. water and LNAPL) in one void space have a greater energy than molecules of the same fluid located within the bulk volume due to cohesive forces between the molecules. The excess energy associated with a fluid interface results in interfacial tension between the fluids, and surface tension between the liquid and vapor.

These relationships are incorporated into the API model for determining formation specific volume under vertical equilibrium.

## B.5 LNAPL EFFECTIVE PERMEABILITY

Water, air, and LNAPL are in competition for the interstitial spaces within the formation. Relative permeability describes the ability of one fluid to flow in the presence of other fluids, compared to the ability of the fluid to flow if it were the only fluid present. Typically, these differences in permeability between water and LNAPL are observed as LNAPL reaches the water table in sufficient quantities, pools, and spreads laterally as a floating layer.

The API modeling approach is to predict the LNAPL saturation and relative permeability distributions under vertical equilibrium conditions. The effective saturation and relative permeability values depend on the LNAPL thicknesses within the formation, for which the apparent monitoring well LNAPL thicknesses serve as a useful measure. The modeling objective is to replace the layer with varying saturation and relative permeability with an equivalent layer with vertically uniform characteristics.

For each well with reported apparent LNAPL thickness, the API model was run to determine the effective relative permeability of LNAPL within that well. As a first approximation, the residual saturation of LNAPL (the portion of LNAPL that is adhered to soil and not recoverable) was considered to be zero for the calculation of effective relative permeability. The residual saturation of LNAPL will be determined based on the soil grain size, fluid saturation and capillary curves for the recoverability analysis.

## B.6 SOIL INTRINSIC PERMEABILITY

The intrinsic permeability of the soil was estimated using the following equation:

$$k_{soil} = \frac{K_W \mu_W}{\rho_W g} \tag{F.2}$$

where,

$k_{soil}$ = permeability of soil

$K_w$ = hydraulic conductivity of groundwater for fill horizon

$\mu_w$ = dynamic viscosity of water

$p_w$ = density of water

g = gravity

The estimates of the ground water density and viscosity were used to determine the intrinsic soil permeability. The gravity constant was assumed to be 32.2 feet/s$^2$ (9.81 m/s$^2$).

## B.7 LNAPL HYDRAULIC CONDUCTIVITY AT SATURATION

To estimate the seepage velocity of the free-phase LNAPL, the hydraulic conductivity of the formation with respect to LNAPL must be known. The hydraulic conductivity of LNAPL is first calculated at 100% saturation at the LNAPL phase. Then it is corrected from the effective LNAPL relative permeability. This corrected hydraulic conductivity of LNAPL is the hydraulic conductivity of LNAPL in the formation at the estimated saturation of LNAPL. This can be estimated based on the following equation:

$$K_{oil} = k_{ro} \frac{k_{soil} \rho_{oil} g}{\mu_{oil}} \qquad \text{(F.3)}$$

where,

$K_{oil}$ = hydraulic conductivity of LNAPL in the soil at saturation

$k_{ro}$ = effective LNAPL relative permeability

$k_{soil}$ = permeability of soil relative to groundwater (Equation D.2)

$\mu_{oil}$ = dynamic viscosity of LNAPL

$p_{oil}$ = density of LNAPL

g = gravity

## B.8 LNAPL SPECIFIC DISCHARGE

The result of the corrected hydraulic conductivity for LNAPL saturation (Equation F.3) was used to calculate the specific velocity of the LNAPL based on hydraulic gradient of the groundwater using the following equation:

$$q_{oil} = K_{oil} \times i_W \qquad \text{(F.4)}$$

where,

$q_{oil}$ = LNAPL specific velocity of LNAPL discharge

$K_{oil}$ = hydraulic conductivity of LNAPL in the soil at the corrected saturation

$i_w$ = water table gradient

The water table gradient was assumed to be similar to the LNAPL table gradient. Based on the groundwater monitoring data collected to date, average water table gradients were selected.

The seepage velocity or mobility of the LNAPL was calculated based on the specific velocity calculated in Equation F.4, and correcting it for the effective porosity of the formation as follows:

$$v_{oil} = \frac{q_{oil}}{\phi_{eff}} \quad \text{(F.5)}$$

where,

$v_{oil}$ = LNAPL seepage velocity

$q_{oil}$ = LNAPL specific velocity of LNAPL discharge

$\phi_{eff}$ = effective porosity

The specific velocity of the LNAPL discharge from the previous calculation was divided by the effective porosity to determine the seepage velocity of LNAPL for all wells. For this calculation, total porosity values associated with each soil type were reduced for use as an effective porosity for LNAPL mobility.

Located in Tables B-2 and B-3 are the output results of the LNAPL modeling. Also included on these tables are the previous LNAPL modeling results from the CCR. Located in Table B-4 of this attachment is the LNAPL characterization data provided by Torkelson Laboratories.

**Table B-2**
**Seepage Velocity Calculations**
**Sunoco Philadelphia Refinery**
**AOI 10**
**Philadelphia, Pennsylvania**

| AOI | Well ID | Sample Date | Porosity | API Database USCS Soil Type Equivalent | LNAPL Density | Dominant LNAPL Type at Each Well Location | API Model Calculated Relative LNAPL Permeabilty | Effective Porosity | Groundwater Density @ 60F (kg/m$^3$) | Groundwater Dynamic Viscosity (N·s/m$^2$) | Soil Permeabililty (m$^2$) | Kro (%) | Groundwater Gradient | Dynamic Viscosity of SPL (N·s/m2) | SPL Density (kg/m3) | NAPL K @ 100% Saturation (m/day) | Corrected NAPL K (m/day) | NAPL Specific Discharge (m/day) | NAPL Seepage Velocity (m/year) | NAPL Seepage Velocity (cm/sec) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | untiless | | (gm/cc) | | API Model (unitless) | API Database | Literature Value | API Database | API Database | API Model (unitless) | Site Contour Maps/SWLOAD | API/Env. Canada Databases | Torkelson Geochemistry Inc. | Calculated | Calculated | Calculated | Calculated | Calculated |
| AOI 10 | W-8 | 11/02/03 | 0.426 | SW-SM | 0.912 | Res Oil | 1.340E-10 | 0.39 | 999.19 | 1.124E-03 | 6.15E-12 | 0.00% | 3.000E-03 | 2.300E-02 | 912.10 | 2.07E-01 | 2.77E-11 | 8.31E-14 | 7.78E-11 | 2.45E-16 |
| | W-8 | 04/27/11 | 0.426 | SW-SM | 0.9515 | Res Oil | 2.390E-04 | 0.388 | 999.19 | 1.124E-03 | 6.15E-12 | 0.02% | 4.600E-03 | 2.300E-02 | 951.50 | 2.16E-01 | 5.15E-05 | 2.37E-07 | 2.23E-04 | 7.03E-10 |
| | W-14 | 04/27/11 | 0.426 | SW-SM | 0.9478 | Res Oil | 1.650E-06 | 0.388 | 999.19 | 1.124E-03 | 6.15E-12 | 0.00% | 4.600E-03 | 2.300E-02 | 947.80 | 2.15E-01 | 3.54E-07 | 1.63E-09 | 1.53E-06 | 4.84E-12 |
| | W-18 | 04/27/11 | 0.426 | SW-SM | 0.9478 | Res Oil | 9.790E-10 | 0.388 | 999.19 | 1.124E-03 | 6.15E-12 | 0.00% | 4.600E-03 | 2.300E-02 | 947.80 | 2.15E-01 | 2.10E-10 | 9.67E-13 | 9.10E-10 | 2.87E-15 |

NOTES:
The physical characteristics of LNAPL at W-18 are assumed to be similar to LNAPL at W-14

# Table B-3
# LNAPL Model And Seepage Velocity Output Summary
# AOI 10
# Sunoco Philadelphia Refinery
# Philadelphia, Pennsylvania

| AOI | Well ID | Date Apparent Thickness Gauged | Apparent LNAPL Thickness (ft) | API Model Calculated LNAPL Specific Volume (feet) | Calculated LNAPL Seepage Velocity (cm/sec) |
|---|---|---|---|---|---|
| AOI10 | W-8 | 11/02/03 | 0.010 | 4.880E-10 | 2.45E-16 |
| | | 04/27/11 | 0.590 | 4.410E-04 | 7.03E-10 |
| | W-14 | 04/27/11 | 0.11 | 3.130E-06 | 4.84E-12 |
| | W-18 | 04/27/11 | 0.01 | 2.130E-09 | 2.87E-15 |

# Table B-4
# LNAPL Characterization Summary Table
# AOI 10
# Sunoco Philadelphia Refinery
# Philadelphia, Pennsylvania

| Interpretation of Product Types, Proportions, and Weathering | | | | |
|---|---|---|---|---|
| ***Characterization Results Compiled for CCR (TGI Job No. 04046 - Analyzed in February 2004)*** | | | | |
| **Well ID** | **Density g/cc (60°F)** | **LNAPL Type(s)** | **Torkelson LNAPL Type(s)** | **Weathering** |
| W-8 | 0.9121 | Residual Oil | Residual Oil | Extreme |
| ***Characterization Results Compiled for AOI 10 Site Characterization Activities (TGI Job No. 11047 - Analyzed in May 2011)*** | | | | |
| W-8 | 0.9515 | Residual Oil | Residual Oil | Extreme |
| W-14 | 0.9478 | Residual Oil | Residual Oil | Extreme |
| W-18 | QNS | Residual Oil | Residual Oil | Extreme |

Notes:

The physical characteristics of LNAPL at W-18 are assumed to be similar to LNAPL at W-14
Heavier material could either be crude oil or residual oil
g/cc - Grams per cubic centimeter
TGI - Torkelson Geochemistry, Inc.
NA - Not Applicable
? - Tentative identification
CCR - 2004 Sunoco Current Conditions Report
LNAPL - Light Non Aqueous Phase Liquid
All LNAPL results reported were analyzed by TGI
Product interpretations were provided by TGI
QNS - Quantity of sample not sufficient for analysis

W-8

# van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

**Enter Data in Yellow Region**

| Maximum Monitoring Well LNAPL Thickness [feet] | |
|---|---|
| $b_o$ = | 0.590 |

| Soil Characteristic | | |
|---|---|---|
| $n$ = | 0.388 | porosity |
| $N$ = | 2.040 | van Genuchten "N" |
| $\alpha$ = | 1.990 | van Genuchten "$\alpha$" [$ft^{-1}$] |
| $S_{wr}$ = | 0.253 | irreducible water saturation |
| $S_{orv}$ = | 0.000 | residual LNAPL saturation (vadose) |
| $S_{ors}$ = | 0.000 | residual LNAPL saturation (saturated) |

| Fluid Characteristics: | | |
|---|---|---|
| $\rho_o$ = | 0.952 | LNAPL density [gm/cc] |
| $\sigma_{aw}$ = | 65.000 | air/water surface tension [dyne/cm] |
| $\sigma_{ao}$ = | 32.100 | air/LNAPL surface tension [dyne/cm] |
| $\sigma_{ow}$ = | 30.200 | LNAPL/water surface tension [dyne/cm] |

| Calculated Parameters | | |
|---|---|---|
| $M$ = | 0.510 | van Genuchten "M" |
| $\alpha_{ao}$ = | 3.834 | air/LNAPL "$\alpha$" [$ft^{-1}$] |
| $\alpha_{ow}$ = | 0.208 | LNAPL/water "$\alpha$" [$ft^{-1}$] |
| $z_{ao}$ = | 0.029 | elevation of air-LNAPL interface [ft] |
| $z_{ow}$ = | -0.561 | elevation of LNAPL-water interface [ft] |
| $z_{max}$ = | 0.069 | maximum free-product elevation [ft] |
| $\lambda$ = | 0.773 | pore-size distribution index |
| $\Psi_b$ = | 0.313 | B-C displacement pressure head [ft] |

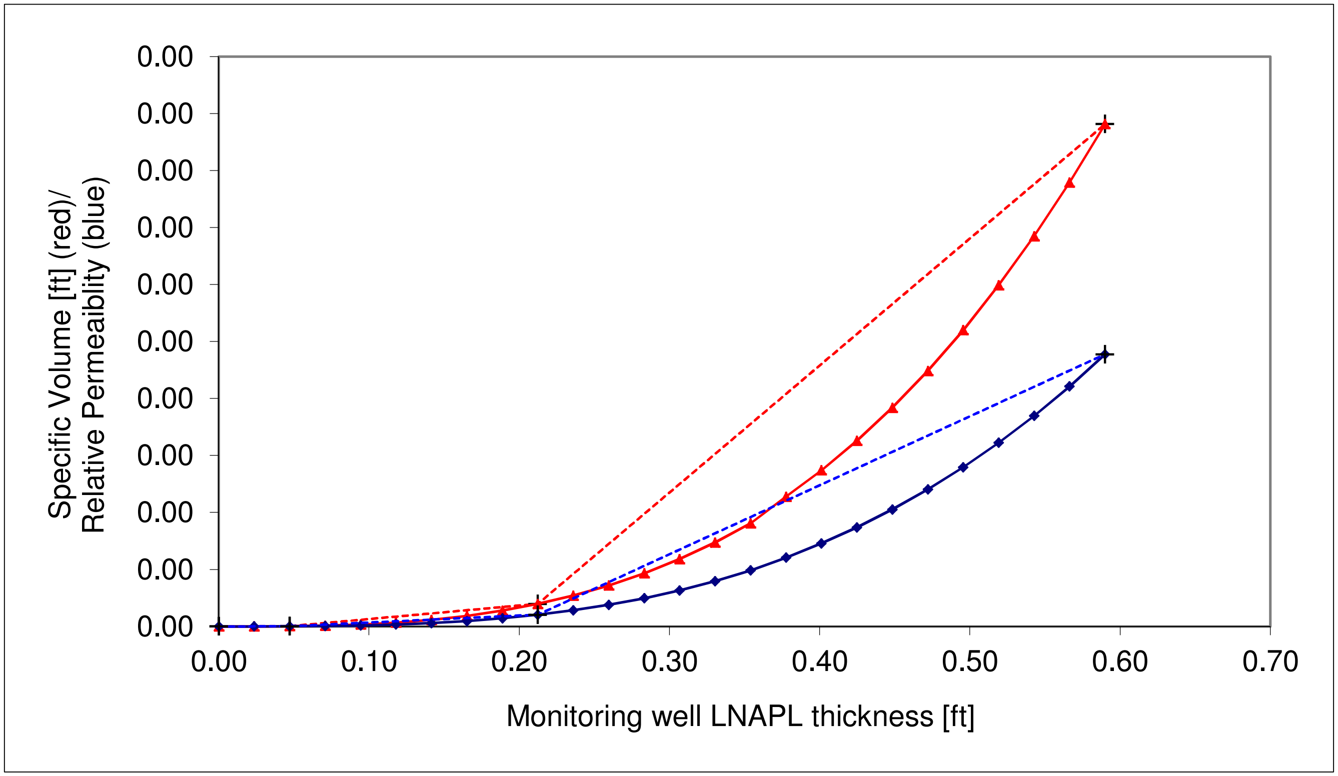
**Set *Tools* > *Option* > *Calculations* tab to "Manual."**

**Press Ctrl+Shift+S to calculate sheet**

11/1/2011

## W-8

| Data for curve-fitting segments | | | Press Ctrl+Shift+S to calculate sheet | | | | | |
|---|---|---|---|---|---|---|---|---|
| $b_o$ [ft] | $D_o$ [ft] | $k_{ro}$ | χ [ft] | β | ξ [ft] | η | | |
| 0.000 | 0.000 | 0.000 | | | | | | |
| 0.047 | 0.000 | 0.000 | 0.0000 | 0.000004 | 0.0000 | 0.000002 | | |
| 0.212 | 0.000 | 0.000 | 0.0455 | 0.000118 | 0.0456 | 0.000061 | 0.0001 | Eps-Do |
| 0.590 | 0.000 | 0.000 | 0.1947 | 0.001115 | 0.1956 | 0.000605 | 0.0001 | Eps-kro |

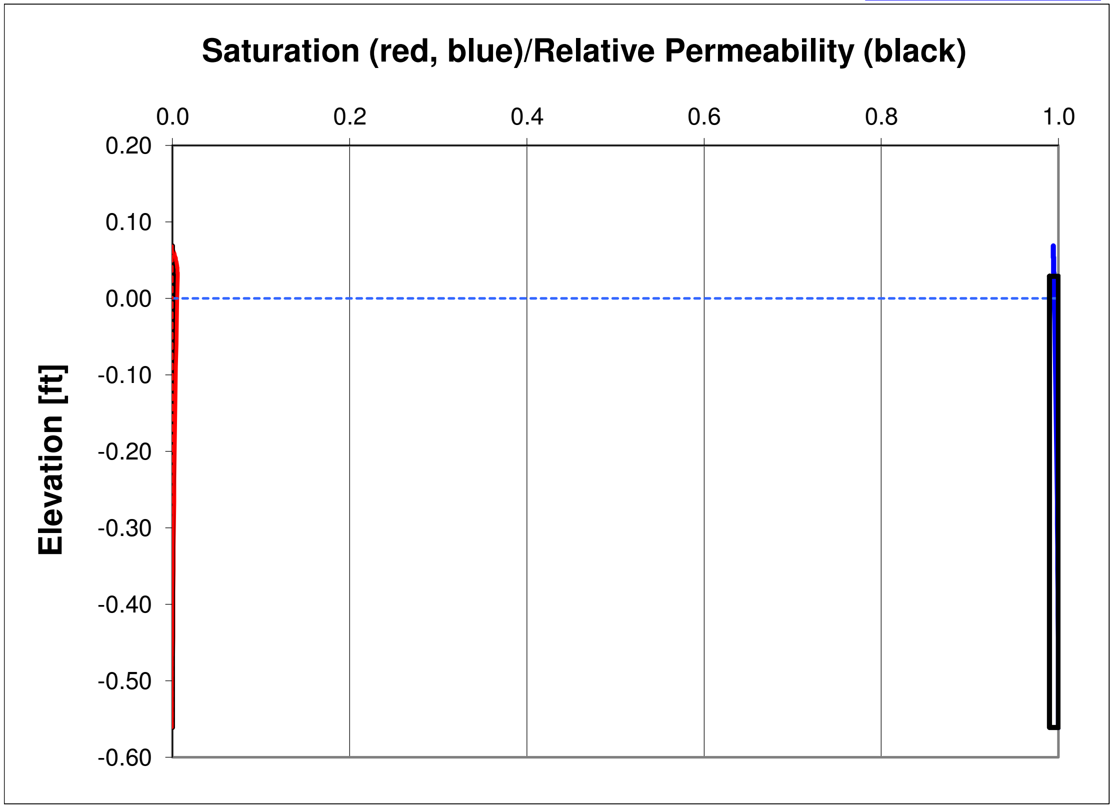


## W-8

| Monitoring Well LNAPL Thickness $b_o$ [ft] = | | | 0.590 |
|---|---|---|---|
| $D_o$ [ft] = | 0.000 | $k_{ro}$ = | 0.000 |

*Enter $b_o$ value here to plot corrsponding profiles*

**Press Ctrl+Shift+S to calculate sheet**



11/1/2011

## W-14

# van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

**Enter Data in Yellow Region**

| Maximum Monitoring Well LNAPL Thickness [feet] | |
|---|---|
| $b_o$ = | 0.110 |

| Soil Characteristic | | |
|---|---|---|
| $n$ = | 0.388 | porosity |
| $N$ = | 2.040 | van Genuchten "N" |
| $\alpha$ = | 1.990 | van Genuchten "$\alpha$" [$ft^{-1}$] |
| $S_{wr}$ = | 0.253 | irreducible water saturation |
| $S_{orv}$ = | 0.000 | residual LNAPL saturation (vadose) |
| $S_{ors}$ = | 0.000 | residual LNAPL saturation (saturated) |

| Fluid Characteristics: | | |
|---|---|---|
| $\rho_o$ = | 0.948 | LNAPL density [gm/cc] |
| $\sigma_{aw}$ = | 65.000 | air/water surface tension [dyne/cm] |
| $\sigma_{ao}$ = | 32.100 | air/LNAPL surface tension [dyne/cm] |
| $\sigma_{ow}$ = | 30.200 | LNAPL/water surface tension [dyne/cm] |

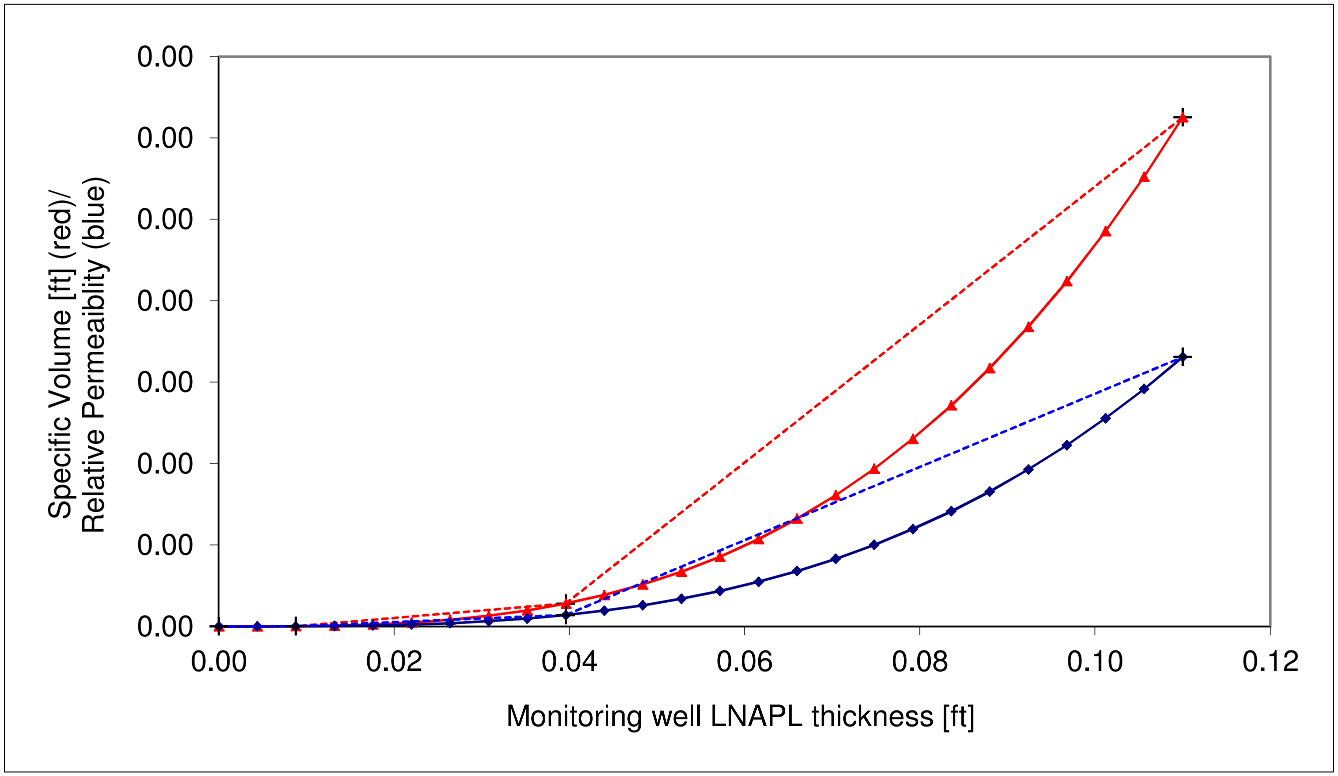
| Calculated Parameters | | |
|---|---|---|
| $M$ = | 0.510 | van Genuchten "M" |
| $\alpha_{ao}$ = | 3.820 | air/LNAPL "$\alpha$" [$ft^{-1}$] |
| $\alpha_{ow}$ = | 0.223 | LNAPL/water "$\alpha$" [$ft^{-1}$] |
| $z_{ao}$ = | 0.006 | elevation of air-LNAPL interface [ft] |
| $z_{ow}$ = | -0.104 | elevation of LNAPL-water interface [ft] |
| $z_{max}$ = | 0.016 | maximum free-product elevation [ft] |
| $\lambda$ = | 0.773 | pore-size distribution index |
| $\Psi_b$ = | 0.313 | B-C displacement pressure head [ft] |

**Set *Tools* > *Option* > *Calculations* tab to "Manual."**

**Press Ctrl+Shift+S to calculate sheet**

# W-14

| Data for curve-fitting segments | | | Press Ctrl+Shift+S to calculate sheet | | | | | |
|---|---|---|---|---|---|---|---|---|
| $b_o$ [ft] | $D_o$ [ft] | $k_{ro}$ | χ [ft] | β | ξ [ft] | η | | |
| 0.000 | 0.000 | 0.000 | | | | | | |
| 0.009 | 0.000 | 0.000 | 0.0000 | 0.000000 | 0.0000 | 0.000000 | | |
| 0.040 | 0.000 | 0.000 | 0.0085 | 0.000005 | 0.0085 | 0.000002 | 0.0001 | Eps-Do |
| 0.110 | 0.000 | 0.000 | 0.0363 | 0.000042 | 0.0365 | 0.000023 | 0.0001 | Eps-kro |

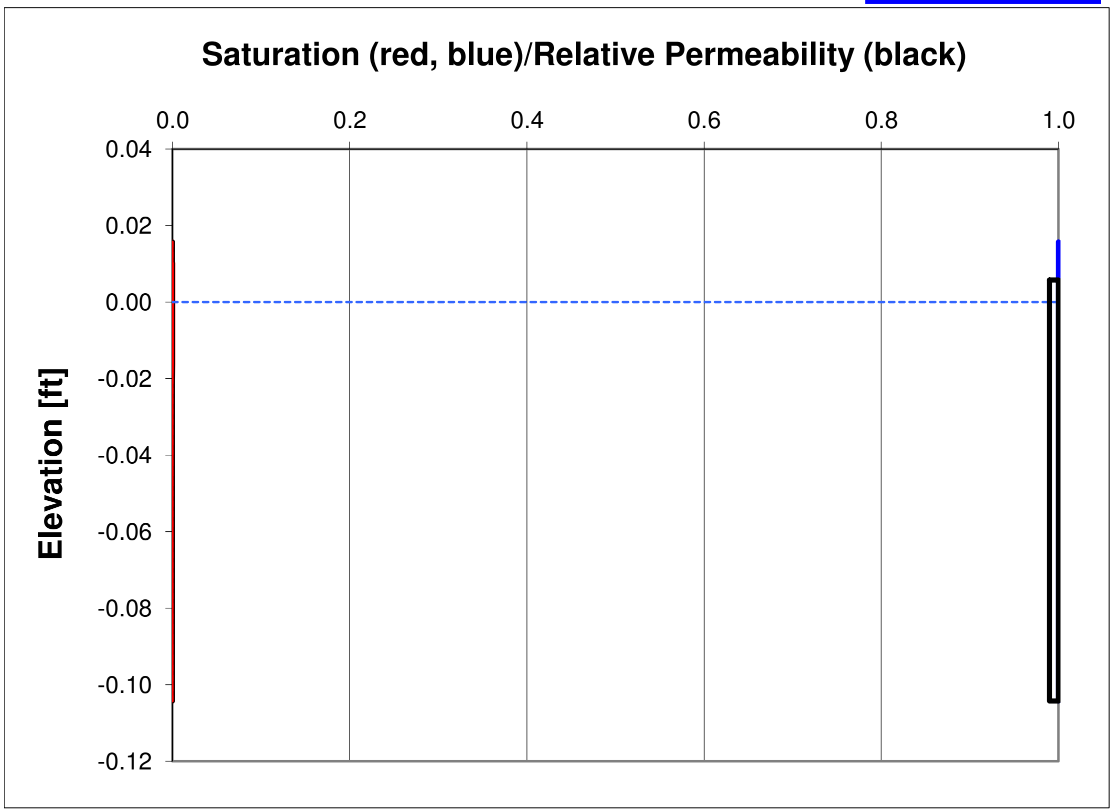


# W-14

| Monitoring Well LNAPL Thickness $b_o$ [ft] = | | | 0.110 |
|---|---|---|---|
| $D_o$ [ft] = | 0.000 | $k_{ro}$ = | 0.000 |

*Enter $b_o$ value here to plot corrsponding profiles*

**Press Ctrl+Shift+S to calculate sheet**



# W-18

## van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability

**Enter Data in Yellow Region**

| Maximum Monitoring Well LNAPL Thickness [feet] | |
|---|---|
| $b_o$ = | 0.010 |

| Soil Characteristic | | |
|---|---|---|
| $n$ = | 0.388 | porosity |
| $N$ = | 2.040 | van Genuchten "N" |
| $\alpha$ = | 1.990 | van Genuchten "$\alpha$" [$ft^{-1}$] |
| $S_{wr}$ = | 0.253 | irreducible water saturation |
| $S_{orv}$ = | 0.000 | residual LNAPL saturation (vadose) |
| $S_{ors}$ = | 0.000 | residual LNAPL saturation (saturated) |

| Fluid Characteristics: | | |
|---|---|---|
| $\rho_o$ = | 0.948 | LNAPL density [gm/cc] |
| $\sigma_{aw}$ = | 65.000 | air/water surface tension [dyne/cm] |
| $\sigma_{ao}$ = | 32.100 | air/LNAPL surface tension [dyne/cm] |
| $\sigma_{ow}$ = | 30.200 | LNAPL/water surface tension [dyne/cm] |

| Calculated Parameters | | |
|---|---|---|
| $M$ = | 0.510 | van Genuchten "M" |
| $\alpha_{ao}$ = | 3.820 | air/LNAPL "$\alpha$" [$ft^{-1}$] |
| $\alpha_{ow}$ = | 0.223 | LNAPL/water "$\alpha$" [$ft^{-1}$] |
| $z_{ao}$ = | 0.001 | elevation of air-LNAPL interface [ft] |
| $z_{ow}$ = | -0.009 | elevation of LNAPL-water interface [ft] |
| $z_{max}$ = | 0.011 | maximum free-product elevation [ft] |
| $\lambda$ = | 0.773 | pore-size distribution index |
| $\Psi_b$ = | 0.313 | B-C displacement pressure head [ft] |

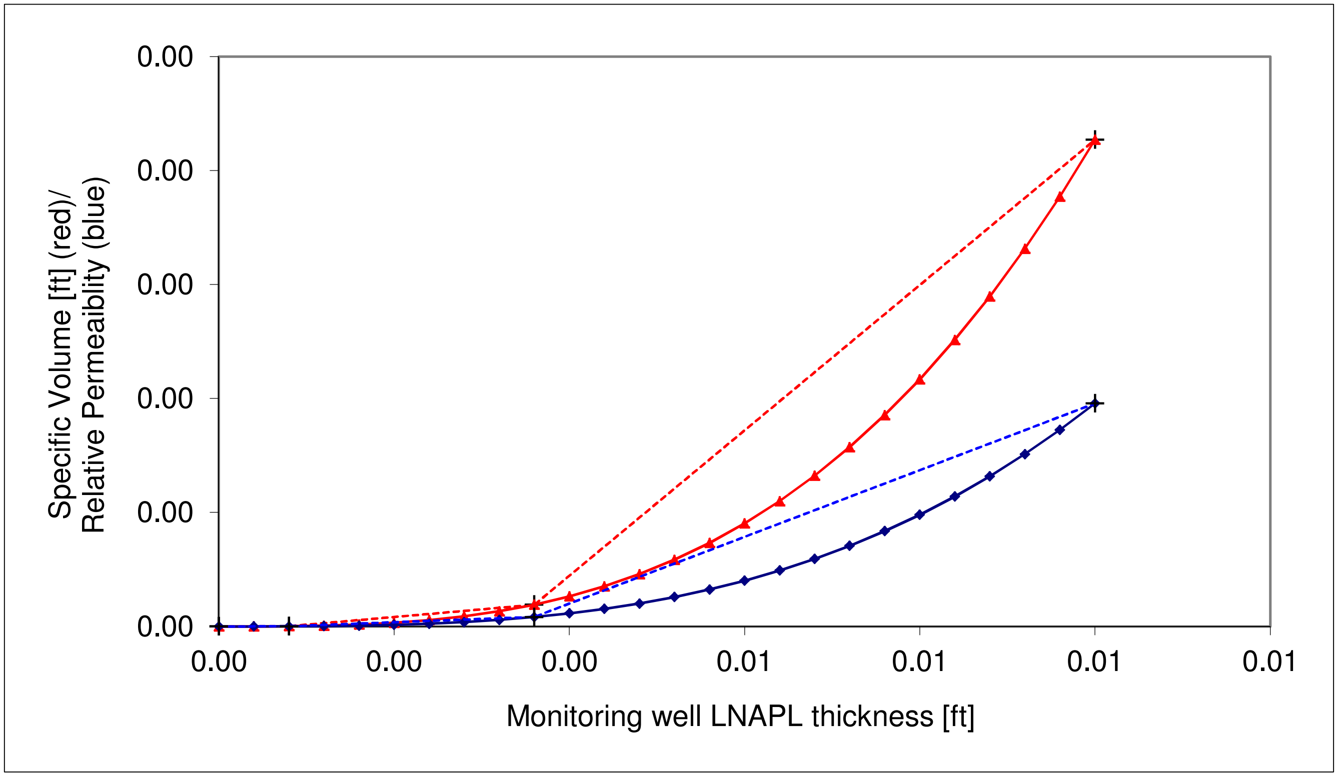
**Set *Tools* > *Option* > *Calculations* tab to "Manual."**

**Press Ctrl+Shift+S to calculate sheet**

11/1/2011

# W-18

| Data for curve-fitting segments | | | Press Ctrl+Shift+S to calculate sheet | | | | | |
|---|---|---|---|---|---|---|---|---|
| $b_o$ [ft] | $D_o$ [ft] | $k_{ro}$ | χ [ft] | β | ξ [ft] | η | | |
| 0.000 | 0.000 | 0.000 | | | | | | |
| 0.001 | 0.000 | 0.000 | 0.0000 | 0.000000 | 0.0000 | 0.000000 | | |
| 0.004 | 0.000 | 0.000 | 0.0008 | 0.000000 | 0.0008 | 0.000000 | 0.0001 | Eps-Do |
| 0.010 | 0.000 | 0.000 | 0.0033 | 0.000000 | 0.0033 | 0.000000 | 0.0001 | Eps-kro |

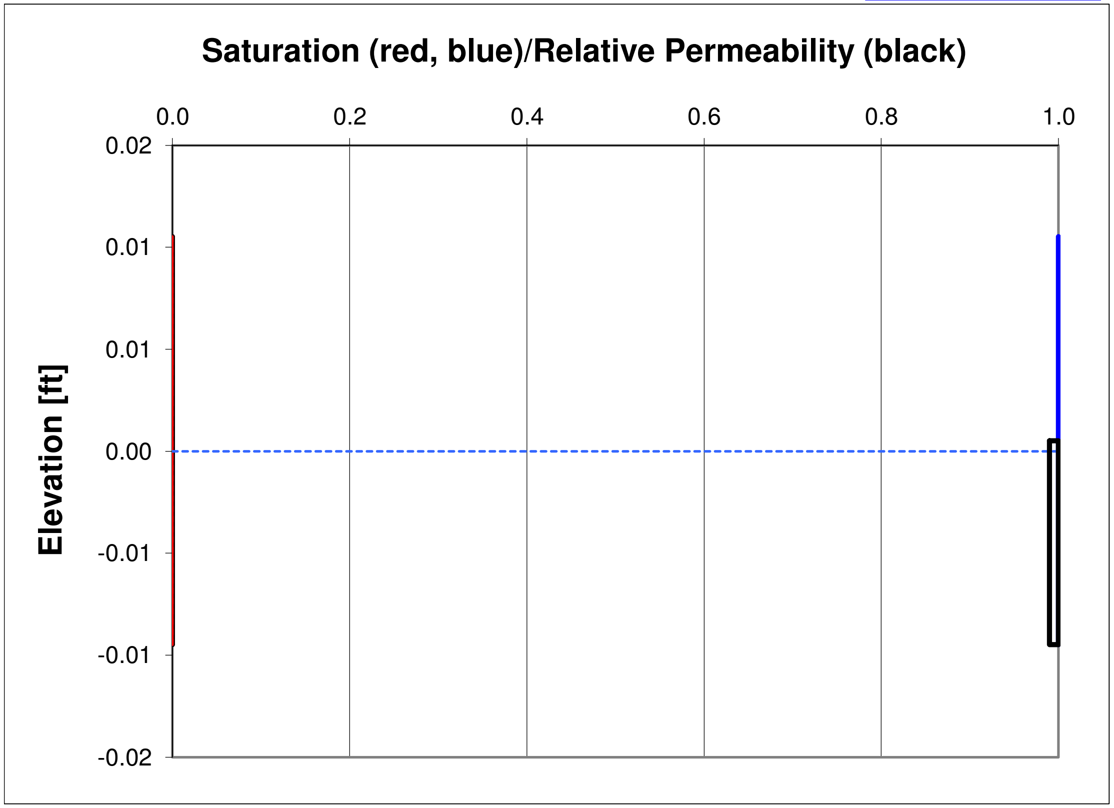


# W-18

| Monitoring Well LNAPL Thickness $b_o$ [ft] = | | | 0.010 |
|---|---|---|---|
| $D_o$ [ft] = | 0.000 | $k_{ro}$ = | 0.000 |

*Enter $b_o$ value here to plot corrsponding profiles*

Press Ctrl+Shift+S to calculate sheet




N
W E
S

## Legend

- W-8 4.410E-04 — Wells with Measureable LNAPL and Calculated LNAPL Specific Volumes (ft.)[4]
- W-24 — Wells with No Measureable LNAPL (<0.01ft.) (April 2011)
- W-21 — Abandoned/Unable to Locate
- Past Disposal Area (PDA) - Corrective Action Management Unit (CAMU)
- Area of Interest Boundary (AOI)

**LNAPL Type and Specific LNAPL Volume (ft.)**

**Residual Oil**

- $10^{-4}$
- $10^{-5}$
- $10^{-6}$
- $10^{-7}$
- $10^{-8}$
- $10^{-9}$

**LNAPL Model And Seepage Velocity Output Summary**

| AOI | Well ID | Date Apparent Thickness Gauged | Apparent LNAPL Thickness (ft) | API Model Calculated LNAPL Specific Volume (feet) | Calculated LNAPL Seepage Velocity (cm/sec) |
|---|---|---|---|---|---|
| AOI10 | W-8 | 11/02/03 | 0.010 | 4.880E-10 | 2.45E-16 |
| | | 04/27/11 | 0.590 | 4.410E-04 | 7.03E-10 |
| | W-14 | 04/27/11 | 0.11 | 3.130E-06 | 4.84E-12 |
| | W-18 | 04/27/11 | 0.01 | 2.130E-09 | 2.87E-15 |

Notes:
1. Bings Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Past disposal area digitzed from ENSR Figure 9 - Deep Aquifer Piezometric Map dated April 17, 1992. PDA boundaries updated based on 2011 delineation borings.
3. All LNAPL thicknesses are in feet.
4. LNAPL thinckness and mobility calculations based on the American Petroleum Institute's van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability.
5. LNAPL Type was based on density, distillation curve, etc. and are intended to qualify LNAPL mobility and recoverability, not to identify historic source.

Figure B-1 - Estimated LNAPL Specific Volumes
AOI-10 Site Characterization Report/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 150 300 Feet

SCALE: 1" = 300'
DATE: October 31, 2011
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

Path: \\langan.com\data\DT\data6\2574601\ArcGIS\MapDocuments\AOI 10 SCR\Figure B-1 - Estimated LNAPL Specific Volumes_rev11-1-11.mxd


**LNAPL Model And Seepage Velocity Output Summary**

| AOI | Well ID | Date Apparent Thickness Gauged | Apparent LNAPL Thickness (ft) | API Model Calculated LNAPL Specific Volume (feet) | Calculated LNAPL Seepage Velocity (cm/sec) |
|---|---|---|---|---|---|
| AOI10 | W-8 | 11/02/03 | 0.010 | 4.880E-10 | 2.45E-16 |
| | | 04/27/11 | 0.590 | 4.410E-04 | 7.03E-10 |
| | W-14 | 04/27/11 | 0.11 | 3.130E-06 | 4.84E-12 |
| | W-18 | 04/27/11 | 0.01 | 2.130E-09 | 2.87E-15 |

N
W E
S

## Legend

Wells with Measureable LNAPL and LNAPL Mobility Values (cm/sec)

W-24 Wells with No Measureable LNAPL (<0.01ft.) (April 2011)

W-21 Abandoned/Unable to Locate

Past Disposal Area (PDA) - Corrective Action Management Unit (CAMU)

Area of Interest Boundary (AOI)

**LNAPL Type and Seepage Velocity (cm/sec)**

**Residual Oil**

- $10^{-10}$
- $10^{-11}$
- $10^{-12}$
- $10^{-13}$
- $10^{-14}$
- $10^{-15}$

Notes:

1. Bings Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Past disposal area digitzed from ENSR Figure 9 - Deep Aquifer Piezometric Map dated April 17, 1992. PDA boundaries updated based on 2011 delineation borings.
3. All LNAPL thicknesses are in feet.
4. LNAPL thinckness and mobility calculations based on the American Petroleum Institute's van Genuchten-Mualem Model of LNAPL Distribution and Relative Permeability.
5. LNAPL Type was based on density, distillation curve, etc. and are intended to qualify LNAPL mobility and recoverability, not to identify historic source.

Figure B-2 - Calculated LNAPL Mobility Values
AOI-10 Site Characterization Report/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 150 300 Feet

SCALE: 1" = 300'
DATE: October 31, 2011
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

Path: \\langan.com\data\DT\data6\2574601\ArcGIS\MapDocuments\AOI 10 SCR\Figure B-2 - Calculated LNAPL Mobility Values_rev11-1-11.mxd

**Torkelson Geochemistry, Inc.**
2528 S. Columbia Place
Tulsa, OK 74114-3233
Phone: 918-749-8441
Fax: 918-749-6005
e-mail: BTorkelson@torkelsongeochemistry.com


# CHAIN-OF-CUSTODY RECORD



Project: Philadelphia Refinery - AOI-10
Location: Philadlephia, Pa

Proj. No.:
P.O.:
Sampled By: Shaun Sykes

Report/Bill To: Aquaterra Technologies, Inc
Address: PO Box 744
West Chester, Pa 19381
Phone: 610-431-5733 x.109
Fax: 610-431-5734
e-mail: td@aquaterra-tech.com

**Additional Instructions**
Please include a brief interpretation of product type consistant with other samples from the refinery

Requested Turn-Around Time: normal

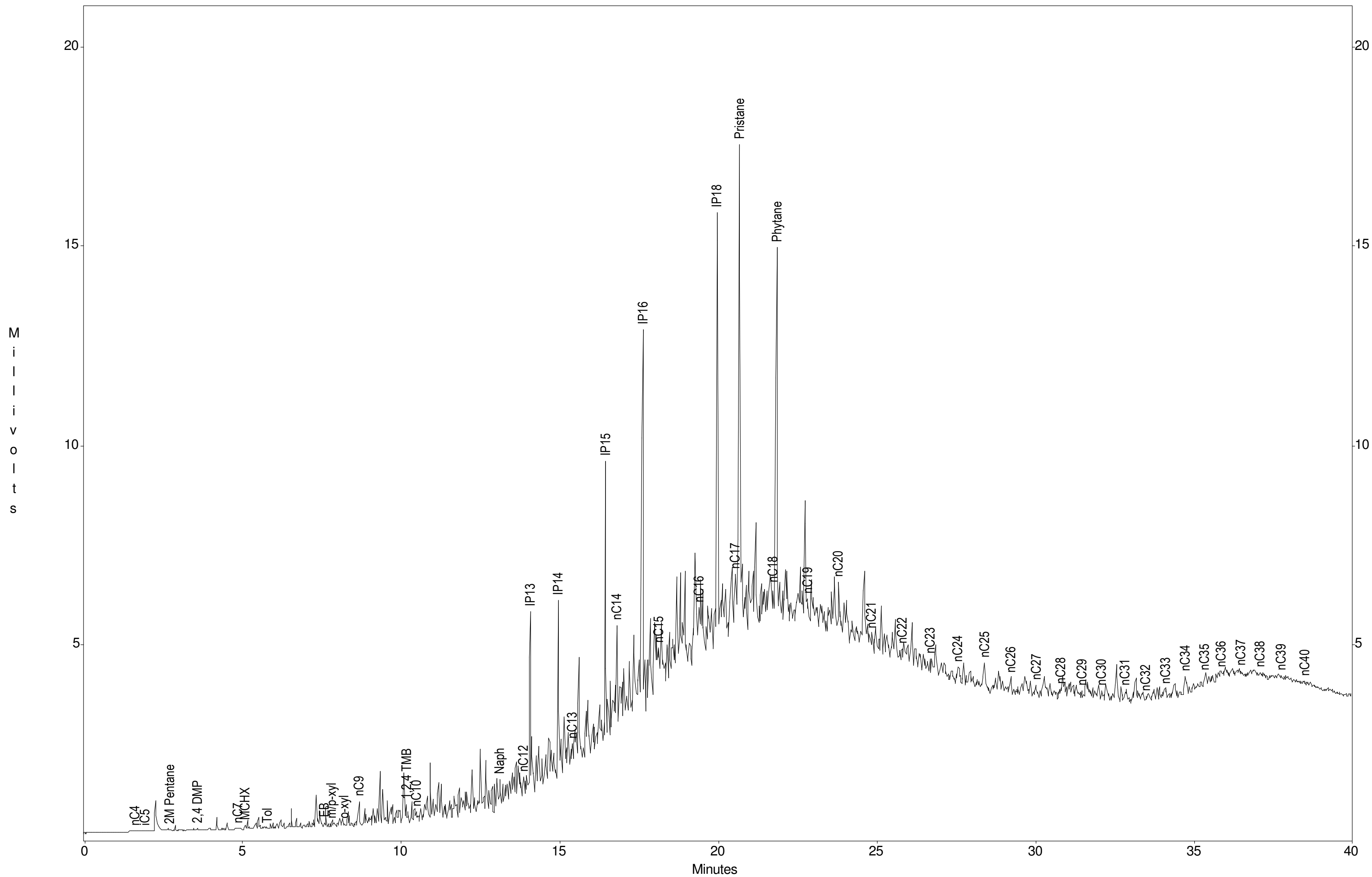
| ITEM NO. | SAMPLE DESCRIPTION | DATE | MATRIX | LAB NO. | Total # Of Vials | PRESERVATIVES: None | | | | | ANALYSES REQUESTED: GC Characterization | Density | Viscosity | Water Surface Tension | NAPL Surface Tension | NAPL/Water Interfac. Tens. | Lead | Sulfur | | | | | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | W-8 | 4/27/11 | | | 1 | | | | | | x | x | | | | | x | | | | | | |
| 2 | W-14 | 4/27/11 | | | 1 | | | | | | x | x | | | | | x | | | | | | |
| 3 | W-18 | 4/27/11 | | | 1 | | | | | | x | x | | | | | x | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | |

| | RELINQUISHED BY | ACCEPTED BY | DATE | TIME |
|---|---|---|---|---|
| | [signature] | Fed Ex | 5/5/11 | 1700 |
| | | [signature] | 5-10-11 | 0910 |
| | | | | |

# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : W-8
Acquired : May 11, 2011 09:37:00

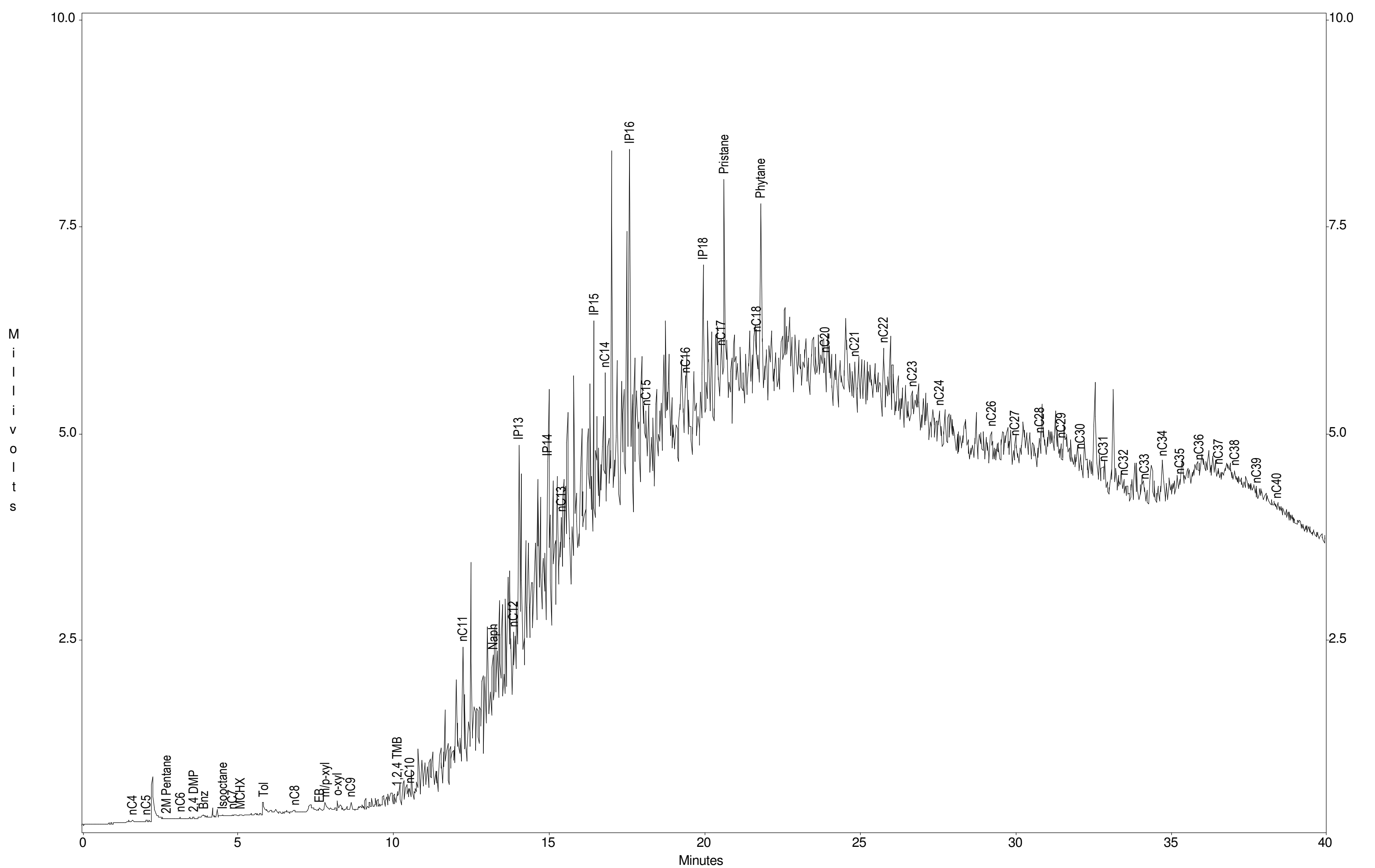
c:\ezchrom\chrom\11076\w-8 -- Channel A



# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : W-14
Acquired : May 11, 2011 12:10:20

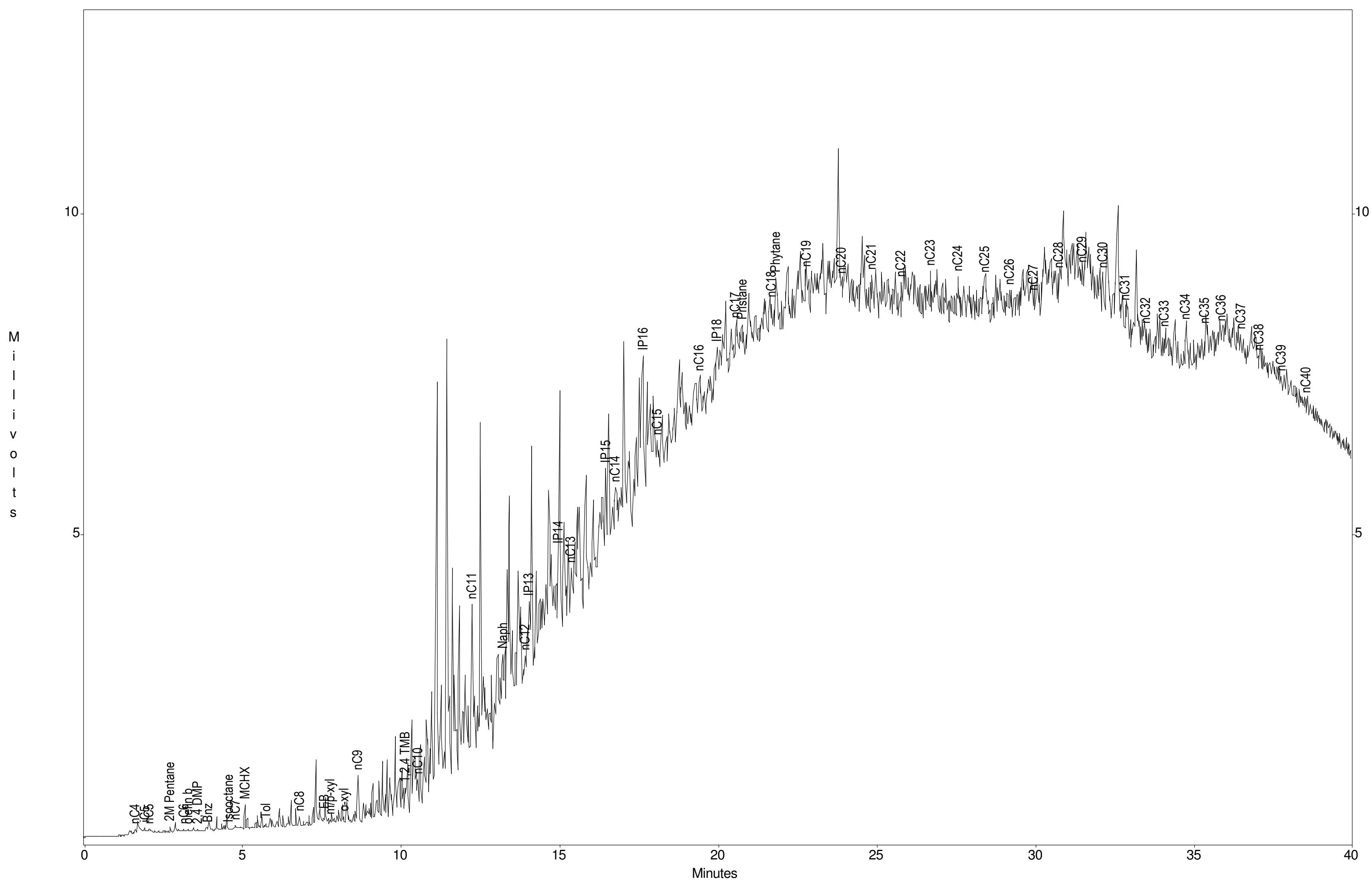
c:\ezchrom\chrom\11076\w-14 -- Channel A



# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : W-18
Acquired : May 11, 2011 14:41:20

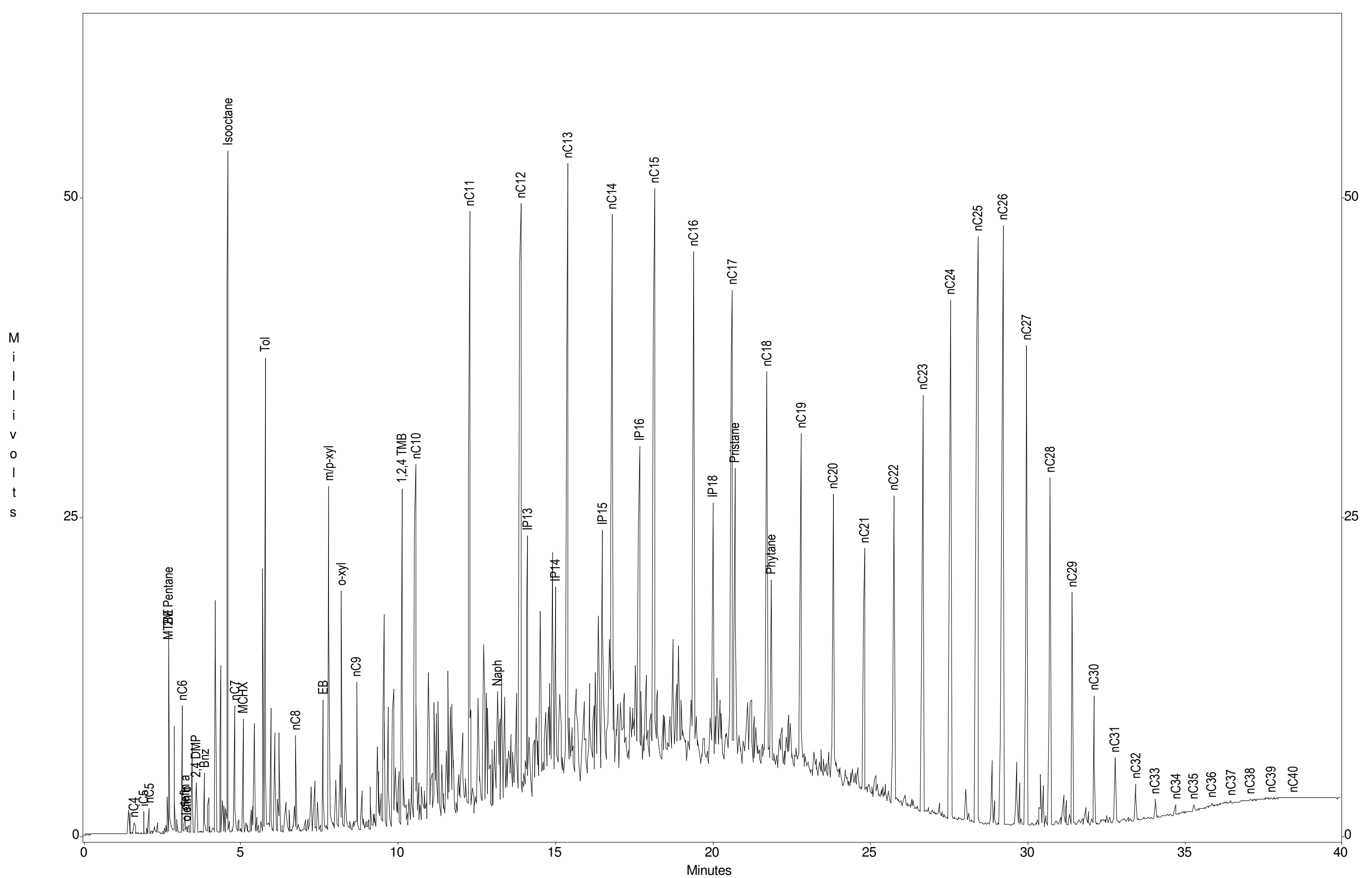
c:\ezchrom\chrom\11076\w-18 -- Channel A



# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : Gas/Dies/Wax std
Acquired : May 11, 2011 08:45:38

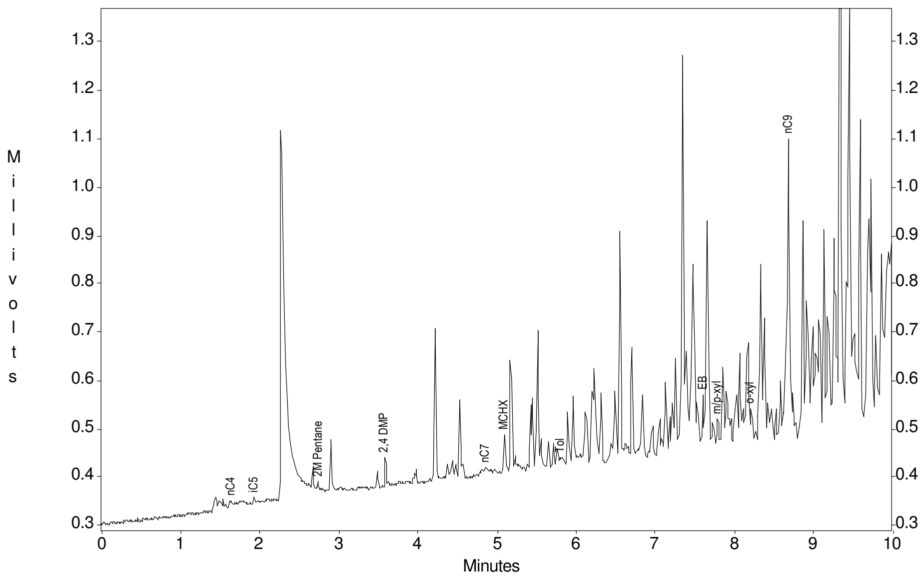
c:\ezchrom\chrom\11076\gadiwax2 -- Channel A



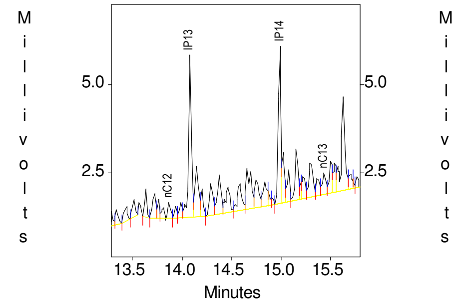
# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : W-8
Acquired : May 11, 2011 09:37:00

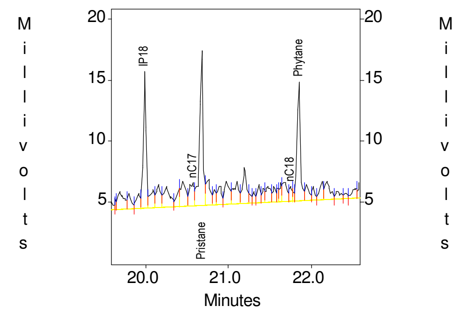
c:\ezchrom\chrom\11076\w-8 -- Channel A



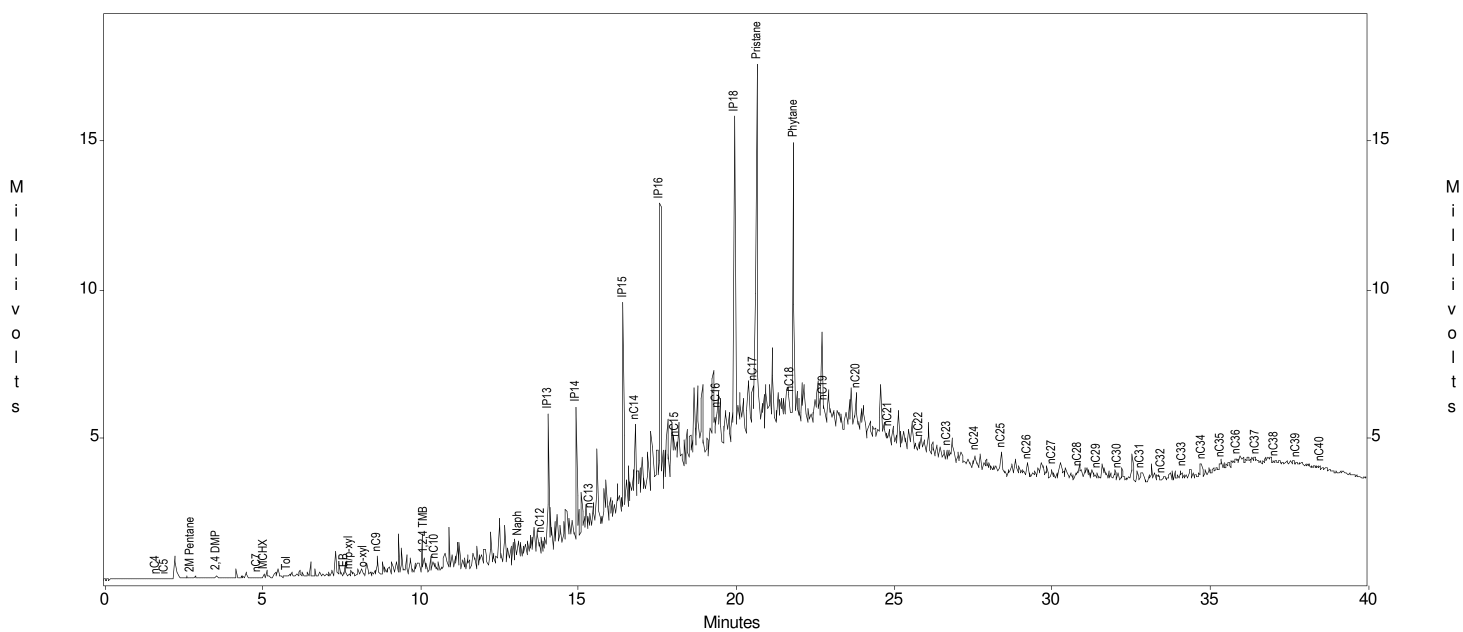

c:\ezchrom\chrom\11076\w-8 -- Channel A




c:\ezchrom\chrom\11076\w-8 -- Channel A




c:\ezchrom\chrom\11076\w-8 -- Channel A



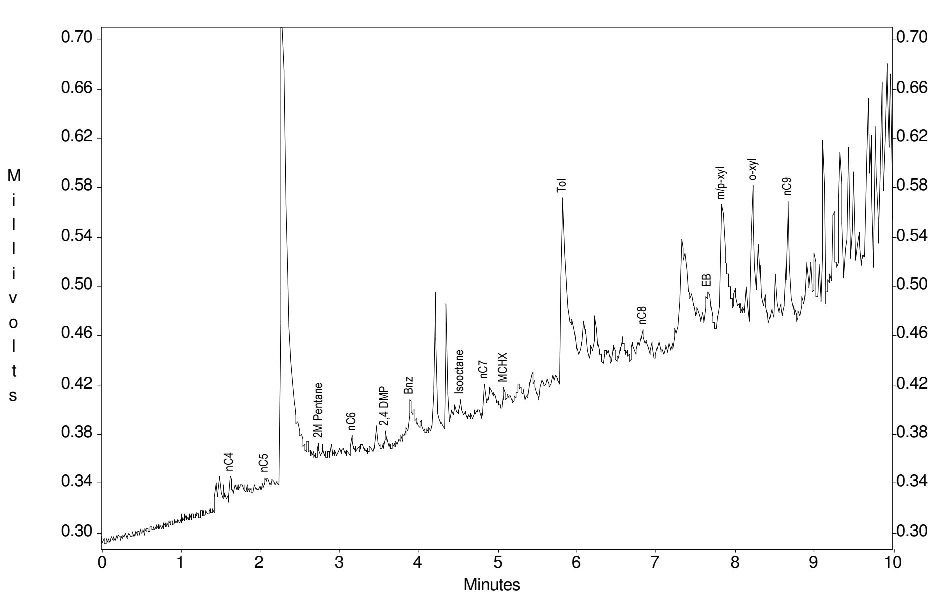

Channel A Results

| Peak | Area | Height |
|---|---|---|
| nC4 | 26 | 9 |
| iC5 | 13 | 14 |
| nC5 | 0 | 0 |
| MTBE | 0 | 0 |
| 2M Pentane | 26 | 18 |
| nC6 | 0 | 0 |
| olefin a | 0 | 0 |
| olefin b | 0 | 0 |
| olefin c | 0 | 0 |
| 2,4 DMP | 71 | 61 |
| Bnz | 0 | 0 |
| Isooctane | 0 | 0 |
| nC7 | 12 | 6 |
| MCHX | 137 | 80 |
| Tol | 60 | 18 |
| nC8 | 0 | 0 |
| EB | 184 | 116 |
| m/p-xyl | 122 | 61 |
| o-xyl | 192 | 73 |
| nC9 | 1278 | 623 |
| 1,2,4 TMB | 1428 | 463 |
| nC10 | 625 | 271 |
| nC11 | 0 | 0 |
| Naph | 1924 | 690 |
| nC12 | 1373 | 426 |
| IP13 | 8332 | 4543 |
| IP14 | 6898 | 4436 |
| nC13 | 1666 | 583 |
| IP15 | 10866 | 6887 |
| nC14 | 5080 | 2616 |
| IP16 | 21224 | 9646 |
| nC15 | 1338 | 380 |
| nC16 | 2931 | 1460 |
| IP18 | 27062 | 11195 |
| nC17 | 8600 | 1948 |
| Pristane | 35844 | 12690 |
| nC18 | 2310 | 1203 |
| Phytane | 26486 | 9732 |
| nC19 | 1722 | 579 |
| nC20 | 4027 | 1396 |
| nC21 | 1280 | 471 |
| nC22 | 1111 | 362 |
| nC23 | 792 | 339 |
| nC24 | 2373 | 429 |
| nC25 | 4148 | 691 |
| nC26 | 1682 | 434 |
| nC27 | 838 | 287 |
| nC28 | 1048 | 250 |
| nC29 | 333 | 189 |
| nC30 | 298 | 154 |
| nC31 | 131 | 91 |
| nC32 | 86 | 78 |
| nC33 | 241 | 133 |
| nC34 | 667 | 194 |
| nC35 | 121 | 34 |
| nC36 | 62 | 20 |
| nC37 | 99 | 75 |
| nC38 | 164 | 45 |
| nC39 | 39 | 62 |
| nC40 | 92 | 57 |

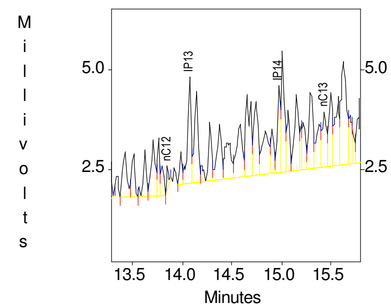
# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : W-14
Acquired : May 11, 2011 12:10:20

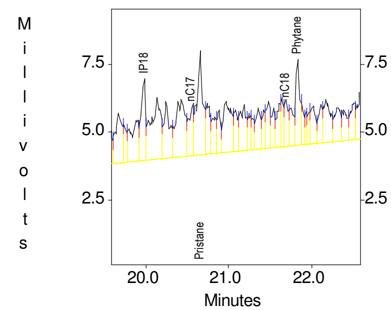
c:\ezchrom\chrom\11076\w-14 -- Channel A



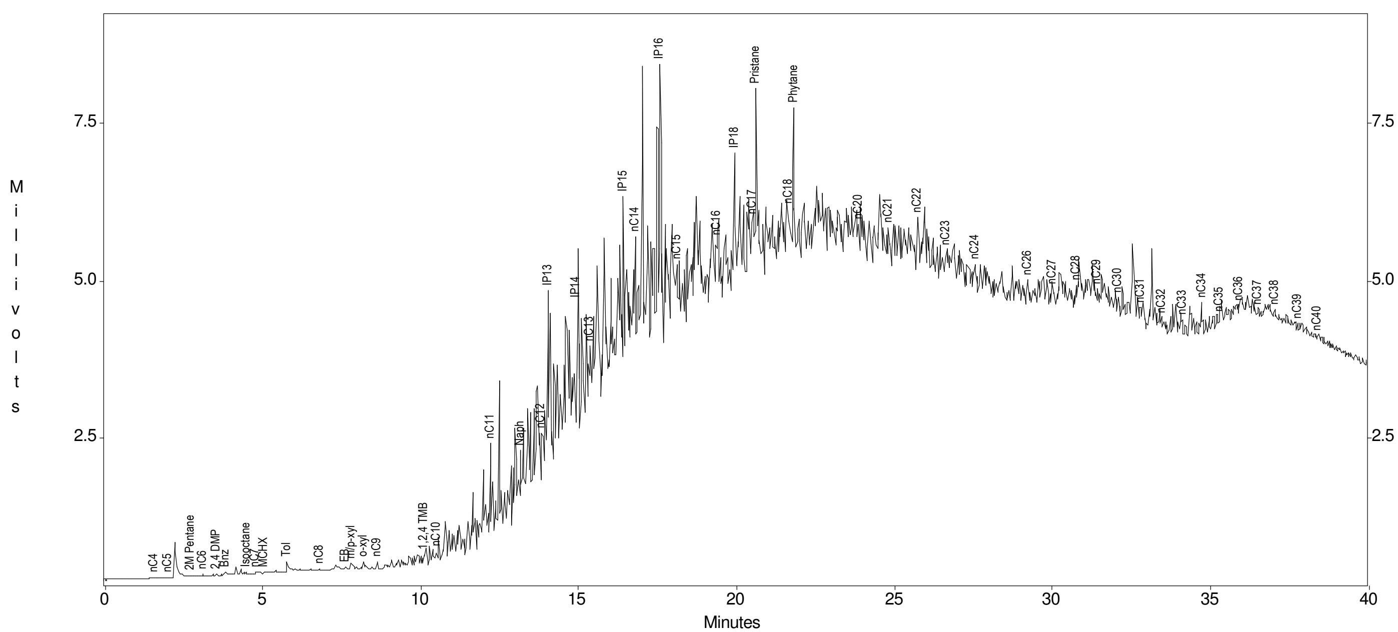

c:\ezchrom\chrom\11076\w-14 -- Channel A




c:\ezchrom\chrom\11076\w-14 -- Channel A




c:\ezchrom\chrom\11076\w-14 -- Channel A



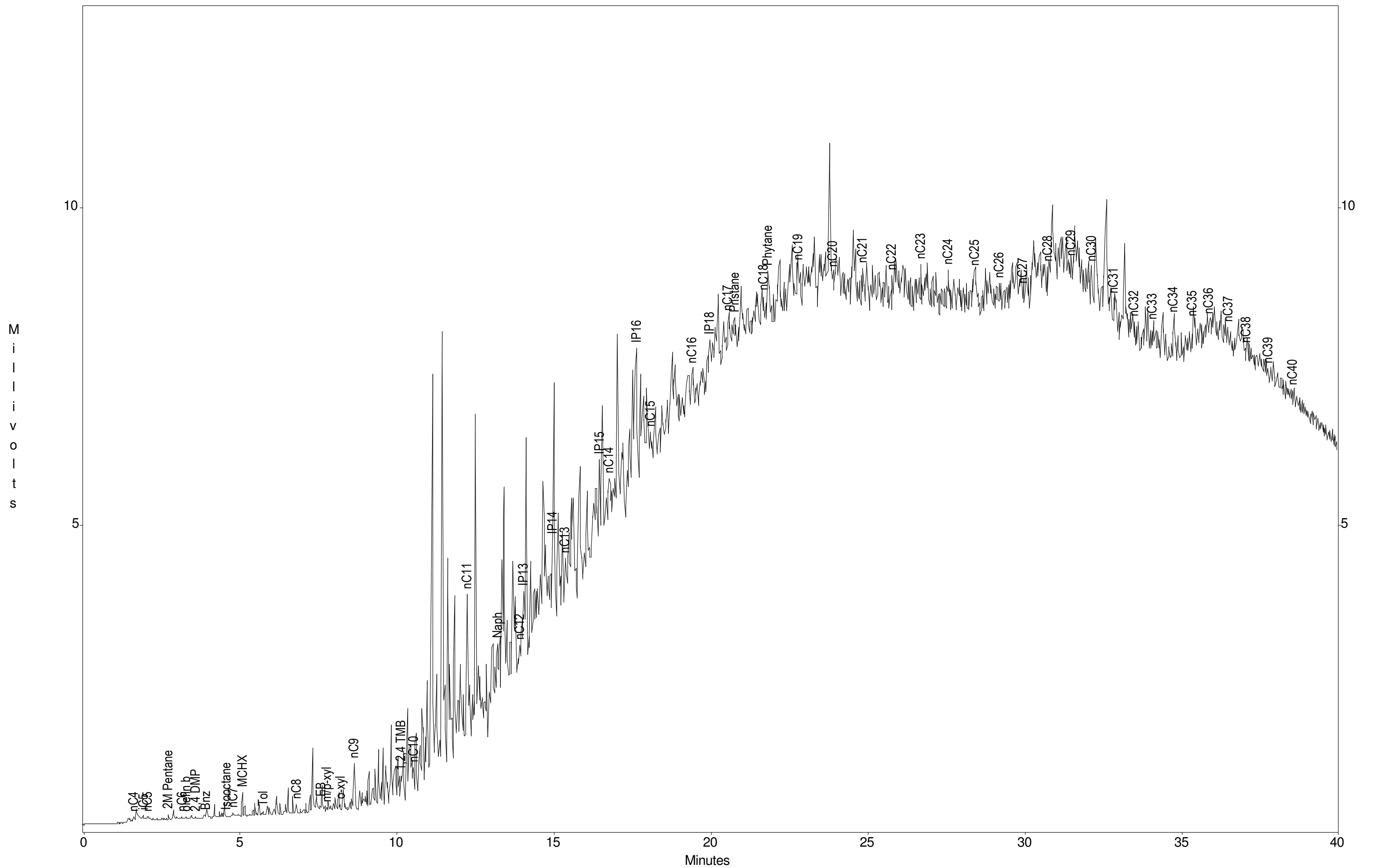

Channel A Results

| Peak | Area | Height |
|---|---|---|
| nC4 | 30 | 18 |
| iC5 | 0 | 0 |
| nC5 | 16 | 6 |
| MTBE | 0 | 0 |
| 2M Pentane | 15 | 11 |
| nC6 | 26 | 13 |
| olefin a | 0 | 0 |
| olefin b | 0 | 0 |
| olefin c | 0 | 0 |
| 2,4 DMP | 19 | 13 |
| Bnz | 60 | 24 |
| Isooctane | 31 | 15 |
| nC7 | 37 | 22 |
| MCHX | 18 | 12 |
| Tol | 696 | 150 |
| nC8 | 122 | 26 |
| EB | 219 | 41 |
| m/p-xyl | 666 | 108 |
| o-xyl | 310 | 117 |
| nC9 | 235 | 99 |
| 1,2,4 TMB | 365 | 168 |
| nC10 | 255 | 161 |
| nC11 | 2662 | 1386 |
| Naph | 1804 | 664 |
| nC12 | 596 | 515 |
| IP13 | 6689 | 2668 |
| IP14 | 4029 | 2196 |
| nC13 | 3982 | 1383 |
| IP15 | 7913 | 3433 |
| nC14 | 6859 | 2697 |
| IP16 | 18715 | 5161 |
| nC15 | 6080 | 1832 |
| nC16 | 7165 | 1833 |
| IP18 | 11154 | 3036 |
| nC17 | 8304 | 1828 |
| Pristane | 17353 | 3866 |
| nC18 | 5348 | 1639 |
| Phytane | 10753 | 3207 |
| nC19 | 0 | 0 |
| nC20 | 2476 | 721 |
| nC21 | 966 | 475 |
| nC22 | 2746 | 912 |
| nC23 | 1084 | 511 |
| nC24 | 1885 | 428 |
| nC25 | 0 | 0 |
| nC26 | 1608 | 389 |
| nC27 | 1420 | 262 |
| nC28 | 1183 | 308 |
| nC29 | 314 | 191 |
| nC30 | 559 | 212 |
| nC31 | 127 | 126 |
| nC32 | 218 | 130 |
| nC33 | 102 | 129 |
| nC34 | 483 | 202 |
| nC35 | 82 | 75 |
| nC36 | 144 | 84 |
| nC37 | 52 | 26 |
| nC38 | 143 | 88 |
| nC39 | 123 | 97 |
| nC40 | 270 | 63 |

# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : W-18
Acquired : May 11, 2011 14:41:20

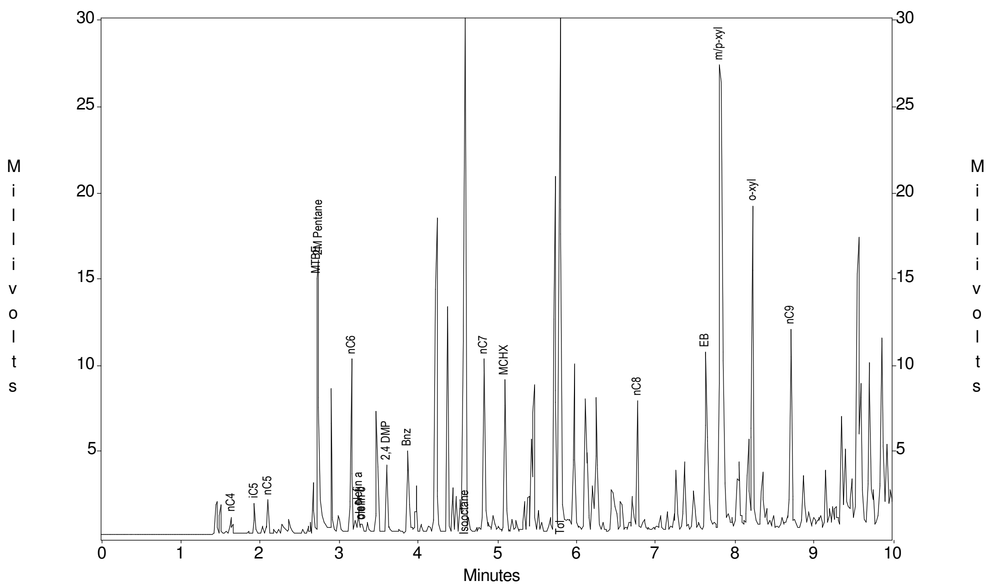
c:\ezchrom\chrom\11076\w-18 -- Channel A



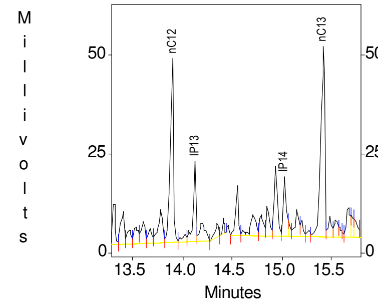
# Torkelson Geochemistry, Inc.

Philadelphia Refinery - AOI-10, Philadelphia, PA
Sample ID : Gas/Dies/Wax std
Acquired : May 11, 2011 08:45:38

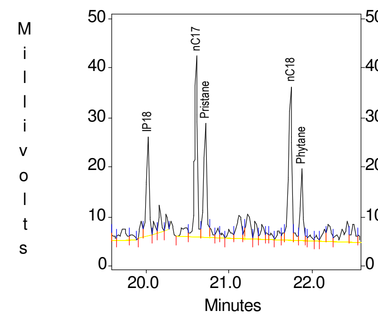
c:\ezchrom\chrom\11076\gadiwax2 -- Channel A



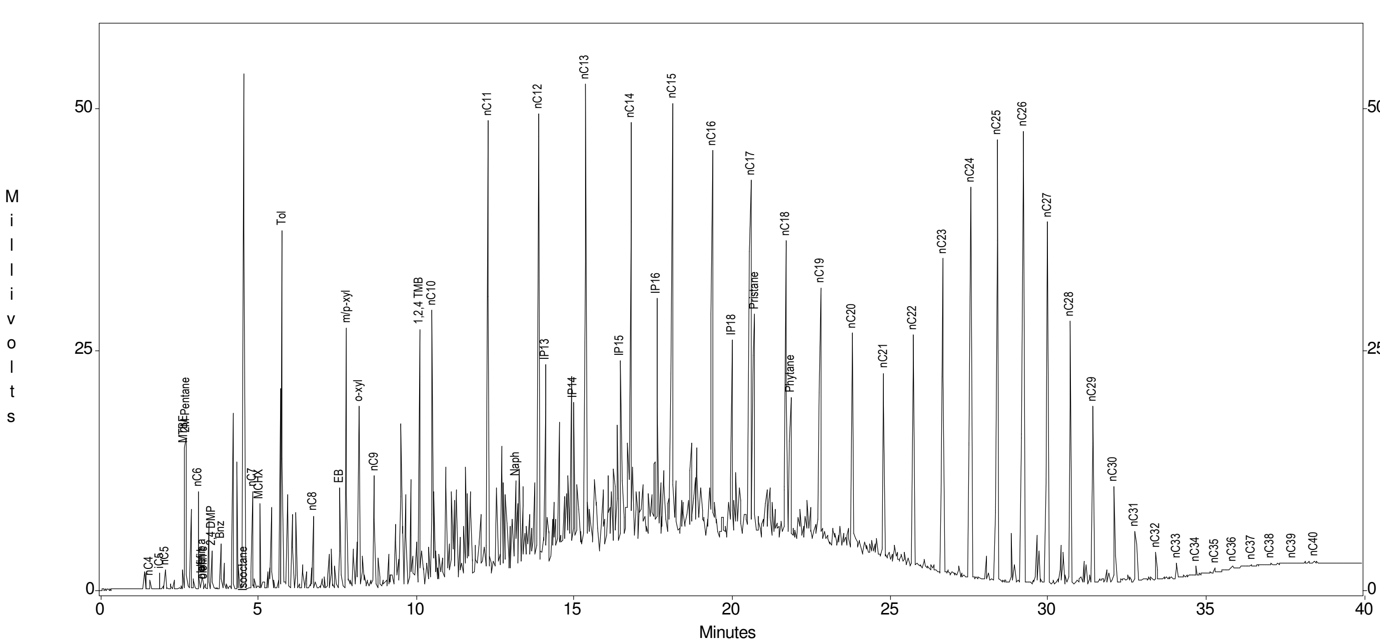

c:\ezchrom\chrom\11076\gadiwax2 -- Channel A




c:\ezchrom\chrom\11076\gadiwax2 -- Channel A




c:\ezchrom\chrom\11076\gadiwax2 -- Channel A




Channel A Results

| Peak | Area | Height |
|---|---|---|
| nC4 | 882 | 909 |
| iC5 | 1633 | 1749 |
| nC5 | 1940 | 1953 |
| MTBE | 8850 | 14569 |
| 2M Pentane | 18459 | 15652 |
| nC6 | 10279 | 9981 |
| olefin a | 1514 | 1289 |
| olefin b | 601 | 484 |
| olefin c | 615 | 477 |
| 2,4 DMP | 4152 | 3895 |
| Bnz | 6800 | 4664 |
| Isooctane | 72556 | 53339 |
| nC7 | 13271 | 9974 |
| MCHX | 11206 | 8826 |
| Tol | 57982 | 37077 |
| nC8 | 9634 | 7484 |
| EB | 18905 | 10280 |
| m/p-xyl | 61342 | 26945 |
| o-xyl | 29293 | 18689 |
| nC9 | 18569 | 11567 |
| 1,2,4 TMB | 51680 | 26364 |
| nC10 | 47623 | 28216 |
| nC11 | 122201 | 47154 |
| Naph | 23589 | 9025 |
| nC12 | 106065 | 46620 |
| IP13 | 44181 | 20448 |
| IP14 | 27510 | 14987 |
| nC13 | 136271 | 48220 |
| IP15 | 40217 | 19413 |
| nC14 | 127674 | 44012 |
| IP16 | 58532 | 25574 |
| nC15 | 127948 | 45568 |
| nC16 | 109771 | 40258 |
| IP18 | 46900 | 19832 |
| nC17 | 97658 | 36773 |
| Pristane | 58335 | 22987 |
| nC18 | 78896 | 31071 |
| Phytane | 35304 | 14857 |
| nC19 | 79141 | 26845 |
| nC20 | 54013 | 22611 |
| nC21 | 41857 | 19064 |
| nC22 | 54172 | 24047 |
| nC23 | 86519 | 32680 |
| nC24 | 132481 | 40589 |
| nC25 | 156315 | 45816 |
| nC26 | 157441 | 46917 |
| nC27 | 118660 | 37602 |
| nC28 | 74059 | 27225 |
| nC29 | 40797 | 18246 |
| nC30 | 19773 | 9898 |
| nC31 | 9574 | 4849 |
| nC32 | 5379 | 2820 |
| nC33 | 2901 | 1511 |
| nC34 | 1690 | 857 |
| nC35 | 1012 | 480 |
| nC36 | 527 | 254 |
| nC37 | 561 | 177 |
| nC38 | 191 | 86 |
| nC39 | 196 | 88 |
| nC40 | 101 | 49 |

Torkelson Geochemistry, Inc.

## Physical Properties Measurements

| Sample | TGI Job Number | Density of NAPL (gm/ml) | Viscosity of NAPL (centipoise) | Surface Tension Air/Water (dynes/cm) | Interfacial Tension NAPL/Water (dynes/cm) | Surface Tension Air/NAPL (dynes/cm) | Temperature of Measurements |
|---|---|---|---|---|---|---|---|
| W-8 | 11047 | 0.9515 | NA | NA | NA | NA | 60F |
| W-14 | 11047 | 0.9478 | NA | NA | NA | NA | 60F |
| W-18 | 11047 | QNS | NA | NA | NA | NA | 60F |

QNS = Quantity of sample Not Sufficient for analysis
NA = Not Analyzed

6825 East 38th Street
Tulsa, Oklahoma 74145-1105
www.greencountrytesting.com

**Green Country TESTING**

Telephone 918.828.9977
Telephone 800.324.5757
Facsimile 918.828.7750

Bruce Torkelson
Torkelson Geochemistry
2528 South Columbia Place
Tulsa, OK 74114
TEL: (918) 749-8441
FAX (918) 749-6005

May 27, 2011
Order No.: T11050348

RE: Samples

Dear Bruce Torkelson:

Green Country Testing, Inc. received 2 samples on 5/20/2011 for the analyses presented in the following report.

In accordance with your instructions, Green Country Testing conducted the analysis shown on the following pages on samples submitted by your company. The results related only to the items tested. Unless otherwise noted, all analysis was conducted using EPA approved methodologies. Test reports meet all the NELAC requirements. All relevant sampling information is on the attached chain-of-custody form. The initials SUB as the analyst designate any testing sub-contracted by Green Country Testing.

Certifications/Accreditation: OK - 7604
AR - ADEQ
KS - E-10232
LA - 4002

A scope of Certified/Accredited parameters is available upon request. If you have any questions regarding these tests results, please feel free to call.

Sincerely,

Approved By: ______________________
Brian Duzan, Director
Environmental Services

6825 East 38th Street
Tulsa, Oklahoma 74145-1105
www.greencountrytesting.com

# Green Country TESTING

Telephone 918.828.9977
Telephone 800.324.5757
Facsimile 918.828.7750

**CLIENT:** Torkelson Geochemistry
**Lab Order:** T11050348 **Date Received:** 5/20/2011
**Project:** Samples **Date Reported:** *27-May-11*

**Lab ID: T11050348-01** **Collection Date: 4/27/2011** **Sample ID: W-8 11076**

**Matrix: OIL**

| Analyses | Result | Detection Limit | Qual | Units | Date Analyzed | Analyst |
|---|---|---|---|---|---|---|
| **METALS IN SOIL OR SLUDGE BY ICP** | **SW6010B** | | | | | **KR** |
| Lead | < 0.500 | 0.500 | | mg/Kg | 5/26/2011 | |

**Lab ID: T11050348-02** **Collection Date: 4/27/2011** **Sample ID: W-14 11076**

**Matrix: OIL**

| Analyses | Result | Detection Limit | Qual | Units | Date Analyzed | Analyst |
|---|---|---|---|---|---|---|
| **METALS IN SOIL OR SLUDGE BY ICP** | **SW6010B** | | | | | **KR** |
| Lead | 1.89 | 0.500 | | mg/Kg | 5/26/2011 | |

**Qualifiers:**
ND - Not Detected at the Reporting Limit
J - Analyte detected below quantitation limits
B - Analyte detected in the associated Method Blank
* - Value exceeds MCL or Permit Limitation
S - Spike Recovery outside accepted recovery limits
R - RPD outside accepted recovery limits
MI+ - Matrix Interference
H - Exceeds Holding Time

6825 East 38th Street
Tulsa, Oklahoma 74145-1105
www.greencountrytesting.com

Green Country
TESTING

Telephone 918.828.9977
Telephone 800.324.5757
Facsimile 918.828.7750

**CLIENT:** Torkelson Geochemistry
**Work Order:** T11050348
**Project:** Samples

# QC SUMMARY REPORT

| TestCode | Analyte | BatchID | QCType | Result | PQL | Units | %Rec | %RPD |
|---|---|---|---|---|---|---|---|---|
| MET_S_ICP | Lead | 5654 | MBLK | < 0.12 | 0.125 | mg/Kg | | |
| | Lead | 5654 | LCS | 48 | 0.125 | mg/Kg | 96.2 | |
| | Lead | 5654 | LCS | 47.36 | 0.125 | mg/Kg | 94.9 | 1.34 |
| | Lead | 5654 | MS | 191.1 | 0.5 | mg/Kg | 97.1 | |
| | Lead | 5654 | MSD | 191.7 | 0.5 | mg/Kg | 97.4 | 0.303 |

# Green Country Testing . Chain of Custody Record

Laboratory Number: T1105034 8

Page 1 of 1

| Client Information: | | Billing Information: | PO Number: | Project Name/Number: |
|---|---|---|---|---|
| Company Name: | Torkelson Geochemistry | | Quote Number: | Sampler's Signature |
| Contact Name: | Bruce Torkelson | | Required QC Level | |
| Address: | | | | |
| City, State, Zip: | | | | |
| Phone Number: | 749-8441 Ext: | Ext: | Bill Monthly ☐ Yes ☒ No | Shipping Method: UPS / FedEx / Airborne DHL / GCT / (Hand) / Mail |
| Fax Number: | | | | |
| Email Address: | | | | |

Turn Time
☒ Standard
☐ 1 Day
☐ 2 Day
☐ Other
(Rush turn times will incur a surcharge and must be pre-approved by lab.)

Which Regulations Apply:
☐RCRA ☐Drinking Water
☐POTW ☐Distribution
☐NPDES ☐Special
☐USDA/FDA ☐State
☐RECAP/RISC ☐Other

Matrix Code:
AQ = Aqueous, SO = Soil
DW = Drinking, O = Oil
WW = Waste, SL = Sludge
MW = Monit. Well, F = Food
LQ = Liquid, SW = Swab
SOL = Solid

| Sample ID/Description | Date | Time | Grab / Composite | Matrix | Container Quantity | Container Type (P=Plastic, G=Glass, V=Vail) | Pres. (HCl, $HNO_3$, $H_2SO_4$, NaOH, $Na_2S_2O_3$) | Requested Tests: Lead | Comments |
|---|---|---|---|---|---|---|---|---|---|
| W-8 11076 | 4-7-11 | — | G | O | 1 | G | none | ✓ | |
| W-14 11076 | 4-7-11 | — | G | O | 1 | G | none | ✓ | |

| | Relinquished by | Date/Time | Received by | Date/Time |
|---|---|---|---|---|
| 1 | [signature] | 5-20-11/1535 | [signature] | 5/20/11 1535 |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

Field Notes:
Received on ice? ☒ Yes ☒ No (crossed out)
Temp: 23°c

All samples submitted to Green Country Testing for analysis are accepted on a custodial basis only. Ownership of the material remains with the client submitting the samples.
Green Country Testing reserves the right to return unused sample protions.

**Green Country Testing**
**6825 East 38th Street • Tulsa, OK 74145**
**918-828-9977 • Fax (918) 828-7756**

Part 1 - Laboratory Copy Part 2 - Report Copy Part 3 - Client's Temporary Copy

# Torkelson Geochemistry, Inc.

2528 S. Columbia Place
Tulsa, OK 74114-3233

Phone: 918-749-8441 e-mail: BTorkelson@aol.com
Fax: 918-749-6005


# CHAIN-OF-CUSTODY RECORD

Project: Sun- Philadelphia Refinery COA
Location: Philadelphia, PA

Proj. No.:
P.O.:
Sampled By: M. Brad Spancake & Tim Delk

Report/Bill To: Colleen Costell0
Address: 30 South 17th St, Suite 1500
Philadelphia, PA 19103

Phone: 215.864.0640
Fax: 215.864.0671
e-mail:

**Additional Instructions**

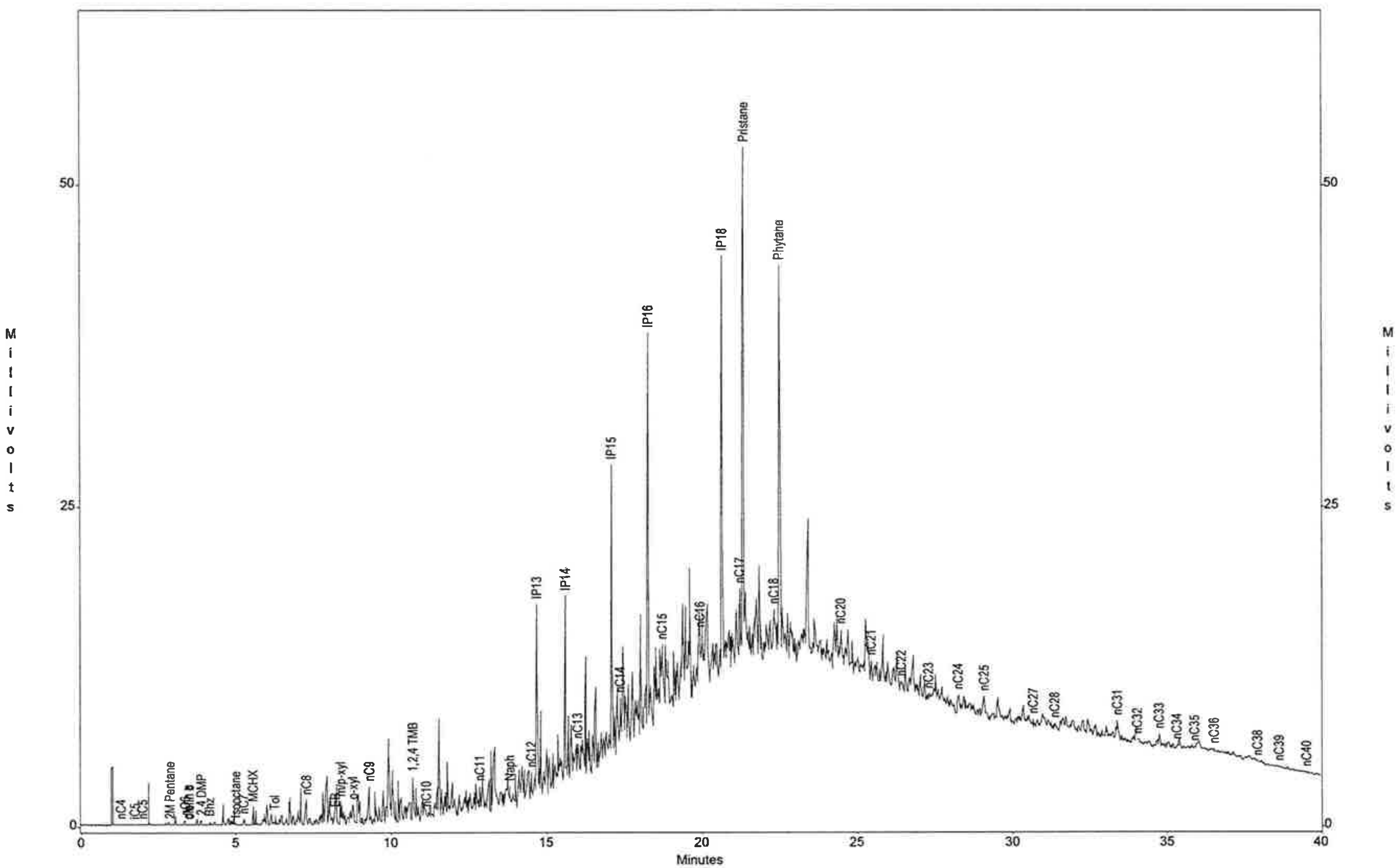
Requested Turn-Around Time:

| ITEM NO. | SAMPLE DESCRIPTION | DATE | MATRIX | LAB NO. | Total # OF Vials | PRESERVATIVES: None | GC Characterization | Specific Gravity | REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | West Yard W8 | 2/27/04 | Product | | 1 | X | X | X | |
| 2 | A-13 | ↓ | ↓ | | 1 | X | X | X | |
| 3 | B-144 | ↓ | ↓ | | 1 | X | X | X | |
| 4 | C-106 | ↓ | ↓ | | 1 | X | X | X | |
| 5 | A-133 | ↓ | ↓ | | 1 | X | X | X | |
| 6 | C-65 | ↓ | ↓ | | 1 | X | X | X | |
| 7 | B-43 | ↓ | ↓ | | 1 | X | X | X | |
| 8 | B-39 | ↓ | ↓ | | 1 | X | X | X | |
| 9 | A-136 | ↓ | ↓ | | 1 | X | X | X | Sorbent Pad Sample |
| 10 | C-107 | | | | 1 | X | X | X | |

| RELINQUISHED BY | ACCEPTED BY | DATE | TIME |
|---|---|---|---|
| M. Brad [signature] | FED EX | 3/1/04 | |
| | [signature] | 3-2-04 | 1705 |
| | | | |

Sun - Philadelphia Refinery COA
Sample ID : West Yard W8
Acquired : Mar 07, 2004 08:54:39

c:\ezchrom\chrom\04046\wyw8 -- Channel A



# ATTACHMENT C

AOI 10 Existing Natural Resources Plan


N W E S

## Legend

- Floodway
- 0.2% Annual Chance of Flood
- AE - 100 Year Flood
- X - Areas Determined to be Outside the 0.2% Annual Chance Floodplain
- PSS1 - Palustrine Scrub Shrub Wetland
- U - Upland
- Past Disposal Area (PDA)
- Area of Interest Boundary (AOI)

Notes:

1. Bings Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Floodway and flood hazard areas derived from the Digital Flood Insurance Rate Map Database (DFIRM) for Pennsylvania, by the Federal Emergency Management Agency (FEMA) 2005.
3. Wetlands from the National Wetlands Inventory for Pennsylvania, by the U.S. Fish and Wildlife Service, published September 25, 2009.

Attachment C - Natural Resources Plan
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

SCALE: 1" = 300'
DATE: October 27, 2011
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601

Path: \\langan.com\data\DT\data6\2574601\ArcGIS\MapDocuments\AOI 10 Workplan\AOI-10 Natural Resources Plan 11x17.mxd