APPENDIX A

PADEP CORRESPONDENCE AND REPORT NOTICES

PADEP Correspondence

pennsylvania
DEPARTMENT OF ENVIRONMENTAL
PROTECTION

March 28, 2016

Mr. James Oppenheim
Evergreen Resources Management Operations
2 Righter Parkway, Suite 200
Wilmington, DE 19803

Re: Disapproval of Remedial Investigation Report
Philadelphia Refinery AOI 9
eFACTS PF No. 778379
Mingo Avenue
City of Philadelphia
Philadelphia County

Dear Mr. Oppenheim:

The Department of Environmental Protection (DEP) has reviewed the December 31, 2015 document titled "Remedial Investigation Report, Area of Interest 9" for the Schuylkill River Tank Farm located on Mingo Avenue, Philadelphia. The report was prepared by Langan Engineering and Environmental Services, Inc. and submitted to DEP in accordance with the Land Recycling and Environmental Remediation Standards Act (Act 2). It constitutes a remedial investigation report as defined in Chapter 3 of Act 2.

DEP notes the following deficiencies in the report and disapproves it in accordance with the provisions of Act 2:

1. Site characterization data indicate that groundwater concentrations of benzene and other substances are elevated at the western property boundary, along Essington Avenue. There are no wells west of the property line to characterize the offsite extent of contamination. Delineating the horizontal extent of groundwater contamination is required by Title 25 Pa. Code Sections 250.408(a), (b), and (e).

2. Groundwater elevations and flow directions are inadequately determined at the western property boundary. Characterizing groundwater flow is required by Section 250.408(e).

3. A better understanding of groundwater flow and the extent of groundwater contamination is necessary to assess potentially complete offsite exposure pathways as per Section 250.404.

4. The report does not evaluate the inhalation exposure pathway for onsite outdoor workers to vapors from contaminated soil, groundwater, and LNAPL. This pathway must be addressed pursuant to Section 250.404.

In order for your site to be in compliance with applicable requirements of Act 2, these items must be addressed. The department is willing to work with you to develop an approvable submittal. ***Please note that the required fee(s) must be repaid and public notification must be repeated for all new submittals.***

If you wish to discuss these deficiencies, please contact Mr. C. David Brown at 484.250.5796 or by email at.cdbrown@pa.gov.

Any person aggrieved by this action may appeal, pursuant to Section 4 of the Environmental Hearing Board Act, 35 P.S. Section 7514, and the Administrative Agency Law, 2 Pa.C.S. Chapter 5A, to the Environmental Hearing Board, Second Floor, Rachel Carson State Office Building, 400 Market Street, P.O. Box 8457, Harrisburg, PA 17105-8457, 717.787.3483. TDD users may contact the Board through the Pennsylvania Relay Service, 800.654.5984. Appeals must be filed with the Environmental Hearing Board within 30 days of receipt of written notice of this action unless the appropriate statute provides a different time period. Copies of the appeal form and the Board's rules of practice and procedure may be obtained from the Board. The appeal form and the Board's rules of practice and procedure are also available in braille or on audiotape from the Secretary to the Board at 717.787.3483. This paragraph does not, in and of itself, create any right of appeal beyond that permitted by applicable statutes and decisional law.

If you want to challenge this action, your appeal must reach the Board within 30 days. You do not need a lawyer to file an appeal with the Board.

Important legal rights are at stake, however, so you should show this document to a lawyer at once. If you cannot afford a lawyer, you may qualify for free pro bono representation. Call the secretary to the Board (717.787.3483) for more information.

Sincerely,

Stephan Sinding
Regional Manager
Environmental Cleanup and Brownfields

cc: Mr. Barksdale- PES
Mr. McKeever - Langan
Mr. Bilash - EPA Region 3
Philadelphia Health Department
Mr. Brown, P.G.
Ms. Warren
Ms. Bass
Regional File
Re 30 (cm16ecb) 088-1

From: Brown, C David <cdbrown@pa.gov>
Sent: Thursday, March 10, 2016 1:28 PM
To: Tiffani Doerr; Kevin McKeever
Cc: OPPENHEIM, JIM; Kevin Bilash (bilash.kevin@epa.gov); Kennedy, Susan
Subject: comments on Philadelphia Refinery AOI 9 remedial investigation report

Tiffani and Kevin,

I have reviewed the AOI 9 RIR dated 12/31/2015 and my comments follow. The primary concern is with the delineation of groundwater contamination at the western property boundary, and I discuss this first below. Some of the other comments also include regulatory deficiencies and they are enumerated after.

1. Site characterization data indicates that benzene and other substances exceed Statewide health standard MSCs at the western property boundary, along Essington Avenue. Exceedences were found at monitoring wells S-113, S-115, S-135, and S-115D. There are no offsite wells west of the property line. The report acknowledges that the plume is not delineated in this area (Appendix I), and this is exemplified by the open concentration contour lines in Figures I-16 and I-18. Concerns with adequate characterization of groundwater contamination at this boundary were previously communicated in DEP's 4/28/2011 comments on the Oct 2009 AOI 9 RIR, in the 9/12/2013 comments on the Jun 2013 AOI 11 final report, and at the 4/17/2015 meeting to discuss the AOI 9 work plan. Delineating the horizontal extent of groundwater contamination is required by Title 25 Pa. Code Section 250.408(a), (b), and (e). (Other comments relevant to this deficiency follow.)

2. The RIR refers to the May 2009 work plan for site characterization and the Oct 2009 site characterization report. Please incorporate these documents with the RIR by providing them as a supplemental appendix on CD-ROM. (In general, previous characterization reports being utilized to satisfy the RIR requirements should be included as electronic appendices.) [§250.408(c)]

3. Groundwater elevation data was provided only for Aug and Nov 2015 (Table 3). Certain wells were sampled in Jan 2009, Aug 2009, Jan 2015, and Mar 2015. If available, provide well gauging and groundwater elevation data for those events. [§250.408(c)]

4. Several wells were installed circa 1986. Is there no analytical data for them before 2009? All available data should be provided. Likewise for pre-2009 soil data. (This requirement was noted in previous comments on the AOIs 4, 6, and 7 RIRs.) [§250.408(c)]

5. There are seven open storage tank corrective action incidents for six tanks in AOI 9 (Facility ID 51-11557).

Release Date	Incident ID	Sunoco Tank	DEP Tank	Material
2/14/1991	46760	SR-33	025A	No. 6 fuel oil
10/29/1994	46764	SR-59	041A	heavy platformate
5/30/2001	4407	SR-59	041A	gasoline
7/7/2003	31881	SR-90	055A	No. 6 fuel oil
1/21/2004	33031	SR-7	007A	gasoline

3/20/2012	43616	SR-16	011A	gasoline
4/18/2012	45951	SR-26	021A	gasoline

Based on the contents of the RIR, Evergreen has characterized soil and groundwater at these tanks. However, the reporting requirements of Section 245.310(a) have not been satisfied. For instance, information was not provided on interim remedial actions, free product recovery, soil excavation and disposal, descriptions of the contamination or releases, the rationale of soil boring and sampling locations, conceptual site models for individual tank cases, an explanation of the disposition of site characterization wastes, worker health and safety plans, investigation derived waste plans, and QA/QC plans. Evergreen should provide a schedule for submission of SCRs for the tank incidents.

6. Why weren't cumene and naphthalene analyzed for the indoor air samples? Method TO-15 is capable of analyzing both substances, they are contaminants of concern, and they have OSHA PELs. It's unclear that VI has been addressed for these chemicals without analytical data. (This point was raised previously in comments on the 2013 AOI 6 and 7 RIRs.)

7. I recommend that you compare the indoor air data also to other recommended limits, such as NIOSH RELs and ACGIH TLVs, in addition to PELs.

8. If Evergreen intends to rely on OSHA regulations to address the vapor intrusion pathway, then certain requirements will apply. All workers in the buildings must be subject to the OSHA rules that pertain to exposures of the chemicals of concern at the facility. The OSHA rules must be properly implemented. An environmental covenant restriction will be required to maintain the OSHA program for all building occupants.

9. Sections 7 and 9 of the RIR do not address the outdoor worker inhalation exposure pathway. This is a potentially complete pathway in areas with LNAPL, soil direct contact standard exceedences, and groundwater MSC exceedences. (The need to address this pathway was noted previously in the 7/23/2014 meeting on the AOI 1 work plan.) [§250.404]

10. The report doesn't provide or reference information on potential groundwater use offsite to the west. (A possible historic well in the area was noted in DEP's Sep 2013 comments on the AOI 11 final report.) In addition, the potential offsite vapor intrusion exposure pathway is not discussed. [§250.404]

11. Please provide more detailed information on the blending area recovery system. When was it installed? What quantity of LNAPL was recovered? What volume of groundwater? What were the estimated masses of recovered contaminants?

12. A 2015 PNDI review is described in Section 9 of the RIR. All associated documents should be provided. [§250.402(d)]

13. There are some discrepancies in Table 2. For many of the 2015 monitoring wells the screen length is given as equal to the well completion depth.

14. There are errors with some figures.
    - Figure 3 indicates MW-1 is damaged or abandoned, but it was gauged and sampled in 2015.
    - Labels for the wells were left out in Figures 7 and 9.
    - In Figures I-16 and I-20 S-135 is classified as an alluvium well. This well was screened to 20', which was below the clay unit.

- The label and map in the hardcopy Figure I-18 depict the alluvium MTBE concentrations for Aug 2015 rather than the Lower Sand benzene concentrations.

15. A sampling and analysis plan and a QA/QC plan are required for the RIR. The report may reference previously submitted documents for this purpose. [§250.408(c)]

16. In Appendix C I was unable to find boring logs for S-27, S-76D, and S-106D.

17. There are contradictory classifications of wells S-111, 112, and 116 as screened either in alluvium or the Lower Sand. In terms of contamination they are alluvium wells (Figure I-16), but in terms of groundwater flow they are Lower Sand wells (Figure I-6).

18. Langan has interpreted the Potomac-Raritan-Magothy Lower/Middle Clay member to be present across much of AOI 9, with the exception of a "hole" in the west-central area. I'm uncertain if this interpretation is correct, and further discussion would be beneficial.
    - Where the L/M Clay exists, the Trenton Gravel should be present above it. This doesn't usually seem to be the case.
    - The clay unit is shallow and relatively thin. It seems possible that it is the Holocene clay/silt layer common to the Coastal Plain, not part of the PRM.
    - Interpretations are made more difficult by pre-clearing of many borings to 10′, resulting in no stratigraphic information.
    - Wells S-111, 112, 116, and 122 were considered to be in the L/M Clay hole. However, they had no recovery through depths of 2–8′. Other wells that were logged in this area with shallower recovery showed clay to be present only in the upper 10′ (e.g., S-110D, 115D, and 135). The presence or absence of clay at S-111, 112, 116, and 122 seems to be indeterminate.
    - I agree that the clay unit is absent in some locations, based on the information in the boring logs (e.g., S-76, 77, 77D, 78,79).
    - S-74D stands apart from other wells with a thick section of clay (10–36′). In this area the PRM L/M Clay might be present.

19. The groundwater potentiometric surface and flow are not well determined at the western boundary. Understanding flow there is important for the fate-and-transport analysis and delineating contamination. [§250.408(e)]
    - Closed groundwater elevation contours are plotted for the alluvium aquifer (Figures 8, 10, and I-5), but there are no alluvium wells in the vicinity of S-135 to know if that is true.
    - The long-term average groundwater elevation data indicate a gradient from S-113 toward S-81 (to the east) (Figure I-6). But several recent measurements (in Mar 2013, May 2014, May, Aug, and Nov 2015) indicate the opposite gradient. Benzene concentrations have typically been lower in S-81 than in S-113. There is no well to the west of S-113.
    - There have been only two gauging events at the S-114 and 135 well pair (Aug, Nov 2015). They indicate contrary gradient directions. Benzene is higher in S-114 than in S-135. There is no well to the west of S-135.
    - Groundwater flow is inferred to the southwest at S-115. Benzene is elevated at this well. There is no well downgradient of S-115.

- I recommend quarterly gauging of the monitoring wells on the western side of AOI 9 for at least a year. Better mapping of the potentiometric surface and interpretation of flow may require additional offsite wells.

20. The sporadic groundwater sampling collected to date is inadequate to reliably infer contaminant trends (Appendix I). It will be important to demonstrate stable or decreasing trends to attain the site-specific standard [§250.702(b)(2)]. An attainment monitoring plan can be described in the cleanup plan.

The RIR is not approvable as submitted. I request that we have a conference call next week to discuss the deficiencies; I should be available any day but March 16th. Our review deadline is 3/31/2016.

-David

C. David Brown P.G. | Licensed Professional Geologist
Department of Environmental Protection | Southeast Regional Office
2 East Main Street | Norristown, PA 19401
Phone: 484.250.5796 | Fax: 484.250.5961
www.dep.pa.gov

Report Notices

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January 19, 2017

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Ms. Leigh Anne Rainford
Sanitation Supervisor
Philadelphia Department of Public Health
Environmental Engineering Section
321 University Avenue
Philadelphia, Pennsylvania 19104

Re: Remedial Investigation Report Addendum
Area of Interest (AOI) 9
Philadelphia Energy Solutions (PES) Facility
3144 West Passyunk Avenue
Philadelphia, Philadelphia County, Pennsylvania
Langan Project No.: 2574602

Dear Ms. Rainford:

Notice is hereby given that Evergreen Resources Group LLC (Evergreen), (Remediator), is in the process of submitting a Remedial Investigation Report (RIR) Addendum to the Pennsylvania Department of Environmental Protection for AOI 9 located at the Philadelphia Energy Solutions Refining and Marketing LLC Facility, Philadelphia County, Philadelphia, PA. The report is being submitted in accordance with the site-specific remediation standards.

This notice is made under the provision of the Land Recycling and Environmental Standards Act, the Act of May 19, 1995, P.L. #4, No. 2.

Please call me at (215) 491-6500 if you have any questions concerning the proposed remediation.

Sincerely,
Langan Engineering and Environmental Services, Inc.

Meredith L. Mayes

Meredith L. Mayes
Staff Engineer

cc: Tiffani Doerr, Evergreen
Charles Barksdale, PES

\\langan.com\data\DYL\data6\2574601\Office Data\Reports\Remedial Investigation Reports\AOI 9\RIR\RIR Addendum\Notifications\2017_0119_AOI 9_Philadelphia Department of Public Health RIR Addendum Notice.docx

Proof of Publication in The Philadelphia Daily News
Under Act. No 587, Approved May 16, 1929

STATE OF PENNSYLVANIA
COUNTY OF PHILADELPHIA

Copy of Notice of Publication

Notification of Submittal of a Remedial Investigation Report

Notice is hereby given that Evergreen Resources Group LLC (Remediator), is in the process of submitting a Remedial Investigation Report Addendum to the Pennsylvania Department of Environmental Protection, Southeast Regional Office for Area of Interest 9 located at the Philadelphia Energy Solutions Refining and Marketing LLC Facility, Philadelphia County, Philadelphia, PA.

The report is being submitted in accordance with the site-specific remediation standards established under the Land Recycling and Environmental Remediation Standards Act. This notice is made under the provision of the Land Recycling and Environmental Remediation Standards Act, the Act of May 19, 1995, P.L. #4, No. 2

Helene Sweeney being duly sworn, deposes and says that **The Philadelphia Daily News** is a newspaper published daily, except Sunday, at Philadelphia, Pennsylvania, and was established in said city in 1925, since which date said newspaper has been regularly issued in said County, and that a copy of the printed notice of publication is attached hereto exactly as the same was printed and published in the regular editions and issues of the said newspaper on the following dates:

January 23, 2017

Affiant further deposes and says that she is an employee of the publisher of said newspaper and has been authorized to verify the foregoing statement and that she is not interested in the subject matter of the aforesaid notice of publication, and that all allegations in the foregoing statement as to time, place and character of publication are true.

Helene Sweeney

Sworn to and subscribed before me this 23rd day of January, 2017.

Cindy Jakubowski
Notary Public

My Commission Expires:

CINDY JAKUBOWSKI, Notary Public
My Commission Expires November 30, 2020

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Leigh Anne Rainford
Philadelphia Department of Public Healtł
Environmental Engineering Section
321 University Avenue
Philadelphia, Pennsylvania 19104

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PS Form 3800, April 2015 PSN 7530-02-000-9047 **See Reverse for Instructions**

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January 19, 2017

VIA EMAIL- MLOGAN@PHILLYNEWS.COM

Legal Advertising Department – Daily News
P.O. Box 8263 – 4th Floor
Philadelphia, PA 19101
Attn: Mary Anne Logan
215-854-5834

Re: Remedial Investigation Report Addendum
Area of Interest (AOI) 9
Philadelphia Energy Solutions (PES) Facility
3144 West Passyunk Avenue
Philadelphia, Philadelphia County, Pennsylvania
Langan Project No.: 2574602

On behalf of Evergreen Resources Group LLC (Evergreen), Langan Engineering and Environmental Services, Inc. requests that the following Public Notice be published in the Philadelphia Daily News under the legal notices section.

Notification of Submittal of a Remedial Investigation Report

Notice is hereby given that Evergreen Resources Group LLC (*Remediator), is in the process of submitting a Remedial Investigation Report Addendum to the Pennsylvania Department of Environmental Protection, Southeast Regional Office for Area of Interest 9 located at the Philadelphia Energy Solutions Refining and Marketing LLC Facility, Philadelphia County, Philadelphia, PA.*

The report is being submitted in accordance with the site-specific remediation standards established under the Land Recycling and Environmental Remediation Standards Act. This notice is made under the provision of the Land Recycling and Environmental Remediation Standards Act, the Act of May 19, 1995, P.L. #4, No. 2.

Please publish the notice as soon as possible and fax the proof of publication to me at (215) 491-6501. Please also mail the hard copy of the proof of publication and your invoice to my attention at the following address:

Langan Engineering & Environmental Services
Attn: Meredith Mayes
2700 Kelly Road
Warrington, Pa. 18976

Should you have any questions or comments regarding the request, please contact me at (215) 491-6500.

Sincerely,
Langan Engineering and Environmental Services, Inc.

Meredith L. Mayes

Meredith L. Mayes
Staff Engineer

cc: Tiffani Doerr, Evergreen
Charles Barksdale, PES

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pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

BUREAU OF FORESTRY

November 5, 2015 **PNDI Number: 20150930533660**

Alexandra Ventresca
Langan Engineering and Environmental Services
601 Technology Drive, Suite 200
Canonsburg, PA 15317
Email: aventresca@langan.com (hard copy will not follow)

Re: Evergreen/ PES AOI 9
Philadelphia Township, Philadelphia County, PA

Dear Alexandra Ventresca,

Thank you for the submission of the Pennsylvania Natural Diversity Inventory (PNDI) Environmental Review Receipt Number **20150930533660** for review. PA Department of Conservation and Natural Resources screened this project for potential impacts to species and resources under DCNR's responsibility, which includes plants, terrestrial invertebrates, natural communities, and geologic features only.

No Impact Anticipated

PNDI records indicate species or resources under DCNR's jurisdiction are located in the vicinity of the project. However, based on the information you submitted concerning the nature of the project, the immediate location, and our detailed resource information, DCNR has determined that no impact is likely. No further coordination with our agency is needed for this project.

This response represents the most up-to-date review of the PNDI data files and is valid for two (2) years only. If project plans change or more information on listed or proposed species becomes available, our determination may be reconsidered. Should the proposed work continue beyond the period covered by this letter, please resubmit the project to this agency as an "Update" (including an updated PNDI receipt, project narrative and accurate map). As a reminder, this finding applies to potential impacts under DCNR's jurisdiction only. Visit the PNHP website for directions on contacting the Commonwealth's other resource agencies for environmental review.

Should you have any questions or concerns, please contact Jaci Braund, Ecological Information Specialist, by phone (717-214-3813) or via email (c-jbraund@pa.gov).

Sincerely

Greg Podniesinski

Greg Podniesinski, Section Chief
Natural Heritage Section

PENNSYLVANIA FISH & BOAT COMMISSION
established 1866
Pennsylvania Fish & Boat Commission

Division of Environmental Services
Natural Diversity Section
450 Robinson Lane
Bellefonte, PA 16823
814-359-5237

November 10, 2015

IN REPLY REFER TO
SIR# 45100

AECOM
Deborah Poppel
625 W. Ridge Pike
Conshohocken, Pennsylvania 19428

RE: Species Impact Review (SIR) – Rare, Candidate, Threatened and Endangered Species
PNDI Search No. 20150908530651 and 20150908530661
SRTF-Main & Riverside
PHILADELPHIA County: Philadelphia City

Dear Ms. Poppel:

This responds to your inquiry about a Pennsylvania Natural Diversity Inventory (PNDI) Internet Database search "potential conflict" or a threatened and endangered species impact review. These projects are screened for potential conflicts with rare, candidate, threatened or endangered species under Pennsylvania Fish & Boat Commission jurisdiction (fish, reptiles, amphibians, aquatic invertebrates only) using the Pennsylvania Natural Diversity Inventory (PNDI) database and our own files. These species of special concern are listed under the Endangered Species Act of 1973, the Wild Resource Conservation Act, and the Pennsylvania Fish & Boat Code (Chapter 75), or the Wildlife Code.

You evaluated the habitats on site to determine their potential to support the species of concern. According to the report, aquatic areas around the perimeter of the site would support the Eastern Redbelly Turtle (*Pseudemys rubriventris*) and Eastern Mudminnow (*Umbra pygmaea*). However, areas within the project boundary do not contain potential habitat for the species of concern. I concur with the results of your evaluation; therefore, provided that no direct or indirect impacts to the Mingo Creek or Schuylkill River result from this project, then I do not foresee the proposed project resulting in adverse impacts to the Eastern Mudminnow (*Umbra pygmaea*) or Eastern Redbelly Turtle (*Pseudemys rubriventris*).

This response represents the most up-to-date summary of the PNDI data and our files and is valid for two (2) years from the date of this letter. An absence of recorded species information does not necessarily imply species absence. Our data files and the PNDI system are continuously being updated with species occurrence information.

Should project plans change or additional information on listed or proposed species become available, this determination may be reconsidered, and consultation shall be re-initiated.

If you have any questions regarding this review, please contact Kathy Gipe at 814-359-5186 and refer to the SIR # 45100. Thank you for your cooperation and attention to this important matter of species conservation and habitat protection.

Sincerely,

Christopher A. Urban

Christopher A. Urban, Chief
Natural Diversity Section

CAU/KDG/dn

APPENDIX B

AOI 9 RIR SUPPLEMENTAL SUBMISSION

(ON CD)

APPENDIX C

SOIL BORING LOGS, MONITORING WELL CONSTRUCTION SUMMARIES, AND GROUNDWATER PARAMETER SHEETS

LANGAN

Log of Boring **AOI9-BH-16-01** Sheet 1 of 1

Project Philadelphia Energy Solutions (PES) Facility		Project No. 25746012	
Location Philadelphia, Pa		Elevation and Datum --	
Drilling Company Langan		Date Started 9/19/16	Date Finished 9/19/16
Drilling Equipment Stainless Steel Hand Auger		Completion Depth 3.5 ft	Rock Depth NE
Size and Type of Bit		Number of Samples	Disturbed / Undisturbed / Core
Casing Diameter (in) NA	Casing Depth (ft) NA	Water Level (ft.)	First ▽ NE / Completion ▼ / 24 HR. ▼
Casing Hammer NA / Weight (lbs) NA	Drop (in) NA	Drilling Foreman Valentina Miller	
Sampler Hand Auger		Field Engineer Valentina Miller	
Sampler Hammer NA / Weight (lbs) NA	Drop (in) NA		

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
▨		Loose dark brown sandy SILT with metal, brick and glass. (dry) [FILL]	0 0 0 0 0 0	0 1 2 3						Collect sample AOI9-BH-16-01_1-1.5 for lead. Collect sample AOI9-BH-16-01_3-3.5 for lead
				4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20						

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Log of Boring **AOI9-BH-16-02** Sheet 1 of 1

Project Philadelphia Energy Solutions (PES) Facility		Project No. 25746012	
Location Philadelphia, Pa		Elevation and Datum --	
Drilling Company Langan		Date Started 9/19/16	Date Finished 9/19/16
Drilling Equipment Stainless Steel Hand Auger		Completion Depth 2.5 ft	Rock Depth NE
Size and Type of Bit		Number of Samples	Disturbed / Undisturbed / Core
Casing Diameter (in) NA	Casing Depth (ft) NA	Water Level (ft.)	First ▽ NE / Completion ▼ / 24 HR. ▼
Casing Hammer NA / Weight (lbs) NA	Drop (in) NA	Drilling Foreman Valentina Miller	
Sampler Hand Auger		Field Engineer Valentina Miller	
Sampler Hammer NA / Weight (lbs) NA	Drop (in) NA		

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
▨		Loose dark brown sandy SILT with metal, brick and glass. (dry) [FILL]	0 0 0	0 1						Collect sample AOI9-BH-16-02_1-1.5 for lead.
▨		Loose dark brown sandy SILT with metal, brick and glass. Trace 1/2 to 1-inch diameter peices of platey white/red/blak material.(dry) [FILL]	0 0	2						Collect sample AOI9-BH-16-01_2-2.5 for lead
				3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20						

LANGAN

Log of Boring **AOI9-BH-16-03** Sheet 1 of 1

Project: Philadelphia Energy Solutions (PES) Facility
Project No.: 25746012
Location: Philadelphia, Pa
Elevation and Datum: --
Drilling Company: Langan
Date Started: 9/19/16
Date Finished: 9/19/16
Drilling Equipment: Stainless Steel Hand Auger
Completion Depth: 2.5 ft
Rock Depth: NE
Size and Type of Bit:
Number of Samples: Disturbed: Undisturbed: Core:
Casing Diameter (in): NA
Casing Depth (ft): NA
Water Level (ft.): First ▽ NE Completion ▼ 24 HR. ▼
Casing Hammer: NA Weight (lbs): NA Drop (in): NA
Drilling Foreman: Valentina Miller
Sampler: Hand Auger
Field Engineer: Valentina Miller
Sampler Hammer: NA Weight (lbs): NA Drop (in): NA

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data Number	Sample Data Type	Sample Data Recov. (in)	Sample Data Penetr. resist BL/6in	Sample Data N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
▨		Loose dark brown sandy SILT with metal, brick and glass. (dry) [FILL]	0	0						
▨		Loose light brown sandy SILT, brick and glass fragments. Trace platey red/white/black fragments. (dry) [FILL]	0 0 0 0	1 2						Collect sample AOI9-BH-16-03._1-1.5 for lead. Collect sample AOI9-BH-16-03_2-2.5 for lead
				3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20						

Log of Boring **S-137SRTF** Sheet 1 of 2

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation and Datum --
Drilling Company Parratt Wolff	Date Started 8/23/16 — Date Finished 8/31/16
Drilling Equipment Hydrovac, Hollow Stem Auger	Completion Depth 46 ft — Rock Depth NE
Size and Type of Bit 8"	Number of Samples — Disturbed — Undisturbed — Core
Casing Diameter (in) 4 — Casing Depth (ft) NA	Water Level (ft.) — First ▽ 8 — Completion ▼ — 24 HR. ▼
Casing Hammer NA — Weight (lbs) NA — Drop (in) NA	Drilling Foreman Glenn Lansing
Sampler Hand Auger, Split Spoon	Field Engineer Valentina Miller
Sampler Hammer NA — Weight (lbs) NA — Drop (in) NA	

MATERIAL SYMBOL	Elev. (ft)	Sample Description	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		SILT with coarse gravel, sand, cobbles, and boulders. (moist) [FILL]	0						All-State hydro-vac clears new location from 0-8 ft bgs 9/22/2016 Start hollow-stem auger drilling 9/22/2016
		Dark brown silty CLAY, some gravel, trace sand. (moist) [FILL]	4						
		Rust red medium SAND and GRAVEL. (moist)	5.5						
		Dark gray medium plastic CLAY, trace organics. (moist)	6.5						
		Soft dark grey CLAY, trace f sand, trace organics. (moist)	8 ▽						
		Very soft dark grey CLAY, trace f sand, trace f gravel (wet)	12						
		Loose dark grey m-c SAND and f-m GRAVEL, some clay. (wet)	16						
		Loose dark grey clayey m-c SAND, some m-c gravel (up to 1-inch diameter pieces). (wet)	18						
		NO RECOVERY	20						
			21						

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Log of Boring **S-137SRTF** Sheet 2 of 2

Project	Project No.
Philadelphia Energy Solutions (PES) Facility	25746012
Location	**Elevation and Datum**
Philadelphia, Pa	--

MATERIAL SYMBOL	Elev. (ft)	Sample Description	Depth Scale	Sample Data					Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
				Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	
			21						
		Stiff dark brown clayey SILT, trace f-sand. (wet)	22 23						
		Stiff dark grey plastic CLAY, trace organics. (wet)	24 25 26 27						
		Loose brown silty SAND and f GRAVEL, some clay. Apparent Trenton Gravel.	28 29						
		Loose brown f-m SAND, some silt, some f-m gravel. Apparent Trenton Gravel (wet)	30 31						
		NO SAMPLE	32 33						
		Medium dark brown silty very f SAND, some clay. (wet)	34 35						
		NO SAMPLE	36 37 38						
		Loose brown f-m SAND, some silt, some f-m gravel. (wet)	39 40						
		NO SAMPLE	41 42 43						
		Loose brown m-c SAND and f-m GRAVEL, some silt. Multicolored grains. (wet)	44						
		End of boring 45 ft bgs	45 46 47						

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Log of Boring **S-138SRTF** Sheet 1 of 5

Project: Philadelphia Energy Solutions (PES) Facility	Project No.: 25746012
Location: Philadelphia, Pa	Elevation and Datum: --
Drilling Company: Parratt Wolff	Date Started: 8/23/16 — Date Finished: 8/31/16
Drilling Equipment: Hydrovac, Mud Rotory	Completion Depth: 103 ft — Rock Depth: 101 ft
Size and Type of Bit: 8"	Number of Samples — Disturbed: 28 — Undisturbed: — Core:
Casing Diameter (in): 4 — Casing Depth (ft): NA	Water Level (ft.) — First ▽ 8 — Completion ▼ — 24 HR. ▼
Casing Hammer: NA — Weight (lbs): NA — Drop (in): NA	Drilling Foreman: Glenn Lansing
Sampler: Hand Auger, Split Spoon	
Sampler Hammer: NA — Weight (lbs): NA — Drop (in): NA	Field Engineer: Valentina Miller

Depth Scale	Sample Description	PID Reading (ppm)	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
0	SILT with coarse gravel, sand, cobbles, boulders. (moist) [FILL]	0 0						All-State hydro-vac clears from 0-8 ft bgs Stone building mateiral (block with mortar). Collect sample for site specific COCs.
1		0 0						
2		0 0						
3		0 0						
4	Dark brown silty CLAY, some gravel, trace sand. (moist) [FILL]	0 0						
5	Rust red medium SAND and GRAVEL. (moist)	0 0						
6	Dark gray medium plastic CLAY, trace organics. (moist)	0 0						
7	▽	0 0						
8	Soft dark grey CLAY, trace f sand, trace organics. (moist)	0 0	1	SS	20	1 1 1 1	2	Collect sample for site specific COCs. Start mud rotory drilling.
9		0 0						
10		0 0	2	SS	11	1 1 1 1	2	Hit refusal ~10 ft bgs. (possible PVC or concrete). Move to hole cleared for S-137.
11		0 0						
12	Very soft dark grey CLAY, trace f sand, trace f gravel (wet)	0 0	3	SS	14	1 2 2 6	4	
13		0 0						
14		0 0	4	SS	8.5	1 3 3 4	6	
15		0 0						
16	Loose dark grey m-c SAND and f-m GRAVEL, some clay. (wet)	0 0	5	SS	5	9 11 7 5	18	
17		0 0						
18	Loose dark grey clayey m-c SAND, some m-c gravel (up to 1-inch diameter pieces). (wet)	0 0	6	SS	17	11 11 6 3	17	
19		0 0						
20								

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Log of Boring **S-138SRTF** Sheet 2 of 5

Project	Project No.
Philadelphia Energy Solutions (PES) Facility	25746012
Location	**Elevation and Datum**
Philadelphia, Pa	--

Depth Scale	Elev. (ft)	Sample Description	PID Reading (ppm)	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
20		NO RECOVERY	0 0 0 0	7	SS	6	3 4 4 2	8	
22		Stiff dark brown clayey SILT, trace f sand. (wet)	0 0 0 0	8	SS	14	1 3 3 3	6	
24		Stiff dark GREY plastic CLAY, trace organics. (wet)	0 0 0 0	9	SS	20	10 2 2 9	4	
26			0 0 0 0	10	SS	5	3 25 20 20	45	Muddy.
28		Loose brown silty SAND and f GRAVEL, some clay. Apparent Trenton Gravel.	0 0 0 0	11	SS	13	18 15 23 26	38	
30		Loose brown f-m SAND, some silt, some f-m gravel. Apparent Trenton Gravel (wet)	0 0 0 0	12	SS	11.5	10 11 11 26	22	
32		NO SAMPLE							
34		Medium dark brown silty very f SAND, some clay. (wet)	0 0 0 0	13	SS	11	3 5 7 11	12	
36		NO SAMPLE							
39		Loose brown f-m SAND, some silt, some f-m gravel. (wet)	0 0 0 0	14	SS	9	4 6 7 11	13	
41		NO SAMPLE							Driller notes ~30 gallons of mud loss and tough dirlling indicating large gravel 42-42 ft bgs.
44		Loose brown m-c SAND and f-m GRAVEL, some silt. Multicolored grains. (wet)	0 0	15	SS	12	9 11	25	
45									

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Log of Boring **S-138SRTF** Sheet 3 of 5

Project	Project No.
Philadelphia Energy Solutions (PES) Facility	25746012
Location	**Elevation and Datum**
Philadelphia, Pa	--

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
			0 0	45	15	SS	12	14 6	25	
		NO SAMPLE		46 47 48						
		Medium-loose tan silty f-SAND, trace clay. (wet)	0 0	49	16	SS	14	8 8		
		Medium-loose tan f-c SAND, some silt, trace clay. Orange mottling. (wet)	0 0	50				7 7	15	
		NO SAMPLE		51 52 53						
		Medium-loose yellow-tan very f silty SAND, some clay. (wet)	0 0 0 0	54 55	17	SS	2	8 12 12 11	24	
		NO SAMPLE		56 57 58						
		Medium light grey clayey very f SAND, some silt. (wet)	0 0 0	59 60	18	SS	21	12 8 8	16	
		Medium tan clayey very f SAND, some silt. Orange mottling. (wet)	0					10		
		NO SAMPLE		61 62 63						
		Loose tan-white silty c SAND and m-c GRAVEL. Gravel includes multicolored rounded and angular pieces. (wet)	0 0 0	64 65	19	SS	14	29 54 NA NA		
		NO SAMPLE		66 67 68						
		Very stiff light grey CLAY, some f-sand, trace silt. Brown-orange mottling. (wet)	0 0	69	20	SS	10	16 50		
				70						

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Log of Boring **S-138SRTF** Sheet 4 of 5

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation and Datum --

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Loose grey well-sorted f-m SAND. Orange mottling. (wet)		70	20	SS	10	NA NA		
		NO SAMPLE		71 72 73						
		Loose grey well-sorted f-m SAND. Orange mottling. (wet)	0 0 0 0	74 75	21	SS	14	49 46 12 14	58	
		NO SAMPLE		76 77 78						
		Medium-dense yellow-tan to light grey well sorted f-SAND, trace clay and silt. Black mottling. (wet)	0 0 0 0	79 80	22	SS	6	54 NA NA NA		
		NO SAMPLE		81 82 83						
		Loose yellow-tan to white c-SAND and m-c GRAVEL, trace silt. Multicolored grains. Gravel up to 1-inch diameter near bottom of split spoon. (wet)	0 0 0 0	84 85	23	SS	10	36 20 36 36	56	
		NO SAMPLE		86 87 88						Driller notes high water in boring at ~86 ft from groundwater.
		Medium light grey clayey f-SAND. Tan-orange mottling. (wet) Stiff light grey CLAY, trace f-sand. (wet) Medium light grey clayey f-SAND. (wet) Stiff light grey CLAY, trace f-sand (wet)	0 0 0	89 90	24	SS	19	20 26 50 NA	76	Driller notes ~70 gallon of drilling fluid loss.
		Loose tan-orange v-fine well sorted SAND. Orange-red mottling. (wet) NO SAMPLE Stiff light grey CLAY with v-fine-sand, trace clay lenses. Red-orange mottling. (wet)	0 0 0	91 92	25	SS	17	20 34 85 NA	119	
		NO SAMPLE Loose yellow-tan f-m SAND, trace f-gravel. (wet) Loose white-grey v-fine well sorted SAND. Orange, red, black mottling. (wet)	0 0 0 0	93 94 95	26	SS	18	35 45 49 49	94	

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Log of Boring **S-138SRTF** Sheet 5 of 5

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation and Datum --

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data Number	Sample Data Type	Sample Data Recov. (in)	Sample Data Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		NO SAMPLE		95 96 97 98						
▨		Medium white silty CLAY, some mica grains, trace sand. (wet)	0 0 0	99 100	27	SS	21	23 48 43 40	91	
▨		Medium white-grey silty CLAY and weathered schist. Contains mica. Apparent weathered bedrock. (wet)	0 0 0 0 0	101 102	28	SS	22	NA NA NA NA		
		End of boring 103 feet bgs		103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120						

LANGAN Log of Boring **S-139SRTF** Sheet 1 of 2

Project: Philadelphia Energy Solutions (PES) Facility		Project No.: 25746012	
Location: Philadelphia, Pa		Elevation and Datum: --	
Drilling Company: Parratt Wolff		Date Started: 8/24/16	Date Finished: 9/20/16
Drilling Equipment: Hydrovac, Hollow Stem Auger		Completion Depth: 40 ft	Rock Depth: NE
Size and Type of Bit: 8"		Number of Samples: Disturbed 8	Undisturbed Core
Casing Diameter (in): 4	Casing Depth (ft): NA	Water Level (ft.): First ▽ 7.5	Completion ▼ 24 HR. ▼
Casing Hammer: NA	Weight (lbs): NA Drop (in): NA	Drilling Foreman: Glenn Lansing	
Sampler: Hand Auger, Split Spoon			
Sampler Hammer: NA	Weight (lbs): NA Drop (in): NA	Field Engineer: Valentina Miller	

MATERIAL SYMBOL	Elev. (ft)	Sample Description	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
▨		White, black, brown SILT with ash, slag, glass, brick, bottles, and gravel. (dry to moist) [FILL] ▽	0						All-State hydro-vac clears from 0-8 ft bgs Collect sample for site specific COCs.
		NO SAMPLE	8						Start hollow-stem auger drilling 9/20/2016
⠿		Loose yellow-brown poorly sorted m SAND, trace silt. (wet)	10	1	SS	3	1 2 2 2	4	
		NO SAMPLE	12						
▨		Medium brown CLAY with silt. (wet)	15	2	SS	15	1 2 3 3	5	
		NO SAMPLE	17						
			20						

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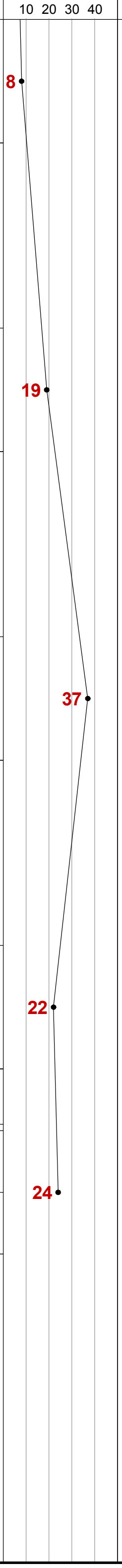
Log of Boring **S-139SRTF** Sheet 2 of 2

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation and Datum --

Elev. (ft)	Sample Description	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
	Loose brown poorly sorted m-c SAND and f-m GRAVEL, trace silt. Mulicolored grains. Rounded and angular gravel up to 1-inch diameter. (wet)	20–22	3	SS	7	1 2 6 12	8	
	NO SAMPLE	22–25						
	Loose multicolored poorly sorted m-c SAND and f-m GRAVEL, trace silt. Apparent Trenton Gravel. (wet)	25–27	4	SS	6	3 9 10 7	19	
	NO SAMPLE	27–30						
	Loose brown f-m SAND, some f-m GRAVEL, trace silt. Multicored grains. Poorly sorted. (wet)	30–32	5	SS	8	6 19 18 35	37	
	NO SAMPLE	32–35						
	Loose tan-brown f-m SAND, some silt, trace f-gravel. Multicolored grains. (wet)	35–37	6	SS	10	4 6 16 32	22	
	M-loose brown silty m-c GRAVEL and m-c SAND. Multicolor and white angular grains. Gravel up to 1-inch diameter. (wet)	37–38	7	SS	12	45 50 NA NA		
	NO SAMPLE	38						
	M-loose brown silty m-c GRAVEL and m-c SAND. Multicolor and white angular grains. Gravel up to 1-inch diameter. (wet)	38–39	8	SS	15	20 12 12 14	24	
	Dense red-brown clayey SILT, trace f sand. (wet)	39–40						
	End of boring 40 feet bgs	40						



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Log of Boring **S-140SRTF** Sheet 1 of 1

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation and Datum --
Drilling Company Parratt Wolff	Date Started 8/26/16 Date Finished 9/15/16
Drilling Equipment Hydrovac, Hollow Stem Auger	Completion Depth 42 ft Rock Depth NE
Size and Type of Bit 8"	Number of Samples: Disturbed 2; Undisturbed; Core
Casing Diameter (in) 4 Casing Depth (ft) NA	Water Level (ft.): First ∇ 7; Completion ▼; 24 HR. ▼
Casing Hammer NA; Weight (lbs) NA; Drop (in) NA	Drilling Foreman Glenn Lansing
Sampler Hand Auger, Split Spoon	Field Engineer Valentina Miller
Sampler Hammer NA; Weight (lbs) NA; Drop (in) NA	

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
▩		Loose dark brown low plasticity SILT, some gravel, trace clay. (dry) [FILL]	0 0 0 0	0–2						All-State hydro-vac clears from 0-8 ft bgs Topsoil first 0.5 ft bgs. Increasing clay content with depth 0.5-2 ft bgs. Collect sample for site specific COCs.
▥		Dark brown to blue-grey silty CLAY, some f gravel. (moist)	0 0 0 0	2–4						
▓		Dark brown medium density m SAND and GRAVEL, some clay. (wet)	0 0 0 0	4–6						
▨		Loose muddy dark grey CLAY, some gravel, trace sand. (wet) ∇	0 0 0 0	6–8						Boulders 6 ft bgs Collect sample for site specific COCS.
▨		Medium black-grey CLAY, trace f sand. (wet)	0 0 0 0	8–10	1	SS	14	1 1 1 1	2	Start hollow-stem auger dirlling 9/7/2016
		NO SAMPLE		10–13						
▨		Soft dark grey CLAY, trace f sand, trace f gravel, trace organics. (wet)	0 0 0 0	13–15	2	SS	12	1 1 1 1	2	
		End boring 15.5 ft bgs		15–20						

\\LANGAN.COM\DATA\DYL\DATA6\2574601\ENGINEERING DATA\ENVIRONMENTAL\GINT\SUNOCO PES SITEWIDE-MERGED.GPJ ... 1/25/2017 3:42:37 PM ... Report: Log - LANGAN

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Log of Boring **S-141SRTF** Sheet 1 of 2

Project: Philadelphia Energy Solutions (PES) Facility		Project No.: 25746012	
Location: Philadelphia, Pa		Elevation and Datum: --	
Drilling Company: Parratt Wolff		Date Started: 8/26/16	Date Finished: 9/15/16
Drilling Equipment: Hydrovac, Hollow Stem Auger		Completion Depth: 46 ft	Rock Depth: NE
Size and Type of Bit: 8"		Number of Samples: Disturbed 8	Undisturbed / Core
Casing Diameter (in): 4	Casing Depth (ft): NA	Water Level (ft.): First ▽ 7	Completion ▼ / 24 HR. ▼
Casing Hammer: NA	Weight (lbs): NA / Drop (in): NA	Drilling Foreman: Glenn Lansing	
Sampler: Hand Auger, Split Spoon		Field Engineer: Valentina Miller	
Sampler Hammer: NA	Weight (lbs): NA / Drop (in): NA		

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
▩		Loose dark brown low plasticity SILT, some gravel, trace clay. (dry) [FILL]		0–2						All-State hydro-vac clears from 0-8 ft bgs
▨		Dark brown to blue-grey silty CLAY, some fine gravel. (moist)		2–4						
⁘		Dark brown medium density m-SAND and GRAVEL, some clay. (wet)		4–6						
▨		Loose muddy dark grey CLAY, some gravel, trace sand. (wet) ▽		6–8						
▨		Medium black-grey CLAY, trace f sand. (wet)		8–10	1	SS	14	1 1 1 1	2	Start hollow-stem auger drilling 9/15/2016
		NO SAMPLE		10–13						
▨		Soft dark grey CLAY, trace f sand, trace f gravel, trace organics. (wet)		13–15	2	SS	12	1 1 1 1	2	
▨		Medium black-grey CLAY, some f sand. (wet)	0 0 0 0	15–17	3	SS	11	1 1 1 1	2	Petroleum-like odor 15-17 ft bgs. Stained. Soil-water agitation test shows some black sheen on water with soil settled out.
		NO SAMPLE		17–20						

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Log of Boring **S-141SRTF** Sheet 2 of 2

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation and Datum --

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data Number	Sample Data Type	Sample Data Recov. (in)	Sample Data Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Medium black-grey CLAY, some f sand. (wet)	0	20	4	SS	15	1		Petroleum-like odor 20-22 ft bgs. Stained.
		Medium black-grey CLAY, trace f sand, trace f-m rounded gravel. (wet)	0 0 0	21				NA NA NA		
		NO SAMPLE		22 23 24						
		Dense dark grey CLAY, trace very f sand. (wet)	0	25	5	SS	11	7		
		Medium-loose brown f SAND and m-c GRAVEL, some silt, trace clay. Multicolored grains. Rounded and angular gravel. Trace red mottling. Apparent Trenton Gravel. (wet)	0 0 0	26				6 8 4	14	
		NO SAMPLE		27 28 29						End drilling for day, 16:11 on 9/15/2016. Start dirlling 7:45 on 9/16/2016
		Loose brown poorly sorted m-c SAND with m-c angular gravel, trace silt. Multicolored grains. Trenton Gravel. (wet)	0 0 0 0	30 31	6	SS	16	6 4 8 14	12	
		NO SAMPLE		32 33 34						
		Loose brown poorly sorted m-c SAND with m-c rounded and angular gravel, trace silt. Multicolored grains. Trenton Gravel. (wet)	0 0 0 0	35 36	7	SS	6	3 4 9 12	13	
		NO SAMPLE		37 38 39						
		Loose brown poorly sorted m-c SAND with m-c rounded and angular gravel, trace silt. Multicolored grains. Trenton Gravel. (wet)	0 0 0	40 41	8	SS	10	9 8 10	18	
		Medium dark grey plastic CLAY, trace silt. (wet)	0					11		
		End boring 42 ft bgs		42 43 44 45						

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Log of Boring **S-144SRTF** Sheet 1 of 3

Project	Philadelphia Energy Solutions (PES) Facility	Project No.	25746012
Location	Philadelphia, Pa	Elevation and Datum	--
Drilling Company	Parratt Wolff	Date Started	8/26/16
		Date Finished	9/15/16
Drilling Equipment	Hydrovac, Hollow Stem Auger	Completion Depth	62 ft
		Rock Depth	NE
Size and Type of Bit	8"	Number of Samples	Disturbed 11 / Undisturbed / Core
Casing Diameter (in)	4	Water Level (ft.)	First ▽ 7 / Completion ▼ / 24 HR. ▼
Casing Depth (ft)	NA	Drilling Foreman	Glenn Lansing
Casing Hammer	NA	Field Engineer	Valentina Miller
Weight (lbs)	NA		
Drop (in)	NA		
Sampler	Hand Auger, Split Spoon		
Sampler Hammer	NA		
Weight (lbs)	NA		
Drop (in)	NA		

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Silty GRAVEL. (dry) [FILL]		0						All-State hydro-vac clears from 0-8 ft bgs
		Loose dark brown sandy SILT, some gravel, some clay, glass, and slag. (moist) [FILL]		1						Collect sample for site specific COCs.
				2						
				3						
		Reddish brown sandy CLAY, some silt. (moist)		4						
		Reddish brown clayey SAND. (moist)		5						
		Brown f SAND, some silt. (moist) ▽		6						
		Brown sandy CLAY. (wet)		7						Collect sample for site specific COCs and duplicate.
		NO SAMPLE		8						Start drilling with hollow-stem augers 9/20/2016
				9						
		Medium-loose grey m-c SAND and f-m angular GRAVEL, trace silt. Multicolored grains. Appears stained, shiny. (wet)	289 245 357 171	10	1	SS	10	4 10 12 12	22	Chemical-like odor 10-12 ft bgs. Soil water agitation test shows sheen.
				11						
		NO SAMPLE		12						End boring for day at 16:45 on 9/20/2016.
				13						
				14						
		Loose yellow-brown m-c SAND, trace silt, trace m angular gravel. (wet)	75 24 229 34	15	2	SS	6	11 9 6 8	15	Start boring at 8:30 on 9/21/2016.
				16						
		NO SAMPLE		17						
				18						
				19						
				20						

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Log of Boring **S-144SRTF** Sheet 2 of 3

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation and Datum --

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data					Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
					Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	
⁘		Loose tan f-m SAND. Multicolored grains. (wet)	17 44 84 47	20 21	3	SS	8	2 3 3 4	6	
		NO SAMPLE		22 23 24						
●		Loose brown m-c SAND and m-c GRAVEL, trace silt. Multiclored grains. Anuglar and rounded gravel up to 1-inch diameter. Some red mottling. (wet)	2 0 0 0	25 26	4	SS	13	4 11 16 36	27	
		NO SAMPLE		27 28 29						
●		Loose tan m-c GRAVEL with f sand and silt. (wet)	0 30	30	5	SS	8	12 24 18 18	42	
⁘		Loose tan-orange m-c SAND, trace m-c gravel, trace clay, trace silt. (wet)	3 0	31						
		NO SAMPLE		32 33 34						
⁘		Loose dark grey f-m SAND, trace silt. (wet)	0 0	35	6	SS	11	25 32 30 34	62	
●		Loose brown m-c SAND and m-c GRAVEL, trace silt, trace clay, trace red mottling. Poorly sorted. (wet)	5 0	36						
		NO SAMPLE		37 38 39						
⁘		Medium-loose red-orange well sorted f-m SAND, some silt, trace f-m gravel, trace clay. (wet)	0 0 0 0	40 41	7	SS	7	17 29 31 28	60	
		NO SAMPLE		42 43 44 45						

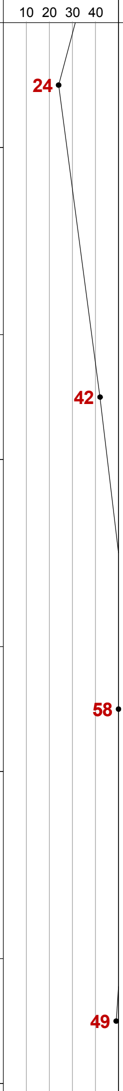
Project: Philadelphia Energy Solutions (PES) Facility

Project No.: 25746012

Location: Philadelphia, Pa

Elevation and Datum: --

Material Symbol	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data					Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
					Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	
		Medium-loose red-orange well-sorted f-m SAND with f-m rounded and angular gravel, some silt, trace clay. (wet)	0 0 0 0	45 46	8	SS	8	18 11 13 14	24	
		NO SAMPLE		47 48 49						
		Loose tan-orange poorly sorted m-c SAND, trace silt. (wet)	0 0 0 0	50 51	9	SS	7	21 21 21 21	42	
		NO SAMPLE		52 53 54						
		Medium-loose light brown f SAND, trace silt. (wet) GRAVEL. Angular fractions 1/4 to 1-inch diameter. (wet) Loose red-orange f SAND with f-m rounded gravel, trace silt, trace clay. (wet)	0 0 0 0	55 56	10	SS	10	28 34 24 18	58	
		NO SAMPLE		57 58 59						
		Loose red-orange well sorted f SAND, trace silt, trace clay. (wet)	0 0 0 0	60 61	11	SS	7	25 28 21 25	49	
		End boring 62 ft bgs		62 63 64 65 66 67 68 69 70						



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Log of Boring **S-145SRTF** Sheet 1 of 2

Project	Philadelphia Energy Solutions (PES) Facility	Project No.	25746012
Location	Philadelphia, Pa	Elevation and Datum	--
Drilling Company	Parratt Wolff	Date Started / Date Finished	8/26/16 / 9/15/16
Drilling Equipment	Hydrovac, Hollow Stem Auger	Completion Depth / Rock Depth	39 ft / NE
Size and Type of Bit	8"	Number of Samples	Disturbed 8 / Undisturbed / Core
Casing Diameter (in) / Casing Depth (ft)	4 / NA	Water Level (ft.)	First ▽ 7 / Completion ▼ / 24 HR. ▼
Casing Hammer / Weight (lbs) / Drop (in)	NA / NA / NA	Drilling Foreman	Glenn Lansing
Sampler	Hand Auger, Split Spoon	Field Engineer	Valentina Miller
Sampler Hammer / Weight (lbs) / Drop (in)	NA / NA / NA		

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft)	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Light tan silty GRAVEL. (dry) [FILL]	0	0						All-State hydro-vac clears from 0-8 ft bgs Collect sample for site specific COCs.
		Orange-brown gravelly CLAY, some silt, some brick. (moist) [FILL]	0 0 1	1						
		Medium grey plastic CLAY. (moist)	109 78 150 104 750 862	3						
		Red-brown fine clayey SAND. (moist) ▽	999+ 999+ 999+	6						
		NO SAMPLE		8						Collect sample for site specific COCs. Start hollow-stem auger drilling at 14:04 on 9/26/2016.
		Loose dark brown f SAND, trace silt, trace clay. (wet)	999+ 999+ 999+ 999+	10	1	SS	11	3 4 2 4	6	
		NO SAMPLE		12						
		Loose brown poorly sorted m-c SAND, trace silt. Multicolored grains. (wet)	1 10 40 19	15	2	SS	10	4 8 14 19	22	
		NO SAMPLE		17						
				20						

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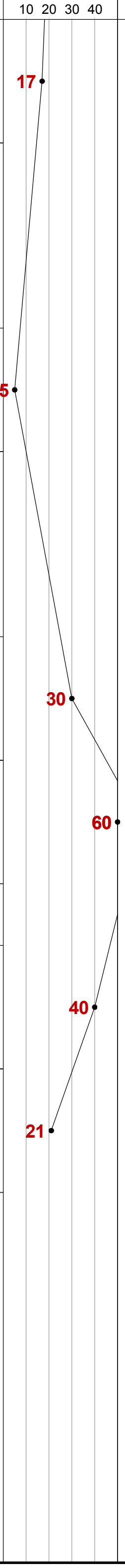
Log of Boring **S-145SRTF** Sheet 2 of 2

Project	Project No.
Philadelphia Energy Solutions (PES) Facility	25746012
Location	**Elevation and Datum**
Philadelphia, Pa	--

MATERIAL SYMBOL	Elev. (ft)	Sample Description	PID Reading (ppm)	Depth Scale	Sample Data: Number	Type	Recov. (in)	Penetr. resist BL/6in	N-Value (Blows/ft) 10 20 30 40	Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.)
		Loose brown c SAND and f-m rounded and angular GRAVEL, trace silt. Apparent Trenton Gravel. (wet)	0 0 0 0	20 21	3	SS	10	4 8 9 15	17	
		NO SAMPLE		22 23 24						
		Loose brown f-m GRAVEL, trace c-sand, trace silt. Multicolored grains. (wet)	0 0 0 0	25 26	4	SS	15	4 2 3 10	5	
		NO SAMPLE		27 28 29						
		Loose brown f-m GRAVEL, trace c-sand, trace silt. Multicolored grains. (wet) Loose brown-red angular GRAVEL, some silt. Gravel 1/2-inch diameter. (wet)	0 0 0 0	30 31	5	SS	14	2 6 24 24	30	
		Medium-tight brown rounded GRAVEL, trace angular gravel, some silt, trace m-c sand. Gravel up to 1-inch diameter. (wet)	0 0 0 0	32 33	6	SS	5	15 25 35 28	60	
		NO SAMPLE		34						
		Medium well sorted f SAND with silt, trace clay. (wet) Loose c GRAVEL, some silt. Gravel up to 1-inch diameter. (wet)	0 0 0 0	35 36	7	SS	8	4 25 15 10	40	End drilling at 16:35 on 9/26/2016 Start drilling at 8:15 on 9/27/2016
		Medium well sorted f SAND with silt, trace clay, trace f-m gravel. (wet)	0 0 0 0	37 38	8	SS	14	15 12 9 10	21	
		End boring 39 ft bgs		39 40 41 42 43 44 45						



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WELL CONSTRUCTION SUMMARY

Well No. S-137SRTF

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation And Datum --
Drilling Agency Parratt Wolff	Date Started 8/23/2016 Date Finished 9/22/2016
Drilling Equipment Hollow Stem Auger	Driller Glenn Lansing
Size And Type of Bit 8"	Inspector Valentina Miller

Method of Installation

Well S-137SRTF was installed using an 8-inch diameter hollow stem auger on 9/22/2016. The boring was advanced to 45ft bgs and a 15 ft screen and 32.5 ft of riser were installed. Filter sand was installed to 28 ft bgs. and bentonite seal was installed to 25.5 ft bgs. A cement bentonite slurry was installed to ground surface. Then the well casing was installed and concreted in place.

Method of Well Development

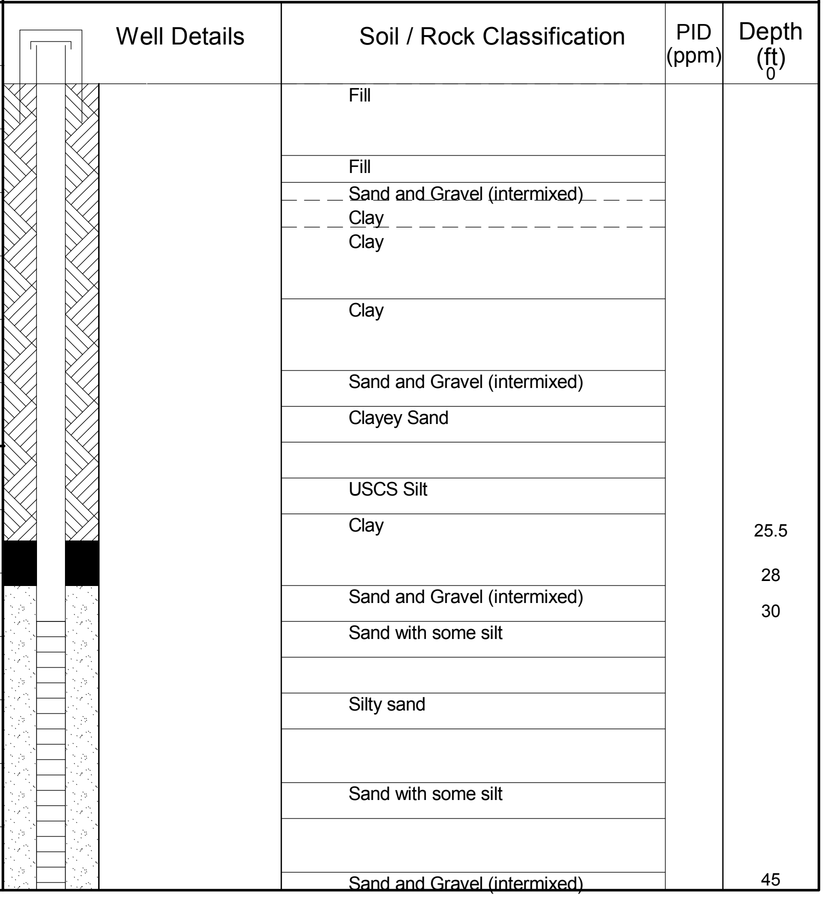
Well was surged for approximately 15 minutes then pumped for an hour until discharge was clear.

Type of Casing PVC	Diameter 4 inch	Type of Backfill Material
Type of Screen PVC	Diameter 4 inch	Type of Seal Material Bentonite
Borehole Diameter	8 inch	Type of Filter Material Filter Sand

Top of Casing	Elevation	Depth
Top of Seal	Elevation	Depth 25.5' bgs
Top of Filter	Elevation	Depth 28' bgs
Top of Screen	Elevation	Depth 30' bgs
Bottom of Filter	Elevation	Depth
Bottom of Well	Elevation	Depth 45' bgs
Screen Length 15.0'		Slot Size 0.020

GROUNDWATER ELEVATIONS (ft)
(Measured from the Top of Casing)

Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date



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WELL CONSTRUCTION SUMMARY

Well No. S-138SRTF

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation And Datum --
Drilling Agency Parratt Wolff	Date Started 8/23/2016 Date Finished 9/7/2016
Drilling Equipment Mud Rotory	Driller Glenn Lansing
Size And Type of Bit 8"	Inspector Valentina Miller

Method of Installation

Well S-138SRTF was installed using an 4-inch diameter mud rotory on 9/7/2016. The boring was advanced to 91 ft bgs and a 10 ft screen and 83.5 ft of riser were installed. Filter sand was installed to 78 ft bgs. and bentonite seal was installed to 75 ft bgs. A cement bentonite slurry was installed to ground surface. Then the well casing was installed and concreted in place.

Method of Well Development

Well was surged for approximately 15 minutes then pumped for an hour until discharge was clear.

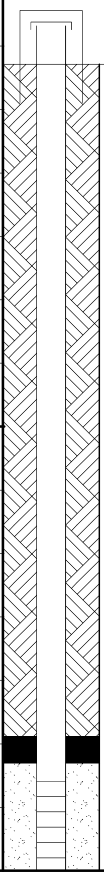
Type of Casing PVC	Diameter 2 inch	Type of Backfill Material
Type of Screen PVC	Diameter 2 inch	Type of Seal Material Bentonite
Borehole Diameter	4 inch	Type of Filter Material Filter Sand

Top of Casing	Elevation	Depth
Top of Seal	Elevation	Depth 75' bgs
Top of Filter	Elevation	Depth 78' bgs
Top of Screen	Elevation	Depth 80' bgs
Bottom of Filter	Elevation	Depth
Bottom of Well	Elevation	Depth 90' bgs
Screen Length 10.0'		Slot Size 0.020

GROUNDWATER ELEVATIONS (ft)
(Measured from the Top of Casing)

Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date

Well Details



Soil / Rock Classification	PID (ppm)	Depth (ft)
		0
Fill	0	
	0	
Fill	0	
Sand and Gravel (intermixed)	0	
Clay	0	
	0	
Clay	0	
Clay	0	
Sand and Gravel (intermixed)	0	
Clayey Sand	0	
USCS Silt	0	
Clay	0	
	0	
Sand and Gravel (intermixed)	0	
Sand with some silt	0	
Silty sand	0	
	0	
Sand with some silt	0	
	0	
	0	
Sand and Gravel (intermixed)	0	
	0	
Silty sand	0	
Sand with some silt	0	
Silty sand	0	
	0	
Clayey Sand	0	
	0	
Clayey Sand	0	
Sand and Gravel (intermixed)	0	
	0	
Clay	0	
SAND	0	
SAND	0	75
	0	78
SAND	0	80
	0	
Sand and Gravel (intermixed)	0	
	0	
	0	90

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WELL CONSTRUCTION SUMMARY

Well No. S-139SRTF

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation And Datum --
Drilling Agency Parratt Wolff	Date Started 8/24/2016
	Date Finished 9/20/2016
Drilling Equipment Hollow Stem Auger	Driller Glenn Lansing
Size And Type of Bit 8"	Inspector Valentina Miller

Method of Installation

Well S-139SRTF was installed using an 8-inch diameter hollow stem auger on 9/20/2016. The boring was advanced to 39 ft bgs and a 15 ft screen and 27.5 ft of riser were installed. Filter sand was installed to 22 ft bgs. and bentonite seal was installed to 20 ft bgs. A cement bentonite slurry was installed to ground surface. Then the well casing was installed and concreted in place.

Method of Well Development

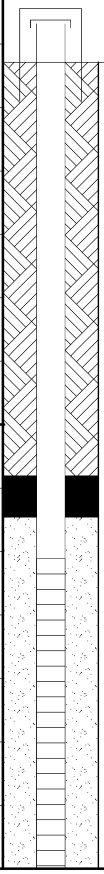
Well was surged for approximately 15 minutes then pumped for an hour until discharge was clear.

Type of Casing PVC	Diameter 4 inch	Type of Backfill Material
Type of Screen PVC	Diameter 4 inch	Type of Seal Material Bentonite
Borehole Diameter	8 inch	Type of Filter Material Filter Sand

	Elevation	Depth
Top of Casing		
Top of Seal		20' bgs
Top of Filter		22' bgs
Top of Screen		24' bgs
Bottom of Filter		
Bottom of Well		39' bgs
Screen Length	15.0'	Slot Size 0.020

GROUNDWATER ELEVATIONS (ft)
(Measured from the Top of Casing)

Elevation	DTW	Date



Well Details	Soil / Rock Classification	PID (ppm)	Depth (ft)
			0
	Fill		
	SAND		
	Clay		
			20
	Sand and Gravel (intermixed)		22
			24
	Sand and Gravel (intermixed)		
	Sand with some gravel (has rounded fragments)		
	Sand with some silt		
	Sand and Gravel (intermixed)		
	Sand and Gravel (intermixed)		39

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WELL CONSTRUCTION SUMMARY

Well No. S-140SRTF

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation And Datum --
Drilling Agency Parratt Wolff	Date Started 8/24/2016 Date Finished 9/7/2016
Drilling Equipment Hollow Stem Auger	Driller Glenn Lansing
Size And Type of Bit 8"	Inspector Valentina Miller

Method of Installation

Well S-140SRTF was installed using an 8-inch diameter hollow stem auger on 9/7/2016. The boring was advanced to 15.5 ft bgs and a 10 ft screen and 8 ft of riser were installed. Filter sand was installed to 4 ft bgs. and bentonite seal was installed to 2 ft bgs. Then the well casing was installed and concreted in place.

Method of Well Development

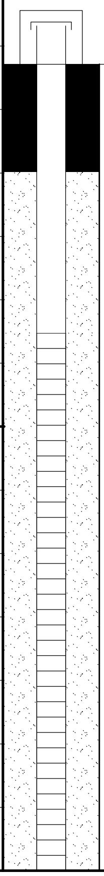
Well was surged for approximately 15 minutes then pumped for an hour until discharge was clear.

Type of Casing PVC	Diameter 4 inch	Type of Backfill Material
Type of Screen PVC	Diameter 4 inch	Type of Seal Material Bentonite
Borehole Diameter	8 inch	Type of Filter Material Filter Sand

Top of Casing	Elevation	Depth
Top of Seal	Elevation	Depth 0' bgs
Top of Filter	Elevation	Depth 2' bgs
Top of Screen	Elevation	Depth 5' bgs
Bottom of Filter	Elevation	Depth
Bottom of Well	Elevation	Depth 15' bgs
Screen Length 10.0'		Slot Size 0.020

GROUNDWATER ELEVATIONS (ft)
(Measured from the Top of Casing)

Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date



Well Details	Soil / Rock Classification	PID (ppm)	Depth (ft)
			0
	Fill	0 0 0 0	2
	USCS Silt	0 0 0 0	
	Sand and Gravel (intermixed)	0 0 0 0	5
	Clay	0 0 0 0	
	Clay	0 0 0 0	
	Clay	0 0 0 0	15

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WELL CONSTRUCTION SUMMARY

Well No. S-141SRTF

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012
Location Philadelphia, Pa	Elevation And Datum --
Drilling Agency Parratt Wolff	Date Started 8/24/2016
	Date Finished 9/19/2016
Drilling Equipment Hollow Stem Auger	Driller Glenn Lansing
Size And Type of Bit 8"	Inspector Valentina Miller

Method of Installation

Well S-141SRTF was installed using an 8-inch diameter hollow stem auger on 9/19/2016. The boring was advanced to 41t bgs and a 15 ft screen and 28.5 ft of riser were installed. Filter sand was installed to 23 ft bgs. and bentonite seal was installed to 21 ft bgs. A cement bentonite slurry was installed to ground surface. Then the well casing was installed and concreted in place.

Method of Well Development

Well was surged for approximately 15 minutes then pumped for an hour until discharge was clear.

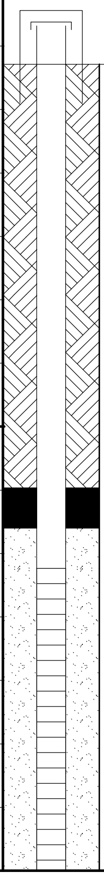
Type of Casing PVC	Diameter 4 inch	Type of Backfill Material
Type of Screen PVC	Diameter 4 inch	Type of Seal Material Bentonite
Borehole Diameter	8 inch	Type of Filter Material Filter Sand

Top of Casing	Elevation	Depth
Top of Seal	Elevation	Depth 21' bgs
Top of Filter	Elevation	Depth 23' bgs
Top of Screen	Elevation	Depth 25' bgs
Bottom of Filter	Elevation	Depth
Bottom of Well	Elevation	Depth 40' bgs
Screen Length 15.0'		Slot Size 0.020

GROUNDWATER ELEVATIONS (ft)
(Measured from the Top of Casing)

Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date
Elevation	DTW	Date

Well Details



Soil / Rock Classification
Fill
USCS Silt
Sand and Gravel (intermixed)
Clay
Clay
Clay
Clay
Clay
Clay
Clay
Sand and Gravel (intermixed)
SAND
SAND

PID (ppm)

0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0

Depth (ft)

0
21
23
25
40

LANGAN

WELL CONSTRUCTION SUMMARY

Well No. S-144SRTF

Project: Philadelphia Energy Solutions (PES) Facility

Project No.: 25746012

Location: Philadelphia, Pa

Elevation And Datum: --

Drilling Agency: Parratt Wolff

Date Started: 8/26/2016

Date Finished: 9/21/2016

Drilling Equipment: Hollow Stem Auger

Driller: Glenn Lansing

Size And Type of Bit: 8"

Inspector: Valentina Miller

Method of Installation

Well S-144SRTF was installed using an 8-inch diameter hollow stem auger on 9/21/2016. The boring was advanced to 60.5 ft bgs and a 20 ft screen and 40 ft of riser were installed. Filter sand was installed to 38ft bgs. and bentonite seal was installed to 35.5 ft bgs. A cement bentonite slurry was installed 1 ft bgs. Then the well casing was installed and concreted in place.

Method of Well Development

Well was surged for approximately 15 minutes then pumped for an hour until discharge was clear.

Type of Casing: PVC

Diameter: 4 inch

Type of Backfill Material:

Type of Screen: PVC

Diameter: 4 inch

Type of Seal Material: Bentonite

Borehole Diameter: 8 inch

Type of Filter Material: Filter Sand

	Elevation	Depth
Top of Casing		
Top of Seal		35.5' bgs
Top of Filter		38' bgs
Top of Screen		40' bgs
Bottom of Filter		
Bottom of Well		60' bgs

Screen Length: 20.0'

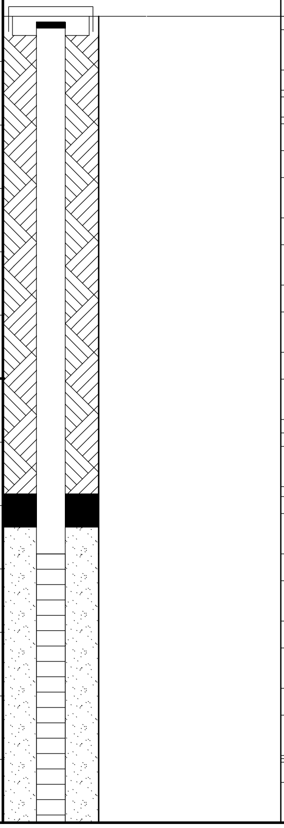
Slot Size: 0.020

GROUNDWATER ELEVATIONS (ft)

(Measured from the Top of Casing)

Elevation	DTW	Date

Well Details



Soil / Rock Classification

- Fill
- Fill
- sandy clay (intermixed)
- Clayey Sand
- Sand with some silt
- sandy clay (intermixed)
- Sand and Gravel (intermixed)
- SAND
- SAND
- Sand and Gravel (intermixed)
- Gravel
- SAND
- SAND
- Sand and Gravel (intermixed)
- SAND
- Sand with gravel (more gravel than "some" and less than "and")
- SAND
- SAND
- Gravel
- Sand with gravel (more gravel than

PID (ppm)

289
245
357
171
75
24
229
34
17
44
84
47
2
0
0
0
0
30
3
0
0
0
5
0
0
0
0
0
0
0
0
0
0
0

Depth (ft)

35.5
38
40
60

\\LANGAN.COM\DATA\DYL\DATA6\2574601\ENGINEERING DATA\ENVIRONMENTAL\GINT\SUNOCO PES SITEWIDE-MERGED.GPJ ... 1/25/2017 4:04:47 PM ... Report: Log - LANGAN_WELL_CONSTRUCTION_SUMMARY

LANGAN

WELL CONSTRUCTION SUMMARY

Well No. S-145SRTF

Project Philadelphia Energy Solutions (PES) Facility	Project No. 25746012	
Location Philadelphia, Pa	Elevation And Datum --	
Drilling Agency Parratt Wolff	Date Started 8/26/2016	Date Finished 9/27/2016
Drilling Equipment Hollow Stem Auger	Driller Glenn Lansing	
Size And Type of Bit 8"	Inspector Valentina Miller	

Method of Installation

Well S-145SRTF was installed using an 8-inch diameter hollow stem auger on 9/27/2016. The boring was advanced to 36.5 ft bgs and a 15 ft screen and 27.5 ft of riser were installed. Filter sand was installed to 18 ft bgs. and bentonite seal was installed to 16 ft bgs. A cement bentonite slurry was installed 1 ft bgs. Then the well casing was installed and concreted in place.

Method of Well Development

Well was surged for approximately 15 minutes then pumped for an hour until discharge was clear.

Type of Casing PVC	Diameter 4 inch	Type of Backfill Material
Type of Screen PVC	Diameter 4 inch	Type of Seal Material Bentonite
Borehole Diameter	8 inch	Type of Filter Material Filter Sand

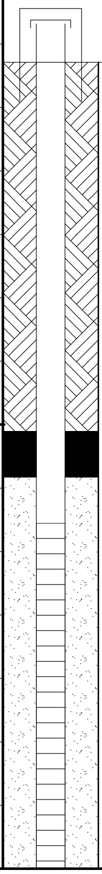
	Elevation	Depth
Top of Casing		
Top of Seal		16' bgs
Top of Filter		18' bgs
Top of Screen		20' bgs
Bottom of Filter		
Bottom of Well		35' bgs

Screen Length	Slot Size
15.0'	0.020

GROUNDWATER ELEVATIONS (ft)
(Measured from the Top of Casing)

Elevation	DTW	Date

Well Details



Soil / Rock Classification	PID (ppm)	Depth (ft)
Fill	0	
Fill	0	
	0	
Clay	1	
	109	
	78	
	150	
SAND	104	
	750	
	862	
	999+	
SAND	999+	
	999+	
	999+	
	999+	
	999+	
	999+	
SAND	1	16
	10	
	40	18
	19	
		20
Sand and Gravel (intermixed)	0	
	0	
	0	
	0	
	0	
Gravel	0	
	0	
	0	
	0	
Gravel	0	
Gravel	0	
Gravel	0	
	0	
	0	35

Page 1 of 1

MONITORING WELL LOG: S-110SRTF

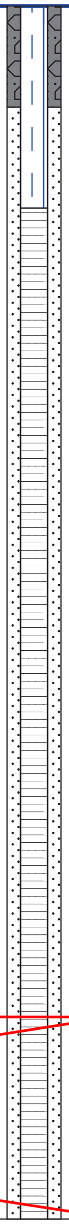
PROJECT: **Sunoco - Philadelphia Refinery**
SITE LOCATION: **AOI-9 - SRTF**
JOB NO.:
LOGGED BY: **Shaun Sykes**
DATES DRILLED: **6/22/2009**
TOTAL DEPTH: **12'**

DRILLING CO.: **Total Quality Drilling**
DRILLING METHOD: **6" Hollow Stem Auger**
SAMPLING METHOD: **Split Spoon Sampling**
SCREEN/RISER DIAMETER: **4"**
WELLBORE DIAMETER: **6"**
ELEVATION: **-**

Depth (feet)	OVM (ppm)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION
	0.0		Fill, orange-brown sandy silt, slightly moist, no odor		
	0.5		Orange-brown silty sand, slightly moist, no odor	Sample taken from 1-2' on 6/1/2009	2' PVC Riser
-5				Cleared to 10', backfilled with sand	
-10	~~1.7~~		~~Wet, coarse sand and mixed gravels (brown/tan), no odor~~		~~10' PVC Screen~~
	~~1.5~~		~~Same as above~~		

5-feet of bentonite was added to monitoring well S-110SRTF in September 2016 to adjust depth to bottom and screen length. Well now screened from 2'-10'.

WELL DIAGRAM



Page 1 of 1

Aquaterra
Technologies, Inc.

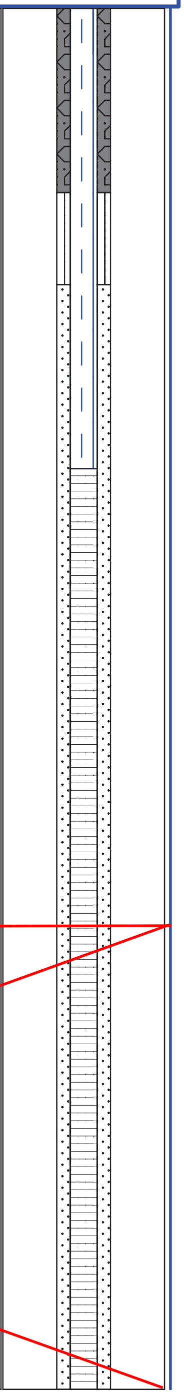
MONITORING WELL LOG: S-123SRTF

PROJECT: **Sunoco - Philadelphia Refinery**
SITE LOCATION: **AOI-9 - SRTF**
JOB NO.:
LOGGED BY: **Shaun Sykes**
DATES DRILLED: **6/29/2009**
TOTAL DEPTH: **15'**

DRILLING CO.: **Total Quality Drilling**
DRILLING METHOD: **6" Hollow Stem Auger**
SAMPLING METHOD: **Split Spoon Sampling**
SCREEN/RISER DIAMETER: **4"**
WELLBORE DIAMETER: **6"**
ELEVATION: **-**

Depth (feet)	OVM (ppm)	USCS	LITHOLOGY	COMMENTS	WELL CONSTRUCTION	WELL DIAGRAM
0			Asphalt & gravel, fill	No 2' sample - Asphalt	5' PVC Riser	
-5				Cleared to 10', backfilled with sand		
-10	~~550~~		~~Medium brown, fine sandy clay, wet, strong odor~~		~~10' PVC Screen~~	
	~~1120~~		~~Medium brown, fine sand and clay, wet, strong odor~~			
	~~987~~		~~Same as above~~			
	~~801~~		~~Same as above~~			
	~~302~~		~~Medium brown, mixed sands, trace clay, wet, odors~~ ~~Same as above~~			
-15						

5-feet of bentonite was added to monitoring well S-123SRTF in September 2016 to adjust depth to bottom and screen length. Well now screened from 5'-10'.



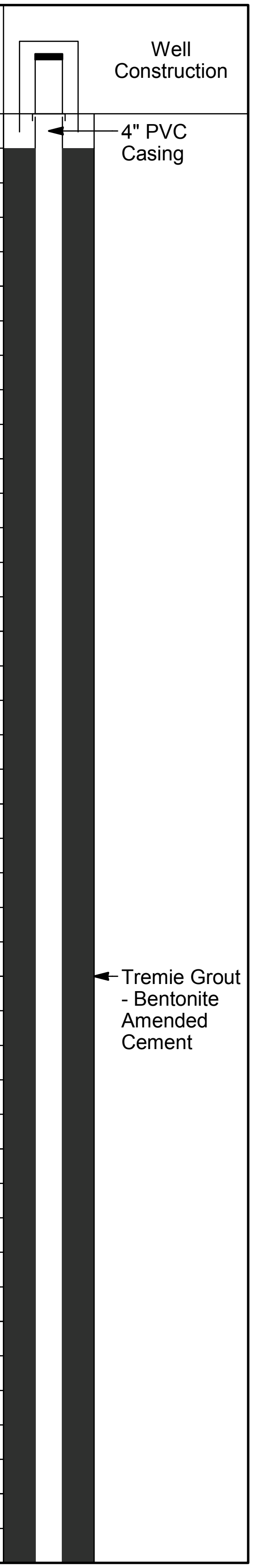
PROJECT: **PHRO - Corrective Measures Program**
LOCATION: **AOI 9 Remedial Investigation**
PROJECT NUMBER: **213402599**

WELL / PROBEHOLE / BOREHOLE NO:
PAGE 1 OF 3 **S-143SRTF**

DRILLING: STARTED **9/8/16** COMPLETED: **9/12/16**
INSTALLATION: STARTED **9/12/16** COMPLETED: **9/14/16**
DRILLING COMPANY: **Parratt Wolff**
DRILLING EQUIPMENT: **Truck-Mounted CME-75**
DRILLING METHOD: **HSA/Mud Rotary**
SAMPLING EQUIPMENT: **Split Spoon; Cuttings**

*NORTHING (ft): **214389.81**
*EASTING (ft): **2677279.73**
*GROUND ELEV (ft): **4.6**
*TOC ELEV (ft): **6.77**
INITIAL DTW (ft): **Not Encountered**
BOREHOLE DEPTH (ft): **122**
STATIC DTW (ft): **16.57**
WELL DEPTH (ft): **70**
WELL CASING DIAMETER (in): **4**
BOREHOLE DIAMETER (in): **8**
LOGGED BY: **ADK**
CHECKED BY: **ANP**
*COORDINATE SYSTEM AND DATUMS: PA STATE PLANE SOUTH, NAD83; NAVD 88

Depth (feet)	USCS	Description	Sample ID	Measured Recov. (feet)	Blow Count	Headspace PID (ppm)
0		0-8' VACUUM TRUCK EXCAVATED AND LOGGED BY LANGAN ENGINEERING				
2		APPARENT FILL [dark brown gravelly silt, some sand (some cobbles, trace boulders with depth) (dry)]				
4		APPARENT FILL [coarse sand and gravel, some silt (coarsens with depth, cobbles and gravel) (moist to wet)]				
8		APPARENT FILL [dark gray clay/silt, little to some fine sand, little pea gravel, trace medium to coarse gravel, trace organic material (roots), trace brick fragments (wet-saturated)]	S-143SRTF@ 8-10'	1.2	2 2 2 3	0.0
10		SAME (wet)	S-143SRTF@ 10-12'	0.1	2 1 2 2	0.0
12		SAME (mottled/variegated appearance) (wet)	S-143SRTF@ 12-14'	0.9	2 2 3 3	0.0
14		SAME (brick fragments, trace stone) (wet)	S-143SRTF@ 14-16'	0.8	2 2 3 3	0.0
16		SAME (wet to saturated)	S-143SRTF@ 16-18'	1.5	2 1 3 7	0.0
17	SC	APPARENT TOP OF PLEISTOCENE DEPOSITS [Light reddish brown fine to very coarse SAND, some granular sand, little fine to medium gravel, trace coarse gravel (quartz and gneiss; angular to sub-rounded), little to trace clay/silt (wet)]				
18	SP-SM		S-143SRTF@ 18-20'	1.1	8 3 3 7	0.0
20	GW-GM	Light reddish brown fine to medium SAND, little to some coarse sand, trace silt, trace fine gravel (sand fraction is red, green, white, gray) (slighlty stratified with coarse sand laminations) (coarse gravel in drive shoe) (saturated)				
23			S-143SRTF@ 23-25'	1.2	48 49 42 27	0.0
25		Reddish yellow very coarse to fine GRAVEL and coarse to fine SAND, trace silt/clay (heterogenous gravels, various sizes and shapes) (saturated)				
28		SAME (6 inch very fine sand and silt lens) (saturated)	S-143SRTF@ 28-30'	1.2	5 13 58 35	0.0
33		SAME (saturated)	S-143SRTF@ 33-35'	1.1	18 35 38 41	0.0
38		SAME (mostly very coarse gravel) (saturated)	S-143SRTF@ 38-40'	0.7	14 21 24 35	0.0



PROJECT: **PHRO - Corrective Measures Program**
LOCATION: **AOI 9 Remedial Investigation**
PROJECT NUMBER: **213402599**

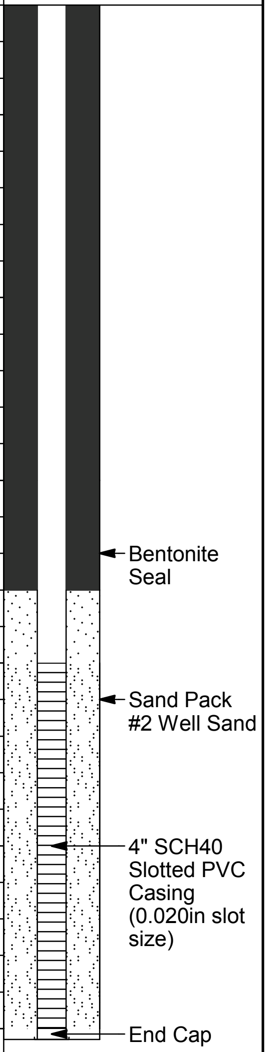
WELL / PROBEHOLE / BOREHOLE NO:
PAGE 2 OF 3 **S-143SRTF**

DRILLING: STARTED **9/8/16** COMPLETED: **9/12/16**
INSTALLATION: STARTED **9/12/16** COMPLETED: **9/14/16**
DRILLING COMPANY: **Parratt Wolff**
DRILLING EQUIPMENT: **Truck-Mounted CME-75**
DRILLING METHOD: **HSA/Mud Rotary**
SAMPLING EQUIPMENT: **Split Spoon; Cuttings**

*NORTHING (ft): **214389.81**
*EASTING (ft): **2677279.73**
*GROUND ELEV (ft): **4.6**
*TOC ELEV (ft): **6.77**
INITIAL DTW (ft): **Not Encountered**
BOREHOLE DEPTH (ft): **122**
STATIC DTW (ft): **16.57**
WELL DEPTH (ft): **70**
WELL CASING DIAMETER (in): **4**
BOREHOLE DIAMETER (in): **8**
LOGGED BY: **ADK**
CHECKED BY: **ANP**
*COORDINATE SYSTEM AND DATUMS: PA STATE PLANE SOUTH, NAD83; NAVD 88

Depth (feet)	Graphic Log	USCS	Description	Sample	Sample ID	Measured Recov. (feet)	Blow Count	Headspace PID (ppm)	Depth (feet)
43 44 45 46 47		GW-GM	SAME (yellow color) (varicolored gravels weathered in place) (saturated)		S-143SRTF@ 43-45'	0.9	15 16 26 19	0.0	45
48 49 50 51 52		SP CL	APPARENT TOP OF CRETACEOUS DEPOSITS [Very pale brown and yellowish brown fine SAND, little medium to coarse sand, trace to no silt (strong brown pea gravel in shoe) (saturated)]		S-143SRTF@ 48-50'	0.9	10 10 8 8	0.0	50
53 54 55 56 57			Light gray, very pale brown and yellow CLAY/SILT, and to some coarse to fine sand (few thin lenses of clay/silt with gravel) (wet)		S-143SRTF@ 53-55'	0.3	2 2 3 10	0.0	55
58 59 60 61 62		SP	White to pale yellow coarse SAND, little fine to medium sand, trace to no silt (moderately well-sorted) (saturated)		S-143SRTF@ 58-60'	1.2	35 40 39 26	0.0	60
63 64 65 66 67			SAME (yellow color) (trace silty lenses) (saturated)		S-143SRTF@ 63-65'	0.5	35 50/4"	0.0	65
68 69 70 71 72			SAME (coarser than above, mostly very coarse to coarse sand, trace to no silt, trace clay as grain coatings) (few rip-up clay/silt clasts) (saturated)		S-143SRTF@ 68-70'	0.9	31 42 50/3"	0.0	70
73 74 75 76 77		SW-GW	White to yellow very coarse to coarse SAND and fine to coarse GRAVEL, trace to no silt (white lenses have trace silt) (saturated)		S-143SRTF@ 73-75'	0.8	49 37 46 50	0.0	75
78 79 80 81 82			SAME (few thin lenses of clayey sand) (few heavy mineral laminations) (saturated)		S-143SRTF@ 78-80'	0.6	25 45 48 47	0.0	80
83		GP-GC	White fine to coarse GRAVEL and coarse to		S-143SRTF@		45		

Well Construction



PROJECT: **PHRO - Corrective Measures Program**
LOCATION: **AOI 9 Remedial Investigation**
PROJECT NUMBER: **213402599**

WELL / PROBEHOLE / BOREHOLE NO:
PAGE 3 OF 3 **S-143SRTF**

DRILLING: STARTED **9/8/16** COMPLETED: **9/12/16**
INSTALLATION: STARTED **9/12/16** COMPLETED: **9/14/16**
DRILLING COMPANY: **Parratt Wolff**
DRILLING EQUIPMENT: **Truck-Mounted CME-75**
DRILLING METHOD: **HSA/Mud Rotary**
SAMPLING EQUIPMENT: **Split Spoon; Cuttings**

*NORTHING (ft): **214389.81**
*EASTING (ft): **2677279.73**
*GROUND ELEV (ft): **4.6**
*TOC ELEV (ft): **6.77**
INITIAL DTW (ft): **Not Encountered**
BOREHOLE DEPTH (ft): **122**
STATIC DTW (ft): **16.57**
WELL DEPTH (ft): **70**
WELL CASING DIAMETER (in): **4**
BOREHOLE DIAMETER (in): **8**
LOGGED BY: **ADK**
CHECKED BY: **ANP**
*COORDINATE SYSTEM AND DATUMS: PA STATE PLANE SOUTH, NAD83; NAVD 88

Depth (feet)	Graphic Log	USCS	Description	Sample	Sample ID	Measured Recov. (feet)	Blow Count	Headspace PID (ppm)	Depth (feet)	Well Construction
85		GP-GC	fine SAND, trace clay (as white grain coatings) (few white clay stringers) (wet)	■	83-85'	0.6	45 50/3"	0.0	85	
87		GP								
89			White coarse to fine GRAVEL, some coarse to fine sand, trace to no silt/clay (wet to saturated)	■	S-143SRTF@ 88-90'	0.6	45 48 47 50	0.0	90	
91		SC								
99			White very coarse SAND, little to some clay/silt (coarsely micaceous) (5" light gray clay/silt lens with very fine reddish yellow mottles) (moist)	■	S-143SRTF@ 98-100'	1	36 45 50/2"	0.0	100	
103			SAME (6" white clay/silt lens then yellow coarse to fine gravel and sand in drive shoe) (saturated)	■	S-143SRTF@ 103-104'	1	63 120	0.0		
105		GW-GM							105	
109			NO RECOVERY (hard drilling)	■	S-143SRTF@ 108-110'	0	100/2"	NA	110	
111			Varicolored coarse to fine GRAVEL, some fine to coarse sand, trace to little clay/silt (few rounded quartz gravels and angular quartzite) (moist to wet)	■	S-143SRTF@ 110-112'	0.3	110/4"	0.0	115	
121			APPARENT WEATHERED BEDROCK [varicolored clay/silt and fine sand (rock fabric preserved) (apparent mica schist) (moist)]	■	S-143SRTF@ 120-122'	1.8	59 47 60 69	0.0	120	
125									125	

Appendix C
Summary of Groundwater Field Sample Reports - November 2016
AOI 9 Remedial Investigation Report Addendum
PES Philadelphia Refining Complex
Philadelphia, Pennsylvania

Date and Time	Depth to Water (ft bTOC)	Temp (°C)		DO (mg/L)		Conductivity (mS/cm)		ORP (mV)		Turbidity		pH	
S-106DSRTF													
2016/11/08 13:46:00	19.05	17.01		4.4		0.733		-86.1		1.8	100.0%	6.64	6.64
2016/11/08 13:51:00	19.05	16.55	2.8%	3.48	26.4%	0.737	0.5%	-87	0.9	0.5	260.0%	6.55	0.09
2016/11/08 13:56:00	19.05	16.45	0.6%	3.39	2.7%	0.732	0.7%	-88.3	1.3	0.4	25.0%	6.51	0.04
2016/11/08 14:01:00	19.06	16.44	0.1%	3.34	1.5%	0.733	0.1%	-87	1.3	0.4	0.0%	6.52	0.01
2016/11/08 14:06:00	19.06	16.46	0.1%	6.54	48.9%	0.745	1.6%	-92.6	5.6	0.4	0.0%	6.55	0.03
S-110DSRTF													
2016/11/09 14:11:00	11.72	15.56		4.96		1.323		43.3		103.1		6.25	
2016/11/09 14:16:00	11.74	15.97	2.6%	5.04	1.6%	1.329	0.5%	42.6	0.7	104.6	1.4%	6.24	0.01
2016/11/09 14:21:00	11.75	16.16	1.2%	5.04	0.0%	1.343	1.0%	41.3	1.3	103.9	0.7%	6.24	0
2016/11/09 14:26:00	11.75	15.98	1.1%	5.2	3.1%	1.342	0.1%	41.4	0.1	98.6	5.4%	6.24	0
2016/11/09 14:31:00	11.75	16.01	0.2%	5.3	1.9%	1.342	0.0%	42.6	1.2	94.2	4.7%	6.24	0
S-115DSRTF													
2016/11/09 11:07:00	11.84	15.58		3.98		1.466		-68.4		14.4		6.63	
2016/11/09 11:12:00	11.83	15.59	0.1%	4.04	1.5%	1.467	0.1%	-71.2	2.8	13.1	9.9%	6.62	0.01
2016/11/09 11:17:00	11.84	15.55	0.3%	4.12	1.9%	1.464	0.2%	-75	3.8	13.8	5.1%	6.62	0
2016/11/09 11:22:00	11.84	15.58	0.2%	4.14	0.5%	1.465	0.1%	-76.2	1.2	13.1	5.3%	6.62	0
S-118DSRTF													
2016/11/09 10:13:00	12.75	15.19		4.09		1.409		-65.8		2.7		6.56	
2016/11/09 10:18:00	12.84	15.36	1.1%	4.21	2.9%	1.411	0.1%	-65	0.8	2.7	0.0%	6.55	0.01
2016/11/09 10:23:00	12.87	15.32	0.3%	4.28	1.6%	1.428	1.2%	-65.4	0.4	2.8	3.6%	6.55	0
2016/11/09 10:27:00	12.90	15.36	0.3%	4.34	1.4%	1.42	0.6%	-66.1	0.7	2.8	0.0%	6.55	0
S-120DSRTF													
2016/11/09 09:09:00	21.95	16.29		3.77		0.747		-150.3		106.7		7.07	
2016/11/09 09:14:00	22.19	16.19	0.6%	3.45	9.3%	0.741	0.8%	-152.4	2.1	85.8	24.4%	7.05	0.02
2016/11/09 09:19:00	22.19	16.29	0.6%	3.28	5.2%	0.738	0.4%	-146	6.4	64.9	32.2%	7.01	0.04
2016/11/09 09:24:00	22.20	16.33	0.2%	3.16	3.8%	0.736	0.3%	-145.9	0.1	60.2	7.8%	6.99	0.02
2016/11/09 09:29:00	22.21	16.38	0.3%	3.08	2.6%	0.737	0.1%	-143.1	2.8	58.4	3.1%	6.98	0.01
S-138SRTF													
2016/11/08 12:25:00	19.09	17.31		2.69		0.945		-162.5		27.2		7.18	
2016/11/08 12:30:00	19.22	17.3	0.1%	2.34	15.0%	0.945	0.0%	-163.7	1.2	40	32.0%	7.12	0.06
2016/11/08 12:35:00	19.20	17.19	0.6%	2.06	13.6%	0.934	1.2%	-169.8	6.1	58.8	32.0%	7.14	0.02
2016/11/08 12:40:00	19.22	17.16	0.2%	2.04	1.0%	0.881	6.0%	-150.1	19.7	486.9	87.9%	6.98	0.16
2016/11/08 12:45:00	19.21	17.16	0.0%	2.21	7.7%	0.809	8.9%	-131.1	19.0	1146.3	57.5%	6.79	0.19
2016/11/08 12:50:00	19.18	17.23	0.4%	2.33	5.2%	0.79	2.4%	-120.8	10.3	445.1	157.5%	6.74	0.05
2016/11/08 12:55:00	19.19	17.22	0.1%	2.45	4.9%	0.778	1.5%	-118	2.8	59.2	651.9%	6.73	0.01
2016/11/08 13:00:00	19.18	17.16	0.3%	2.53	3.2%	0.773	0.6%	-117.2	0.8	13.6	335.3%	6.71	0.02
2016/11/08 13:05:00	19.17	17.14	0.1%	2.63	3.8%	0.772	0.1%	-113.9	3.3	3.4	300.0%	6.7	0.01
2016/11/08 13:10:00	19.17	17.19	0.3%	2.7	2.6%	0.773	0.1%	-114.7	0.8	0.5	580.0%	6.72	0.02

Appendix C
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PES Philadelphia Refining Complex
Philadelphia, Pennsylvania

Date and Time	Depth to Water (ft bTOC)	Temp (°C)		DO (mg/L)		Conductivity (mS/cm)		ORP (mV)		Turbidity		pH	
S-143SRTF													
2016/11/08 10:31:00	16.63	16.21		2.17		0.797		-52.8		69.6		6.71	
2016/11/08 10:36:00	16.64	16.66	2.7%	1.55	40.0%	0.824	3.3%	-56.7	3.9	46.6	49.4%	6.68	0.03
2016/11/08 10:41:00	16.64	16.73	0.4%	1.76	11.9%	0.829	0.6%	-55	1.7	49.5	5.9%	6.7	0.02
2016/11/08 10:46:00	16.64	16.89	0.9%	2.04	13.7%	0.832	0.4%	-52.6	2.4	36.5	35.6%	6.71	0.01
2016/11/08 10:51:00	16.63	17.02	0.8%	2.19	6.8%	0.835	0.4%	-48.7	3.9	40.7	10.3%	6.73	0.02
2016/11/08 10:56:00	16.63	17.01	0.1%	2.11	3.8%	0.836	0.1%	-50.3	1.6	35.7	14.0%	6.71	0.02
2016/11/08 11:01:00	16.63	17.06	0.3%	2.25	6.2%	0.837	0.1%	-48.3	2.0	34.8	2.6%	6.7	0.01
2016/11/08 11:06:00	16.63	17.16	0.6%	2.34	3.8%	0.838	0.1%	-48	0.3	31.7	9.8%	6.66	0.04
2016/11/08 11:11:00	16.63	17.2	0.2%	2.57	8.9%	0.845	0.8%	-46.9	1.1	28	13.2%	6.72	0.06
2016/11/08 11:16:00	16.63	17.05	0.9%	2.58	0.4%	0.839	0.7%	-47.5	0.6	28.6	2.1%	6.68	0.04
S-144SRTF													
2016/11/09 12:41:00	9.36	16.86		3.53		0.722		56.9		96		6.64	
2016/11/09 12:46:00	9.39	16.97	0.6%	3.46	2.0%	0.719	0.4%	56.3	0.6	87	10.3%	6.63	0.01
2016/11/09 12:51:00	9.39	16.58	2.4%	3.43	0.9%	0.71	1.3%	53.7	2.6	121.5	28.4%	6.61	0.02
2016/11/09 12:56:00	9.40	16.47	0.7%	3.44	0.3%	0.71	0.0%	55.9	2.2	133.7	9.1%	6.62	0.01
2016/11/09 13:01:00	9.40	16.54	0.4%	3.5	1.7%	0.714	0.6%	57.6	1.7	118.4	12.9%	6.65	0.03
2016/11/09 13:06:00	9.39	16.42	0.7%	3.54	1.1%	0.712	0.3%	58.7	1.1	109.7	7.9%	6.66	0.01
2016/11/09 13:11:00	9.39	16.42	0.0%	3.62	2.2%	0.713	0.1%	59.7	1.0	110	0.3%	6.67	0.01

Appendix C
Summary of Groundwater Field Sample Reports - November 2016
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PES Philadelphia Refining Complex
Philadelphia, Pennsylvania

Well ID	**Depth to Water (feet)**	**Depth to Product (feet)**	**Product Thickness (feet)**	Temp (°C)	DO (mg/L)	Conduct-ivity (mS/cm)	ORP (mV)	Turbidity	pH	Temp (°C)	DO (mg/L)	Conduct-ivity (mS/cm)	ORP (mV)	Turbidity	pH	Temp (°C)	DO (mg/L)	Conduct-ivity (mS/cm)	ORP (mV)	Turbidity	pH	Temp (°C)	DO (mg/L)	Conduct-ivity (mS/cm)	ORP (mV)	Turbidity	pH
				FIELD READINGS (pre-purge)						FIELD READINGS (during purge)						FIELD READINGS (pre-sample)						FIELD READINGS (post-sample)					
S-106SRTF	7.65	--	--	18.91	4.04	0.705	-112.5	68.8	7.05	19.49	4.67	0.737	-106.1	12.4	6.95	20.05	4.77	0.745	-106.9	9.3	6.94	--	--	--	--	--	--
S-112SRTF	10.8	--	--	17.32	0.83	1.413	-129.7	847.8	6.63	17.27	0.77	1.42	133.4	1047	6.68	17.28	0.68	1.434	-134.2	677.8	6.68	17.32	1.35	1.412	-134.5	360.4	6.68
S-113SRTF	12.35	--	--	18.35	0.52	0.611	-219.8	60.2	6.15	18.45	0.07	1.168	-223.7	13.6	6.42	18.41	0.08	1.36	-192	2	6.5	18.4	0.9	1.388	-192.1	0.8	6.51
S-115SRTF	12.25	--	--	17.81	0.71	1.052	-82.7	21.7	6.32	17.93	0.77	1.025	-83.7	30.3	6.37	18.27	0.61	1.038	-83.4	18	6.4	18.28	0.43	1.074	-83.7	9.6	6.38
S-116SRTF	10.79	--	--	18.27	9.72	0.49	-38.2	49.7	6.21	18.28	9.42	0.686	-61	13.2	6.22	18.28	9.4	0.716	-66.1	8.1	6.2	--	--	--	--	--	--
S-120SRTF	10.76	--	--	19.71	5.14	0.619	-90.3	104.2	6.78	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S-121SRTF	9.13	--	--	19.56	9.48	0.558	-111.7	123.3	6.68	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
S-130SRTF	9.36	--	--	18.7	3.96	0.905	-135.3	436.8	7.05	--	--	--	--	--	--	18.45	3.23	0.913	-149.8	678.2	7.07	--	--	--	--	--	--
S-135SRTF	11.4	--	--	17.56	0.57	0.399	-51.4	669	6.16	17.5	0.6	0.401	-80.8	1069	6.15	17.16	0.61	0.888	-108	646.7	6.4	17.11	0.62	1.056	-117	109	0.63
S-137SRTF	19.66	--	--	18.2	3.79	0.784	-107	8.4	6.96	18.85	3.84	0.787	-114.1	9.6	6.98	18.53	4.39	0.808	-113.7	7.4	6.86	--	--	--	--	--	--
S-139SRTF	18.9	--	--	14.37	0.92	0.704	-119	28.5	6.71	14.13	0.92	0.713	-132	568.6	6.78	14.14	0.85	0.725	-133.7	89.7	6.69	--	0.82	0.732	-136.5	12	6.66
S-140SRTF	6.73	--	--	18.16	4.66	0.75	-47.3	247.8	6.66	--	--	--	--	--	--	--	--	--	--	--	--	17.72	4.58	0.882	-95.7	87.1	6.64
S-141SRTF	20.55	--	--	16.84	3.22	0.884	-118.2	101.2	6.99	18.76	3.56	0.928	-114.4	29.2	7	17.2	3.94	0.896	-123.1	16.2	7	--	--	--	--	--	--
S-142SRTF	17.42	--	--	14.44	4.68	0.761	-28.5	154.3	6.77	15.55	4.44	0.826	-76.9	20.5	6.83	15.87	4.03	0.843	-79.6	11.7	6.9	--	--	--	--	--	--
S-145SRTF	10.33	--	--	17.32	0.21	1.497	-134	1064.4	6.89	--	0.22	1.498	-134.8	1064.5	6.89	17.33	--	--	134.7	1064.4	6.89	17.32	0.21	1.497	-134.7	1064	6.89
S-78SRTF	10.35	--	--	20.32	0.32	2.578	-134.7	554.7	6.55	21.14	0.23	2.122	-100.8	316.4	6.57	21.21	0.07	1.712	-113.5	183.9	--	21.23	0.02	1.432	-114.5	141.7	6.59
S-81SRTF	10.67	--	--	18.93	0.01	0.971	-153.7	40.4	6.5	18.85	0.04	1.239	-151.5	18.1	6.58	18.84	0.05	1.265	-153.7	5.5	6.59	18.86	0.06	1.268	-155.3	3.3	--
S-118SRTF	13.25	--	--	Well Went Dry. No Readings Collected.																							

Notes:
1. Field Parameters measured by Aquaterra during the November 2016 groundwater sampling event
°C - Degrees Celcius
mg/L - milligrams per liter
mS/cm - millisiemens per centimeter
mV - millivolt
ORP - Oxidation Reduction Potential

APPENDIX D

STANTEC QUANTITATIVE FATE AND TRANSPORT REPORT

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT OF PLUME 2 BENZENE USING QUICK DOMENICO AREA OF INTEREST 9

Philadelphia Refining Complex
3144 Passyunk Avenue
Philadelphia, Pennsylvania
Sitewide PADEP Facility ID No. 780190
Area of Interest 9 PADEP Facility ID No. 778379

Stantec

Prepared for:
Philadelphia Refinery Operations,
a series of Evergreen Resources Group, LLC

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January 27, 2017

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT OF PLUME 2 BENZENE USING QUICK DOMENICO
AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Avenue, Philadelphia, Pennsylvania

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AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Avenue, Philadelphia, Pennsylvania

1.0 INTRODUCTION

Stantec Consulting Services Inc. (Stantec) has prepared this assessment on behalf of Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC (Evergreen), to evaluate potential risk associated with the fate-and-transport of benzene in shallow groundwater at Area of Interest 9 (AOI 9), also known as the Schuylkill River Tank Farm (SRTF), of the Philadelphia Energy Solutions Refining and Marketing, LLC (PES) Philadelphia Refining Complex (complex). This report is intended to supplement the qualitative fate-and-transport assessment incorporated in the AOI 9 Remedial Investigation Report (RIR) submitted to the Pennsylvania Department of Environmental Protection (PADEP) on December 31, 2015, by Langan Engineering (Langan) (Langan, 2015). It is understood that the PADEP provided comments to the AOI 9 RIR in a letter dated March 10, 2016, and that Langan is presently preparing an AOI 9 RIR Addendum (Langan, 2017). This report was prepared in collaboration with Langan's ongoing characterization work at AOI 9 to address PADEP's comments regarding the delineation of dissolved petroleum-related constituents in groundwater at the western boundary of AOI 9, and to assess the potential for dissolved constituents of concern to extend offsite. Specifically, dissolved benzene within the Plume 2 area (Langan, 2015) is further evaluated through use of a groundwater fate-and-transport model.

2.0 BACKGROUND AND APPROACH

The analysis of the potential fate-and-transport of benzene in Plume 2 groundwater presented herein was performed using the Quick Domenico (QD) groundwater fate-and-transport model spreadsheet developed by the PADEP, in general accordance with the User's Manual for the Quick Domenico Groundwater Fate-and-Transport Model (PADEP, 2014) and Pennsylvania's Land Recycling Program Technical Guidance Manual Section IV.A.2 (Fate-and-Transport Analysis) (PADEP, 2002). In general, the QD spreadsheet provides a user-friendly interface through which predictions of the fate-and-transport of dissolved contaminant plumes can be evaluated using the analytical solution of Domenico (1987) for solute transport in groundwater. The QD solution is most applicable in aquifers exhibiting relatively uniform hydrogeologic conditions and impacted by a contaminant source that remains constant in time.

As summarized in **Section 3** of this report and detailed in RIRs for other AOIs in the complex, subsurface conditions beneath AOI 9 and vicinity can be relatively complex and when considered in conjunction with numerous anthropogenic influences and river tides, result in a dynamic environment. As previously indicated by Stantec (2016), it is the intention of Evergreen to present a complex-wide, numerical groundwater flow model to the PADEP that may be used to comprehensively simulate and more reliably predict the future extent of groundwater contamination and potential impacts to identified receptors. However, the model is presently being refined and calibrated to recently collected hydrostratigraphic information. Upon completion, the numerical groundwater model may be used to refine the present understanding of the fate-and-transport of dissolved constituents of concern at the complex, such as the AOI 9 Plume 2 area evaluated in this report.

To provide a timely response to the above-referenced PADEP concern at AOI 9 and on behalf of Evergreen, Stantec has applied a conservative approach to analytical modeling that utilizes QD to evaluate the future extent of Plume 2 area dissolved benzene with the intention of identifying a "worst case" based on the current understanding of groundwater flow, hydrostratigraphy, and source area contaminant distribution. Two continuous source areas are evaluated within the broadly-defined Plume 2 area that characterize the local groundwater flow paths. The downgradient limit of the first source area is defined by monitoring well S-112SRTF. The downgradient limit of the second area is defined by monitoring well S-115SRTF. Conservative input values were utilized in the analyses to counter the uncertainty associated with the heterogeneous aquifer conditions and allow for constructive inference of potential benzene plume lengths and potential offsite impacts from the model results. Further information regarding qualitative plume delineation and contaminant concentration trends in AOI 9 can be found in Langan (2017). The analyses presented herein are intended to address the concern regarding whether dissolved benzene at presently observed concentrations has the potential to migrate offsite. The approach may be further applied to model other constituents of concern, such as methyl tertiary butyl ether (MTBE), present near the AOI 9 points of compliance, if necessary, and used to compare to future predictions simulated by the numerical model.

3.0 QD APPLICABILITY, LIMITATIONS, AND INPUT VALUES

PADEP (2014) discusses the applicability of QD to contaminant transport problems and outlines the limitations of the model that must be considered by the user. In the following sections, Stantec presents a summary of the input values utilized in these assessments and a discussion of the QD applicability under the observed conditions. QD model input values, model sensitivity, and input value ranges considered in the model calibration are discussed in the following sections and are also summarized in **Table 1** and **Table 2**.

3.1 AQUIFER PROPERTIES

Langan's AOI 9 RIR Addendum will present a refinement of the interpretation of the SRTF hydrostratigraphy. Importantly, several of the monitoring wells previously utilized to evaluate shallow groundwater occurrence and flow at AOI 9 have been interpreted to be screened within a perched water table that is locally present within fill deposits, or screened across both the perched water table and deeper water-bearing strata. As constructed, those wells may exhibit mixed hydraulic head and can provide misleading results when incorporated into evaluation of groundwater flow. Additional wells, such as well S-117SRTF, have significantly fouled screened intervals and as such, are subject to poor hydraulic communication with the surrounding saturated-zone deposits, which adversely affect groundwater sampling results.

With discretion, Stantec has selected a subset of appropriately-constructed AOI 9 monitoring wells and has utilized the subsurface information available from those wells in this fate-and-transport assessment (see **Figure 1** and **Appendix A**). It is noted that this interpretation of aquifer properties resulted from review of lithologic and groundwater data obtained from recently installed monitoring wells meant to address data gaps, which included groundwater flow near the points of compliance, hydrostratigraphy, hydraulic properties of the water-bearing strata, and hydraulic gradients. This fate-and-transport assessment also incorporates additional water-table monitoring and slug test data collected by Stantec and discussed in **Section 3.1.1** and **Section 3.2.1**.

In general, QD applies to solute transport in homogeneous and isotropic aquifers. Irrespective of the SRTF geologic interpretation regarding published geologic units and unit boundaries, it is well-documented from the many subsurface investigations to date that the lithologies present in the shallow subsurface beneath the regional zone of saturation are heterogeneous. The deposits vary laterally and vertically to include muds rich in organic material to dense sands and gravels with limited matrix fines. On a very basic level, the depositional model of the Delaware estuary through the Holocene supports that the shallow geology observed beneath AOI 9 may be complex and irregular, having resulted from the geologically-recent inundation and subsequent infilling of the Schuylkill River valley by rising eustatic sea level (Kraft, 1971). An analytical model such as QD cannot account for the variability noted, which would primarily affect the groundwater seepage velocity and flow path(s) through the model calculation domain. However, aquifers that have a high degree of heterogeneity and anisotropy in their geologic and hydrogeologic properties may be approximated through simulation of representative properties based upon the study scale and purpose.

To apply QD as a conservative metric for a fate-and-transport assessment of benzene within the area of Plume 2, Stantec reviewed select subsurface data and observed that dissolved benzene contamination in this area of concern appears to be concentrated in the more permeable sand and gravel deposits that are prevalent beneath a surficial layer of fill and/or fine-grained alluvium. For this assessment, it is assumed that the saturated thickness of the unconfined aquifer [see Langan (2017) for a discussion of the hydrostratigraphic units present beneath AOI 9] is composed entirely of sand and gravel deposits and represented in the QD model by a relatively high hydraulic conductivity established for AOI 9 through slug testing of wells screened within that aquifer.

3.1.1 Hydraulic Conductivity

In October 2016, Stantec performed slug tests on five of the recently-installed and developed monitoring wells at AOI 9, including wells S-137SRTF, S-139SRTF, S-141SRTF, S-142SRTF, and S-144SRTF (see **Figure 1**). The purpose of the slug testing was to establish a range of site-specific unconfined aquifer hydraulic conductivity values to apply to the QD analysis. A pneumatic slug assembly was used to pressurize the well casings and initiate instantaneous water-level displacements from which the recovery data could be evaluated (rising-head tests). Slug tests were performed in general accordance with the *Evergreen Field Procedures Manual* (Stantec, 2016).

AQTESOLV Version 4.5 Professional was used to fit slug test solutions to the normalized data (see **Appendix B**). Where an overdamped response was indicated, Stantec applied either the Hvorslev (1951) or KGS Model (Hyder et al., 1994) to fit the data and estimate hydraulic conductivity. Where an underdamped response was apparent (inertial effects common to wells screened in high hydraulic conductivity formations), either the Springer-Gelhar (1991) or Butler (1998) solutions were utilized. The following unconfined aquifer hydraulic conductivity values were estimated for the tested wells:

- S-137SRTF: 271 feet per day (ft/d)
- S-139SRTF: 125 ft/d
- S-141SRTF: 130 ft/d
- S-142SRTF: 35 ft/d
- S-144SRTF: 237 ft/d

Based on the slug test results and on the conservative approach noted, an input hydraulic conductivity value of 195 ft/d was applied to the QD analyses presented. This value is biased toward the high end of hydraulic conductivities estimated for AOI 9 and is based upon the upper confidence limit (0.01%) for the estimated mean value. This hydraulic conductivity value is in the range of previous testing results for the complex (Stantec, 2016) and for the nearby Enterprise Avenue Landfill site's Pleistocene-age sand and gravel unit (Scheinfeld and Davenger, 2006). Based upon the conservative hydraulic conductivity selected, calibration to the site data was limited to varying longitudinal dispersivity and the decay constant based on reasonable ranges for those parameters found in literature.

3.1.2 Soils Laboratory Data

Langan (2015) provided site-specific geotechnical laboratory data for AOI 9 and that data was utilized in this analysis (see **Appendix C**). The samples were collected from inferred minimally contaminated zones of the aquifer matrix within a depth range applicable to this assessment. Based on the available data, the weight fraction of organic carbon is reported to range from one to three percent. In general, relatively high organic carbon contents are common to the geologically recent deposits at the complex. Because organic carbon acts to retard transport of dissolved hydrocarbons in groundwater plumes by way of adsorption to the solid phase, higher weight contents such as those estimated for AOI 9 tend to reduce the extent of contamination predicted. To be conservative, Stantec has assumed that the organic carbon weight fraction present in the aquifer is one percent. An effective porosity of 22.5% and a sediment bulk density of 1.76 grams per cubic centimeter were also estimated from the sample data provided in **Appendix C** and applied to the QD model.

3.2 GROUNDWATER FLOW DIRECTION AND GRADIENT

To evaluate unconfined aquifer groundwater flow pattern(s), Stantec analyzed well gauging data collected by Aquaterra Technologies, Inc. (Aquaterra) on November 7 through November 9, 2016. Stantec also reviewed historical gauging data available for 10 of the wells included in this assessment (see **Figure 2**). The purpose of reviewing historical data was to evaluate the persistence of present water-table conditions. The hydraulic head data from a total of 19 monitoring wells was utilized.

Stantec used a geographic information system (GIS) to interpolate and contour the water-table surface presented on **Figure 3**. Ordinary point Kriging was selected as the gridding method. Grid residuals were reviewed and the geometric mean grid residual was 0.003 feet indicating good agreement between the interpolated water-table surface and well gauging data. Based on the November 2016 data presented, water-table elevations in the assessment area ranged from -4.63 feet referenced to the North American Vertical Datum of 1988 (NAVD 88) at well S-74D2SRTF to -10.31 feet NAVD 88 at well S-142SRTF. The pattern of groundwater flow appears divergent from a centralized high, broadly defined by wells S-122SRTF, S-79SRTF, and S-74D2SRTF. Within the QD model calculation domains presented, the inferred groundwater flow direction would be to the southwest along a hydraulic gradient of approximately 0.0027 feet per foot (ft/ft). The hydrographs presented on **Figure 2** support that this groundwater flow field has been relatively persistent since approximately 2011.

It is important to note that the water-table contours presented on **Figure 3** do not represent an equilibrium surface. As further discussed below in **Section 3.2.1**, they appear to reflect a surface of differential drawdown that could be the result of several factors acting in conjunction with dewatering activities at Mingo Creek basin: more permeable aquifer material on the western side of AOI 9 when compared to the east (well S-145SRTF compared to S-74D2SRTF) supporting higher transmissivity and preferential flow to Mingo Creek basin, groundwater infiltration into the Mingo Avenue sewer that drains into Mingo basin, groundwater flow towards buried and exposed portions of former Mingo Creek to the southwest of Plume 2 (see **Figure 1**), and/or enhanced groundwater recharge (groundwater mounding) along the western edge of the fill-supported perched water table.

The QD solution assumes that groundwater flow within the modeled area is unidirectional and that velocities are constant (PADEP, 2014). It is clear from the data presented that these conditions are not present in the unconfined aquifer beneath AOI 9. However, because the overall pattern of groundwater flow appears relatively consistent through time (dynamic equilibrium) and there is no indication that the City of Philadelphia Water Department (PWD) will cease dewatering activities at Mingo Creek basin in the future, it can be reasonably assumed in a worst case scenario that a “steady-state” southwestern hydraulic gradient/groundwater flow direction is applicable to the potential migration of dissolved benzene from the Plume 2 area. In addition, while there is some degree of radial flow indicated, the flow direction is consistently away from a groundwater high in the central portion of AOI 9.

3.2.1 Local Water-Table Conditions

Review of historical topographic maps, aerial photographs through time, and archived images of the City of Philadelphia indicate that prior to industrialization, the AOI 9 area was characterized by a marsh/wetland environment that fringed the Schuylkill River and was dissected by several small creeks and/or man-made ditches. In the Coastal Plain, the water-table equilibrium surface typically intersects the ground surface in these low-lying areas and groundwater discharge to surface water should occur under natural conditions. Through industrialization and development of the SRTF and local area, several key modifications to the natural environment are apparent:

- Filling of the area wetlands with anthropogenic debris and soil, the extent of which can be estimated by review of detailed topography (see **Figure 1**);
- Re-routing, infilling, and placement of streams into culverts and conveyance structures;
- Shoreline advancement and hardening along the Schuylkill River;
- Construction of numerous sewers; and
- Damming and subsequent widening and deepening of one of the more prominent area creeks, Mingo Creek, into a large basin.

Of the anthropogenic modifications noted, the transformation of Mingo Creek from a tidal creek to a water detention area may be the most significant with regard to groundwater flow at AOI 9. Historical references indicate that as early as the late 1800s, dewatering in the Mingo Creek area was performed to create farmland. Paulachok and Wood (1984) created a water-table map for the City of Philadelphia and noted that at that time, the water-level in Mingo Creek was controlled through continual pumping at an elevation of 6 feet below sea level and contributed to a localized cone of depression in the water-table surface. Dames and Moore (2001) indicated that the Mingo basin is approximately 25 feet deep, although aerial photography suggests that some siltation and shoaling of the basin have likely occurred in the time since it was originally excavated and/or last dredged. Scheinfeld and Davenger (2006) noted that within the shallow aquifer near the Philadelphia International Airport, groundwater flow was to the north-northwest toward Mingo Creek basin because of dewatering operations conducted by the PWD.

In late 2015, Stantec contacted the PWD to inquire about current ownership and operation of the pump house, known as the Mingo Pumping Station, located near the mouth of former Mingo Creek. The purpose of the inquiry was to evaluate the magnitude of groundwater withdrawal, if applicable, to reasonably simulate steady-state conditions during calibration of the complex-wide numerical model. Per PWD, pumping from the Mingo Creek basin occurs approximately every 1 to 3 days depending on water-level conditions. Large-capacity pumps are programmed to control the basin's water surface elevation between -10.5 and -11 feet NAVD 88. The pumps have the capacity to transfer water from the Mingo Creek basin to the Schuylkill River at up to 53,000 gallons per minute (gpm). PWD has indicated that pumping the basin water level down from elevation -10.5 feet to -11 feet NAVD 88 requires approximately 1 hour of runtime and that the span volume of the basin between those controlled elevations is approximately 3 million gallons of water.

More recently, Langan performed a Pennsylvania One Call to request design information related to construction of the Mingo Creek basin and area sewers. Drawings received indicate that when Mingo Creek basin was constructed, up to three former creeks including Mingo, Church, and Eagle Creeks, were routed into the basin through large concrete box culverts. Additionally, two large area sewers are noted to be present including the Mingo Avenue storm sewer which runs along the western boundary of AOI 9 and discharges to Mingo Creek Basin, and the Schuylkill West Side Interceptor which runs beneath AOI 9 and conveys wastewater to the City of Philadelphia Southwest Water Pollution Control Plant near the Philadelphia International Airport (see **Figure 1**). Based on the invert elevations provided on the plans, both sewers are submerged below present water-table conditions. Sewers, subway tunnels, and other man-made structures in Philadelphia have a documented history of groundwater infiltration (Paulachok, 1991). Perhaps less significant but of additional importance to AOI 9 water levels are river tides, documented by others to impact aquifer water levels proximal to the Delaware and Schuylkill Rivers (Greenman et al., 1961; Paulachok, 1991; Weston, 2004).

In general, monitoring wells screened within the water-table aquifer in AOI 9 indicate that water-table elevations continuously remain several feet below NAVD 88 and are lowest near the Mingo Creek basin where near-continuous dewatering activities are occurring. The information provided above supports the conclusion that water-table conditions within the Plume 2 area of interest to this fate and transport assessment are continuously affected by Mingo Creek basin dewatering activities. It is also apparent that the significant hydraulic control exhibited by Mingo Basin pumping may also influence the flow of water through culverts (and possibly the Mingo Avenue storm sewer) on the west side of AOI 9 that are connected to the basin, which could add to the magnitude of the southwestern hydraulic gradient evaluated in this report.

3.2.2 Water-Level Monitoring

To provide evidence supporting a hydraulic connection between Mingo Creek basin and the unconfined aquifer beneath AOI 9 and to evaluate the presence or absence of a river tide signal, Stantec monitored water levels within monitoring well S-137SRTF and has provided those observations on **Figure 4**. The water level within well S-137SRTF was continuously monitored for a period of approximately 23 hours using a data logger set to record water depth at 1-minute intervals. Water depths were converted to water-level elevations using surveyed top of casing elevation and manual depth to water measurements collected throughout the data acquisition period. Based on the data collected, it is concluded that Schuylkill River tides impact unconfined aquifer water levels at the location of well S-137SRTF (approximately 1,200 feet from the Schuylkill River) and that the tidal amplitude may be approximately 0.15 feet. The tidal signal appears to be in phase with Schuylkill River tides at 30th Street (see upper plot of **Figure 4**). In addition, the water-level data collected appear to have recorded an apparent pumping cycle that may reflect operation of the Mingo Pumping Station, although operational records from the Mingo Pumping Station were unavailable. However, it is reasonable to assume that the anomalously low water-table elevations present throughout much of AOI 9 are the result of pumping from Mingo Creek basin.

3.3 BENZENE SOURCE

To evaluate present concentrations and distribution of dissolved-phase benzene in unconfined aquifer groundwater at Plume 2, Stantec reviewed groundwater sampling data collected by Aquaterra on November 7 through November 9, 2016, and analyzed by Pace Analytical (Pace). Stantec also reviewed plume maps and historical trends presented by Langan (2015) and Langan (2017). The November 2016 sampling data indicates that the highest benzene groundwater concentration in the Plume 2 area was observed at well S-112SRTF at a concentration of 8,440 micrograms per liter (ug/L). This concentration of benzene is the highest ever quantified at well S-112SRTF and as such is utilized as the source concentration in this conservative assessment (see **Table** 1). Assuming a southwestern hydraulic gradient, downgradient well S-113SRTF had a groundwater benzene concentration of 332 ug/L during the same sampling event and is utilized for model calibration. On the up-gradient side, the benzene plume source area is generally delineated by wells S-144SRTF, S-78SRTF, and S-145SRTF supporting a source width of approximately 500 feet. Boring log photoionization detector (PID) readings and observations indicate that the source thickness for the benzene plume in this area is approximately 10 feet. QD assumes that these source dimensions and concentration are constant throughout the analysis period.

To the south and west of well S-112SRTF, elevated benzene was also observed at wells S-114SRTF and S-115SRTF. Recent concentrations of dissolved benzene in groundwater collected from well S-115SRTF have been consistently higher than the concentrations measured in adjacent unconfined aquifer wells to the north within the Plume 2 area (e.g., well S-113SRTF and recently installed well S-145SRTF). This pattern supports that a second benzene source may exist within the overall plume (not originating from transport of a S-112SRTF area continuous source). As such, a second scenario is modeled nearer the western property boundary using well S-115SRTF as a source well with a source concentration of 644 ug/L. Due to the proximity of well S-115SRTF to the property boundary, no downgradient calibration wells are available. As such, a conservative scenario is presented (see **Table 2** and **Appendix D**). Wells S-74D2SRTF and S-79SRTF were not sampled [although benzene was not detected in these wells in 2015 (Langan, 2015)]. Boring log PID readings and observations indicate that a reasonable source thickness for the benzene plume in this area is approximately 15 feet.

It is noted that light non-aqueous phase liquid (LNAPL) was observed at up-gradient well S-122SRTF and side gradient well S-114SRTF during the November 2016 gauging event. Based on fingerprint analysis, Pace indicates that the LNAPL is primarily weathered gasoline with a smaller percentage of diesel or #2 fuel oil (relatively undegraded at well S-114SRTF) (Langan, 2017). The presence of LNAPL at these two locations is indicative of more recent release(s), as LNAPL had not been observed in these wells prior to

May 2016 and October 2016 for wells S-122SRTF and S-114SRTF, respectively. This LNAPL has the potential to influence future dissolved benzene concentrations in the Plume 2 area. However, during the November 2016 gauging event the highest observed dissolved benzene concentrations were not located beneath the observed LNAPL.

3.4 DISPERSIVITIES

Stantec utilized values of 50 feet, 5 feet, and 0.001 feet for the longitudinal, transverse, and vertical components of mechanical dispersion to estimate spreading of dissolved benzene from a well S-112SRTF source through the model calculation domain based on guidance provided by the PADEP (2014). At well S-115SRTF, these values were modeled at 20 feet, 2 feet, and 0.001 feet, respectively (see **Appendix** D). Longitudinal dispersion from a S-112SRTF source was evaluated as a calibration parameter and was co-varied along with the decay constant until a best fit was obtained to the calibration well concentration. Of the values considered, the modeled value is approximately 1/10th the distance to the AOI 9 property boundary along the plume centerline. Lacking calibration well data, the S-115SRTF source analysis utilized a longitudinal dispersivity that represents approximately 1/10th the distance to the property boundary in the direction of groundwater flow.

The small value for vertical dispersivity applied to both models conservatively approximates two-dimensional transport. Transverse dispersivity is estimated at 1/10th the longitudinal value. The longitudinal dispersivities applied to the models estimated at 10% of the plume length generally result in slightly longer steady-state plumes with slightly lower benzene endpoint concentrations (more mixing ahead of the advective front) than those utilizing values estimated by the Xu and Eckstein equation (PADEP, 2014) but are deemed more conservative in evaluating the potentially impacted downgradient properties.

3.5 DECAY CONSTANT

The range of decay constants utilized in this assessment to characterize the biodegradation rate of benzene after leaving the source area were estimated from literature. PADEP estimates this decay rate (degradation coefficient) at 35 percent per year (approximately 0.1 percent per day) in Table 5A of Appendix A of Act 2. The Environmental Protection Agency (EPA) estimates this decay rate at 0.1 to 1 percent per day from field and laboratory studies (EPA, 2002). Stantec used the referenced decay constant range during model calibration and based on evaluation of plume attenuation in the context of field data, utilized a decay constant of 0.5 percent per day in the analysis of dissolved benzene attenuation from the well S-112SRTF source area. At well S-115SRTF, the lack of calibration wells justified the assumptive use of a more conservative transport decay value of 0.1 percent per day (see **Appendix D**) (PADEP, 2014).

3.6 ORGANIC CARBON PARTITION COEFFICIENT

A benzene organic carbon partitioning coefficient of 58 liters per kilogram (L/kg) was utilized per Table 5A in Appendix A of Act 2 (PADEP, 2014).

3.7 QD MODEL CALCULATION DOMAINS

The QD model calculation domains for both scenarios are presented on **Figure 3** and summarized on **Tables 1** and **2**. These areas generally represent the steady-state plume centerline lengths predicted by QD for benzene to attenuate below the PADEP Medium Specific Concentration (MSC) of 5 ug/L for non-residential properties overlying used aquifers with Total Dissolved Solids (TDS) less than or equal to 2,500 ug/L [the Statewide Health Standard (SHS)]. Simulation of the S-112SRTF source area results in an estimated plume that is approximately 900 feet long by 500 feet wide and extends southwest from the source area, across Essington Avenue, and onto an offsite property. Per City of Philadelphia property records, that non-residential property is 7001 Essington Avenue. Simulation of the S-115SRTF source area results in an estimated plume that is approximately 1,750 feet long by 250 feet wide and extends to the southwest, intersecting a portion of up to four non-residential, offsite properties. These properties, with increasing distance from AOI 9, are identified as 7601 Essington Avenue, 7750 Holstein Avenue, 7600 Holstein Avenue, and 7700 Holstein Avenue. As discussed in **Section 4** of this report, model usage of a higher transport decay rate for the S-115SRTF source area (0.5% per day biodegradation rate from the calibrated S-112SRTF source area model) results in a shorter predicted plume attenuation length that indicates a sole potential offsite property impact to 7601 Essington Avenue. Parcel ownership information obtained from the online PWD Stormwater Map Viewer for the identified properties is included in **Appendix E**.

4.0 QD MODEL RESULTS AND RECOMMENDATION

The QD analyses presented in this report indicate that Plume 2 area dissolved benzene, present in shallow groundwater near the western boundary of AOI 9, has the potential to migrate offsite. The maximum plume centerline distances where the concentration of benzene is predicted in these conservative assessments to attenuate below the PADEP SHS are approximately 900 feet and 1,750 feet for sources originating near AOI 9 wells S-112SRTF and S-115SRTF, respectively (see **Figure 3**). Analyses indicate that plumes of the estimated lengths would extend onto adjacent properties and information pertaining to those properties is included in **Appendix E**. These assessments are based on simulation times of approximately 5 to 10 years to "steady-state" conditions and provide "worst-case" scenarios of potential benzene fate-and-transport. For example, in the case of well S-115SRTF source area plume attenuation, it is noted that using the transport decay value from the calibrated S-112SRTF model results in a benzene plume length that is approximately two-thirds shorter. Both potential plume lengths are shown on **Figure 3** for comparative purposes.

In accordance with PADEP comments received (i.e., Comment #10), Stantec recommends a file review of documents pertaining to the Enterprise Leasing Company of Philadelphia (PADEP Facility ID 719112) property located at 7001 Essington Avenue. Evergreen intends to collect additional water-level and dissolved contaminant data in this area to support refinement of the complex-wide numerical model.

5.0 REFERENCES

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TABLES

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT OF PLUME 2 BENZENE USING QUICK DOMENICO

AREA OF INTEREST 9

Philadelphia Refining Complex
3144 Passyunk Ave, Philadelphia, Pennsylvania

Table 1

Summary of Quick Domenico Model Input Parameter Values - S-112SRTF Source Area

Potential Fate-and-Transport of Plume 2 Benzene

Area of Interest (AOI) 9

Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

Model Parameter/ Field Data	**Symbol**	**Model Units**	**Values Considered in Model Sensitivity Analysis and/or Calibration**				**Justification for QD Model Value**	**Data Source or Reference**
			Minimum	**Maximum**	**Model Value**	**Model Parameter Sensitivity**		
Source Concentration	C_o	mg/L	0.023	8.44	8.44	high	Maximum observed benzene concentration at well S-112SRTF in Plume 2 area for November 2016 sampling event; highest concentration observed for the period of record at that well (since 9/2/2009)	Figure 3 Analytical Data
Longitudinal Dispersivity	α_x (Ax)	ft	0	100	50	high	calibration parameter; 1/10th distance from source well to property boundary at Essington Ave.; results in slightly longer plume than Xu and Eckstein equation at modeled plume length; may be more appropriate considering aquifer heterogeneity	PADEP, 2014
Transverse Dispersivity	α_y (Ay)	ft	0	10	5	high	1/10th the longitudinal dispersivity; conservative approach minimizes lateral spreading	PADEP, 2014
Vertical Dispersivity	α_z (Az)	ft	0.001	0.1	0.001	high	conservative approach; approximates 2-dimensional transport; vertical contaminant distribution data in unconfined aquifer insufficient for site-specific calibration	PADEP, 2014
Decay Constant	λ	day^{-1}	0.001	0.01	0.005	high	Calibration parameter along inferred axis of plume; evaluated 0.1-1% per day biodegradation rate; covaried with longitudinal dispersivity to obtain best match to field data and historical data (model validation)	EPA, PADEP Guidance
Source Width	Y	ft	100	500	500	medium	Well analytical data near modeled source area	Figure 3 Analytical Data
Source Thickness	Z	ft	5	30	10	low	Inferred smear zone in Plume 2 area near well S-112SRTF	S-112SRTF, S-113SRTF Well Logs
Time	t	days	100	5000	2000	medium	Time to steady-state	PADEP, 2014
Hydraulic Conductivity	K	ft/day	35	271	195	high	conservative scenario based upon the upper confidence limit (0.01%) for the estimated mean value from slug testing	Appendix B
Hydraulic Gradient	i	ft/ft	0.002	0.01	0.0027	medium	Interpolation of November 2016 water-level elevation data; highest gradient measured along southern edge of S-112SRTF source area	Figure 3
Effective Porosity	n_e	- -	0.225	0.282	0.225	low	Laboratory testing data S-110DSRTF (10-12' bgs)	Appendix C
Bulk Density	ρ_b	g/cm^3	1.76	1.76	1.760	low	Laboratory testing data S-110DSRTF (10-12' bgs)	Appendix C
Organic Carbon Partition Coefficient	K_{oc}	L/kg	- -	- -	58	low	Act 2 Appendix A Table 5	PADEP, 2014
Fraction of Organic Carbon	f_{oc}	- -	0.01	0.03	0.01	low	Laboratory testing data S-110DSRTF (10-12' bgs) and S-118DSRTF (42-44' bgs) indicate relatively high organic carbon contents are present in the water-table aquifer	Appendix C
Point Concentration Location	x_s,y_s,z_s	ft	- -	- -	650, 0, 0	- -	Approximate distance to nearest offsite property boundary	Figure 3, Appendix D
Model Calculation Domain	L,W	ft, ft	- -	- -	900, 250	- -	Steady-state plume length and half-width predicted for attenuation of benzene to a plume centerline concentration below the SHS (5 ug/L)	Figure 3, Appendix D

Notes:

1. in = inches
2. ft = feet
3. cm = centimeter
4. L = liter
5. kg = kilogram
6. g= gram
7. mg = milligram
8. SHS = Statewide Health Standard
9. bgs - feet below ground surface
10. ug/L = micrograms per liter of groundwater; mg/L = milligrams per liter of groundwater
11. PID = photoionization detector

Table 2
Summary of Quick Domenico Model Input Parameter Values - S-115SRTF Source Area
Potential Fate-and-Transport of Plume 2 Benzene
Area of Interest (AOI) 9
Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

Model Parameter/ Field Data	Symbol	Model Units	Values Considered in Model Sensitivity Analysis and/or Calibration				Justification for QD Model Value	Data Source or Reference
			Minimum	Maximum	Model Value	Model Parameter Sensitivity		
Source Concentration	C_o	mg/L	0.023	8.44	0.644	high	Observed benzene concentration at well S-115SRTF in Plume 2 area for November 2016 sampling event; fits the range of recent observations for this well	Figure 3 Analytical Data
Longitudinal Dispersivity	α_x (Ax)	ft	0	50	20	high	1/10th distance from source area well S-115SRTF to adjacent parcel boundary; results in slightly longer plume than Xu and Eckstein equation at modeled plume length; may be more appropriate considering aquifer heterogeneity in the area	PADEP, 2014
Transverse Dispersivity	α_y (Ay)	ft	0	5	2	high	1/10th the longitudinal dispersivity; conservative approach minimizes lateral spreading	PADEP, 2014
Vertical Dispersivity	α_z (Az)	ft	0.001	0.1	0.001	high	conservative approach; approximates 2-dimensional transport; vertical contaminant distribution data in unconfined aquifer insufficient for site-specific calibration	PADEP, 2014
Decay Constant	λ	day^{-1}	0	0.005	0.001	high	Conservative model lacking downgradient calibration wells; assume minimal transport decay; evaluated up to 0.5% per day from calibrated S-112SRTF model assuming subsurface conditions are similar	PADEP, 2014
Source Width	Y	ft	100	250	250	medium	Well analytical data near modeled source area	Figure 3 Analytical Data
Source Thickness	Z	ft	5	30	15	low	Inferred smear zone in Plume 2 area near well S-115SRTF based on 2015 PID observations (S-115DSRTF continuous core)	S-115SRTF, S-115DSRTF Well Logs
Time	t	days	100	5000	3700	medium	Time to steady-state	PADEP, 2014
Hydraulic Conductivity	K	ft/day	35	271	195	high	conservative scenario based upon the upper confidence limit (0.01%) for the estimated mean value from slug testing	Appendix B
Hydraulic Gradient	i	ft/ft	0.003	0.01	0.0027	medium	Interpolation of November 2016 water-level elevation data; highest gradient measured upgradient from and extending to well S-115SRTF	Figure 3
Effective Porosity	n_e	- -	0.225	0.282	0.225	low	Laboratory testing data S-110DSRTF (10-12' bgs) result	Appendix C
Bulk Density	ρ_b	g/cm^3	1.76	1.76	1.760	low	Laboratory testing data S-110DSRTF (10-12' bgs)	Appendix C
Organic Carbon Partition Coefficient	K_{oc}	L/kg	- -	- -	58	low	Act 2 Appendix A Table 5	PADEP, 2014
Fraction of Organic Carbon	f_{oc}	- -	0.01	0.03	0.01	low	Laboratory testing data S-110DSRTF (10-12' bgs) and S-118DSRTF (42-44' bgs) indicate relatively high organic carbon contents are present in the water-table aquifer	Appendix C
Point Concentration Location	x_s,y_s,z_s	ft	- -	- -	200, 0, 0	- -	Approximate distance to nearest offsite property boundary	Figure 3, Appendix D
Model Calculation Domain	L,W	ft, ft	- -	- -	1750, 125	- -	Steady-state plume length and half-width predicted for attenuation of benzene to a plume centerline concentration below the SHS (5 ug/L)	Figure 3, Appendix D

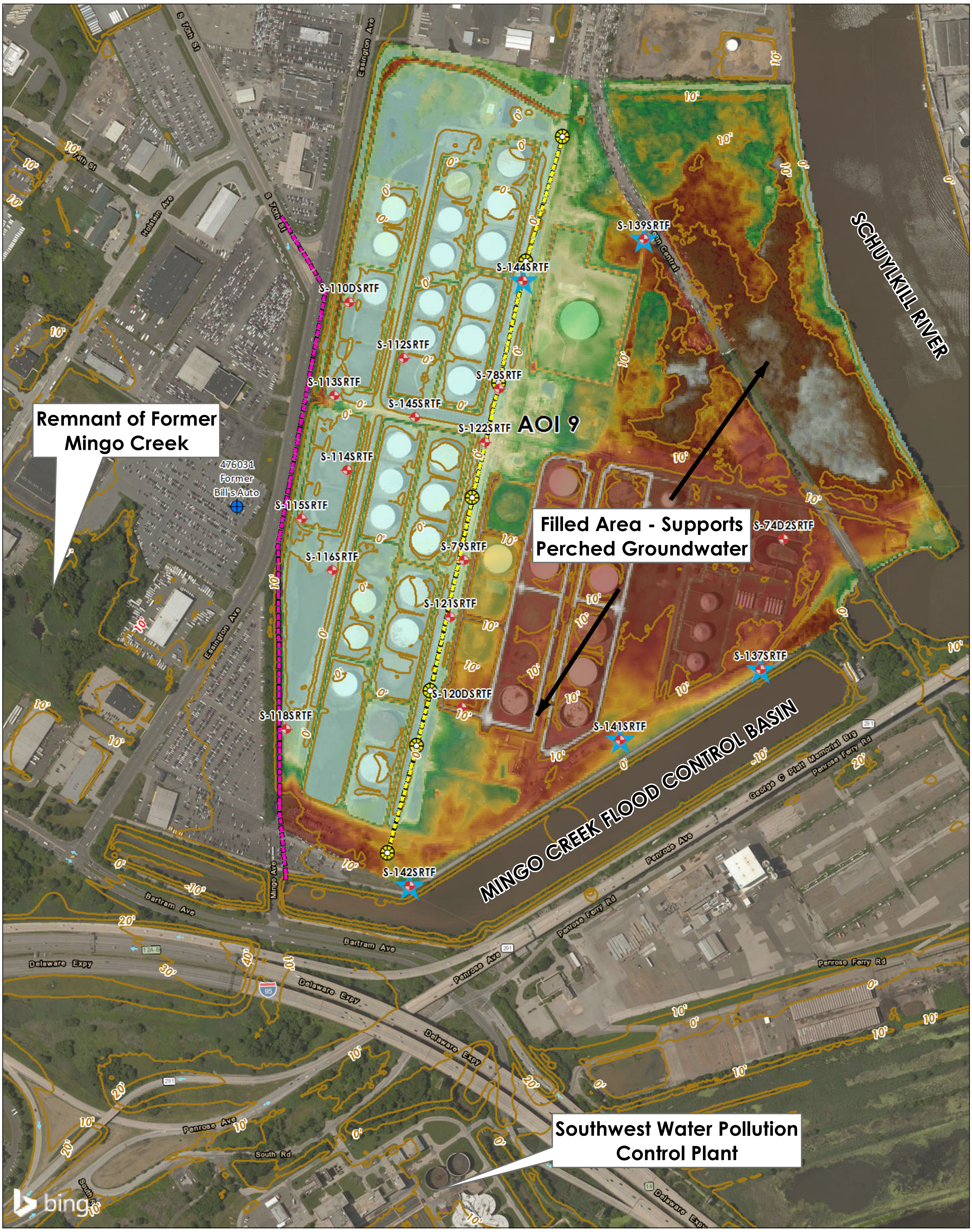
Notes:
1. in = inches
2. ft = feet
3. cm = centimeter
4. L = liter
5. kg = kilogram
6. g= gram
7. mg = milligram
8. SHS = Statewide Health Standard
9. bgs - feet below ground surface
10. ug/L = micrograms per liter of groundwater; mg/L = milligrams per liter of groundwater
11. PID = photoionization detector

FIGURES

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT OF PLUME 2 BENZENE USING QUICK DOMENICO

AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Ave, Philadelphia, Pennsylvania

Stantec



Legend

- ⊕ Monitoring Well (utilized in this assessment)
- ★ Indicates Slug Testing Was Performed
- ⊕ PaGWIS Identified Offsite Monitoring Well

Approximate Sewer Location

- ▪▪▪ Mingo Avenue Sewer
- ▫▫▫ Schuylkill West Side Interceptor
- ⊛ Approximate Sewer Manhole Location
- ▭ Area of Interest 9
- — 2015 Topographic Contour (c.i. 10 feet)

2010 USGS National Elevation Dataset

Value

17.8 feet

0 feet

150 0 150 300 Feet

1:6,000 (At Original document size of 11x17)

N

Notes

1. Vertical Datum: North American Vertical Datum of 1988 (NAVD 88)
2. Coordinate System: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet
3. Source: Stantec
4. Service Layer Credits: Image courtesy of USGS Earthstar Geographics SIO © 2017 Microsoft Corporation
   Copyright:© 2013 National Geographic Society, i-cubed
   Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors
   c.i. = contour interval; contours obtained from the Pennsylvania Spatial Data
5. Access (PASDA)
   PaGWIS = Pennsylvania Groundwater Information System
6.

Project Location
Philadelphia Refining Complex
Schuylkill River Tank Farm

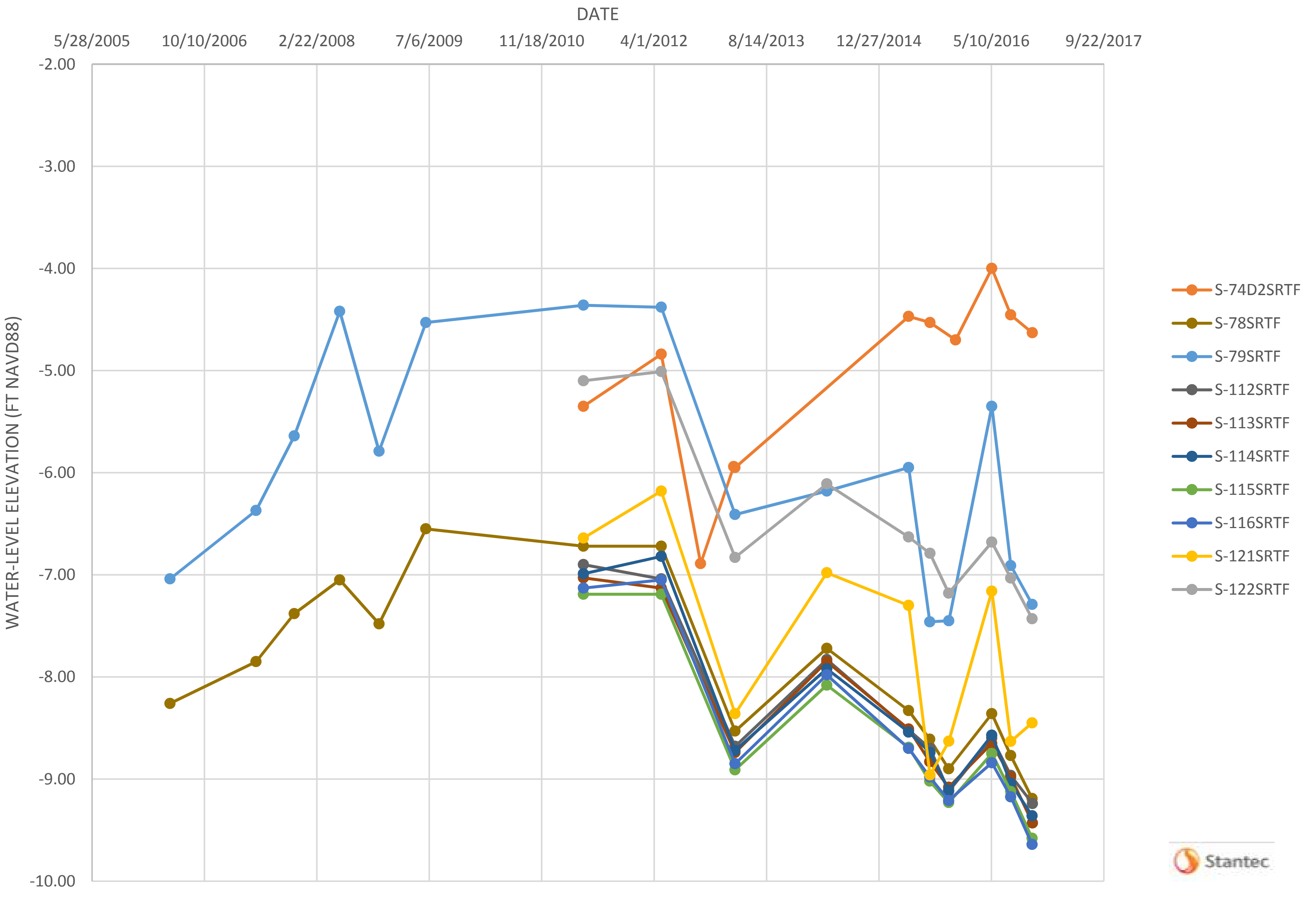
213402599
Prepared by ADK on 10/26/2016
Technical Review by JT on 12/12/2016
Independent Review by MN on 12/12/2016

Client/Project
PHILADELPHIA REFINERY OPERATIONS
A SERIES OF EVERGREEN RESOURCES GROUP, LLC
3144 PASSYUNK AVENUE
PHILADELPHIA, PA 19145

Figure No.
1

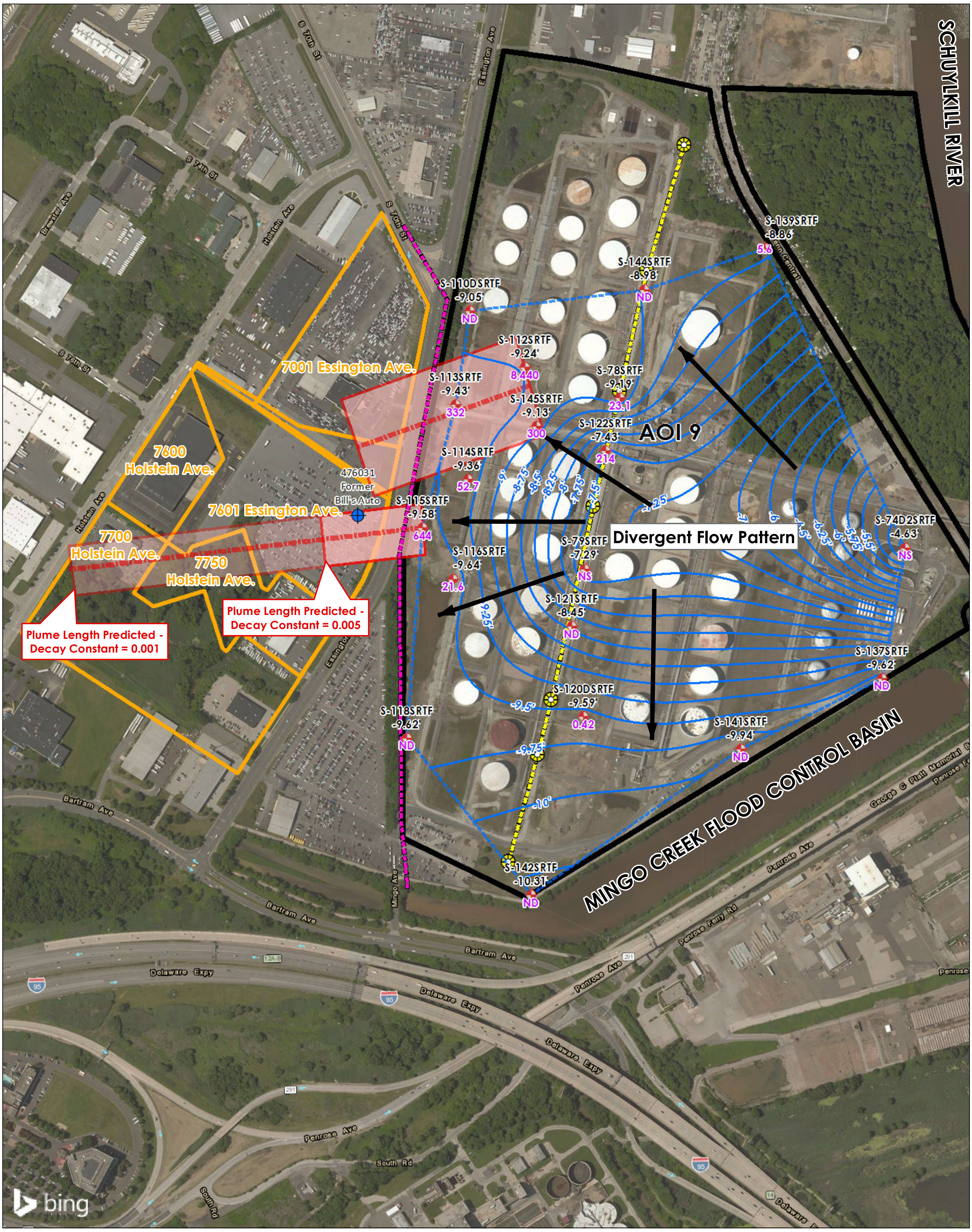
Title
AOI 9 SITE PLAN FOR QD ANALYSES

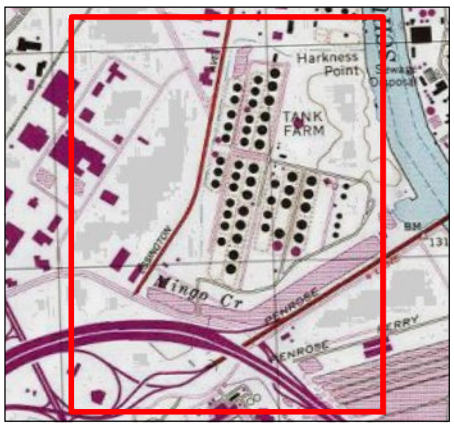
FIGURE 2. SELECT AOI 9 MONITORING WELL HYDROGRAPHS



NOTE:

FT NAVD 88 = FEET NORTH AMERICAN VERTICAL DATUM OF 1988





Notes

1. Vertical Datum: North American Vertical Datum of 1988 (NAVD 88)
2. Coordinate System: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet
3. Source: Stantec
4. Service Layer Credits: Image courtesy of USGS Earthstar Geographics SIO © 2017 Microsoft Corporation
   Copyright:© 2013 National Geographic Society, i-cubed
   Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors
5. c.i. = contour interval; ug/L = micrograms per liter of groundwater
6. ND = analyzed for but not detected; NS = not sampled
7. PaGWIS = Pennsylvania Groundwater Information System
8. City of Philadelphia parcel boundary features obtained from Langan Engineering

* QD model predicted benzene plume attenuation lengths to +/- 5 ug/L

Legend

Monitoring Well

⊕ (labels denote water-table elevation in feet NAVD88)

⊕ PaGWIS Identified Offsite Monitoring Well

Approximate Sewer Location

▪▪▪▪ Mingo Avenue Sewer

▪▪▪▪ Schuylkill West Side Interceptor

⊛ Approximate Sewer Manhole Location

▭ Area of Interest 9

▭ City of Philadelphia Parcel Boundary

Water-Level Elevation (feet NAVD88)

— November 2016 (c.i. = 0.25 feet)

⬚ Limits of Selected Monitoring Well Data

🟥 QD Model Calculation Domain

▬ ▪ ▬ Approximate Benzene Plume Centerline*

8,440 November 2016 Benzene Concentration (ug/L)

150 0 150 300
Feet
1:6,000 (At Original document size of 11x17)

N

Project Location
Philadelphia Refining Complex
Schuylkill River Tank Farm

213402599
Prepared by ADK on 10/26/2016
Technical Review by JT on 12/12/2016
Independent Review by MN on 12/12/2016

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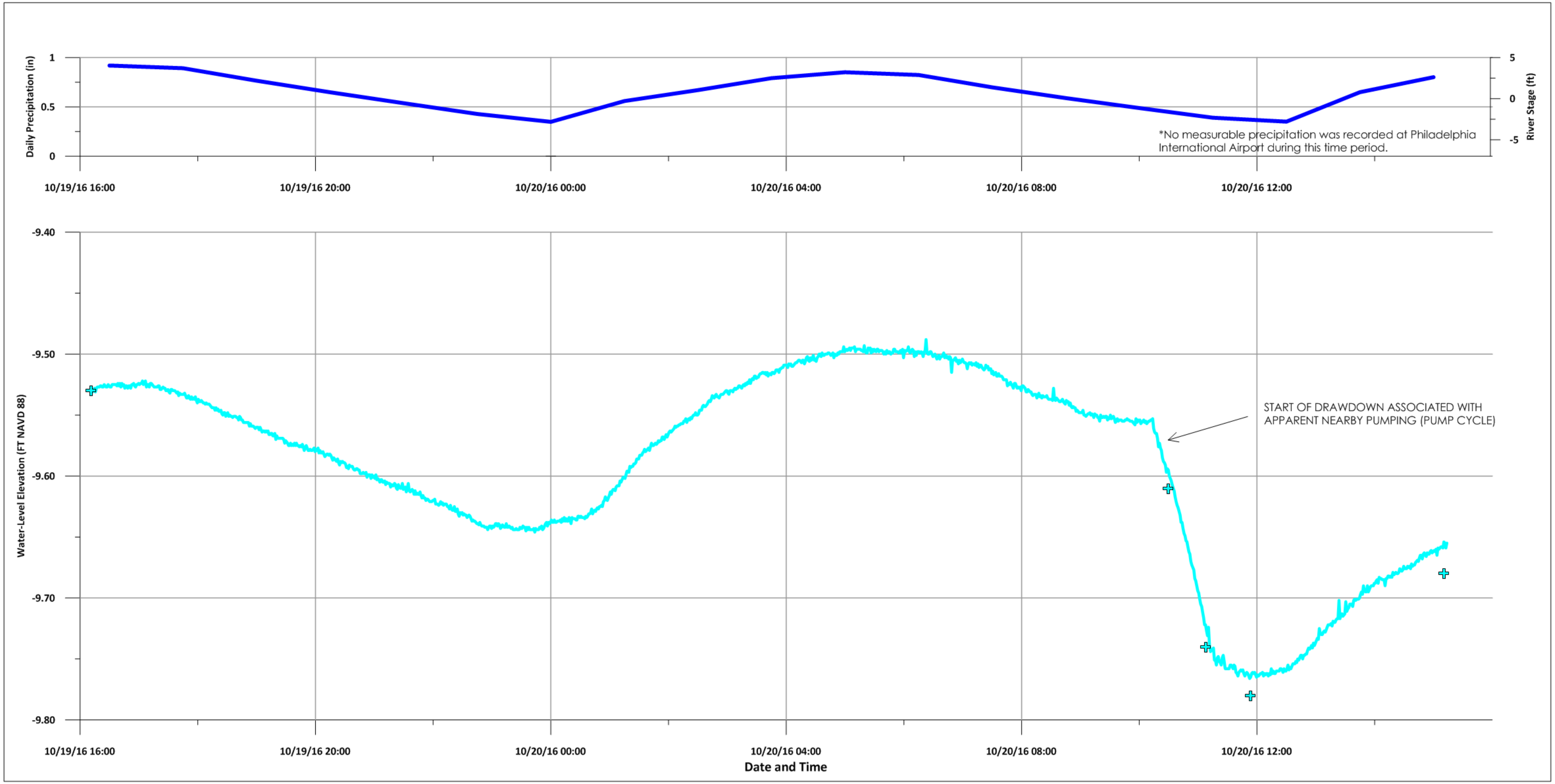
PHILADELPHIA, PA 19145

Figure No.
3

Title
QD MODEL CALCULATION DOMAINS



Legend (Upper Plot)

- River Stage - Schuylkill River (near 30th St)
- 🟥 PHL Total Daily Precipitation (in)

Legend (Lower Plot)

- S-137SRTF Water-Level Elevation
- ✚ S-137SRTF Gauging Data

Notes

1. S-137SRTF water levels were continuously recorded using a vented data logger set to record water depth at one minute intervals. Water depths were converted to water-level elevations using surveyed top of well casing elevations and were verified using manual water-level measurements.
2. River stage data obtained from the United States Geological Survey for Gage Station 01474501.
3. Precipitation data obtained from the NOAA National Climate Data Center (NCDC) for Philadelphia International Airport (PHL). No measurable precipitation was recorded for the groundwater monitoring period.
4. Aerial photograph obtained from the Pennsylvania Spatial Data Access (PASDA) internet mapping service.
5. FT NAVD 88 = feet referenced to the North American Vertical Datum of 1988
6. in = inches; ft = feet

Stantec

Project Location
Philadelphia Refining Complex
Schuylkill River Tank Farm

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PHILADELPHIA, PA 19145

Figure No.
4

Title
WATER-LEVEL MONITORING DATA, S-137SRTF

APPENDIX A
Monitoring Well Gauging Data For Select AOI 9 Wells

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT
OF PLUME 2 BENZENE USING QUICK DOMENICO
AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Ave, Philadelphia, Pennsylvania

APPENDIX A. MONITORING WELL GUAGING DATA FOR SELECT WELLS
AREA OF INTEREST (AOI) 9
PHILADELPHIA REFINERY OPERATIONS, A SERIES OF EVERGREEN RESOURCES GROUP, LLC

Well ID	Event Name	Measurement Date	Depth to Water (ft btoc)[2]	Depth to LNAPL (ft btoc)[2]	Product Thickness (ft)[2]	Corrected Water-Level Elevation[1]	Top of Casing Elevation[1]	LNAPL Reference Well ID	LNAPL Density
S-110DSRTF	2016Q4_PHL_AOI9_GAUGE	11/9/2016	11.72			-9.05	2.67		
S-112SRTF	2011 Annual Gauging Data	5/23/2011	8.41			-6.90	1.52		
S-112SRTF	2012 Annual Gauging Data (May)	5/3/2012	8.55			-7.04	1.52		
S-112SRTF	2013 PHL Annual Gauging	3/27/2013	10.19			-8.68	1.52		
S-112SRTF	2014 Annual Groundwater Gauging	5/9/2014	9.34			-7.83	1.52		
S-112SRTF	Annual Groundwater Gauging	5/8/2015	10.03			-8.52	1.52		
S-112SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/11/2015	10.21			-8.70	1.52		
S-112SRTF	2015-11 PHL AOI9 GAUGING	11/2/2015	10.63			-9.12	1.52		
S-112SRTF	2016 Annual Gauging	5/12/2016	10.11			-8.60	1.52		
S-112SRTF	NA	8/4/2016	10.48			-8.97	1.52		
S-112SRTF	2016Q4_PHL_AOI9_GAUGE	11/9/2016	10.75			-9.24	1.52		
S-113SRTF	2011 Annual Gauging Data	5/23/2011	10.05			-7.03	3.02		
S-113SRTF	2012 Annual Gauging Data (May)	5/3/2012	10.15			-7.13	3.02		
S-113SRTF	2013 PHL Annual Gauging	3/27/2013	11.76			-8.74	3.02		
S-113SRTF	2014 Annual Groundwater Gauging	5/9/2014	10.87			-7.85	3.02		
S-113SRTF	Annual Groundwater Gauging	5/8/2015	11.53			-8.51	3.02		
S-113SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/10/2015	11.85			-8.83	3.02		
S-113SRTF	2015-11 PHL AOI9 GAUGING	11/2/2015	12.10			-9.08	3.02		
S-113SRTF	2016 Annual Gauging	5/12/2016	11.67			-8.65	3.02		
S-113SRTF	NA	8/4/2016	12.00			-8.98	3.02		
S-113SRTF	2016Q4_PHL_AOI9_GAUGE	11/9/2016	12.45			-9.43	3.02		
S-114SRTF	2011 Annual Gauging Data	5/23/2011	9.15			-6.99	2.16		
S-114SRTF	2012 Annual Gauging Data (May)	5/3/2012	8.98			-6.82	2.16		
S-114SRTF	2013 PHL Annual Gauging	3/27/2013	10.88			-8.72	2.16		
S-114SRTF	2014 Annual Groundwater Gauging	5/9/2014	10.08			-7.92	2.16		
S-114SRTF	Annual Groundwater Gauging	5/8/2015	10.70			-8.54	2.16		
S-114SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/11/2015	10.90			-8.74	2.16		
S-114SRTF	2015-11 PHL AOI9 GAUGING	11/2/2015	11.27			-9.11	2.16		
S-114SRTF	2016 Annual Gauging	5/12/2016	10.73			-8.57	2.16		
S-114SRTF	NA	8/4/2016	11.20			-9.04	2.16		
S-114SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	11.60	11.51	0.09	-9.36	2.16	S-114SRTF	0.822
S-115SRTF	2011 Annual Gauging Data	5/23/2011	9.94			-7.19	2.75		
S-115SRTF	2012 Annual Gauging Data (May)	5/3/2012	9.94			-7.19	2.75		
S-115SRTF	2013 PHL Annual Gauging	3/27/2013	11.66			-8.91	2.75		
S-115SRTF	2014 Annual Groundwater Gauging	5/9/2014	10.83			-8.08	2.75		
S-115SRTF	Annual Groundwater Gauging	5/8/2015	11.44			-8.69	2.75		
S-115SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/10/2015	11.77			-9.02	2.75		
S-115SRTF	2015-11 PHL AOI9 GAUGING	11/2/2015	11.98			-9.23	2.75		
S-115SRTF	2016 Annual Gauging	5/12/2016	11.50			-8.75	2.75		
S-115SRTF	NA	8/4/2016	11.87			-9.12	2.75		
S-115SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	12.33			-9.58	2.75		
S-116SRTF	2011 Annual Gauging Data	5/23/2011	8.00			-7.13	0.87		
S-116SRTF	2012 Annual Gauging Data (May)	5/3/2012	7.92			-7.05	0.87		
S-116SRTF	2013 PHL Annual Gauging	3/27/2013	9.72			-8.85	0.87		
S-116SRTF	2014 Annual Groundwater Gauging	5/9/2014	8.85			-7.98	0.87		
S-116SRTF	Annual Groundwater Gauging	5/8/2015	9.57			-8.70	0.87		
S-116SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/10/2015	9.85			-8.98	0.87		
S-116SRTF	2015-11 PHL AOI9 GAUGING	11/2/2015	10.08			-9.21	0.87		
S-116SRTF	2016 Annual Gauging	5/12/2016	9.71			-8.84	0.87		
S-116SRTF	NA	8/4/2016	10.04			-9.17	0.87		
S-116SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	10.51			-9.64	0.87		
S-118SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	13.26			-9.62	3.63		
S-120DSRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	21.96			-9.59	12.37		
S-121SRTF	2011 Annual Gauging Data	5/23/2011	7.65			-6.64	1.01		

APPENDIX A. MONITORING WELL GUAGING DATA FOR SELECT WELLS
AREA OF INTEREST (AOI) 9
PHILADELPHIA REFINERY OPERATIONS, A SERIES OF EVERGREEN RESOURCES GROUP, LLC

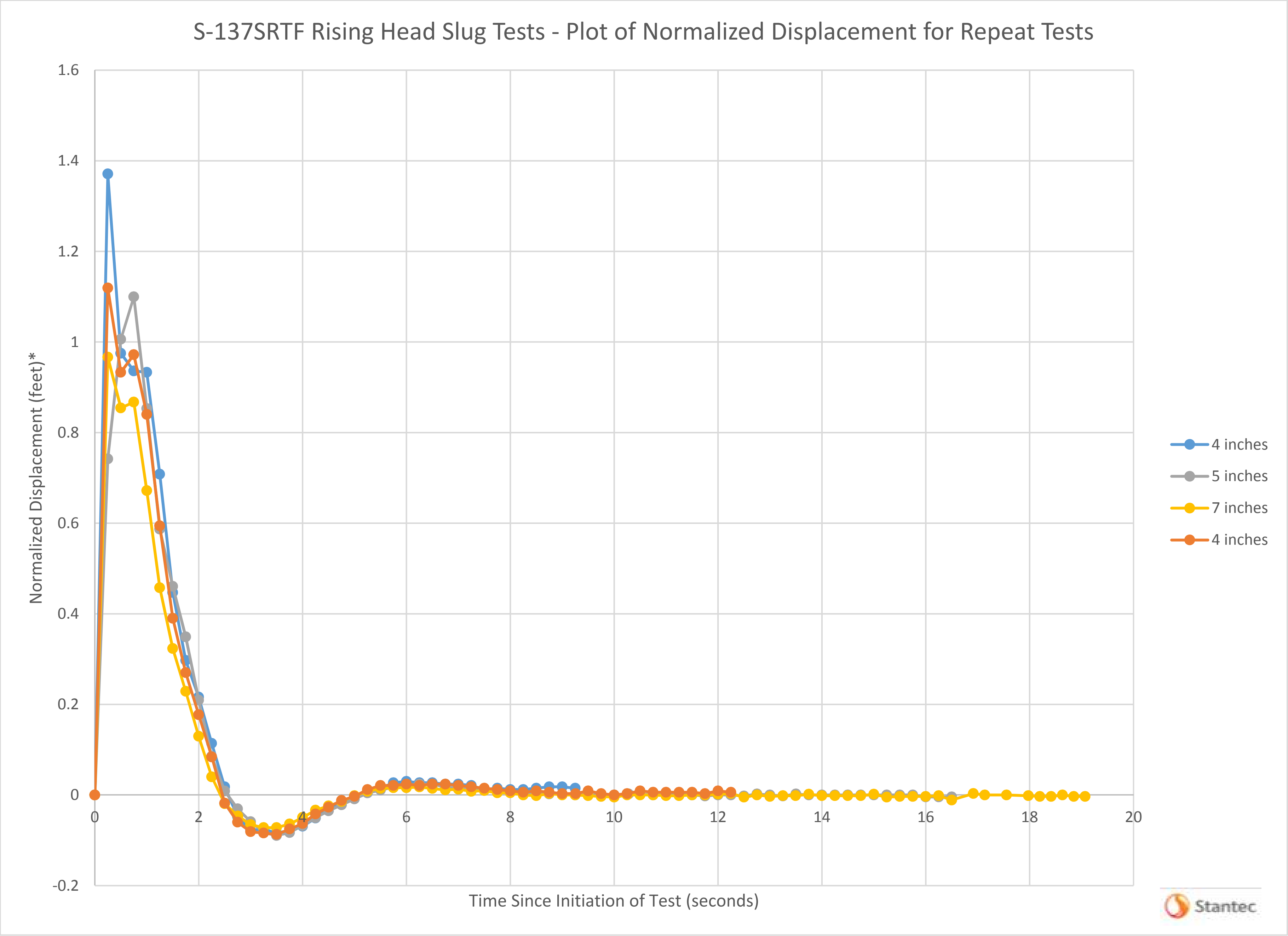
Well ID	Event Name	Measurement Date	Depth to Water (ft btoc)[2]	Depth to LNAPL (ft btoc)[2]	Product Thickness (ft)[2]	Corrected Water-Level Elevation[1]	Top of Casing Elevation[1]	LNAPL Reference Well ID	LNAPL Density
S-121SRTF	2012 Annual Gauging Data (May)	5/3/2012	7.19			-6.18	1.01		
S-121SRTF	2013 PHL Annual Gauging	3/27/2013	9.37			-8.36	1.01		
S-121SRTF	2014 Annual Groundwater Gauging	5/9/2014	7.99			-6.98	1.01		
S-121SRTF	Annual Groundwater Gauging	5/8/2015	8.31			-7.30	1.01		
S-121SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/11/2015	9.97			-8.96	1.01		
S-121SRTF	2015-11 PHL AOI9 GAUGING	11/3/2015	9.64			-8.63	1.01		
S-121SRTF	2016 Annual Gauging	5/12/2016	8.17			-7.16	1.01		
S-121SRTF	NA	8/4/2016	9.64			-8.63	1.01		
S-121SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	9.46			-8.45	1.01		
S-122SRTF	2011 Annual Gauging Data	5/23/2011	7.52			-5.10	2.42		
S-122SRTF	2012 Annual Gauging Data (May)	5/3/2012	7.43			-5.01	2.42		
S-122SRTF	2013 PHL Annual Gauging	3/27/2013	9.25			-6.83	2.42		
S-122SRTF	2014 Annual Groundwater Gauging	5/9/2014	8.53			-6.11	2.42		
S-122SRTF	Annual Groundwater Gauging	5/8/2015	9.05			-6.63	2.42		
S-122SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/11/2015	9.21			-6.79	2.42		
S-122SRTF	2015-11 PHL AOI9 GAUGING	11/2/2015	9.60			-7.18	2.42		
S-122SRTF	2016 Annual Gauging	5/12/2016	9.11	9.10	0.01	-6.68	2.42	S-122SRTF	0.825
S-122SRTF	NA	8/4/2016	9.46	9.45	0.01	-7.03	2.42	S-122SRTF	0.825
S-122SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	10.31	9.76	0.55	-7.43	2.42	S-122SRTF	0.825
S-137SRTF	2016Q4_PHL_AOI9_GAUGE	11/8/2016	19.58			-9.62	9.96		
S-139SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	18.91			-8.86	10.05		
S-141SRTF	2016Q4_PHL_AOI9_GAUGE	11/8/2016	20.40			-9.94	10.46		
S-142SRTF	2016Q4_PHL_AOI9_GAUGE	11/8/2016	17.25			-10.31	6.94		
S-144SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	9.50			-8.98	0.52		
S-145SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	10.35			-9.13	1.22		
S-74D2SRTF	2011 Annual Gauging Data	5/23/2011	18.63			-5.35	13.09		
S-74D2SRTF	2012 Annual Gauging Data (May)	5/3/2012	18.12			-4.84	13.09		
S-74D2SRTF	NA	10/25/2012	20.18			-6.89	13.09		
S-74D2SRTF	NA	3/21/2013	19.22			-5.94	13.09		
S-74D2SRTF	2013 PHL Annual Gauging	3/27/2013	19.23			-5.95	13.09		
S-74D2SRTF	Annual Groundwater Gauging	5/8/2015	17.55			-4.47	13.09		
S-74D2SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/11/2015	17.61			-4.53	13.09		
S-74D2SRTF	2015-12_PHL_AOI9_GW RESAMPLE	12/3/2015	17.78			-4.70	13.09		
S-74D2SRTF	2016 Annual Gauging	5/12/2016	17.08			-4.00	13.09		
S-74D2SRTF	NA	8/4/2016	17.54			-4.46	13.09		
S-74D2SRTF	2016Q4_PHL_AOI9_GAUGE	11/8/2016	17.72			-4.63	13.09		
S-78SRTF	NA	5/10/2006	9.76			-8.26	1.50		
S-78SRTF	NA	5/28/2007	9.35			-7.85	1.50		
S-78SRTF	NA	11/14/2007	8.88			-7.38	1.50		
S-78SRTF	NA	6/3/2008	8.55			-7.05	1.50		
S-78SRTF	NA	11/25/2008	8.98			-7.48	1.50		
S-78SRTF	2009 Q2	6/21/2009	8.05			-6.55	1.50		
S-78SRTF	2011 Annual Gauging Data	5/23/2011	8.22			-6.72	1.50		
S-78SRTF	2012 Annual Gauging Data (May)	5/3/2012	8.22			-6.72	1.50		
S-78SRTF	2013 PHL Annual Gauging	3/27/2013	10.03			-8.53	1.50		
S-78SRTF	2014 Annual Groundwater Gauging	5/9/2014	9.22			-7.72	1.50		
S-78SRTF	Annual Groundwater Gauging	5/8/2015	9.83			-8.33	1.50		
S-78SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/10/2015	10.11			-8.61	1.50		
S-78SRTF	2015-11 PHL AOI9 GAUGING	11/2/2015	10.40			-8.90	1.50		
S-78SRTF	2016 Annual Gauging	5/12/2016	9.86			-8.36	1.50		
S-78SRTF	NA	8/4/2016	10.27			-8.77	1.50		
S-78SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	10.69			-9.19	1.50		
S-79SRTF	NA	5/10/2006	8.88			-7.04	1.84		
S-79SRTF	NA	5/28/2007	8.21			-6.37	1.84		

APPENDIX A. MONITORING WELL GUAGING DATA FOR SELECT WELLS
AREA OF INTEREST (AOI) 9
PHILADELPHIA REFINERY OPERATIONS, A SERIES OF EVERGREEN RESOURCES GROUP, LLC

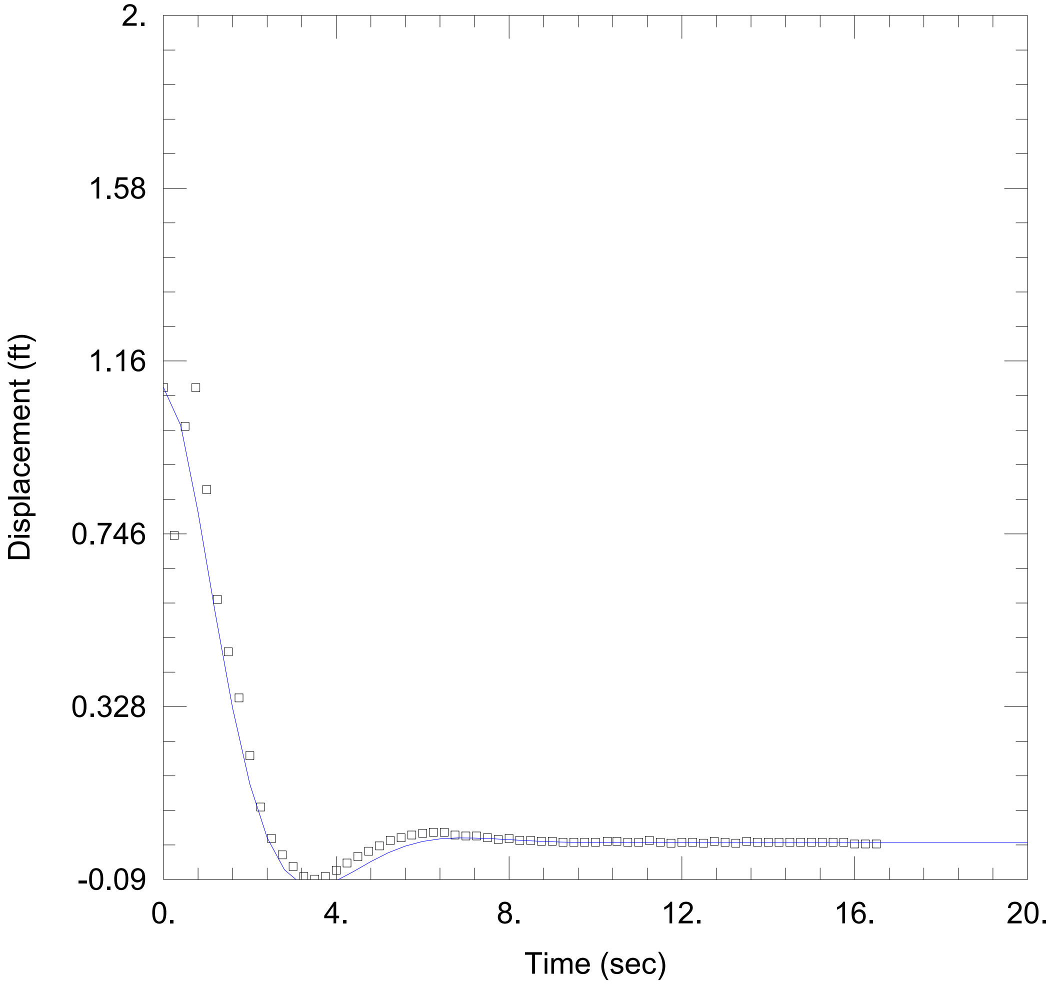
Well ID	**Event Name**	**Measurement Date**	**Depth to Water (ft btoc)^{2}**	**Depth to LNAPL (ft btoc)^{2}**	**Product Thickness (ft)^{2}**	**Corrected Water-Level Elevation^{1}**	**Top of Casing Elevation^{1}**	**LNAPL Reference Well ID**	**LNAPL Density**
S-79SRTF	NA	11/14/2007	7.48			-5.64	1.84		
S-79SRTF	NA	6/3/2008	6.26			-4.42	1.84		
S-79SRTF	NA	11/25/2008	7.63			-5.79	1.84		
S-79SRTF	2009 Q2	6/21/2009	6.37			-4.53	1.84		
S-79SRTF	2011 Annual Gauging Data	5/23/2011	6.20			-4.36	1.84		
S-79SRTF	2012 Annual Gauging Data (May)	5/3/2012	6.22			-4.38	1.84		
S-79SRTF	2013 PHL Annual Gauging	3/27/2013	8.25			-6.41	1.84		
S-79SRTF	2014 Annual Groundwater Gauging	5/9/2014	8.02			-6.18	1.84		
S-79SRTF	Annual Groundwater Gauging	5/8/2015	7.79			-5.95	1.84		
S-79SRTF	2015-08 PHL AOI9 GW Gauging Sampling	8/10/2015	9.30			-7.46	1.84		
S-79SRTF	2015-11 PHL AOI9 GAUGING	11/3/2015	9.29			-7.45	1.84		
S-79SRTF	2016 Annual Gauging	5/12/2016	7.19			-5.35	1.84		
S-79SRTF	NA	8/4/2016	8.75			-6.91	1.84		
S-79SRTF	2016Q4_PHL_AOI9_GAUGE	11/7/2016	9.13			-7.29	1.84		
NOTES:									
1. Elevations are in feet referenced to the North American Vertical Datum of 1988									
2. ft = feet; btoc = below top of casing									

APPENDIX B
Slug Test Analysis Plots

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT
OF PLUME 2 BENZENE USING QUICK DOMENICO
AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Ave, Philadelphia, Pennsylvania



*Water-level displacement data was normalized by dividing the observed displacement data by the expected initial displacement, indicated in the plot legend (in inches of water).



WELL TEST ANALYSIS

Data Set: V:\...\s137srtf_analysis_unconfined_springer.aqt
Date: 11/04/16 Time: 15:41:24

PROJECT INFORMATION

Company: Stantec Consulting
Client: Evergreen Resources Management
Project: 213402599
Location: Philadelphia Refinery AOI 9
Test Well: S-137SRTF
Test Date: 10/20/16

AQUIFER DATA

Saturated Thickness: 20.49 ft Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (S-137SRTF)

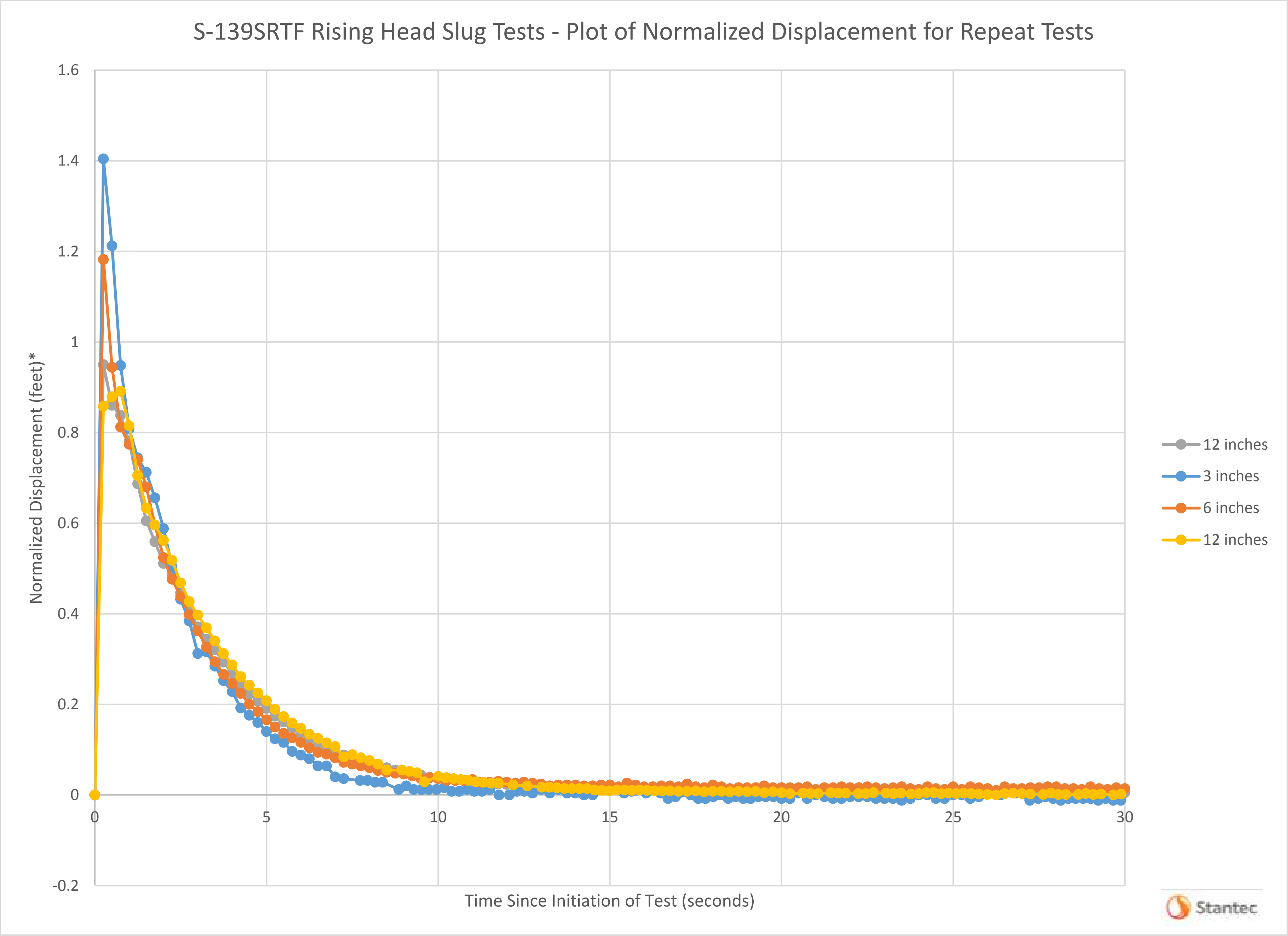
Initial Displacement: 1.1 ft
Total Well Penetration Depth: 20.49 ft
Casing Radius: 0.1678 ft

Static Water Column Height: 20.49 ft
Screen Length: 15. ft
Well Radius: 0.1678 ft
Gravel Pack Porosity: 0.

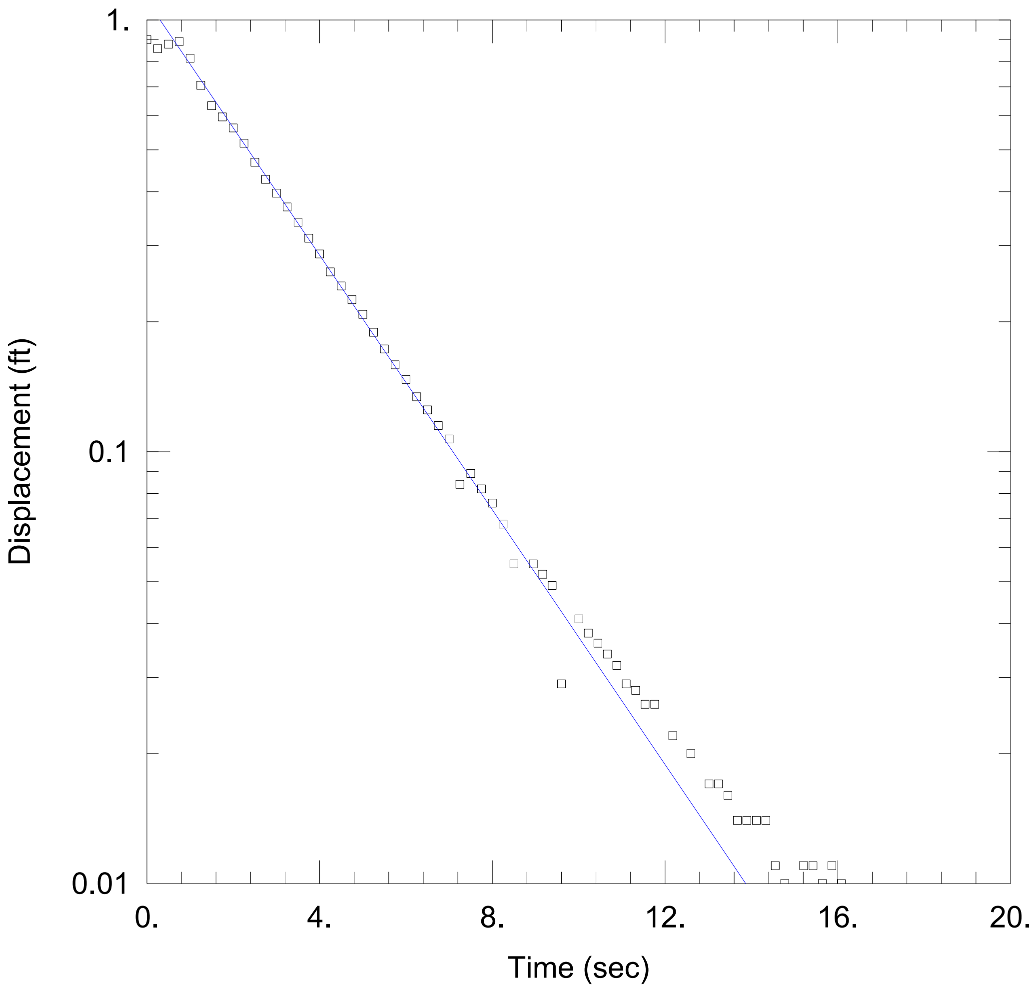
SOLUTION

Aquifer Model: Unconfined Solution Method: Springer-Gelhar

K = 271.3 ft/day Le = 25.45 ft



*Water-level displacement data was normalized by dividing the observed displacement data by the expected initial displacement, indicated in the plot legend (in inches of water).



WELL TEST ANALYSIS

Data Set: V:\...\s139srtf_analysis_unconfined_hvorslev.aqt
Date: 12/12/16 Time: 16:24:20

PROJECT INFORMATION

Company: Stantec Consulting
Client: Evergreen Resources Management
Project: 213402599
Location: Philadelphia Refinery AOI 9
Test Well: S-139SRTF
Test Date: 10/20/16

AQUIFER DATA

Saturated Thickness: 20. ft
Anisotropy Ratio (Kz/Kr): 1.

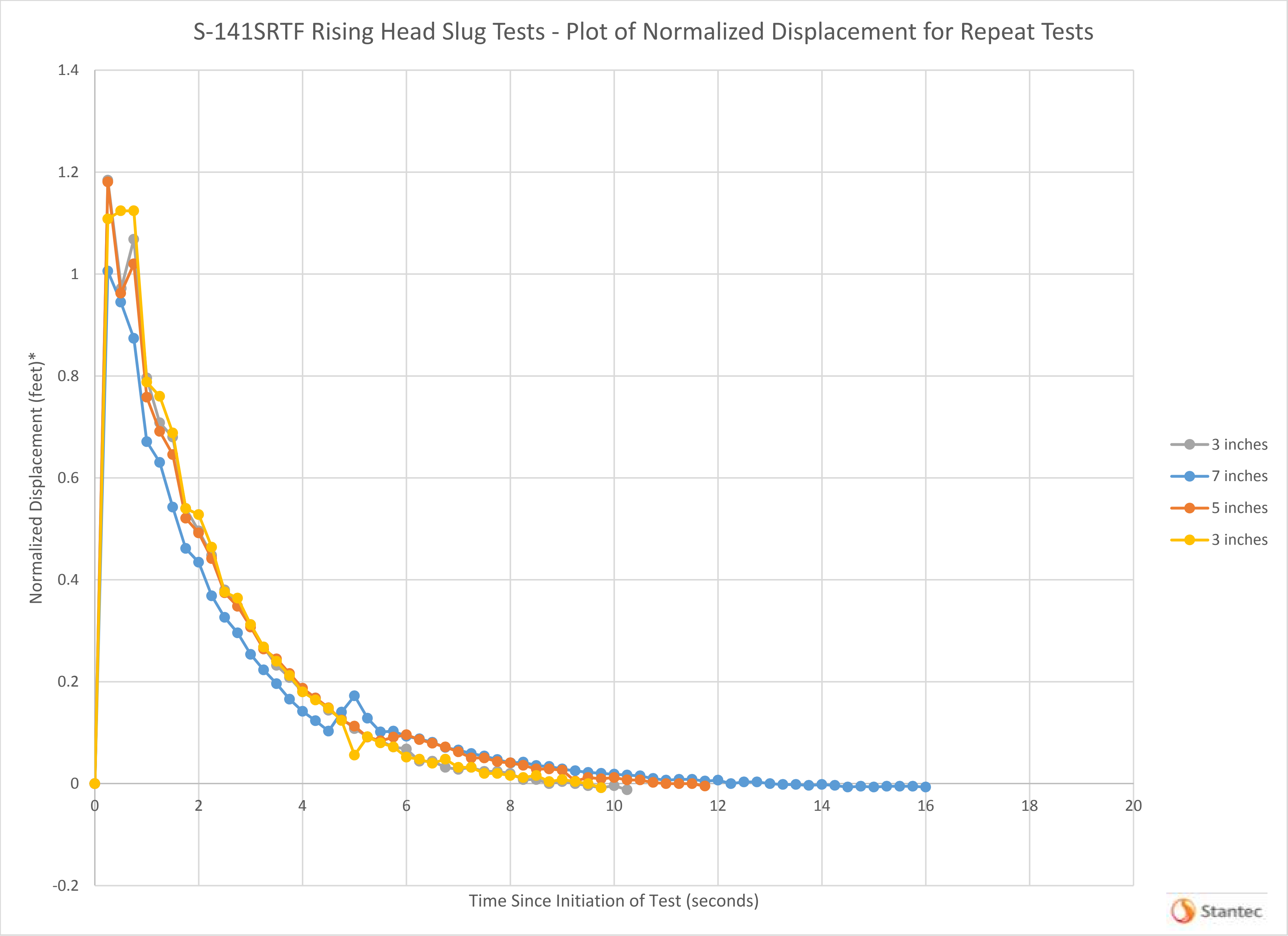
WELL DATA (S-139SRTF)

Initial Displacement: 0.9 ft
Total Well Penetration Depth: 20. ft
Casing Radius: 0.1678 ft
Static Water Column Height: 20. ft
Screen Length: 15. ft
Well Radius: 0.1678 ft
Gravel Pack Porosity: 0.

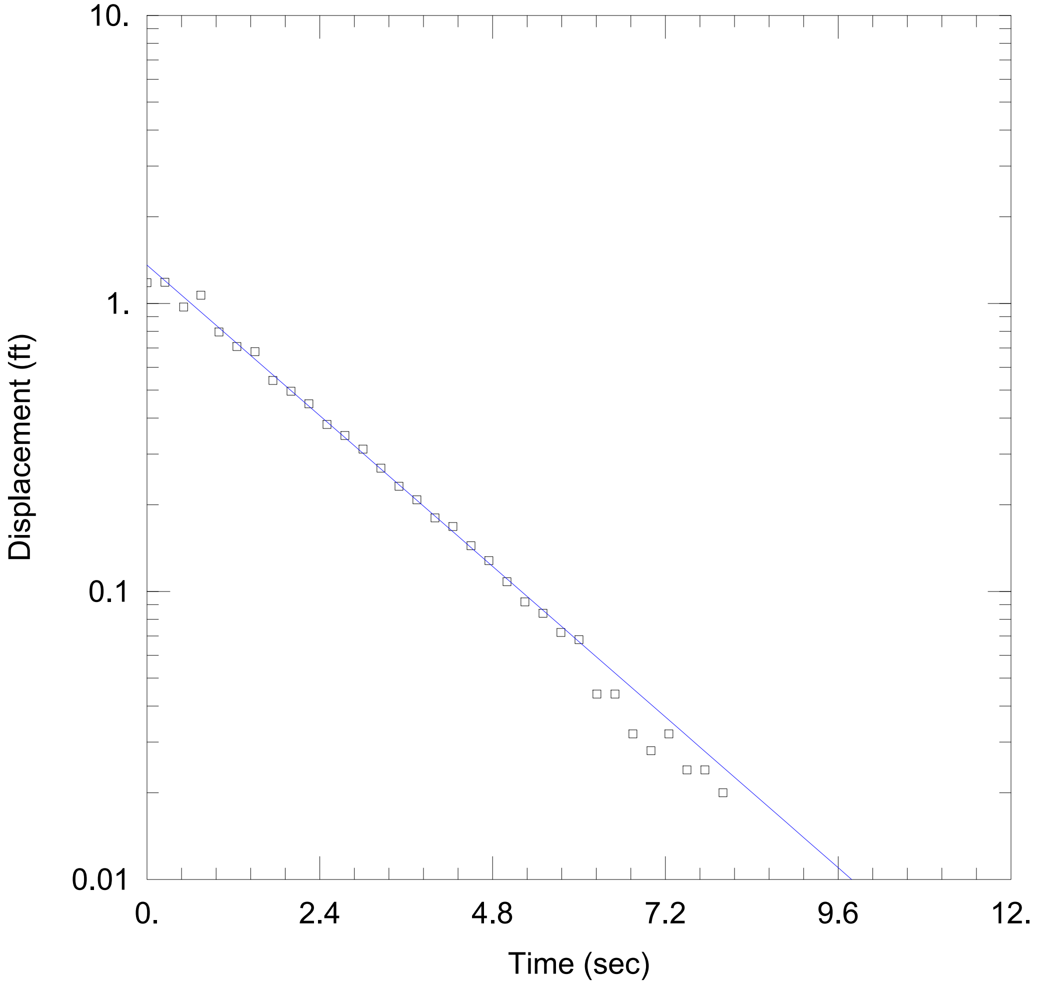
SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 124.6 ft/day
y0 = 1.109 ft



*Water-level displacement data was normalized by dividing the observed displacement data by the expected initial displacement, indicated in the plot legend (in inches of water).



WELL TEST ANALYSIS

Data Set: V:\...\s141srtf_analysis_unconfined_hvorslev.aqt
Date: 12/12/16 Time: 17:01:28

PROJECT INFORMATION

Company: Stantec Consulting
Client: Evergreen Resources Management
Project: 213402599
Location: Philadelphia Refinery AOI 9
Test Well: S-141SRTF
Test Date: 10/20/16

AQUIFER DATA

Saturated Thickness: 20.44 ft
Anisotropy Ratio (Kz/Kr): 0.9999

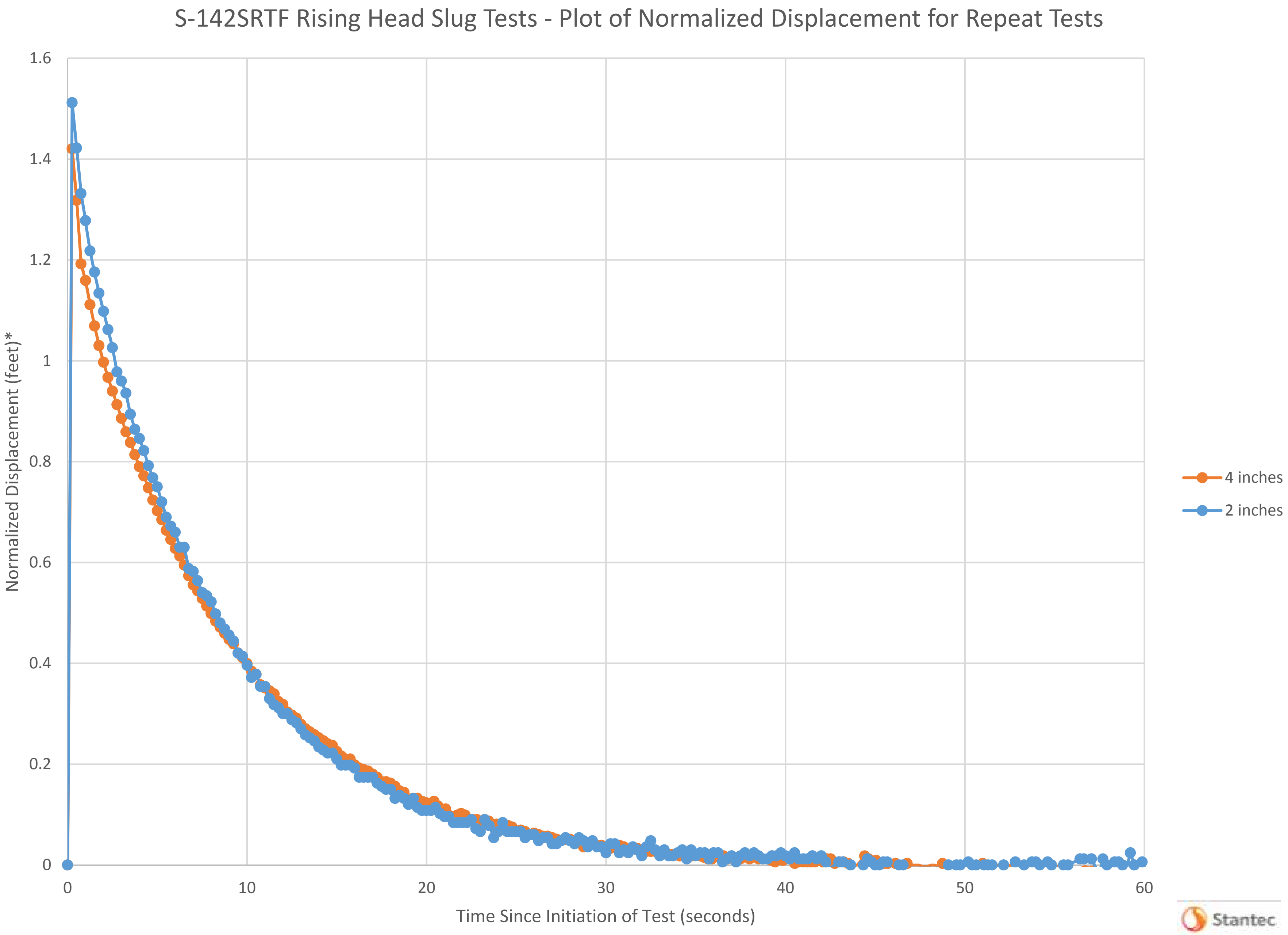
WELL DATA (S-141SRTF)

Initial Displacement: 1.18 ft
Total Well Penetration Depth: 19.44 ft
Casing Radius: 0.1678 ft
Static Water Column Height: 19.44 ft
Screen Length: 15. ft
Well Radius: 0.1678 ft
Gravel Pack Porosity: 0.

SOLUTION

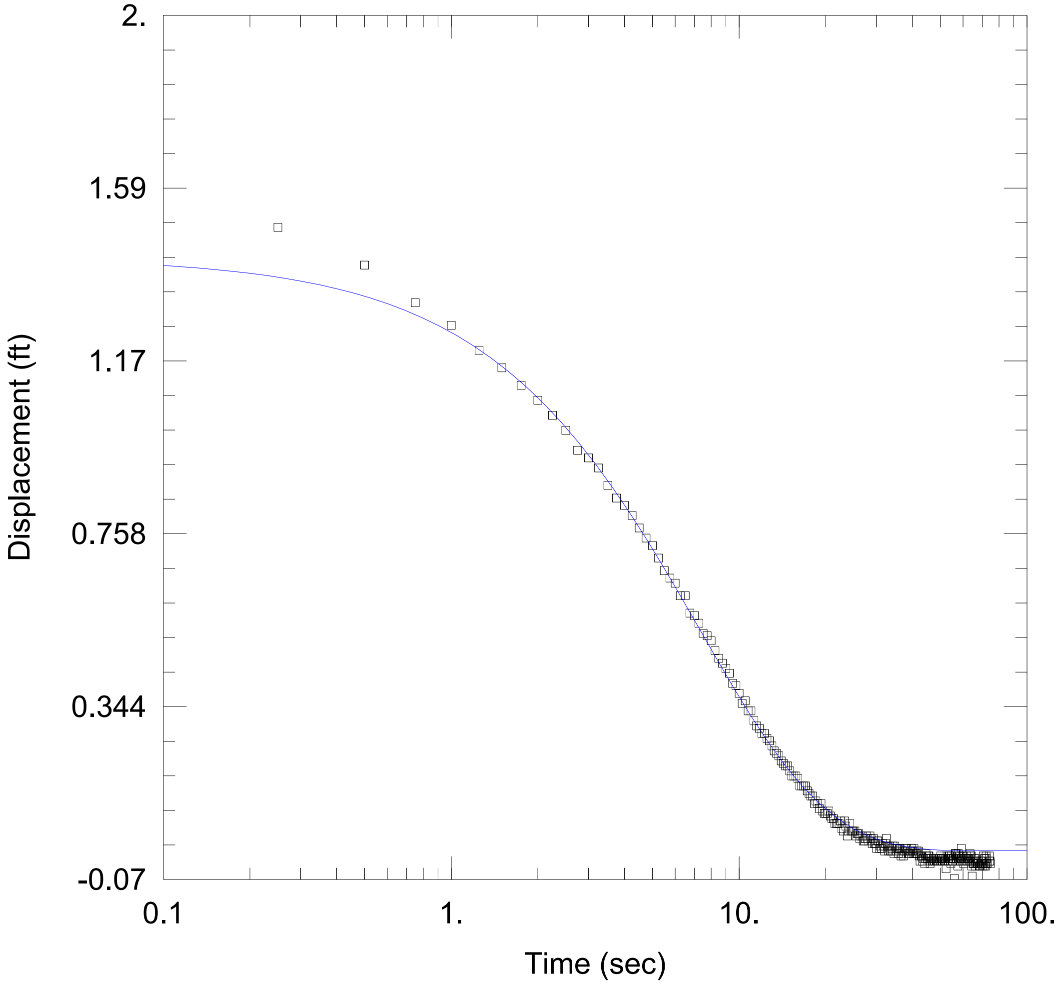
Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 130.2 ft/day
y0 = 1.359 ft



Stantec

*Water-level displacement data was normalized by dividing the observed displacement data by the expected initial displacement, indicated in the plot legend (in inches of water).



WELL TEST ANALYSIS

Data Set: V:\...\s142srtf_analysis_unconfined_kgsmodel.aqt
Date: 11/04/16 Time: 16:42:14

PROJECT INFORMATION

Company: Stantec Consulting
Client: Evergreen Resources Management
Project: 213402599
Location: Philadelphia Refinery AOI 9
Test Well: S-142SRTF
Test Date: 10/20/16

AQUIFER DATA

Saturated Thickness: 31.61 ft

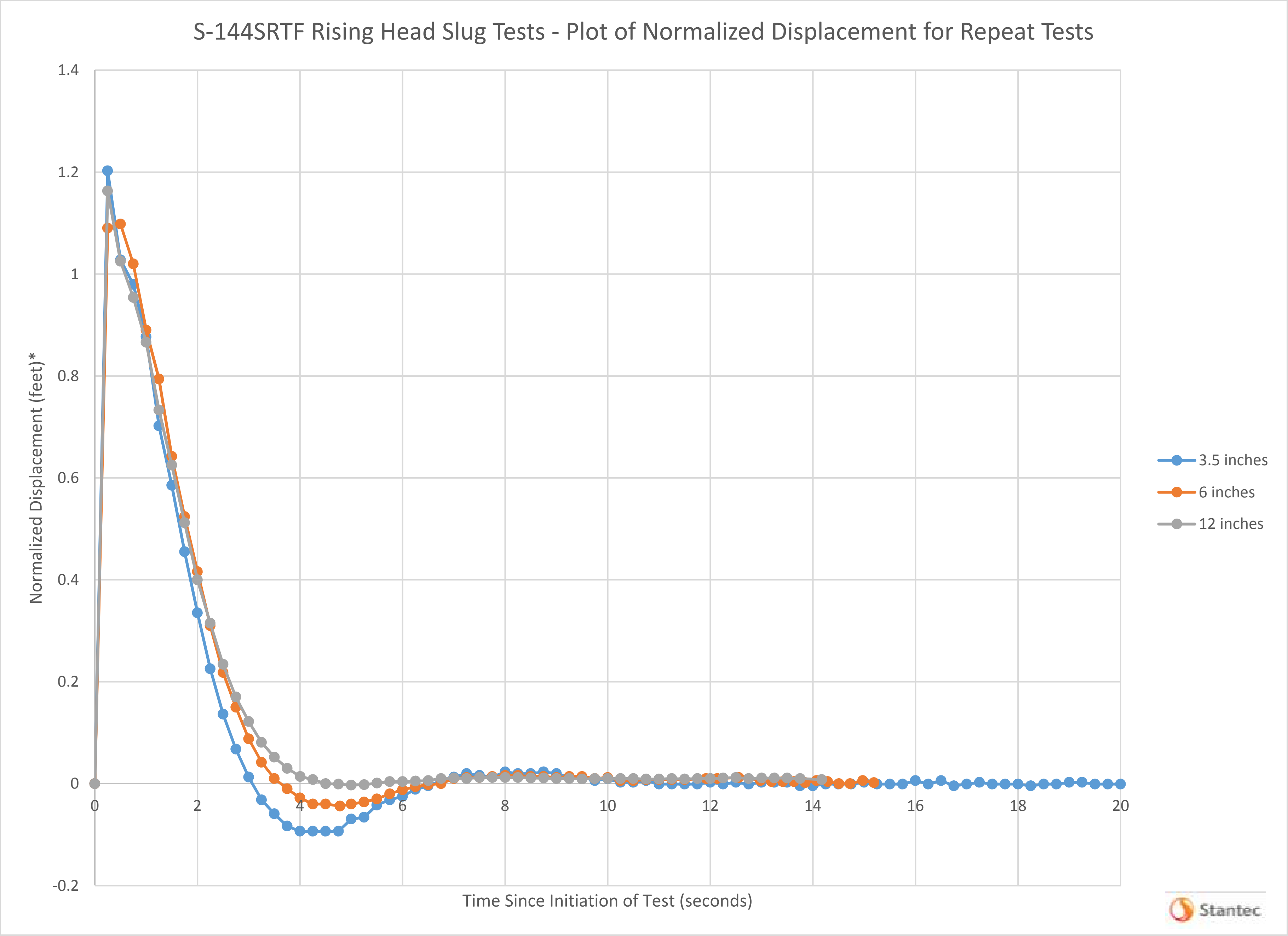
WELL DATA (S-142SRTF)

Initial Displacement: 1.42 ft
Total Well Penetration Depth: 27.61 ft
Casing Radius: 0.1678 ft
Static Water Column Height: 27.61 ft
Screen Length: 20. ft
Well Radius: 0.1678 ft

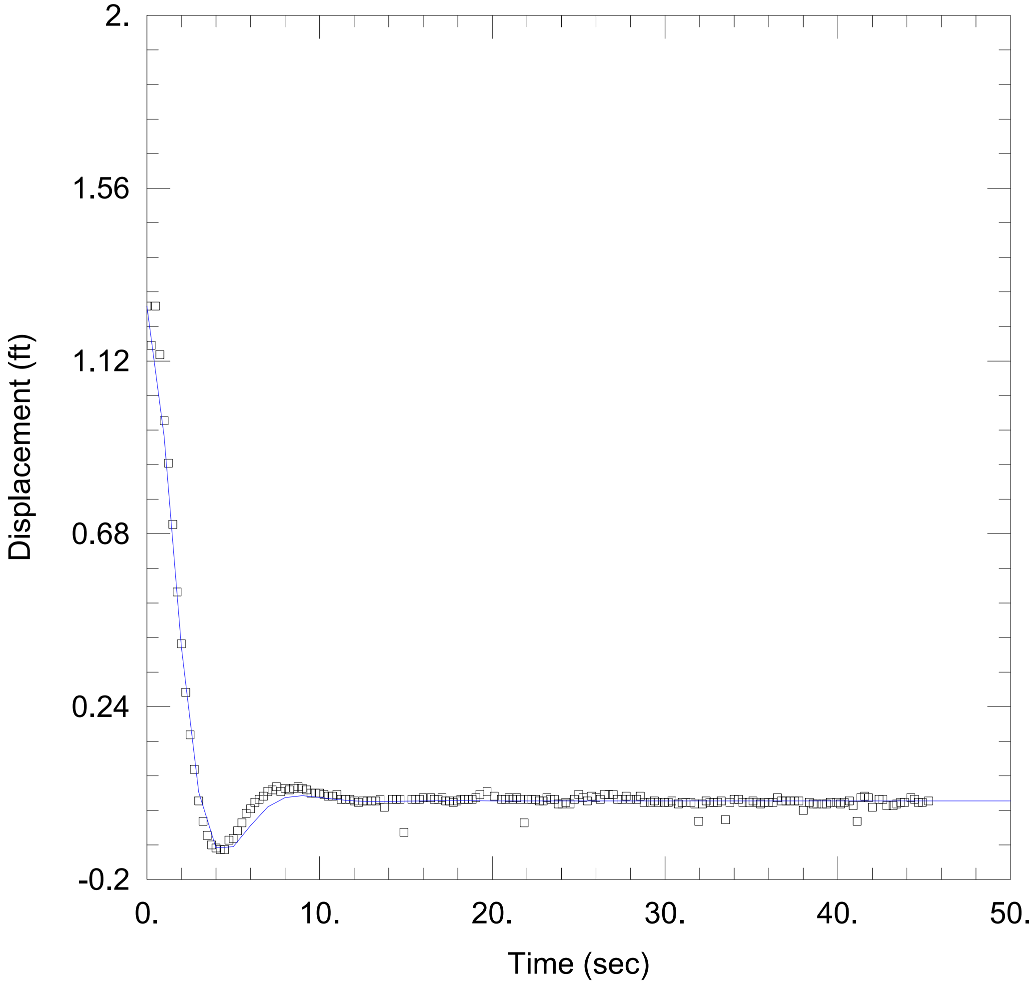
SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 34.61 ft/day
Kz/Kr = 1.
Ss = 1.667E-12 ft^{-1}



*Water-level displacement data was normalized by dividing the observed displacement data by the expected initial displacement, indicated in the plot legend (in inches of water).



WELL TEST ANALYSIS

Data Set: V:\...\s144srtf_analysis_unconfined_springer_gelhar_rev.aqt
Date: 12/12/16 Time: 16:55:15

PROJECT INFORMATION

Company: Stantec Consulting
Client: Evergreen Resources Management
Project: 213402599
Location: Philadelphia Refinery AOI 9
Test Well: S-144SRTF
Test Date: 10/20/16

AQUIFER DATA

Saturated Thickness: 35. ft
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (S-144SRTF)

Initial Displacement: 1.26 ft
Total Well Penetration Depth: 50. ft
Casing Radius: 0.1678 ft
Static Water Column Height: 35. ft
Screen Length: 20. ft
Well Radius: 0.1678 ft
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined
Solution Method: Springer-Gelhar

K = 237.1 ft/day
Le = 41.91 ft

APPENDIX C
AOI 9 Geotechnical Laboratory Testing Results

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT
OF PLUME 2 BENZENE USING QUICK DOMENICO
AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Ave, Philadelphia, Pennsylvania

GeoStructures
GEOTECHNICAL ENGINEERING CONSULTANTS

Bashar S. Qubain, Ph.D., P.E.
Eric J. Seksinsky, P.G., P.E.
Jianchao Li, P.E.

Project No. G15-104
August 28, 2015

Ms. Tiffani Doerr, PG
Aquaterra Technologies, Inc.
122 S. Church St.
West Chester, PA 19381

Re: Geotechnical Laboratory Testing Results
Philadelphia Refinery AOI-9

GeoStructures received two (2) *Shelby tube* samples from Aquaterra (see attached chain of custody form). The soil parameters determined are as follows: visual classification; moist bulk density and dry density; total and effective porosity, and fraction organic carbon. Refer to the testing summary below for sample descriptions and test results.

Laboratory Testing Summary

Sample	Visual Description & Remarks	Moist Bulk Density (pcf)[1]	Dry Density (pcf)[1]	Total Porosity[2] (%)	Effective Porosity[2] (%)	Water Content (%)	Fraction Organic Carbon[3] (%)
AOI9-S-118DSRTF, 42'-44'	Sand and gravel	120.9	101.1	35.5	28.2	19.6	1.0
AOI9-S-110DSRTF, 10'-12'	Sand and gravel	121.0	109.8	28.1	22.5	10.2	3.0

[1] ASTM D7263
[2] ASTM D425M.
[3] ASTM D2974, Method D.

We appreciate your request for services. Please call if you have any questions.

Sincerely,

Eric J. Seksinsky

Eric J. Seksinsky, P.G., P.E.
Associate

1000 West 9th Avenue, King of Prussia, PA 19406 Ph. 610.265.1818, Fx. 610.265.1833 www.geostructures.net

APPENDIX D
Quick Domenico Calculation Sheets

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT
OF PLUME 2 BENZENE USING QUICK DOMENICO
AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Ave, Philadelphia, Pennsylvania

Appendix D
NEW QUICK DOMENICO

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

Project: Fate and Transport Simulation of Plume 2 Benzene - AOI 9 Well S-112SRTF Source
Date: 12/16/2016 Prepared by: ADK
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

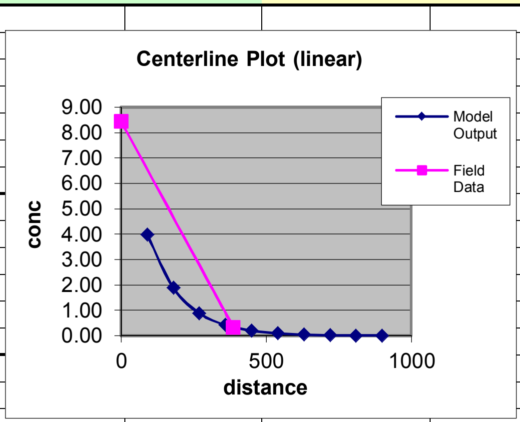
SOURCE CONC (MG/L)	**Ax (ft)**	**Ay (ft)**	**Az (ft) >=.001**	**LAMBDA day-1**	**SOURCE WIDTH (ft)**	**SOURCE THICKNESS (ft)**	**Time (days) (days)**
8.44	**5.00E+01**	**5.00E+00**	**1.00E-03**	**0.005**	**500**	**10**	**2000**

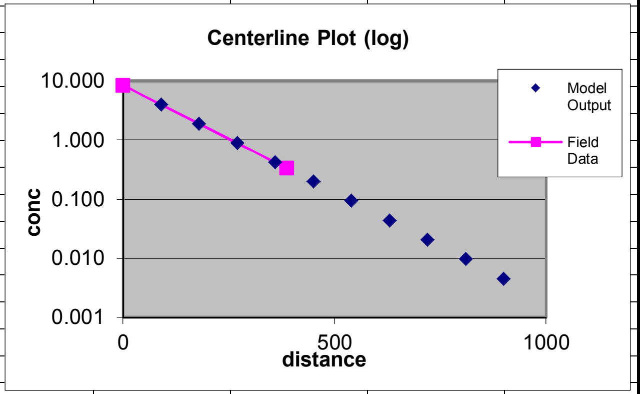
Hydraulic Cond (ft/day)	**Hydraulic Gradient (ft/ft)**	**Porosity (dec. frac.)**	**Soil Bulk Density (g/cm^3)**	**KOC**	**Frac. Org. Carb.**	**Retardation (R)**	**V (=K*i/n*R) (ft/day)**
1.95E+02	**0.0027**	**0.225**	**1.76**	**58**	**1.00E-02**	**5.536888889**	**0.422620003**

Point Concentration

x(ft)	**y(ft)**	**z(ft)**
650	**0**	**0**

	x(ft)	**y(ft)**	**z(ft)**
Conc. At	**650**	**0**	**0**
at	**2000**	**days =**	**0.037**
			mg/l


Centerline Plot (linear)


Centerline Plot (log)

AREAL MODEL	**CALCULATION DOMAIN**
Length (ft)	900
Width (ft)	250

	90	*180*	*270*	*360*	*450*	*540*	*630*	*720*	*810*	*900*
250	**1.991**	**0.939**	**0.443**	**0.209**	**0.099**	**0.047**	**0.022**	**0.010**	**0.005**	**0.002**
125	**3.982**	**1.876**	**0.879**	**0.410**	**0.191**	**0.089**	**0.041**	**0.019**	**0.009**	**0.004**
0	**3.982**	**1.879**	**0.886**	**0.418**	**0.197**	**0.093**	**0.044**	**0.021**	**0.010**	**0.005**
-125	**3.982**	**1.876**	**0.879**	**0.410**	**0.191**	**0.089**	**0.041**	**0.019**	**0.009**	**0.004**
-250	**1.991**	**0.939**	**0.443**	**0.209**	**0.099**	**0.047**	**0.022**	**0.010**	**0.005**	**0.002**

Field Data:							
Centerline C Concentration	8.44	0.332					
Distance from Source	0	387					

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

Project: Fate and Transport Simulation of Plume 2 Benzene - AOI 9 S-115SRTF Source
Date: 1/11/2017 Prepared by: ADK
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

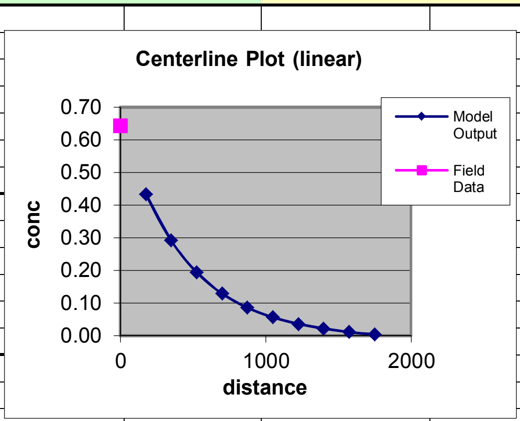
SOURCE CONC (MG/L)	**Ax (ft)**	**Ay (ft)**	**Az (ft) >=.001**	**LAMBDA day-1**	**SOURCE WIDTH (ft)**	**SOURCE THICKNESS (ft)**	**Time (days) (days)**
0.644	**2.00E+01**	**2.00E+00**	**1.00E-03**	**0.001**	**250**	**15**	**3700**

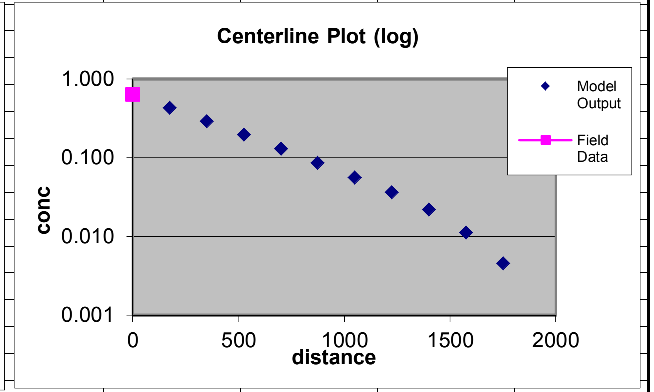
Hydraulic Cond (ft/day)	**Hydraulic Gradient (ft/ft)**	**Porosity (dec. frac.)**	**Soil Bulk Density (g/cm^3)**	**KOC**	**Frac. Org. Carb.**	**Retard-ation (R)**	**V (=K*i/n*R) (ft/day)**
1.95E+02	**0.0027**	**0.225**	**1.76**	**58**	**1.00E-02**	**5.536888889**	**0.422620003**

Point Concentration

x(ft)	**y(ft)**	**z(ft)**
200	**0**	**0**

	x(ft)	**y(ft)**	**z(ft)**
Conc. At	**200**	**0**	**0**
at	**3700**	**days =**	**0.410** mg/l





AREAL CALCULATION
MODEL DOMAIN
Length (ft) 1750
Width (ft) 125

	175	*350*	*525*	*700*	*875*	*1050*	*1225*	*1400*	*1575*	*1750*
125	**0.217**	**0.146**	**0.098**	**0.066**	**0.044**	**0.030**	**0.020**	**0.012**	**0.006**	**0.003**
62.5	**0.429**	**0.278**	**0.179**	**0.116**	**0.076**	**0.049**	**0.032**	**0.019**	**0.010**	**0.004**
0	**0.433**	**0.291**	**0.195**	**0.130**	**0.086**	**0.056**	**0.036**	**0.022**	**0.011**	**0.005**
-62.5	**0.429**	**0.278**	**0.179**	**0.116**	**0.076**	**0.049**	**0.032**	**0.019**	**0.010**	**0.004**
-125	**0.217**	**0.146**	**0.098**	**0.066**	**0.044**	**0.030**	**0.020**	**0.012**	**0.006**	**0.003**
Field Data:	**Centerline C**	**Concentration**		0.644						
	Distance from Source			0						

APPENDIX E
PWD Stormwater Billing Parcel Ownership Information

PREDICTIVE ANALYSIS OF THE POTENTIAL FATE-AND-TRANSPORT
OF PLUME 2 BENZENE USING QUICK DOMENICO
AREA OF INTEREST 9
Philadelphia Refining Complex
3144 Passyunk Ave, Philadelphia, Pennsylvania

PHILADELPHIA WATER

BRT/OPA Account Number: 882170250
Stormwater Billing Class: Non-Residential
Parcel Address: 7001 ESSINGTON AVE
Parcel Owner: PINGREE 2000 REAL ESTATE

Legend

🟥 Selected Parcel
🟦 Other Parcels
Impervious Surfaces
🟨 Roof
🟪 Other Impervious

Parcel Area (square feet)

	Gross Area		Impervious Area
Total:	598,693	Total:	494,933
Credit:	0	Credit:	0

Monthly Stormwater Charge

Fiscal Year	*07/01/2013 - 06/30/2014*	*07/01/2014 - 06/30/2015*	*07/01/2015 - 06/30/2016*	*07/01/2016 - 06/30/2017*	*07/01/2017 - 06/30/2018*
Parcel - Total	**$5125.06**	**$5407.55**	**$5407.55**	**$5380.67**	**$5622.91**
Account # - 055-32200-07001-003	$5125.06	$5407.55	$5407.55	$5380.67	$5622.91

BRT/OPA Account Number: 884167020

Stormwater Billing Class: Non-Residential

Parcel Address: 7601 ESSINGTON AVE

Parcel Owner: INTERPORT PHILADELPHIA L

Legend

🟥 Selected Parcel

🟦 Other Parcels

Impervious Surfaces

🟨 Roof

🟪 Other Impervious

Parcel Area (square feet)

	Gross Area	Impervious Area
Total:	500,626	431,714
Credit:	333,704	333,704

Monthly Stormwater Charge

Fiscal Year	***07/01/2013 - 06/30/2014***	***07/01/2014 - 06/30/2015***	***07/01/2015 - 06/30/2016***	***07/01/2016 - 06/30/2017***	***07/01/2017 - 06/30/2018***
Parcel - Total	**$1075.10**	**$1134.21**	**$1134.21**	**$1130.85**	**$1181.64**
Account # - 055-32200-07601-001	$1075.10	$1134.21	$1134.21	$1130.85	$1181.64

PHILADELPHIA WATER

BRT/OPA Account Number: 884167016

Stormwater Billing Class: Non-Residential

Parcel Address: 7600 HOLSTEIN AVE

Parcel Owner: INTERPORT PHILA L P

Legend

- 🟥 Selected Parcel
- 🟦 Other Parcels

Impervious Surfaces

- 🟨 Roof
- 🟪 Other Impervious

Parcel Area (square feet)

	Gross Area		Impervious Area
Total:	338,200	Total:	218,551
Credit:	0	Credit:	0

Monthly Stormwater Charge

Fiscal Year	*07/01/2013 - 06/30/2014*	*07/01/2014 - 06/30/2015*	*07/01/2015 - 06/30/2016*	*07/01/2016 - 06/30/2017*	*07/01/2017 - 06/30/2018*
Parcel - Total	**$2350.96**	**$2480.37**	**$2480.37**	**$2471.07**	**$2582.21**
Account # - 055-43300-07600-001	$2350.96	$2480.37	$2480.37	$2471.07	$2582.21

BRT/OPA Account Number: 884167030
Stormwater Billing Class: Non-Residential
Parcel Address: 7700 HOLSTEIN AVE
Parcel Owner: KIRK LYNN TR

Legend

🟥 Selected Parcel
🟦 Other Parcels
Impervious Surfaces
🟨 Roof
🟪 Other Impervious

Parcel Area (square feet)

	Gross Area		Impervious Area
Total:	130,750	Total:	89,080
Credit:	0	Credit:	0

Monthly Stormwater Charge

Fiscal Year	*07/01/2013 - 06/30/2014*	*07/01/2014 - 06/30/2015*	*07/01/2015 - 06/30/2016*	*07/01/2016 - 06/30/2017*	*07/01/2017 - 06/30/2018*
Parcel - Total	**$953.83**	**$1006.30**	**$1006.30**	**$1002.69**	**$1047.72**
Account # - 055-43300-07700-001	$953.83	$1006.30	$1006.30	$1002.69	$1047.72

PHILADELPHIA WATER

BRT/OPA Account Number: 885058530
Stormwater Billing Class: Exempt
Parcel Address: 7750 HOLSTEIN AVE
Parcel Owner: PHILA IND DEV CORP

Legend

🟥 Selected Parcel
🟦 Other Parcels
Impervious Surfaces
🟨 Roof
🟪 Other Impervious

Parcel Area (square feet)

	Gross Area		Impervious Area
Total:	518,745	Total:	0
Credit:	0	Credit:	0

Monthly Stormwater Charge

Fiscal Year	*07/01/2013 - 06/30/2014*	*07/01/2014 - 06/30/2015*	*07/01/2015 - 06/30/2016*	*07/01/2016 - 06/30/2017*	*07/01/2017 - 06/30/2018*
Parcel - Total	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**

APPENDIX E

EVERGREEN QA/QC PLAN AND FIELD PROCEDURES MANUAL

Quality Assurance/ Quality Control Plan and Field Procedures Manual

Sunoco Partners Marcus Hook Industrial Complex and Philadelphia Energy Solutions (PES) Philadelphia Refinery Complex

Evergreen Resources Management Operations
May 20, 2016

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Appendix

1.0 INTRODUCTION

This Quality Assurance/Quality Control Plan and Field Procedures Manual (QA/QC Plan) outlines the procedures developed to ensure the collection and analysis of quality data for investigations completed under the United States Environmental Protection Agency (USEPA) Resource Conservation and Recovery Act (RCRA), Pennsylvania Department of Environmental Protection (PADEP) Act 2, and Pennsylvania and Delaware's Tank programs at the Sunoco Partners Marketing and Terminals, LP (Sunoco Partners) Marcus Hook Industrial Complex (MHIC) and the Philadelphia Energy Solutions Refining and Marketing, LLC (PES) Philadelphia Refinery Complex (PRC) on behalf of Evergreen Resources Management Operations (Evergreen). This document shall be used in conjunction with the site-specific work plans developed for each site and Standard Operating Procedures (SOPs) for field work as incorporated as Appendix A of this QA/QC Plan.

The QA/QC Plan is a planning document that provides a "blueprint" for obtaining the type and quality of data needed to support environmental decision making. The QA/QC Plan integrates relevant technical and quality aspects of a project and documents quality assurance and quality control.

The selection criteria and evaluation specified in this document will be used for validating the data in accordance with the USEPA Guidance on Environmental Data Verification and Data Validation (USEPA 240-R-02-004), dated November 2002 (EPA QA/G-8), USEPA Contract Laboratory Program National Functional Guidelines (NFGs) for Superfund Organic Methods Data Review (USEPA 540-R-08-01), dated June 2008 (SOM02.2) and USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Data Review (USEPA 540-R-10-011), dated January 2010 (ISM02.2). Qualifiers assigned to the data will be consistent with the data qualifiers specified in the NFGs and the USEPA Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use (USEPA 540-R-08-01), collectively referred to herein as validation guidance.

2.0 QUALITY CONTROL REQUIREMENTS

The field and laboratory QC requirements for the characterization and remediation activities are discussed in the following subsections. Specific QC checks and acceptance criteria are provided in the referenced analytical methods.

2.1 Field Sampling Quality Control

The field QC requirements include analyzing reference standards for field instrument calibration and for routine calibration verifications. All initial and continuing calibration procedures will be implemented by trained personnel following the manufacturer's instructions to ensure the equipment is functioning within the specified tolerances. The calibration and maintenance history of the project-specific field instrumentation will be maintained in an active field logbook.

Field QC samples for this project include field duplicate samples to assess the overall precision of the sampling and analysis event, equipment rinse blanks to ensure proper cleaning of non-dedicated equipment is conducted between samples to avoid potential cross contamination (also generally referred to as field blanks), and trip blank samples to monitor cross contamination of water samples by volatile organic compounds (VOCs) during sample transport.

The frequency of collection of equipment rinse blanks will be one per sampling event. Field duplicate samples will only be prepared for groundwater samples, not for soil sampling events, at a collection frequency of 1 in 20 samples. One trip blank will be included for every shipment of samples to an analytical laboratory, at a minimum frequency of one trip blank per sample shipment which contains samples for VOCs analyses.

2.2 Analytical Quality Control

The laboratory QC requirements for the analyses may include evaluating chemical/thermal preservation, holding times, handling requirements, method blanks, instrument performance checks, initial calibration standards, calibration verification standards, internal standards, surrogate compound spikes, interference check samples, serial dilution samples, matrix spike/matrix spike duplicate (MS/MSD) samples, and laboratory control samples (LCS). The acceptance criteria for the above identified requirements will be generated by the laboratory and included in the laboratory reports, along with the other laboratory QC requirements.

3.0 DATA VERIFICATION, VALIDATION, AND USABILITY

All field and laboratory data will be reviewed, verified, and/or validated. These terms are defined as follows:

- Data review is the in-house examination to ensure that the data have been recorded, transmitted, and processed correctly.
- Data verification is the process for evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, and/or contractual requirements.
- Data validation is an analyte-specific and sample-specific process that extends the evaluation of data beyond method, procedure, or contractual compliance (i.e., data verification) to determine the quality of a specific data set relative to the end use.

Field data and logbooks will be reviewed to ensure that the requirements of the sampling program, including the number of samples and locations, sampling, and sample handling procedures, were fulfilled.

Data verification, validation, and usability assessments performed on a percentage of lab packages to ensure that the data are scientifically defensible, properly documented, of known quality, and meet the project objectives, are described in the following sections. Data determined to be unusable may require corrective action be taken. Data use limitations will be identified in the data validation and usability assessment (VUA) report, which will be generated as required for characterization or final reporting to the agencies.

3.1 Data Review, Verification, and Validation Requirements

Data review, verification, and validation of the analytical data will be performed by each consultant completing the field activities. The exception to this scenario will be Aquaterra Technologies, Inc. (Aquaterra), in which case Aquaterra will review/verify the data and the consultant company working with Aquaterra will subsequently validate the samples.

Field information will be reviewed to ensure that all field measurements were conducted in accordance with the requirements of the site-specific work plan and this QA/QC Plan including applicable SOPs. Field measurements obtained using procedures inconsistent with the requirements of these documents will be evaluated and may require that additional samples are collected or the use of the data be restricted.

Stage 1 Verification and Validation Checks

One hundred percent of the sample results will go through a Stage 1 verification and validation. As part of the data management process, each consultant will complete verification and validation based on the validation guidance. Data verification and validation will consist of the following items based on the guidance stated.

Stage 1 verification and validation of the laboratory analytical data package consists of checks for the compliance of sample receipt conditions, sample characteristics (e.g., percent moisture), and analytical results (with associated information). It is recommended that the following minimum baseline checks (as relevant) be performed on the laboratory analytical data package received for a Stage 1 validation label:

1. Documentation identifies the laboratory receiving and conducting analyses, and includes documentation for all samples submitted by the project or requester for analyses.
2. Requested analytical methods were performed and the analysis dates are present.
3. Requested target analyte results are reported along with the original laboratory data qualifiers and data qualifier definitions for each reported result.
4. Requested target analyte result units are reported.
5. Requested reporting limits for all samples are present and results at and below the requested (required) reporting limits are clearly identified (including sample detection limits if required).
6. Sampling dates (including times if needed), date and time of laboratory receipt of samples, and sample conditions upon receipt at the laboratory (including preservation, pH and temperature) are documented.
7. Sample results are evaluated by comparing sample conditions upon receipt at the laboratory (e.g., preservation checks) and sample characteristics (e.g., percent moisture) to the validation guidance.

Stage 2 Verification and Validation Checks

A minimum of 10 percent of the samples will be flagged for VUA. When a laboratory work order is selected, the entire work order will undergo Stage 2 validation. Laboratory work orders or sample delivery groups (SDGs) that are selected for VUA will undergo validation based on the NFGs.

The selection of samples that will undergo VUA process is designed to meet the needs of the site investigation, characterization, remediation, and closure programs, such as tank closures. Sampling that falls outside these programs will not undergo the VUA process. This includes samples that are collected for permit compliance, such as RCRA and effluent wastewater, as well as product samples, onsite soil reuse samples, and waste characterization samples.

Ten percent of samples will be selected based on the following additional conditions:

1. Sample package selected will contain a field duplicate sample.
2. Sample package selected will contain an equipment rinse blank.
3. Sample package selected will be representative of the contracted analytical laboratories, sample media, parameters, time, and project goals.

QC samples that are collected in the field will provide the best information for completing the VUA reports. The conditions for selection of samples are designed to provide the most useful information regarding sample analysis. Therefore, field duplicate samples have been identified as a priority condition. However, field duplicate samples will only be prepared for groundwater samples, not for soil sampling events. This is due to the known, inherent heterogeneity of soil at the sites. For program efficiency, entire SDGs will be selected for submission in the VUA process. Individual samples should not be selected and processed unless there is an overriding reason to do so, such as a point of compliance sample result that when compared to the historic data set appears to be anomalous.

Stage 2 data validation includes a review of the following QC data deliverables:

1. Technical holding times
2. Method blanks
3. Surrogate spikes
4. MS/MSD results
5. LCS results
6. Field duplicates

7. Trip and equipment rinse blank samples

Stage 2B Verification and Validation Checks

Stage 2B verification and validation will be completed on inorganic analytical data and will contain the following (in addition to Stage 1 verification):

1. Requested methods (handling, preparation, cleanup, and analytical) are performed.
2. Method dates (including dates, times and duration of analysis for radiation counting measurements and other methods, if needed) for handling (e.g., Toxicity Characteristic Leaching Procedure), preparation, cleanup and analysis are present, as appropriate.
3. Sample-related QC data and QC acceptance criteria (e.g., method blanks, surrogate recoveries, deuterated monitoring compounds (DMC) recoveries, laboratory control sample (LCS) recoveries, duplicate analyses, matrix spike and matrix spike duplicate recoveries, serial dilutions, post digestion spikes, standard reference materials) are provided and linked to the reported field samples (including the field quality control samples such as trip and equipment blanks).
4. Requested spike analytes or compounds (e.g., surrogate, DMCs, LCS spikes, post digestion spikes) have been added, as appropriate.
5. Sample holding times (from sampling date to preparation and preparation to analysis) are evaluated.
6. Frequency of QC samples is checked for appropriateness (e.g., one LCS per twenty samples in a preparation batch).
7. Sample results are evaluated by comparing holding times and sample-related QC data to the requirements in the data validation guidance.
8. Initial calibration data (e.g., initial calibration standards, initial calibration verification [ICV] standards, initial calibration blanks [ICBs]) are provided for all requested analytes and linked to field samples reported. For each initial calibration, the calibration type used is present along with the initial calibration equation used including any weighting factor(s) applied and the associated correlation coefficients, as appropriate. Recalculations of the standard concentrations using the initial calibration curve are present, along with their associated percent recoveries, as appropriate (e.g., if required by the project, method, or contract). For the ICV standard, the associated percent recovery (or percent difference, as appropriate) is present.
9. Appropriate number and concentration of initial calibration standards are present.

10. Continuing calibration data (e.g., continuing calibration verification [CCV] standards and continuing calibration blanks [CCBs]) are provided for all requested analytes and linked to field samples reported, as appropriate. For the CCV standard(s), the associated percent recoveries (or percent differences, as appropriate) are present.
11. Reported samples are bracketed by CCV standards and CCBs standards as appropriate.
12. Method specific instrument performance checks are present as appropriate (e.g., tunes for mass spectrometry methods, DDT/Endrin breakdown checks for pesticides and aroclors, instrument blanks and interference checks for ICP methods).
13. Frequency of instrument QC samples is checked for appropriateness (e.g., gas chromatography-mass spectroscopy [GC-MS] tunes have been run every 12 hours).
14. Sample results are evaluated by comparing instrument-related QC data to the requirements in the data validation guidance.

Stage 3 Verification and Validation Checks

Stage 3 verification and validation will be completed on organic analytical data and will contain the following (in addition to Stage 2B):

1. Instrument response data (e.g., GC peak areas, ICP corrected intensities) are reported for requested analytes, surrogates, internal standards, and DMCs for all requested field samples, matrix spikes, matrix spike duplicates, LCS, and method blanks as well as calibration data and instrument QC checks (e.g., tunes, DDT/Endrin breakdowns, interelement correction factors, and Florisil cartridge checks).
2. Reported target analyte instrument responses are associated with appropriate internal standard analyte(s) for each (or selected) analyte(s) (for methods using internal standard for calibration).
3. Fit and appropriateness of the initial calibration curve used or required (e.g., mean calibration factor, regression analysis [linear or non-linear, with or without weighting factors, with or without forcing]) is checked with recalculation of the initial calibration curve for each (or selected) analyte(s) from the instrument response.
4. Comparison of instrument response to the minimum response requirements for each (or selected) analyte(s).
5. Recalculation of each (or selected) opening and closing CCV (and CCB) response from the peak data reported for each (or selected) analyte(s) from the instrument response, as appropriate.

6. Compliance check of recalculated opening and/or closing CCV (and CCB) response to recalculated initial calibration response for each (or selected) analyte(s).
7. Recalculation of percent ratios for each (or selected) tune from the instrument response, as appropriate.
8. Compliance check of recalculated percent ratio for each (or selected) tune from the instrument response.
9. Recalculation of each (or selected) instrument performance check (e.g., DDT/Endrin breakdown for pesticide analysis, instrument blanks, interference checks) from the instrument response.
10. Recalculation and compliance check of retention time windows (for chromatographic methods) for each (or selected) analyte(s) from the laboratory reported retention times.
11. Recalculation of reported results for each reported (or selected) target analyte(s) from the instrument response.
12. Recalculation of each (or selected) reported spike recovery (surrogate recoveries, DMC recoveries, LCS recoveries, duplicate analyses, matrix spike and matrix spike duplicate recoveries, serial dilutions, post digestion spikes, standard reference materials etc.) from the instrument response.
13. Each (or selected) sample result(s) and spike recovery(ies) are evaluated by comparing the recalculated numbers to the laboratory reported numbers according to the requirements in the data validation guidance.

Stage 4 Verification and Validation Checks

Additional data validation may be completed for selected sites and/or sampling events, up to EPA Level 4 data review, which will require a laboratory data package inclusive of raw data. Stage 4 verification and validation includes all of the elements of the previous stages of validation and the following:

1. Evaluation of instrument performance checks (GC/MS)
2. Initial and continuing calibration checks (organic and inorganic analyses)
3. Review of internal standards (GC/MS)
4. Instrument blanks (inorganics)
5. Interference check samples (metals)
6. Recalculations of sample results and reporting limits

3.2 Validation Codes

Consultant specific validation codes will be added to the database. This will allow quick identification of the consultant that has performed the verification and/or VUA. Stantec may append additional codes for data management purposes to the codes provided in dt_result table approval_code field. Valid codes are as follows:

Langan:

- LAN1 – Historical data collected by Langan Level 1 Validation (Verification)
- LAN-VER – Langan performed verification
- LAN-USB – Langan performed usability

GHD:

- GHD-VER – GHD performed verification
- GHD-USB – GHD performed usability

Stantec:

- STN-VER – Stantec performed verification
- STN-USB – Stantec performed usability

This methodology creates a means for consultants to perform verification and usability on data collected by another consultant.

3.3 Data Updates in the Electronic Data Deliverables

All consultants will request EQuIS 4 file format Electronic Data Deliverables (EDDs) for data management from the analytical laboratories. In order to facilitate the data updates in the database, the following methodology will be used.

1. The consultant chemist / chemist team will open the .RES file for the EDD that has been selected to be validated for usability. The file can be opened using Excel, Access, Notepad, or similar tool. Although, it is a best practice to open the file in a way to preserve the textual nature of the EDD, it is not necessary.
2. The chemist will use the result_comment field in the .RES file to enter the qualifiers associated with the record and add a semicolon as a delimiter (;) followed by the reason code for the qualification.

3. The .RES file is to be saved with a .USB extension at the end of the file. This file is to be separate from the original .RES file provided and should not be used to over write the original .RES file that was sent with the EDD. This will result in the laboratory work order undergoing VUA having five files instead of four for the EDD. For example:
    - 1234.SMP
    - 1234.TST
    - 1234.BCH
    - 1234.RES
    - 1234.RES.USB
4. Stantec will use the fifth file to update the database with the appropriate qualifiers and codes in validator_qualifiers and approval_a through approval_d fields in dt_result table in the database.
5. Stantec will also change the validated y/n field in dt_result table in the database for the particular EDD.

3.4 Validation Qualifiers

The following qualifiers should be used during the validation/usability process. These are based on the NFGs, validation guidance, and commonly used qualifiers.

Data Qualifiers and Definitions

U	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
J+	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample, potentially biased high.
J-	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample, potentially biased low.
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.
NJ	The analyte has been "tentatively identified" or "presumptively identified" as present and the associated numerical value is the estimated concentration in the sample.

R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.
B	The analyte was detected in the method, field, and/or trip blank. This qualifier is not pursuant to the NFGs.

If additional qualifiers are required, please forward the suggestions to the Stantec Data Management Team and they will be added to the list of approved codes.

Submitting Data and Validation Codes for Inclusion in the Database

EDDs will be submitted to the database using the SharePoint portal intake forms. The appropriate qualifiers and codes that have been added to the result_comment field in the .RES.USB file will be included in the submission.

Reason Codes

Following is a list of reason codes available for validation. If additional codes are required, please forward the suggestions to the Stantec Data Management Team and they will be added to the list of approved codes.

Reason Code	Reason Description
General Use	
EC	Result exceeds the calibration range.
HT	Holding time requirement was not met
MB	Method blank or preparation blank contamination
LCS	Laboratory control sample evaluation criteria not met
FB	Field blank contamination
RB	Rinsate blank contamination
SQL	The analysis meets all qualitative identification criteria, but the measured concentration is less than the reporting limit.
FD	Field duplicate evaluation criteria not met
TvP	Total to Partial criteria not met
RL	Reporting limit exceeds decision criteria (for non-detects)
Inorganic Methods	
ICV	Initial calibration verification evaluation criteria not met
CCV	Continuing calibration verification evaluation criteria not met
CCB	Continuing calibration blank contamination
PB	Preparation Blank
ICS	Interference check sample evaluation criteria not met
D	Laboratory duplicate or spike duplicate precision evaluation criteria not met
MS	Matrix spike recovery outside acceptance range
PDS	Post-digestion spike recovery outside acceptance range
MSA	Method of standard additions correction coefficient _0.995
DL	Serial dilution results did not meet evaluation criteria
Organic Methods	
TUNE	Instrument performance (tuning) criteria not met
ICAL	Initial calibration evaluation criteria not met
CCAL	Continuing calibration evaluation criteria not met
SUR	Surrogate recovery outside acceptance range
MS/SD	Matrix spike/matrix spike duplicate precision criteria not met
MS	Matrix spike recovery outside acceptance range
IS	Internal standard evaluation criteria not met
LM	The PFK lock mass SICPs indicate that ion suppression evident
ID	Target compound identification criteria not met
Results Reported for Analytes Analyzed Multiple Times	
NSR	Not selected for reporting because the result was qualified as unusable
NSDL	Not selected for reporting because diluted resulted was selected for reporting
NSQ	Not selected for reporting because result was lesser quality based on data validation
NSO	Not selected for reporting because of other reason
Bias Codes	
H	Bias in sample result likely to be high
L	Bias in sample result likely to be low
I	Bias in sample result is indeterminate

3.4 Verification and Validation Summary

Verification of sample collection procedures will consist of reviewing sample collection documentation for compliance with the requirements of the site-specific work plan and this QA/QC Plan. If alternate sampling procedures were used, the acceptability of the procedure will be evaluated to determine the effect on the usability of the data. Data usability will not be affected if the procedure used is determined to be an acceptable alternative that fulfills the measurement performance criteria in this QA/QC Plan.

The results of the data verification and validation procedure will identify data that do not meet the measurement performance criteria of this QA/QC Plan. Data verification and validation will determine whether the data are acceptable, of limited usability (qualified as estimated), or rejected. Data qualified as estimated will be reviewed and a discussion of the usability of estimated data will be included in the VUA report.

Data determined to be unusable may require corrective action to be taken. Potential types of corrective action may include resampling by the field team or reanalysis of samples by the laboratory. The corrective actions taken are dependent upon the ability to mobilize the field team and whether or not the data are critical for project data quality objectives to be achieved. Data use limitations will be identified in VUA report, which will be generated as required for characterization or final reporting to the agencies. Each consultant will be responsible for their own VUA reports.

Revision History

Revision	Description	Prepared By	Date
1.0	Initial creation of document as SOP for VUA	Stantec (Gus Sukkurwala/Jennifer Menges/Andrew Bradley)	5/31/2015
2.0	Incorporation into QA/QC Plan	GHD (Colleen Costello)	3/21/2016
3.0	Inclusion of Field Procedures. Edits from Langan (Emily Strake & Kevin McKeever)	Stantec (Jennifer Menges)	5/13/2016

APPENDIX A
EVERGREEN FIELD PROCEDURES MANUAL

Evergreen
Field Procedures Manual

Sunoco Partners Marcus Hook Industrial Complex and Philadelphia Energy Solutions (PES) Philadelphia Refinery Complex

Evergreen Resources Management Operations

May 20, 2016

Table of Contents

1.0 INTRODUCTION

This Field Procedures Manual outlines the standard operating procedures developed to ensure the collection and analysis of quality data for investigations completed under the United States Environmental Protection Agency (USEPA) Resource Conservation and Recovery Act (RCRA) program, Pennsylvania Department of Environmental Protection (PADEP) Act 2 program and Pennsylvania and Delaware's Tank programs at the Sunoco Partners Marketing and Terminals, LP (Sunoco Partners) Marcus Hook Industrial Complex (MHIC) and the Philadelphia Energy Solutions Refining and Marketing, LLC (PES) Philadelphia Refinery Complex (PRC) on behalf of Evergreen Resources Management Operations (Evergreen). The MHIC and PRC are herein referred to as facility or site.

Evergreen's consultants collect data in pursuit of site characterization and remediation that will meet the expectations of the appropriate regulatory agencies. This document shall be used in conjunction with the site-specific work plans developed for each site and the QA/QC Plan of which this manual was incorporated as Appendix A.

1.1 Training Qualifications

All field personnel involved in field work at MHIC and the PRC shall have completed and where applicable, be current with OSHA 40-hour HAZWOPER training, annual OSHA 8-hour HAZWOPER refresher, Process Safety Management (PSM) training, site-specific safety module training for current facility badges (including fire watch and hole watch, if required), TWIC Card, annual drug screening, and annual respirator fit testing. All field personnel new to the facility should be provided with onsite health and safety (H&S) orientation by an experienced member of the project team. The onsite orientation should include review of the facility's emergency action plan and training on Evergreen and site-specific H&S requirements. Appropriately qualified personnel should perform field work, based on the work scope and experience level required by the task to be executed.

1.2 Health and Safety Requirements

All consultants performing work at the referenced sites on behalf of Evergreen shall comply with the *Evergreen Resources Management Operations Health and Safety Requirements* dated June 1, 2014. This includes contractors, sub-contractors, and third party companies performing work for Evergreen at MHIC and the PES PRC. Each consultant must also have their own site-specific health and safety plan (HASP) submitted to and approved by Evergreen prior to performing any work. A site-specific HASP must be reviewed and signed by all field personnel prior to commencement of field activities.

1.3 PPE Requirements

The minimum standard PPE at the facilities includes fire resistant clothing (FRC; coveralls may be Nomex or other FRC, 6 ounce minimum, orange in color) with the name of the company displayed on the back of the garment, hard hat, sturdy safety-toe boots, safety glasses, long-gauntlet leather gloves, and personal H_2S monitors. Nitrile gloves for chemical protection and hearing protection may also be required depending on the location and type of work. Workers are to be trained on these PPE requirements before being permitted onsite. An appropriate respirator may be required if site-specific air monitoring action levels are met, in accordance with the site-specific HASP. If a worker has a particular sensitivity or concern, a respirator may be worn regardless of OSHA action levels. During winter weather conditions, slip prevention footwear such as crampons or overshoes should be worn for traction. Task-specific PPE will be further identified in following sections.

1.4 Site Controls

Safety cones and/or caution tape should be used in high traffic areas. The "Buddy System" may also be employed in high traffic areas, in areas where other contractors are working, and in remote areas. Additional task-specific site controls will be detailed in following sections.

1.5 Equipment and Decontamination

Numerous practices are employed throughout the processes of site investigation and sampling to assure the integrity of the resulting data. The risk in use of non-dedicated equipment at multiple sampling locations lies in the potential for cross-contamination. While the threat of cross-contamination is always present, it can be minimized through the implementation of a consistent decontamination program during sensitive site measurement and data collection activities.

All site equipment to be used in multiple locations (non-dedicated) for sampling of soil, sediment, and/or groundwater will be decontaminated immediately prior to initial use and between uses at each location according to the following steps:

- Remove particulates with a sorbent pad or towel and/or initial rinse with clean potable tap water;
- Wash equipment with clean sponge, soft cloth, or scrub brush as necessary in a solution of tap water/laboratory grade detergent (Alconox®, Liquinox®, or equivalent);
- Rinse with tap water;
- Rinse with deionized or distilled water; and
- Air dry for as long as possible.

Rinse water generated during decontamination procedures will be treated onsite by passing the water through a bucket or tube filled with activated carbon prior to discharge to the ground surface. Additional decontamination procedures may be appropriate depending on the task, and will be identified in the following sections, as applicable.

1.6 Documentation

All site activities and conditions for characterization activities should be recorded by field personnel in a field computer (e.g., YUMA) using the EQuIS Data Gathering Engine (EDGE) application, or if necessary, a field book may be used. The entry shall include at a minimum, the date, time, weather conditions, location, personnel present onsite, field readings, sampling methodology, as well as additional comments or observations. Task specific observations which should also be recorded will be identified in the following applicable sections.

2.0 LIQUID LEVEL ACQUISITION (WELL GAUGING) PROCEDURES

2.1 Potential Hazards

Traffic, pinch points, chemical (airborne and physical contact), and biological are all likely hazards to be encountered as well as slip/trip/fall potential during onsite well gauging activities. Additional hazards may be mentioned in the site-specific HASP and/or the daily job safety analysis (JSA).

2.2 Materials and Equipment Necessary for Task Completion

Optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy, decontamination supplies (laboratory-grade detergent, deionized or distilled water, appropriate containers, scrub brush, and sorbent pads or paper towels), socket set, flathead screwdriver (or pry bar or manhole cover lifter), clear bailers with string for confirmation of light non-aqueous phase liquids (LNAPL), if necessary, and air monitoring instruments (optional, based on previous site visits).

2.3 Methodology

This task involves the deployment of an optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy into a well (in most cases), recording the measurement, and decontaminating the probe. The recorded field measurements may then be utilized for one of several applications including: well sampling, water table gradient mapping, LNAPL occurrence, LNAPL thickness, and/or gradient mapping, and various testing procedures. Wells should be gauged in order of least to most contaminated, based on existing sampling data or LNAPL occurrence, to minimize the potential for cross-contamination between wells. If LNAPL is detected in a well that does not typically have LNAPL, it should be confirmed with a clear bailer.

The proper procedure for liquid level acquisition is as follows:

1) Decontaminate the optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy prior to initial deployment, and again after each well measurement to prevent cross-contamination between wells.

2) If warranted, mark off a work area surrounding the well(s) to be gauged with safety cones and/or caution tape in order to protect personnel from auto traffic; the "Buddy System" may also be employed.

3) Where applicable, lift the manhole cover off of the well head (a screwdriver, pry bar, or manhole cover lifter may be used to lift the cover depending on the size of the manhole) or open protective well casing (stickup) and remove the well plug, if present.

4) Most wells should contain a mark or notch in the top edge of the casing from which normalized readings are to be measured (reference point elevation). Slowly lower the optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy into the well until the instrument signals contact with liquid. Note whether or not the instrument's tone is indicative of the presence of free-phase LNAPL (commonly a solid tone), or water (commonly an oscillating or beeping tone). If LNAPL is present, record the depth at which LNAPL was first indicated to the nearest hundredth of a foot, as measured from the top of well casing mark/notch. Slowly lower the probe through the LNAPL until the instrument's tone changes to indicate the presence of water. Record the depth at which water was first indicated to the nearest hundredth of a foot. A clear bailer may be used to verify the existence or approximate amount and appearance of LNAPL. If no LNAPL is apparent, record the depth to water.

5) Retract the probe from the well and secure the well appropriately.

6) Note the date and time of measurement for gauging and record all measurements and observations in the field computer or, if necessary, in a field book for subsequent electronic data entry.

7) Decontaminate the probe in accordance with the decontamination procedure outlined in Section 1.5.

8) Clean up the work area, remove gauging equipment, and remove any traffic control devices.

3.0 GROUNDWATER MONITORING PROCEDURES

3.1 Potential Hazards

Traffic, pinch points, chemical (airborne and physical contact), and biological are all likely hazards to be encountered as well as slip/trip/fall potential during onsite well gauging activities. Additional hazards may be mentioned in the site-specific HASP and/or the daily JSA.

3.2 Materials and Equipment Necessary for Task Completion

A list of equipment required to access, gauge, purge, and sample site monitoring wells is presented below. Also listed are materials necessary to store, label, preserve, and transport groundwater samples.

- Current site map detailing well locations;
- Field book and/or field computer for recording site data;
- Graduated, optical oil/water interface probe;
- Keys and tools to provide well access;
- Appropriate, laboratory prepared sample containers and labels;
- Appropriate well purging apparatus as determined by volume of groundwater to be purged and compounds to be analyzed;
- Water quality meter for monitoring indicator field parameters (DO, pH, specific conductance, redox potential, and turbidity if available);
- Dedicated polyethylene bottom-loading bailer or well pump and disposable tubing for groundwater sample collection;
- Clean nylon or polypropylene bailer cord;
- Disposable nitrile sampling gloves;
- Decontamination supplies;
- Calibrated five-gallon bucket and watch or stopwatch to determine discharge rate during purging;
- Blank chain-of-custody forms; and

- Cooler(s) and ice for sample preservation.

3.3 Methodology for Three Well Volume Sampling

Prior to site visitation for the groundwater sampling event, the following data will be reviewed to ensure proper preparation for field activities:

- Most recent liquid level data from all wells;
- Most recent analytical data from all wells to determine gauging and sampling sequence; and
- Well construction characteristics.

Each monitoring well to be sampled will be gauged to obtain liquid level data immediately prior to initiation of the sampling process (refer to well gauging procedures above). Liquid level data should be recorded in a field computer or if necessary, a field book. Should free-phase LNAPL be detected by the gauging process, routine groundwater sampling will not be conducted at that location. If groundwater sampling under LNAPL is warranted, refer to the sub-LNAPL sampling section and methodology in Section 3.6.

Groundwater sampling will be initiated by purging from the well a minimum of three well volumes, except in cases where the well is pumped dry, as referenced below. Well purging is performed to remove stagnant water and to draw representative water from the aquifer into the well for subsequent sampling and analysis. In extreme cases where a well is pumped dry and/or shows little recharge capacity, the well should be evacuated once prior to sampling. Wellbore storage volume should be estimated using as-built information stored in the field computer or as indicated on the well log, and the depth to water measurement obtained immediately prior to sampling.

Water quality should be monitored and readings recorded in the field computer or field book while purging, typically through use of a multi-parameter water quality meter with a flow through cell or cord for down-well measurements. Water quality readings should be recorded a minimum of three times (pre-purge, during purge, and post-purge/sample collection) or four times (pre-purge and following each well volume). The parameters to be monitored and recorded are dissolved oxygen, pH, specific conductance, redox potential, temperature, and turbidity if available.

Well purging can be performed with various equipment including: a dedicated bailer for hand bailing low volumes of water; a surface mounted electric centrifugal pump with dedicated polyethylene tubing; and/or submersible pump (particularly when the depth to water is greater than 20 feet) with dedicated polyethylene tubing. During pumping, the intake will be placed directly below the static water surface and slowly lowered during the purging process. This procedure may not be necessary in low-yielding wells but is important in high-yielding, permeable strata where an intake initially placed deep in a well may draw laterally and have little influence in exchanging water from shallower depths within the well bore.

Flow rate during well purging will be approximated by the bucket and stop watch method. The duration of pumping required to remove three well volumes will be calculated directly from this flow rate. All fluids removed during purging will be treated onsite with activated carbon or in accordance with an approved work plan.

The sequence of obtaining groundwater samples will be based upon available historical site data for existing wells and photoionization detector (PID) readings for newly installed wells. Monitoring wells will be sampled in order of those having the lowest to highest concentration of constituents of concern (or PID readings for new wells), based upon the most recent available set of laboratory analyses, to reduce the potential for cross-contamination. For general monitoring events, groundwater samples will not be obtained for analysis from any well containing measurable free product. If groundwater sampling under LNAPL is warranted, refer to the sub-LNAPL sampling section and methodology in Section 3.6.

The following sequence of procedures will be implemented for the collection of groundwater samples from monitoring wells.

1) Establish a clean work area where sampling equipment will not come in contact with the ground or any potentially contaminated surfaces.
2) Use a dedicated polyethylene sampling bailer for each well.
3) Use a clean pair of nitrile gloves.

4) Attach an appropriate length of unused, clean nylon or polypropylene cord to the designated sampling bailer.

5) Select appropriate laboratory-provided sample containers.

6) Slowly lower sampling bailer into well until water surface is encountered; continue to lower the sampling bailer into the standing water column to one foot below the water surface.

7) Retrieve bailer at a steady rate to avoid excess agitation.

8) Visually inspect bailed sample to ensure that no free product or organic detritus has been collected.

9) Uncap first designated sample vial and fill from bailer as rapidly as possible but minimizing agitation; secure septum and lid.

10) Inspect sealed sample for entrapped air; if air is present, remove the lid and gently top off sample in vial, seal and inspect. Repeat until no air is apparent.

11) Repeat Steps 9 and 10 for the remaining sample vials based on the laboratory and/or regulatory protocol.

12) Complete and attach labels to sample containers noting sample collector, date, time, and location of sample; record same data in field computer or field book.

13) Place samples in ice-filled cooler in such a manner as to avoid breakage. Samples will be maintained at a temperature of approximately 4°C.

14) Dispose of gloves, bailer, and bailer cord as solid waste and move to next sample location.

3.4 Methodology for Low-Flow Purging and Sampling

For wells that will be purged and sampled via low-flow methodology, the USEPA Region III Bulletin QAD023: *Procedure for Low-Flow Purging and Sampling of Groundwater Monitoring Wells* will be followed. The following data will be reviewed for each well in order to set the pump intake for the low-flow sampling:

- Soil boring lithologic log;
- Well construction log showing the screened interval;
- Identification of the most permeable zone screened by the well;
- Approximate depth to static water;

- Proposed pump intake setting; and
- Technical rationale for the pump intake setting, preferably across from the most impacted/contaminated subsurface interval.

Adjustable rate, submersible, bladder pumps in conjunction with polyethylene tubing for purging and sampling will be used. An alternate set up could include a stainless steel submersible pump, such as a Hurricane® pump or a Monsoon® pump with dedicated polyethylene tubing. The tubing diameter will be between 3/16-inch and ½-inch inner diameter and the length of the tubing extended outside of the well should be minimized. Flow-through cells will be used to monitor groundwater quality parameters during sampling. Monitoring well information, equipment specifications, water level measurements, parameter readings, and other pertinent information will be recorded during well purging and sampling.

The following sequence of procedures will be implemented for the collection of groundwater samples from monitoring wells by the low-flow methodology.

1) PID Screening of Well: A PID measurement may be collected at the rim of the well immediately after the well cap is removed and recorded in the field computer or field book, if historic data is not available.
2) Depth to Water Measurement: A depth to water measurement will be collected and recorded. To avoid disturbing accumulated sediment and to prevent the inadvertent mixing of stagnant water, measuring the total depth of the well should be done at the completion of sampling.
3) Low Stress Purging Startup: Water pumping will commence at a rate of 100 to 400 milliliters per minute (mL/min). This pumping should cause very little drawdown in the well (less than 0.2-0.3 feet) and the water level should stabilize. Water level measurements are made frequently, and flow rate will be recorded in mL/min on the sampling form or field computer.
4) Low Stress Purging and Sampling: The water level and pumping rate will be monitored and recorded every five minutes during purging, and any pumping rate adjustments will be recorded. During the early phase of purging, emphasis will be placed on minimizing and stabilizing pumping stress, and recording any necessary adjustments. Adjustments, when necessary, will be made in the first 15 minutes of purging. If necessary, pumping rates will

be reduced to the minimum capabilities of the pump to avoid well dewatering. If the minimal drawdown exceeds 0.3 feet, but the water level stabilizes above the pump intake setting, purging will continue until indicator field parameters stabilize, as detailed in Step 5 below. If the water level drops below the pump intake setting at the absolute minimum purge rate, the pump will remain in place and the water level will be allowed to recover repeatedly until there will be sufficient water volume in the well to permit the collection of samples.

5) Indicator Field Parameter Monitoring: During well purging, indicator field parameters (DO, pH, specific conductance, redox potential, and turbidity if available) will be monitored every five minutes (or less frequently, if appropriate). Purging will be considered complete and sampling can commence when all the indicator field parameters have stabilized. Stabilization will be achieved when three consecutive readings, taken at five minute intervals (or less frequently, if appropriate), are within the following limits:
    - DO (±10 percent);
    - turbidity (±10 percent);
    - specific conductance (±3 percent);
    - pH (± 0.1 unit); and
    - redox potential ([Eh] ±10 mv).

   Temperature and depth to water will be also monitored during purging. Should any of the parameter-specific components of the water quality meter fail during monitoring, the sampling team will attempt to locate a replacement multi-meter or individual criteria meter. If none are available, the sampling team will continue recording the parameters that are operational, and proceed with the sampling. Any other field observations relating to sample quality, such as odor, foaming, effervescence, and sheens, will also be recorded in the field computer or on the sampling form.

6) Collection of Ground Water Samples: Water samples for laboratory analyses will be collected prior to the flow-through cell by either using a bypass assembly or by temporarily disconnecting the flow-through cell. All sample containers will be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. During purging and sampling, the tubing should remain filled with water in order to minimize possible changes in water chemistry upon contact with the atmosphere. Methods employed to ensure that the outlet tubing will be filled include adjusting the tubing angle upward to

completely fill the tubing and restricting the diameter of the tubing near the outlet of the tubing.

The order in which samples will be collected is as follows:

- Volatile organics;
- Gas sensitive (e.g., Fe^{+2}, CH_4, H_2S/HS);
- Base neutrals or PAHs;
- Total petroleum hydrocarbons;
- Total metals;
- Dissolved metals;
- Cyanide;
- Sulfate and chloride;
- Nitrate and ammonia;
- Preserved inorganic;
- Non-preserved inorganic; and
- Bacteria.

After the appropriate laboratory-provided glassware is filled and labeled, the samples shall be placed in an ice-filled cooler and maintained at approximate 4°C for submittal to the laboratory. Upon completion of sampling at the well, decontaminate non-dedicated equipment in accordance with the decontamination procedure outlined in Section 1.5, and dispose of all dedicated equipment (gloves, tubing, etc.) as solid waste before moving to the next location.

3.5 Methodology for Passive (No-Purge) Sampling for Groundwater Collection

There are many passive groundwater sampling devices that allow for accurate sample collection without purging. Each device has specific uses and conditions for which they are more applicable. This methodology presents details for the use of HydraSleeve samplers.

The HydraSleeve is a disposable, single use device for the collection of representative groundwater samples for laboratory analysis of physical and chemical parameters.

HydraSleeves are placed within the screened interval (or other defined interval) of the well and activated after an equilibrium period. When used according to the manufacturer's instruction, the HydraSleeve will collect a groundwater sample without purging, thus causing no drawdown, agitation, or water column mixing. The HydraSleeve collects a sample from the screened interval only, and excludes water (or other fluids) from other parts of the well by use of check valve that seals when the sampler is full. The HydraSleeve takes advantage of the continuous natural movement of groundwater, which produces an equilibrium condition between the water in a well screen and the adjacent formation. HydraSleeves produce reliable data from low yield wells where other sample methods cannot due to well screen dewatering and associated alteration in water chemistry.

The HydraSleeve consists of the following components:

1) A long (usually 3 to 5 feet), flexible, lay-flat polyethylene sample sleeve, which is sealed at the bottom, and is equipped with a reed valve at the top allowing water to enter the HydraSleeve only during active sample retrieval.
2) A reusable, stainless steel weight attached with a clip to the bottom of the sleeve. The weight is used to carry the sample sleeve down the well to the specified depth (usually the bottom of the well screen). An optional top weight is also available to compress the sleeve in wells with short well screens.
3) A tether line attached to a spring clip at the top of the sample sleeve to deploy the device within the well and later retrieve it for sample collection.
4) A discharge tube is supplied with the device, which is used to puncture the wall of the sleeve after it is recovered to allow direct filling of sample bottles.

<u>Deployment</u>

Upon retrieval, the HydraSleeve is designed to effectively collect a "core" of water from within the well screen, which is equivalent in length and diameter to the sample sleeve. The upward motion opens the valve at the top, which then allows the device to fill with water. The Hydrasleeve should be installed with the top of the sample sleeve as close to the desired sample interval as possible. This will allow the sampler to fill and the check valve to close before the top of the device is pulled past the top of the sample interval.

To assemble and deploy the HydraSleeve:

1) Remove the Hydrasleeve from its package and hold it by the top, pinching the top at the holes.
2) Attach the spring clip and tether in the holes.
3) Slide the clip and bottom weight assembly into the holes at the bottom of the sleeve.
4) Lower the Hydrasleeve by the tether to the bottom or to the specified depth and secure the tether at the wellhead (Note: do not pull the HydraSleeve upward at any time during deployment, as this could cause the check valve to open and water to fill the sleeve inadvertently).

Sample Collection

Although the HydraSleeve only displaces approximately 100 milliliters (ml) of water during deployment, the well should be allowed to stabilize prior to sample collection so that natural flow conditions and contaminant distribution can return to equilibrium conditions. In certain jurisdictions, regulatory directives may prescribe a minimum equilibration period. When used for periodic monitoring programs, such as quarterly or semi-annual sampling, the HydraSleeve can be installed and remain in the well until the next sampling event, thus providing ample time for the well to equilibrate.

To collect a sample:

1) Be sure the tether is secured to the top of the well.
2) In one smooth motion, pull the tether upward at a rate of approximately 1 foot per second. The weight of the sampler will be felt when the valve closes. Continue pulling upward until the HydraSleeve is clear of the well.
3) Discard the water trapped at the top of the HydraSleeve above the reed valve.
4) Hold the HydraSleeve at the reed valve, and puncture the sleeve with the discharge tube just below the reed valve.
5) Decant the water into sample containers.
6) Discard the HydraSleeve as solid waste and process the excess water through activated carbon prior to discharge to the ground surface.

The weight and clips should be decontaminated prior to deploying a replacement HydraSleeve in the well. Tethers can be dedicated to individual wells or decontaminated and reused.

3.6 Methodology for Sub-LNAPL Sampling

The following section describes the methodology used for obtaining groundwater samples from the water column beneath LNAPL. Wells for sub-LNAPL sampling are not purged of three well volumes prior to sampling. This will prevent the potential of drawing LNAPL into the sample and to be representative of steady-state groundwater conditions beneath the LNAPL.

The following data will be reviewed for each well in order determine the appropriate equipment necessary:

- Well construction log showing diameter and total depth of the well;
- Approximate depth to LNAPL; and
- Approximate depth to static water.

A list of equipment for sub-LNAPL sampling is presented below:

- Field book or field computer for recording site data;
- Optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy;
- Keys and tools to provide well access;
- Peristaltic pump;
- Polyethylene tubing specifications of 0.25-inch outer diameter x 0.17-inch inner diameter is preferable as this small diameter assists in achieving lower flow rates;
- Silicone tubing of appropriate diameter to operate peristaltic pump;
- Polyvinyl chloride (PVC) drop tube (1.5-inch or other appropriate diameter);
- PVC rod (0.5-inch or other appropriate diameter);
- PVC end cap for drop tube;
- Tether for end cap;
- Clamps for securing drop tube to well casing;
- Appropriate sample containers and labels;

- Decontamination supplies;
- Blank chain-of-custody forms; and
- Cooler and ice for sample preservation.

The following sequence of procedures will be implemented for the collection of sub-LNAPL groundwater samples.

1) Determine LNAPL Thickness: Use an optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy to collect depth to LNAPL and depth to water measurements.
2) Installing Sampling Equipment: Deploy a 1.5-inch (or other appropriate diameter) PVC pipe (drop tube), with an attached end cap, through the LNAPL layer in the well. The end cap should be tethered to the drop tube so it is not lost in the well when removed and in a way that allows the drop tube to be sealed during installation. Lower the drop tube until the bottom of the tube is approximately two feet into the water column below the bottom of the LNAPL. Secure the drop tube to the well, and allow the system to equilibrate, approximately one half hour. The end cap is then removed by inserting a 0.5-inch (or other appropriate diameter) PVC rod into the drop tube and pushing on the cap until the lid is removed. The cap will be removed along with the tube upon completion of sampling.
3) Collection of Groundwater Samples: Lower polyethylene tubing through the 1.5-inch drop tube into the water column. Connect the polyethylene tubing to silicon tubing and engage the peristaltic pump for groundwater retrieval. Set the flow rate to the lowest pumping rate that can be sustained so that the LNAPL is not drawn into the tubing. Begin collecting groundwater in the sample container and continue until enough volume is obtained for all bottleware required by the laboratory for the requested analyses.

3.7 Decontamination Requirements

Of particular significance to the procedures of groundwater measurement and sampling is the limitation, whenever possible, of materials inserted into a well bore and, even more importantly, of materials transferred from well to well.

Many items can be discarded between well sampling and/or gauging locations without significantly impacting project costs. Dedicated sampling equipment which can be discarded between well sampling locations, will be used whenever possible to preclude decontamination requirements. Sampling equipment included in this category are polyethylene bailers, bailer cord, nitrile gloves, and sampling tubing. However, other monitoring and sampling equipment, such as oil/water interface probes and submersible sampling pumps, must be reused from well to well.

All site equipment to be used in multiple locations (non-dedicated) for gauging and/or sampling of groundwater will be decontaminated immediately prior to initial use and between uses at each location according to the following steps:

- Remove particulates with a sorbent pad or towel and/or initial rinse with clean potable tap water;
- Wash equipment with clean sponge, soft cloth, or scrub brush as necessary in a solution of tap water/laboratory grade detergent (Alconox®, Liquinox®, or equivalent);
- Rinse with tap water;
- Rinse with deionized or distilled water; and
- Air dry for as long as possible.

Rinse water generated during decontamination procedures will be treated onsite by passing the water through a bucket filled with activated carbon prior to disposal.

3.8 Documentation

All site activities and conditions at the time of purging and groundwater sampling should be recorded by field personnel in a field computer via the EDGE application or, if necessary, a field book may be used. The entry shall include the date, time, weather conditions, location (well name), personnel present onsite, PID readings, sampling methodology, purge rate, purge volume, and the aforementioned groundwater indicator parameters. A field qualifier “SL” shall be applied to each sub-LNAPL sample entry to denote sample collection as sub-LNAPL. Additional comments or observations (e.g., well damage, nearby pumping, LNAPL sheen) should also be recorded.

4.0 SOIL SAMPLING & WELL INSTALLATION PROCEDURES

4.1 Site Controls

Prior to hand augering, hydroexcavation, utilizing a backhoe, or deploying any drilling apparatus to the site, an underground utility line protection request must be made (i.e., Pennsylvania One Call) for mark-out of known subsurface utilities and associated laterals proximal to the drilling location. Site plans, if available, should be reviewed to document and avoid the location of onsite utilities.

After review of all known mapped and marked utilities, a site reconnaissance will be performed to document the location of utility meters and storm sewer drains. In addition, the location of overhead utilities must be documented. After completing the subsurface and overhead utility review, the area to drill may be considered clear of utilities, or the location may be adjusted to a nearby location, which must also be cleared.

Lastly, any drilling activities must be preceeded by clearing of the borehole, prior to advancement of augers or split spoons. To ensure the safety of workers, the borehole will be cleared by hand, hydroexcavator, or backhoe to a depth of approximately 8 feet below ground surface.

4.2 Potential Hazards

Traffic, pinch points, chemical (airborne and physical contact), and biological are all likely hazards to be encountered during soil sampling and well installation, as well as slip/trip/fall potential. Drilling is considered a high risk activity which requires facility approval prior to implementation. Additional hazards are identified in the site-specific HASP and/or the daily JSA.

4.3 Materials and Equipment Necessary for Task Completion

A list of equipment required to oversee test boring advancement and, where applicable, sample soil is presented below. Also listed are materials necessary to store, label, preserve, and transport soil samples.

- Current site map detailing well locations;
- Field computer and/or field book for recording site data;

- Appropriate, laboratory prepared sample containers and labels;
- PID;
- Single-use, disposable plastic scoops or stainless steel scoop for collecting soil samples;
- Single-use, disposable, laboratory-supplied syringes for soil sample collection (if applicable);
- Scale for weighing samples (e.g., methanol kits, if necessary);
- Disposable nitrile sampling gloves;
- Measuring tape (for measuring core recovery);
- Munsell soil color chart/book (recommended);
- Decontamination equipment (if applicable);
- Blank chain-of-custody forms; and
- Cooler(s) and ice for sample preservation.

4.4 Decontamination Requirements

All down-hole drilling equipment must be steam cleaned prior to drilling at each soil boring or well location. All soil sampling equipment must be cleaned with detergent and rinsed with deionized or distilled water prior to deployment into the borehole. All well construction materials (i.e. PVC well casing, PVC well screen, sand pack, bentonite) should be clean and dedicated to each borehole.

4.5 Methodology for Soil Boring Installation

4.5.1. Borehole Advancement

During test drilling activities, a borehole is advanced into the subsurface via a rotary or direct-push drilling technique. Various types of drilling methods could be deployed at these facilities to advance the borehole and gain access to the subsurface for characterization and sampling. A description of the most commonly utilized drilling methods is included below:

4.5.1.1 Hollow Stem Auger

A hollow, steel pipe (available diameters vary) with welded, exterior steel “flights” is used to convey subsurface material to the surface when rotated clockwise. A bit at the bottom of the lead auger cuts into the subsurface material, and the rotation conveys the loosened material (cuttings) up the flights, allowing the hole to be advanced (cuttings may not always return to the surface, such as when drilling in soft, saturated materials). The hollow center of the auger allows the driller to access the subsurface for soil sample collection and, where applicable, well installation during borehole advancement. During borehole advancement, a center stem of steel rods connected to an auger plug prevent soil cuttings from entering the drill column. Once a desired drilling depth is reached, the center plug and rods can be pulled out, leaving the auger stem in place to prevent borehole collapse. A split-spoon sampler can be threaded onto the rods in place of the plug and driven via a hammer to obtain a sample (Standard Penetration Test), or if terminal depth has been reached a monitoring well could be installed through the augers.

4.5.1.2 Air and Mud Rotary

Rotary drilling methods are similar to hollow stem auger drilling, however specialized drilling bits at the bottom of rods are used to cut into the subsurface material using compressed air, vibration, and/or pressurized drilling mud. Compressed air or mud is forced through the drilling rods via an air compressor or pump, and escapes through small holes in the drill bit. The circulation of drilling mud, or air combined with introduced water or formation water, conveys the soil cuttings to the surface (while also cooling the drilling bit and preventing borehole collapse).

4.5.1.3 Geoprobe®

A direct-push drilling method, Geoprobe® sampling utilizes a hydraulic hammer to drive steel rods into the subsurface for soil sampling. This method advances a core barrel lined with a plastic Macro-Core® sleeve into the soil column for continuous soil core collection.

4.5.1.4 Hand Auger

A stainless steel or aluminum hand auger is physically advanced to a desired soil sampling depth through rotation of the auger and head.

4.5.2 Soil Sampling

Soil samples will be obtained for lithologic logging and where appropriate, for laboratory analysis with one of three different sampling devices: Split barrel spoon sampler, hand auger, or Geoprobe® soil sampler. For either method, the sampling devices are lowered through the hollow-stem augers or open borehole to allow sampling of undisturbed sediments below the bit or drive shoe. Soil samples will be collected at regular intervals for subsurface characterization and selection of appropriate well screen interval(s). Soils which appear to be visually impacted or from intervals which exhibit the highest deflections on the screening device (PID or similar) will be sampled for laboratory analysis in accordance with an approved sampling plan.

4.5.2.1. Split barrel spoon sampler (split spoon)

The split spoon sampler will be driven into the soil column in accordance with ASTM Standard Method D1586 (Reference A6, Appendix E). Soil sampling by split spoon is characterized by drilling a borehole with a hollow-stem auger to the desired sampling depth (the standard calls for one sample per five foot depth interval). The split spoon sampler is attached to the drilling rods after removal of the auger plug. The drill operator will drive the sampler into the undisturbed soil by repeatedly striking the drilling rods with a 140 pound safety hammer over a 30 inch drop. Field personnel will record the number of blows required to drive the split spoon sampler for each successive six-inch interval. After the sampler has been filled, the driller will remove the rods and sampler from the borehole and should provide the intact sampler to field personnel for opening (the drive shoe and head can be loosened). Field personnel should split the spoon, scan with PID, measure sample recovery, thoroughly describe the soil lithology, note visual observations and odors, note degree of saturation, and where applicable collect soil sample(s) utilizing a stainless steel or disposable scoop. An approved, retractable knife may be used to trim the top and edges of the sample, and once prepared the sample should be containerized in appropriate sample containers.

4.5.2.2. Geoprobe®

The Geoprobe® operator will advance the drilling rods into the subsurface using a truck or track-mounted drill with a hydraulic hammer. A dedicated Geoprobe® Macro-Core® liner is inserted into the core barrel to collect continuous core samples, usually one per 4 foot interval. The Geoprobe® operator will remove the soil filled liner from the core barrel, cut the liner, and provide field personnel with the intact cores. After retrieval of the sample, the liner may be removed by field personnel and the soil core should be scanned with a PID and logged, including documentation of core recovery, soil lithology, visual observations and odors, and degree of saturation. Where applicable, field staff should remove the soil sample utilizing a stainless steel or disposable scoop and containerize in an appropriate sample container.

4.5.2.3. Hand Auger

The self-powered hand auger allows for soil from the desired interval to be collected directly through removal of the soil sample that is collected in the auger head for every six inches of advancement.

4.6 Methodology for Leaded Tank Bottoms Soil Sampling

Leaded tank bottom material is described as containing materials distinguished by distinctive rust/red to black, metallic, mostly oxidized scale materials, sometimes in a matrix of petroleum wax sludge. The approach for identifying leaded tank bottom materials is summarized below:

- If materials are encountered within the previously designated leaded tank bottom areas, matching the physical description given above for leaded tank bottoms, then samples should be collected for lead analysis.
- If total lead results are above the site-specific standard (SSS) for lead of 2,240 milligrams per kilogram (mg/kg) then samples should be analyzed for lead via Toxicity Characteristic Leaching Procedure (TCLP), EPA Test Method 1311.
- Delineated areas that exhibit soils that physically resemble leaded tank bottoms, exhibit lead concentrations greater than 2,240 mg/kg, and exceed 5 milligrams per liter (mg/l) for lead in the TCLP leachate (which is characteristically hazardous for lead) will retain the leaded tank bottom designation. If no soils are encountered that meet all three of these criteria, then the area will no longer be classified as a leaded tank bottom area.

4.7 Methodology for Monitoring Well or Recovery Well Installation

4.7.1 Well Construction

After drilling to a desired terminal depth via any of the drilling methods referenced above, permanent monitoring wells can be installed to allow access to groundwater for future monitoring and groundwater sampling. In general, monitoring wells are constructed of pipe with a slotted interval(s) (screen) through which groundwater can flow into the well from a desired water-bearing stratum. In most cases, PVC materials are utilized for monitoring well construction.

- For applications where LNAPL thickness measurement is necessary, the screened interval should extend above the presumed highest groundwater level.
- For applications where the shallowest groundwater interval is to be monitored (e.g., water-table aquifer), a single well casing is installed.
- For applications where multiple water bearing strata will be penetrated and where deep groundwater conditions are selected for monitoring, a double-cased well may be installed to prevent the vertical migration of contaminants to the deeper water bearing zone from shallower zone(s).

Each well construction type and considerations for field staff regarding how many casings are needed have been provided below.

4.7.1.1 Single Casing Construction

The most commonly installed monitoring well at the facilities have single casings and are constructed of PVC. To determine the length of screen used, seasonal groundwater table or tidal fluctuations should be considered to allow the water table to intercept the well screen throughout the year. Field personnel should advise the driller on the required well diameter, total well depth, screen interval, screen length, and slot size based on available subsurface information prior to drilling. Once the borehole is completed and the drilling crew has been advised on the desired construction, the drilling crew will thread the well screen onto an end cap at the wellhead and will lower the well into the borehole, adding lengths of casing until the terminal depth is reached.

While the well is held near the center of the borehole, the annular space between the well screen and formation is carefully backfilled with a sand filter pack, which consists of clean, sorted quartz sand sized to the formation grain size (typically #1 or #2 sand). The sand pack establishes continuity with the formation and acts as a filter to prevent soil from entering the well (the well screen slot size should be sized according to the formation median grain size to mitigate sediment intrusion, however is most commonly available from suppliers as 0.01 or 0.02-inch diameter slot size).

The sand pack should extend one to two feet above the top of well screen, and care must be taken by the driller to not bridge the sand or overshoot the top of sand target depth (particularly when installing wells through the auger stem). Above the sand pack, a seal (grout) is installed in the annular space between the well casing and the soil. The seal is comprised of hydrated bentonite, sometimes amended with pellets or a grout consisting of hydrated Portland cement, bentonite powder, or a blend of the two. A conventional grout blend is 95% Portland cement and 5% bentonite powder. The purpose of the seal is to prevent surface water from infiltrating the well screen. It is installed from the top of the sand to one to two feet below ground surface.

In circumstances where the top of well sand terminates below the water table (e.g., deeper groundwater or submerged screen), grout should be mixed into a slurry at the ground surface and pumped via tremmie pipe or hose to prevent bridging. Above the well seal, the annular space can be backfilled with granular bentonite or concrete. A cement cap or well pad is placed at the surface to further mitigate potential infiltration of surface water. A locking, steel protective casing (stand pipe) or a locking, flush-mounted curb box should be installed to protect the well.

4.7.1.2 Double Casing Construction

Construction of a double cased well is similar to that of a single case well; however, to prevent groundwater infiltration from shallower water bearing zones, a second casing is installed through a surface casing. This type of construction requires drilling two different diameter boreholes.

During drilling through the shallower groundwater bearing zone(s), a larger diameter borehole is drilled and should be sized according to the desired well and/or outer casing diameter. This may require reaming of the borehole depending on the conditions and drilling equipment. An outer (surface) casing is installed and the annulus is grouted. After the outer casing is installed and the grout has set, the borehole is advanced through the surface casing with a smaller diameter drill stem and bit. When the desired terminal depth is reached, a monitoring well is installed through the inner casing using the above-referenced single casing construction procedure (the annular space between the outer and inner casings above the well filter sand should be pressure grouted).

4.7.2 Handling of Soil Cuttings

Soil cuttings generated during drilling will be containerized or stockpiled on plastic until sampling and analytical data can be obtained. Soil cutting final placement (onsite soil reuse or offsite disposal) will be performed in accordance with Pennsylvania Department of Environmental Protection (PADEP) approved onsite soil reuse plans for each facility.

4.7.3 Well Development

After installation, monitoring wells will be developed to remove residual soil from within the well and filter media and to establish communication between the well and formation. Pump and surge methodology, either through use of a ditch pump or air compressor connected to black polyethylene pipe and surge block, should be utilized to successively agitate relatively clear groundwater from the well. Surging should begin from the bottom of the screened interval and continue iteratively to the top of the well screen in approximately 2 to 4-foot intervals (i.e., pump and surge each 2 to 4 foot interval of well screen several times until relatively clear discharge water is maintained, then move up to the next screen interval until all of the screen has been developed).

Alternately, a submersible pump may be used to pump water from the screened interval of shallow wells, with the screen of the well surged to evacuate silt that remains in the sand pack. The well should be alternately surged and purged until groundwater flowing from the well appears relatively free of sediments. A vacuum truck may be used for development for wells that contains product. Well development water should be managed/treated in accordance with the site-specific work plan.

4.8 Documentation

All site activities and conditions at the time of soil sampling, well installation, and well development should be recorded by field personnel in a field computer via the EDGE application or, if necessary, a field book may be used. The entry shall include the date, time, weather conditions, location (well or boring name), personnel present onsite, and the aforementioned lithologic data and well construction information. The entry shall include detailed data required to create representative soil boring lithologic logs and well as-built logs (if a well is constructed). This data should include but not be limited to soil type, soil texture (e.g., USCS), soil color, relative moisture content, depth of apparent water table, PID readings, blow counts (if split spoon samples are collected), sample recovery, total depth of borehole, length of well screen, length of well casing, sand pack interval, filter sand size, grout materials used, well seal interval, and all well construction materials. Notes should also include well development pumping rate, duration, and observations. Additional comments or observations should also be recorded, as appropriate.

5.0 LIGHT NON-AQUEOUS PHASE LIQUID (LNAPL) SAMPLING PROCEDURES

5.1 Potential Hazards

Traffic, pinch points, chemical (airborne and physical contact), and biological are all likely hazards to be encountered during LNAPL sampling, as well as slip/trip/fall potential. Additional hazards may be mentioned in the site-specific HASP and/or the daily JSA. If significant amounts of LNAPL are being handled, a Tyvek suit should also be worn.

5.2 Materials and Equipment Necessary for Task Completion

A list of equipment required to sample LNAPL from a monitoring well is presented below:

- Current site map detailing well locations;
- Field book or field computer for recording site data;
- Optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy;
- Keys and tools to provide well access;
- Appropriate sample containers and labels. LNAPL samples will be collected in laboratory provided glassware with appropriate preservative, if applicable. A minimum of 10 ml is required for most laboratory analyses. In the case that sufficient volume is not obtained, a swabbing technique (described below) could be used;
- Sorbent pads (required for swabbing technique);
- Stainless steel or clear bottom-loading or top-loading bailer, depending on product thickness;
- Clean nylon or polypropylene bailer cord;
- Decontamination supplies;
- Blank chain-of-custody forms; and
- Cooler and ice for sample preservation.

5.3 Decontamination Requirements

During LNAPL sampling activities, dedicated sampling equipment (i.e., clear bailers, nitrile gloves, and bailer cord) may be utilized; thereby, minimizing decontamination requirements. However, a stainless steel bailer may be used and decontaminated between LNAPL sampling locations. The optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy used to record the presence or absence and approximate thickness of LNAPL prior to sampling also requires decontamination between sampling locations. Decontamination procedures are detailed in Section 1.5.

5.4 Sampling Procedure

Immediately prior to sampling, each monitoring well should be gauged to obtain liquid levels (i.e., depth to LNAPL and depth to water) for estimation of current LNAPL thickness. Refer to Section 3.0 for appropriate well gauging procedures. Liquid level data should be recorded in a field book or field computer through the EDGE application or, if necessary, a field book.

LNAPL sampling may be performed via two different methods, based upon the LNAPL thickness/availability at the time of sampling: direct sample or swabbing. As indicated above, a minimum LNAPL volume of 10 mL is typically required by the analytical laboratory for most LNAPL characterization.

The following sequence of procedures will be implemented for the collection of LNAPL samples from monitoring wells:

1) A clean work area will be established so that sampling equipment will not come in contact with the ground surface or any other potentially contaminated surfaces near the wellhead.
2) A pre-cleaned stainless steel bailer or dedicated disposable bailer will be used for each well.
3) A new pair of nitrile gloves will be worn during sampling and replaced for each well.
4) Based on the gauged depth to LNAPL, an appropriate length of dedicated nylon or polypropylene cord will be tied to the sampling bailer.
5) An appropriately sized (i.e., 40 ml glass vial with plastic cap fitted with Teflon® lined septum) laboratory-provided sample container will be used to containerize the LNAPL sample.

6) The sampling bailer will be slowly lowered into the well until the liquid level is encountered. Once encountered, the sampling bailer should be lowered into the standing liquid column to a depth of approximately 1 foot, or other appropriate depth based on product thickness.

7) The bailer should be retrieved at a steady rate to avoid excess agitation.

8) The bailed sample should be visually evaluated for the presence or absence of LNAPL. If sufficient LNAPL volume is present (>10 ml), a direct sample of the LNAPL will be collected into the laboratory vial. If less than 10 ml of LNAPL is apparent, a sorbent pad may be used to absorb the LNAPL from the surface of the groundwater sample and the swab placed in the laboratory vial. The site-specific work plan should dictate whether a swab sample should be analyzed, or if the well should be monitored at a later date for re-sampling.

9) Labels will be completed and attached to the sample vials, indicating the sample collector's name, date, time, and location of sample; record same data in field computer or field notebook.

10) Store samples in a secure location until possession is transferred to the laboratory.

11) Nitrile gloves, bailer, bailer cord, and any other trash will be disposed of as solid waste.

5.5 Documentation

All site activities and conditions at the time of sampling should be recorded by field personnel in a field computer via the EDGE application or, if necessary, a field book may be used. The entry shall include the date, time, weather conditions, location (well name), personnel present onsite, and the aforementioned well gauging parameters. Additional comments or observations (e.g., color or apparent viscosity of LNAPL) should be recorded.

6.0 INDOOR AND AMBIENT AIR SAMPLING PROCEDURES

In preparation for indoor and/or ambient air sampling, appropriate facility personnel should be notified of intended sampling prior to mobilization. The purpose of this would be to confirm that there are not any non-routine activities occurring in the building, such as painting of indoor walls, which would cause incidental contamination of the samples.

6.1 Materials and Equipment Necessary for Task Completion

A list of equipment required to collect indoor and/or ambient air samples is presented below:

- Field data book or field computer for recording site data;
- Laboratory certified Summa canisters (standard size is 6 liters);
- Flow controllers (standard duration is 8-hours) with integrated vacuum gauge;
- Equipment for elevating sample intake height (examples: extended sampling inlets, zip ties to attach units to fencing, tables, etc);
- Camera; and
- Blank chain-of-custody forms.

6.2 Precautions to Avoid Incidental Contamination

EPA Method TO-15 is the most common method used for analysis of air samples at these sites. This method is highly sensitive to trace concentrations of volatile organic compounds (VOCs). To avoid incidental contamination:

- Do not wear cologne or fragrance on day of sampling;
- Do not use hand sanitizers or lotions;
- Do not store canisters near containers of gasoline, or any fuel; and
- Make sure there are no sources of VOCs in the vehicle used to transport the canisters.

6.3 Sampling Procedure

1) Set Up Summa Canister. Inlets of the flow controllers are to be placed in the breathing zone, approximately 4 to 6 feet above the ground surface. Elevate Summa canisters using appropriate materials available onsite or use laboratory-provided extended inlets (approximately 3 ft long sampling canes). Indoor air samples should be representative of air

in the buildings and should be placed away from obvious ventilation to outdoor air or sources of VOCs. Securely attach flow controller and extended sampling inlet if applicable.

2) Start Air Sample Collection. Open the valve. Document the initial vacuum (should be between approximately -30 inHg and -26 inHg) and the start time of the test. If the vacuum is significantly outside of the range or has a high rate of change, consider using an alternate canister or flow controller as there may be leakage.
3) Monitoring Summa Condition During Sampling Period. Several times during the sampling period, verify that the Summa is in good condition and that the vacuum is decreasing at an appropriate rate several times during the sampling period. An example of a reasonable frequency would be every two hours during an 8-hour event. During these checks, record the time, remaining vacuum, and canister condition. If necessary, obtain a permit to operate a camera, and take a least one photo of each sampling location.
4) Completing Air Sample Collection. Near the end of the sampling period, monitor the gauge more frequently. The sample collection should be stopped when the gauge reads approximately -5 inHg. At this point, close the canister valve. Record the sample end time and sample end vacuum. Ensure that the canister is labeled with the sample ID. Remove all of the attached equipment from the canister. Pack the canisters, flow controller wrapped in bubble wrap, chain of custody (additional information in the following section), and any other laboratory provided equipment back into the original packaging.

6.4 Documentation

All site activities and conditions at the time of air sampling should be recorded by field personnel. The entry shall include the date, time, weather conditions (including wind direction and start/end barometric pressure), sample locations and IDs, and personnel present onsite. Any observation that could influence the level of VOCs in the samples should be noted.

7.0 SURFACE WATER SAMPLING PROCEDURES

7.1 Field Procedures for Surface Water Sampling

7.1.1 General

Surface water sampling is performed to obtain samples for surface water bodies that are representative of existing surface water conditions. Surface water sampling (or gauging) within 3 feet of a bulkhead at certain facilities will require field personnel to wear a life vest.

Surface water sampling locations for surface water quality and groundwater interaction studies are selected based on the following:

1) Study objectives
2) Location of point surface discharges
3) Non-point source discharges and tributaries
4) Presence of structures (e.g., bridge, dam)
5) Accessibility

During surface water sampling it is important to obtain samples that are not impacted by the re-suspension of sediment produced because of improper or poor surface water sampling techniques.

7.1.2 Surface Water Sample Location Selection

Prior to conducting surface water sampling activities, the first requirement is the consideration and development of surface water sampling locations. It is important that all surface water sampling locations be selected in accordance with the work plan.

Wading for surface water samples increases the chances of disturbance of sediments from the floor of the surface water body. When wading for surface water samples be aware of potential safety and health risks. A life vest and safety line must be worn at all times where footing is unstable or when sampling in fast moving or more than 3 feet (0.9 m) deep. A two-person team is required for most surface water sampling activities. If the site conditions require the use of the life vest and safety line, the two people involved in the sampling must be competent swimmers.

Surface water samples must be collected with no suspended sediments. Surface water samples are collected commencing with the furthest downstream location to avoid sediment interference with upstream locations.

7.1.2.1 Rivers, Streams, and Creeks

Surface water samples are generally collected in areas of surface water bodies that are representative of the surface water body conditions. Representative surface water samples will usually be collected in sections of surface water bodies that have a uniform cross section and flow rate. Mixing is influenced by turbulence and water velocity, therefore the selection of surface water sampling locations immediately downstream of a riffle area (i.e., fast flow zone) will ensure good vertical mixing. These locations are also likely areas for deposition of sediment since this occurs in areas of decreased flow velocity.

Surface water sampling locations should not be established in areas near point source discharges. Surface water sampling of these source discharge points can be performed to assess the impact of these source areas on overall surface water quality. Sample tributaries as close to the mouth as possible. It is important to select surface water sample locations considering the impact downstream, including tributary flow and sediment.

In all instances, properly document all surface water sampling locations. Documentation may include photographs and tie-ins to known structures.

7.1.2.2. Sampling Equipment and Techniques

When collecting surface water samples, direct dipping of the sample container into the stream or water is acceptable unless the sample container contains preservatives. If preserved, a pre-cleaned unpreserved sample container should be used to collect the surface water sample. The surface water sample is then transferred to the appropriate preserved sample container. When collecting surface water samples, submerse the inverted bottle to the desired sample depth and tilt the opening of the sample container upstream to fill. During surface water sample collection, wading or movement may cause sediment deposits to be re-suspended and can result in biased samples. Wading is acceptable if the stream has a noticeable current and the samples are collected directly in the sample container when faced upstream. If the stream is too deep to wade in or if addition samples must be collected at various depths, additional sampling equipment will be required. Surface water samples should be collected about 6 inches (15 cm) below the surface, with the sample bottles being completely submerged. Taking the surface water sample at this depth eliminates the collection of floating debris in the sample container.

Surface water sample collection where the flow depth is less than 1 inch (<2.5 cm) requires the use of special equipment to eliminate sediment disturbance. Surface water sampling may be conducted with a container then transferred to the appropriate sample container, or collection may be performed using a peristaltic pump. A small excavation in the stream bed to create a sump for sample collection can also be considered but should be prepared in advance to allow all the sediment to settle prior to surface water sampling activities.

Teflon™ bailers can be used for surface water sampling if it is not necessary to collect surface water samples at specific depths. A bottom loading bailer with a check ball is sufficient. When the bailer is lowered through the water, the water is continually displaced through the bailer until the desired depth is reached. The bailer is retrieved and the check ball prohibits the release of the collected surface water sample. Bailers are not suitable in surface water bodies with strong currents, or where depth-specific sampling is required. For discrete and specified depth surface water sampling, and the parameters to be monitored do not require a Teflon™ coated sampling device, a standard Kemmerer or Van Dorn sampler can be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the sampler ends open while the sampler is being lowered. The sampler is lowered in a vertical position to allow water to pass through. The Van Dorn sampler is plastic and is lowered in a horizontal position. For both samplers, a messenger is sent down a rope when the sampler has reached the required depth. The messenger causes the stopper on the sampler to close. The sampler is then retrieved and the surface water sample can be collected through a valve. DO sample bottles can be filled by allowing overflow using a rubber tube attached to the valve. During depth-specific surface water sampling, take care not to disturb bottom sediments.

Glass beakers or stainless steel cups may also be used to collect surface water samples if parameter interference does not occur. The beaker or cup must be rinsed at least three times with the surface water sample prior to sample collection.

All equipment must be thoroughly decontaminated.

7.1.2.3 Field Notes for Surface Water Sampling

Record daily surface sampling activities, describe surface water sampling locations, sampling techniques, and, if applicable, provide a description of photographs taken. Visual observations are important and provide valuable information when interpreting surface water quality results. Observations include:

1) Weather conditions
2) Stream flow directions
3) Stream physical conditions (width, depth, etc.)
4) Tributaries
5) Effluent discharges
6) Impoundments
7) Bridges
8) Railway trestles
9) Oil sheens
10) Odors
11) Buried debris
12) Vegetation
13) Algae
14) Fish and other aquatic life
15) Surrounding industrial areas

The following factors should be considered for surface water sampling:

1) Predominant Surrounding Land Use: Observe the prevalent land use type in the vicinity and note any other land uses in the area which, although not dominant, may potentially affect surface water quality.

2) Local Watershed Erosion: Note the existing or potential erosion of soil in the local watershed and its movement into the stream. Erosion can be rated through visual observation of watershed stream characteristics including increases or decreases in turbidity.

3) Local Watershed Non-Point Source Pollution: This refers to problems or potential problems other than erosion and sedimentation. Nonpoint source pollution can be diffuse agricultural and urban runoff. Other factors may include feed lots, wetlands, septic systems, dams, impoundments, and mine seepage.

4) Estimated Stream Width: The estimated distance from shore at a transect representative of the stream width in the area.

5) Estimated Stream Depth: Riffle (rocky area), run (steady flow area), and pool (still area). Estimate the vertical distance from the water surface to the bottom of the surface water body at a representative depth at three locations.

6) High Water Mark: Estimate the vertical distance from the bank of the surface water body to the peak overflow level, as indicated by debris hanging in bank or flood plain vegetation, and deposition of silt. In instances where bank flow is rare, high water marks may not be evident.

7) Velocity: Record or measure the stream velocity in a representative run area.

8) Dam Present: Indicate the presence or absence of a dam upstream or downstream of the surface water sampling location. If a dam is present, include specific information detailing the alteration of the surface water flow.

9) Channelized: Indicate if the area surrounding the surface water sampling location is channelized.

10) Canopy Cover: Note the general proportion of open to shaded areas which best describes the amount of cover at the surface water sampling location.

7.2 References

For additional information pertaining to surface water sampling, the user of this manual may reference the following:

ASTM D5358 Practice for Sampling with a Dipper or Pond Sampler

ASTM D4489 Practices for Sampling of Waterborne Oils

ASTM D3325 Practice for the Preservation of Waterborne Oil Samples

ASTM D4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents

ASTM D4411 Guide for Sampling Fluvial Sediment in Motion

ASTM D4823 Guide for Core-Sampling Submerged, Unconsolidated Sediments

ASTM D3213 Practice for Handling, Storing, and Preparing Soft Undisturbed Marine Soil

ASTM D3976 Practice for Preparation of Sediment Samples for Chemical Analysis

ASTM E1391 Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing

ASTM D4581 Guide for Measurement of Morphologic Characteristics of Surface Water Bodies

ASTM D5906 Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths

ASTM D5073 Practice for Depth Measurement of surface water

8.0 SEDIMENT SAMPLING PROCEDURES

8.1. Introduction

Sediment sampling is conducted to obtain samples that are representative of existing chemical and/or physical conditions of sediment.

8.2 Equipment Decontamination

On environmental sites, sediment sampling equipment (e.g., split spoons, trowel, spoons, shovels, bowls, dredges, corers, scoops) are typically cleaned as follows:

1) Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates.
2) Rinse with tap water.
3) Rinse with deionized water.
4) Air dry for as long as possible.

Additional or different decontamination procedures may be necessary if sampling for some parameters, including VOCs and metals.

8.3 Sample Site Selection

Before any sampling is conducted, the first requirement is to consider suitable sampling locations. Sampling locations should be selected in accordance with the work plan. Wading for sediment samples in lagoons, lakes, ponds, and slow-moving rivers and streams must be done with caution since bottom deposits are easily disturbed. Sampling must only be attempted where safe conditions exist and samples must be collected from undisturbed sediments. All sediment samples are to be collected commencing with the most downstream sample to avoid sediment interference with other downstream samples. A life vest and safety line should be worn in all cases where footing is unstable or where water is fast moving or over 3 feet (0.85 m) in depth. A second person may also be required for most of the sampling scenarios.

8.3.1. Rivers, Streams, and Creeks

Sediment samples may be collected along a cross-section of a river or stream in order to adequately characterize the bed material, or from specific sediment deposits as described in the work plan. A common procedure is to sample at quarter points along the cross-section of the sampling site selected. Samples may be composited as described in the work plan. Samples of dissimilar composition (e.g., grain size, organic content) should not be combined. Representative samples can usually be collected in portions of the surface water body that have a uniform cross-section and flow rate. Since mixing is influenced by turbulence and water velocity, the selection of a site immediately downstream of a riffle area (e.g., fast flow zone) are likely areas for deposition of sediment since the greatest deposition occurs where stream velocity slows.

A site that is clear of immediate point sources (e.g., tributaries and industrial and municipal effluents) is preferred for the collection of sediment samples unless the sampling is being performed to assess these sources.

8.4 Sampling Equipment and Techniques

8.4.1. General

Any equipment or sampling technique(s) [e.g., stainless steel, polyvinyl chloride (PVC)] used to collect a sample is acceptable so long as it provides a sample which is representative of the area being sampled and is consistent with the work plan.

8.4.2. Sediment Sampling Equipment and Techniques

A variety of methods may be used to collect sediment samples from a stream, river, or lake bed. Dredging (Peterson, Ponar, Van Veen), coring and scooping are acceptable sediment sample collection techniques. Precautions shall be taken to ensure that a representative sample of the targeted sediment is collected. Caution should be exercised when wading in shallow water so as not to disturb the area to be sampled. Samplers should be selected based on the interval to be sampled, type of sediment/sludge (silt, sand, gravel), and required sample volume. More than one sampler is often required to implement a sampling program at a site. The following describes some of these methods. Manufacturer's information should be consulted to determine the limitations of each type of sampling equipment.

8.4.3 Dredging

The Peterson dredge is best used for rocky bottoms, in very deep water, or when the stream velocity is rapid. The dredge should be lowered slowly as it approaches the bottom, so as to not disturb the lighter sediments.

The Ponar dredge is similar to the Peterson dredge in size and weight. The Ponar dredge is a "clam-shell" type unit that closes on contact with the river/lake bottom. Depending on the size of the unit, a winch is required for larger units, whereas smaller units are available for lowering by a hand line. Once retrieved, the unit is opened and the sample extracted using a sample scoop or spoon. The unit has been modified by the addition of side plates and a screen on top of the sample compartment. This permits water to pass through the sampler as it descends.

The Ponar grab sampler functions by the use of a spring-latch-messenger arrangement. The sampler is lowered to the bottom of the water body by means of a rope, then the messenger is sent down to trip the latch causing the sampler to close on the sediments. The sampler is then raised slowly to minimize the disturbance of the lighter sediments. Sediment is then placed into a stainless steel bowl, homogenized, and placed into the appropriate sample container (if collecting for VOC parameters, fill the VOC jars before homogenization).

8.4.4. Corers

Core samplers are used to obtain vertical columns of sediment. Many types of coring devices are available, depending on the depth of water from which the sample is to be collected, the type of bottom material, and the length of core to be obtained. They vary from hand-push tubes to weight or gravity-driven devices to vibrating penetration devices.

Coring devices are useful in contaminant monitoring due to the minimal disturbance created during descent. The sample is withdrawn intact, allowing the removal of only those layers of interest. Core liners consisting of plastic or Teflon may also be added, thereby reducing the potential for sample contamination and maintaining a stratified sample. The samples may be shipped to the lab in the tubes in which they were collected. The disadvantage of coring devices is that only a small sampling surface area and sample size is obtained, often necessitating repetitive sampling in order to collect the required amount of sediment for analysis. It is also often difficult to extract the sediment sample back out through the water column without losing the sample.

The core tube is pushed/driven into the sediment until only 4 inches (10 cm) or less of tube is above the sediment-water interface. When sampling hard or coarse sediments, a slight rotation of the tube while it is pushed will create greater penetration and reduce compaction. Cap the tube with a Teflon plug or a sheet of Teflon. The tube is then slowly withdrawn, keeping the sample in the tube. Before pulling the bottom part of the core above the water surface, it must be capped.

8.4.5 Scooping

The easiest way to collect a sediment sample is to scoop the sediment using a stainless steel spoon or scoop. This may be done by wading into the stream or pond and, while facing upstream (into the current), scooping the sample from along the bottom in an upstream direction. This method is only practical in very shallow water.

8.4.6 Mixing

Sediment samples collected for chemical analysis should be thoroughly mixed (except for VOCs) in a stainless steel bowl prior to placement in the appropriate sample container. Standard procedures exist for preparation of sediment samples (ASTM D3976). These should be followed or the laboratory informed of applicable procedures.

8.4.7 Air Monitoring

Prior to sediment/sludge sampling, measure the breathing space above the sample location with a PID, should the potential for volatiles be present, and use a hydrogen sulfide meter should hydrogen sulfide be present. Repeat these measurements during sampling. If either of these measurements exceed any of the air quality criteria established in the HASP, air purifying respirators (APRs) or supplied air systems will be required.

8.4.8 Sample Location Tie-In/Surveying

The recording of the sample locations and depth on the site plan is extremely important. This may be accomplished by manual measurement (i.e., swing ties), global positioning system (GPS) survey, or stadia methods. Manual measurements for each sample location should be tied into three permanent features (e.g., buildings, utility poles, hydrants). Diagrams with measurements should be included in the field book.

8.5 Field Notes

A bound field book is used to record daily activities, describe sampling locations and techniques, and describe photographs (if taken). Visual observations are important, as they may prove invaluable in interpreting water or sediment quality results. Observations shall include (as applicable) weather, stream flow conditions, stream physical conditions (width, depth, etc.), tributaries, effluent discharges, impoundments, bridges, railroad trestles, oil sheens, odors, buried debris, vegetation, algae, fish or other aquatic life, and surrounding industrial areas. The following observations should be considered:

- Predominant Surrounding Land Use: Observe the prevalent land use type in the vicinity (noting any other land uses in the area which, although not predominant, may potentially affect water quality).
- Local Watershed Erosion: The existing or potential erosion of soil within the local watershed (the portion of the watershed that drains directly into the stream) and its movement into a stream is noted. Erosion can be rated through visual observation of watershed and stream characteristics. (Note any turbidity observed during water quality assessment.)
- Local Watershed Non-point Source Pollution: This item refers to problems and potential problems other than siltation. Non-point source pollution is defined as diffuse agricultural and urban runoff (e.g., stormwater runoff). Other compromising factors in a watershed that may affect water quality are feedlots, wetlands, septic systems, dams and impoundments, and/or mine seepage.
- Estimated Stream Width: Estimate the distance from shore at a transect representative of the stream width in the area.

- Estimated Stream Depth: Riffle (rocky area), run (steady flow area), and pool (still area). Estimate the vertical distance from water surface to stream bottom at a representative depth at each of the three locations.
- High Water Mark: Estimate the vertical distance from the stream bank to the peak overflow level, as indicated by debris hanging in bank or floodplain vegetation, and deposition of silt or soil. In instances where bank overflow is rare, a high water mark may not be evident.
- Velocity: Record an estimate of stream velocity in a representative run area (see Section 12.0).
- Dam Present: Indicate the presence or absence of a dam upstream or downstream of the sampling station. If a dam is present, include specific information relating to alteration of flow.
- Channelized: Indicate whether the area around the sampling station is channelized.
- Canopy Cover: Note the general proportion of open to shaded area which best describes the amount of cover at the sampling station.
- Sediment Odors: Disturb sediment and note any odors described (or include any other odors not listed) which are associated with sediment in the area of the sampling station.
- Sediment Oils: Note the term which best describes the relative amount of any sediment oils observed in the sampling area.
- Sediment Characteristics: Note the grain size, color, consistency, layering, presence of biological organisms, man-made debris, etc. in accordance with standard ASTM soil description protocols.
- Sediment Deposits: Note those deposits described (or include any other deposits not listed) which are present in the sampling area. Also indicate whether the undersides of rocks not deeply embedded are black (which generally indicates low dissolved oxygen or anaerobic conditions).

8.6 References

For additional information pertaining to this topic, the user of this manual may reference the following:

ASTM D5358	Practice for Sampling with a Dipper or Pond Sampler
ASTM D4489	Practices for Sampling of Waterborne Oils
ASTM D3325	Practice for the Preservation of Waterborne Oil Samples

ASTM D4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents
ASTM D4416 Guide for Sampling Fluvial Sediment in Motion
ASTM D4823 Guide for Core-Sampling Submerged, Unconsolidated Sediments
ASTM D3213 Practice for Handling, Storing, and Preparing Soft Undisturbed Marine Soil
ASTM D3976 Practice for Preparation of Sediment Samples for Chemical Analysis
ASTM E1391 Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing
ASTM D4581 Guide for Measurement of Morphologic Characteristics of Surface Water Bodies
ASTM D5906 Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths
ASTM D5073 Practice for Depth Measurement of Surface Water
ASTM D5413 Test Methods for Measurement of Water Levels in Open-Water Bodies

9.0 SLUG TEST PROCEDURES

9.1 Materials and Equipment Necessary for Task Completion

Water level (data) logger capable of recording pressure and/or depth at sub-second time intervals (preferably a vented logger capable of advanced logging modes); vented, direct-read cable of sufficient length (with dessicant); interface tape/probe or water level meter; solid (mechanical) slug, pneumatic slug, or packer system [the introduction or removal of water is not recommended (e.g., bailer or bucket)]; 5 gallon bucket, traffic cones and/or barricades, deionized or distilled water and Alconox®; decontamination bucket and brush; and laptop computer or rugged reader.

9.2 Decontamination Requirements

Equipment utilized during slug testing must be thoroughly decontaminated with Alconox® and deionized/distilled water prior to and between uses at each test well to prevent cross contamination between wells. Any groundwater removed from the well during testing must be containerized and either treated and discharged to ground surface, or disposed of in an approved manner, preferably in a properly installed, onsite holding tank. If LNAPL is encountered/recovered, it should be containerized and properly disposed onsite. However, the preferred test initiation methods (solid and/or pneumatic slug) do not generate any groundwater.

9.3 Methodology for Slug Testing

Slug tests are utilized to provide in-situ estimations of hydraulic conductivity (k) in saturated media, most often in geologic formations that exhibit aquifer properties (low k media can also be tested with special consideration). Slug tests involve rapidly displacing the static water level in a well, and analyzing the well's rate and pattern of recovery back to near-static conditions. Falling head or slug-in tests involve analysis of displacement due to the addition of volume, and rising head or slug-out tests involve the analysis of displacement due to the removal of volume. Displacement is initiated using either a solid or pneumatic slug. Water level response is monitored immediately following the initial displacement and for the ensuing time period until the water level has returned to near-static level (generally within 5% of static). Water level response should be recorded using a water level (data) logger capable of recording pressure and/or depth at sub-second time intervals (preferably a vented logger). Logarithmic logging modes are preferred to shorten the data file while still providing high resolution data just after test initiation.

9.4 Field Procedures

1) Test Well Construction and Configuration - Well construction details are needed to perform slug test calculations and are important considerations when selecting appropriate wells for testing. Important as-built details include: total well depth, well screened interval(s), depth to (static) water, casing diameter, screen diameter, filter pack diameter, filter pack size, and filter pack interval. While these details should be documented on the well log, static water level and total well depth should be field-confirmed before the test. Of particular importance to the testing procedure is the relationship between static water level and well screened interval, and the degree of well development. Test results for poorly or insufficiently-developed wells may be strongly affected by drilling debris/disturbance in the formation that can create skin effects, lowering the apparent formation k. Analysis of testing data for wells screened across the water-table should consider drainage of the filter pack media. In addition, a pneumatic slug assembly should not be utilized unless the test well is screened below the water table and the water level remains above the screen throughout the test.

2) Test Setup and Initiation - Upon arrival, the test well should be gauged for static depth to water and total well depth so that the total water column length can be estimated. Well gauging data should be recorded in a rugged reader using an EDGE file, if available, or field form or book.

   a. Solid Slug
   The displacement volume of the slug is needed. It is suggested that the slug be prefabricated and calibrated for displacement volume prior to site use. Calculate the expected initial well displacement, using the slug volume and well casing radius, and deploy the data logger/cable to a depth just below that level while considering the slug length (to avoid conflict and tangling of the slug and transducer). Also consider the submergence depth limit of the data logger (usually indicated on the logger body). Generally, placing the data logger a foot or two below the bottom of the slug is good practice. Once submerged, allow the

data logger temperature to equilibrate with groundwater prior to initiating the test (up to 30 minutes).

While the data logger temperature equilibrates, secure the slug to an adequate length of disposable string or rope and hang in the well to a depth just above the water surface. Mark the string/rope to accommodate the slug length and tie off. Using the rugged reader or field computer, set up a new test (logarithmic mode or sub-second recording interval) in the data logger supplied software and start the test. Indicate in the file name the type of test and test number (e.g., rising or falling head; test 1 or 2). Once logging is initiated, quickly and smoothly lower the slug (slug-in or falling head test) to the submerged depth and tie off the string/rope (displacement should be instantaneous). Monitor the data logger data until the water level has returned to near-static level. Stop the falling head test.

Without moving the slug or data logger, set up a new test in the data logger supplied software with the same settings and indicate in the file name the type of test being performed (rising head or slug out). Start the test and once the data logger is running, instantaneously lift the slug and tie off the string/rope to its pre-test position (just above static). Monitor the data being recorded by the data logger and stop the test when the water level has returned to near-static.

b. Pneumatic Slug

If a high formation k is anticipated, solid slug removal is found to be too slow to capture well recovery, or to minimize equipment decontamination for wells with submerged screens, a pneumatic slug assembly should be utilized.

Open air release valve, secure pneumatic slug assembly to well casing and tighten coupling to provide an air tight seal. Insert the data logger/cable and deploy to the target submergence depth [it is generally best to keep the data logger shallow (~1-2 feet below static water level) and use small initial displacements to avoid dynamic recovery effects in high k formations]. Close the air release valve and attach the air pump or compressor. Pressurize the well and use the pressure gauge to set initial displacement. Check for air leaks using a soapy water mixture and sprayer (assembly must be air tight). Allow the water level to return to static and remove the air pump. Using the rugged reader or field computer, set up a new test (logarithmic mode or sub-second recording interval) in the data logger supplied software and start the test. Indicate in the file name the type of test and test number (e.g., rising head; test number). Once logging is initiated, open the air release valve and monitor the test data. Stop the test when the water level has returned to near-static.

3) Test Monitoring and Guidelines - The following are general guidelines for slug testing performance as published by Midwest Geosciences Group in “Field Guide for Slug Testing and Data Analysis:”

- Conduct at least three or more tests per well and if possible conduct both rising and falling head test data.
- Use two or more initial displacement values (2 slug sizes or air pressures applied) that vary by an order of magnitude or more.
- Final slug test initial displacement should be nearly equivalent to the first test’s displacement.
- Allow tests to run until near-static conditions are achieved (+/- 5% of static)
- Digital slug test data files collected with the data loggers and/or EDGE files should be backed up to either a thumb drive, corporate email server, and/or corporate file server immediately after collection.

4) Test Data Reduction and Processing - Prior to slug test analyses, digital data logger files should be normalized so that multiple tests conducted on the same test well can be compared for the assessment of test validity and well conditions. Reducing the data as follows:

- From each raw data file, estimate the time of test initiation and the head (depth or pressure) under static conditions.

- In each slug test data file, subtract the time of test initiation from the elapsed time and save to a new field (normalized time or test time; start of test should be time zero).
- In each slug test data file, subtract the static pressure head from the test period pressure head values and save to a new field (deviation from static).
- To normalize the deviation from static values, divide that field by the displacement expected based upon the slug volume or air pressure head applied.
- Create a graphical plot of the normalized head data versus test time for each test performed on the test well. Review the data plots and confirm that the testing data for each repeat test roughly concur. Also confirm that the actual and expected initial displacements are nearly equal.
- If repeat testing data and/or expected versus actual initial displacements vary widely, review well completion details and testing methods prior to performing further analysis (step 5 below) as the results may not be valid (e.g., the well screen interval may be poorly developed or fouled, the data logger may have moved or placed too deep in the well, slug was removed too slowly). The well may need to be retested.

5) Test Data Analysis - For the purposes of this standard operating procedural document, it is assumed that slug test analysis software will be used to apply standard solution methods to the testing data. Various computer programs are available, such as AQTESOLV Professional. Choose an appropriate test solution method by considering the following well configurations (in AQTESOLV, use the Solution Expert):

   a. Submerged Screen and/or Confined Aquifer Well - If the well screen fully penetrates the intersecting aquifer, utilize the Cooper et al. Model or Hvorslev Model and analyze the curve match and/or best fit. If well is partially penetrating a confined formation, utilize the KGS Model or Hvorslev Model. If well screen is submerged in an unconfined formation, utilize the KGS Model or Bouwer and Rice Model.

b. Water-Table Intersects Well Screen - If the well screen is intersected by the water table, utilize the Bouwer and Rice Model (double straight line effect) or KGS Model.

c. Rapid Well Recovery in High k Formations - If well response to displacement is extremely rapid and normalized head plots display an oscillatory or concave-downward form, utilize the Butler and Zhan Model (most comprehensive solution available) or High-k Hvorslev Model for confined wells, or the High-k Bouwer and Rice Model.

9.5 Limitations

In general, results of slug test data analyses provide an initial estimate of formation k and have a small scale of relevance (particularly in high k settings). Slug tests can be strongly affected by the degree of well development and can be used diagnostically to assess the degree of well development. In most cases, slug testing should be performed on several wells in an area of interest to develop an understanding of the formation characteristics (e.g., heterogeneous or homogeneous formations).

10.0 PUMP TEST PROCEDURES

10.1 Materials and Equipment Necessary for Task Completion

Water-level (data) loggers (transducers) capable of recording pressure and/or depth at sub-second time intervals (preferably a vented logger capable of advanced logging modes for at least the pumping well); vented, direct-read cables of sufficient length (with dessicant packs); interface tape/probe or water-level meter; well pump (preferably a submersible pump), drop pipe and layflat or comparable discharge line of sufficient length, totalizing flow meter (recommended) and 5 gallon bucket, stop watch, rain gauge or nearby weather station; materials needed to monitor surface water bodies near the test site (e.g., staff gauge, weir, stakes, data logger, camera with permission from refinery personnel); traffic cones and/or barricades, deionized or distilled water and Alconox®; decontamination bucket and brush; laptop computer or rugged reader; portable generator or other power supply appropriate for the submersible pump; and containment (e.g., frac tank) or activated carbon filtration for the temporary staging or filtering of discharge water.

10.2 Decontamination Requirements

Equipment utilized during pumping tests must be thoroughly decontaminated with Alconox® and deionized/distilled water prior to and between uses at each test well to prevent cross contamination between wells. Any groundwater removed from the tested well must be containerized and either treated (filtered as appropriate) and discharged to ground surface, or disposed of in an approved manner, preferably in a properly installed, onsite holding tank. If LNAPL is encountered/recovered, it should be containerized and properly disposed of on or off-site.

10.3 Methodology for Pump Testing

10.3.1 Pre-test Considerations

In general, pumping tests are performed to estimate large-scale in-situ hydraulic properties of water-bearing strata in the subsurface (i.e., transmissivity and storativity) and average out local-scale heterogeneity that can limit the applicability of smaller-scale testing methods, such as slug tests. The geographical area influenced by a pumping test will be determined by the hydraulic properties of the strata being tested (including hydraulic properties of other strata supplying recharge to the pumped formation), boundary conditions, and on the duration of the test.

Pumping tests are also commonly performed to generate drawdown data from which hydraulic boundary conditions, hydraulic flow regime (e.g., anisotropy), and aquifer type (i.e., unconfined or confined, leaky confined) may be estimated. Smaller-scale pumping tests may also be utilized to address pumping efficiency and/or signal to noise ratio (pumping rate) at the pumping well, or to assist in remedial system design. However at this scale, the assumptions of some data analysis methods may not be applicable and should be considered prior to testing.

Appropriate design of a pumping test should include review of site-specific information regarding the geology and hydrogeology of the test area. Pumping test design should also consider the goal(s) of the test (i.e., scale of application of derived aquifer properties, identification of boundary influences, sources of recharge, well efficiency). This should include review of available lithologic well logs or test boring logs, geologic maps, cross sections, structure contour maps, isopach maps, and any other available information so that a conceptual model relating geologic units to hydrostratigraphic units or water-bearing strata can be developed. Additional pre-test considerations should include identification of any potential positive or negative hydraulic barriers, tidal effects, and/or influence from other wells that may be pumping in the test area. Without sufficient knowledge of factors influencing water-levels and hydrology of the test area, test results could be misinterpreted.

Often times, budget considerations and/or time limitations will necessitate the use of an existing monitoring well as the pumping well and/or existing wells as observation points. While this is generally acceptable, the wells must be screened appropriately with respect to the goals of the test and knowledge of well construction is critical to applying test solutions. Wells should also be redeveloped prior to testing if they are relatively old or if records of sufficient well development at the time of installation are not readily available.

Pumping tests can be divided into two general classifications: step-drawdown tests and constant rate tests. Step tests typically involve pumping a well at progressively higher rates or “steps” at intervals of one or two hours per step (typically up to 3 steps). They are often used to estimate the yield a well will sustain during a constant rate pumping test and to evaluate well efficiency (frictional head losses between the screen/gravel pack and the formation). Constant rate pumping tests are used primarily to evaluate hydraulic properties of water-bearing strata for design of groundwater treatment systems and/or water supply purposes (e.g., groundwater allocation). Where budgets permit, the best pumping test approach is to first perform a step-drawdown test on the pumping well to evaluate well efficiency and sustainable yield (and to gauge whether or not the pumping well needs additional development), allow recovery to near-static conditions, and then initiate a constant rate test.

The test duration is subject to goals of the test and to budget considerations. Optimally, a constant rate test should be run until all drawdowns have stabilized or boundary conditions are identified, and gravity drainage effects are curtailed; however, this is seldom practical due to time limitations. In most instances, an 8 hour constant rate test will be adequate, and a 24 hour test will be sufficient for higher sensitivity sites. Occasionally a 72 hour pumping test is warranted, though this is usually reserved for large scale water supply work. If there are any unexplained water level anomalies observed toward the scheduled end of a test, the test should be continued if at all possible.

The approximate test flow rate needs to be determined in advance for proper pump and discharge design selection, and sizing of discharge containment. If it is not appropriate to perform a step test, sustainable yield can be estimated from slug test data or a brief (<30 minutes) pumping episode the day before the actual test. Generally, it is best to pump the test well at a rate that maximizes the signal to noise ratio (a higher pumping rate does not influence test scale and should not be used as a means to shorten the test duration).

If testing must be performed in an area where contamination is known to be present, careful consideration of the impacts of the test scale should be considered prior to testing so that the spread of subsurface contamination is not increased. If floating product (LNAPL) is present at or near the pumping well, drawdown should be limited so as to not impact uncontaminated soils below the static water table (i.e., create a “smear” zone or allow for the significant migration of free-phase product). Discharge water must be either 1) treated prior to discharge or 2) containerized for on or off-site disposal. If it is to be discharged directly on-site and allowed to infiltrate, it must be routed sufficiently far enough from the test area as to avoid any artificial recharge effects. All appropriate withdrawal and discharge permits must be obtained and complied with. If discharge water is to be treated on-site, proper contaminant loading calculations for the test flow rate, approximate contaminant loading and test duration must be performed in advance to insure treatment is sufficient. Any on-site treatment should also include at least one discharge effluent sample analysis by an approved laboratory to document treatment effectiveness.

10.3.2 Pre-Test Water Level Monitoring

Water-level conditions in the test area should be monitored for at least one week prior to initiation of testing to identify background trends and factors influencing groundwater levels in the test area. Data loggers should be deployed in all wells to be utilized in the pumping test and set to record depth or pressure at a resolution that is high enough to identify any potential trends (generally a 15 minute recording interval is sufficient for background monitoring). A manual water level should be measured with a water-level meter or interface probe and referenced to the top of casing mark to calibrate the data logger data at the time of deployment and at sufficient intervals throughout the recording period to validate the data and provide backup data in the event that a data logger was to fail.

Ideally, groundwater levels should be static prior to starting a pumping test so that pumping influences alone can be readily evaluated. Any significant precipitation events within the previous several days (documented through use of a site rain gauge or nearby weather station) will usually result in noticeable water level changes. If there are any major water level changes observed that cannot be explained prior to testing, additional investigation into possible area influences (e.g., local well pumping or construction de-watering) should be conducted.

10.3.3 Pumping Test Set Up

Prior to starting the test, all well measuring points (i.e. top of casing) should be clearly marked and preferably surveyed to the nearest 0.01 feet in elevation. The horizontal distance between all wells utilized should be measured and illustrated on a base map. If there are any surface water bodies in the vicinity, a staff gauge (or similar measuring device) should be set up and surveyed to evaluate possible test influences on water levels or stream flow.

The preferred pump to be used for a pumping test is a submersible centrifugal pump powered by either existing site power or a portable generator. These pumps are not explosion proof, so a conductivity probe must be tied into the pump controls to alleviate any possibility of product coming into contact with the pump (if product is anticipated). If the test pump is designed to pump total fluids (e.g. air operated double diaphragm pump, jack pump, etc.) discharge must either be containerized, or treatment must include an oil/water separator to handle any floating product. The submersible pump should be set deep enough to maintain flow during the test period or at a maximum of just above the screened interval, using a handling line to support the pump's weight [**NOTE:** extreme care must be taken that the power cord is neither bearing any of the pumps weight, nor damaged during installation due to the potential for severe electric shock]. A check valve (or two check valves) should be installed above the pump in the discharge line to prevent backflow into the well after testing.

Discharge piping from the pump should include a flow meter (preferably with totalizer), followed by a flow adjustment valve. The flow meter should be installed in a straight section of hard piping of sufficient length to avoid meter distortion caused by turbulence (typically about 10 pipe diameters on either side of the meter). In low-flow pumping tests, flow rate can be calculated by measuring the exact time required to fill a known-sized container (bucket and stop watch) several times throughout the testing period. The bucket and stop watch method of estimating flow should also be used to back up and check the flow meter data.

Precise and frequent water-level measurements (to the nearest 0.01 feet) and time denotations before, during, and after pumping tests are critical to achieving accurate test results. In terms of prioritization, data loggers should be utilized in at least the pumping well and observation wells closest to the pumping well. Wells further from the pumping well may be manually monitored, due to the reduced likelihood that early-time drawdown will be critical at distal locations. Back-up manual measurements should be collected at least hourly during the first 8 hours of the test, and then at least every 3 hours, to verify data logger measurements. Readings from the transducers are not completely reliable until they have been submerged for at least 30 minutes (sensor equilibration period). All field personnel should have watches with a second hand, and they should all be calibrated to the same time. Liquid level measurements should be obtained using an optical oil/water interface probe with a graduated measuring tape to 0.01 foot accuracy for those wells with floating product. For wells without product, a water-level meter may be sufficient. All non-dedicated probes must be properly decontaminated after each level reading to prevent any possibility of cross- contamination between wells.

Data loggers should be deployed in each selected well to a depth that will maintain submergence through the test period. Data loggers selected should be capable of being submerged to that anticipated depth (typically noted on the instrument body). The transducer cable should be secured at the wellhead (manufacturer supplied hangers, well caps, or electrical tape/cable ties) to minimize any movement of the sensor. Care must be taken that the transducer cable is not damaged from rough edges at the well head, and that no vehicles run over the cable. The data logger installed in the pumping well will need to be installed at a depth that will maintain submergence through the test, but also remain clear of the submersible pump (and pump noise if possible). In addition, wells with floating product may require an inner PVC stilling well surrounding the data logger cable to prevent damage from contact with the product. A stilling well may also eliminate the need for any water-level corrections for product thickness.

10.3.4 Running the Test

Once the data loggers have been deployed and secured, tests should be set up in each device and each device either started or “future” started to begin logging when the pump is turned on. The data logger in the pumping well should be set to logarithmic logging mode to capture sub-second data during the early portion of the test. If possible, the pump discharge control valve should be have been pre-set (based on the step test or mini pump test) to the desired flow rate prior to turning on the pump. However, depending on the test pumps performance curves, minor flow rate adjustments are generally needed during the first hour or two of the test to correct for the additional lift required by the pump due to increasing drawdown. In addition, movement of the discharge hose after the test has been started should be avoided, since any change in the elevation of the discharge will affect the pumping rate. All changes in flow rate should be recorded and time stamped.

A minimum of two field personnel are needed to run a pumping test, with additional personnel required for tests with multiple observations wells or additional complexity. One person should be designated to turn on the pump, monitor and adjust flow rate, maintain discharge and treatment, maintain the generator, etc. The second person should be responsible for data logger management and manual water-level measurements. As a rule of thumb regarding the frequency of manual well gauging, one measurement every half minute during the first 5 to 10 minutes, followed by one measurement every 3 to 5 minutes during the first hour, one measurement every 10 to 20 minutes for the second hour, and one hourly measurement thereafter is acceptable.

Throughout the test, data loggers should be downloaded in real time through use of direct-read, vented cables (or non-vented with a barometric logger for compensation) to monitor water-level conditions. It is essential that some data reduction be accomplished in the field, so that major water level trends are recognized during the test. At a minimum, drawdown trends from the pumping well and two of the nearest monitoring wells need to be semi-log plotted against time so that deviations indicative of boundary conditions can be discerned before pumping is ceased. This will allow decisions to be made about whether the test should run longer than planned.

Generally, water quality samples are collected during a pumping test for laboratory analysis of constituents of concern. These are generally collected after the first hour of pumping and just prior to pump shutdown. If the test is of more than 24 hours duration, it is advisable to collect additional samples during the testing period. All groundwater samples should be collected following Evergreen Field Procedures.

10.3.5 Post-test Recovery

At the conclusion of the test, water level recovery data should be collected until near-static conditions are re-established. This requires the installation of a check valve in the discharge line above the submersible pump to prevent backflow. The recovery data has the advantage in that there are no variations in the curve produced due to variations in pumping rate and is independent of test length. In water-table aquifers, however, the effects of formation de-watering can cause the recovery trends to be substantially different from drawdown trends. Consequently, recovery (residual drawdown) data should be used in conjunction with drawdown data where possible.

10.3.6 Data Analysis

The data collected during pumping tests are analyzed to estimate aquifer hydraulic properties, such as transmissivity, conductivity, and storage. Data collected by transducers must be downloaded and transformed (dimensionless drawdown or displacement from static) prior to analysis. Analysis typically involves curve matching of site data to type curves established in literature for particular flow regimes. Curve matching is commonly performed utilizing computer software, such as HydroSOLV’s AQTESOLV program, along with diagnostic methods and derivative analysis to best estimate aquifer properties through identification of flow regimes and conditions.

It is noted that the mathematical solutions used in pumping test analysis include many assumptions that must be considered in the context of each test area (e.g., the formation is of uniform thickness and of infinite areal extent). In addition, some of the values incorporated into typical pumping test solutions are not actually measured, but are educated estimates (e.g., porosity based on lithology, etc.). Many problems associated with pumping test data evaluation are due to not recognizing, and/or correcting for, deviations from the theoretical solution employed. Some of the more common analytical errors occur due to: partial well penetration effects, formation de-watering effects, casing storage effects, poor pumping well efficiency and/or the application of incorrect equations or units. Consequently, a thorough understanding of the underlying assumptions inherent to the solution employed is required before the validity of the results can be trusted.

APPENDIX F

SOIL, GROUNDWATER AND INDOOR AIR ANALYTICAL REPORTS (ON CD)

APPENDIX G

GHD AIR DATA EVALUATION LETTER

Image courtesy of USGS Earthstar Geographics SIO © 2016 Microsoft Corporation

Source: Microsoft Product Screen Shot(s) Reprinted with permission from Microsoft Corporation, Acquisition Date: June 2014, Accessed: 2016.

0 500 1000ft

Coordinate System:
PENNSYLVANIA SOUTH
NAD83

N

GHD

PHILADELPHIA ENERGY SOLUTIONS FACILITY
PHILADELPHIA, PENNSYLVANIA

INDOOR AIR SAMPLING LOCATIONS

11102524-02

May 6, 2016

FIGURE 1

CAD File: P:\drawings\11100000s\11102524\11102524-reports\11102524-02(001)\11102524-02(001)GN\11102524-02(001)GN-WA001.dwg

Memorandum

To:	Colleen Costello	Ref. No.:	11109626
From:	Paul McMahon/adh/1 Pm	Date:	May 10, 2016
CC:	David Steele		

Re: **Analytical Results and Reduced Validation**
Air Investigation
Evergreen Resources Philadelphia
Philadelphia, Pennsylvania
March - April 2016

1. Introduction

The following document details a reduced validation of analytical results for air samples collected in support of the investigation at the Philadelphia, Pennsylvania site during March - April 2016. The samples were analyzed for volatile organic compounds (VOCs) by Eurofins Lancaster Laboratories Environmental, located in Lancaster, Pennsylvania and ESC Lab Sciences in Mount Juliet, Tennessee. A sample collection and analysis summary is presented in Table 1. A summary of the analytical methodology is presented in Table 2.

Copies of the fully executed chain of custody forms are attached.

Standard GHD report deliverables were submitted by the laboratory. The final results and supporting quality assurance/quality control (QA/QC) data were assessed. Evaluation of the data was based on information obtained from the chain of custody forms, finished report forms, method blank data, and recovery data from laboratory control samples (LCS).

The QA/QC criteria by which these data have been assessed are outlined in the analytical method referenced in Table 2 and applicable guidance from the "USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review", United States Environmental Protection Agency (USEPA) 540 R 08 01, June 2008.

2. Sample Holding Time and Preservation

The sample holding time criterion for the analyses is summarized in Table 2. The sample chain of custody documents and analytical reports were used to determine sample holding times. All samples were analyzed within the required holding times.

GHD Services Inc.
2055 Niagara Falls Boulevard Niagara Falls New York 14304 USA
T 716 297 6150 **F** 716 297 2265 **W** www.ghd.com

3. Laboratory Method Blank Analyses

Method blanks are prepared from a purified matrix and analyzed with investigative samples to determine the existence and magnitude of sample contamination introduced during the analytical procedures.

For this study, laboratory method blanks were analyzed at a minimum frequency of one per analytical batch.

Most method blank results were non-detect. Naphthalene was detected in one method blank; all associated sample results were non-detect and were not impacted.

4. Laboratory Control Sample Analyses

LCS are prepared and analyzed as samples to assess the analytical efficiencies of the method employed, independent of sample matrix effects.

For this study, LCS were analyzed at a minimum frequency of one per analytical batch.

The LCS contained all compounds of interest. All LCS recoveries were within the laboratory control limits, demonstrating acceptable analytical accuracy.

5. Field QA/QC Samples

To assess the analytical and sampling protocol precision, field duplicate samples were collected and submitted "blind" to the laboratory, as specified in Table 1. The relative percent differences (RPDs) associated with these duplicate samples must be less than 50 percent. If the reported concentration in either the investigative sample or its duplicate is less than five times the reporting limit (RL), the evaluation criterion is one times the RL value.

Most field duplicate results were within acceptable agreement, demonstrating acceptable sampling and analytical precision. Results that did show variability were qualified as estimated (see Table 3).

6. Analyte Reporting

The laboratories reported detected results down to the laboratory's method detection limit (MDL) for each analyte. Positive analyte detections less than the RL but greater than the MDL were qualified as estimated (J) unless qualified otherwise in this memorandum. Non-detect results were presented as non-detect at the RL.

7. Conclusion

Based on the assessment detailed in the foregoing, the data are acceptable with the noted qualifications.

Table 1

Sample Collection and Analysis Summary
Air Investigation
Evergreen Resources Philadelphia
Philadelphia, Pennsylvania
March - April 2016

Sample Identification	Location	Matrix	Collection Date (mm/dd/yyyy)	Collection Time (Start) (hr:min)	Collection Time (Stop) (hr:min)	Analysis/Parameters	Comments
						VOCs	
IA-AOI3-018	AOI3-AI-16-009	Air	03/29/2016	07:14	14:55	X	
IA-AOI6-726	AOI6-AI-16-006	Air	03/29/2016	07:37	15:39	X	
IA-AOI6-178	AOI6-AI-16-007	Air	03/29/2016	07:43	15:42	X	
IA-AOI6-OUTDOOR-032916	AOI6-AA-16-002	Air	03/29/2016	07:50	15:45	X	
IA-AOI6-295-1	AOI6-AI-16-008	Air	03/29/2016	08:02	15:54	X	
IA-AOI6-295-2	AOI6-AI-16-009	Air	03/29/2016	08:07	15:56	X	
IA-AOI7-595	AOI7-AI-16-001	Air	03/29/2016	08:21	16:04	X	
IA-AOI7-450-1	AOI7-AI-16-002	Air	03/29/2016	08:39	16:13	X	
IA-AOI7-450-2	AOI7-AI-16-003	Air	03/29/2016	08:48	16:18	X	
IA-AOI7-450-3	AOI7-AI-16-004	Air	03/29/2016	08:55	16:21	X	
IA-AOI7-450-4	AOI7-AI-16-005	Air	03/29/2016	08:58	15:23	X	
IA-AOI7-450-5	AOI7-AI-16-006	Air	03/29/2016	09:04	15:26	X	
IA-AOI7-442	AOI7-AI-16-007	Air	03/29/2016	09:19	16:38	X	
IA-AOI7-711	AOI7-AI-16-008	Air	03/29/2016	09:30	17:20	X	
IA-AOI7-OUTDOOR	AOI7-AA-16-001	Air	03/29/2016	09:28	17:01	X	
IA-AOI7-6622	AOI7-AI-16-009	Air	03/29/2016	09:40	17:30	X	
IA-AOI7-6626	AOI7-AI-16-0010	Air	03/29/2016	09:47	17:35	X	
IA-AOI7-6625	AOI7-AI-16-011	Air	03/29/2016	09:59	17:42	X	
IA-AOI8-6642	AOI8-AI-16-001	Air	03/29/2016	10:26	18:35	X	
IA-AOI8-6641	AOI8-AI-16-002	Air	03/29/2016	10:30	17:57	X	
IA-AOI8-3326	AOI8-AI-16-003	Air	03/29/2016	10:42	18:10	X	
IA-AOI8-27	AOI8-AI-16-004	Air	03/29/2016	10:52	18:16	X	
IA-AOI8-27-DUP	AOI8-AI-16-004	Air	03/29/2016	10:52	18:16	X	Duplicate of IA-AOI8-27
IA-AOI8-OUTDOOR	AOI8-AA-16-001	Air	03/29/2016	11:08	16:30	X	
						X	
IA-AOI1-2429	AOI1-AI-16-001	Air	03/22/2016	08:12	16:01	X	
IA-AOI2-5920	AOI2-AI-16-001	Air	03/22/2016	08:32	16:22	X	
IA-AOI2-6628	AOI2-AI-16-002	Air	03/22/2016	08:44	16:30	X	
IA-AIO2-2435	AOI2-AI-16-003	Air	03/22/2016	09:00	16:40	X	
IA-AIO2-6624	AOI2-AI-16-004	Air	03/22/2016	09:15	17:43	X	
IA-AIO2-2520	AOI2-AI-16-005	Air	03/22/2016	09:28	17:00	X	
IA-AOI2-AMBIENT	AOI2-AA-16-001	Air	03/22/2016	09:40	17:08	X	
IA-AOI3-SAFWAY	AOI3-AI-16-001	Air	03/22/2016	10:00	18:43	X	

Table 1

Sample Collection and Analysis Summary
Air Investigation
Evergreen Resources Philadelphia
Philadelphia, Pennsylvania
March - April 2016

						Analysis/Parameters	
Sample Identification	Location	Matrix	Collection Date (mm/dd/yyyy)	Collection Time (Start) (hr:min)	Collection Time (Stop) (hr:min)	VOCs	Comments
IA-AOI3-3324-1	AOI3-AI-16-002	Air	03/22/2016	10:19	18:05	X	
IA-AIO3-3324-2	AOI3-AI-16-003	Air	03/22/2016	10:39	18:02	X	
IA-AOI3-3324-3	AOI3-AI-16-004	Air	03/22/2016	10:47	18:33	X	
IA-AOI3-3324-4	AOI3-AI-16	Air	03/22/2016	10:59	18:30	X	
IA-AOI3-3324-5	AOI3-AI-16	Air	03/22/2016	10:59	18:30	X	Duplicate of IA-AOI3-3324-4
IA-AOI3-3324-6	AOI3-AI-16-007	Air	03/22/2016	11:02	18:35	X	
IA-AOI9-SR2	AOI9-AI-16-001	Air	04/05/2016	08:09	16:09	X	
IA-AOI9-OUTDOOR	AOI9-AA-16-001	Air	04/05/2016	08:23	15:24	X	
IA-AOI9-SR9	AOI9-AI-16-002	Air	04/05/2016	08:43	16:15	X	
IA-AOI9-SR9-DUP	AOI9-AI-16-002	Air	04/05/2016	08:43	16:15	X	Duplicate of IA-AOI9-SR9
IA-AOI3-TRAILER13	AOI3-AI-16-008	Air	03/28/2016	07:47	15:35	X	
IA-AOI3-OUTDOOR	AOI3-AA-16-001	Air	03/28/2016	07:58	15:40	X	
IA-AOI5-625	AOI5-AI-16-001	Air	03/28/2016	08:27	15:57	X	
IA-AOI5-526-2	AOI5-AI-16-002	Air	03/28/2016	08:45	16:17	X	
IA-AOI5-526-1	AOI5-AI-16-003	Air	03/28/2016	08:52	17:17	X	
IA-AOI5-501	AOI5-AI-16-004	Air	03/28/2016	09:04	16:31	X	
IA-AOI5-GPDOCK-2	AOI5-AI-16-005	Air	03/28/2016	09:23	17:01	X	
IA-AOI5-034A/B	AOI5-AI-16-006	Air	03/28/2016	09:36	17:30	X	
IA-AOI5-OUTDOOR	AOI5-AA-16-001	Air	03/28/2016	09:45	17:08	X	
IA-AOI2-011	AOI2-AI-16-006	Air	03/28/2016	10:07	17:42	X	
IA-AOI2-475	AOI6-AI-16-001	Air	03/28/2016	10:23	18:23	X	
IA-AOI6-745	AOI6-AI-16-002	Air	03/28/2016	10:33	18:00	X	
IA-AOI6-6627	AOI6-AI-16-003	Air	03/28/2016	10:42	18:08	X	
IA-AOI6-6636	AOI6-AI-16-004	Air	03/28/2016	10:57	18:18	X	
IA-AOI6-739	AOI6-AI-16-005	Air	03/28/2016	11:10	18:33	X	
IA-AOI6-OUTDOOR-739	AOI6-AA-16-001	Air	03/28/2016	11:15	18:29	X	

Notes:

VOCs - Volatile Organic Compounds

Table 2

Analytical Method and Holding Time Criterion
Air Investigation
Evergreen Resources Philadelphia
Philadelphia, Pennsylvania
March - April 2016

			Holding Time
Parameter	**Method**	**Matrix**	**Collection to Analysis (Days)**
Volatile Organic Compounds (VOCs)	TO-15	Air	30

Notes:

EPA Method TO-15 - "Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air", EPA-625/R-96/010b, January 1999

Table 3

Qualified Sample Data Due to Variability in Field Duplicate Results
Air Investigation
Evergreen Resources Philadelphia
Philadelphia, Pennsylvania
March - April 2016

Parameter	Analyte	RPD/Diff		Sample ID	Qualified Result		Field Duplicate Sample ID	Qualified Result		Units
VOCs	Toluene	59	11	IA-AOI3-3324-4	13	J	IA-AOI3-3324-5	24	J	µg/m^3
	m/p-Xylene	97	3.6		5.5	J		1.9	J	µg/m^3

Notes:

Diff - Difference (i.e., >1X RL)
RPD - Relative Percent Difference
J - Estimated concentration

Summa Canister Field Test Data/Chain of Custody

eurofins | Lancaster Laboratories Environmental

For Eurofins Lancaster Laboratories Environmental use only

Acct. # 10177 Group # 1644037 Sample # 8302469-82 Bottle Order (SCR) # ____

Client Information

Client: EVERGREEN
Account #:
Project Name/#: PHILA REFINERY
Project Manager: DAVE STEELE
P.O. #:
Sampler: Rich Burns
Quote #:
Name of state where samples were collected: PA

Turnaround Time Requested (TAT) (circle one)

Standard [✓ Rush (specify)] ____

Data Package Required?		EDD Required?	
Yes	No	Yes	No

	Temperature (F)		Pressure ("Hg)	
	Start	Stop	Start	Stop
Ambient				
Maximum				
Minimum				

Analyses Requested

Sample Identification	Start Date/Time (24-hour clock)	Stop Date/Time (24-hour clock)	Canister Pressure in Field ("Hg) (Start)	Canister Pressure in Field ("Hg) (Stop)	Interior Temp. (F) (Start)	Interior Temp. (F) (Stop)	Flow Reg. ID	Can ID	Can Size (L)	Controller Flowrate (mL/min)	EPA TO - 15	EPA 18	EPA 25 (select range below)	Helium as tracer	O2/CO2	Library Search	☐ BTEX ☐ MTBE
IA-AOI1-2429	0812	1601	-30	-9	66.1	72	236464	1372	6	16.7	X						
IA-AOI2-5920	0832	1622	-30	-7	70	71	824841	1373	6	16.4	X						
IA-AOI2-6628	0844	1630	-30	-14	71	70	399352	1374	6	10.1	X						
IA-AOI2-2435	0900	1640	-30	-9	62	68	675018	1375	6	10.7	X						
IA-AOI2-6624	0915	1743	-30	-17	64	71	415317	1376	6	10.5	X						
IA-A012-2500	0928	1700	-30	-10	63	71	399388	1377	6	10.0	X						
OA-A012-AMBIENT	0940	1708	-30	-7	—	—	336682	1378	6	10.7	X						
IA-A013-SAFWAY	1000	1843	-29	-12	61	70	339251	1379	6	10.0	X						
IA-A013-3324-1	1019	1805	-30	-10	60	72	675022	1349	6	10.1	X						
IA-A013-3324-2	1039	18022	-30	-8	64	74	303934	1350	6	10.5	X						
IA-A013-3324-3	1047	1833	-30	-10.5	66	72	824852	1351	6	10.3	X						

Instructions/QC Requirements & Comments
see short list of VOCS on SSOW

EPA 25 (check one)
☐ C1 - C4
☐ C2 - C10
☐ C1 - C10
☐ C4 - C10 (GRO)
☐ C2 - C4

Canisters Shipped by: 23:30	Date/Time: 3/18/16	Canisters Received by: Rich Burns	Date/Time:	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by: Rich Burns	Date/Time: 3.22 0830	Received by:	Date/Time: 3-23-16 0830	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time: 3/23/16 1541	Received by:	Date/Time:	Relinquished by:	Date/Time:	Received by:	Date/Time: 3/23/16 1545

The white copy should accompany samples to Eurofins Lancaster Laboratories Environmental. The yellow copy should be retained by the client.

Summa Canister Field Test Data/Chain of Custody

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For Eurofins Lancaster Laboratories Environmental use only
Acct. # 10177 Group # 1644037 Sample # 8302409-82 Bottle Order (SCR) # ______

Client Information

Client: EVERGREEN
Account #:
Project Name/#: EVERGREEN PHILA Refinery
Project Manager: DAVE STEELE
P.O. #:
Sampler: RICH BURNS
Quote #:
Name of state where samples were collected: PA

Turnaround Time Requested (TAT) (circle one)

Standard [✓ Rush (specify)] ______

Data Package Required? Yes No

EDD Required? Yes No

	Temperature (F)		Pressure ("Hg)	
	Start	Stop	Start	Stop
Ambient				
Maximum				
Minimum				

Analyses Requested

Sample Identification	Start Date/Time (24-hour clock)	1830 Stop Date/Time (24-hour clock)	Canister Pressure in Field ("Hg) (Start)	Canister Pressure in Field ("Hg) (Stop)	Interior Temp. (F) (Start)	Interior Temp. (F) (Stop)	Flow Reg. ID	Can ID	Can Size (L)	Controller Flowrate (mL/min)	EPA TO - 15	EPA 18 ☐ BTEX ☐ MTBE	EPA 25 (select range below)	Helium as tracer	O2/CO2	Library Search	
IA-AOI3-3324-4	1059	~~1828~~	-30	-10	66	73	337701	1352	6	10.5	X						
IA-AOI3-3324-5	1059	~~1828~~	-30	-9	66	73	204636	1353	6	10.2	X						
IA-AOI3-3324-6	1102	1835	-30	-9	64	73	415324	1354	6	10.6	X						
							329155	1355	6	10.3							
							338046	1356	6	10.4							
							824845	1357	6	10.2							
							993910	1381	6	10.3							
							710628	1382	6	10.6							
							342379	1383	6	10.5							
							824856	1384	6	10.7							
							824844	1385	6	10.4							

Instructions/QC Requirements & Comments

EPA 25 (check one)
☐ C1 - C4
☐ C2 - C10
☐ C1 - C10
☐ C4 - C10 (GRO)
☐ C2 - C4

Canisters Shipped by: 23:30	Date/Time: 3/18/16	Canisters Received by: Rick Burns	Date/Time: 3.22/0730	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by: Rick Burns	Date/Time: 3-23 830	Received by:	Date/Time: 3-23-16 0830	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time: 3-23-16 (1241)	Received by:	Date/Time:	Relinquished by:	Date/Time:	Received by:	Date/Time: 3/23/16 1545

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Summa Canister Field Test Data/Chain of Cust

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Acct. # 10177 Group # 1646959 Sample # 8316882-97 Bottle Order (SCR) # ______

Client Information

Client: Evergreen
Account #:

Project Name/#: PES

Project Manager: DAVE STEELE
P.O. #:

Sampler: Rich Burns
Quote #:

Name of state where samples were collected: PA

Turnaround Time Requested (TAT) (circle one)

[✓ Standard] Rush (specify) ______

Data Package Required? Yes No

EDD Required? Yes No

	Temperature (F)		Pressure ("Hg)	
	Start	Stop	Start	Stop
Ambient				
Maximum				
Minimum				

Analyses Requested

Sample Identification	3.28.16 Start Date/Time (24-hour clock)	3.28.16 Stop Date/Time (24-hour clock)	Canister Pressure in Field ("Hg) (Start)	Canister Pressure in Field ("Hg) (Stop)	Interior Temp. (F) (Start)	Interior Temp. (F) (Stop)	Flow Reg. ID	Can ID	Can Size (L)	Controller Flowrate (mL/min)	EPA TO-15	EPA 18	EPA 25 (select range below)	Helium as tracer	O2/CO2	Library Search	☐ BTEX ☐ MTBE
IA-A013-TRAILER 13	0747	1535	-29.5	-7	72.5	74	329159	1355	6		X						
IA-A013-OUTDOOR	0758	1540	-29.5	-1	—	—	415304	1387	6		X						
IA-A015-625	0827	1557	-30	-9	69	74	415271	1385	6		X						
IA-A015-526-2	0845	1617	-30	-9	69	74	824844	1386	6		X						
IA-A015-526-1	0852	1717	-30	-10	63	70	710536	1360	6		X						
IA-A015-501	0904	1631	-30	-6.5	70	80	710595	1388	6		X						
IA-A015-GP DOCK 2	0923	1701	-30	-9	72	83	415275	1359	6		X						
IA-A015-034A/B	0936	1730	-30	-7	68	70	824845	1381	6		X						
IA-A015-OUTDOOR	0945	1708	-30	-7	—	—	338046	1366	6		X						
IA-A012-011	1007	1742	-28.5	-7	67	73	993910	1357	6		X						
IA-A012-475 +	1023	1823	-30	-10+	68	71	809827	1362	6		X						

401-16 per PM.

Instructions/QC Requirements & Comments

see SSOW for petroleum short LIST.

Page 1 of 2

6 Boxes

EPA 25 (check one)

☐ C1 - C4
☐ C2 - C10
☐ C1 - C10
☐ C4 - C10 (GRO)
☐ C2 - C4

Canisters Shipped by: 23:30	Date/Time: 3/18/16	Canisters Received by:	Date/Time:	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time: 4.1.16 1545	Received by: Warehous	Date/Time: 4.1.16 1545	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time: 4/4/16 0840	Received by:	Date/Time: 4/4/16 0840	Relinquished by:	Date/Time: 4-4-16 1630	Received by:	Date/Time: 4/4/16 1630

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7056 10

Summa Canister Field Test Data/Chain of Custody

eurofins | Lancaster Laboratories Environmental

For Eurofins Lancaster Laboratories Environmental use only
Acct. # 10177 Group # 1646959 Sample # 8316887-97 Bottle Order (SCR) # ______

Client Information

Client: Evergreen
Account #:
Project Name/#: PES
Project Manager: Dave Steele
P.O. #:
Sampler: Rick Burs
Quote #:
Name of state where samples were collected: VA

Turnaround Time Requested (TAT) (circle one)

[✓ Standard] Rush (specify) ______

Data Package Required? Yes No

EDD Required? Yes No

	Temperature (F)		Pressure ("Hg)	
	Start	Stop	Start	Stop
Ambient				
Maximum				
Minimum				

Analyses Requested

Sample Identification	3.28.16 Start Date/Time (24-hour clock)	3.28.16 Stop Date/Time (24-hour clock)	Canister Pressure in Field ("Hg) (Start)	Canister Pressure in Field ("Hg) (Stop)	Interior Temp. (F) (Start)	Interior Temp. (F) (Stop)	Flow Reg. ID	Can ID	Can Size (L)	Controller Flowrate (mL/min)	EPA TO-15	EPA 18 ☐ BTEX ☐ MTBE	EPA 25 (select range below)	Helium as tracer	O2/CO2	Library Search		
IA-A016-745	1033	1800	-30	-9.5	68	68	824836	1363	6		X							
IA-A016-6627	1042	1808	-30	-8	65	72	303421	1361	6		X							
IA-A016-6636	1057	1818	-20	-2	64	70	342379	1384	6		X							
IA-A016-739	1110	1833	-30	-8.5	66	67	710628	1382	6		X							
IA-A016-outdoor 739	1115	1829	-23	-23	—	—	824856	1383	6		X							
									6									
									6									
									6									
									6									

Instructions/QC Requirements & Comments

see SSOW for petroleum shortlist
Page 2 of 2

EPA 25 (check one)
☐ C1 - C4 ☐ C2 - C10
☐ C1 - C10 ☐ C4 - C10 (GRO)
☐ C2 - C4

Canisters Shipped by: 23:30	Date/Time: 3/18/16	Canisters Received by:	Date/Time:	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time: 4.4.16 1545	Received by:	Date/Time: 4.4.16 1545	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time: 4/4/16 0840	Received by: 4	Date/Time: 4-4-16 0840	Relinquished by: 4	Date/Time: 4-4-16 1630	Received by:	Date/Time: 4/4/16 1630

The white copy should accompany samples to Eurofins Lancaster Laboratories Environmental. The yellow copy should be retained by the client.

Summa Canister Field Test Data/Chain of Custody

eurofins | Lancaster Laboratories Environmental

For Eurofins Lancaster Laboratories Environmental use only
Acct. # 10177 Group # 1648332 Sample # 8322922-5 Bottle Order (SCR) # ______

Client Information

Client: Evergreen
Account #:
Project Name/#: PES
Project Manager: DAVE STEELE
P.O. #:
Sampler: RICH BURNS
Quote #:
Name of state where samples were collected: PA

Turnaround Time Requested (TAT) (circle one)
[✓ Standard] Rush (specify) ______

Data Package Required? Yes No

EDD Required? Yes No

	Temperature (F)		Pressure ("Hg)	
	Start	Stop	Start	Stop
Ambient				
Maximum				
Minimum				

Analyses Requested

Sample Identification	4.5.16 Start Date/Time (24-hour clock)	4.5.16 Stop Date/Time (24-hour clock)	Canister Pressure In Field ("Hg) (Start)	Canister Pressure In Field ("Hg) (Stop)	Interior Temp. (F) (Start)	Interior Temp. (F) (Stop)	Flow Reg. ID	Can ID	Can Size (L)	Controller Flowrate (mL/min)	EPA TO - 15	EPA 18 ☐ BTEX ☐ MTBE	EPA 25 (select range below)	Helium as tracer	O2/CO2	Library Search	
IA-AOI9-SR2	0809	1609	-30	8	59	60	710568	1203	6	10.6	X						
IA-AOI9-OUTDOOR	0823	1524	-30	0	—	—	344364	1255	6	10.3	X						
IA-AOI9-SR9	0843	1615	-29	8	70	70	252265	1282	6	10.5	X						
IA-AOI9-SR9-DUP	0843	1615	-30	6	70	70	336758	1263	6	10.7	X						

Instructions/QC Requirements & Comments

2 Boxes
Order # 186547

EPA 25 (check one)
☐ C1 - C4 ☐ C2 - C10
☐ C1 - C10 ☐ C4 - C10 (GRO)
☐ C2 - C4

Canisters Shipped by: 13:47	Date/Time: 3/31/16	Canisters Received by:	Date/Time:	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time:	Received by:	Date/Time: 4.7.16 1105	Relinquished by:	Date/Time:	Received by:	Date/Time:
Relinquished by:	Date/Time: 4.7.16 1629	Received by:	Date/Time:	Relinquished by:	Date/Time:	Received by:	Date/Time: 4/7/16 1629

Eurofins Lancaster Laboratories Environmental, LLC • 2425 New Holland Pike, Lancaster, PA 17601 • 717-656-2300
The white copy should accompany samples to Eurofins Lancaster Laboratories Environmental. The yellow copy should be retained by the client.

7056 1015

Chain of Custody Page 1 of ___

ESC
LAB SCIENCES
YOUR LAB OF CHOICE

12065 Lebanon Rd
Mount Juliet, TN 37122
Phone: 615-758-5858
Phone: 800-767-5859
Fax: 615-758-5859

unoco/GHD

055 Niagara Falls Boulevard
iagara Falls, NY 14304

Billing Information:
Paul McMahon
1755 Wittington Pl., Ste. 500
Dallas, TX 75234

eport to: **aul McMahon**

Email To: Paul.McMahon@ghd.com, David.Steele@ghd.com, Richard.Burns@ghd.com

roject
escription: **Sunoco/Evergeen**

City/State Collected: Phila, PA

hone: **716-297-6150**

ax:

Client Project # **11102524**

Lab Project # **SUNGHD-11102524**

Collected by (print): Rick Burns

Site/Facility ID # PES

P.O. #

Collected by (signature): Rich Burns

Rush? (Lab MUST Be Notified)
___ Same Day 200%
___ Next Day 100%
___ Two Day 50%
___ Three Day 25%

Date Results Needed

Email? ___No X Yes
FAX? ___No ___Yes

mmediately
Packed on Ice N ____ Y ____

Analysis / Container / Preservative

L # L827327

Table #

Acctnum: **SUNGHD**
Template: **T110832**
Prelogin: **P546860**
TSR: 134 - Mark W. Beasley
PB:
Shipped Via: **FedEX Standard**

Sample ID	Comp/Grab	Matrix *	Depth	Date	Time	No. of Cntrs	TO-15 Summa	Rem./Contaminant	Sample # (lab only)
IA-A013-018	—	Air	—	3.29.16	0714/1455	1	X		-01
IA-A016-726	—	Air	—	3.29.16	0737/1539	1	X		-02
IA-A016-178	—	Air	—	3.29.16	0743/1542	1	X		-03
IA-A016-OUTDOOR-032916	—	Air	—	3.29.16	0750/1545	1	X		-04
IA-A016-295-1	—	Air	—	3.29.16	0802/1554	1	X		-05
IA-A016-295-2	—	Air	—	3.29.16	0807/1556	1	X		-06
IA-A017-595	—	Air	—	3.29.16	0821/1604	1	X		-07
IA-A017-450-1	—	Air	—	3.29.16	0839/1613	1	X		-08
IA-A017-450-2	—	Air	—	3.29.16	0848/1618	1	X		-09
IA-A017-450-3	—	Air	—	3.29.16	0855/1621	1	X		-10

* Matrix: SS - Soil GW - Groundwater WW - WasteWater DW - Drinking Water OT - Other________

6711 0333 3505 3457
3480 3468
3479 3446

Remarks: see SSOW for Short List TO-15
6 Large Boxes, 1 small Box

pH ________ Temp ________
Flow ________ Other ________

Hold #

Condition: (lab use only) TD

Relinquished by : (Signature) Rich Burns
Date: 4.1.16
Time: 1500
Received by: (Signature) FedEx

Samples returned via: ☐ UPS ☒ FedEx ☐ Courier ☐ ____

Relinquished by : (Signature)
Date:
Time:
Received by: (Signature)

Temp: Amb. °C Bottles Received: 25

COC Seal Intact: ___Y ___N ✓ NA ok

Relinquished by : (Signature)
Date:
Time:
Received for lab by: (Signature)

Date: 4-4-16 Time: 0930

pH Checked:
NCF:

Chain of Custody Page 2 of

ESC
L·A·B S·C·I·E·N·C·E·S

12065 Lebanon Rd
Mount Juliet, TN 37122
Phone: 615-758-5858
Phone: 800-767-5859
Fax: 615-758-5859

L# L827327

Table #

Acctnum: **SUNGHD**
Template: **T110832**
Prelogin: **P546860**
TSR: 134 - Mark W. Beasley
PB:
Shipped Via: **FedEX Standard**

unoco/GHD

055 Niagara Falls Boulevard
liagara Falls, NY 14304

Billing Information:
Paul McMahon
1755 Wittington Pl., Ste. 500
Dallas, TX 75234

eport to:
aul McMahon

Email To: **Paul.McMahon@ghd.com, David.Steele@ghd.com, Richard.Burns@ghd.com**

roject
escription: **Sunoco/Evergeen**

City/State Collected: Phila, PA

hone: **716-297-6150**
ax:

Client Project # **11102524**

Lab Project # **SUNGHD-11102524**

Collected by (print): Rich Burns

Site/Facility ID # PES

P.O. #

Collected by (signature):
Immediately Packed on Ice N ____ Y ____

Rush? (Lab MUST Be Notified)
____ Same Day 200%
____ Next Day 100%
____ Two Day 50%
____ Three Day 25%

Date Results Needed

Email? ___No X Yes
FAX? ___No ___Yes

Analysis / Container / Preservative

Sample ID	Comp/Grab	Matrix *	Depth	Date	Time	No. of Cntrs	TO-15 Summa	Rem./Contaminant	Sample # (lab only)
IA-A017-450-4	—	Air	—	3.29.16	0858/1523	1	X		-11
IA-A017-450-5	—	Air	—	3.29.16	0904/1526	1	X		-12
IA-A017-442	—	Air	—	3.29.16	0919/1628	1	X		-13
IA-A017-711	—	Air	—	3.29.16	0930/1720	1	X		-14
IA-A017-OUTDOOR	—	Air	—	3.29.16	0928/1701	1	X		-15
IA-A017-6622	—	Air	—	3.29.16	0940/1730	1	X		-16
IA-A017-6626	—	Air	—	3.29.16	0947/1735	1	X		-17
IA-A017-6625	—	Air	—	3.29.16	0959/1742	1	X		-18
IA-A018-6642	—	Air	—	3.29.16	1026/1835	1	X		-19
IA-A018-6641	—	Air	—	3.29.16	1030/1757	1	X		-20

* Matrix: SS - Soil GW - Groundwater WW - WasteWater DW - Drinking Water OT - Other________

Remarks: SEE SSOW FOR SHORT LIST TO-15

pH ________ Temp ________
Flow ________ Other ________

Hold #

Relinquished by : (Signature) Rich Burns
Date: 4.1.16
Time: 1500
Received by: (Signature) FedEx

Samples returned via: ☐ UPS
☒ FedEx ☐ Courier ☐ ______

Condition: (lab use only) TD OK

Relinquished by : (Signature)
Date:
Time:
Received by: (Signature)

Temp: Amb. °C
Bottles Received: 25

COC Seal Intact: ___Y ___N ✓ NA

Relinquished by : (Signature)
Date:
Time:
Received for lab by: (Signature)

Date: 4.4.16
Time: 0930

pH Checked:
NCF:

Chain of Custody Page 2 of 2

3 3

ESC
L·A·B S·C·I·E·N·C·E·S

12065 Lebanon Rd
Mount Juliet, TN 37122
Phone: 615-758-5858
Phone: 800-767-5859
Fax: 615-758-5859

Sunoco/GHD

2055 Niagara Falls Boulevard
Niagara Falls, NY 14304

Billing Information:

Paul McMahon
1755 Wittington Pl., Ste. 500
Dallas, TX 75234

Report to:
Paul McMahon

Email To: **Paul.McMahon@ghd.com, David.Steele@ghd.com, Richard.Burns@ghd.com**

Project Description: **Sunoco/Evergeen**

City/State Collected: Phila, PA

Phone: **716-297-6150**
Fax:

Client Project # **11102524**

Lab Project # **SUNGHD-11102524**

Collected by (print): Rich Burns

Site/Facility ID # PES

P.O. #

Collected by (signature):

Immediately Packed on Ice N ___ Y ___

Rush? (Lab MUST Be Notified)
___ Same Day 200%
___ Next Day 100%
___ Two Day 50%
___ Three Day 25%

Date Results Needed

Email? ___No X Yes
FAX? ___No ___Yes

L #

Table #

Acctnum: **SUNGHD**
Template: **T110832**
Prelogin: **P546860**
TSR: 134 - Mark W. Beasley
PB:
Shipped Via: **FedEX Standard**

Analysis / Container / Preservative

Sample ID	Comp/Grab	Matrix *	Depth	Date	Time	No. of Cntrs	TO-15 Summa	Rem./Contaminant	Sample # (lab only)
IA-A018-3326	—	Air	—	3.29.16	1042/1810	1	X		-21
IA-A018-27	—	Air	—	3.29.16	1052/1816	1	X		-22
IA-A018-27-DUP	—	Air	—	3.29.16	1052/1816	1	X		-23
IA-A018-OUTDOOR	—	Air	—	3.29.16	1105/1830	1	X		-24
		Air				1	X		~~-25~~
		Air				1	X		~~-26~~
		Air				1	X		
		Air				1	X		
		Air				1	X		
		Air				1	X		
FIELD BLANK	—	Air	—	3.29.16	—	1	X		-25

* Matrix: SS - Soil GW - Groundwater WW - WasteWater DW - Drinking Water OT - Other______

Remarks: FIELD BLANK CAN 1992   SEE SSOW FOR TO-15 SHORT LIST

pH ______ Temp ______

Flow ______ Other ______

Hold #

Samples returned via: ☐ UPS
☒ FedEx ☐ Courier ☐ ______

Condition: (lab use only) TD ✓ OK

Relinquished by : (Signature)	Date:	Time:	Received by: (Signature)
Rich Burns	4.1.16	1500	FEDEX
Relinquished by : (Signature)	Date:	Time:	Received by: (Signature)
Relinquished by : (Signature)	Date:	Time:	Received for lab by: (Signature)

Temp: Amb. °C Bottles Received: 25

Date: 4.4.16 Time: 0930

COC Seal Intact: ___Y ___N ___NA

pH Checked:

NCF:

Table
March and April 2016 Air Sampling Data
Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

DRAFT

							AOI 1	AOI 2						
Sample Location							**AOI1-AI-16-001**	**AOI2-AA-16-001**	**AOI2-AI-16-001**	**AOI2-AI-16-002**	**AOI2-AI-16-003**	**AOI2-AI-16-004**	**AOI2-AI-16-005**	**AOI2-AI-16-006**
							Control Room, Block BRM	**Outdoor Near River**	**Bio Area**	**Bio Area, Bldg 6628**	**Control Room, Kitchen, on Stove**	**Control Room**	**Control Room**	**Short Pier Building 11**
Sample Date							**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**28-Mar-16**
Sample ID							**IA-AOI1-2429**	**OA-AOI2-AMBIENT**	**IA-AOI2-5920**	**IA-AOI2-6628**	**IA-AOI2-2435**	**IA-AOI2-6624**	**IA-AOI2-2520**	**IA-AOI2-011**
Sampling Company							**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**
Laboratory							**LL**	**LL**	**LL**	**LL**	**LL**	**LL**	**LL**	**LL**
Laboratory Work Order							**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF24**
Laboratory Sample ID							**8302469**	**8302475**	**8302470**	**8302471**	**8302472**	**8302473**	**8302474**	**8316891**
Sample Type	**Units**	**VI-PA**	**OSHA**	**USEPA RSL**	**ACGIH TLV**	**NIOSH**								
Volatile Organic Compounds														
BENZENE	µg/m3	16^{A}	3190^{B}	1.6^{CD}	1600^{E}	319^{F}	***12*** ^{CD}	***1.9 J*** ^{CD}	***3.7*** ^{CD}	***4.6*** ^{CD}	***2.8 J*** ^{CD}	***3.2*** ^{CD}	***5.9*** ^{CD}	1.3 J
1,2-DIBROMOETHANE (EDB)	µg/m3	0.2^{A}	153800^{B}	0.02^{CD}	n/v	346^{F}	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*
1,2-DICHLOROETHANE (EDC)	µg/m3	4.7^{A}	202500^{B}	0.47^{CD}	40500^{E}	4000^{F}	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*
ETHYLBENZENE	µg/m3	49^{A}	435000^{B}	4.9^{CD}	86800^{E}	435000^{F}	***7.1*** ^{CD}	1.5 J	ND (4.3)	2.9 J	ND (4.3)	ND (4.3)	1.3 J	ND (4.3)
ISOPROPYLBENZENE (CUMENE)	µg/m3	1800^{A}	245000^{B}	1800^{C} 180^{D}	246000^{E}	245000^{F}	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)
M, P-XYLENES	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	29	3.9 J	1.9 J	7.5	2.1 J	2.1 J	4.5	2.8 J
METHYL TERTIARY BUTYL ETHER	µg/m3	470^{A}	n/v	47^{CD}	180000^{E}	n/v	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)
NAPHTHALENE	µg/m3	n/v	50000^{B}	0.36^{CD}	52000^{E}	50000^{F}	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	***3.0 J*** ^{CD}	*ND (5.2)*
O-XYLENE (1,2-DIMETHYLBENZENE)	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	9.9	2.8 J	ND (4.3)	4.0 J	0.90 J	0.97 J	2.4 J	1.1 J
TOLUENE	µg/m3	22000^{A}	754000^{B}	22000^{C} 2200^{D}	75400^{E}	375000^{F}	48	1.3 J	3.9	8.9	2.6 J	3.0 J	4.4	4.3
1,2,4-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	31^{C} 3.1^{D}	123000^{E}	125000^{F}	***6.6*** ^{D}	*ND (4.9)*	*ND (4.9)*	1.8 J	*ND (4.9)*	*ND (4.9)*	***6.6*** ^{D}	1.2 J
1,3,5-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	n/v	123000^{E}	125000^{F}	2.7 J	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	2.2 J	ND (4.9)

Notes:

VI-PA	PADEP Vapor Intrusion Screening Values
A	Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential (Draft, July 2015)
OSHA	Occupational Safety and Health Administration
B	Permissible Exposure Limits
USEPA RSL	United States Environmental Protection Agency
C	Regional Screening Level for Non-residential indoor air Hazard Index of 1.0.
D	Regional Screening Level for Non-residential indoor air Hazard Index of 0.1.
ACGIH TLV	American Conference of Governmental Industrial Hygienists
E	Threshold Limit Value
NIOSH	National Institute for Occupational Safety and Health
F	Recommended Exposure Limits
6.5 ^{A}	Concentration exceeds the indicated standard.
15.2	Measured concentration did not exceed the indicated standard.
ND (0.50)	Laboratory reporting limit was greater than the applicable standard.
ND (0.03)	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
J	Indicates an estimated value.

Table
March and April 2016 Air Sampling Data
Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

							AOI 3									
Sample Location							**AOI3-AA-16-001** **Outdoor Ambient Near Central Warehouse**	**AOI3-AI-16-001** **Safway Trailer**	**AOI3-AI-16-002** **AOI3 Central Warehouse 3324**	**AOI3-AI-16-003** **Warehouse Near Seal/Safety Store**	**AOI3-AI-16-004** **Central Warehouse Bldg 3324 Walled Office**	**AOI3-AI-16-005** **Central 3324 Bldg Open Warehouse**	**AOI3-AI-16-006** **Central 3324 Bldg Open Warehouse**	**AOI3-AI-16-007** **Central Warehouse Shipping/Receiving Warehouse**	**AOI3-AI-16-008** **Tek-Solv-Trailer Southeast Corner of Trailer Lot**	**AOI3-AI-16-009** **018 Buildiung, Main Contractor Processing Trailer with Skirt**
Sample Date							**28-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**22-Mar-16**	**28-Mar-16**	**29-Mar-16**
Sample ID							**IA-AOI3-OUTDOOR**	**IA-AOI3-SAFWAY**	**IA-AOI3-3324-1**	**IA-AOI3-3324-2**	**IA-AOI3-3324-3**	**IA-AOI3-3324-4**	**IA-AOI3-3324-5**	**IA-AOI3-3324-6**	**IA-AOI3-TRAILER13**	**IA-AOI3-018**
Sampling Company							**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**
Laboratory							**LL**	**LL**	**LL**	**LL**	**LL**	**LL**	**LL**	**LL**	**LL**	**ESC**
Laboratory Work Order							**MHF24**	**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF23**	**MHF24**	**L827327**
Laboratory Sample ID							**8316883**	**8302476**	**8302477**	**8302478**	**8302479**	**8302480**	**8302481**	**8302482**	**8316882**	**L827327-01**
Sample Type	**Units**	**VI-PA**	**OSHA**	**USEPA RSL**	**ACGIH TLV**	**NIOSH**										
Volatile Organic Compounds																
BENZENE	µg/m3	16^{A}	3190^{B}	1.6^{CD}	1600^{E}	319^{F}	1.5 J	***2.1 J*** ^{CD}	***2.4 J*** ^{CD}	***3.0 J*** ^{CD}	***3.0 J*** ^{CD}	***3.7*** ^{CD}	***3.4*** ^{CD}	***3.7*** ^{CD}	***1.8 J*** ^{CD}	***5.25*** ^{CD}
1,2-DIBROMOETHANE (EDB)	µg/m3	0.2^{A}	153800^{B}	0.02^{CD}	n/v	346^{F}	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (1.54)*
1,2-DICHLOROETHANE (EDC)	µg/m3	4.7^{A}	202500^{B}	0.47^{CD}	40500^{E}	4000^{F}	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (0.810)*
ETHYLBENZENE	µg/m3	49^{A}	435000^{B}	4.9^{CD}	86800^{E}	435000^{F}	ND (4.3)	ND (4.3)	ND (4.3)	***6.2*** ^{CD}	1.0 J	2.2 J	ND (4.3)	0.91 J	ND (4.3)	ND (0.867)
ISOPROPYLBENZENE (CUMENE)	µg/m3	1800^{A}	245000^{B}	1800^{C} 180^{D}	246000^{E}	245000^{F}	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	1.13
M, P-XYLENES	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	2.7 J	ND (4.3)	1.4 J	27	2.4 J	5.5 J	1.9 J	2.5 J	2.7 J	2.23
METHYL TERTIARY BUTYL ETHER	µg/m3	470^{A}	n/v	47^{CD}	180000^{E}	n/v	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	0.75 J	ND (3.6)	ND (3.6)	ND (3.6)	ND (0.721)
NAPHTHALENE	µg/m3	n/v	50000^{B}	0.36^{CD}	52000^{E}	50000^{F}	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (3.30)*
O-XYLENE (1,2-DIMETHYLBENZENE)	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	1.1 J	ND (4.3)	ND (4.3)	9.3	1.4 J	3.7 J	ND (4.3)	1.3 J	1.2 J	ND (0.867)
TOLUENE	µg/m3	22000^{A}	754000^{B}	22000^{C} 2200^{D}	75400^{E}	375000^{F}	4.5	1.8 J	3.5 J	13	22	13 J	24 J	13	4.0	4.79
1,2,4-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	31^{C} 3.1^{D}	123000^{E}	125000^{F}	*ND (4.9)*	*ND (4.9)*	*ND (4.9)*	2.1 J	1.9 J	1.8 J	1.1 J	1.6 J	*ND (4.9)*	1.23
1,3,5-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	n/v	123000^{E}	125000^{F}	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (0.982)

Notes:

VI-PA	PADEP Vapor Intrusion Screening Values
A	Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential (Draft, July 2015)
OSHA	Occupational Safety and Health Administration
B	Permissible Exposure Limits
USEPA RSL	United States Environmental Protection Agency
C	Regional Screening Level for Non-residential indoor air Hazard Index of 1.0.
D	Regional Screening Level for Non-residential indoor air Hazard Index of 0.1.
ACGIH TLV	American Conference of Governmental Industrial Hygienists
E	Threshold Limit Value
NIOSH	National Institute for Occupational Safety and Health
F	Recommended Exposure Limits
6.5 ^{A}	Concentration exceeds the indicated standard.
15.2	Measured concentration did not exceed the indicated standard.
ND (0.50)	Laboratory reporting limit was greater than the applicable standard.
ND (0.03)	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
J	Indicates an estimated value.

Table
March and April 2016 Air Sampling Data
Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

							AOI 5						
Sample Location							**AOI5-AA-16-001**	**AOI5-AI-16-001**	**AOI5-AI-16-002**	**AOI5-AI-16-003**	**AOI5-AI-16-004**	**AOI5-AI-16-005**	**AOI5-AI-16-006**
							by Warf on Bldg Dock	**Control Room**	**Dock Warf Office 2nd Floor**	**Sample on Desk**	**Dock Office, Brick Bldg, Steam Heat**	**GP2 Dock**	**034A/B Building**
Sample Date							**28-Mar-16**	**28-Mar-16**	**28-Mar-16**	**28-Mar-16**	**28-Mar-16**	**28-Mar-16**	**28-Mar-16**
Sample ID							**IA-AOI5-OUTDOOR**	**IA-AOI5-625**	**IA-AOI5-526-2**	**IA-AOI5-526-1**	**IA-AOI5-501**	**IA-AOI5-GP DOCK 2**	**IA-AOI5-034A/B**
Sampling Company							**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**
Laboratory							**LL**	**LL**	**LL**	**LL**	**LL**	**LL**	**LL**
Laboratory Work Order							**MHF24**	**MHF24**	**MHF24**	**MHF24**	**MHF24**	**MHF24**	**MHF24**
Laboratory Sample ID							**8316890**	**8316884**	**8316885**	**8316886**	**8316887**	**8316888**	**8316889**
Sample Type	**Units**	**VI-PA**	**OSHA**	**USEPA RSL**	**ACGIH TLV**	**NIOSH**							
Volatile Organic Compounds													
BENZENE	µg/m3	16^{A}	3190^{B}	1.6^{CD}	1600^{E}	319^{F}	***2.4 J*** ^{CD}	1.4 J	***4.3*** ^{CD}	***2.6 J*** ^{CD}	***4.4*** ^{CD}	***1.8 J*** ^{CD}	***1.8 J*** ^{CD}
1,2-DIBROMOETHANE (EDB)	µg/m3	0.2^{A}	153800^{B}	0.02^{CD}	n/v	346^{F}	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*
1,2-DICHLOROETHANE (EDC)	µg/m3	4.7^{A}	202500^{B}	0.47^{CD}	40500^{E}	4000^{F}	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*
ETHYLBENZENE	µg/m3	49^{A}	435000^{B}	4.9^{CD}	86800^{E}	435000^{F}	1.6 J	1.3 J	ND (4.3)	1.2 J	1.1 J	1.9 J	1.9 J
ISOPROPYLBENZENE (CUMENE)	µg/m3	1800^{A}	245000^{B}	1800^{C} 180^{D}	246000^{E}	245000^{F}	2.5 J	9.8	18	8.6	ND (4.9)	ND (4.9)	1.5 J
M, P-XYLENES	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	2.5 J	3.4 J	1.7 J	2.9 J	2.7 J	5.3	7.6
METHYL TERTIARY BUTYL ETHER	µg/m3	470^{A}	n/v	47^{CD}	180000^{E}	n/v	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)
NAPHTHALENE	µg/m3	n/v	50000^{B}	0.36^{CD}	52000^{E}	50000^{F}	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*
O-XYLENE (1,2-DIMETHYLBENZENE)	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	ND (4.3)	1.5 J	ND (4.3)	1.2 J	1.1 J	2.4 J	3.5 J
TOLUENE	µg/m3	22000^{A}	754000^{B}	22000^{C} 2200^{D}	75400^{E}	375000^{F}	1.7 J	3.1 J	5.0	7.9	15	3.1 J	4.6
1,2,4-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	31^{C} 3.1^{D}	123000^{E}	125000^{F}	*ND (4.9)*	*ND (4.9)*	*ND (4.9)*	*ND (4.9)*	*ND (4.9)*	1.1 J	***12*** ^{D}
1,3,5-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	n/v	123000^{E}	125000^{F}	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	3.2 J

Notes:

VI-PA	PADEP Vapor Intrusion Screening Values
A	Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential (Draft, July 2015)
OSHA	Occupational Safety and Health Administration
B	Permissible Exposure Limits
USEPA RSL	United States Environmental Protection Agency
C	Regional Screening Level for Non-residential indoor air Hazard Index of 1.0.
D	Regional Screening Level for Non-residential indoor air Hazard Index of 0.1.
ACGIH TLV	American Conference of Governmental Industrial Hygienists
E	Threshold Limit Value
NIOSH	National Institute for Occupational Safety and Health
F	Recommended Exposure Limits
6.5 ^{A}	Concentration exceeds the indicated standard.
15.2	Measured concentration did not exceed the indicated standard.
ND (0.50)	Laboratory reporting limit was greater than the applicable standard.
ND (0.03)	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
J	Indicates an estimated value.

Table
March and April 2016 Air Sampling Data
Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

DRAFT

							AOI 6										
Sample Location							**AOI6-AA-16-001** **Outdoor**	**AOI6-AA-16-002** **Ambient Outdoor Near Carpenter Shop Open Area**	**AOI6-AI-16-001** **475 Building**	**AOI6-AI-16-002** **745 Building**	**AOI6-AI-16-003** **Control Room, 6627 Building**	**AOI6-AI-16-004** **Truck Scale House, 6636 Building**	**AOI6-AI-16-005** **Control Room, 739 Building**	**AOI6-AI-16-006** **726 Building, Carpenter Shop**	**AOI6-AI-16-007** **178 Building, Carpenter Trade Shop**	**AOI6-AI-16-008** **295 GP Office Building 1st Floor**	**AOI6-AI-16-009** **295 GP Office Building 2nd Floor**
Sample Date							**28-Mar-16**	**29-Mar-16**	**28-Mar-16**	**28-Mar-16**	**28-Mar-16**	**28-Mar-16**	**28-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**
Sample ID							**IA-AOI6-OUTDOOR 739**	**IA-AOI6-OUTDOOR-032916**	**IA-AOI6-475**	**IA-AOI6-745**	**IA-AOI6-6627**	**IA-AOI6-6636**	**IA-AOI6-739**	**IA-AOI6-726**	**IA-AOI6-178**	**IA-AOI6-295-1**	**IA-AOI6-295-2**
Sampling Company							**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**
Laboratory							**LL**	**ESC**	**LL**	**LL**	**LL**	**LL**	**LL**	**ESC**	**ESC**	**ESC**	**ESC**
Laboratory Work Order							**MHF24**	**L827327**	**MHF24**	**MHF24**	**MHF24**	**MHF24**	**MHF24**	**L827327**	**L827327**	**L827327**	**L827327**
Laboratory Sample ID							**8316897**	**L827327-04**	**8316892**	**8316893**	**8316894**	**8316895**	**8316896**	**L827327-02**	**L827327-03**	**L827327-05**	**L827327-06**
Sample Type	**Units**	**VI-PA**	**OSHA**	**USEPA RSL**	**ACGIH TLV**	**NIOSH**											
Volatile Organic Compounds																	
BENZENE	µg/m3	16^{A}	3190^{B}	1.6^{CD}	1600^{E}	319^{F}	**1.8 J ^{CD}**	**3.95 ^{CD}**	**5.5 ^{CD}**	1.3 J	**36 ^{ACD}**	**2.1 J ^{CD}**	**4.5 ^{CD}**	**3.46 ^{CD}**	**5.05 ^{CD}**	**3.97 ^{CD}**	**3.94 ^{CD}**
1,2-DIBROMOETHANE (EDB)	µg/m3	0.2^{A}	153800^{B}	0.02^{CD}	n/v	346^{F}	*ND (11)*	*ND (1.54)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*
1,2-DICHLOROETHANE (EDC)	µg/m3	4.7^{A}	202500^{B}	0.47^{CD}	40500^{E}	4000^{F}	*ND (5.6)*	*ND (0.810)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*
ETHYLBENZENE	µg/m3	49^{A}	435000^{B}	4.9^{CD}	86800^{E}	435000^{F}	*ND (6.0)*	ND (0.867)	1.1 J	ND (4.3)	2.0 J	2.1 J	3.2 J	ND (0.867)	ND (0.867)	ND (0.867)	0.960
ISOPROPYLBENZENE (CUMENE)	µg/m3	1800^{A}	245000^{B}	1800^{C} 180^{D}	246000^{E}	245000^{F}	1.5 J	1.72	9.1	ND (4.9)	7.8	ND (4.9)	2.8 J	1.45	1.60	ND (0.983)	ND (0.983)
M, P-XYLENES	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	2.3 J	ND (1.73)	3.5 J	2.2 J	8.3	5.8	8.8	ND (1.73)	1.76	2.20	2.29
METHYL TERTIARY BUTYL ETHER	µg/m3	470^{A}	n/v	47^{CD}	180000^{E}	n/v	ND (5.0)	ND (0.721)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)
NAPHTHALENE	µg/m3	n/v	50000^{B}	0.36^{CD}	52000^{E}	50000^{F}	**4.1 J ^{CD}**	*ND (3.30)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*
O-XYLENE (1,2-DIMETHYLBENZENE)	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	1.4 J	ND (0.867)	1.2 J	1.1 J	3.6 J	4.0 J	5.3	ND (0.867)	ND (0.867)	ND (0.867)	ND (0.867)
TOLUENE	µg/m3	22000^{A}	754000^{B}	22000^{C} 2200^{D}	75400^{E}	375000^{F}	2.1 J	2.85	3.9	2.2 J	13	2.6 J	3.9	2.06	2.57	3.12	3.11
1,2,4-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	31^{C} 3.1^{D}	123000^{E}	125000^{F}	*ND (6.8)*	ND (0.982)	1.4 J	*ND (4.9)*	**3.6 J ^{D}**	1.1 J	*ND (4.9)*	ND (0.982)	ND (0.982)	2.18	2.04
1,3,5-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	n/v	123000^{E}	125000^{F}	ND (6.8)	ND (0.982)	ND (4.9)	ND (4.9)	1.3 J	ND (4.9)	ND (4.9)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)

Notes:

VI-PA	PADEP Vapor Intrusion Screening Values
A	Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential (Draft, July 2015)
OSHA	Occupational Safety and Health Administration
B	Permissible Exposure Limits
USEPA RSL	United States Environmental Protection Agency
C	Regional Screening Level for Non-residential indoor air Hazard Index of 1.0.
D	Regional Screening Level for Non-residential indoor air Hazard Index of 0.1.
ACGIH TLV	American Conference of Governmental Industrial Hygienists
E	Threshold Limit Value
NIOSH	National Institute for Occupational Safety and Health
F	Recommended Exposure Limits
6.5 ^{A}	Concentration exceeds the indicated standard.
15.2	Measured concentration did not exceed the indicated standard.
ND (0.50)	Laboratory reporting limit was greater than the applicable standard.
ND (0.03)	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
J	Indicates an estimated value.

Table
March and April 2016 Air Sampling Data
Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

DRAFT

							AOI 7											
Sample Location							**AOI7-AA-16-001**	**AOI7-AI-16-001**	**AOI7-AI-16-002**	**AOI7-AI-16-003**	**AOI7-AI-16-004**	**AOI7-AI-16-005**	**AOI7-AI-16-006**	**AOI7-AI-16-007**	**AOI7-AI-16-008**	**AOI7-AI-16-009**	**AOI7-AI-16-010**	**AOI7-AI-16-011**
							Ambient, Near WTP Fence	**595 Canteen Building**	**450 Elect Building, Computer Room**	**450 Building Elect Warehouse, Back Addition on Shelf**	**450 Building Elect Warehouse, North Side**	**450 Building Elect Warehouse, Walled area Middle Bldg, Elect Testing**	**450 Building Elect Warehouse Table East Side Near Open Offices**	**442 Building Firehouse Office Table Office**	**711 Building, WTP**	**6622 Building, Control Room, Rear Table Center of Room**	**6626 Building, Control Room**	**6625 Building, Control Room, MF Unit**
Sample Date							**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**
Sample ID							**IA-AOI7-OUTDOOR**	**IA-AOI7-595**	**IA-AOI7-450-1**	**IA-AOI7-450-2**	**IA-AOI7-450-3**	**IA-AOI7-450-4**	**IA-AOI7-450-5**	**IA-AOI7-442**	**IA-AOI7-711**	**IA-AOI7-6622**	**IA-AOI7-6626**	**IA-AOI7-6625**
Sampling Company							**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**
Laboratory							**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**
Laboratory Work Order							**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**
Laboratory Sample ID							**L827327-15**	**L827327-07**	**L827327-08**	**L827327-09**	**L827327-10**	**L827327-11**	**L827327-12**	**L827327-13**	**L827327-14**	**L827327-16**	**L827327-17**	**L827327-18**
Sample Type	**Units**	**VI-PA**	**OSHA**	**USEPA RSL**	**ACGIH TLV**	**NIOSH**												
Volatile Organic Compounds																		
BENZENE	µg/m3	16^{A}	3190^{B}	1.6^{CD}	1600^{E}	319^{F}	1.32	***4.63*** ^{CD}	1.00	0.860	0.973	1.54	***1.99*** ^{CD}	***1.68*** ^{CD}	***2.22*** ^{CD}	***3.52*** ^{CD}	***3.36*** ^{CD}	***1.63*** ^{CD}
1,2-DIBROMOETHANE (EDB)	µg/m3	0.2^{A}	153800^{B}	0.02^{CD}	n/v	346^{F}	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*
1,2-DICHLOROETHANE (EDC)	µg/m3	4.7^{A}	202500^{B}	0.47^{CD}	40500^{E}	4000^{F}	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*
ETHYLBENZENE	µg/m3	49^{A}	435000^{B}	4.9^{CD}	86800^{E}	435000^{F}	ND (0.867)	ND (0.867)	1.12	ND (0.867)	ND (0.867)	1.19	2.58	1.38	ND (0.867)	***4.94*** ^{CD}	1.60	4.22
ISOPROPYLBENZENE (CUMENE)	µg/m3	1800^{A}	245000^{B}	1800^{C} 180^{D}	246000^{E}	245000^{F}	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	1.27	2.09	ND (0.983)
M, P-XYLENES	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	1.99	2.48	4.58	2.09	ND (1.73)	3.14	7.89	3.63	2.46	16.9	5.15	12.3
METHYL TERTIARY BUTYL ETHER	µg/m3	470^{A}	n/v	47^{CD}	180000^{E}	n/v	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)
NAPHTHALENE	µg/m3	n/v	50000^{B}	0.36^{CD}	52000^{E}	50000^{F}	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*
O-XYLENE (1,2-DIMETHYLBENZENE)	µg/m3	n/v	435000^{B}	44^{CD}	434000^{E}	435000^{F}	ND (0.867)	0.891	1.67	ND (0.867)	ND (0.867)	1.32	2.87	1.36	1.04	7.79	2.04	4.75
TOLUENE	µg/m3	22000^{A}	754000^{B}	22000^{C} 2200^{D}	75400^{E}	375000^{F}	4.05	5.51	10.5	3.15	4.12	8.91	49.8	19.1	3.93	7.29	3.06	71.4
1,2,4-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	31^{C} 3.1^{D}	123000^{E}	125000^{F}	ND (0.982)	1.09	1.05	ND (0.982)	ND (0.982)	1.23	2.13	1.22	2.94	***21.6*** ^{D}	***3.81*** ^{D}	***6.40*** ^{D}
1,3,5-TRIMETHYLBENZENE	µg/m3	31^{A}	n/v	n/v	123000^{E}	125000^{F}	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	0.984	6.81	1.19	1.78

Notes:

VI-PA	PADEP Vapor Intrusion Screening Values
^{A}	Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential (Draft, July 2015)
OSHA	Occupational Safety and Health Administration
^{B}	Permissible Exposure Limits
USEPA RSL	United States Environmental Protection Agency
^{C}	Regional Screening Level for Non-residential indoor air Hazard Index of 1.0.
^{D}	Regional Screening Level for Non-residential indoor air Hazard Index of 0.1.
ACGIH TLV	American Conference of Governmental Industrial Hygienists
^{E}	Threshold Limit Value
NIOSH	National Institute for Occupational Safety and Health
^{F}	Recommended Exposure Limits
6.5 ^{A}	Concentration exceeds the indicated standard.
15.2	Measured concentration did not exceed the indicated standard.
ND (0.50)	Laboratory reporting limit was greater than the applicable standard.
ND (0.03)	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
J	Indicates an estimated value.

Table
March and April 2016 Air Sampling Data
Philadelphia Refinery Operations, a series of Evergreen Resources Group, LLC

DRAFT

							AOI 8						AOI 9				QC
Sample Location							**AOI8-AA-16-001**	**AOI8-AI-16-001**	**AOI8-AI-16-002**	**AOI8-AI-16-003**	**AOI8-AI-16-004**		**AOI9-AA-16-001**	**AOI9-AI-16-001**	**AOI9-AI-16-002**		**FIELD_BLANK**
							Ambient, Near 6641 on Concrete Block	**6642 Building, North Yard Trailers**	**6641 Building, North Yard Trailer**	**3326 Building North Yard Scale House**	**27 Building, North Yard Old Scale House**	**27 Building, North Yard Old Scale House**	**Outdoor**	**SR2 Corner Office**	**Loading Dock Office SR9**	**Loading Dock Office SR9**	
Sample Date							**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**29-Mar-16**	**5-Apr-16**	**5-Apr-16**	**5-Apr-16**	**5-Apr-16**	**29-Mar-16**
Sample ID							**IA-AOI8-OUTDOOR**	**IA-AOI8-6642**	**IA-AOI8-6641**	**IA-AOI8-3326**	**IA-AOI8-27**	**IA-AOI8-27-DUP**	**IA-AOI9-OUTDOOR**	**IA-AOI9-SR2**	**IA-AOI9-SR9**	**IA-AOI9-SR9-DUP**	**FIELD BLANK**
Sampling Company							**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**	**GHD**
Laboratory							**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**ESC**	**LL**	**LL**	**LL**	**LL**	**ESC**
Laboratory Work Order							**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**L827327**	**MHF26**	**MHF26**	**MHF26**	**MHF26**	**L827327**
Laboratory Sample ID							**L827327-24**	**L827327-19**	**L827327-20**	**L827327-21**	**L827327-22**	**L827327-23**	**8322923**	**8322922**	**8322924**	**8322925**	**L827327-25**
Sample Type	**Units**	**VI-PA**	**OSHA**	**USEPA RSL**	**ACGIH TLV**	**NIOSH**						**Field Duplicate**				**Field Duplicate**	**Field Blank**
Volatile Organic Compounds																	
BENZENE	µg/m3	16[A]	3190[B]	1.6[CD]	1600[E]	319[F]	ND (0.639)	ND (0.639)	ND (0.639)	ND (0.639)	ND (0.639)	ND (0.639)	***1.8 J***[CD]	1.3 J	0.71 J	0.64 J	ND (0.639)
1,2-DIBROMOETHANE (EDB)	µg/m3	0.2[A]	153800[B]	0.02[CD]	n/v	346[F]	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (1.54)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (7.7)*	*ND (1.54)*
1,2-DICHLOROETHANE (EDC)	µg/m3	4.7[A]	202500[B]	0.47[CD]	40500[E]	4000[F]	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (0.810)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (4.0)*	*ND (0.810)*
ETHYLBENZENE	µg/m3	49[A]	435000[B]	4.9[CD]	86800[E]	435000[F]	ND (0.867)	ND (0.867)	ND (0.867)	ND (0.867)	ND (0.867)	ND (0.867)	ND (4.3)	2.9 J	ND (4.3)	1.5 J	ND (0.867)
ISOPROPYLBENZENE (CUMENE)	µg/m3	1800[A]	245000[B]	1800[C] 180[D]	246000[E]	245000[F]	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (0.983)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (0.983)
M, P-XYLENES	µg/m3	n/v	435000[B]	44[CD]	434000[E]	435000[F]	ND (1.73)	ND (1.73)	ND (1.73)	1.78	ND (1.73)	ND (1.73)	2.4 J	8.9	1.1 J	4.0 J	ND (1.73)
METHYL TERTIARY BUTYL ETHER	µg/m3	470[A]	n/v	47[CD]	180000[E]	n/v	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (0.721)	ND (3.6)	ND (3.6)	ND (3.6)	ND (3.6)	ND (0.721)
NAPHTHALENE	µg/m3	n/v	50000[B]	0.36[CD]	52000[E]	50000[F]	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (3.30)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (5.2)*	*ND (3.30)*
O-XYLENE (1,2-DIMETHYLBENZENE)	µg/m3	n/v	435000[B]	44[CD]	434000[E]	435000[F]	ND (0.867)	ND (0.867)	ND (0.867)	ND (0.867)	ND (0.867)	ND (0.867)	1.1 J	5.6	ND (4.3)	3.0 J	ND (0.867)
TOLUENE	µg/m3	22000[A]	754000[B]	22000[C] 2200[D]	75400[E]	375000[F]	8.26	1.23	2.56	1.14	ND (0.753)	1.01	3.3 J	4.1	0.88 J	0.88 J	ND (0.753)
1,2,4-TRIMETHYLBENZENE	µg/m3	31[A]	n/v	31[C] 3.1[D]	123000[E]	125000[F]	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	1.0 J	1.2 J	*ND (4.9)*	*ND (4.9)*	ND (0.982)
1,3,5-TRIMETHYLBENZENE	µg/m3	31[A]	n/v	n/v	123000[E]	125000[F]	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (0.982)	ND (4.9)	ND (4.9)	ND (4.9)	ND (4.9)	ND (0.982)

Notes:

VI-PA	PADEP Vapor Intrusion Screening Values
[A]	Indoor Air Statewide Health Standard Vapor Intrusion Screening Values, Non-Residential (Draft, July 2015)
OSHA	Occupational Safety and Health Administration
[B]	Permissible Exposure Limits
USEPA RSL	United States Environmental Protection Agency
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[D]	Regional Screening Level for Non-residential indoor air Hazard Index of 0.1.
ACGIH TLV	American Conference of Governmental Industrial Hygienists
[E]	Threshold Limit Value
NIOSH	National Institute for Occupational Safety and Health
[F]	Recommended Exposure Limits
6.5[A]	Concentration exceeds the indicated standard.
15.2	Measured concentration did not exceed the indicated standard.
ND (0.50)	Laboratory reporting limit was greater than the applicable standard.
ND (0.03)	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
J	Indicates an estimated value.

APPENDIX H

LNAPL CHARACTERIZATION

Appendix H
LNAPL Characterization Data for AOI 9
AOI 9 Remedial Investigation Report Addendum
Philadelphia Energy Solutions Refining Complex
Philadelphia, Pennsylvania

Characterization Results Compiled for Remedial Investigation Report Interpretation of Product Type(s), Proportion, Weathering					
Well ID	**Specific Gravity**	**LNAPL Type(s)**	**LNAPL Types(s)***	**Proportion (%)**	**Weathering**
MW-1SRTF	0.780	Light Distillate	Crude	2	Moderate
			Gasoline	98	Moderate
MW-2SRTF	0.801	Light Distillate	Gasoline	NS	Weathered
MW-3SRTF	0.841	Light Distillate	Gasoline	NS	Weathered
S-114SRTF	0.822	Mixes of Light/Middle Distillates	Gasoline	NS	Weathered
			Diesel or #2 Fuel Oil	NS	Undegraded
S-122SRTF	0.825	Mixes of Light/Middle Distillates	Gasoline	NS	Weathered
			Diesel or #2 Fuel Oil	NS	Degraded

Notes:

1. Characterization Data Provided by Torkelson Geochemistry of Tulsa, OK and Pace Analytical Laboratory of Pittsburgh, PA
2. NS- Not Specified

* LNAPL characterization for MW-2SRTF, MW-3SRTF, S-114SRTF, and S-122SRTF and specific gravity for MW-1SRTF were analyzed by Pace Analytical Laboratory. MW-1SRTF LNAPL type, proportion, and weathering are from Torkelson . Torkelson notes that "heavier material" could either be crude oil or residual oil. Residual oil was selected due to abundance of residual oil identified in CCR. The Torkelson description of MW-1SRTF LNAPL type is in agreement with Pace Analytical Laboratory results.

From: Alan Jeffrey <Alan.Jeffrey@pacelabs.com>
Sent: Thursday, November 24, 2016 4:55 PM
To: ns@aquaterra-tech.com; Ruth Welsh
Cc: tldoerr@evergreenresmgt.com; Kevin McKeever
Subject: Re: PH REF ADI 9

Ms. Stroik,

I have reviewed the analytical data for the five product samples for this project, and my interpretation of the product identities are as follows:

All five samples contain weathered gasoline; S-114SRTF-PRODUCT-20161013, S-122SRTF-PRODUCT-20161013 also contain diesel or #2 fuel oil that is relatively undegraded in S-114SRTF-PRODUCT-20161013, and degraded in S-122SRTF-PRODUCT-20161013.

MW-1SRT-PRODUCT-20161013 and MW- 2SRTF-PRODUCT-20161013 contain different gasolines

MW-3SRFT-PRODUCT-20161013 and S-114SRTF-PRODUCT-20161013 may contain a gasoline mixture containing differing amounts of MW-1SRT-PRODUCT-20161013 and MW- 2SRTF-PRODUCT-20161013.

Analysis of oxygenate and alkyl lead gasoline additives may help to determine the relationship of the gasoline components.

Best regards,

Alan Jeffrey, PhD
Senior Geochemist
Pace Analytical/Zymax Forensics

>>> Noelle Stroik <ns@aquaterra-tech.com> 11/22/16 6:59 AM >>>
Hi Ruth,

On the chain of custody, a brief description of product types was also requested. I did not receive any descriptions. How long will it take to receive them? We need them ASAP. We requested additional analyses, based on the lab's recommendation, to aid the lab in interpreting the product types.

Please let me know when I can expect to receive the descriptions.

Thanks,

Noelle Stroik

Environmental Scientist
Aquaterra Technologies, Inc.

Ph: 610-431-5733
Cell: 443-350-6377
Fax: 610-431-5734

From: "Ruth Welsh" <Ruth.Welsh@pacelabs.com>
To: "Noelle Stroik" <ns@aquaterra-tech.com>
Sent: Monday, November 21, 2016 7:45:09 AM
Subject: PH REF ADI 9

Please see the attached report and invoice for the project referenced above

Pace Analytical Energy Services will be closed on Thursday and Friday November 24 and 25 in observance of Thanksgiving

Ruth Welsh
Customer Service
Pace Analytical Energy Services, LLC
220 William Pitt Way
Pittsburgh, PA 15238
412-826-4482 (direct)
412-826-5245 (main)
412-826-3433 (fax)

Pace Analytical®
Energy Services™

November 18, 2016

Noelle Stroik
Aquaterra
122 South Church
West Chester, PA 19381

RE: PH REF ADI 9
Project Number

Pace Analytical received 5 sample(s) received on October 27, 2016 for analysis labeled MW-1SRT-PRODUCT-20161013, MW- 2SRTF-PRODUCT-20161013, MW-3SRFT-PRODUCT-20161013, S-114SRTF-PRODUCT-20161013, S-122SRTF-PRODUCT-20161013. Per client request, the following analyses were performed:

1. Simulated Distialltion (ASTM 2287)
2. Specific Gravity
3. Whole Oil (ASTM D3328)

The sample was performed in house under laboratory number 20791

Please call the lab at 412-826-5245, or you may email any questions or concerns to ruth.welsh@pacelabs.com regarding any analytical data reports.

Respectfully submitted,

Ruth Welsh

Ruth Welsh
Project Manager

Pace Analytical®
www.pacelabs.com

20191

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page: 1 of 1

2062380

Section A
Required Client Information:

Company: AQUATERRA
Address: 122 SO CHURCH
WEST CHESTER PA
Email To: MS@AQUATERRATECH.COM
Phone: 610 431 5733 Fax:
Requested Due Date/TAT:

Section B
Required Project Information:

Report To:
Copy To:
Purchase Order No.:
Project Name: PH REF ADF 9
Project Number: PRODUCT SAMPLES

Section C
Invoice Information:

Attention:
Company Name:
Address:
Pace Quote Reference:
Pace Project Manager:
Pace Profile #:

REGULATORY AGENCY

☐ NPDES ☐ GROUND WATER ☐ DRINKING WATER
☐ UST ☐ RCRA ☐ OTHER ____________

Site Location
STATE: PA

Section D
Required Client Information

SAMPLE ID
(A-Z, 0-9 / ,-)
Sample IDs MUST BE UNIQUE

Matrix Codes MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Tissue	TS
Other	OT

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED COMPOSITE START DATE	COLLECTED COMPOSITE START TIME	COMPOSITE END/GRAB DATE	COMPOSITE END/GRAB TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H_2SO_4	HNO_3	HCl	NaOH	$Na_2S_2O_3$	Methanol	Other	Analysis Test Y/N	Simulated Distillation by ASTM D2887	C3-C44 Whole Oil by ASTM D3328	Density & Sp. Grav. by ASTM D1217	Residual Chlorine (Y/N)	Pace Project No./ Lab I.D.
1	MW-1SRTF-PRODUCT-20161013	OL	G	10/13	1145				3	X									X	X	X		
2	MW-2SRTF-PRODUCT-20161013	OL	G	10/13	1235				3	X									X	X	X		
3	MW-3SRTF-PRODUCT-20161013	OL	G	10/13	1330				3	X									X	X	X		
4	S-114SRTF-PRODUCT-20161013	OL	G	10/13	0830				3	X									X	X	X		
5	S-122SRTF-PRODUCT-20161013	OL	G	10/13	1030				3	X									X	X	X		
6																							
7																							
8																							
9																							
10																							
11																							
12																							

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME
Basic email interpretation required. - Thank you	Luke Mokrick	10/13/16	1600	AQUATERRA SAMPLE FRIDGE	10/13	1600
	Rob Dewey	10/13/16	11:15		10/25/16	1115
		10/25/16	1315		10/25/16	1430
		10/25/16	2330	Ashley Rose / Pace	10-25-16	2330

SAMPLE CONDITIONS

Temp in °C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)
3.9	Y	N	Y

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: Luke Mokrick
SIGNATURE of SAMPLER:
DATE Signed (MM/DD/YY): 10/13/16

ORIGINAL

10-27-16 1:25

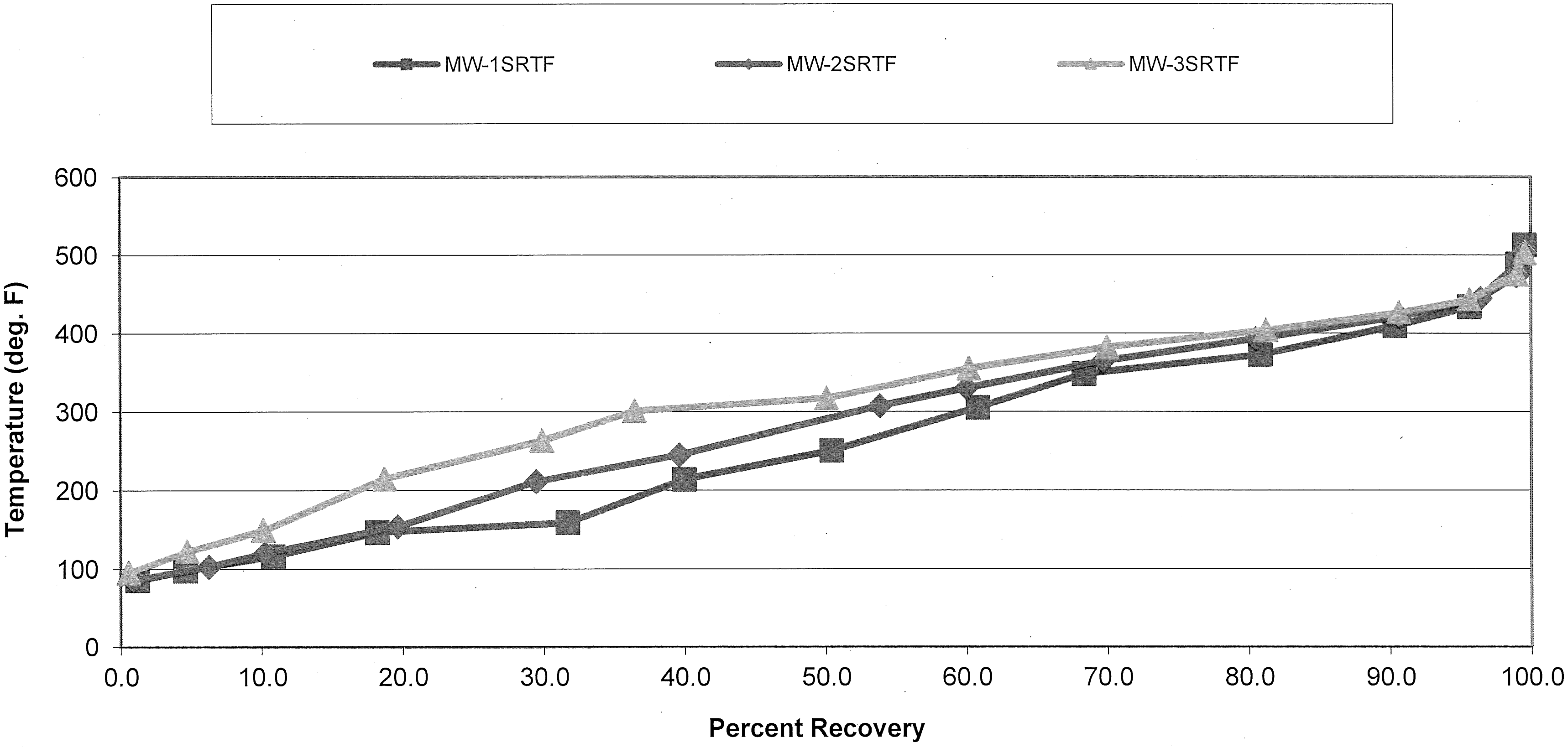
*Important Note: By signing this form you are accepting Pace's NET 30 day payment terms and agreeing to late charges of 1.5% per month for any invoices not paid within 30 days.

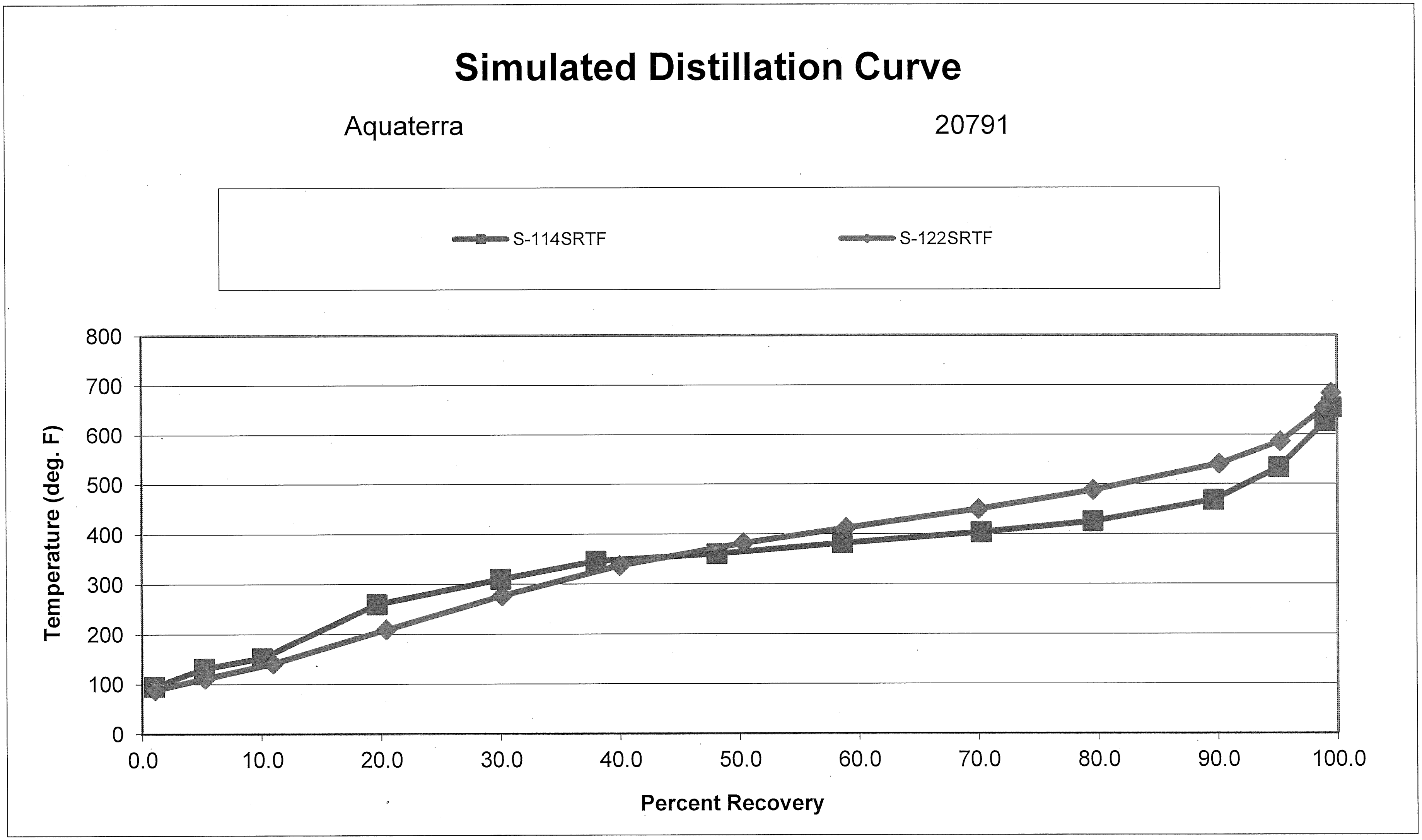
F-ALL-Q-020rev.07, 15-May-2007

Received: [illegible] PAES 10.27.16 1400

Simulated Distillation Curve

Aquaterra 20791





Simulated Distillation Curve

Aquaterra 20791

REPORT OF ANALYTICAL RESULTS

Client: Mike Sarcinello
Aquaterra
122 South Church
West Chester, PA 19381

Lab Number:	**20791**
Collected:	**10/13/2016**
Received:	**10/27/2016**
Matrix:	**Product**

Project: PH REF AOI9

Project Number: PRODUCT SAMPLE
Collected by: -

Sample Description: See Below

Analyzed: 11/16/2016
Method: ASTM D1217

SPECIFIC GRAVITY

LAB NUMBER	SAMPLE DESCRIPTION	SPECIFIC GRAVITY
20791-1	MW-1SRTF-PRODUCT-20161013	0.780
20791-2	MW-2SRTF-PRODUCT-20161013	0.801
20791-3	MW-3SRTF-PRODUCT-20161013	0.841
20791-4	S-114SRTF-PRODUCT-20161013	0.822
20791-5	S-122SRTF-PRODUCT-20161013	0.825

10/29/2016

ZymaX ID	20791-1
Sample ID	MW-1SRTF-PRODUCT-20161013
Evaporation	
n-Pentane / n-Heptane	0.65
2-Methylpentane / 2-Methylheptane	1.98
Waterwashing	
Benzene / Cyclohexane	5.96
Toluene / Methylcyclohexane	4.23
Aromatics / Total Paraffins (n+iso+cyc)	0.59
Aromatics / Naphthenes	7.23
Biodegradation	
(C4 - C8 Para + Isopara) / C4 - C8 Olefins	44.00
3-Methylhexane / n-Heptane	2.07
Methylcyclohexane / n-Heptane	0.77
Isoparaffins + Naphthenes / Paraffins	11.27
Octane rating	
2,2,4,-Trimethylpentane / Methylcyclohexane	17.13
Relative percentages - Bulk hydrocarbon composition as PIANO	
% Paraffinic	5.07
% Isoparaffinic	52.07
% Aromatic	36.52
% Naphthenic	5.05
% Olefinic	1.28

10/29/2016

ZymaX ID		20791-1
Sample ID		MW-1SRTF-PRODUCT-20161013

		Relative Area %
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.03
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.73
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.06
11	Pentane	0.80
12	trans-2-Pentene	0.06
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.15
15	2,2-Dimethylbutane	0.13
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.75
18	2-Methylpentane	2.47
19	3-Methylpentane	1.81
20	Hexane	1.56
21	trans-2-Hexene	0.25
22	3-Methylcyclopentene	0.22
23	3-Methyl-2-pentene	0.07
24	cis-2-Hexene	0.21
25	3-Methyl-trans-2-pentene	0.11
26	Methylcyclopentane	1.36
27	2,4-Dimethylpentane	1.27
28	Benzene	0.24
29	5-Methyl-1-hexene	0.16
30	Cyclohexane	0.04
31	2-Methylhexane/TAME	2.23
32	2,3-Dimethylpentane	2.12
33	3-Methylhexane	2.53
34A	1-trans-3-Dimethylcyclopentane	0.46
34B	1-cis-3-Dimethylcyclopentane	0.41
35	2,2,4-Trimethylpentane	16.26
I.S. #1	à,à,à-Trifluorotoluene	0.00

	ZymaX ID Sample ID	20791-1 MW-1SRTF-PRODUCT-20161013
		Relative Area %
36	n-Heptane	1.23
37	Methylcyclohexane	0.95
38	2,5-Dimethylhexane	1.79
39	2,4-Dimethylhexane	2.57
40	2,3,4-Trimethylpentane	6.41
41	Toluene/2,3,3-Trimethylpentane	4.02
42	2,3-Dimethylhexane	2.46
43	2-Methylheptane	1.25
44	4-Methylheptane	0.51
45	3,4-Dimethylhexane	0.46
46A	3-Ethyl-3-methylpentane	0.74
46B	1,4-Dimethylcyclohexane	1.33
47	3-Methylheptane	1.56
48	2,2,5-Trimethylhexane	0.28
49	n-Octane	0.76
50	2,2-Dimethylheptane	0.26
51	2,4-Dimethylheptane	0.14
52	Ethylcyclohexane	0.50
53	2,6-Dimethylheptane	0.37
54	Ethylbenzene	1.83
55	m+p Xylenes	8.62
56	4-Methyloctane	0.40
57	2-Methyloctane	0.52
58	3-Ethylheptane	0.10
59	3-Methyloctane	0.60
60	o-Xylene	0.62
61	1-Nonene	0.00
62	n-Nonane	0.43
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.27
64	3,3,5-Trimethylheptane	0.10
65	2,4,5-Trimethylheptane	0.14
66	n-Propylbenzene	0.55
67	1-Methyl-3-ethylbenzene	1.80
68	1-Methyl-4-ethylbenzene	1.35
69	1,3,5-Trimethylbenzene	1.98
70	3,3,4-Trimethylheptane	1.09

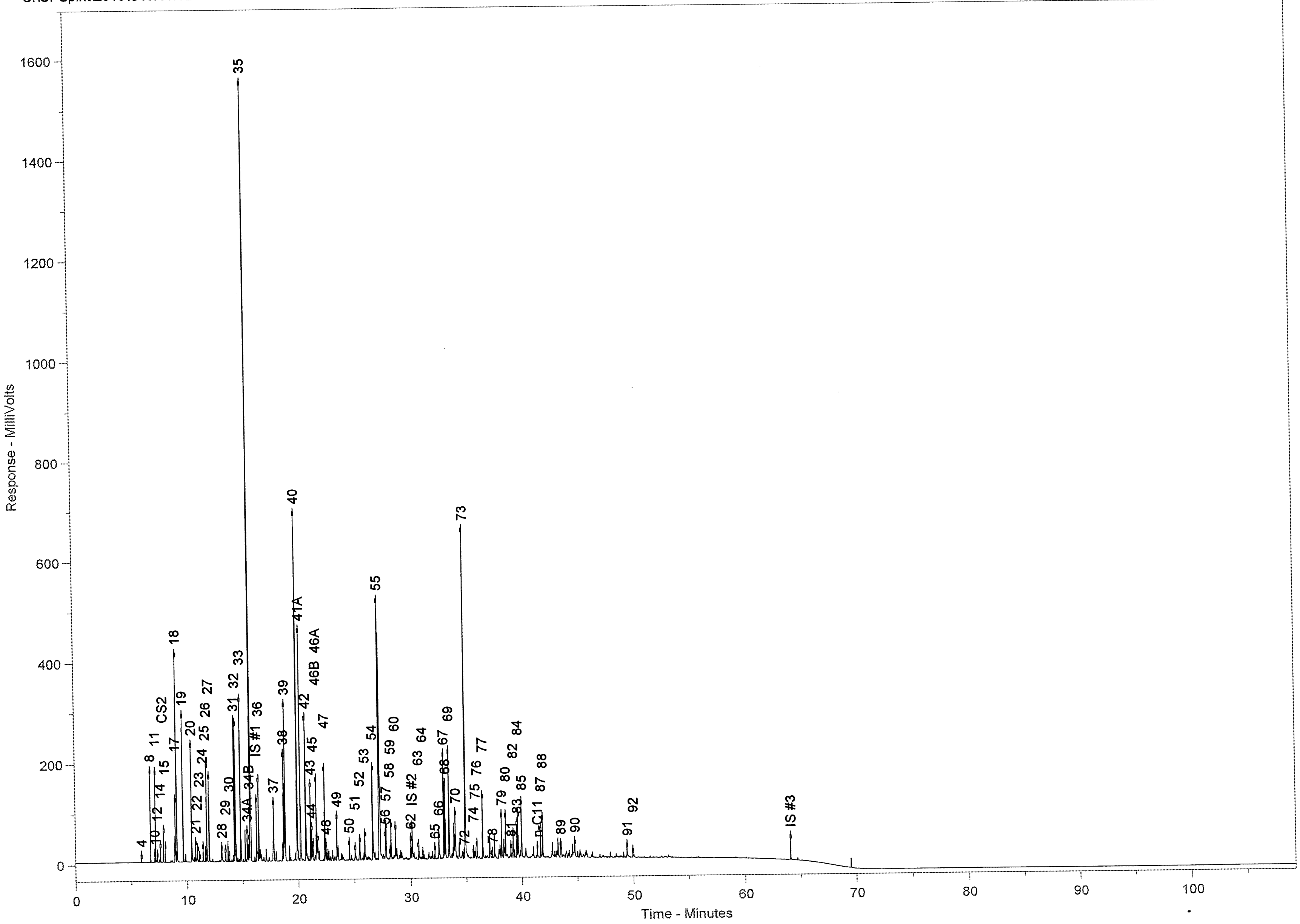
ZymaX ID	20791-1
Sample ID	MW-1SRTF-PRODUCT-20161013

		Relative Area %
71	1-Methyl-2-ethylbenzene	0.00
72	3-Methylnonane	0.04
73	1,2,4-Trimethylbenzene	6.45
74	Isobutylbenzene	0.10
75	sec-Butylbenzene	0.12
76	n-Decane	0.26
77	1,2,3-Trimethylbenzene	1.21
78	Indan	0.08
79	1,3-Diethylbenzene	0.88
80	1,4-Diethylbenzene	0.80
81	n-Butylbenzene	0.32
82	1,3-Dimethyl-5-ethylbenzene	0.60
83	1,4-Dimethyl-2-ethylbenzene	0.65
84	1,3-Dimethyl-4-ethylbenzene	0.93
85	1,2-Dimethyl-4-ethylbenzene	1.14
86	Undecene	0.00
87	1,2,4,5-Tetramethylbenzene	0.52
88	1,2,3,5-Tetramethylbenzene	0.70
89	1,2,3,4-Tetramethylbenzene	0.25
90	Naphthalene	0.22
91	2-Methyl-naphthalene	0.20
92	1-Methyl-naphthalene	0.08

Chrom Perfect Chromatogram Report

— C:\CPSpirit\2016\Oct16\102916\102916.0027.RAW

20791-1 [MW-1SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1



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Chrom Perfect Chromatogram Report

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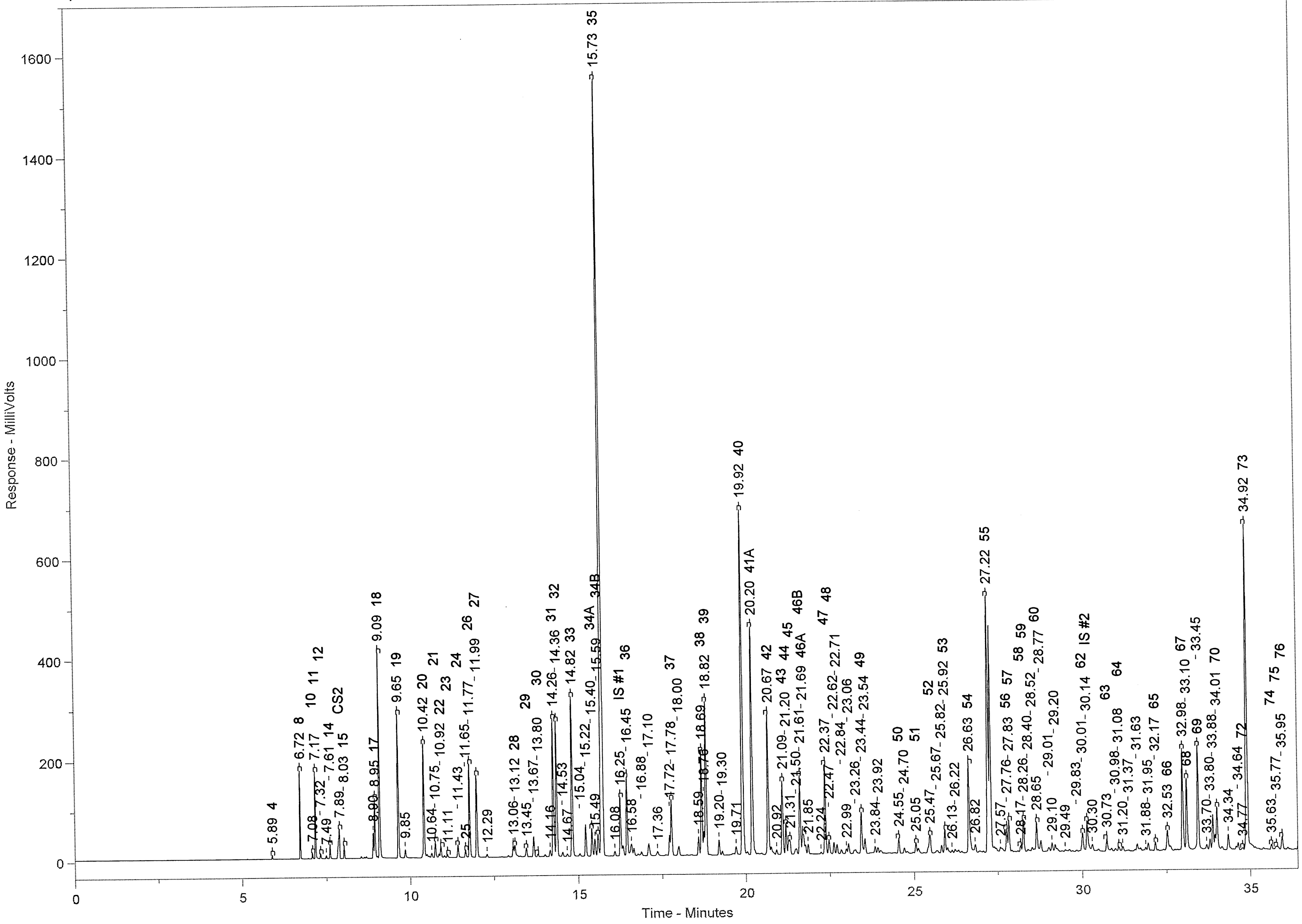

Chrom Perfect Chromatogram Report

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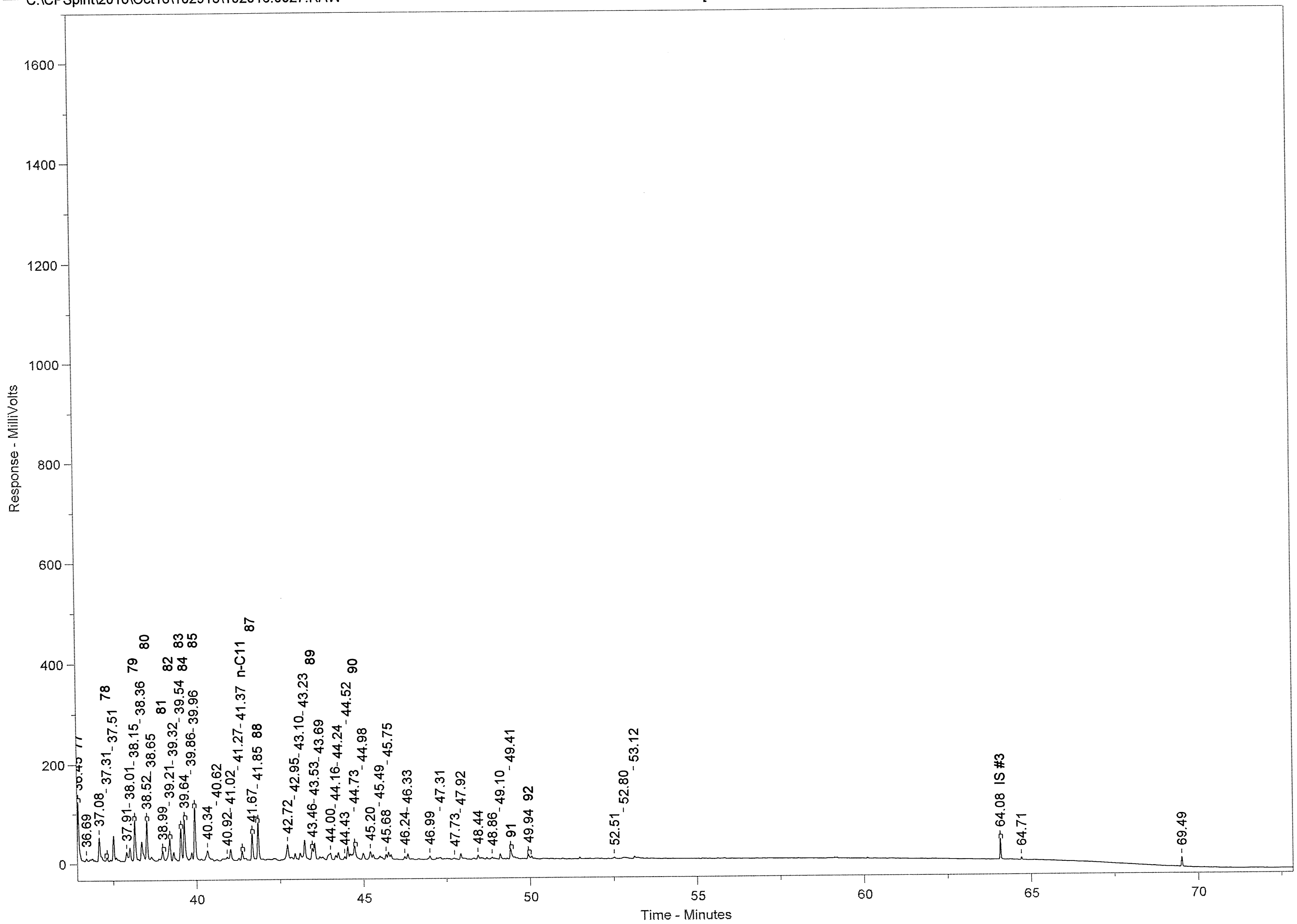

Chrom Perfect Chromatogram Report

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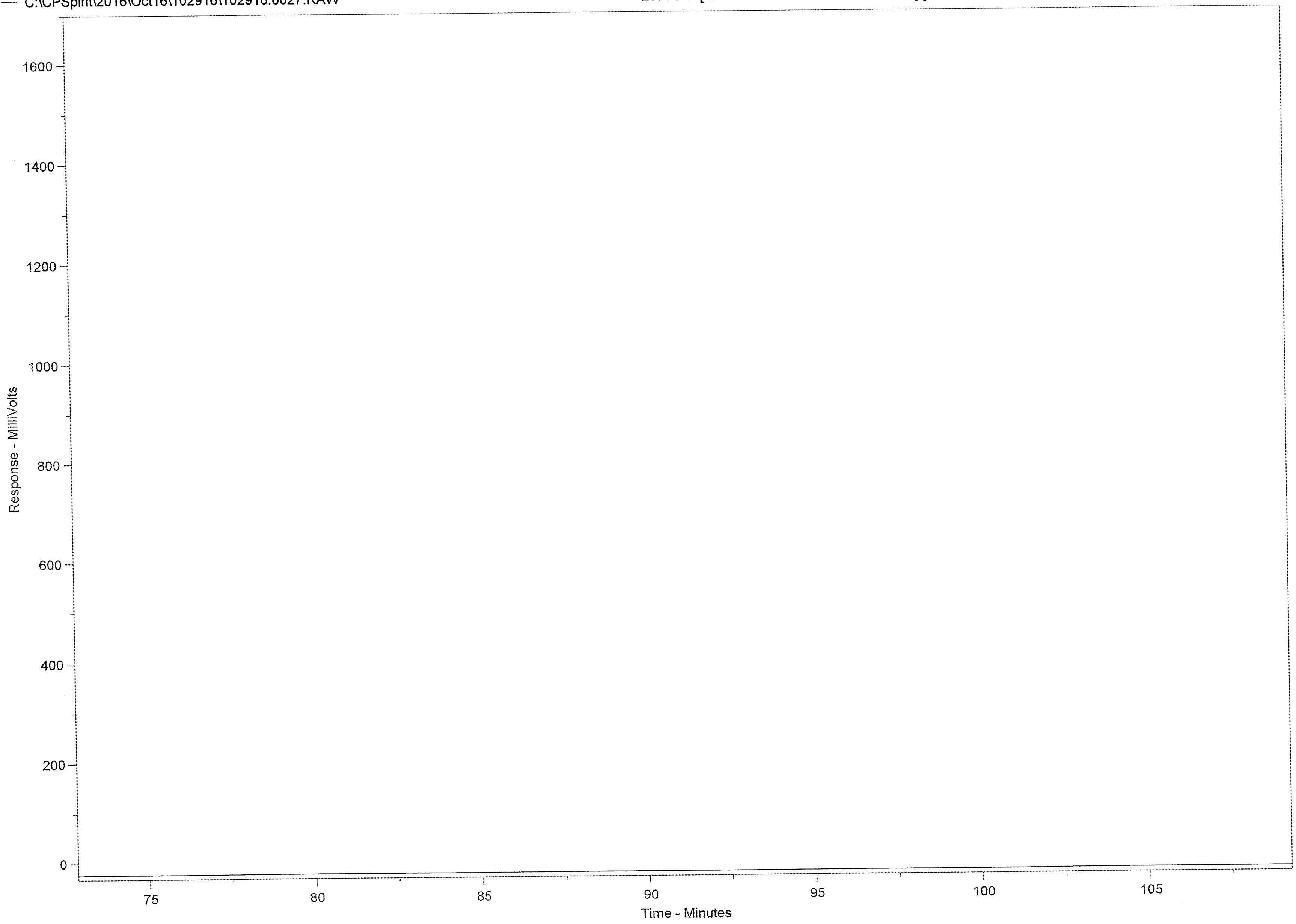

Printed on 11/17/2016 11:47:26 PM

Chrom Perfect Chromatogram Report

Sample Name = **20791-1 [MW-1SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

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Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\20791.cal

Date Taken (end) = 11/4/2016 7:45:02 AM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
4	5.89	0.0237	8734.68
8	6.72	0.6026	222004.30
10	7.08	0.0462	17004.21
11	7.17	0.6671	245755.00
12	7.32	0.0489	18013.34
	7.49	0.0281	10355.12
14	7.61	0.1236	45536.12
CS2	7.89	0.4565	168183.60
15	8.03	0.1101	40552.93
	8.90	0.2387	87957.86
17	8.95	0.6260	230613.80
18	9.09	2.0494	755053.00
19	9.65	1.5007	552885.20
	9.85	0.1138	41929.08
20	10.42	1.2955	477302.10
	10.64	0.0623	22965.72
21	10.75	0.2105	77548.89
22	10.92	0.1860	68534.77
23	11.11	0.0551	20298.95
24	11.43	0.1728	63680.66
25	11.65	0.0938	34562.49
26	11.77	1.1323	417171.30
27	11.99	1.0545	388479.70
	12.29	0.0410	15115.47
	13.06	0.1356	49969.94
28	13.12	0.1954	71995.44
29	13.45	0.1292	47582.34
	13.67	0.2694	99258.48
30	13.80	0.0328	12085.80
	14.16	0.0886	32641.42
31	14.26	1.8530	682671.90
32	14.36	1.7603	648528.40
	14.53	0.0599	22079.75
	14.67	0.0357	13160.38
33	14.82	2.1062	775963.00
	15.04	0.0399	14695.35
	15.22	0.4250	156574.60
34A	15.40	0.3827	140979.80
	15.49	0.2470	91005.09
34B	15.59	0.3409	125611.60
35	15.73	13.5130	4978430.00
	16.08	0.0645	23763.51
IS #1	16.25	0.9493	349736.20
36	16.45	1.0188	375327.10
	16.58	0.1586	58421.26
	16.88	0.0457	16826.62
	17.10	0.2180	80300.68
	17.36	0.0795	29303.55
	17.72	0.2670	98379.98
37	17.78	0.7887	290572.40
	18.00	0.1691	62304.45
	18.59	0.2569	94632.39
38	18.69	1.4886	548414.60
	18.76	0.3035	111826.10
39	18.82	2.1334	785984.60

Peak Name	Ret. Time	Area %	Area
	19.20	0.2119	78072.48
	19.30	0.0550	20278.24
	19.71	0.1570	57836.95
40	19.92	5.3259	1962143.00
41A	20.20	3.3393	1230271.00
42	20.67	2.0427	752550.30
	20.92	0.0648	23858.18
43	21.09	1.0376	382272.10
44	21.20	0.4249	156525.30
45	21.31	0.3806	140218.50
	21.50	0.1284	47297.09
46B	21.61	1.1011	405667.00
46A	21.69	0.6111	225147.00
	21.85	0.1330	49008.11
	22.24	0.0291	10723.68
47	22.37	1.2979	478164.70
48	22.47	0.2300	84727.88
	22.62	0.1619	59634.09
	22.71	0.1368	50404.40
	22.84	0.0681	25091.32
	22.99	0.0700	25771.80
	23.06	0.1526	56231.64
	23.26	0.1201	44245.61
49	23.44	0.6329	233158.50
	23.54	0.2410	88783.04
	23.84	0.0832	30635.86
	23.92	0.0668	24611.71
50	24.55	0.2197	80950.33
	24.70	0.0680	25049.44
51	25.05	0.1201	44248.58
52	25.47	0.4185	154179.10
	25.67	0.0619	22786.83
	25.82	0.0967	35615.55
53	25.92	0.3050	112362.20
	26.13	0.0320	11774.98
	26.22	0.0394	14523.03
54	26.63	1.5243	561591.70
	26.82	0.1513	55758.96
55	27.22	7.1641	2639369.00
	27.57	0.1019	37524.48
56	27.76	0.3310	121958.20
57	27.83	0.4282	157761.40
58	28.17	0.0823	30322.12
59	28.26	0.4975	183283.50
	28.40	0.0517	19051.36
	28.52	0.0752	27717.68
60	28.65	0.5168	190403.40
	28.77	0.1946	71687.82
	29.01	0.0724	26667.74
	29.10	0.1357	50010.51
	29.20	0.1541	56774.39
	29.49	0.0271	9972.76
	29.83	0.0253	9322.64
62	30.01	0.3589	132233.00
IS #2	30.14	0.5782	213032.50
	30.30	0.1206	44432.70
63	30.73	0.2222	81859.67
	30.98	0.0509	18755.58
64	31.08	0.0809	29789.92
	31.20	0.0813	29965.98
	31.37	0.0348	12838.56
	31.63	0.1527	56241.10
	31.88	0.0453	16703.63
	31.95	0.1139	41956.54
65	32.17	0.1169	43057.83
66	32.53	0.4539	167225.30
67	32.98	1.4961	551203.70

Chrom Perfect Chromatogram Report

Peak Name	Ret. Time	Area %	Area
68	33.10	1.1199	412594.90
69	33.45	1.6420	604930.80
	33.70	0.0996	36712.34
	33.80	0.1690	62259.44
	33.88	0.5197	191464.80
70	34.01	0.9093	335007.90
	34.34	0.2792	102855.30
	34.64	0.1608	59230.64
72	34.77	0.0310	11417.37
73	34.92	5.3569	1973587.00
74	35.63	0.0853	31431.75
75	35.77	0.1010	37204.94
76	35.95	0.2151	79233.29
77	36.45	1.0083	371477.80
	36.69	0.0350	12897.10
	37.08	0.4765	175540.40
78	37.31	0.0624	22992.49
	37.51	0.4505	165982.80
	37.91	0.1885	69448.68
	38.01	0.2330	85855.24
79	38.15	0.7318	269593.00
	38.36	0.4426	163047.80
80	38.52	0.6665	245556.80
	38.65	0.1181	43492.58
81	38.99	0.2640	97265.24
82	39.21	0.5001	184235.40
	39.32	0.1851	68191.73
83	39.54	0.5433	200171.00
84	39.64	0.7735	284975.80
	39.86	0.1514	55768.96
85	39.96	0.9444	347919.90
	40.34	0.3155	116251.90
	40.62	0.0335	12353.75
	40.92	0.1436	52921.07
	41.02	0.2185	80508.51
	41.27	0.0319	11737.93
n-C11	41.37	0.1285	47332.07
87	41.67	0.4312	158870.40
88	41.85	0.5798	213600.30
	42.72	0.3299	121533.40
	42.95	0.1012	37271.80
	43.10	0.1167	43010.07
	43.23	0.3924	144572.40
89	43.46	0.2050	75515.43
	43.53	0.2717	100086.50
	43.69	0.0229	8432.13
	44.00	0.2096	77211.60
	44.16	0.0721	26581.32
	44.24	0.1224	45102.61
	44.43	0.0349	12862.72
	44.52	0.1484	54689.12
90	44.73	0.1845	67957.84
	44.98	0.1200	44203.72
	45.20	0.1073	39522.71
	45.49	0.0876	32271.33
	45.68	0.0538	19814.90
	45.75	0.0648	23886.22
	46.24	0.0440	16197.91
	46.33	0.0815	30028.91
	46.99	0.0797	29355.91
	47.31	0.1006	37046.34
	47.73	0.0457	16832.79
	47.92	0.1324	48777.01
	48.44	0.0530	19527.21
	48.86	0.0623	22965.93
	49.10	0.0822	30290.38
91	49.41	0.1693	62390.81

Peak Name	Ret. Time	Area %	Area
92	49.94	0.0662	24393.42
	52.51	0.0369	13579.13
	52.80	0.0658	24249.45
	53.12	0.0278	10241.74
IS #3	64.08	0.2228	82083.67
	64.71	0.0285	10497.08
	69.49	0.1095	40360.02

Total Area = 3.684182E+07 Total Height = 1.27813E+07 Total Amount = 0

10/29/2016

ZymaX ID	20791-3
Sample ID	MW-3SRTF-PRODUCT-20161013

Evaporation

n-Pentane / n-Heptane	0.17
2-Methylpentane / 2-Methylheptane	0.90

Waterwashing

Benzene / Cyclohexane	2.59
Toluene / Methylcyclohexane	5.88
Aromatics / Total Paraffins (n+iso+cyc)	1.80
Aromatics / Naphthenes	9.73

Biodegradation

(C4 - C8 Para + Isopara) / C4 - C8 Olefins	55.72
3-Methylhexane / n-Heptane	0.92
Methylcyclohexane / n-Heptane	0.95
Isoparaffins + Naphthenes / Paraffins	4.30

Octane rating

2,2,4,-Trimethylpentane / Methylcyclohexane	1.53

Relative percentages - Bulk hydrocarbon composition as PIANO

% Paraffinic	6.72
% Isoparaffinic	22.29
% Aromatic	63.92
% Naphthenic	6.57
% Olefinic	0.49

10/29/2016

ZymaX ID 20791-3
Sample ID MW-3SRTF-PRODUCT-20161013

		Relative Area %
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.00
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.30
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.00
11	Pentane	0.35
12	trans-2-Pentene	0.00
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.00
15	2,2-Dimethylbutane	0.08
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.37
18	2-Methylpentane	1.30
19	3-Methylpentane	0.96
20	Hexane	0.91
21	trans-2-Hexene	0.14
22	3-Methylcyclopentene	0.00
23	3-Methyl-2-pentene	0.00
24	cis-2-Hexene	0.14
25	3-Methyl-trans-2-pentene	0.09
26	Methylcyclopentane	0.87
27	2,4-Dimethylpentane	0.48
28	Benzene	1.11
29	5-Methyl-1-hexene	0.13
30	Cyclohexane	0.43
31	2-Methylhexane/TAME	1.54
32	2,3-Dimethylpentane	0.87
33	3-Methylhexane	1.87
34A	1-trans-3-Dimethylcyclopentane	0.42
34B	1-cis-3-Dimethylcyclopentane	0.51
35	2,2,4-Trimethylpentane	2.96
I.S. #1	à,à,à-Trifluorotoluene	0.00

10/29/2016

ZymaX ID 20791-3
Sample ID MW-3SRTF-PRODUCT-20161013

		Relative Area %
36	n-Heptane	2.03
37	Methylcyclohexane	1.93
38	2,5-Dimethylhexane	0.60
39	2,4-Dimethylhexane	0.76
40	2,3,4-Trimethylpentane	1.46
41	Toluene/2,3,3-Trimethylpentane	11.36
42	2,3-Dimethylhexane	0.94
43	2-Methylheptane	1.44
44	4-Methylheptane	0.49
45	3,4-Dimethylhexane	0.00
46A	3-Ethyl-3-methylpentane	1.17
46B	1,4-Dimethylcyclohexane	1.35
47	3-Methylheptane	0.34
48	2,2,5-Trimethylhexane	0.35
49	n-Octane	1.89
50	2,2-Dimethylheptane	0.07
51	2,4-Dimethylheptane	0.13
52	Ethylcyclohexane	1.06
53	2,6-Dimethylheptane	0.31
54	Ethylbenzene	3.42
55	m+p Xylenes	13.17
56	4-Methyloctane	0.51
57	2-Methyloctane	0.64
58	3-Ethylheptane	0.13
59	3-Methyloctane	0.78
60	o-Xylene	4.63
61	1-Nonene	0.00
62	n-Nonane	1.09
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.37
64	3,3,5-Trimethylheptane	0.00
65	2,4,5-Trimethylheptane	0.20
66	n-Propylbenzene	0.64
67	1-Methyl-3-ethylbenzene	3.07
68	1-Methyl-4-ethylbenzene	1.44
69	1,3,5-Trimethylbenzene	1.84
70	3,3,4-Trimethylheptane	1.23

10/29/2016

ZymaX ID 20791-3
Sample ID MW-3SRTF-PRODUCT-20161013

		Relative Area %
71	1-Methyl-2-ethylbenzene	0.00
72	3-Methylnonane	0.00
73	1,2,4-Trimethylbenzene	5.55
74	Isobutylbenzene	0.00
75	sec-Butylbenzene	0.00
76	n-Decane	0.45
77	1,2,3-Trimethylbenzene	1.62
78	Indan	0.09
79	1,3-Diethylbenzene	1.53
80	1,4-Diethylbenzene	1.56
81	n-Butylbenzene	0.61
82	1,3-Dimethyl-5-ethylbenzene	0.13
83	1,4-Dimethyl-2-ethylbenzene	1.36
84	1,3-Dimethyl-4-ethylbenzene	1.48
85	1,2-Dimethyl-4-ethylbenzene	2.70
86	Undecene	0.00
87	1,2,4,5-Tetramethylbenzene	1.31
88	1,2,3,5-Tetramethylbenzene	1.79
89	1,2,3,4-Tetramethylbenzene	1.08
90	Naphthalene	1.55
91	2-Methyl-naphthalene	0.41
92	1-Methyl-naphthalene	0.14

Chrom Perfect Chromatogram Report

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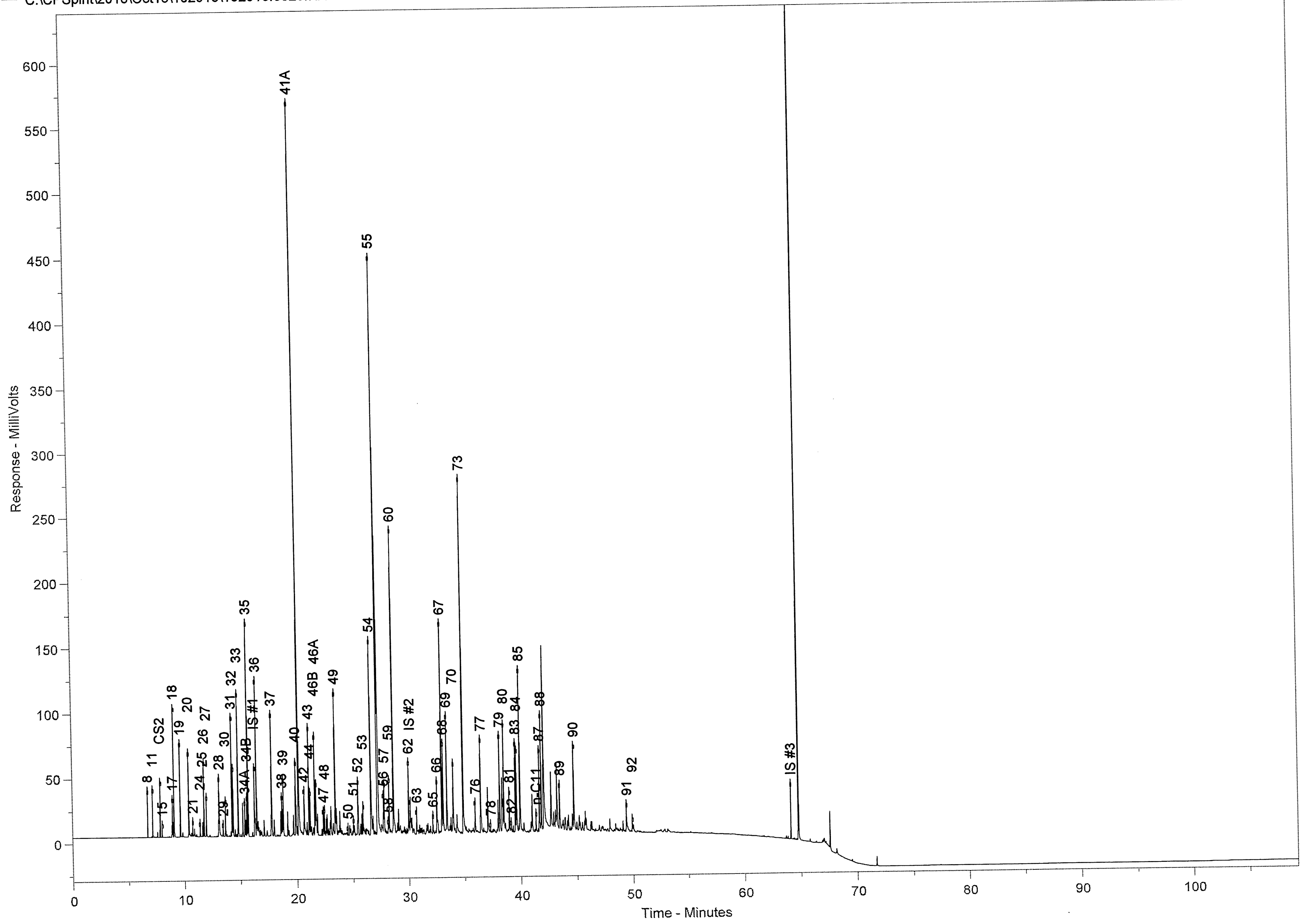
20791-3 [MW-3SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1



Printed on 11/17/2016 11:42:15 PM

Chrom Perfect Chromatogram Report

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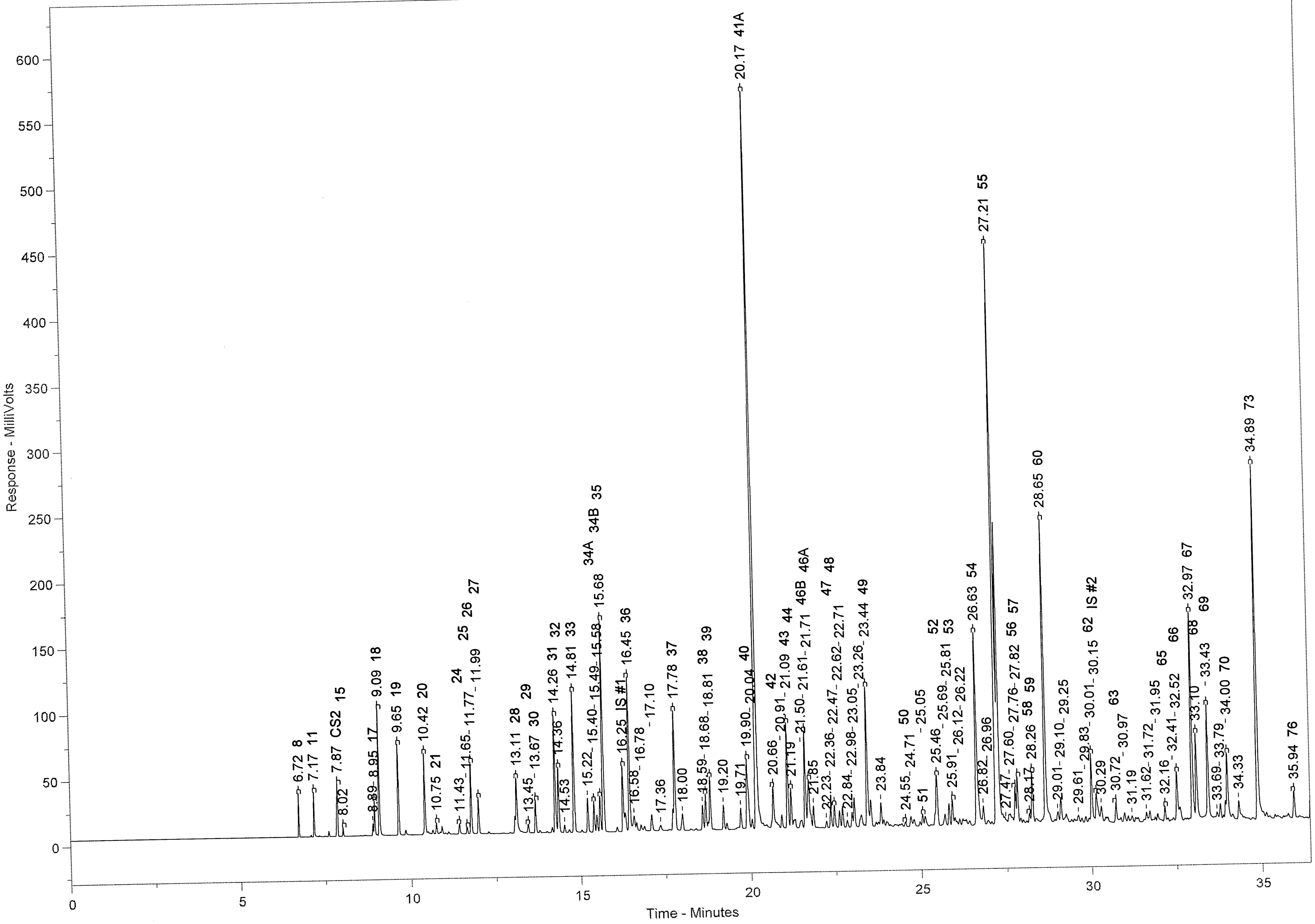
20791-3 [MW-3SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1



Chrom Perfect Chromatogram Report

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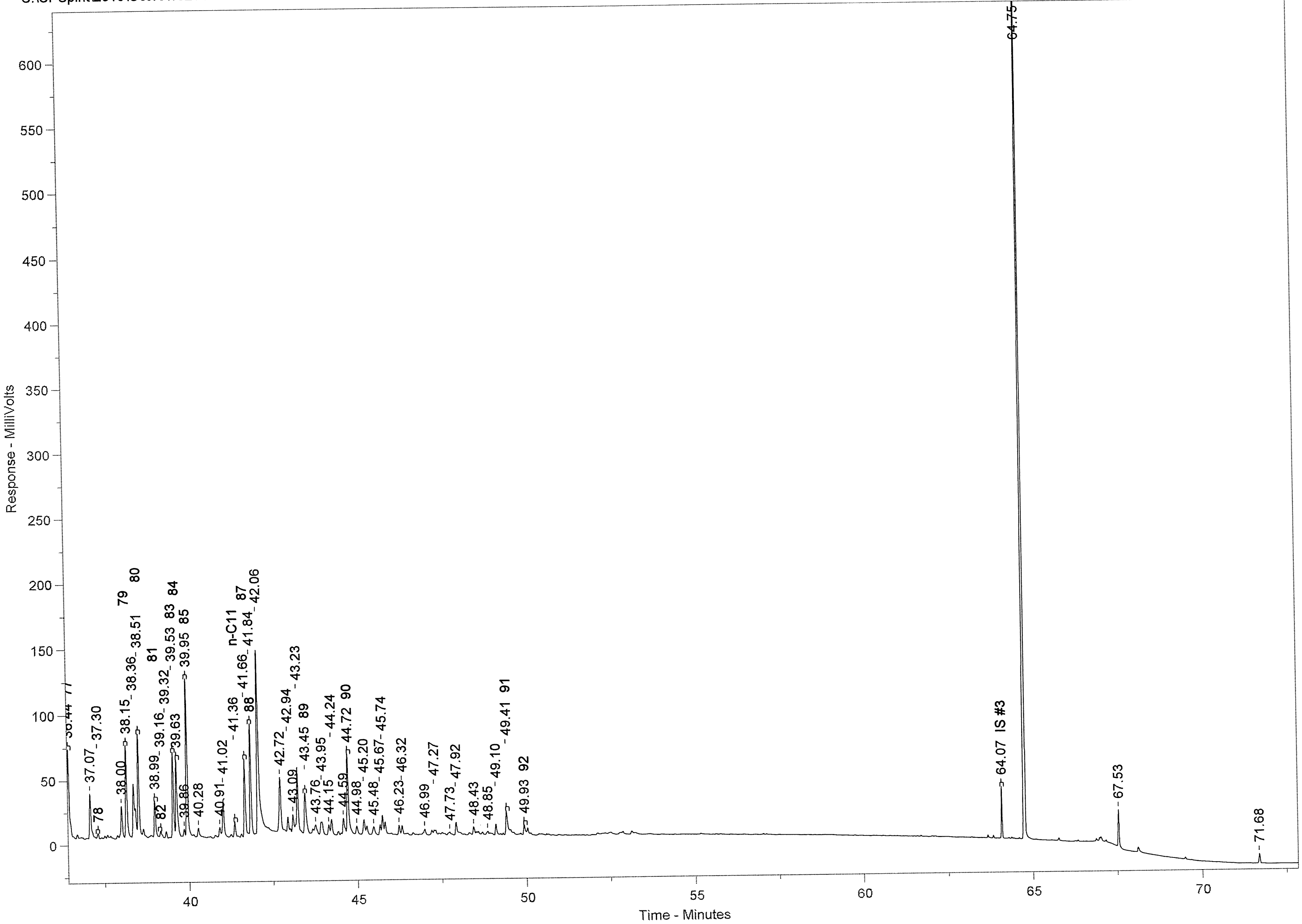

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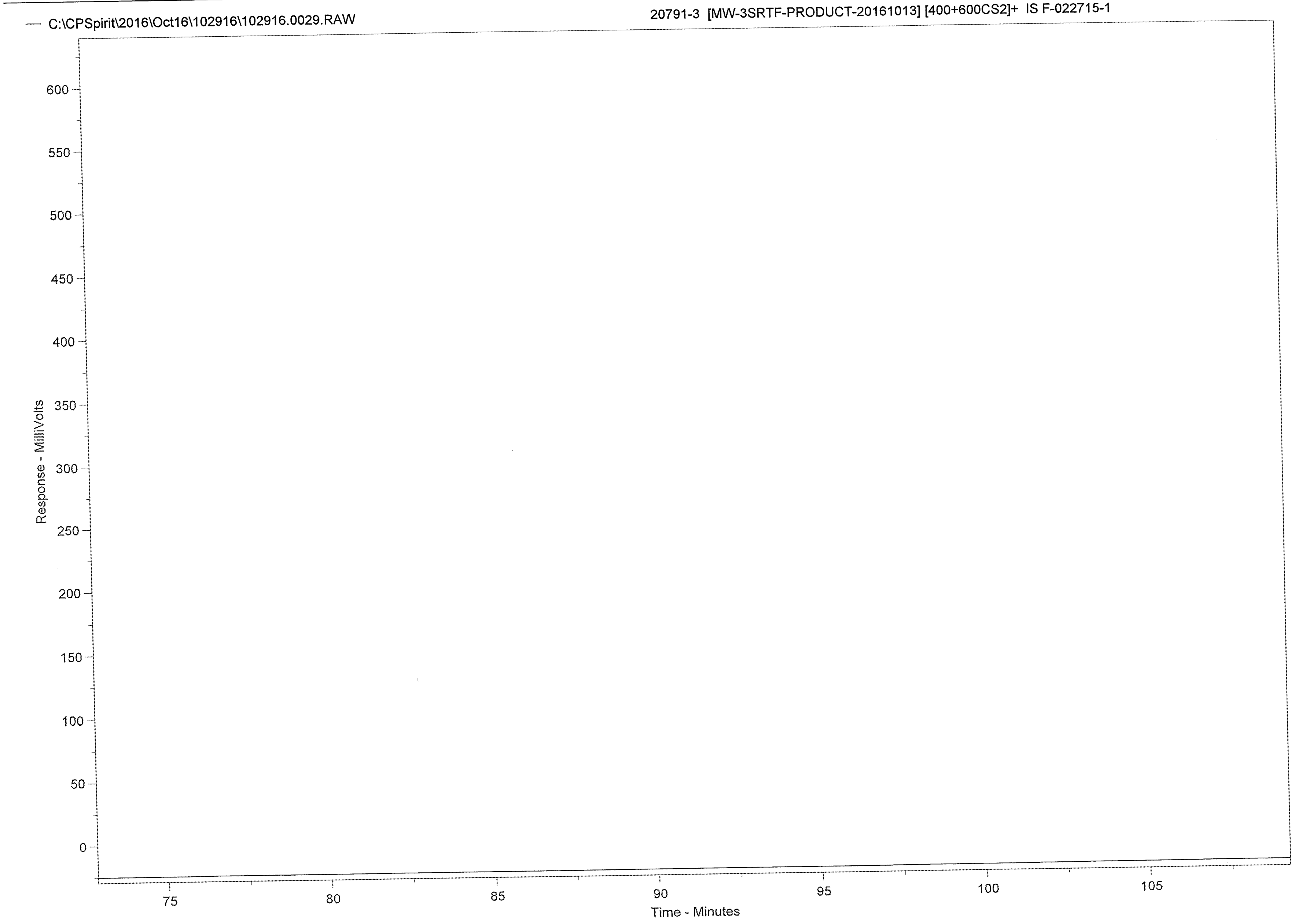
Chrom Perfect Chromatogram Report



Chrom Perfect Chromatogram Report

Sample Name = **20791-3 [MW-3SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

Raw File Name = **C:\CPSpirit\2016\Oct16\102916\102916.0029.RAW**
Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\20791.cal

Date Taken (end) = 11/4/2016 11:58:37 AM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
8	6.72	0.2069	42494.11
11	7.17	0.2406	49427.11
CS2	7.87	0.4322	88770.63
15	8.02	0.0557	11440.78
	8.89	0.0770	15823.25
17	8.95	0.2529	51956.62
18	9.09	0.8824	181256.00
19	9.65	0.6517	133856.50
20	10.42	0.6173	126798.10
21	10.75	0.0927	19044.61
24	11.43	0.0951	19534.86
25	11.65	0.0578	11872.49
26	11.77	0.5933	121865.00
27	11.99	0.3271	67182.03
28	13.11	0.7519	154455.80
29	13.45	0.0891	18292.31
30	13.67	0.2903	59620.34
31	14.26	1.0459	214832.40
32	14.36	0.5916	121512.20
	14.53	0.0668	13722.84
33	14.81	1.2725	261376.80
	15.22	0.3099	63651.83
34A	15.40	0.2832	58169.89
	15.49	0.1571	32279.81
34B	15.58	0.3471	71289.30
35	15.68	2.0064	412141.50
IS #1	16.25	0.4908	100822.90
36	16.45	1.3781	283065.40
	16.58	0.1416	29076.33
	16.78	0.0479	9831.19
	17.10	0.1826	37515.15
	17.36	0.0770	15821.85
37	17.78	1.3117	269442.80
	18.00	0.1894	38898.46
	18.59	0.2370	48684.14
38	18.68	0.4064	83477.80
39	18.81	0.5151	105798.80
	19.20	0.2246	46142.52
	19.71	0.2704	55539.43
40	19.90	0.9911	203572.00
	20.04	0.0950	19517.48
41A	20.17	7.7078	1583259.00
42	20.66	0.6412	131706.90
	20.91	0.1287	26442.14
43	21.09	0.9801	201323.10
44	21.19	0.3301	67800.66
	21.50	0.1337	27454.05
46B	21.61	0.9169	188340.70
46A	21.71	0.7947	163236.60
	21.85	0.2046	42032.18
	22.23	0.0622	12783.49
47	22.36	0.2333	47917.73
48	22.47	0.2395	49190.21
	22.62	0.1660	34097.57
	22.71	0.2136	43872.80

Peak Name	Ret. Time	Area %	Area
	22.84	0.0776	15946.78
	22.98	0.1439	29549.61
	23.05	0.3021	62050.82
	23.26	0.1866	38337.01
49	23.44	1.2815	263227.80
	23.84	0.1975	40571.82
50	24.55	0.0448	9197.31
	24.71	0.0849	17446.52
51	25.05	0.0853	17517.37
52	25.46	0.7189	147660.10
	25.69	0.1348	27680.50
	25.81	0.1968	40429.76
53	25.91	0.2121	43564.61
	26.12	0.0496	10189.48
	26.22	0.1352	27777.67
54	26.63	2.3233	477218.50
	26.82	0.2211	45417.12
	26.96	0.0554	11384.52
55	27.21	8.9360	1835524.00
	27.47	0.0066	1360.81
	27.60	0.2098	43094.32
56	27.76	0.3431	70468.99
57	27.82	0.4342	89190.30
58	28.17	0.0881	18092.31
59	28.26	0.5286	108585.30
60	28.65	3.1420	645400.70
	29.01	0.1090	22390.93
	29.10	0.2541	52184.57
	29.25	0.1345	27623.18
	29.61	0.0679	13940.97
	29.83	0.0635	13034.64
62	30.01	0.7380	151590.10
IS #2	30.15	0.4597	94423.52
	30.29	0.1931	39662.06
63	30.72	0.2523	51815.81
	30.97	0.1150	23627.29
	31.19	0.0818	16804.38
	31.62	0.0820	16839.12
	31.72	0.0932	19151.12
	31.95	0.0910	18690.07
65	32.16	0.1327	27255.67
	32.41	0.0397	8161.07
66	32.52	0.4345	89256.38
67	32.97	2.0834	427955.60
68	33.10	0.9740	200063.70
69	33.43	1.2465	256043.30
	33.69	0.0655	13459.21
	33.79	0.1433	29443.18
70	34.00	0.8355	171612.20
	34.33	0.2347	48210.60
73	34.89	3.7639	773136.50
76	35.94	0.3055	62757.59
77	36.44	1.1009	226130.30
	37.07	0.5758	118278.60
78	37.30	0.0607	12476.60
	38.00	0.3564	73198.99
79	38.15	1.0368	212977.20
	38.36	0.8710	178911.80
80	38.51	1.0555	216803.00
81	38.99	0.4172	85704.54
82	39.16	0.0902	18525.40
	39.32	0.0621	12753.53
83	39.53	0.9227	189528.20
84	39.63	1.0019	205806.20
	39.86	0.0982	20161.53
85	39.95	1.8297	375844.90
	40.28	0.1346	27643.22

Chrom Perfect Chromatogram Report

Peak Name	Ret. Time	Area %	Area
	40.91	0.1150	23620.25
	41.02	0.4793	98462.36
n-C11	41.36	0.1817	37330.79
87	41.66	0.8888	182560.20
88	41.84	1.2164	249849.90
	42.06	3.4957	718051.70
	42.72	1.1108	228176.70
	42.94	0.3225	66250.02
	43.09	0.2861	58775.63
	43.23	0.9931	203991.80
89	43.45	0.7304	150039.20
	43.76	0.2067	42457.79
	43.95	0.2767	56826.39
	44.15	0.1228	25223.08
	44.24	0.1949	40043.48
	44.59	0.2120	43554.32
90	44.72	1.0511	215910.80
	44.98	0.1081	22208.56
	45.20	0.1349	27704.26
	45.48	0.1308	26867.42
	45.67	0.0754	15495.48
	45.74	0.1410	28962.66
	46.23	0.0986	20261.61
	46.32	0.0907	18634.86
	46.99	0.0842	17294.91
	47.27	0.1658	34060.32
	47.73	0.0639	13129.51
	47.92	0.1969	40439.96
	48.43	0.0751	15423.68
	48.85	0.0865	17763.32
	49.10	0.1158	23777.81
91	49.41	0.2751	56516.42
92	49.93	0.0940	19308.30
IS #3	64.07	0.3525	72400.07
	64.75	11.5754	2377679.00
	67.53	0.3092	63504.25
	71.68	0.0887	18225.12

Total Area = 2.054087E+07 Total Height = 7070633 Total Amount = 0

10/29/2016

ZymaX ID	20791-2
Sample ID	MW-2SRTF-PRODUCT-20161013

Evaporation

n-Pentane / n-Heptane	0.38
2-Methylpentane / 2-Methylheptane	1.67

Waterwashing

Benzene / Cyclohexane	6.83
Toluene / Methylcyclohexane	4.48
Aromatics / Total Paraffins (n+iso+cyc)	0.82
Aromatics / Naphthenes	7.07

Biodegradation

(C4 - C8 Para + Isopara) / C4 - C8 Olefins	32.59
3-Methylhexane / n-Heptane	1.39
Methylcyclohexane / n-Heptane	0.79
Isoparaffins + Naphthenes / Paraffins	7.03

Octane rating

2,2,4,-Trimethylpentane / Methylcyclohexane	6.87

Relative percentages - Bulk hydrocarbon composition as PIANO

% Paraffinic	6.75
% Isoparaffinic	41.23
% Aromatic	44.31
% Naphthenic	6.27
% Olefinic	1.43

10/29/2016

ZymaX ID 20791-2
Sample ID MW-2SRTF-PRODUCT-20161013

		Relative Area %
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.00
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.76
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.04
11	Pentane	0.70
12	trans-2-Pentene	0.00
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.16
15	2,2-Dimethylbutane	0.12
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.75
18	2-Methylpentane	2.45
19	3-Methylpentane	1.80
20	Hexane	1.42
21	trans-2-Hexene	0.33
22	3-Methylcyclopentene	0.27
23	3-Methyl-2-pentene	0.07
24	cis-2-Hexene	0.29
25	3-Methyl-trans-2-pentene	0.11
26	Methylcyclopentane	1.46
27	2,4-Dimethylpentane	1.10
28	Benzene	0.32
29	5-Methyl-1-hexene	0.16
30	Cyclohexane	0.05
31	2-Methylhexane/TAME	2.22
32	2,3-Dimethylpentane	1.89
33	3-Methylhexane	2.56
34A	1-trans-3-Dimethylcyclopentane	0.55
34B	1-cis-3-Dimethylcyclopentane	0.55
35	2,2,4-Trimethylpentane	9.92
I.S. #1	à,à,à-Trifluorotoluene	0.00

10/29/2016

ZymaX ID		20791-2
Sample ID		MW-2SRTF-PRODUCT-20161013

		Relative Area %
36	n-Heptane	1.84
37	Methylcyclohexane	1.44
38	2,5-Dimethylhexane	1.38
39	2,4-Dimethylhexane	1.68
40	2,3,4-Trimethylpentane	4.01
41	Toluene/2,3,3-Trimethylpentane	6.46
42	2,3-Dimethylhexane	1.77
43	2-Methylheptane	1.47
44	4-Methylheptane	0.59
45	3,4-Dimethylhexane	0.35
46A	3-Ethyl-3-methylpentane	1.02
46B	1,4-Dimethylcyclohexane	1.41
47	3-Methylheptane	0.98
48	2,2,5-Trimethylhexane	0.35
49	n-Octane	1.56
50	2,2-Dimethylheptane	0.17
51	2,4-Dimethylheptane	0.14
52	Ethylcyclohexane	0.81
53	2,6-Dimethylheptane	0.36
54	Ethylbenzene	2.46
55	m+p Xylenes	8.87
56	4-Methyloctane	0.48
57	2-Methyloctane	0.59
58	3-Ethylheptane	0.13
59	3-Methyloctane	0.73
60	o-Xylene	2.77
61	1-Nonene	0.00
62	n-Nonane	0.88
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.32
64	3,3,5-Trimethylheptane	0.11
65	2,4,5-Trimethylheptane	0.18
66	n-Propylbenzene	0.61
67	1-Methyl-3-ethylbenzene	2.18
68	1-Methyl-4-ethylbenzene	1.25
69	1,3,5-Trimethylbenzene	1.92
70	3,3,4-Trimethylheptane	1.15

10/29/2016

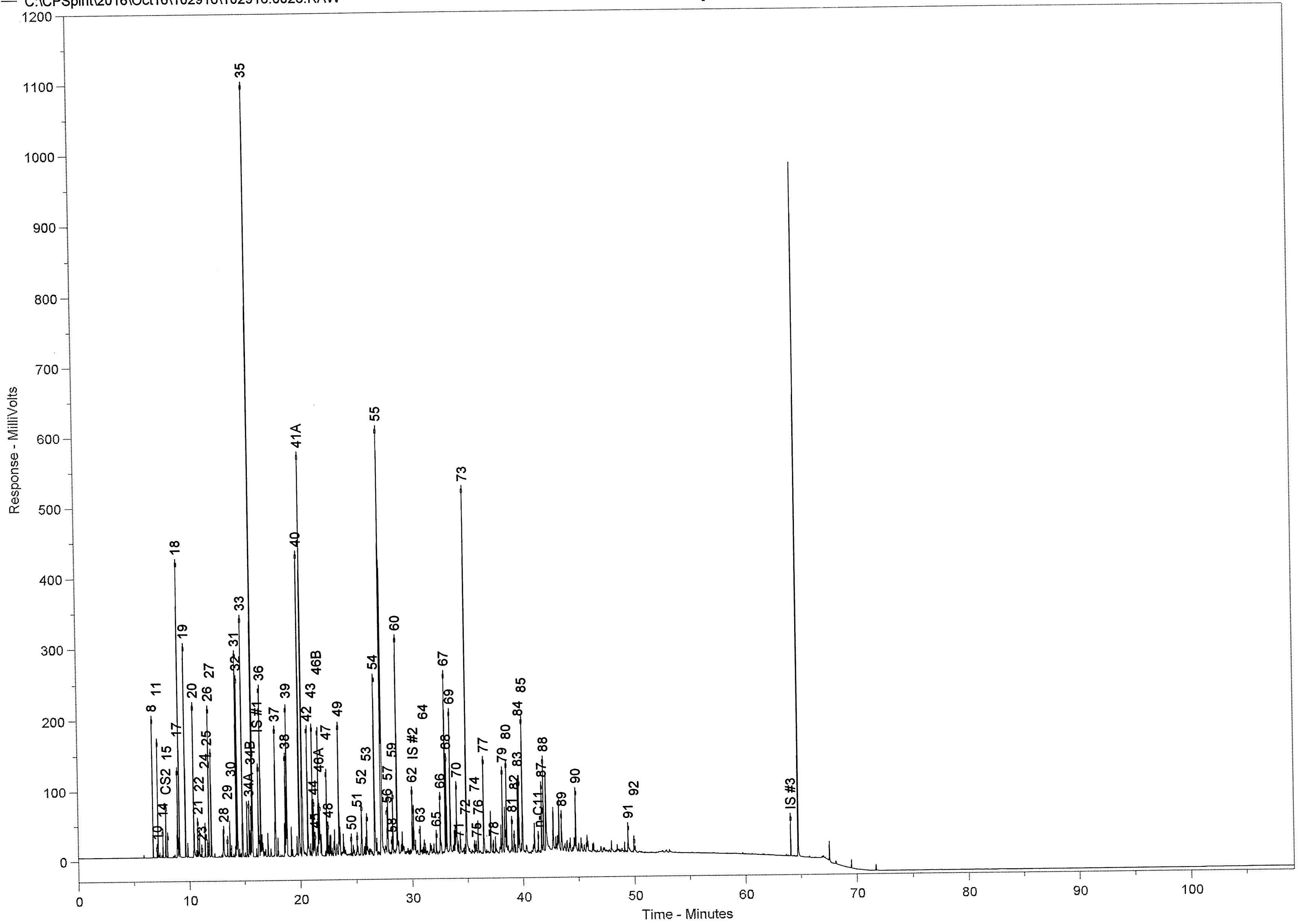
ZymaX ID 20791-2
Sample ID MW-2SRTF-PRODUCT-20161013

		Relative Area %
71	1-Methyl-2-ethylbenzene	0.09
72	3-Methylnonane	0.04
73	1,2,4-Trimethylbenzene	4.80
74	Isobutylbenzene	0.07
75	sec-Butylbenzene	0.11
76	n-Decane	0.35
77	1,2,3-Trimethylbenzene	1.28
78	Indan	0.08
79	1,3-Diethylbenzene	1.13
80	1,4-Diethylbenzene	1.14
81	n-Butylbenzene	0.44
82	1,3-Dimethyl-5-ethylbenzene	0.33
83	1,4-Dimethyl-2-ethylbenzene	0.91
84	1,3-Dimethyl-4-ethylbenzene	1.05
85	1,2-Dimethyl-4-ethylbenzene	1.80
86	Undecene	0.00
87	1,2,4,5-Tetramethylbenzene	0.84
88	1,2,3,5-Tetramethylbenzene	1.10
89	1,2,3,4-Tetramethylbenzene	0.65
90	Naphthalene	0.89
91	2-Methyl-naphthalene	0.30
92	1-Methyl-naphthalene	0.13

Chrom Perfect Chromatogram Report

— C:\CPSpirit\2016\Oct16\102916\102916.0028.RAW

20791-2 [MW-2SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1



Chrom Perfect Chromatogram Report

20791-2 [MW-2SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1

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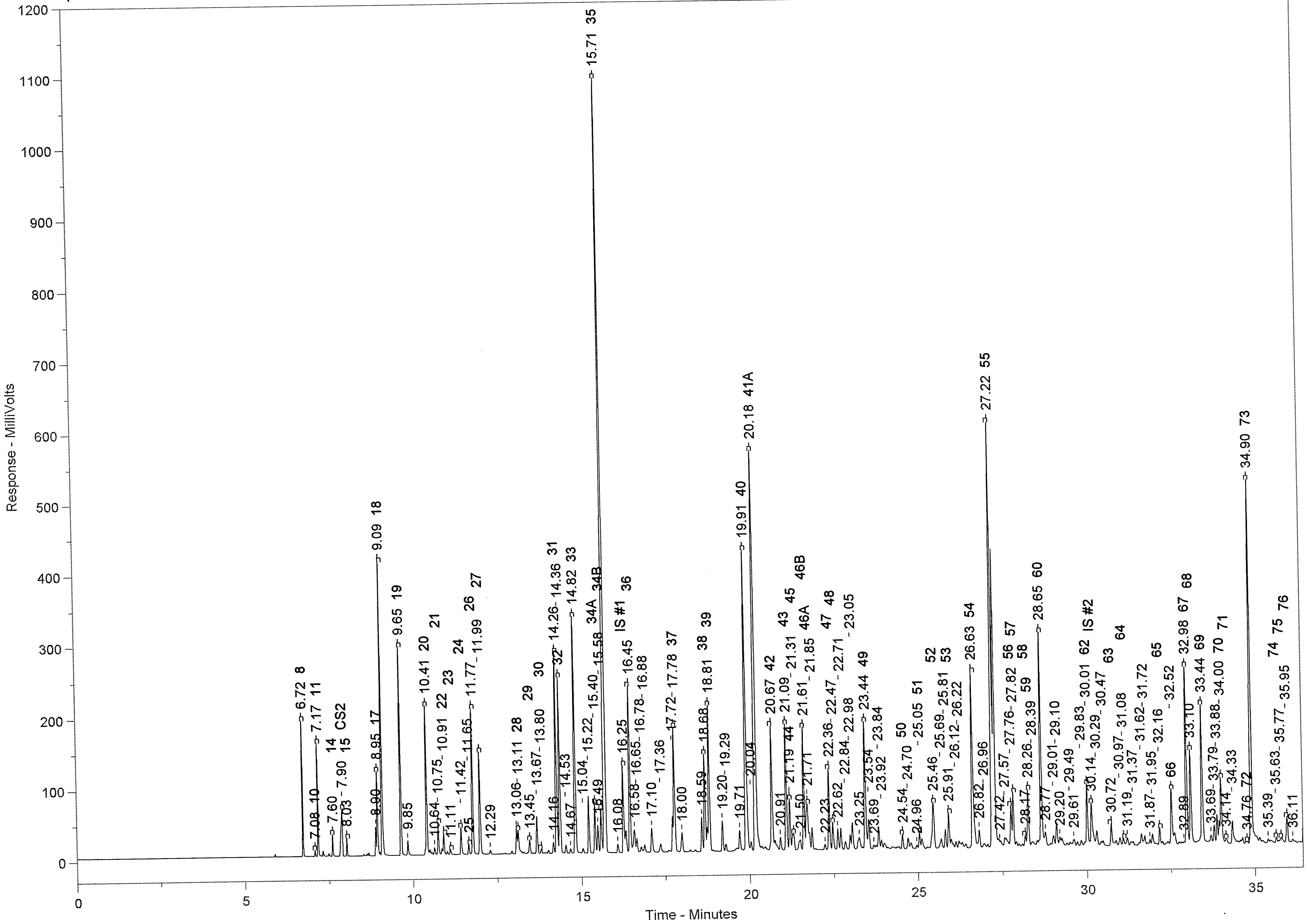

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Chrom Perfect Chromatogram Report

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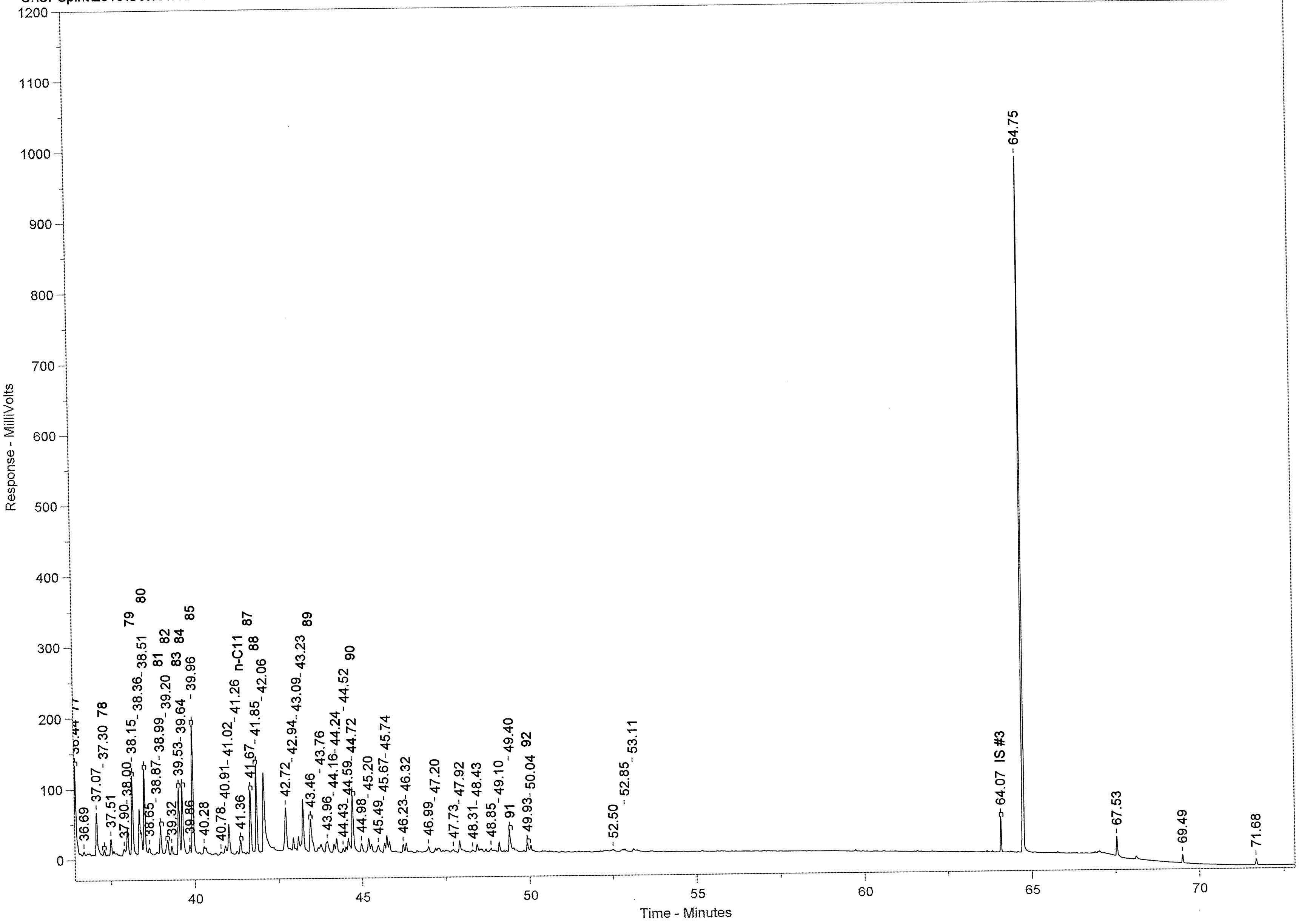
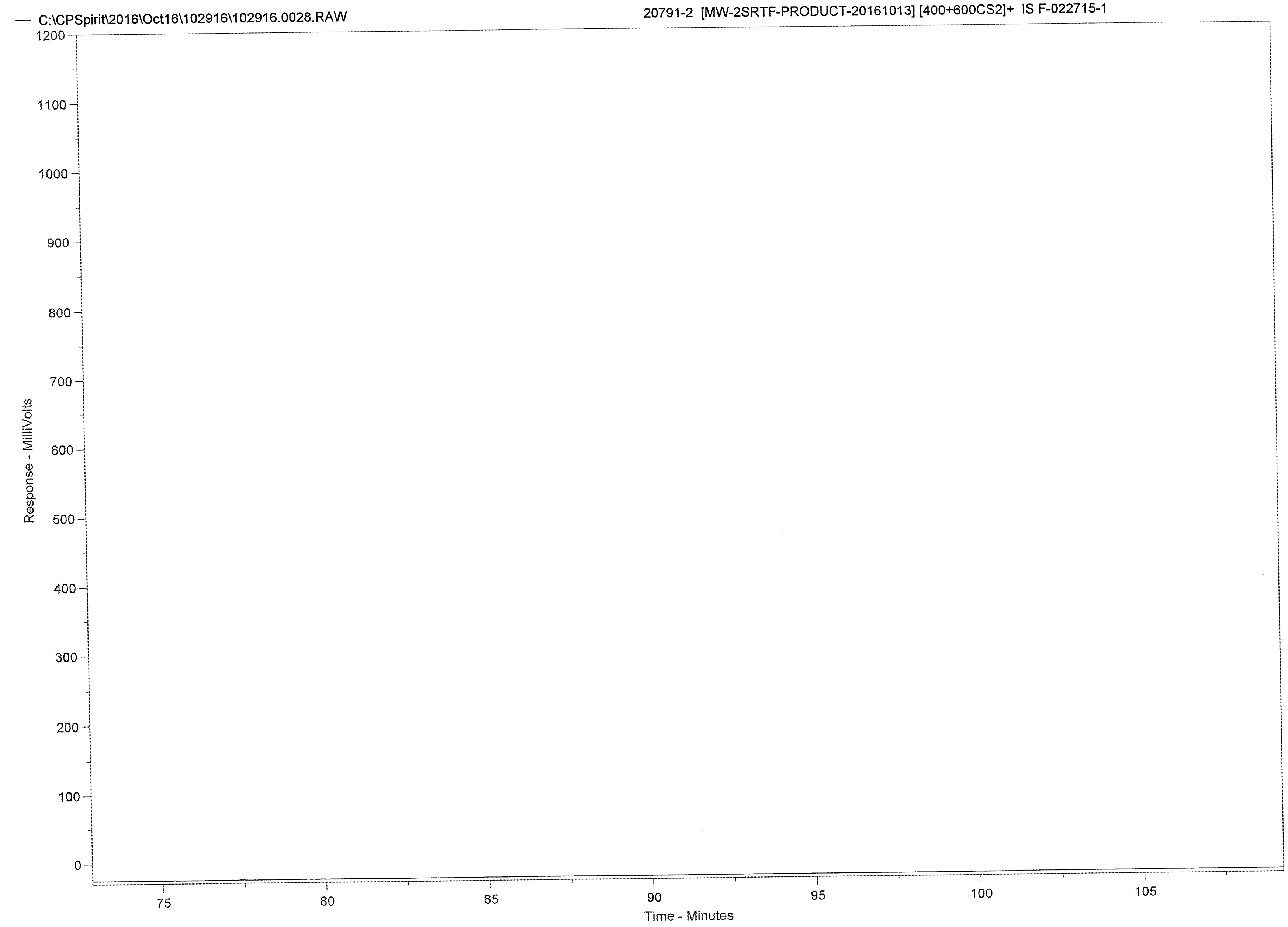


Chrom Perfect Chromatogram Report



Chrom Perfect Chromatogram Report

Sample Name = **20791-2 [MW-2SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

Raw File Name = **C:\CPSpirit\2016\Oct16\102916\102916.0028.RAW**
Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\20791.cal

Date Taken (end) = 11/4/2016 9:51:52 AM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
8	6.72	0.5706	240697.90
10	7.08	0.0299	12625.65
11	7.17	0.5250	221480.80
14	7.60	0.1166	49182.01
CS2	7.90	0.4910	207120.20
15	8.03	0.0912	38474.66
	8.90	0.1638	69087.29
17	8.95	0.5569	234919.70
18	9.09	1.8303	772079.40
19	9.65	1.3468	568110.80
	9.85	0.1193	50327.80
20	10.41	1.0612	447653.30
	10.64	0.0595	25105.05
21	10.75	0.2450	103364.70
22	10.91	0.2044	86209.12
23	11.11	0.0543	22915.66
24	11.42	0.2201	92825.05
25	11.65	0.0803	33873.05
26	11.77	1.0873	458645.80
27	11.99	0.8182	345128.90
	12.29	0.0327	13778.01
	13.06	0.1902	80218.67
28	13.11	0.2364	99703.26
29	13.45	0.1208	50946.85
	13.67	0.2999	126492.30
30	13.80	0.0346	14592.89
	14.16	0.0947	39937.60
31	14.26	1.6556	698362.20
32	14.36	1.4146	596719.60
	14.53	0.0693	29235.01
	14.67	0.0366	15453.77
33	14.82	1.9126	806778.40
	15.04	0.0393	16569.95
	15.22	0.4618	194789.80
34A	15.40	0.4134	174375.10
	15.49	0.2346	98943.60
34B	15.58	0.4072	171755.50
35	15.71	7.4070	3124479.00
	16.08	0.0728	30692.08
IS #1	16.25	0.7345	309839.80
36	16.45	1.3741	579650.60
	16.58	0.2960	124871.90
	16.65	0.1265	53377.08
	16.78	0.0556	23437.42
	16.88	0.0793	33451.83
	17.10	0.2497	105342.30
	17.36	0.1005	42406.79
	17.72	0.2749	115963.20
37	17.78	1.0788	455082.50
	18.00	0.2038	85965.00
	18.59	0.2888	121813.90
38	18.68	1.0292	434151.80
39	18.81	1.2539	528934.50
	19.20	0.2599	109623.30
	19.29	0.0630	26567.12

Peak Name	Ret. Time	Area %	Area
	19.71	0.2564	108137.40
40	19.91	2.9916	1261940.00
	20.04	0.0820	34587.48
41A	20.18	4.8282	2036661.00
42	20.67	1.3212	557339.10
	20.91	0.1095	46205.11
43	21.09	1.0948	461833.00
44	21.19	0.4378	184696.40
45	21.31	0.2617	110390.90
	21.50	0.1506	63511.84
46B	21.61	1.0566	445689.70
46A	21.71	0.7649	322675.00
	21.85	0.1815	76557.88
	22.23	0.0469	19768.46
47	22.36	0.7331	309250.50
48	22.47	0.2606	109926.40
	22.62	0.1812	76426.97
	22.71	0.1927	81282.04
	22.84	0.0817	34447.84
	22.98	0.1287	54279.34
	23.05	0.2494	105204.50
	23.25	0.1987	83799.21
49	23.44	1.1661	491896.90
	23.54	0.2910	122742.10
	23.69	0.0320	13514.10
	23.84	0.1893	79866.93
	23.92	0.0641	27024.86
50	24.54	0.1265	53375.86
	24.70	0.0845	35656.04
	24.96	0.0227	9573.59
51	25.05	0.1055	44490.32
52	25.46	0.6046	255018.90
	25.69	0.1065	44937.29
	25.81	0.1527	64404.05
53	25.91	0.2660	112199.40
	26.12	0.0461	19431.06
	26.22	0.1225	51678.96
54	26.63	1.8384	775469.60
	26.82	0.1935	81630.33
	26.96	0.0450	18974.42
55	27.22	6.6276	2795708.00
	27.42	0.0119	5007.32
	27.57	0.1667	70318.07
56	27.76	0.3570	150611.20
57	27.82	0.4422	186536.00
58	28.17	0.0951	40130.24
59	28.26	0.5453	230032.30
	28.39	0.0817	34463.16
60	28.65	2.0704	873341.50
	28.77	0.1574	66405.11
	29.01	0.1263	53287.32
	29.10	0.2378	100320.90
	29.20	0.1885	79509.43
	29.49	0.0532	22423.45
	29.61	0.0842	35507.72
	29.83	0.0580	24460.53
62	30.01	0.6572	277218.10
IS #2	30.14	0.5425	228826.10
	30.29	0.1841	77663.56
	30.47	0.1046	44128.79
63	30.72	0.2421	102109.70
	30.97	0.0929	39169.82
64	31.08	0.0815	34389.05
	31.19	0.0939	39601.73
	31.37	0.0824	34769.41
	31.62	0.1567	66111.13
	31.72	0.0953	40204.04

Peak Name	Ret. Time	Area %	Area
	31.87	0.0470	19839.10
	31.95	0.1262	53230.62
65	32.16	0.1332	56188.19
66	32.52	0.4555	192157.20
	32.89	0.0704	29675.91
67	32.98	1.6305	687772.60
68	33.10	0.9324	393322.80
69	33.44	1.4340	604899.30
	33.69	0.1147	48404.00
	33.79	0.1804	76116.80
	33.88	0.2583	108967.90
70	34.00	0.8554	360848.50
71	34.14	0.0692	29211.37
	34.33	0.2454	103495.60
72	34.76	0.0313	13219.16
73	34.90	3.5832	1511515.00
	35.39	0.0240	10144.50
74	35.63	0.0515	21737.94
75	35.77	0.0822	34693.15
76	35.95	0.2605	109884.40
	36.11	0.0209	8829.38
77	36.44	0.9548	402776.40
	36.69	0.0313	13216.79
	37.07	0.4822	203398.90
78	37.30	0.0592	24982.19
	37.51	0.1355	57157.34
	37.90	0.0811	34189.79
	38.00	0.3261	137550.20
79	38.15	0.8420	355161.30
	38.36	0.7029	296502.80
80	38.51	0.8515	359198.70
	38.65	0.1196	50447.98
	38.87	0.0597	25169.01
81	38.99	0.3321	140080.40
82	39.20	0.2499	105431.70
	39.32	0.1153	48646.20
83	39.53	0.6783	286122.50
84	39.64	0.7811	329493.70
	39.86	0.1187	50060.71
85	39.96	1.3441	566958.90
	40.28	0.2092	88247.22
	40.78	0.0477	20106.71
	40.91	0.1086	45822.03
	41.02	0.3575	150816.80
	41.26	0.0297	12536.95
n-C11	41.36	0.1299	54774.71
87	41.67	0.6301	265806.40
88	41.85	0.8220	346743.00
	42.06	1.1072	467053.30
	42.72	0.5583	235491.40
	42.94	0.1559	65782.27
	43.09	0.1660	70003.96
	43.23	0.6102	257383.20
89	43.46	0.4891	206328.20
	43.76	0.1709	72072.16
	43.96	0.2010	84771.51
	44.16	0.0902	38051.51
	44.24	0.1551	65440.67
	44.43	0.0387	16317.96
	44.52	0.0521	21996.67
	44.59	0.1951	82309.65
90	44.72	0.6639	280057.60
	44.98	0.1032	43525.99
	45.20	0.1161	48956.81
	45.49	0.1053	44401.48
	45.67	0.0643	27132.80
	45.74	0.1090	45982.01

Chrom Perfect Chromatogram Report

Peak Name	Ret. Time	Area %	Area
	46.23	0.0748	31553.97
	46.32	0.0821	34640.82
	46.99	0.0762	32126.37
	47.20	0.0235	9924.43
	47.73	0.0518	21844.83
	47.92	0.1591	67106.20
	48.31	0.0280	11795.82
	48.43	0.0636	26821.65
	48.85	0.0279	11776.16
	49.10	0.0949	40021.66
91	49.40	0.2216	93496.87
92	49.93	0.0945	39865.66
	50.04	0.0517	21802.26
	52.50	0.0306	12923.20
	52.85	0.0596	25135.69
	53.11	0.0239	10069.40
IS #3	64.07	0.2160	91124.11
	64.75	5.0161	2115938.00
	67.53	0.1595	67274.75
	69.49	0.0575	24239.30
	71.68	0.0518	21856.95

Total Area = 4.218283E+07

Total Height = 1.469222E+07

Total Amount = 0

10/29/2016

ZymaX ID	20791-4
Sample ID	S-114SRTF-PRODUCT-20161013

Evaporation

n-Pentane / n-Heptane	0.53
2-Methylpentane / 2-Methylheptane	1.23

Waterwashing

Benzene / Cyclohexane	0.85
Toluene / Methylcyclohexane	1.64
Aromatics / Total Paraffins (n+iso+cyc)	1.44
Aromatics / Naphthenes	9.00

Biodegradation

(C4 - C8 Para + Isopara) / C4 - C8 Olefins	35.69
3-Methylhexane / n-Heptane	2.60
Methylcyclohexane / n-Heptane	1.93
Isoparaffins + Naphthenes / Paraffins	5.63

Octane rating

2,2,4,-Trimethylpentane / Methylcyclohexane	2.15

Relative percentages - Bulk hydrocarbon composition as PIANO

% Paraffinic	6.14
% Isoparaffinic	28.07
% Aromatic	58.42
% Naphthenic	6.49
% Olefinic	0.88

10/29/2016

ZymaX ID 20791-4
Sample ID S-114SRTF-PRODUCT-20161013

		Relative Area %
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.00
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.56
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.00
11	Pentane	0.41
12	trans-2-Pentene	0.00
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.16
15	2,2-Dimethylbutane	0.00
16	Cyclopentane	0.50
17	2,3-Dimethylbutane/MTBE	0.00
18	2-Methylpentane	1.56
19	3-Methylpentane	1.17
20	Hexane	0.98
21	trans-2-Hexene	0.17
22	3-Methylcyclopentene	0.12
23	3-Methyl-2-pentene	0.00
24	cis-2-Hexene	0.20
25	3-Methyl-trans-2-pentene	0.09
26	Methylcyclopentane	0.96
27	2,4-Dimethylpentane	0.51
28	Benzene	0.26
29	5-Methyl-1-hexene	0.15
30	Cyclohexane	0.30
31	2-Methylhexane/TAME	1.58
32	2,3-Dimethylpentane	1.04
33	3-Methylhexane	1.99
34A	1-trans-3-Dimethylcyclopentane	0.38
34B	1-cis-3-Dimethylcyclopentane	0.40
35	2,2,4-Trimethylpentane	3.18
I.S. #1	à,à,à-Trifluorotoluene	0.00

ZymaX ID	20791-4
Sample ID	S-114SRTF-PRODUCT-20161013

		Relative Area %
36	n-Heptane	0.77
37	Methylcyclohexane	1.48
38	2,5-Dimethylhexane	0.66
39	2,4-Dimethylhexane	0.91
40	2,3,4-Trimethylpentane	1.94
41	Toluene/2,3,3-Trimethylpentane	2.42
42	2,3-Dimethylhexane	1.02
43	2-Methylheptane	1.26
44	4-Methylheptane	0.54
45	3,4-Dimethylhexane	0.00
46A	3-Ethyl-3-methylpentane	1.02
46B	1,4-Dimethylcyclohexane	1.55
47	3-Methylheptane	0.75
48	2,2,5-Trimethylhexane	0.33
49	n-Octane	1.09
50	2,2-Dimethylheptane	0.19
51	2,4-Dimethylheptane	0.27
52	Ethylcyclohexane	0.92
53	2,6-Dimethylheptane	0.70
54	Ethylbenzene	0.42
55	m+p Xylenes	9.47
56	4-Methyloctane	1.02
57	2-Methyloctane	1.16
58	3-Ethylheptane	0.30
59	3-Methyloctane	1.45
60	o-Xylene	3.88
61	1-Nonene	0.00
62	n-Nonane	1.57
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.19
64	3,3,5-Trimethylheptane	0.23
65	2,4,5-Trimethylheptane	0.52
66	n-Propylbenzene	0.32
67	1-Methyl-3-ethylbenzene	5.23
68	1-Methyl-4-ethylbenzene	2.26
69	1,3,5-Trimethylbenzene	4.45
70	3,3,4-Trimethylheptane	2.11

ZymaX ID		20791-4
Sample ID		S-114SRTF-PRODUCT-20161013
		Relative Area %
71	1-Methyl-2-ethylbenzene	0.30
72	3-Methylnonane	0.10
73	1,2,4-Trimethylbenzene	8.25
74	Isobutylbenzene	0.13
75	sec-Butylbenzene	0.22
76	n-Decane	1.32
77	1,2,3-Trimethylbenzene	2.71
78	Indan	0.29
79	1,3-Diethylbenzene	2.21
80	1,4-Diethylbenzene	1.96
81	n-Butylbenzene	0.75
82	1,3-Dimethyl-5-ethylbenzene	0.60
83	1,4-Dimethyl-2-ethylbenzene	1.61
84	1,3-Dimethyl-4-ethylbenzene	1.69
85	1,2-Dimethyl-4-ethylbenzene	2.73
86	Undecene	0.00
87	1,2,4,5-Tetramethylbenzene	1.17
88	1,2,3,5-Tetramethylbenzene	1.63
89	1,2,3,4-Tetramethylbenzene	1.35
90	Naphthalene	0.60
91	2-Methyl-naphthalene	0.83
92	1-Methyl-naphthalene	0.49

Chrom Perfect Chromatogram Report

— C:\CPSpirit\2016\Oct16\102916\102916.0030.RAW

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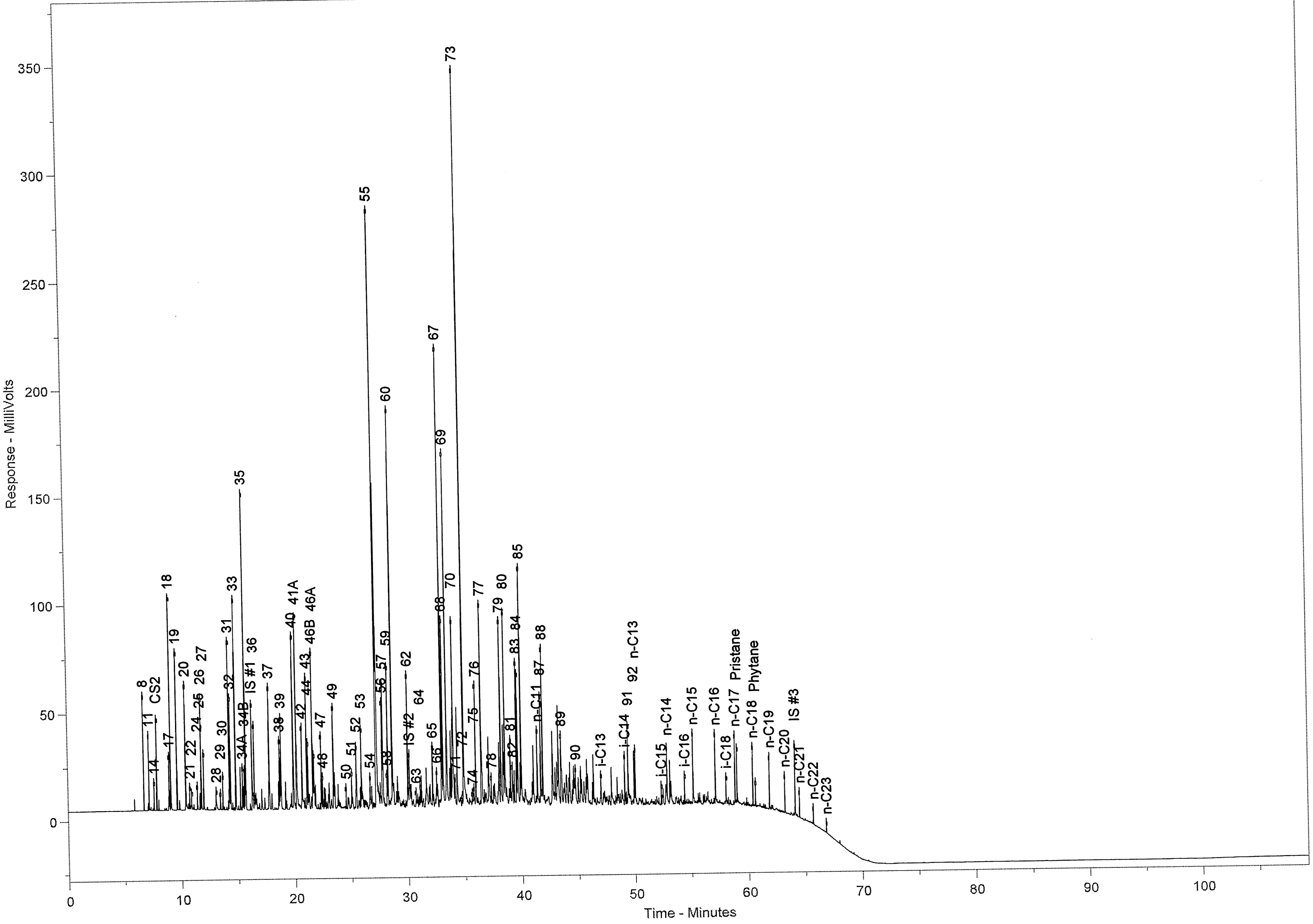

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Chrom Perfect Chromatogram Report

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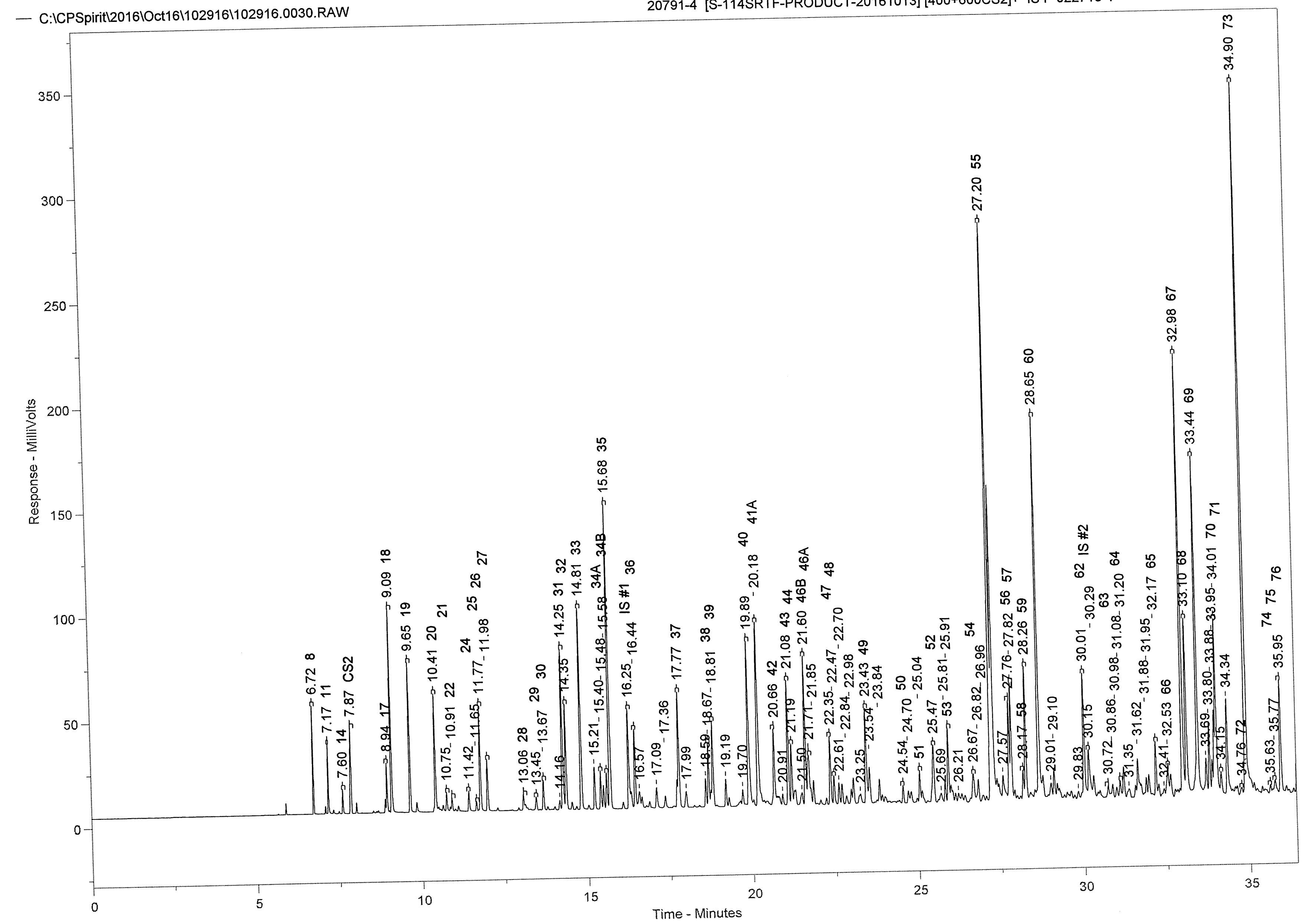

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Chrom Perfect Chromatogram Report

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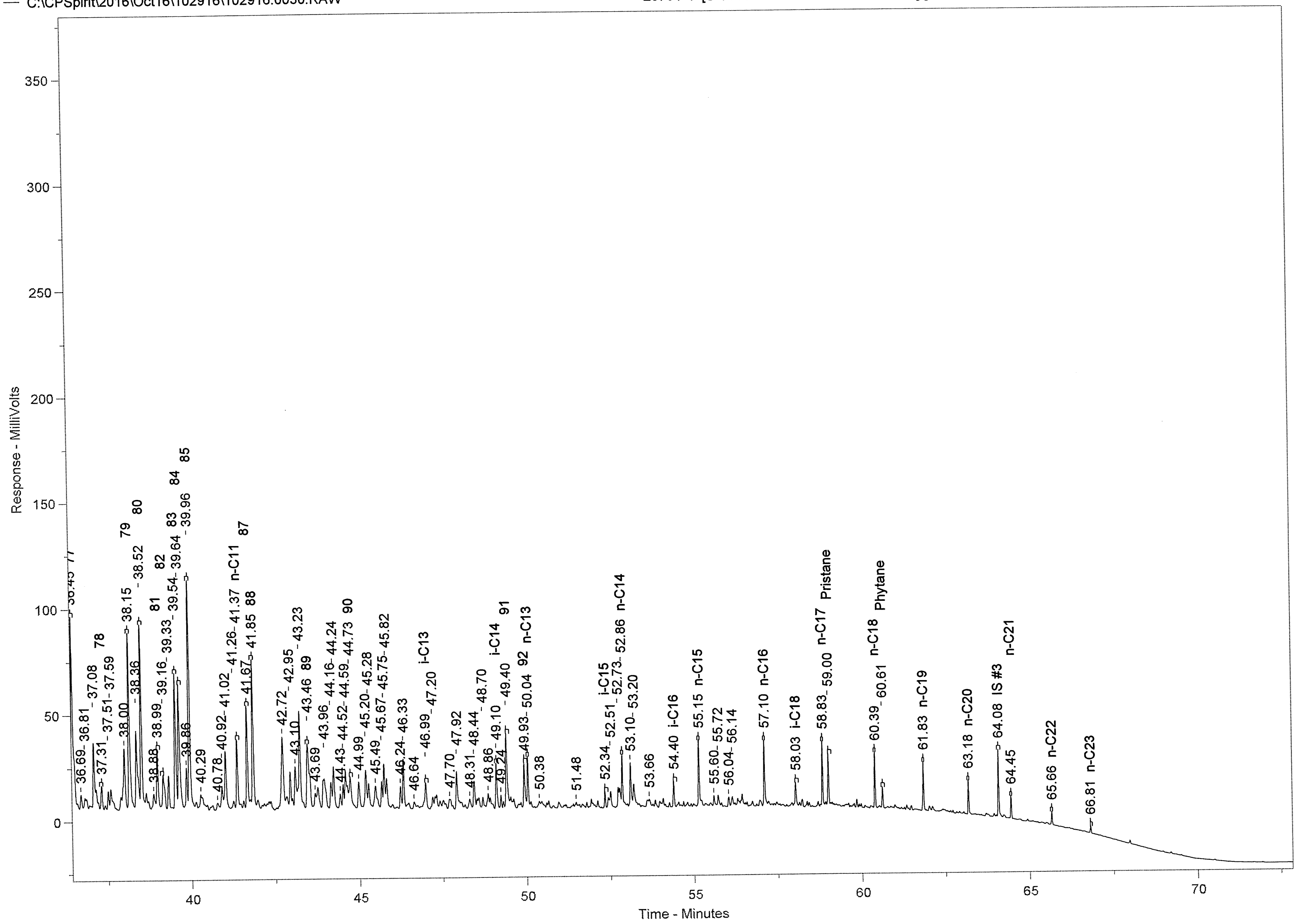

Chrom Perfect Chromatogram Report

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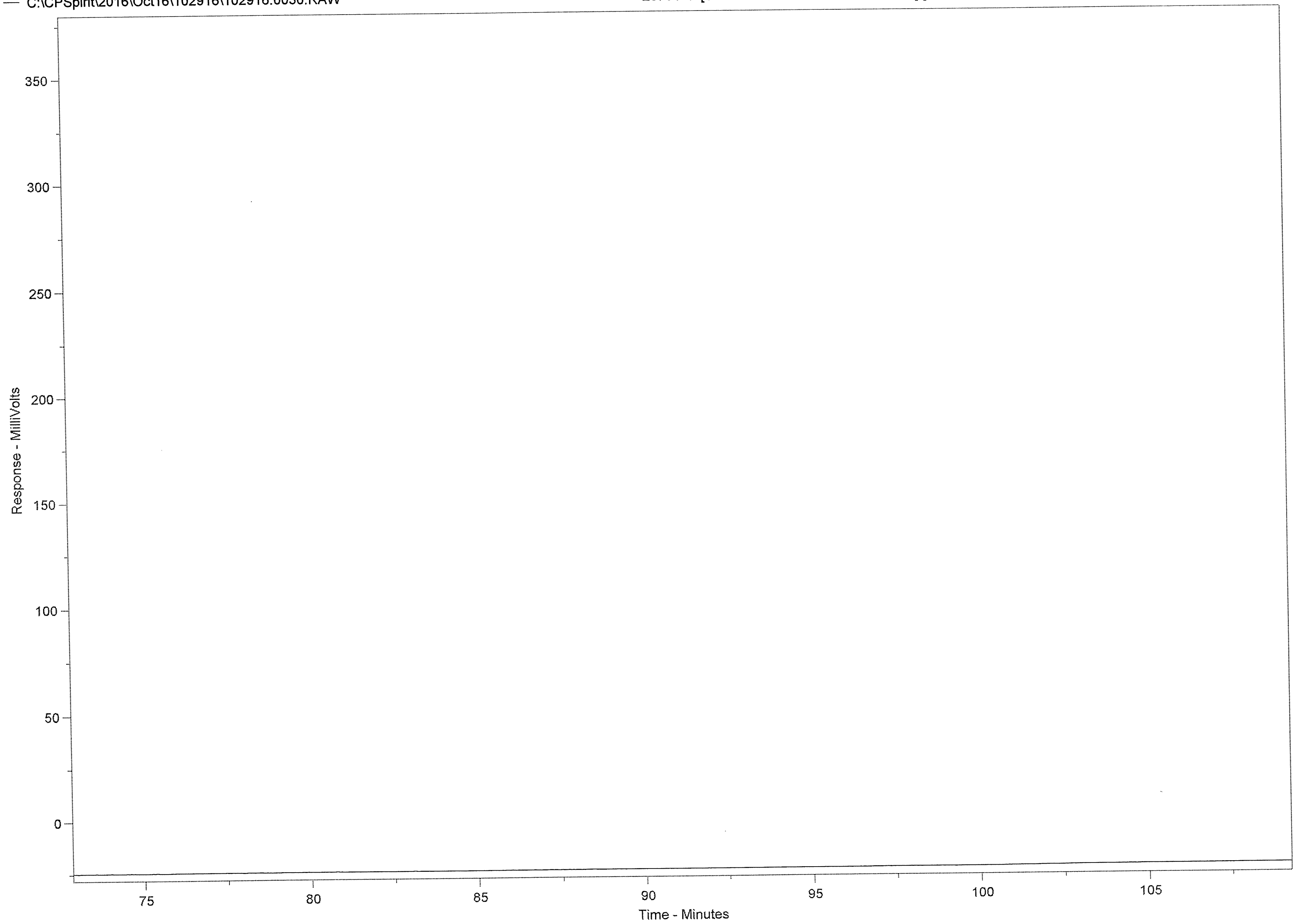

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Chrom Perfect Chromatogram Report

Sample Name = **20791-4 [S-114SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

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Calibration File Name = C:\CPSpirit\20791.cal

Date Taken (end) = 11/4/2016 2:04:42 PM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
8	6.72	0.3867	65638.05
11	7.17	0.2822	47895.21
14	7.60	0.1094	18566.32
CS2	7.87	0.5358	90943.76
17	8.94	0.3487	59182.11
18	9.09	1.0825	183725.00
19	9.65	0.8117	137771.30
20	10.41	0.6797	115368.60
21	10.75	0.1165	19777.98
22	10.91	0.0808	13705.75
24	11.42	0.1408	23890.51
25	11.65	0.0605	10260.31
26	11.77	0.6661	113059.10
27	11.98	0.3569	60576.86
28	13.06	0.1772	30068.91
29	13.45	0.1014	17211.55
30	13.67	0.2086	35397.44
	14.16	0.0664	11271.71
31	14.25	1.0986	186470.80
32	14.35	0.7239	122874.10
33	14.81	1.3806	234334.00
	15.21	0.2930	49726.81
34A	15.40	0.2633	44684.43
	15.48	0.1679	28496.37
34B	15.58	0.2785	47262.90
35	15.68	2.2109	375260.10
IS #1	16.25	0.8324	141283.10
36	16.44	0.5319	90285.68
	16.57	0.1136	19288.26
	17.09	0.1790	30386.33
	17.36	0.1041	17670.79
37	17.77	1.0267	174263.70
	17.99	0.1577	26769.30
	18.59	0.2005	34028.37
38	18.67	0.4584	77808.65
39	18.81	0.6305	107009.80
	19.19	0.1893	32135.72
	19.70	0.1910	32417.05
40	19.89	1.3453	228328.60
41A	20.18	1.6817	285433.90
42	20.66	0.7082	120193.90
	20.91	0.0821	13928.96
43	21.08	0.8775	148928.80
44	21.19	0.3770	63995.41
	21.50	0.1363	23139.34
46B	21.60	1.0753	182506.80
46A	21.71	0.7080	120160.30
	21.85	0.1675	28426.54
47	22.35	0.5212	88455.87
48	22.47	0.2300	39032.46
	22.61	0.1558	26441.36
	22.70	0.1547	26258.09
	22.84	0.0699	11858.53
	22.98	0.0653	11079.10
	23.25	0.1400	23760.48

Peak Name	Ret. Time	Area %	Area
49	23.43	0.7575	128574.50
	23.54	0.3254	55221.76
	23.84	0.1502	25496.80
50	24.54	0.1290	21890.26
	24.70	0.0678	11501.98
51	25.04	0.1909	32393.90
52	25.47	0.6399	108612.70
	25.69	0.0778	13210.62
	25.81	0.1428	24231.61
53	25.91	0.4865	82577.33
	26.21	0.0492	8357.54
54	26.67	0.2895	49130.94
	26.82	0.1975	33519.50
	26.96	0.0632	10726.78
55	27.20	6.5744	1115869.00
	27.57	0.2113	35866.59
56	27.76	0.7087	120288.10
57	27.82	0.8033	136335.50
58	28.17	0.2098	35611.04
59	28.26	1.0042	170437.90
60	28.65	2.6943	457299.30
	29.01	0.1109	18827.30
	29.10	0.1971	33461.57
	29.83	0.0650	11035.94
62	30.01	1.0936	185618.30
IS #2	30.15	0.5469	92828.67
	30.29	0.2080	35310.89
63	30.72	0.1337	22695.61
	30.86	0.1148	19481.22
	30.98	0.0977	16588.45
64	31.08	0.1601	27172.68
	31.20	0.2738	46472.20
	31.35	0.1308	22208.63
	31.62	0.6025	102260.40
	31.88	0.1597	27104.17
	31.95	0.2136	36247.90
65	32.17	0.3626	61542.98
	32.41	0.0549	9314.37
66	32.53	0.2220	37684.57
67	32.98	3.6310	616283.80
68	33.10	1.5725	266903.90
69	33.44	3.0902	524497.10
	33.69	0.3924	66592.87
	33.80	0.5762	97792.65
	33.88	0.2665	45240.73
	33.95	0.5959	101142.00
70	34.01	1.4642	248519.10
71	34.15	0.2118	35946.06
	34.34	0.7725	131109.80
72	34.76	0.0674	11441.52
73	34.90	5.7329	973037.80
74	35.63	0.0936	15891.01
75	35.77	0.1549	26284.69
76	35.95	0.9198	156109.00
77	36.45	1.8811	319281.80
	36.69	0.1301	22088.80
	36.81	0.1911	32429.46
	37.08	0.7871	133592.30
78	37.31	0.2022	34319.88
	37.51	0.1450	24603.14
	37.59	0.2928	49688.11
	38.00	0.7497	127239.80
79	38.15	1.5347	260489.00
	38.36	0.8152	138355.20
80	38.52	1.3584	230550.40
	38.88	0.1721	29207.18
81	38.99	0.5205	88337.16

Peak Name	Ret. Time	Area %	Area
82	39.16	0.4138	70234.97
	39.33	0.2415	40996.93
83	39.54	1.1151	189264.30
84	39.64	1.1726	199027.40
	39.86	0.2941	49922.77
85	39.96	1.8989	322290.30
	40.29	0.1995	33861.33
	40.78	0.0824	13983.32
	40.92	0.2238	37977.90
	41.02	0.5738	97394.63
	41.26	0.0594	10079.74
n-C11	41.37	0.5203	88302.16
87	41.67	0.8123	137868.00
88	41.85	1.1307	191918.10
	42.72	0.8443	143293.10
	42.95	0.2796	47464.46
	43.10	0.4007	68004.97
	43.23	0.9899	168015.30
89	43.46	0.9377	159160.50
	43.69	0.0499	8466.77
	43.96	0.5004	84923.56
	44.16	0.2270	38520.28
	44.24	0.3783	64206.19
	44.43	0.1161	19710.70
	44.52	0.1811	30732.09
	44.59	0.4836	82072.49
90	44.73	0.4182	70976.43
	44.99	0.2701	45840.84
	45.20	0.3879	65829.55
	45.28	0.2282	38724.98
	45.49	0.3113	52839.73
	45.67	0.1997	33889.61
	45.75	0.3715	63055.28
	45.82	0.2454	41657.89
	46.24	0.1666	28282.08
	46.33	0.3612	61312.95
	46.64	0.0522	8863.25
i-C13	46.99	0.2700	45827.03
	47.20	0.0552	9369.38
	47.70	0.1545	26219.89
	47.92	0.2986	50681.68
	48.31	0.0899	15259.48
	48.44	0.2005	34028.75
	48.70	0.0694	11783.02
	48.86	0.0749	12708.73
i-C14	49.10	0.3581	60783.56
	49.24	0.0771	13082.20
91	49.40	0.5751	97614.04
92	49.93	0.3418	58005.03
n-C13	50.04	0.3084	52340.64
	50.38	0.1469	24930.98
	51.48	0.0582	9877.42
i-C15	52.34	0.0993	16856.14
	52.51	0.2298	39006.58
	52.73	0.2846	48311.76
n-C14	52.86	0.3339	56668.00
	53.10	0.3079	52253.59
	53.20	0.2072	35173.16
	53.66	0.1243	21104.24
i-C16	54.40	0.1677	28455.41
n-C15	55.15	0.4493	76253.62
	55.60	0.0740	12567.03
	55.72	0.1163	19747.73
	56.04	0.0631	10715.89
	56.14	0.0895	15197.03
n-C16	57.10	0.4297	72924.50
i-C18	58.03	0.1617	27437.14

Chrom Perfect Chromatogram Report

Peak Name	Ret. Time	Area %	Area
n-C17	58.83	0.3158	53602.32
Pristane	59.00	0.3017	51204.00
n-C18	60.39	0.2792	47382.70
Phytane	60.61	0.1241	21058.71
n-C19	61.83	0.2799	47511.81
n-C20	63.18	0.1785	30304.45
IS #3	64.08	0.3567	60545.86
n-C21	64.45	0.1168	19815.81
n-C22	65.66	0.0748	12690.63
n-C23	66.81	0.0346	5873.69

Total Area = 1.697282E+07 Total Height = 5716985 Total Amount = 16.87369

10/29/2016

ZymaX ID	20791-5
Sample ID	S-122SRTF-PRODUCT-20161013

Evaporation

n-Pentane / n-Heptane	0.31
2-Methylpentane / 2-Methylheptane	1.26

Waterwashing

Benzene / Cyclohexane	12.21
Toluene / Methylcyclohexane	2.61
Aromatics / Total Paraffins (n+iso+cyc)	0.54
Aromatics / Naphthenes	3.39

Biodegradation

(C4 - C8 Para + Isopara) / C4 - C8 Olefins	27.04
3-Methylhexane / n-Heptane	2.76
Methylcyclohexane / n-Heptane	1.39
Isoparaffins + Naphthenes / Paraffins	9.95

Octane rating

2,2,4,-Trimethylpentane / Methylcyclohexane	3.13

Relative percentages - Bulk hydrocarbon composition as PIANO

% Paraffinic	5.82
% Isoparaffinic	47.75
% Aromatic	34.35
% Naphthenic	10.13
% Olefinic	1.95

10/29/2016

ZymaX ID 20791-5
Sample ID S-122SRTF-PRODUCT-20161013

		Relative Area %
1	Propane	0.00
2	Isobutane	0.00
3	Isobutene	0.00
4	Butane/Methanol	0.09
5	trans-2-Butene	0.00
6	cis-2-Butene	0.00
7	3-Methyl-1-butene	0.00
8	Isopentane	0.58
9	1-Pentene	0.00
10	2-Methyl-1-butene	0.04
11	Pentane	0.54
12	trans-2-Pentene	0.09
13	cis-2-Pentene/t-Butanol	0.00
14	2-Methyl-2-butene	0.19
15	2,2-Dimethylbutane	0.17
16	Cyclopentane	0.00
17	2,3-Dimethylbutane/MTBE	0.87
18	2-Methylpentane	2.89
19	3-Methylpentane	2.43
20	Hexane	1.58
21	trans-2-Hexene	0.39
22	3-Methylcyclopentene	0.25
23	3-Methyl-2-pentene	0.09
24	cis-2-Hexene	0.32
25	3-Methyl-trans-2-pentene	0.22
26	Methylcyclopentane	2.09
27	2,4-Dimethylpentane	1.22
28	Benzene	0.73
29	5-Methyl-1-hexene	0.34
30	Cyclohexane	0.06
31	2-Methylhexane/TAME	2.36
32	2,3-Dimethylpentane	2.18
33	3-Methylhexane	4.77
34A	1-trans-3-Dimethylcyclopentane	0.93
34B	1-cis-3-Dimethylcyclopentane	0.89
35	2,2,4-Trimethylpentane	7.56
I.S. #1	à,à,à-Trifluorotoluene	0.00

10/29/2016

ZymaX ID 20791-5
Sample ID S-122SRTF-PRODUCT-20161013

		Relative Area %
36	n-Heptane	1.73
37	Methylcyclohexane	2.41
38	2,5-Dimethylhexane	1.34
39	2,4-Dimethylhexane	1.86
40	2,3,4-Trimethylpentane	3.80
41	Toluene/2,3,3-Trimethylpentane	6.31
42	2,3-Dimethylhexane	2.00
43	2-Methylheptane	2.30
44	4-Methylheptane	0.99
45	3,4-Dimethylhexane	0.43
46A	3-Ethyl-3-methylpentane	1.66
46B	1,4-Dimethylcyclohexane	2.39
47	3-Methylheptane	1.30
48	2,2,5-Trimethylhexane	0.62
49	n-Octane	0.91
50	2,2-Dimethylheptane	0.24
51	2,4-Dimethylheptane	0.27
52	Ethylcyclohexane	1.36
53	2,6-Dimethylheptane	0.72
54	Ethylbenzene	1.20
55	m+p Xylenes	4.07
56	4-Methyloctane	1.00
57	2-Methyloctane	1.02
58	3-Ethylheptane	0.26
59	3-Methyloctane	1.47
60	o-Xylene	1.40
61	1-Nonene	0.00
62	n-Nonane	0.53
I.S.#2	p-Bromofluorobenzene	0.00
63	Isopropylbenzene	0.79
64	3,3,5-Trimethylheptane	0.25
65	2,4,5-Trimethylheptane	0.53
66	n-Propylbenzene	1.16
67	1-Methyl-3-ethylbenzene	1.02
68	1-Methyl-4-ethylbenzene	0.61
69	1,3,5-Trimethylbenzene	1.47
70	3,3,4-Trimethylheptane	0.56

10/29/2016

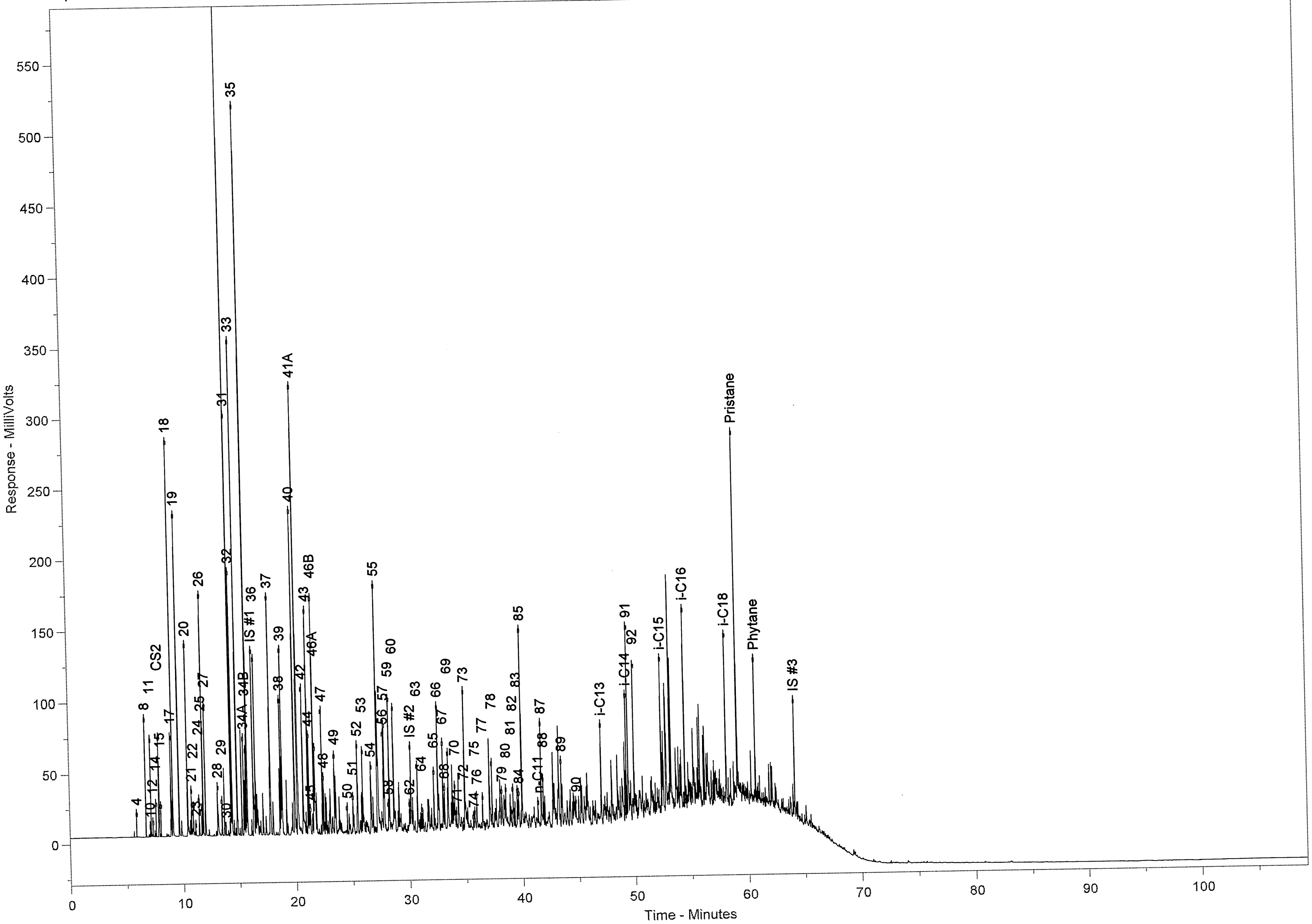
ZymaX ID 20791-5
Sample ID S-122SRTF-PRODUCT-20161013

		Relative Area %
71	1-Methyl-2-ethylbenzene	0.27
72	3-Methylnonane	0.09
73	1,2,4-Trimethylbenzene	1.88
74	Isobutylbenzene	0.13
75	sec-Butylbenzene	0.31
76	n-Decane	0.43
77	1,2,3-Trimethylbenzene	0.35
78	Indan	0.76
79	1,3-Diethylbenzene	0.65
80	1,4-Diethylbenzene	0.35
81	n-Butylbenzene	0.16
82	1,3-Dimethyl-5-ethylbenzene	0.56
83	1,4-Dimethyl-2-ethylbenzene	0.43
84	1,3-Dimethyl-4-ethylbenzene	0.62
85	1,2-Dimethyl-4-ethylbenzene	2.36
86	Undecene	0.00
87	1,2,4,5-Tetramethylbenzene	1.24
88	1,2,3,5-Tetramethylbenzene	0.56
89	1,2,3,4-Tetramethylbenzene	0.76
90	Naphthalene	0.45
91	2-Methyl-naphthalene	2.15
92	1-Methyl-naphthalene	1.61

Chrom Perfect Chromatogram Report

— C:\CPSpirit\2016\Oct16\102916\102916.0031.RAW

20791-5 [S-122SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1



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Chrom Perfect Chromatogram Report

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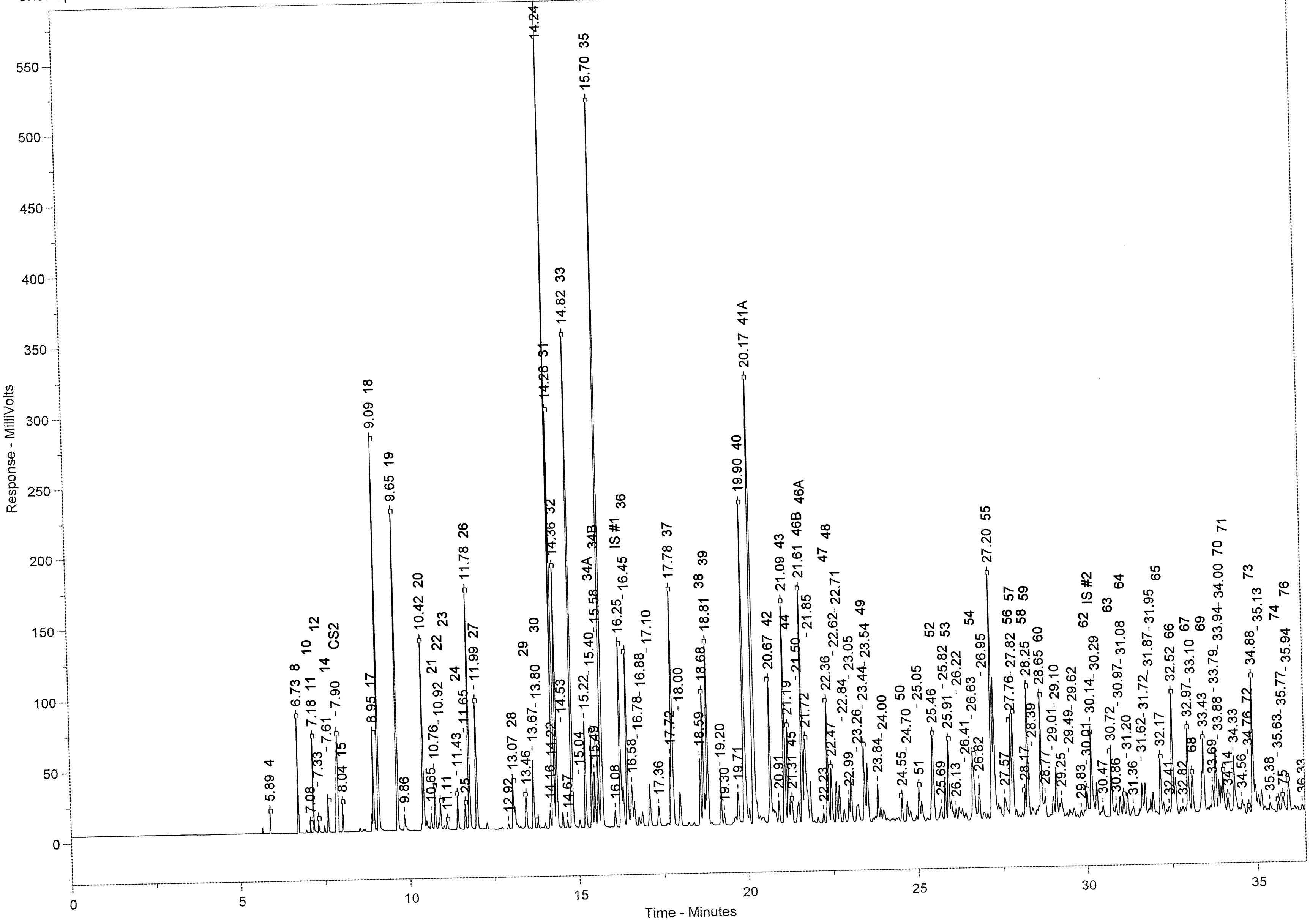

Chrom Perfect Chromatogram Report

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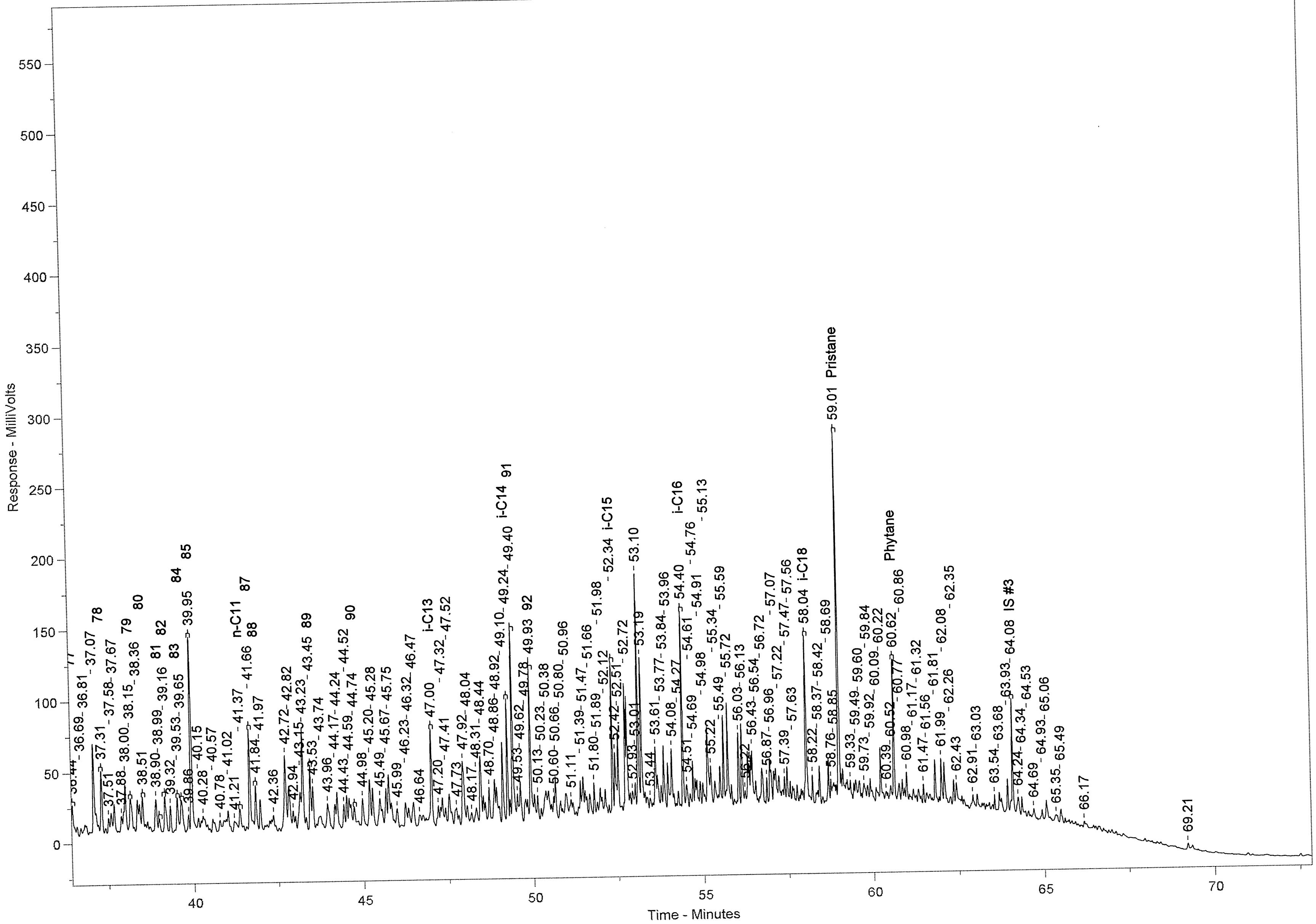
20791-5 [S-122SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1



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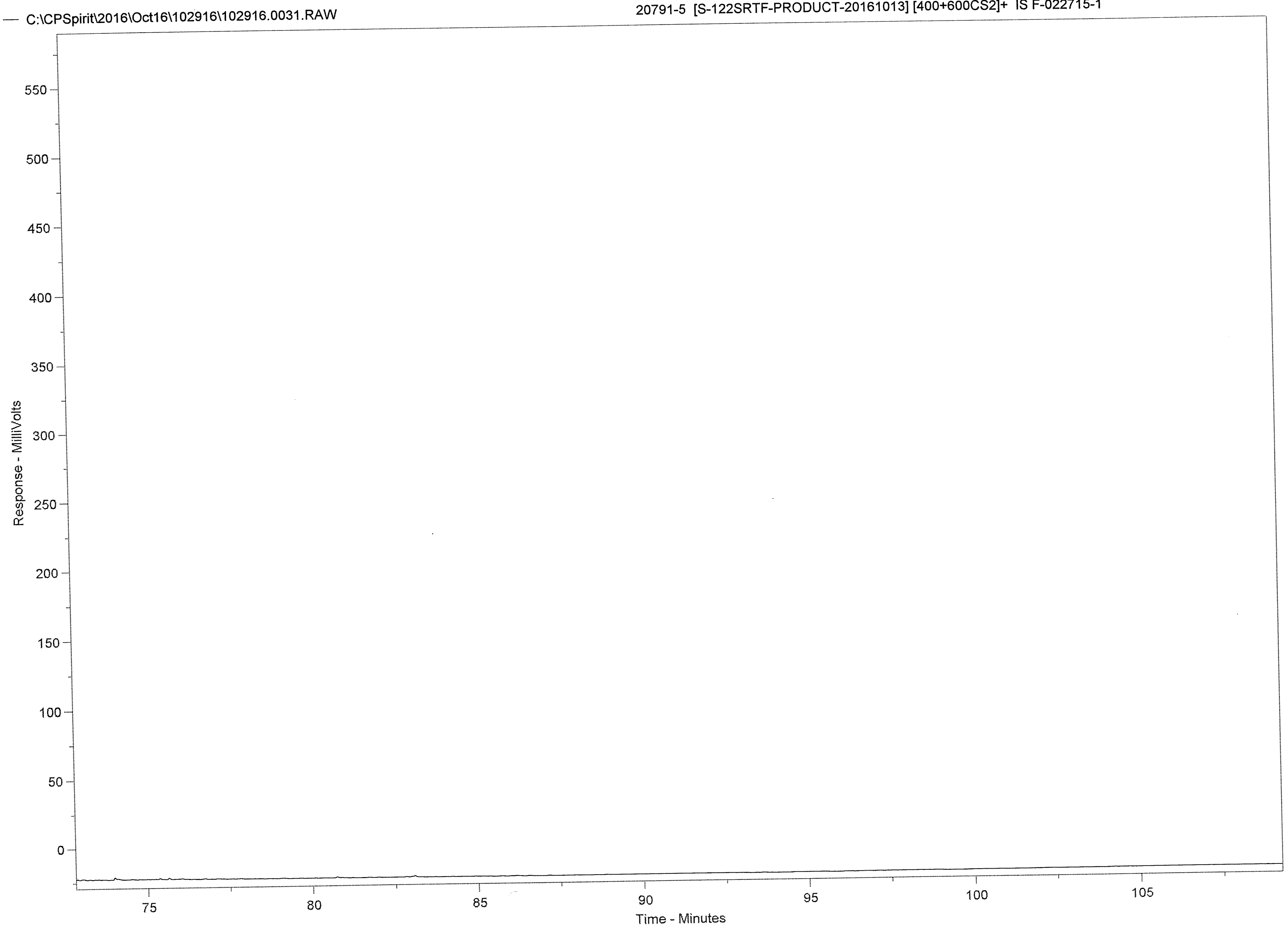
Chrom Perfect Chromatogram Report



Printed on 11/17/2016 2:25:46 PM

Chrom Perfect Chromatogram Report

Sample Name = **20791-5 [S-122SRTF-PRODUCT-20161013] [400+600CS2]+ IS F-022715-1**

Instrument = Instrument 1
Heading 1 =
Heading 2 =

Acquisition Port = DP#

Raw File Name = **C:\CPSpirit\2016\Oct16\102916\102916.0031.RAW**
Method File Name = C:\CPSpirit\C344.met
Calibration File Name = C:\CPSpirit\19956a.cal

Date Taken (end) = 11/4/2016 4:11:38 PM
Method Version = 44
Calibration Version = 1

Peak Name	Ret. Time	Area %	Area
4	5.89	0.0432	16111.04
8	6.73	0.2789	104031.50
10	7.08	0.0211	7869.14
11	7.18	0.2603	97116.74
12	7.33	0.0424	15807.10
14	7.61	0.0927	34598.54
CS2	7.90	0.5800	216395.90
15	8.04	0.0818	30502.11
17	8.95	0.4151	154865.00
18	9.09	1.3805	515001.50
19	9.65	1.1637	434147.30
	9.86	0.0893	33326.65
20	10.42	0.7565	282208.00
	10.65	0.0779	29059.61
21	10.76	0.1888	70418.47
22	10.92	0.1193	44515.39
23	11.11	0.0446	16633.04
24	11.43	0.1549	57779.56
25	11.65	0.1049	39119.04
26	11.78	0.9977	372208.80
27	11.99	0.5815	216929.20
	12.92	0.0222	8269.66
28	13.07	0.3500	130582.80
29	13.46	0.1615	60252.11
	13.67	0.3164	118027.60
30	13.80	0.0287	10696.37
	14.16	0.0875	32640.53
	14.22	0.0009	353.17
	14.24	1.2624	470960.10
31	14.26	1.1264	420225.10
32	14.36	1.0428	389025.60
	14.53	0.0782	29160.89
	14.67	0.0399	14900.18
33	14.82	2.2825	851523.40
	15.04	0.0418	15584.29
	15.22	0.4947	184552.80
34A	15.40	0.4454	166165.80
	15.49	0.2672	99692.74
34B	15.58	0.4264	159063.60
35	15.70	3.6137	1348167.00
	16.08	0.0820	30587.40
IS #1	16.25	0.8642	322386.20
36	16.45	0.8281	308942.30
	16.58	0.2987	111448.20
	16.78	0.0573	21384.29
	16.88	0.0882	32923.02
	17.10	0.2528	94320.32
	17.36	0.1303	48608.02
	17.72	0.3047	113681.30
37	17.78	1.1527	430043.40
	18.00	0.2050	76472.58
	18.59	0.3234	120631.40
38	18.68	0.6397	238637.10
39	18.81	0.8909	332371.80
	19.20	0.2721	101515.00

Peak Name	Ret. Time	Area %	Area
	19.30	0.0602	22441.99
	19.71	0.2356	87887.34
40	19.90	1.8172	677924.40
41A	20.17	3.0142	1124513.00
42	20.67	0.9564	356804.60
	20.91	0.1134	42294.41
43	21.09	1.0983	409736.00
44	21.19	0.4720	176071.90
45	21.31	0.2041	76144.38
	21.50	0.1651	61579.79
46B	21.61	1.1418	425962.10
46A	21.72	0.7939	296161.40
	21.85	0.1924	71763.12
	22.23	0.0483	18021.85
47	22.36	0.6236	232643.60
48	22.47	0.2980	111171.30
	22.62	0.2066	77079.85
	22.71	0.1975	73673.84
	22.84	0.0814	30364.95
	22.99	0.1248	46575.14
	23.05	0.2460	91777.06
	23.26	0.1995	74434.52
49	23.44	0.4327	161415.80
	23.54	0.3410	127231.10
	23.84	0.1686	62893.32
	24.00	0.0647	24121.88
50	24.55	0.1171	43671.64
	24.70	0.0894	33343.54
51	25.05	0.1295	48317.59
52	25.46	0.6519	243200.90
	25.69	0.0924	34488.11
	25.82	0.1896	70744.87
53	25.91	0.3431	127996.70
	26.13	0.0460	17166.86
	26.22	0.0858	32019.07
	26.41	0.0479	17882.92
54	26.63	0.5739	214102.10
	26.82	0.2229	83167.13
	26.95	0.0508	18944.39
55	27.20	1.9437	725114.70
	27.57	0.1772	66090.15
56	27.76	0.4793	178800.50
57	27.82	0.4868	181613.90
58	28.17	0.1220	45507.28
59	28.25	0.7009	261493.00
	28.39	0.0829	30919.39
60	28.65	0.6682	249276.20
	28.77	0.1643	61310.40
	29.01	0.1257	46896.64
	29.10	0.2656	99085.59
	29.25	0.1795	66952.46
	29.49	0.0547	20415.00
	29.62	0.0544	20309.62
	29.83	0.0467	17413.97
62	30.01	0.2554	95290.54
IS #2	30.14	0.5902	220175.30
	30.29	0.2442	91094.29
	30.47	0.0780	29117.46
63	30.72	0.3770	140649.00
	30.86	0.0796	29686.56
	30.97	0.1260	47022.63
64	31.08	0.1218	45458.03
	31.20	0.1405	52429.79
	31.36	0.0827	30855.22
	31.62	0.2257	84211.91
	31.72	0.2052	76559.87
	31.87	0.0831	30995.51

Peak Name	Ret. Time	Area %	Area
	31.95	0.1566	58427.18
65	32.17	0.2533	94494.11
	32.41	0.0266	9919.29
66	32.52	0.5552	207127.00
	32.82	0.0777	28971.94
67	32.97	0.4879	182018.70
68	33.10	0.2896	108053.10
69	33.43	0.7046	262846.50
	33.69	0.1808	67462.17
	33.79	0.3570	133172.00
	33.88	0.1814	67689.84
	33.94	0.1387	51739.14
70	34.00	0.2675	99795.69
71	34.14	0.1302	48582.36
	34.33	0.4595	171436.80
	34.56	0.1338	49932.06
72	34.76	0.0442	16484.57
73	34.88	0.8980	335029.20
	35.13	0.1109	41372.50
	35.38	0.0665	24805.83
74	35.63	0.0615	22955.20
75	35.77	0.1466	54707.86
76	35.94	0.2057	76757.83
	36.33	0.0325	12133.05
77	36.44	0.1654	61717.07
	36.69	0.0436	16274.28
	36.81	0.1288	48057.16
	37.07	0.6890	257026.00
78	37.31	0.3644	135948.70
	37.51	0.0815	30419.52
	37.58	0.1263	47135.81
	37.67	0.1761	65688.78
	37.88	0.0933	34796.77
	38.00	0.3726	139020.10
79	38.15	0.3123	116495.20
	38.36	0.1673	62416.86
80	38.51	0.1659	61909.56
	38.90	0.2191	81741.99
81	38.99	0.0774	28882.23
82	39.16	0.2699	100685.50
	39.32	0.1353	50468.99
83	39.53	0.2076	77456.91
84	39.65	0.2976	111019.10
	39.86	0.0890	33186.38
85	39.95	1.1282	420889.70
	40.15	0.0622	23196.40
	40.28	0.0989	36899.96
	40.57	0.1302	48580.86
	40.78	0.0982	36640.56
	41.02	0.3152	117579.50
	41.21	0.1062	39627.32
n-C11	41.37	0.1244	46405.93
87	41.66	0.5922	220921.20
88	41.84	0.2655	99035.20
	41.97	0.1697	63291.81
	42.36	0.1763	65778.89
	42.72	0.6117	228186.90
	42.82	0.3755	140077.20
	42.94	0.1213	45247.04
	43.15	0.3344	124756.80
	43.23	0.5900	220107.60
89	43.45	0.3635	135592.00
	43.53	0.2448	91319.23
	43.74	0.1974	73628.57
	43.96	0.2590	96623.58
	44.17	0.1422	53042.71
	44.24	0.2294	85577.76

Chrom Perfect Chromatogram Report

Peak Name	Ret. Time	Area %	Area
	44.43	0.1417	52848.94
	44.52	0.1758	65588.41
	44.59	0.2957	110302.90
90	44.74	0.2145	80026.36
	44.98	0.2025	75558.16
	45.20	0.3060	114168.70
	45.28	0.2266	84546.43
	45.49	0.2680	99997.77
	45.67	0.1575	58774.14
	45.75	0.1903	70987.23
	45.99	0.1064	39710.36
	46.23	0.1638	61119.01
	46.32	0.1320	49250.46
	46.47	0.1941	72420.21
	46.64	0.0554	20666.29
i-C13	47.00	0.5366	200172.20
	47.20	0.1309	48840.35
	47.32	0.2509	93596.57
	47.41	0.0941	35089.37
	47.52	0.2727	101738.60
	47.73	0.1090	40673.75
	47.92	0.5074	189280.80
	48.04	0.1100	41036.71
	48.17	0.0697	25995.38
	48.31	0.1033	38523.99
	48.44	0.3515	131121.30
	48.70	0.1637	61075.69
	48.86	0.2671	99632.68
	48.92	0.2712	101176.60
	49.10	0.4216	157279.80
i-C14	49.24	0.5406	201675.50
91	49.40	1.0269	383106.10
	49.53	0.2013	75097.56
	49.62	0.2175	81135.12
	49.78	0.1645	61368.76
92	49.93	0.7692	286967.80
	50.13	0.1320	49261.27
	50.23	0.0336	12537.60
	50.38	0.1105	41233.96
	50.60	0.0694	25892.76
	50.66	0.1808	67437.34
	50.80	0.1557	58080.71
	50.96	0.2320	86559.60
	51.11	0.2197	81969.26
	51.39	0.2017	75238.99
	51.47	0.4402	164214.80
	51.66	0.1518	56636.09
	51.80	0.1419	52956.18
	51.89	0.0661	24667.31
	51.98	0.2387	89047.01
	52.12	0.1582	59032.62
i-C15	52.34	0.5913	220591.70
	52.42	0.3875	144572.00
	52.51	0.4069	151783.50
	52.72	1.0843	404518.60
	52.93	0.1303	48610.86
	53.01	0.1430	53363.90
	53.10	1.0305	384458.70
	53.19	0.8272	308592.80
	53.44	0.0756	28206.27
	53.61	0.5734	213914.40
	53.77	0.1223	45618.43
	53.84	0.3241	120925.20
	53.96	0.2353	87780.96
	54.08	0.3984	148622.50
	54.27	0.0926	34541.68
i-C16	54.40	0.7759	289458.90

Peak Name	Ret. Time	Area %	Area
	54.51	0.1505	56151.65
	54.61	0.0747	27876.66
	54.69	0.1709	63747.53
	54.76	0.2573	95998.34
	54.91	0.1108	41333.41
	54.98	0.1451	54113.45
	55.13	0.4747	177099.60
	55.22	0.1843	68746.21
	55.34	0.1640	61194.14
	55.49	0.1620	60446.93
	55.59	0.3026	112894.90
	55.72	0.4166	155404.90
	56.03	0.3160	117878.10
	56.13	0.3721	138817.50
	56.22	0.0676	25208.62
	56.43	0.8084	301599.70
	56.54	0.1366	50951.09
	56.72	0.2735	102034.50
	56.87	0.0876	32694.87
	56.96	0.2834	105744.90
	57.07	0.0605	22580.88
	57.22	0.0893	33323.63
	57.39	0.1094	40798.25
	57.47	0.1349	50336.56
	57.56	0.0582	21706.44
	57.63	0.0933	34793.39
i-C18	58.04	0.8533	318351.00
	58.22	0.1060	39530.13
	58.37	0.1068	39833.81
	58.42	0.1474	55002.63
	58.69	0.1795	66952.03
	58.76	0.0699	26073.22
	58.85	0.1656	61768.93
Pristane	59.01	1.5660	584233.00
	59.33	0.0437	16312.21
	59.49	0.1854	69159.41
	59.60	0.1429	53323.44
	59.73	0.1420	52957.15
	59.84	0.0888	33127.38
	59.92	0.1624	60603.46
	60.09	0.1081	40343.68
	60.22	0.2765	103168.80
	60.39	0.0829	30943.66
	60.52	0.1065	39747.93
Phytane	60.62	0.5865	218809.20
	60.77	0.1113	41536.40
	60.86	0.0937	34963.56
	60.98	0.1195	44588.37
	61.17	0.0391	14595.24
	61.32	0.1020	38043.04
	61.47	0.0699	26081.67
	61.56	0.0477	17779.90
	61.81	0.1937	72266.95
	61.99	0.1902	70951.61
	62.08	0.2073	77345.54
	62.26	0.0395	14726.86
	62.35	0.1016	37913.13
	62.43	0.1318	49158.73
	62.91	0.1122	41842.90
	63.03	0.0741	27660.42
	63.54	0.0797	29725.95
	63.68	0.0464	17292.13
	63.93	0.1590	59300.32
IS #3	64.08	0.5353	199688.20
	64.24	0.1543	57564.82
	64.34	0.0915	34137.05
	64.53	0.0518	19308.68

Peak Name	Ret. Time	Area %	Area
	64.69	0.0755	28177.01
	64.93	0.0540	20153.45
	65.06	0.1673	62425.70
	65.35	0.0803	29941.63
	65.49	0.0859	32047.80
	66.17	0.0551	20552.08
	69.21	0.0270	10071.01

Total Area = 3.730661E+07 Total Height = 1.339028E+07 Total Amount = 0

Sample Condition Upon Receipt Pittsburgh

20791

Pace Analytical

Client Name: Aquaterra Project #: ____________

Courier: ☐ Fed Ex ☐ UPS ☐ USPS ☐ Client ☐ Commercial ☒ Pace Other ________

Tracking #: ____________

Custody Seal on Cooler/Box Present: ☐ yes ☒ no Seals intact: ☐ yes ☐ no

Thermometer Used 6 Type of Ice: [✓ Wet] Blue None

Cooler Temperature Observed Temp 4.1 °C Correction Factor: -0.2 °C Final Temp: 39 °C

Temp should be above freezing to 6°C

Date and Initials of person examining contents: a9nR 10-26-16

Comments:	Yes	No	N/A	
Chain of Custody Present:	X			1.
Chain of Custody Filled Out:	X			2.
Chain of Custody Relinquished:	X			3.
Sampler Name & Signature on COC:	X			4.
Sample Labels match COC:	X			5. Outside bags also labeled → VOAs labeled but wiped off
-Includes date/time/ID/Analysis Matrix: Oil				
Samples Arrived within Hold Time:	X			6.
Short Hold Time Analysis (<72hr remaining):		X		7.
Rush Turn Around Time Requested:		X		8.
Sufficient Volume:	X			9.
Correct Containers Used:	X			10.
-Pace Containers Used:	X			
Containers Intact:	X			11.
Filtered volume received for Dissolved tests			X	12.
All containers needing preservation have been checked.			X	13.
All containers needing preservation are found to be in compliance with EPA recommendation.			X	
exceptions: [✓ VOA] coliform, TOC, O&G, Phenolics				Initial when completed a9nR Date/time of preservation Lot # of added preservative
Headspace in VOA Vials (>6mm):		X		14.
Trip Blank Present:		X		15.
Trip Blank Custody Seals Present			X	
Rad Aqueous Samples Screened > 0.5 mrem/hr			X	Initial when completed: Date:

Client Notification/ Resolution:

Person Contacted: ____________ Date/Time: ____________ Contacted By: ____________

Comments/ Resolution: ____________

Note: Whenever there is a discrepancy affecting North Carolina compliance samples, a copy of this form will be sent to the North Carolina DEHNR Certification Office (i.e. out of hold, incorrect preservative, out of temp, incorrect containers)

***PM review** is documented electronically in LIMS. When the Project Manager closes the SRF Review schedule in LIMS. The review is in the Status section of the Workorder Edit Screen.

Cooler Receipt Form

Client Name: Aquaterra Project: PH REF AOZ9 Lab Work Order: 20791

A. Shipping/Container Information (circle appropriate response)

Courier: FedEx UPS USPS Client [✓ Other:] Pace-G Air bill Present: Yes No

Tracking Number:

Custody Seal on Cooler/Box Present: Yes [✓ No] Seals Intact: Yes No

Cooler/Box Packing Material: Bubble Wrap Absorbent Foam [✓ Other:]

Type of Ice: Wet Blue [✓ None] Ice Intact: Yes Melted

Cooler Temperature: n/a Radiation Screened: Yes [✓ No] Chain of Custody Present: [✓ Yes] No

Comments:

B. Laboratory Assignment/Log-in (check appropriate response)

	YES	NO	N/A	Comment Reference non-Conformance
Chain of Custody properly filled out	✓			
Chain of Custody relinquished	✓			
Sampler Name & Signature on COC	✓			
Containers intact	✓			
Were samples in separate bags	✓			
Sample container labels match COC Sample name/date and time collected	✓			
Sufficient volume provided	✓			
PAES containers used	✓			
Are containers properly preserved for the requested testing? (as labeled)			✓	
If an unknown preservation state, were containers checked? Exception: VOA's coliform			✓	If yes, see pH form.
Was volume for dissolved testing field filtered, as noted on the COC? Was volume received in a preserved container?			✓	

Comments:

Cooler contents examined/received by : LJ Date: 10.27.16

Project Manager Review : RW Date: 10-28-16

Torkelson Geochemistry, Inc.

2528 S. Columbia Place
Tulsa, OK 74114-3233
Phone: 918-749-8441
Fax: 918-749-6005
e-mail: BTorkelson@aol.com

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

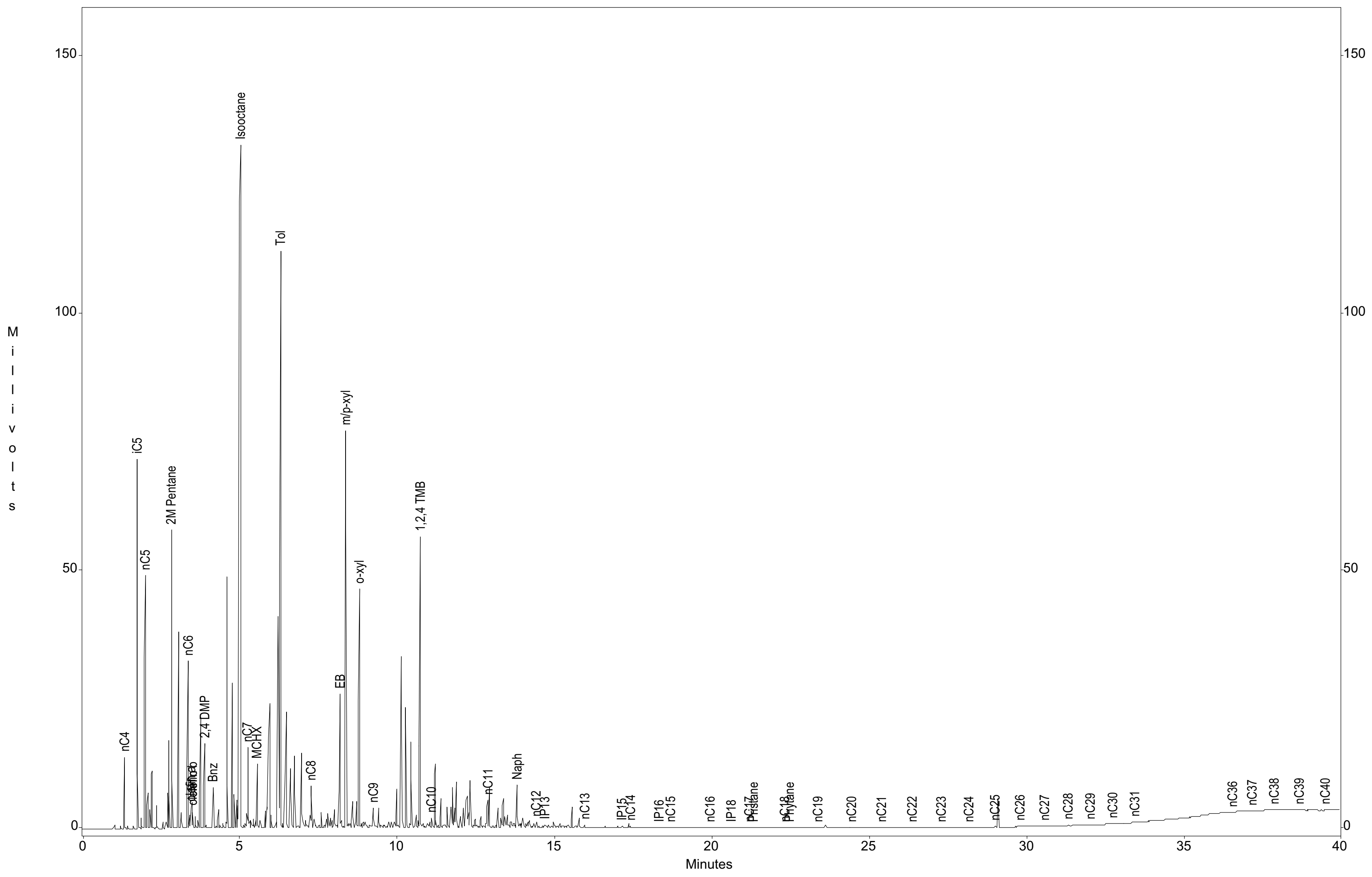
Requested Turn-Around Time:

						PRESERVATIVES	ANALYSES REQUESTED		
ITEM NO.	SAMPLE DESCRIPTION	DATE	MATRIX	LAB NO.	Total # OF Vials	None	GC Characterization	Specific Gravity	REMARKS
1	B-130	2/27/04	Product		1	X	X	X	
2	A-14	↓	↓		1	X	X	X	
3	SRTF MW-1	↓	↓		1	X	X	X	
4	B-129	↓	↓		1	X	X	X	
5	WP 9-2	3/1/04	↓		1	X	X	X	
6	BF-107	↓	↓		1	X	X	X	
7	S-33	↓	↓		1	X	X	X	
8	BF-106	↓	↓		1	X	X	X	
9	A-22	↓	↓		1	X	X	X	
10	S-100	↓	↓		1	X	X	X	

RELINQUISHED BY	ACCEPTED BY	DATE	TIME
M. Brad	Fed Ex	3/1/04	
	Bruce Torkelson	3-2-04	1705

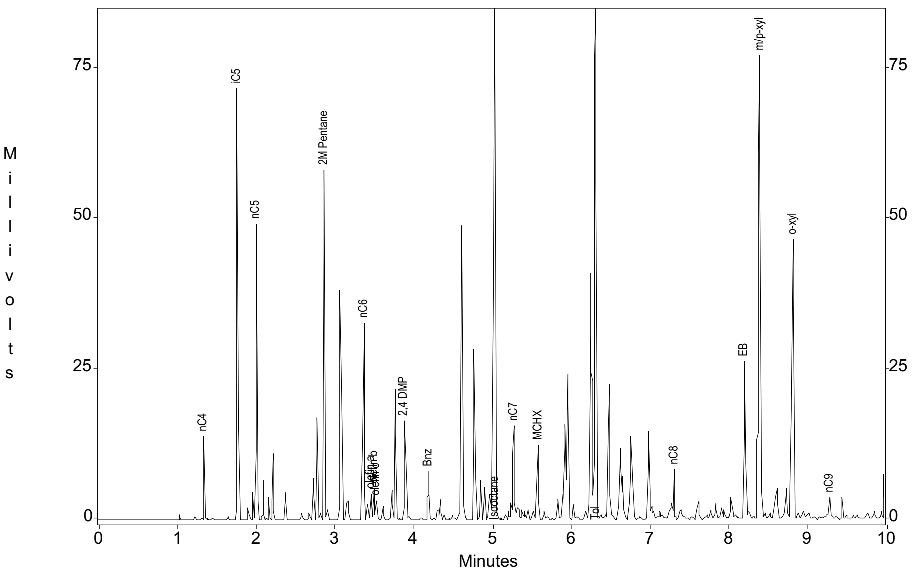
Sun - Philadelphia Refinery COA
Sample ID : SRTF MW-1
Acquired : Mar 08, 2004 15:57:18

c:\ezchrom\chrom\04046\srtfmw1 -- Channel A

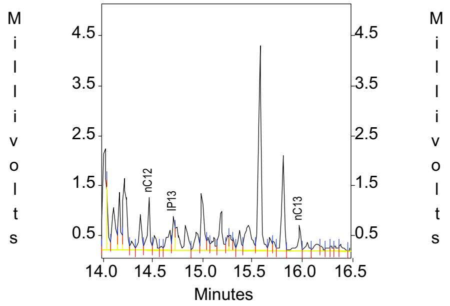


Sun - Philadelphia Refinery COA
Sample ID : SRTF MW-1
Acquired : Mar 08, 2004 15:57:18

c:\ezchrom\chrom\04046\srtfmw1 -- Channel A



c:\ezchrom\chrom\04046\srtfmw1 -- Channel A



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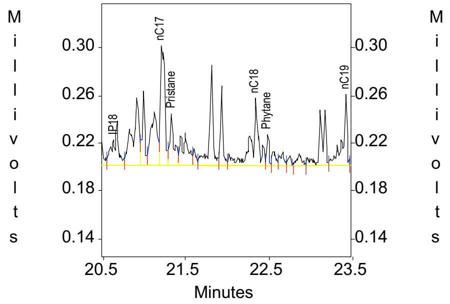
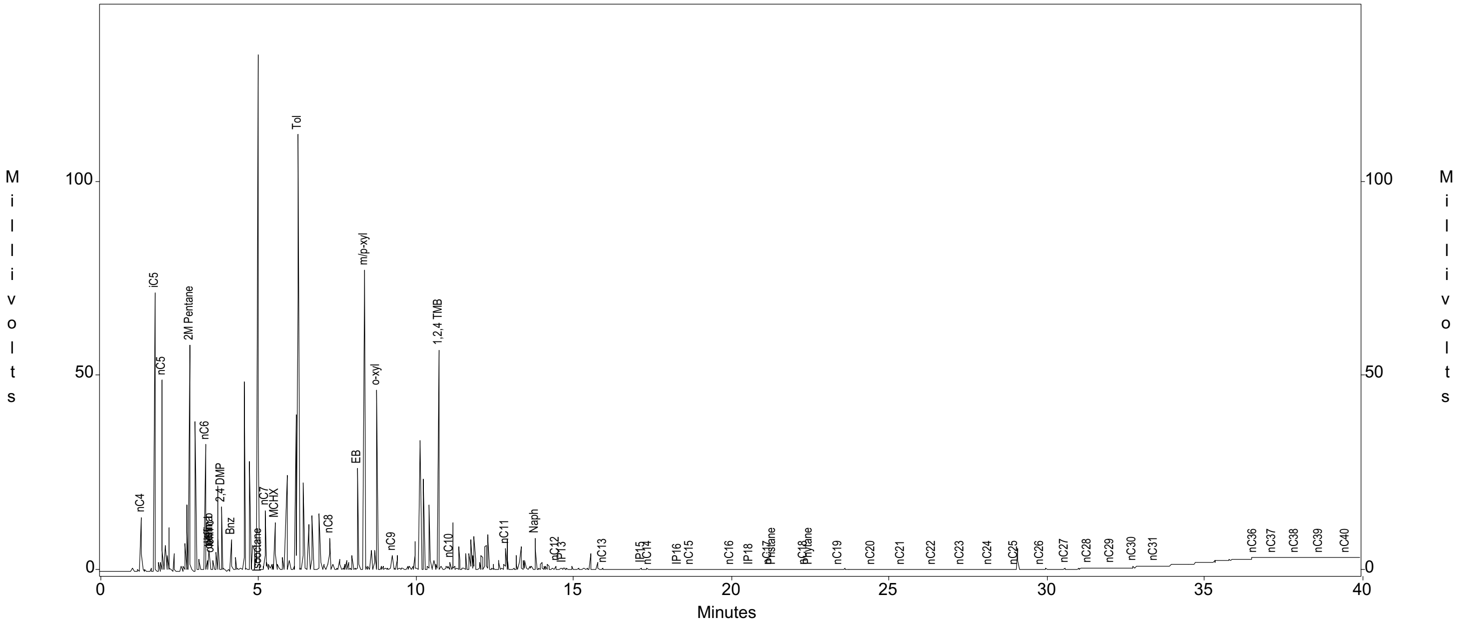


c:\ezchrom\chrom\04046\srtfmw1 -- Channel A



```
Channel A Results

 Peak          Area      Height
 --------------------------------
 nC4            9564      13860
 iC5           55333      71539
 nC5           38959      49065
 MTBE              0          0
 2M Pentane    53997      58104
 nC6           32840      32656
 olefin a       5049       4269
 olefin b       4975       4988
 olefin c       3739       3243
 2,4 DMP       18144      16541
 Bnz           11446       7933
 Isooctane    205290     132762
 nC7           19572      15656
 MCHX          16022      12475
 Tol          193036     112111
 nC8           10330       8259
 EB            35403      26164
 m/p-xyl      143263      77188
 o-xyl         69450      46423
 nC9            5305       3600
 1,2,4 TMB     89849      56478
 nC10           2487       1940
 nC11           8515       5480
 Naph          14461       8355
 nC12           1867       1056
 IP13           1026        659
 IP14              0          0
 nC13           1045        494
 IP15            193        157
 nC14            595        311
 IP16            160         64
 nC15            288        110
 nC16            371         86
 IP18            165         22
 nC17            385        101
 Pristane        151         43
 nC18            342         57
 Phytane          58         27
 nC19            215         59
 nC20            225         40
 nC21             89         44
 nC22            109         51
 nC23            136         61
 nC24            192         73
 nC25            256        133
 nC26            240         90
 nC27            311         97
 nC28            150         69
 nC29            203         76
 nC30             89         38
 nC31            209         53
 nC32              0          0
 nC33              0          0
 nC34              0          0
 nC35              0          0
 nC36           1404         43
 nC37            532         44
 nC38             50         19
 nC39            284         46
 nC40             47         24
```

Torkelson Geochemistry, Inc.

Density Measurements

Paar DMA 512 / DMA 60 | ASTM Method 4052

Sample	Density gm/ml @ 60F	Job Number	Date
A-13	0.9015	04046	3/8/04
A-14	0.9143	04046	3/9/04
A-22	0.9356	04046	3/9/04
A-47	0.8926	04046	3/8/04
A-133	qns	04046	3/9/04
B-39	0.8734	04046	3/8/04
B-43	0.9161	04046	3/9/04
B-129	0.8645	04046	3/9/04
B-130	0.9306	04046	3/8/04
B-144	0.8654	04046	3/9/04
BF-106	0.8199	04046	3/9/04
BF-107	0.8671	04046	3/8/04
C-65	0.9162	04046	3/9/04
C-106	0.9306	04046	3/9/04
C-107	0.9371	04046	3/8/04
N-14	0.9299	04046	3/9/04
N-25	0.0402	04046	3/8/04
N-35	0.9205	04046	3/9/04
N-48	0.9049	04046	3/9/04
N-52	0.8613	04046	3/8/04
N-68	0.9211	04046	3/9/04
N-79	0.8169	04046	3/9/04
PZ-204	0.9016	04046	3/8/04
PZ-502	0.9155	04046	3/9/04
S-21	0.9281	04046	3/9/04
S-29	0.8550	04046	3/8/04
S-32	0.8665	04046	3/8/04
S-33	0.8578	04046	3/9/04
S-50	0.7508	04046	3/8/04
S-56	0.8684	04046	3/9/04
S-59	0.8039	04046	3/9/04
S-60	0.7898	04046	3/8/04
S-76	0.7851	04046	3/8/04
S-79	0.8406	04046	3/8/04
S-81	0.7948	04046	3/9/04
S-89	0.8523	04046	3/8/04
S-92	0.9156	04046	3/9/04
S-97	0.8653	04046	3/8/04
S-100	0.7930	04046	3/9/04
S-103	0.7978	04046	3/9/04
S-104	0.8787	04046	3/8/04
S-117	0.8236	04046	3/9/04
S-124	0.8223	04046	3/9/04
S-130	0.8623	04046	3/8/04
S-138	0.8957	04046	3/9/04
S-158	0.8692	04046	3/9/04
S-162	0.7498	04046	3/8/04
SRTF MW-1	0.7705	04046	3/9/04
West Yard W8	0.9121	04046	3/9/04

	Sun - Philadelphia Refinery COA						
	TGI Job 04046						
	Interpretation of Product Type(s), Proportions and Weathering				**Similarities to Other Samples in this Study**		
Density	**Sample**	**Product Type(s)**	**Proportions**	**Weathering**	**Quite Similar to**	**Fairly Similar to**	**Somewhat Similar to**
0.7705	SRTF MW-1	?Crude	2	Moderate			S-162
	SRTF MW-1	Gasoline	98	Moderate			all other gasolines in this study

APPENDIX I

FATE AND TRANSPORT MODELING

APPENDIX I
Qualitative Fate & Transport Assessment
Remedial Investigation Report Addendum– AOI 9
Philadelphia Energy Solutions Refining & Marketing, LLC
Philadelphia Refining Complex
Philadelphia, Pennsylvania

Introduction

In September 2015, representatives from Evergreen's team, the Pennsylvania Department of Environmental Protection Agency (PADEP) and the United States Environmental Protection Agency (EPA) met to discuss the fate and transport (F&T) approach for the Complex. It was agreed upon during the meeting that AOI Remedial Investigation Reports (RIRs) would provide a qualitative F&T assessment and that a Complex-wide groundwater flow and transport model would be presented for the Complex as part of a separate report. The Complex-wide model will provide a quantitative F&T assessment for the Complex utilizing a Complex-wide numerical groundwater flow and contaminant transport model currently being developed by Stantec and other consultants on behalf of Evergreen.

This appendix contains the qualitative assessment for the AOI 9 RIR Addendum. The assessment includes information regarding the following conditions in AOI 9:

- Geologic framework;
- Hydrogeologic conditions;
- Hydrologic conditions;
- Anthropogenic features (such as the adjacent Mingo Creek Flood Control System);
- Constituent of concern (COC) plume stability; and
- Potential receptors.

The purpose of this assessment is to qualitatively evaluate the potential fate and transport of dissolved petroleum impacts and refine the current conceptual site model (CSM) for AOI 9.

Framework Summary

General Geologic Framework

The Complex lies within the up-dip limits of the Atlantic Coastal Plain, generally within two miles of the "Fall Line," where crystalline bedrock of the Appalachian foothills intersects the ground surface (outcrops). The Atlantic Coastal Plain is a physiographic province that is defined as having relatively flat topography and as being underlain by a characteristic wedge of unconsolidated sediments that thicken in a southeasterly direction, away from sediment source areas in the Appalachian Mountains. These sediments were deposited atop a sloping bedrock surface in complex fluvial, estuarine, and marginal marine environments along the passive Atlantic margin. Overall, subsidence of the Piedmont land surface in conjunction with cyclical sea-level fluctuations have been the primary controlling mechanisms driving periods of deposition, non-deposition and erosion in the Atlantic Coastal Plain (Trapp and Meisler, 1992). In general, the resulting sedimentary record in the vicinity of the Complex is complicated, largely incomplete, and under-represented by only Cretaceous and Quaternary deposits, separated by a regional disconformity. A general summary of those deposits that are identified in AOI 9 is presented below.

Anthropogenic Fill

Throughout most of the Complex the surface is covered by anthropogenic fill. These materials are heterogeneous and have been described on borehole logs as a mixture of compacted soil and anthropogenic debris, including sand, clay, silt, gravel, cinders, concrete, asphalt, crushed stone, ash, glass, brick fragments, and wood.

Quaternary Deposits

A recent (Holocene) alluvium deposit is present throughout most of the Complex beneath the anthropogenic fill. The Holocene alluvium generally consists of predominantly gray, muddy deposits with occasional sandy, gravelly, and organic-rich lenses. These sediments were deposited in dynamic floodplain, channel, and marsh environments through the Holocene. The Trenton Gravel is present throughout most of the Complex beneath the Holocene alluvium. The Trenton Gravel is of Pleistocene Age and is a very heterogeneous unit comprised of a predominant brown to gray sand, gravel and minor amounts of clay (Owens and Minard, 1979).

Cretaceous Deposits

The Cretaceous deposits are configured in a southeasterly-thickening wedge, overlain by the much younger Quaternary deposits, and underlain by the Wissahickon Formation. The wedge is made up of a series of vertically alternating aquifers and confining units called the Potomac-Raritan-Magothy (PRM) aquifer system. Each of the geological units of the PRM progressively pinches-out to the northwest. The PRM aquifer system consists of six units:

- Upper Clay unit;
- Upper Sand unit;
- Middle Clay unit;
- Middle Sand unit;
- Lower Clay unit, and
- Lower Sand unit.

AOI 9-Specific Geological Framework

In AOI 9, surface materials consist of anthropogenic fill and Holocene alluvium with a combined thickness ranging from approximately 2 to 32 feet. Based on the available stratigraphic data, the Holocene alluvium appears to be stratified with layers of silt and sands, and less permeable clay. Two fairly extensive clay layers (upper and lower) were identified within the Holocene alluvium. It appears these clay layers are important hydrogeologic features within AOI 9 and influence recharge to the unconfined aquifer. Therefore, the clay layers were mapped separately from other Holocene alluvium deposits. In the eastern portion of AOI 9, the Holocene clay deposits are thickest, gradually thin to the west, and are absent near the center of AOI 9. Geologic cross-sections of AOI 9 are provided as Figures 6a and 6b in the RIR Addendum.

Beneath the fill and Holocene alluvium is the Trenton Gravel which is older Pleistocene age alluvium. The Trenton Gravel generally ranges from approximately 20 to 30 feet thick throughout AOI 9, with a greatest thickness of 58 feet observed at monitoring well S-144SRTF (displayed in Figure 6a of the RIR Addendum). Below the Trenton Gravel are units of the PRM aquifer system. The shallowest PRM unit present in AOI 9 is the Upper Sand unit (the Upper Clay is not present in AOI 9). The Upper Sand does not appear to be continuous throughout AOI 9, and most likely occurs as thin discontinuous lenses overlying the Middle Clay, where present. The Middle Clay is discontinuous throughout AOI 9. Where present, the Middle Clay is thickest in the south based on monitoring wells S-138SRTF and S-143SRTF (up to 8 feet thick in S-143SRTF). It is assumed the Middle Sand has a similar extent as the overlying Middle Clay, and progressively pinches out to the northwest in the direction of the Fall Line. The Middle Sand ranges in thickness from zero feet to approximately 15 feet and overlies the Lower Clay. The Lower Clay appears to be discontinuous but where present ranges in thickness up to 8.5 feet. The Lower Sand is located approximately 59 to 70 feet below ground surface (bgs) and ranges in thickness between approximately 29 to 45 feet. Beneath the Lower

Sand is the Wissahickon Schist bedrock. The weathered zone of the Wissahickon Schist was encountered approximately 99 to 117 feet bgs.

General Hydrogeologic Framework

The hydrogeologic frame work is defined by grouping geologic units that are laterally extensive and have similar hydrogeologic properties. The generalized hydrostratigraphy of the Complex consists of seven layers (Schreffler, 2001, Sloto 2012):

- Layer 1: Combined anthropogenic fill, Holocene alluvium and Trenton Gravel;
- Layer 2: Upper Clay unit of the PRM (not present in AOI 9);
- Layer 3: Upper Sand unit of the PRM;
- Layer 4: Middle Clay unit of the PRM;
- Layer 5: Middle Sand unit of the PRM;
- Layer 6: Lower Clay unit of the PRM, and
- Layer 7: Lower Sand unit of the PRM.

AOI-9-Specific Hydrogeologic Framework

In the eastern half of AOI 9, significant anthropogenic fill thickness underlain by thick Holocene clay deposits supports a perched aquifer. Generally, within AOI 9 saturated conditions within the anthropogenic fill only exist in areas of perched groundwater. The unconfined aquifer consists of the combined Holocene Alluvium, Trenton Gravel, and Upper Sand (where present). Beneath the unconfined aquifer the Middle Clay, Middle Sand, Lower Clay, and Lower Sand are present as discontinuous units. Therefore, the Middle Sand, Lower Clay, and Lower Sand comprise the lower aquifer. The lower aquifer is a semi-confined aquifer. The lower aquifer lies above the Wissahickon Schist bedrock.

The groundwater elevations in the unconfined aquifer throughout most of AOI 9 generally range from -8 to -10 feet North American Vertical Datum of 1998 (NAVD 88). These low water table elevations throughout the majority of AOI 9 are most likely a result of pumping in Mingo Creek Flood Control basin (Mingo Creek basin). According to the City of Philadelphia Water Department (PWD), pumping from the Mingo Creek basin occurs approximately every 1 to 3 days depending on water level conditions. Large-capacity pumps are programmed to control the basin's water surface elevation between approximately -10.5 and -11 feet NAVD 88. Water-level data (data logger) of the unconfined aquifer collected by Stantec, and presented in

Appendix D of the RIR Addendum, supports the connection between the Mingo Creek basin and the unconfined aquifer beneath AOI 9.

The head differences measured in October 2016 between paired monitoring wells in the unconfined and lower aquifer (S-74D2SRTF/S-7D1SRTF, S-118SRTF/S-118DSRTF S-137SRTF/S-138SRTF, and S-142SRTF/S-143SRTF) ranged between zero (S-118SRTF/S-118DSRTF) to 4.28 (S-74D2SRTF/S-74D1SRTF). The observed head differences correspond to a downward vertical hydraulic gradient of 0.067 feet per feet (ft/ft) near the potentiometric high point of the unconfined aquifer (S-74D2SRTF/S-74D1SRTF) and transition to an upward vertical hydraulic gradient of 0.016 ft/ft (S-142SRTF/S-143SRTF) near Mingo Creek basin. The upward vertical hydraulic gradients observed are most likely attributable to the artificial lowering of the unconfined aquifer potentiometric surface due to the pumping in Mingo Creek basin.

AOI-9 Groundwater Flow Patterns

Interpreted groundwater flow patterns and hydraulic gradients in perched aquifer, unconfined aquifer, and lower aquifer within AOI 9 are depicted on groundwater elevation/potentiometric maps constructed using groundwater gauging data collected in May 2016, August 2016, and October 2016 (Figures 7 through 15 of the AOI 9 RIR Addendum).

As defined above, the perched aquifer is locally present in the eastern half of AOI 9 where significant fill deposits are underlain by thick Holocene clay strata. Several monitoring wells are screened within this perched aquifer. Based on the groundwater elevations as shown in Figures 7 through 9 of the RIR Addendum, the following observations can be made regarding the perched aquifer:

- Groundwater recharge of the perched aquifer occurs at the potentiometric high centered on S-74SRTF. From this high point, perched groundwater flows radially outward and eventually converges on at the center of AOI 9 towards the hole in the Holocene clay under a typical hydraulic gradient of 0.006 ft/ft.

- Perched groundwater recharges the unconfined aquifer at the western extent of the perched aquifer and preferentially where the Holocene clay is missing in the center of AOI 9.

As defined above, the unconfined aquifer is the combined Holocene alluvium/Trenton Gravel which makes up the water table aquifer. Based on the groundwater elevations within the unconfined aquifer as shown in Figures 10 through 12 of the RIR Addendum, the following observations can be made regarding the unconfined aquifer:

- Groundwater in the northern third of AOI 9 generally flows to the south under a typical gradient of 0.009 ft/ft.

- Groundwater flow in the central portion of the site flows radially outward from potentiometric high point centered on S-74D2 under a typical gradient of 0.002 ft/ft.

- It appears that the groundwater contours for the unconfined aquifer displayed on Figures 10 through 12 of the RIR Addendum are representative of differential draw down throughout AOI 9 because of the pumping in Mingo Creek basin. One or more of the following hydrogeologic and anthropogenic conditions may be causing the observed inconsistent drawdown pattern:
    - More permeable aquifer material on the western side of AOI 9 when compared to the east;
    - Groundwater infiltration into the Mingo Avenue sewer which drains into Mingo basin; and/or
    - Perched groundwater recharging the unconfined aquifer along the western edge of the perched aquifer.

As defined above, within AOI 9, the lower aquifer is the combined Middle and Lower Sand, which is a semi-confined aquifer. Based on the groundwater elevations within the lower aquifer as shown in Figures 13 through 15 of the RIR Addendum, the following observations can be made regarding the lower aquifer:

- Groundwater in the lower aquifer generally flows to the south towards the Delaware River under a typical gradient of 0.0004 ft/ft.

- The groundwater contours for the lower aquifer displayed on Figures 13 through 15 of RIR Addendum generally correspond to the flow direction of the 1995-1996 potentiometric surface for the lower sand as modeled (last simulated time step) and observed by Schreffler (Schreffler, 2001).

Aquifer Properties

Hydraulic Conductivity

As reported in Appendix D of the AOI 9 RIR Addendum, Stantec performed slug tests on five monitoring wells at AOI 9 in October 2016, including wells S-137SRTF, S-139SRTF, S-141SRTF, S-142SRTF, and S-144SRTF. Details of the slug test methods and aquifer test analyses are provided in Appendix D. The following unconfined aquifer hydraulic conductivity values were estimated for the tested wells:

- S-137SRTF: 271 feet per day (ft/d);
- S-139SRTF: 125 ft/d;
- S-141SRTF: 130 ft/d;
- S-142SRTF: 35 ft/d; and
- S-144SRTF: 237 ft/d.

A geometric mean of the test results was calculated to be 130 ft/d. In general, this hydraulic conductivity value fits the range of previous testing results for the Complex (Stantec, 2016) and for the nearby Enterprise Avenue Landfill site Pleistocene-age sand and gravel unit (Scheinfeld and Davenger, 2006). The site-specific hydraulic conductivities from AOI-9 were incorporated into Stantec's Predictive Analysis of the Potential Fate-and-Transport of Plume 2 Benzene Using Quick Domenico – Area of Interest 9 (Appendix D of the AOI 9 RIR Addendum) and may be incorporated into the future Complex-wide numerical groundwater flow and contaminant transport model.

Published hydraulic conductivity estimates for the lower aquifer range between 123 to 152 ft/d with a mean of 135 ft/d (Paulachok, 1991). In the calibrated groundwater flow model created by the United States Geologic Survey (USGS) (Schreffler, 2001), the lower aquifer has a hydraulic conductivity of 164 ft/day.

Porosity

In 2015, two soil samples of the Trenton Gravel within AOI 9 were collected to determine soil properties of the unconfined aquifer (refer to Appendix J in the RIR). Soil sample AOI-9-S-110DSRTF was collected at a depth of approximately 10 to 12 feet bgs. A deeper soil sample, AOI-9-S-118DSRTF, was collected at a depth of approximately 42 to 44 feet bgs. The soil sample collected from S-110DSRTF, described as sand and gravel, had a total porosity of 0.281 and an effective porosity of 0.225. The soil sample collected from S-118DSRTF, also described as sand and gravel, had a total porosity of 0.355 and an effective porosity of 0.282. The average total and effective porosities of the two samples are 0.32 and 0.25, respectively. In the calibrated groundwater flow model created by the USGS (Schreffler, 2001), a porosity of 0.3 was used for the unconfined aquifer and the lower aquifer, which is similar to the geotechnical soil analysis results.

Groundwater Seepage Velocities

Groundwater seepage velocity (seepage velocity) is an estimate of the rate of groundwater movement through the pores in a geologic material. Seepage velocity does not take into account processes such as dispersion, sorption or biotransformation, which can significantly affect the migration of dissolved constituent relative to groundwater. The calculation of seepage velocity also assumes homogenous aquifer conditions and a uniform hydraulic gradient. The seepage velocity equation is:

$$V_x = \frac{K \times i}{n_e}$$

Where:

V_x = seepage velocity (Length/Time);
K = hydraulic conductivity (Length/Time);
i = hydraulic gradient (unitless); and
n_e = effective porosity (unitless).

For the unconfined aquifer with K = 130 feet/day, i = 0.002 and n_e = 0.25, the seepage velocity is 1 ft/d or 365 feet per year (ft/yr). For the lower aquifer with a K = 164 feet/day, i = 0.0004 and n_e = 0.3, the seepage velocity is 0.2 ft/d or 73 ft/yr. These seepage velocities are conservative and do not incorporate a retardation factor.

Hydrology

Topography and Drainage

Based on a LiDAR dataset from January, 2010, AOI 9 ground surface elevations range from approximately two feet NAVD 88 at the northwest corner of the property to approximately 16 feet NAVD 88 at the eastern side (see Figure I-7 of the RIR). The vegetated area located between the former railroad right-of-way and the Schuylkill River is topographically higher and is covered with trees. The ground surface in the western and southern portions of the AOI is generally flat and is broken up by tank containment berms ranging in height from approximately 2 to 10 feet.

Rainfall

Average yearly precipitation at Philadelphia International Airport, located about one mile southwest of AOI 9, is 41.45 inches (www.usclimatedata.com). A significant portion of precipitation does not reach the water table due to several processes. In AOI 9, some of the precipitation becomes runoff that is redirected by impermeable surfaces such as roadways and above ground storage tanks (see Figure I-8 of the RIR) and is intercepted by storm water control facilities. Some precipitation likely returns to the atmosphere through evapotranspiration by vegetation, where present.

Surface Water Bodies

Existing surface water bodies in the vicinity of AOI 9 include the Schuylkill River to the east, (Figure I-9 of the RIR), the Mingo Creek Flood Control Basin to the south and an area of standing water surrounded by vegetation in the northwest corner of the property. Based on a review of available historical maps and photos, several small tributaries to the Schuylkill River and Mingo Creek were once present within AOI 9. In 1908, AOI 9 consisted of alluvium and marsh with the eastern extent often submerged as categorized and depicted by the USGS in Figure I-10 in the RIR.

The major surface water body near AOI 9 is the Schuylkill River. The USGS river-gauging station located at the Fairmount Dam, several miles upriver from AOI 9, recorded a mean surface water discharge rate of 2,773 cubic feet per second (cfs) between 1932 and 2005. The lowest elevation of the Schuylkill riverbed near AOI 9 is approximately 45 feet below mean sea level where the bottom has been dredged. The average stage of the Schuylkill River at AOI 9 is approximately 0.5 feet NAVD 88 (Schreffler, 2001).

Dames and Moore (2001) indicated that the Mingo Creek basin is approximately 25 feet deep, however siltation and shoaling for the basin have likely occurred since it was originally excavated and/or last dredged. Scheinfield and Davenger (2006) noted that within the shallow aquifer near the Philadelphia International Airport, groundwater flow was to the north-northwest toward Mingo Creek basin because of dewatering operations conducted by the PWD. As documented by Stantec (Appendix D) and stated above, the PWD indicated pumping from the Mingo Creek basin occurs approximately every 1 to 3 days depending on water level conditions. Large-capacity pumps are programmed to control the basin's water surface elevation between -10.5 and -11 feet NAVD 88. The pumps have the capacity to transfer water from the Mingo Creek basin to the Schuylkill River at up to 53,000 gallons per minute (gpm). PWD has indicated that pumping the basin water level down from an elevation of -10.5 feet to -11 NAVD 88 requires approximately 1 hour of runtime, and that the span volume of the basin between those controlled elevations is approximately 3 million gallons of water. Stantec's water level data indicating the connection between Mingo Creek basin and the unconfined aquifer is provided in Appendix D in the RIR Addendum.

Anthropogenic Site Features

Three groundwater recovery wells, RW-A, RW-B and RW-B5, are located in AOI 9 (Figure I-11 of the RIR). Since 2004, these recovery wells have not been in service due to low recovery of light non-aqueous phase liquid (LNAPL); however it possible that drawdown associated with the operation of remediation wells at nearby sites could have influenced historic water levels beneath AOI 9 (Scheinfeld and Davenger, 2006).

A set of floodgates control direct communication of surface water between the Mingo Creek Flood Control Basin and the Schuylkill River. As documented in Appendix D, it is reasonable to assume the low water table elevations present throughout much of AOI 9 are the result of pumping from Mingo Creek basin.

Constituents of Concern, Groundwater Plumes, and Plume Stability

Consistent with the F&T analysis in the RIR, delineated areas where COC concentrations in groundwater are above their respective medium-specific concentrations (MSCs) have been grouped into three primary groundwater plume areas described below:

- The Blending Area Plume (Plume 1) is located in the vicinity of well MW-1SRTF (Figure I-1). Since active recovery of LNAPL ceased in 2004, MW-1SRTF was the only well in AOI 9 where measureable LNAPL was identified. However, during the October 2016 gauging event, LNAPL was identified in MW-2SRTF and MW-3SRTF, which are immediately adjacent to MW-1SRTF. Refinement of the hydrogeologic framework shows that Plume 1 is constrained to the perched aquifer.

- During the October 2016 gauging, measurable LNAPL was also observed in monitoring wells S-114SRTF and S-122SRTF, which are located in the West Plume Area (Plume 2). Refinement of the hydrogeologic framework shows that Plume 2 is located in the unconfined aquifer.

- Based on the November 2016 limited groundwater sampling event, two additional groundwater plumes were identified which include unconfined aquifer and lower aquifer methyl tertiary butyl ether (MTBE) plumes located in the southern portion in AOI 9 near Mingo Creek basin. These plumes are collectively referred to as Plume 3.

1,2,4-trimethylbenzene (1,2,4-TMB), 1,2-dibromoethane (EDB), 1,3,5-trimethylbenzene (1,3,5-TMB), benzene, ethylbenzene, MTBE, toluene, xylenes (total), benzo(a)pyrene, benzo(g,h,i)perylene, naphthalene, and lead are the COCs in the perched aquifer that were detected above their respective PADEP non-residential groundwater MSCs. All of the AOI 9 COCs, except cumene, were detected in the unconfined aquifer above their respective PADEP non-residential groundwater MSCs. MTBE is the only COC that has been detected above the PADEP non-residential groundwater MSCs in monitoring wells screened in the lower aquifer. For the AOI 9 CSM plume assessments, groundwater concentration trends for benzene and MTBE, the most mobile of the COCs, were the focus.

Plume Stability Assessment

The persistence of a dissolved plumes was assessed by plotting COC concentration versus time from wells located in Plumes 1 and 2 in the RIR. With sufficient analytical data, a decreasing COC concentration trend in a well can be interpreted as the presence of a shrinking plume with respect to that COC at that location. Similarly, an increasing trend can be interpreted as an expanding plume area (USEPA, 2002). No significant changes in groundwater concentration can be interpreted as a stable-plume. Using multiple wells in a single plume, the overall stability of the plume can be assessed. Trend graphs for select wells within Plumes 2 and 3 were updated with the groundwater results from the limited groundwater sampling in November 2016.

Plume stability at AOI 9 was also evaluated by generating isoconcentration maps that depict the horizontal distribution of benzene and MTBE in the perched, unconfined and lower aquifers based on the November 2016 groundwater results. Over time, a reduction, redistribution of mass, and/or a decrease in extent can indicate plume attenuation. Conclusions drawn regarding overall plume stability in AOI 9 are preliminary and qualitative. Refer to Appendix D of the RIR Addendum for a quantitative assessment of the potential fate and transport of benzene from Plume 2.

The qualitative plume stability assessment in AOI 9 is described below.

Plume 1

Groundwater concentration trend graphs for benzene and MTBE at monitoring well MW-2SRTF and well WPB-5 screened in the perched aquifer within Plume 1 were created using analytical results from 2009 and 2015 (Figures I-13 and I-14 in the RIR). The concentration trends of these wells indicated the dissolved phase COCs in Plume 1 are decreasing. As stated above, measurable LNAPL was observed in MW-2SRTF and MW-3SRTF during the October 2016 gauging event. This increase in LNAPL extent indicates the potential for slight LNAPL mobility. However, based on minimal LNAPL thickness measured, ranging from 0.11 to 0.63 feet, and the dissolved phase COC distribution, significant mobility of this LNAPL plume is unlikely.

Groundwater isoconcentration maps for benzene and MTBE in the perched, unconfined and lower aquifers were created using analytical results from the limited groundwater sampling in November 2016 (Figures I-2 through I-6). Interpreting the isoconcentration maps for November 2016 and the previous isoconcentration maps from the RIR, the following summaries can be made for Plume 1:

- A groundwater sample was collected from beneath the LNAPL in MW-1SRTF during the November 2016 sampling.
- Benzene and MTBE concentrations detected at MW-1SRTF in November 2016 were 4,980 μg/l and 269 μg/l, respectively, confirming MW-1SRTF is a source area for Plume 1.

- The horizontal extent of benzene has not changed significantly, therefore, the benzene plume in Plume 1 is stable.
- Both the horizontal extent of MTBE and MTBE concentrations have decreased over time which suggests the MTBE plume in Plume 1 is decreasing.
- COC concentrations in the perched, unconfined, and lower aquifer monitoring wells surrounding Plume 1 indicate this plume is vertically constrained to the perched aquifer by the Holocene clay and horizontally limited to the Blending Area.

Plume 2

To evaluate plume stability in Plume 2, benzene and MTBE concentrations versus time were plotted for wells S-112SRTF, S-113SRTF, S-115SRTF, S-110DSRTF, and S-115DSRTF (Figures I-7 through I-11). Concentrations versus time plots for these wells indicate the benzene source area centered on S-112SRTF is potentially increasing. However, downgradient from S-112SRTF at S-113SRTF, benzene concentrations exhibit fluctuations, but appear to be stable. Benzene concentrations trends at S-115SRTF, which appears to be a separate isolated source area, indicate this plume is decreasing. However, to be conservative in estimating the potential future extent of benzene emanating from this isolated source, a continuous benzene source has been assumed (Appendix D).

Based on the limited groundwater sampling event in November 2016, the highest concentration of MTBE within Plume 2 was detected at S-144SRTF. This monitoring well was installed in September 2016; therefore, this well has only been sampled once. To evaluate the stability of the MTBE in Plume 2, concentration trend graphs were created for downgradient wells S-112SRTF, S-110DSRTF, and S-115DSTRF. With the exception of S-112SRTF, which exhibits increasing MTBE concentrations, these wells indicate the MTBE plume is stable.

Groundwater isoconcentration maps for benzene and MTBE in the perched, unconfined and lower aquifers were created using analytical results from the limited groundwater sampling in November 2016 sampling events (Figures I-2 through I-6). Interpreting the isoconcentration maps for November 2016, the following summaries can be made for Plume 2:

- There appear to be separate source areas associated with Plume 2; a larger plume centered around S-112SRTF for benzene and centered around S-144SRTF for MTBE, and a smaller more isolated plume centered around S-115SRTF for benzene and S-115DSRTF for MTBE.

- The larger plume to the north is possibly associated with the newly identified LNAPL within S-122SRTF and S-114SRTF.
- The larger plume is located in an area where unconfined groundwater flow converges from the north and east.

Based on Stantec's quantitative assessment of benzene migration in this area a southwesterly groundwater flow direction appears to persist (Appendix D, Figure 2 of the RIR Addendum), and dissolved concentrations of benzene in groundwater above the MSC may extend beyond the western boundary of AOI 9.

Plume 3

To evaluate plume stability in Plume 3, MTBE concentrations versus time were plotted for wells S-118DSRTF and S-120DSRTF (Figures I-12 through I-13). Concentrations versus time plots for these wells indicate the MTBE plume is stable in the unconfined aquifer (S-120D) and potentially increasing in the lower aquifer (S-118D).

Groundwater isoconcentration maps illustrating MTBE concentrations in the perched, unconfined and lower aquifers were created using analytical results from the limited groundwater sampling in November 2016 sampling events (Figures I-2 through I-6). Interpreting the isoconcentration maps, the following summaries can be made for Plume 3:

- MTBE is present in both aquifers in this area. Evergreen will continue to evaluate head potentials, water levels, and COC trends in support of the anticipated numerical modeling.
- The MTBE plume in the unconfined aquifer appears to be stable; however, the extent of the MTBE plume in the lower aquifer is not well defined and is potentially from off-site sources. The source of the MTBE plumes in both aquifers will be evaluated during the Complex-wide Cleanup Plan, and incorporated in the anticipated numerical modeling.

Potential Receptors

Potential human health and ecological receptors to COCs in groundwater in AOI 9 include:

- Workers in occupied buildings that are not under positive pressure (from vapor intrusion into indoor air);
- Offsite users of groundwater;

- Offsite workers in occupied buildings that are not under positive pressure (from vapor intrusion into indoor air); and
- Ecological receptors in Mingo Creek and the Schuylkill River.

Qualitative Fate and Transport Assessment Summary

- Perched groundwater flows radially outward from a potentiometric high point in the east and eventually converges at the center of AOI 9 towards the hole in the Holocene clay. Perched groundwater recharges the unconfined aquifer at the western extent of the perched aquifer, and preferentially where the Holocene clay is absent in the center of AOI 9. The potentiometric surface of the unconfined aquifer is believed to be artificially lowered by the pumping in Mingo Creek basin. Due to the pumping in Mingo Creek basin, recharge of perched groundwater at the center of the AOI, possible groundwater infiltration into Mingo Avenue Sewer, and the presence of heterogeneous aquifer material, groundwater flow conditions in the unconfined aquifer are transient, and subject to differential drawdown throughout AOI 9.

- Groundwater in the lower aquifer generally flows to the south.

- All AOI 9 COCs, except for cumene, were detected in groundwater in the November 2016 limited groundwater sampling at concentrations above their respective used-aquifer, non-residential groundwater MSCs.

- Three plume areas have been identified with regard to COC exceedances of PADEP groundwater non-residential MSCs.

    - Plume 1 consists of an LNAPL area near several historical recovery wells in the Blending Area located near the southern property boundary. Based on the limited extent of LNAPL, the limit of the dissolved plume, the limited LNAPL mobility, and presence of an underlying clay aquitard (Holocene clay), the plume appears to be vertically constrained to the perched aquifer and horizontally limited to the Blending Area.

    - Plume 2 is a historically undefined source area located in the west-central part of AOI 9. There appear to be two separate source areas associated with Plume 2: a larger plume centered around well S-112SRTF for benzene and well S-144SRTF for MTBE, and a smaller more isolated plume centered around well S-115SRTF for benzene and well S-115DSRTF for MTBE. Based on the groundwater results at S-112SRTF during the November 2016 sampling and the newly identified LNAPL in S-122SRTF and S-114SRTF, the source area for Plume 2 may be increasing. Based on the groundwater flow direction maps and isoconcentration maps for benzene and MTBE, portions of Plume 2 may have migrated to the west beyond the AOI 9 property boundary.

- Plume 3 is comprised of MTBE plumes in both the unconfined and lower aquifers in the southwest portion of AOI 9. The MTBE plume in the unconfined aquifer appears to be stable. The extent of the MTBE plume in the lower aquifer is not well defined and is potentially from off-site sources. The potential source(s) of MTBE will be evaluated during the Complex-wide Cleanup Plan activities and comprehensively modeled to estimate the future extent of groundwater concentrations.

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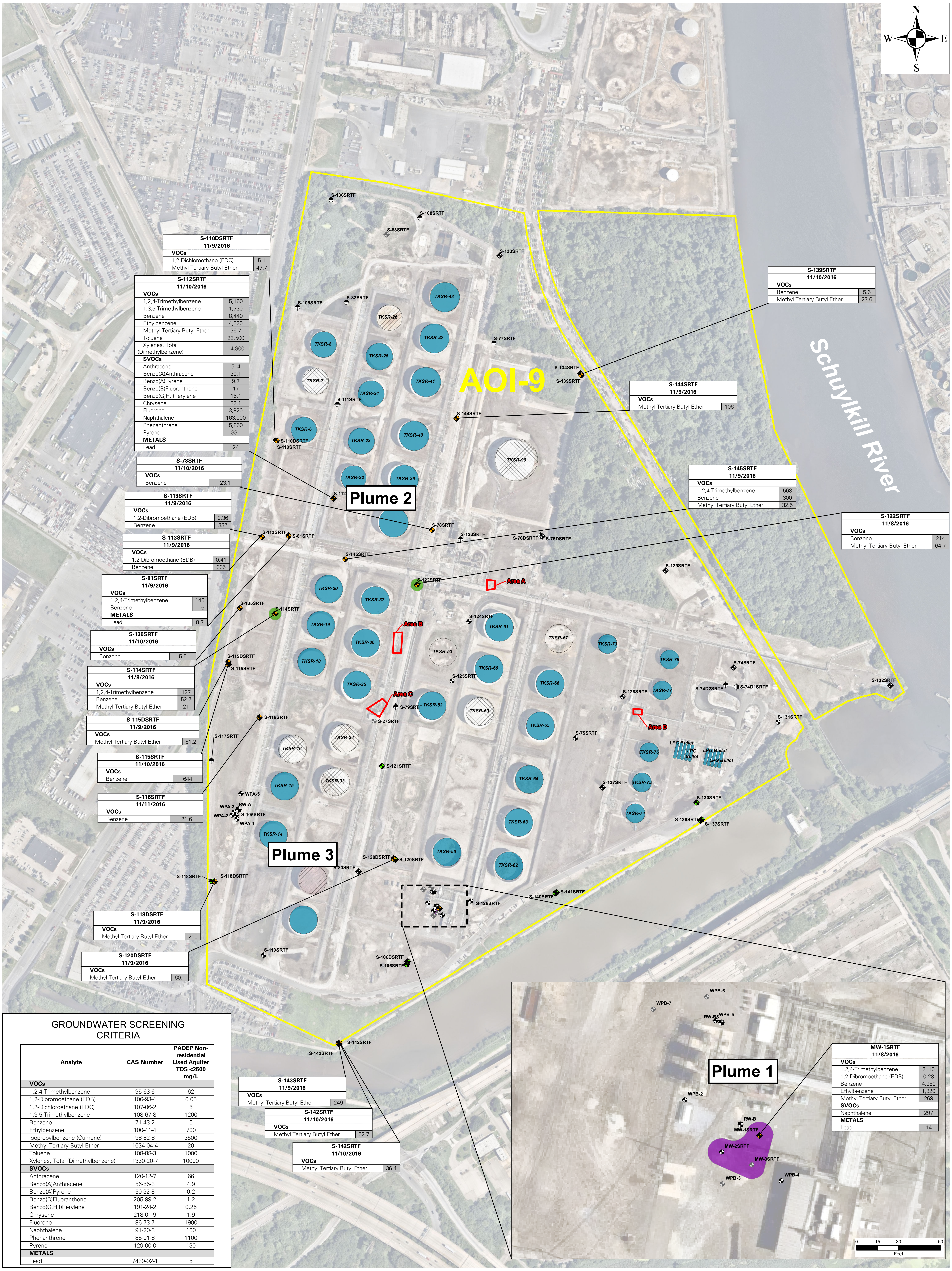

S-110DSRTF	
11/9/2016	
VOCs	
1,2-Dichloroethane (EDC)	5.1
Methyl Tertiary Butyl Ether	47.7

S-112SRTF	
11/10/2016	
VOCs	
1,2,4-Trimethylbenzene	5,160
1,3,5-Trimethylbenzene	1,730
Benzene	8,440
Ethylbenzene	4,320
Methyl Tertiary Butyl Ether	36.7
Toluene	22,500
Xylenes, Total (Dimethylbenzene)	14,900
SVOCs	
Anthracene	514
Benzo(A)Anthracene	30.1
Benzo(A)Pyrene	9.7
Benzo(B)Fluoranthene	17
Benzo(G,H,I)Perylene	15.1
Chrysene	32.1
Fluorene	3,920
Naphthalene	163,000
Phenanthrene	5,860
Pyrene	331
METALS	
Lead	24

S-78SRTF	
11/10/2016	
VOCs	
Benzene	23.1

S-113SRTF	
11/9/2016	
VOCs	
1,2-Dibromoethane (EDB)	0.36
Benzene	332

S-113SRTF	
11/9/2016	
VOCs	
1,2-Dibromoethane (EDB)	0.41
Benzene	335

S-81SRTF	
11/9/2016	
VOCs	
1,2,4-Trimethylbenzene	145
Benzene	116
METALS	
Lead	8.7

S-135SRTF	
11/10/2016	
VOCs	
Benzene	5.5

S-114SRTF	
11/8/2016	
VOCs	
1,2,4-Trimethylbenzene	127
Benzene	52.7
Methyl Tertiary Butyl Ether	21

S-115DSRTF	
11/9/2016	
VOCs	
Methyl Tertiary Butyl Ether	61.2

S-115SRTF	
11/10/2016	
VOCs	
Benzene	644

S-116SRTF	
11/11/2016	
VOCs	
Benzene	21.6

S-118DSRTF	
11/9/2016	
VOCs	
Methyl Tertiary Butyl Ether	210

S-120DSRTF	
11/9/2016	
VOCs	
Methyl Tertiary Butyl Ether	60.1

S-139SRTF	
11/10/2016	
VOCs	
Benzene	5.6
Methyl Tertiary Butyl Ether	27.6

S-144SRTF	
11/9/2016	
VOCs	
Methyl Tertiary Butyl Ether	106

S-145SRTF	
11/9/2016	
VOCs	
1,2,4-Trimethylbenzene	568
Benzene	300
Methyl Tertiary Butyl Ether	32.5

S-122SRTF	
11/8/2016	
VOCs	
Benzene	214
Methyl Tertiary Butyl Ether	64.7

S-143SRTF	
11/9/2016	
VOCs	
Methyl Tertiary Butyl Ether	249

S-142SRTF	
11/10/2016	
VOCs	
Methyl Tertiary Butyl Ether	62.7

S-142SRTF	
11/10/2016	
VOCs	
Methyl Tertiary Butyl Ether	36.4

MW-1SRTF	
11/8/2016	
VOCs	
1,2,4-Trimethylbenzene	2110
1,2-Dibromoethane (EDB)	0.28
Benzene	4,980
Ethylbenzene	1,320
Methyl Tertiary Butyl Ether	269
SVOCs	
Naphthalene	297
METALS	
Lead	14

GROUNDWATER SCREENING CRITERIA

Analyte	CAS Number	PADEP Non-residential Used Aquifer TDS <2500 mg/L
VOCs		
1,2,4-Trimethylbenzene	95-63-6	62
1,2-Dibromoethane (EDB)	106-93-4	0.05
1,2-Dichloroethane (EDC)	107-06-2	5
1,3,5-Trimethylbenzene	108-67-8	1200
Benzene	71-43-2	5
Ethylbenzene	100-41-4	700
Isopropylbenzene (Cumene)	98-82-8	3500
Methyl Tertiary Butyl Ether	1634-04-4	20
Toluene	108-88-3	1000
Xylenes, Total (Dimethylbenzene)	1330-20-7	10000
SVOCs		
Anthracene	120-12-7	66
Benzo(A)Anthracene	56-55-3	4.9
Benzo(A)Pyrene	50-32-8	0.2
Benzo(B)Fluoranthene	205-99-2	1.2
Benzo(G,H,I)Perylene	191-24-2	0.26
Chrysene	218-01-9	1.9
Fluorene	86-73-7	1900
Naphthalene	91-20-3	100
Phenanthrene	85-01-8	1100
Pyrene	129-00-0	130
METALS		
Lead	7439-92-1	5

Legend

- Groundwater Sample with an Exceedance During November 2016
- Groundwater Sample with No Exceedance During November 2016
- Well Abandoned/Destroyed/Unable to Locate
- Perched Aquifer Monitoring Well
- Unconfined Aquifer Monitoring Well
- Lower Aquifer Monitoring Well
- Perched Aquifer Recovery Well

- 🟥 PADEP Inspection Areas (June 24, 2009)

LNAPL Type

- 🟪 Light Distillate
- 🟩 Mixes of Light/Middle Distillate
- ▨ Tank Closed in Place
- ▩ Tank with Release Assessment
- ● Tank in Service
- ○ Removed Tank
- 🟨 AOI-9 SRTF Boundary

Notes:

1. Aerial imagery provided by Nearmap.com, dated 7/29/2015.
2. Groundwater exceedances or criteria displayed in micrograms per liter (µg/L).
3. A 10% data usability assessment has not been completed for the 2016 data presented in this RIR Addendum.
4. µg/L = micrograms per liter
5. VOCs = Volatile Organic Compounds
6. SVOCs = Semi-Volatile Organic Compounds
7. CAS = Chemical Abstract Service
8. PADEP = Pennsylvania Department of Environmental Protection
9. TDS = Total Disolved Solids

Figure I-1: Summary of Groundwater Sample Exceedances
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Philadelphia, Pennsylvania

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Management Operations
2 Righter Parkway, Suite 200
Wilmington, DE 19803

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SCALE: 1" = 200'
DATE: January 25, 2017
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CKD. BY: KM
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Path: \\langan.com\data\DYL\data6\2574601\ArcGIS\MapDocuments\AOI 9 RIR Addendum 2016\Fate and Transport\Figure I-1 - Summary of Groundwater Sample Exceedance.mxd Date: 1/30/2017 User: MMking Time: 1:40:37 PM

Legend

S-120SRTF ND ⊕	Benzene Groundwater Results (November 2016) (µg/L)
—5—	Benzene Contours (µg/L)
→	Groundwater Flow Direction
—1—	October Perched Aquifer Contours (ft amsl)
- - - -	Inferred October Perched Aquifer Contours (ft amsl)
— — —	Interpreted Extent of Perched Aquifer

LNAPL Type

■	Light Distillate
■	Mixes of Light/Middle Distillate
□	AOI Boundary
▨	Holocene Clay Layer Extent

Notes:

1. Aerial imagery provided by Nearmap.com, dated 7/29/2015.
2. Groundwater elevations were obtained from the October 2016 gauging event performed by Langan.
3. S-105SRTF and surrounding wells, as well as S-119SRTF were not used in contouring the perched aquifer. These wells are interpreted as being representative of isolated perched zones not connected to the perched aquifer.
4. ft. amsl = feet above mean sea level
5. µg/L = micrograms per liter

Figure I-2: Perched Aquifer Benzene
Concentrations November 2016
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Path: \\langan.com\data\DYL\data6\2574601\ArcGIS\MapDocuments\AOI 9 RIR Addendum 2016\Fate and Transport\Figure I-2 - Perched Aquifer Benzene Concentrations November 2016.mxd Date: 2/7/2017 User: MMking Time: 10:06:42 AM

Legend

S-120SRTF 0.95 ⊕ MTBE Groundwater Results (November 2016) (µg/L)

—20— MTBE Contours (µg/L)

→ Groundwater Flow Direction

—1— October Perched Aquifer Contours (ft amsl)

- - - - Inferred October Perched Aquifer Contours (ft amsl)

— — — Interpreted Extent of Perched Aquifer

LNAPL Type

🟪	Light Distillate
🟩	Mixes of Light/Middle Distillate
☐	AOI Boundary
🟨	Holocene Clay Layer Extent

Notes:
1. Aerial imagery provided by Nearmap.com, dated 7/29/2015.
2. Groundwater elevations were obtained from the October 2016 gauging event performed by Langan.
3. S-105SRTF and surrounding wells, as well as S-119SRTF were not used in contouring the perched aquifer. These wells are interpreted as being representative of isolated perched zones not connected to the perched aquifer.
4. ft. amsl = feet above mean sea level
5. µg/L = micrograms per liter
6. MTBE = Methyl Tertiary Butyl Ether

Figure I-3: Perched Aquifer MTBE Concentrations
November 2016
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Path: \\langan.com\data\DYL\data6\2574601\ArcGIS\MapDocuments\AOI 9 RIR Addendum 2016\Fate and Transport\Figure I-3 - Perched Aquifer MTBE Concentrations November 2016.mxd Date: 2/7/2017 User: MMking Time: 10:06:35 AM

Legend

S-116SRTF 21.6 ⊕ Benzene Groundwater Results (November 2016) (µg/L)

—5— Benzene Contours (µg/L)

→ Groundwater Flow Direction

—-5— October Unconfined Aquifer Wells (ft amsl)

-------- Inferred October Unconfined Aquifer Wells (ft amsl)

LNAPL Type

🟪 Light Distillate

🟩 Mixes of Light/Middle Distillate

☐ AOI Boundary

▨ Holocene Clay Layer Extent

Notes:
1. Aerial imagery provided by Nearmap.com, dated 7/29/2015.
2. Groundwater elevations were obtained from the October 2016 gauging event performed by Langan.
3. ft. amsl = feet above mean sea level
4. µg/L = micrograms per liter

Figure I-4: Unconfined Aquifer Benzene
Concentrations November 2016
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Path: \\langan.com\data\DYL\data6\2574601\ArcGIS\MapDocuments\AOI 9 RIR Addendum 2016\Fate and Transport\Figure I-4 - Unconfined Aquifer Benzene Concentrations November 2016.mxd Date: 2/7/2017 User: MMking Time: 10:06:18 AM

Legend

S-142SRTF 36.4 ⊕	MTBE Groundwater Results (November 2016) (µg/L)
—20—	MTBE Contours (µg/L)
·······	MTBE Inferred Contours (µg/L)
→	Groundwater Flow Direction
—-5—	October Unconfined Aquifer Wells (ft
- - - -	Inferred October Unconfined Aquifer Wells (ft

LNAPL Type

🟪	Light Distillate
🟩	Mixes of Light/Middle Distillate
☐	AOI Boundary
🟨	Holocene Clay Layer Extent

Notes:
1. Aerial imagery provided by Nearmap.com, dated 7/29/2015.
2. Groundwater elevations were obtained from the October 2016 gauging event performed by Langan.
3. ft. amsl = feet above mean sea level
4. µg/L = micrograms per liter
5. MTBE = Methyl Tertiary Butyl Ether

Figure I-5: Unconfined Aquifer MTBE
Concentrations November 2016
AOI-9 Remedial Investigation Report
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SCALE: 1" = 180'
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JOB#: 2574602

Path: \\langan.com\data\DYL\data6\2574601\ArcGIS\MapDocuments\AOI 9 RIR Addendum 2016\Fate and Transport\Figure I-5 - Unconfined Aquifer MTBE Concentrations November 2016.mxd Date: 2/7/2017 User: MMking Time: 10:07:11 AM

Legend

S-138SRTF 2.3 ⊕	MTBE Groundwater Results (November 2016) (µg/L)
—20—	MTBE Contours (µg/L)
→	Groundwater Flow Direction
—-9—	October Lower Aquifer Wells (ft
- - - - -	Inferred October Lower Aquifer Wells (ft

LNAPL Type

🟪	Light Distillate
🟩	Mixes of Light/Middle Distillate
☐	AOI Boundary

Notes:

1. Aerial imagery provided by Nearmap.com, dated 7/29/2015.
2. Groundwater elevations were obtained from the October 2016 gauging event performed by Langan.
3. ft. amsl = feet above mean sea level
4. µg/L = micrograms per liter
5. MTBE = Methyl Tertiary Butyl Ether

Figure I-6: Lower Aquifer MTBE Concentrations
November 2016
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CKD. BY: KM
JOB#: 2574602

Path: \\langan.com\data\DYL\data6\2574601\ArcGIS\MapDocuments\AOI 9 RIR Addendum 2016\Fate and Transport\Figure I-6 - Lower Aquifer MTBE Concentrations November 2016.mxd Date: 1/31/2017 User: MMking Time: 2:02:17 PM

Figure I-7
Plume 2
Benzene and MTBE Concentration Trends at Well S-112SRTF
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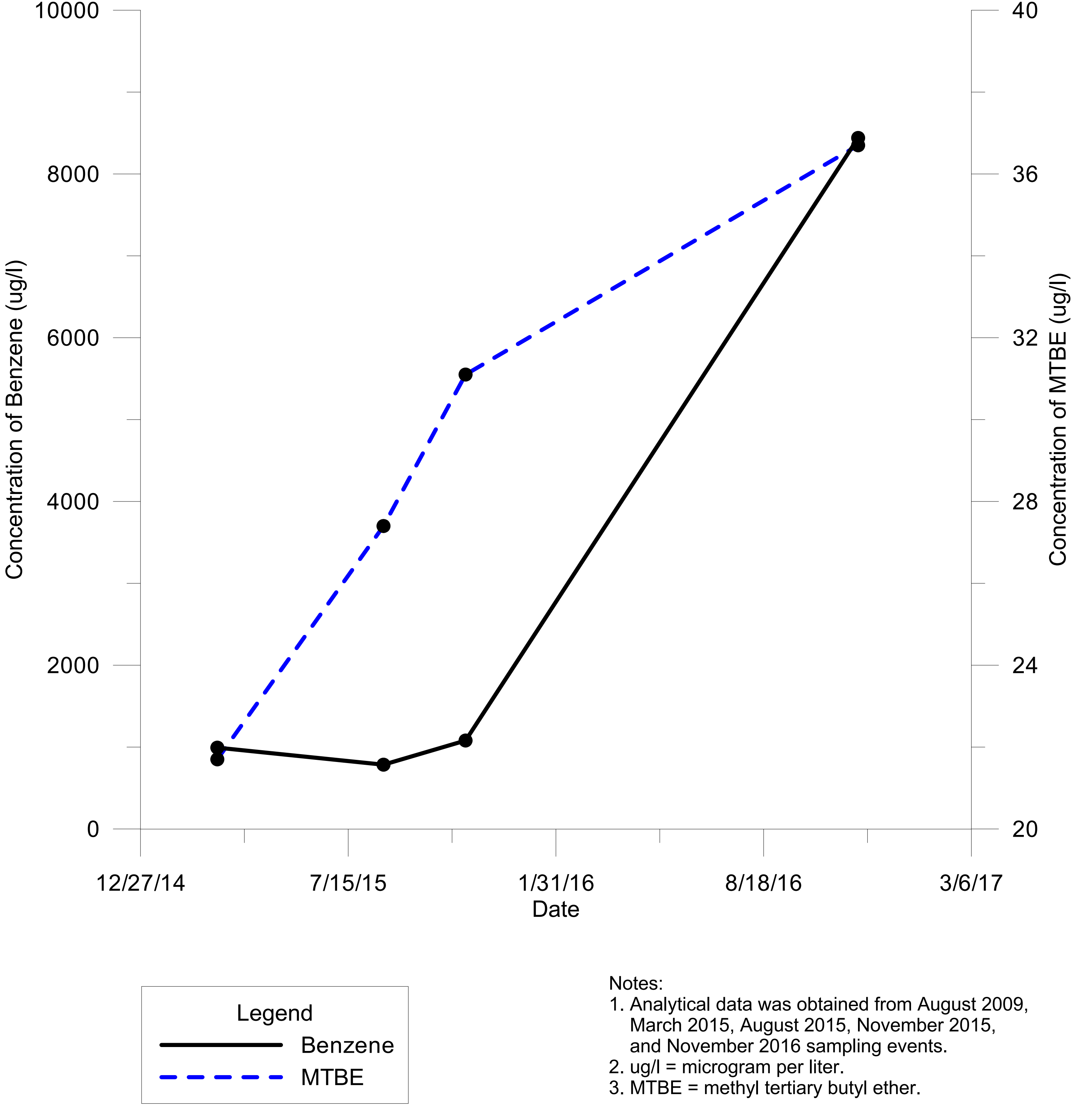
Philadelphia, PA



Notes:
1. Analytical data was obtained from August 2009, March 2015, August 2015, November 2015, and November 2016 sampling events.
2. ug/l = microgram per liter.
3. MTBE = methyl tertiary butyl ether.

Figure I-8
Plume 2
Benzene and MTBE Concentration Trends at Well S-113SRTF
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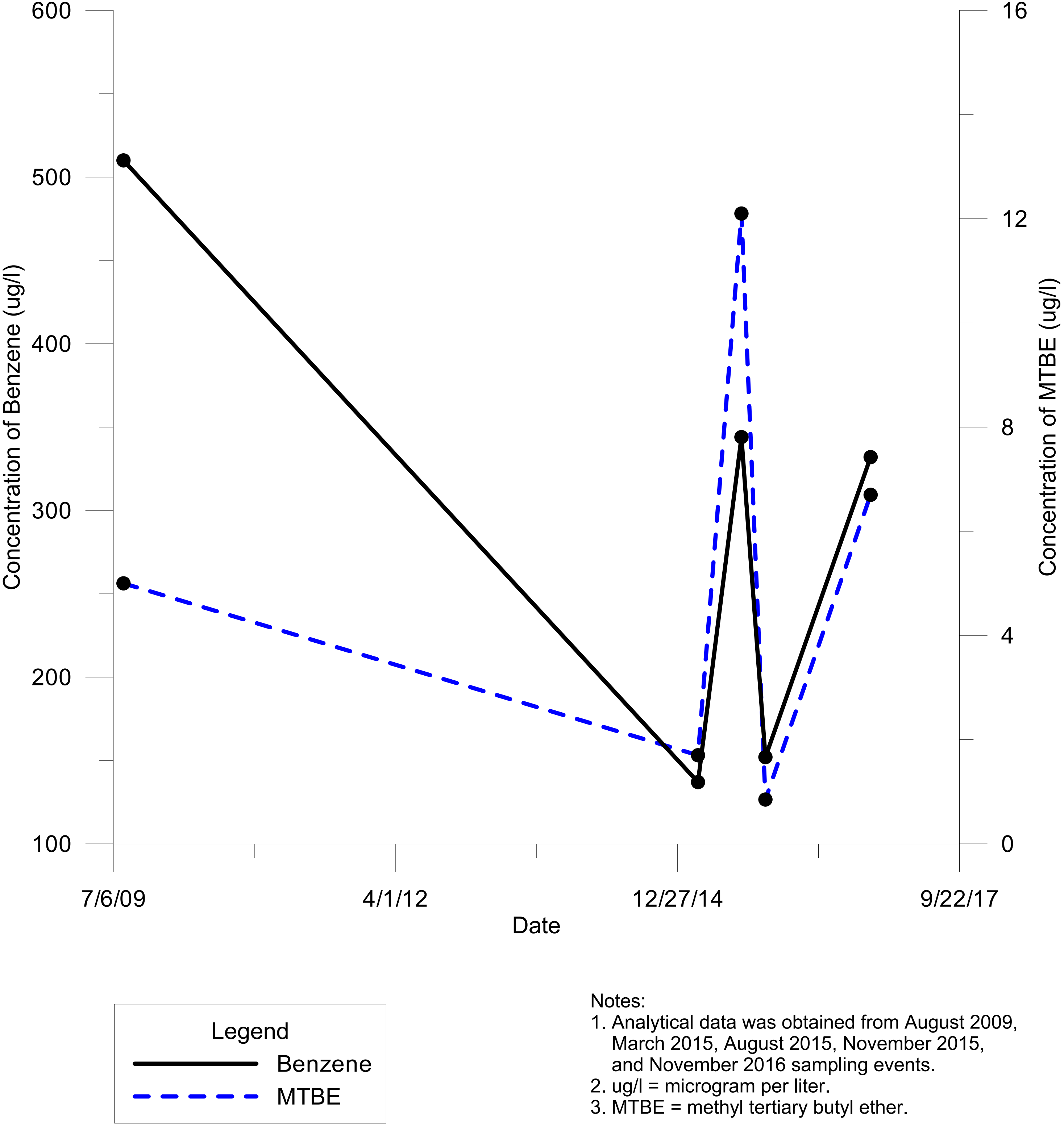
Philadelphia, PA



Notes:
1. Analytical data was obtained from August 2009, March 2015, August 2015, November 2015, and November 2016 sampling events.
2. ug/l = microgram per liter.
3. MTBE = methyl tertiary butyl ether.

Figure I-9
Plume 2
Benzene Concentration Trend at Well S-115SRTF
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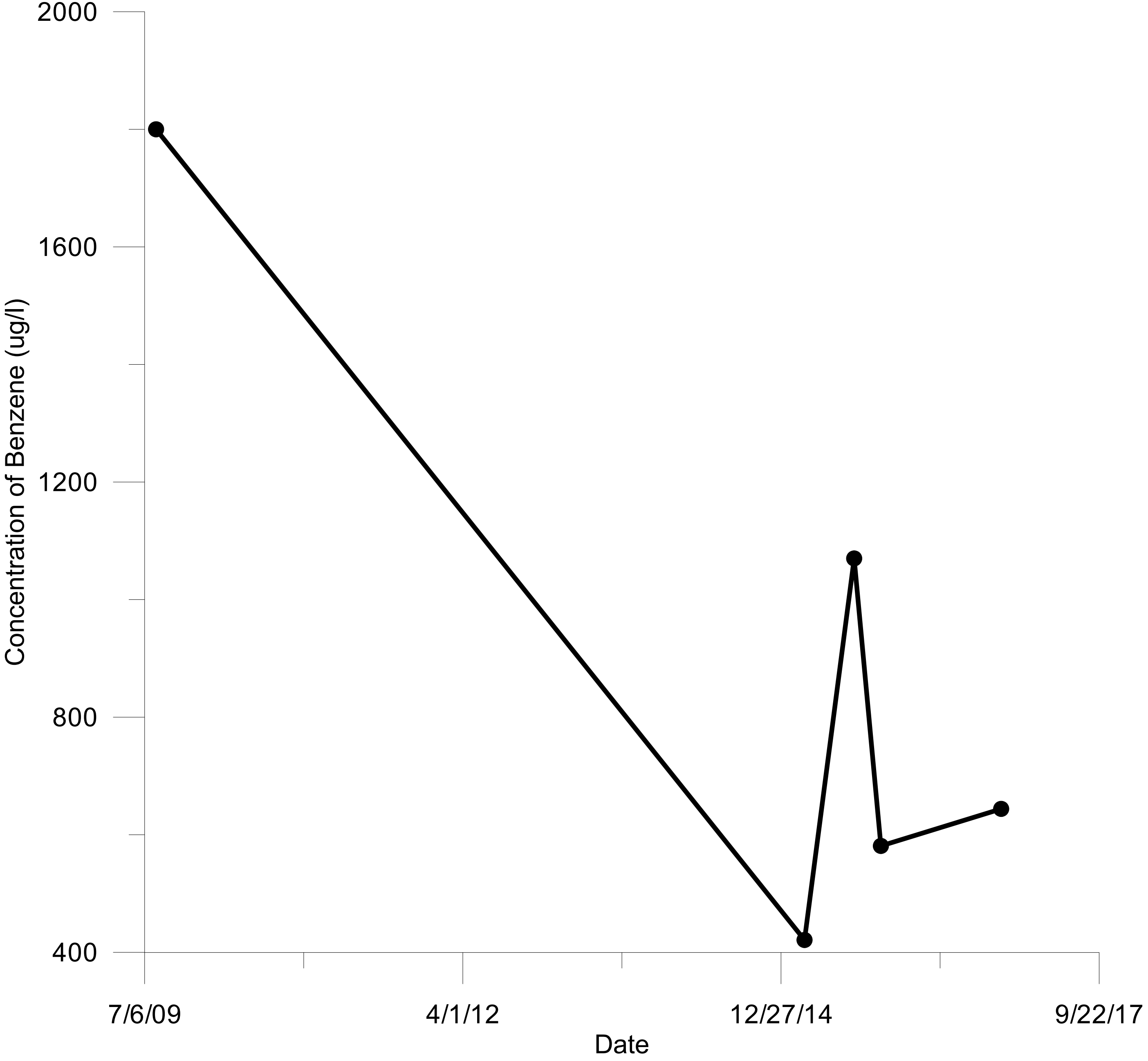

Notes:
1. Analytical data was obtained from August 2009, March 2015, August 2015, November 2015, and November 2016 sampling events.
2. ug/l = microgram per liter.

Figure I-10
Plume 2
MTBE Concentration Trend at Well S-110DSRTF
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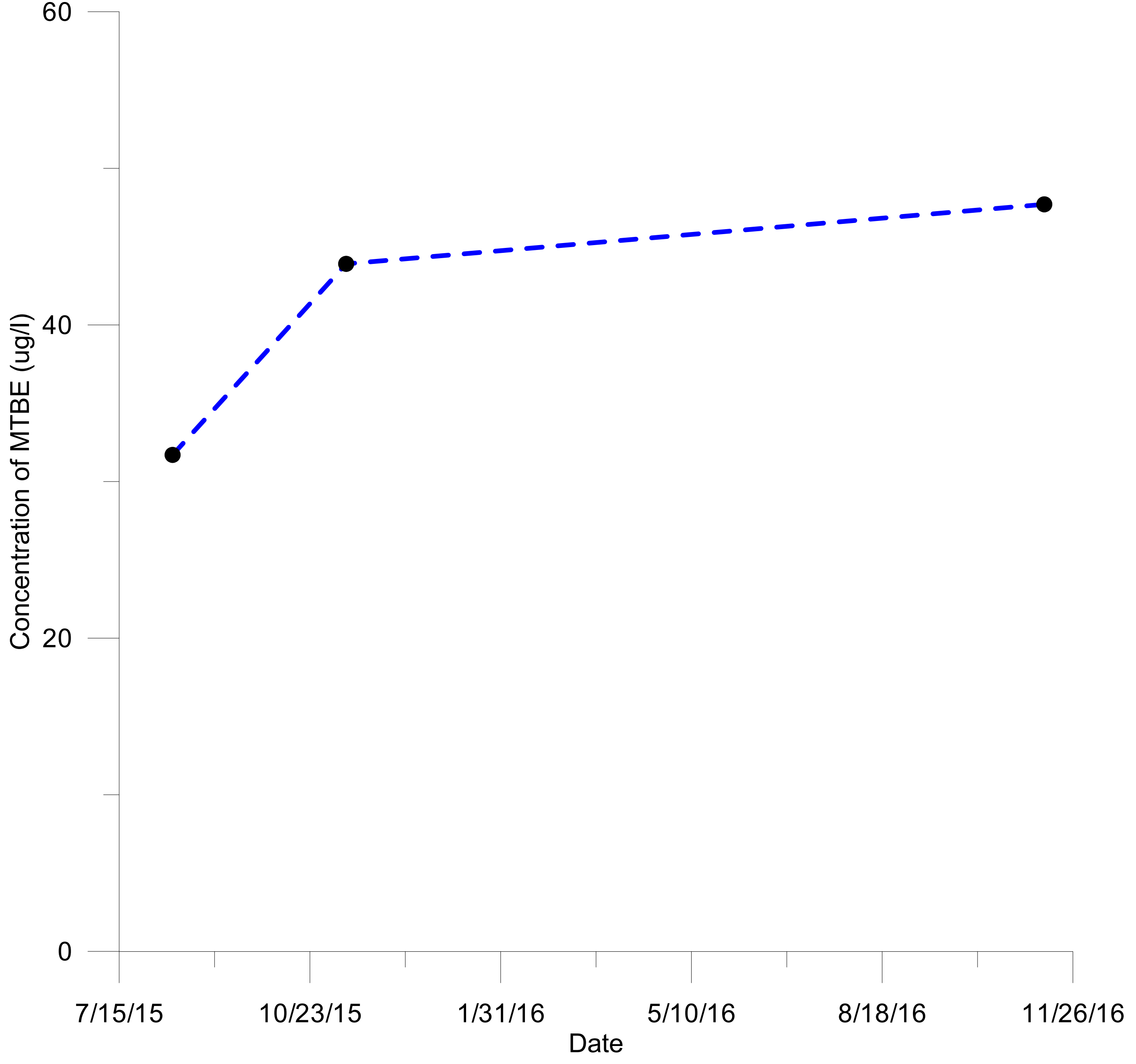

Notes:
1. Analytical data was obtained from August 2015, November 2015,and November 2016 sampling events.
2. ug/l = microgram per liter.
3. MTBE = methyl tertiary butyl ether.

Figure I-11
Plume 2
MTBE Concentration Trend at Well S-115DSRTF
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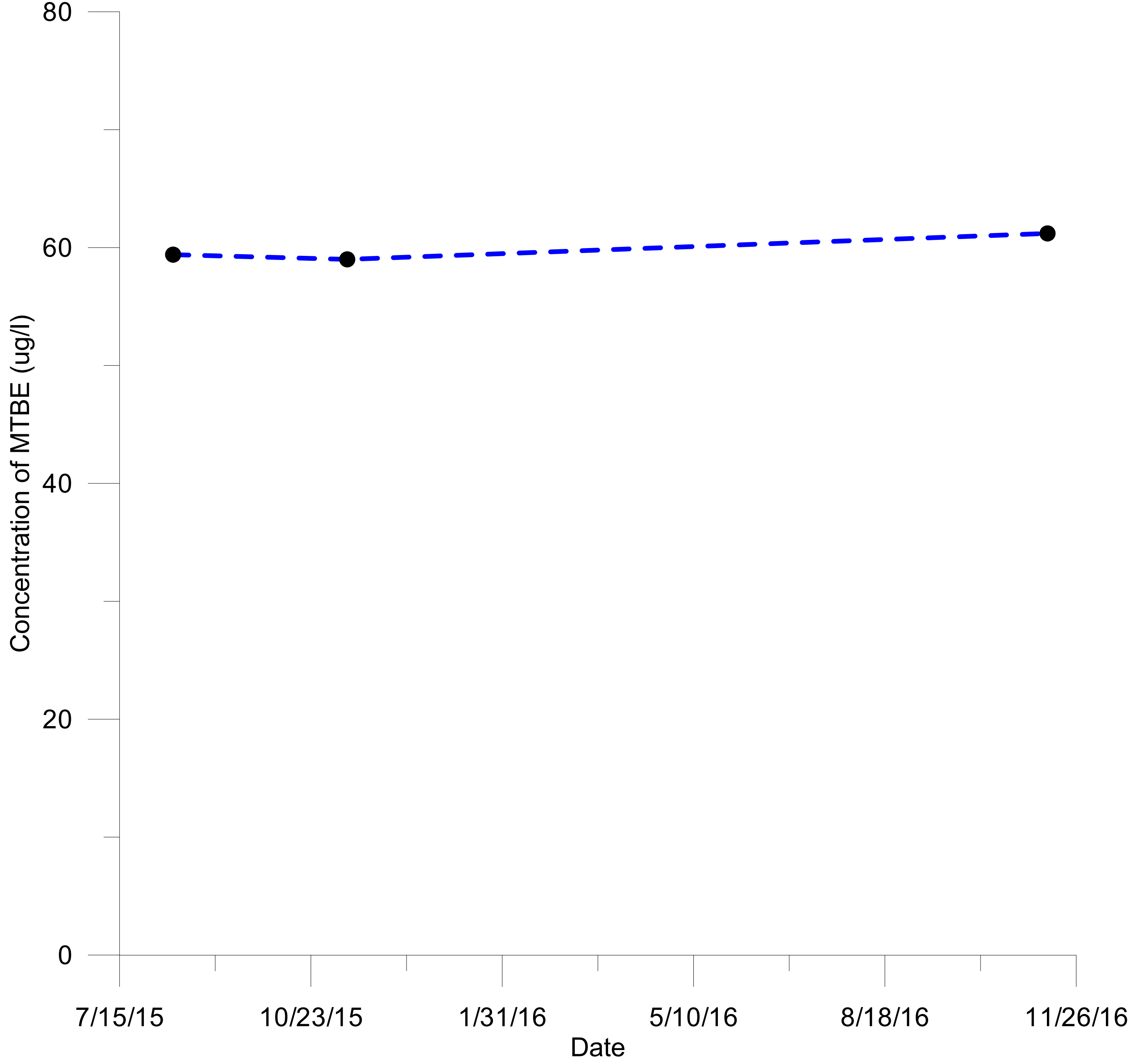

Notes:
1. Analytical data was obtained from August 2015, November 2015,and November 2016 sampling events.
2. ug/l = microgram per liter.
3. MTBE = methyl tertiary butyl ether.

Figure I-12
Plume 3
MTBE Concentration Trend at Well S-118DSRTF
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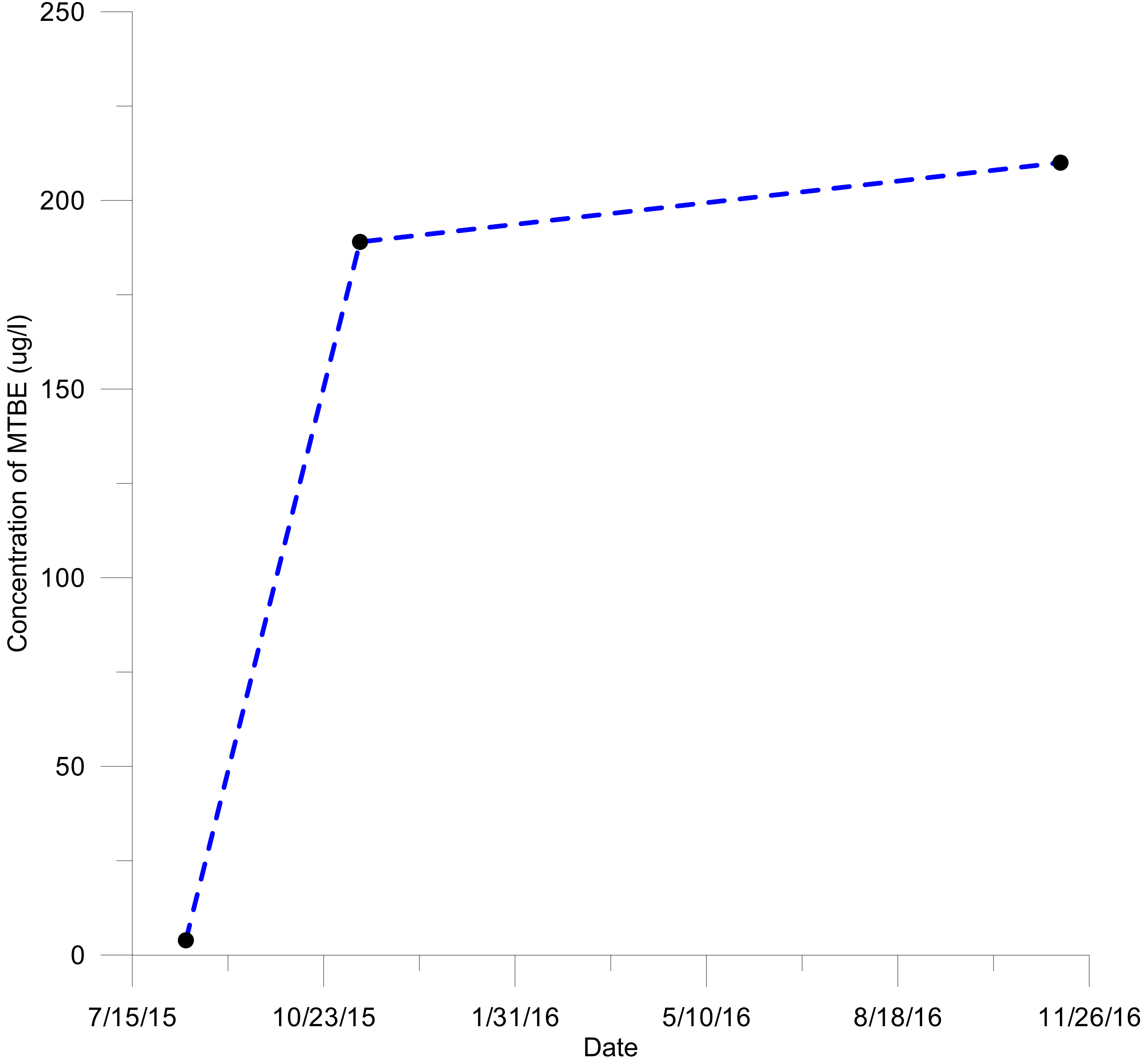

Legend
MTBE

Notes:
1. Analytical data was obtained from August 2015, November 2015,and November 2016 sampling events.
2. ug/l = microgram per liter.
3. MTBE = methyl tertiary butyl ether.

Figure I-13
Plume 3
MTBE Concentration Trend at Well S-120DSRTF
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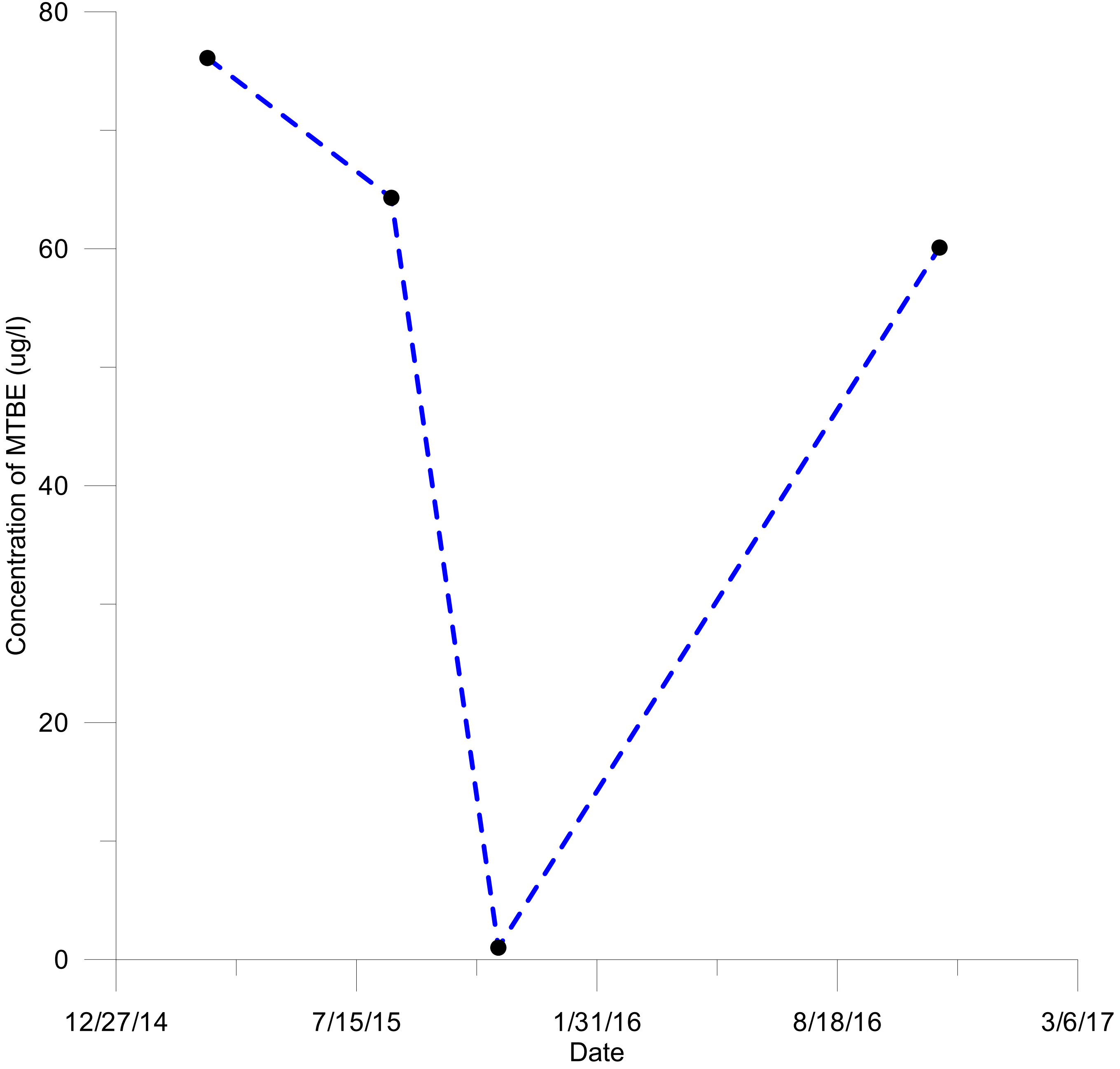

Legend
- - - - MTBE

Notes:
1. Analytical data was obtained from March 2015, August 2015, November 2015, and November 2016 sampling events.
2. ug/l = microgram per liter.
3. MTBE = methyl tertiary butyl ether.