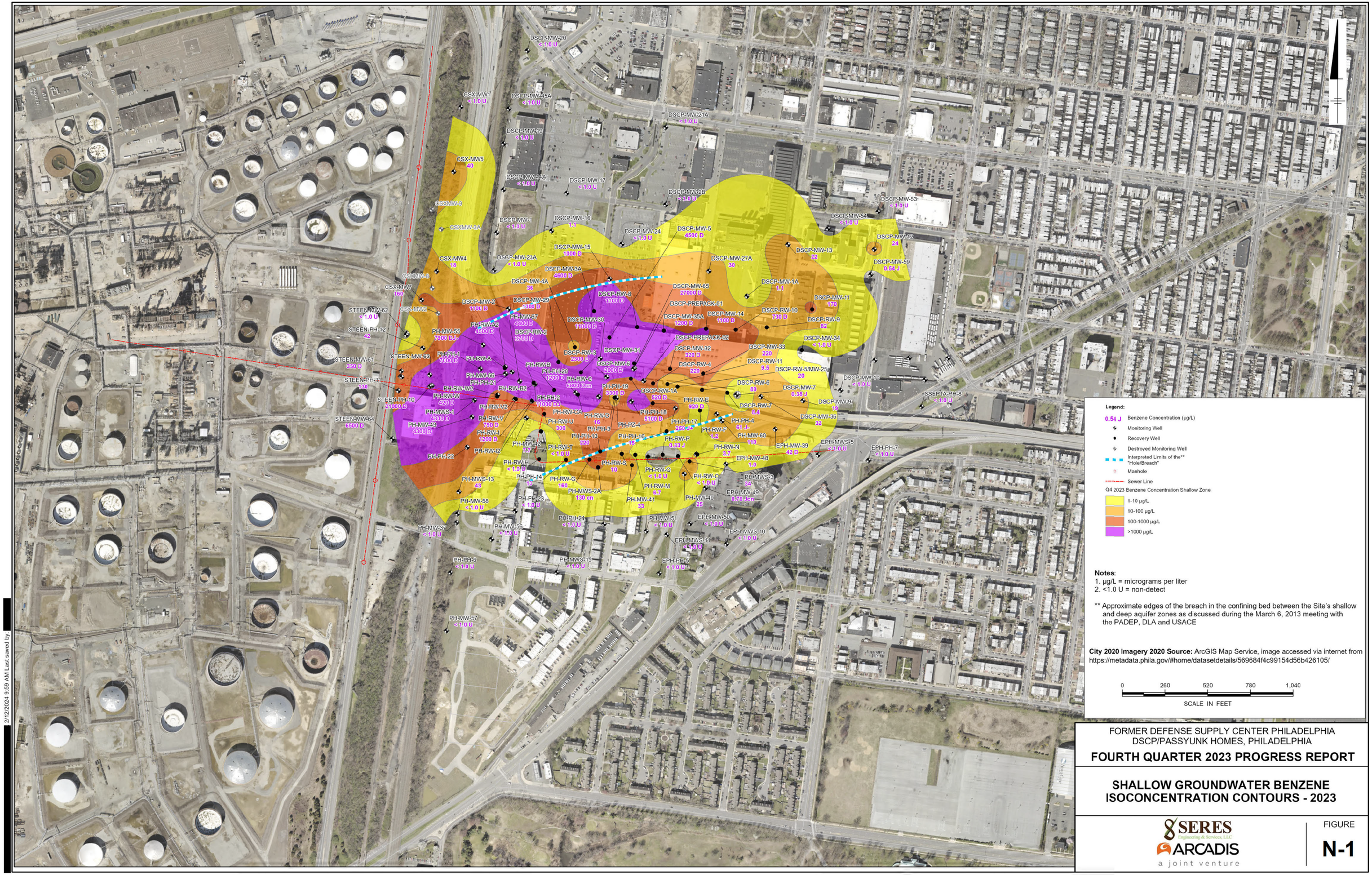
Appendix N

Groundwater
Isoconcentration
Contour Maps



FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

SHALLOW GROUNDWATER BENZENE ISOCONCENTRATION CONTOURS - 2023

SERES Engineering & Services, LLC
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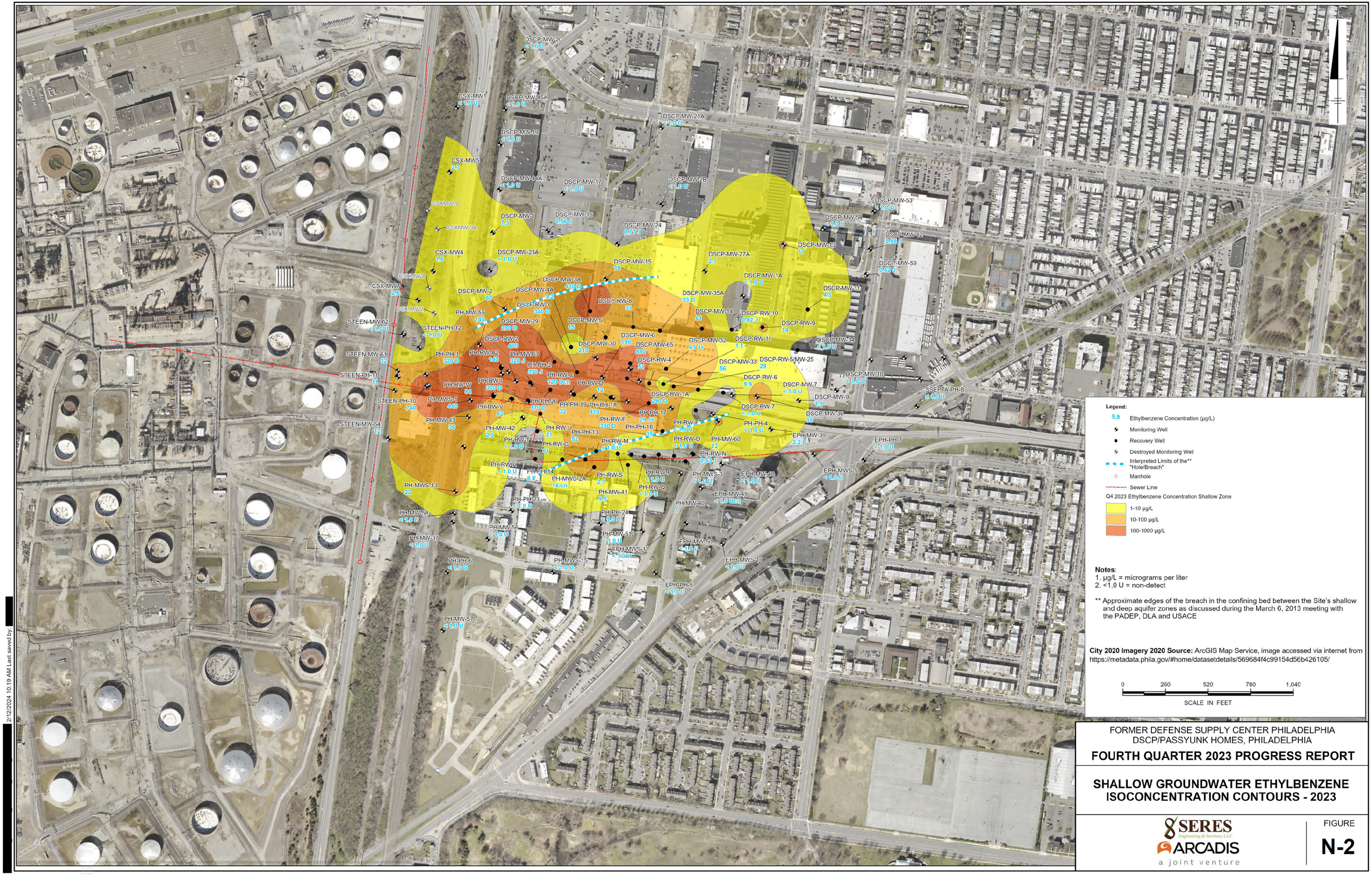
FIGURE
N-1

2/12/2024 9:59 AM Last saved by:



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FOURTH QUARTER 2023 PROGRESS REPORT

SHALLOW GROUNDWATER ETHYLBENZENE ISOCONCENTRATION CONTOURS - 2023

SERES Engineering & Services, LLC
ARCADIS
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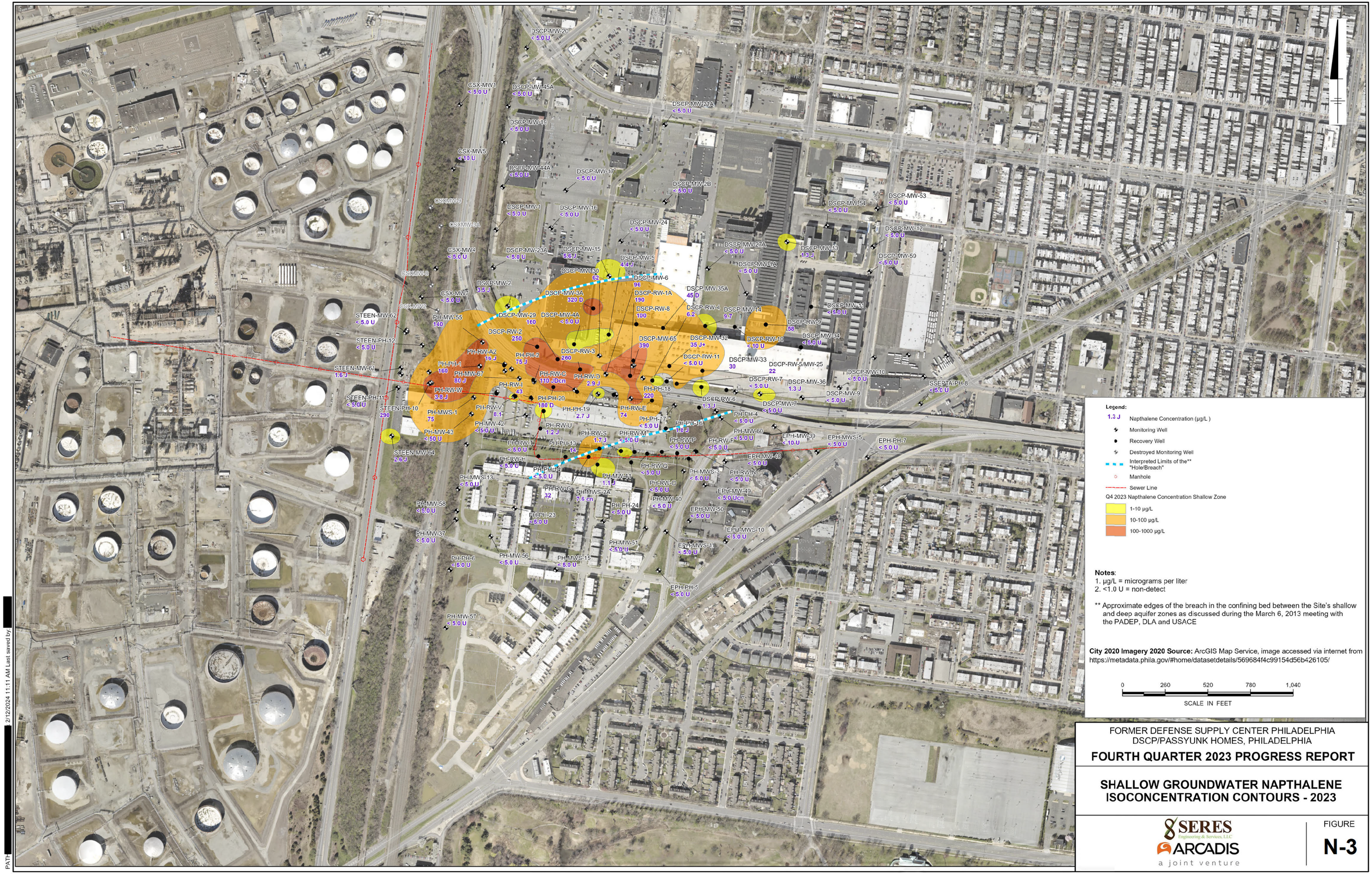
FIGURE
N-2



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FOURTH QUARTER 2023 PROGRESS REPORT

SHALLOW GROUNDWATER NAPTHALENE ISOCONCENTRATION CONTOURS - 2023

SERES Engineering & Services, LLC
ARCADIS a joint venture

FIGURE
N-3

2/12/2024 11:11 AM Last saved by:

PATH:

DSCP-MW-20 < 5.0 U
CSX-MW1 < 5.0 U
DSCP-MW-45A < 5.0 U
DSCP-MW-21A < 5.0 U
DSCP-MW-9 < 5.0 U
CSX-MW5 < 10 U
DSCP-MW-44A < 5.0 U
DSCP-MW-17 < 5.0 U
DSCP-MW-2B < 5.0 U
CSX-MW3
CSX-MW4A
DSCP-MW-1 < 5.0 U
DSCP-MW-16 < 5.0 U
DSCP-MW-24 < 5.0 U
DSCP-MW-54 < 5.0 U
DSCP-MW-53 < 5.0 U
DSCP-MW-12 < 5.0 U
DSCP-MW-13 < 5.0 U
DSCP-MW-59 < 5.0 U
CSX-MW4 < 5.0 U
DSCP-MW-23A < 5.0 U
DSCP-MW-15 12
DSCP-MW-27A 8.2
CSX-MW6
DSCP-MW-2 4.7 J
DSCP-MW-3A 220 D
DSCP-MW-1A < 5.0 U
CSX-MW7 < 5.0 U
DSCP-MW-5 3.7 J
DSCP-MW-35A 51 D
DSCP-RW-10 < 10 U
DSCP-MW-11 4.4 J
CSX-MW2
DSCP-MW-4A < 5.0 U
DSCP-RW-8 110
DSCP-MW-14 13
STEEN-MW-62 < 5.0 U
PH-MW-55 25 J
DSCP-RW-3 320 D
DSCP-RW-9 64
STEEN-PH-12 < 5.0 U
DSCP-MW-29 75
DSCP-MW-30 33
DSCP-MW-65 790
DSCP-MW-34 < 5.0 U
DSCP-RW-2 71
DSCP-MW-6 62
DSCP-RW-4
DSCP-RW-11 2.0 J
STEEN-MW-61 9.5
PH-RW-A2 10 J
PH-PH-2 15 J
DSCP-MW-32 100 J+
PH-PH-1 300 D
PH-PH-20 690 D
DSCP-MW-33 29
DSCP-RW-7 < 5.0 U
PH-MW-67 260 J
PH-RW-C 82 JDcn
DSCP-RW-6 1.4 J
DSCP-MW-10 < 5.0 U
STEEN-PH-11 3.7 J
PH-RW-W 6
PH-RW-D 7.1
DSCP-MW-36 3.3 J
DSCP-RW-1A 250 D
SSEPTA-PH-8 < 5.0 U
STEEN-PH-10 160
PH-RW-I 130
DSCP-RW-5/MW-25 72
PH-MWS-1 27 J
PH-PH-19 30
PH-PH-21 < 5.0 U
DSCP-MW-7 < 5.0 U
DSCP-MW-9 < 5.0 U
PH-RW-V 28
PH-RW-E 310 D
PH-PH-18 33
PH-PH-17 15 J+
PH-MW-43 < 50 U
PH-RW-U < 5.0 U
EPH-MW-39 < 10 U
PH-RW-M < 5.0 U
PH-RW-F < 5.0 U
PH-RW-J < 5.0 U
PH-MW-60 < 5.0 U
PH-MW-42 < 5.0 U
PH-RW-T < 5.0 U
PH-PH-16 10
PH-PH-13 60
PH-RW-P < 5.0 U
EPH-MWS-5 < 5.0 U
EPH-PH-7 < 5.0 U
STEEN-MW-64 1.1 J
PH-RW-N < 5.0 U
PH-RW-H < 5.0 U
PH-PH-14 2.6 J
PH-RW-S 59
PH-RW-S 1.9 J
PH-RW-Q < 5.0 U
PH-RW-O < 5.0 U
PH-MWS-3 < 5.0 U
EPH-MW-48 < 5.0 U
PH-MWS-13 4.9 J
PH-MWS-2A 35 cn
PH-MW-40 < 5.0 U
EPH-MW-49 < 5.0 Ucn
PH-MW-58 < 5.0 U
PH-MW-41 10
EPH-MW-50 < 5.0 U
PH-PH-23 < 5.0 U
PH-MW-51 < 5.0 U
EPH-MWS-10 < 5.0 U
PH-MW-37 < 5.0 U
PH-PH-24 < 5.0 U
EPH-MWS-11 < 5.0 U
PH-MW-56 < 5.0 U
PH-PH-6 < 5.0 U
EPH-PH-5 < 5.0 U
PH-MWS-15 < 5.0 U
PH-MW-57 < 5.0 U

Legend:

- 51 D 1,2,4-TMB Concentration (µg/L)
- Monitoring Well
- Recovery Well
- Destroyed Monitoring Well
- Interpreted Limits of the** "Hole/Breach"
- Manhole
- Sewer Line

Q4 2023 1,2,4-TMB Concentration Shallow Zone

- 1-10 µg/L
- 10-100 µg/L
- 100-1000 µg/L

Notes:
1. µg/L = micrograms per liter
2. <5.0 U = non-detect

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2020 Imagery 2020 Source: ArcGIS Map Service, image accessed via internet from https://metadata.phila.gov/#home/datasetdetails/569684f4c99154d56b426105/

0 260 520 780 1,040
SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

SHALLOW GROUNDWATER 1,2,4-TMB ISOCONCENTRATION CONTOURS - 2023

SERES Engineering & Services, LLC
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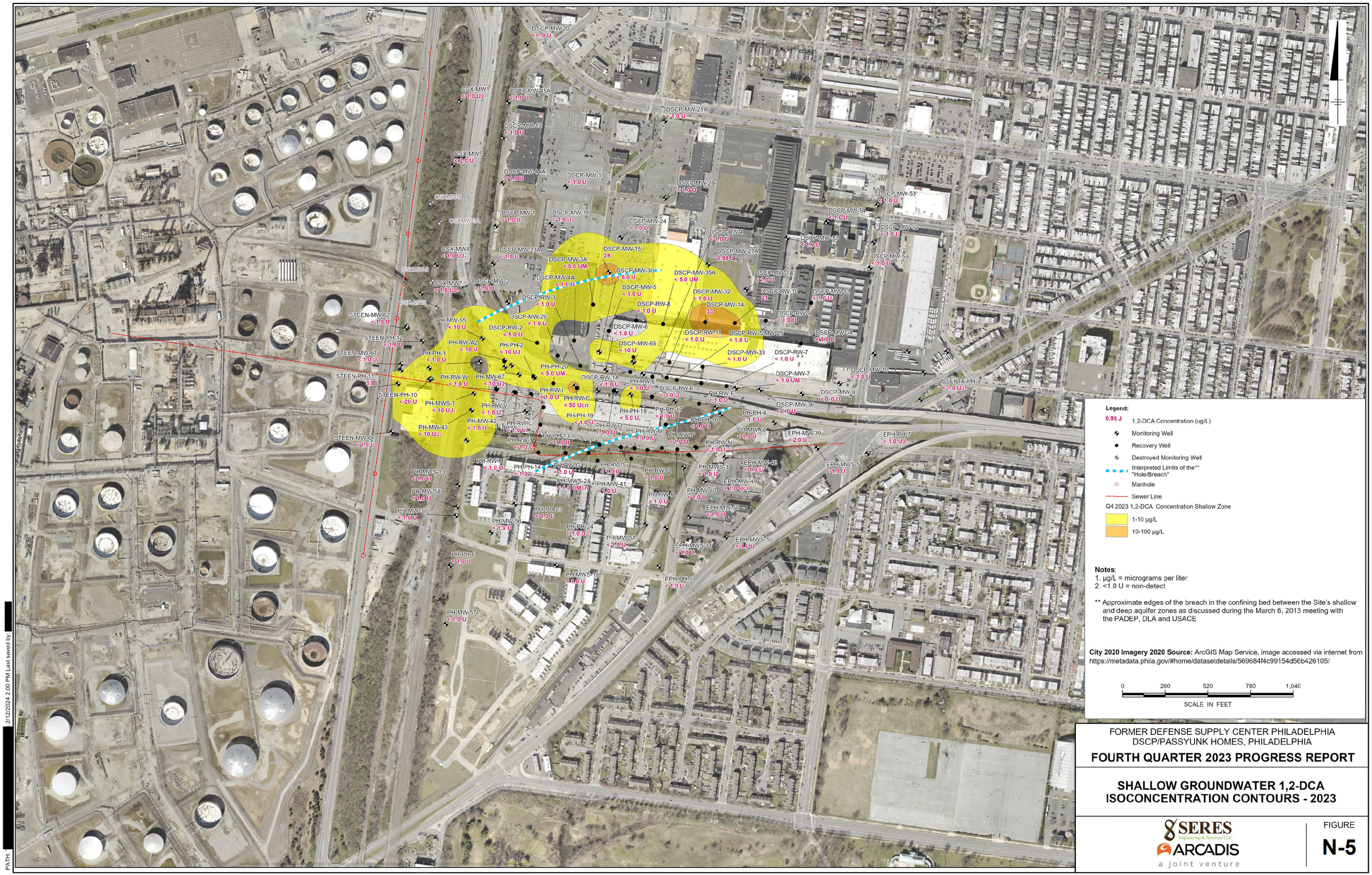
FIGURE
N-4

2/12/2024 12:23 PM Last saved by:

PATH: T:\



FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

SHALLOW GROUNDWATER 1,2-DCA ISOCONCENTRATION CONTOURS - 2023

SERES Engineering & Services, LLC
ARCADIS a joint venture

FIGURE
N-5

PATH: 2/12/2024 2:00 PM Last saved by:

DSCP-MW-20D
< 1.0 U

GSX-DW-5
< 1.0 U

DSCP-DW-6
< 1.0 U

DSCP-DW-1
< 1.0 U

GSX-DW-4
< 1.0 U

STEEN-DW-07
< 1.0 U

DSCP-DW-13
< 1.0 U

STEEN-DW-08
< 1.0 U

STEEN-DW-09
0.45 J

DSCP-DW-12
520 D

PH-DW-10
30

PH-DW-11
11000 D

PH-DW-2
<5

PH-DW-3
5600 D

NOVA-DW-14
< 1.0 U

FDR-DW-15
< 1.0 U

Legend:

- 520 D — Benzene Concentration (µg/L)
- Monitoring Well
- Recovery Well
- Destroyed Monitoring Well
- Sewer Line
- Manhole
- Interpreted Limits of the** "Hole/Breach"

Q4 2023 Benzene Concentration Deep Zone

- 10-100
- 100-1000 µg/L
- >1000 µg/L

Notes:
1. µg/L = micrograms per liter
2. <5.0 U = non-detect

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2020 Imagery 2020 Source: ArcGIS Map Service, image accessed via internet from https://metadata.phila.gov/#home/datasetdetails/569684f4c99154d56b426105/

0 260 520 780 1,040
SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

DEEP GROUNDWATER BENZENE ISOCONCENTRATION CONTOURS - 2023

SERES Engineering & Services, LLC
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FIGURE
N-6

2/12/2024 2:42 PM Last saved by

PATH. T

DSCP-MW-20D
< 1.0 U

CSX-DW-5
< 1.0 U

DSCP-DW-6
< 1.0 U

DSCP-DW-1
< 1.0 U

CSX-DW-4
< 1.0 U

STEEN-DW-07
< 1.0 U

DSCP-DW-13
< 1.0 U

DSCP-DW-12
18

STEEN-DW-08
< 1.0 U

PH-DW-10
< 1.0 U

STEEN-DW-09
< 1.0 U

PH-DW-11
17

PH-DW-2
< 1.0 U

PH-DW-3
3.6 J

NOVA-DW-14
< 1.0 U

FDR-DW-15
< 1.0 U

Legend:

3.6 J Ethylbenzene Concentration (µg/L)

Monitoring Well

Recovery Well

Destroyed Monitoring Well

Sewer Line

Manhole

Interpreted Limits of the** "Hole/Breach"

Q4 2023 EthylBenzene Concentration Deep Zone

1-10 µg/L

10-100 µg/L

Notes:
1. µg/L = micrograms per liter
2. <1.0 U = non-detect

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2020 Imagery 2020 Source: ArcGIS Map Service, image accessed via internet from https://metadata.phila.gov/#home/datasetdetails/56968f4c99154d56b426105/

0 260 520 780 1,040

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

DEEP GROUNDWATER ETHYLBENZENE ISOCONCENTRATION CONTOURS - 2023

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FIGURE
N-7

2/12/2024 2:54 PM Last saved by

PATH:

DSCP-MW-20D
< 5.0 U

CSX-DW-5
< 5.0 U

DSCP-DW-6
< 5.0 U

DSCP-DW-1
< 5.0 U

CSX-DW-4
< 5.0 U

STEEN-DW-07
< 5.0 U

DSCP-DW-13
< 5.0 U

STEEN-DW-08
< 5.0 U

STEEN-DW-09
< 5.0 U

DSCP-DW-12
1.2 J

PH-DW-10
< 5.0 U

PH-DW-11
< 5.0 U

PH-DW-2
< 5.0 U

PH-DW-3
< 25 U

NOVA-DW-14
< 5.0 U

FDR-DW-15
< 5.0 U

Legend:

- 1.2 J — Napthalene Concentration (µg/L)
- Monitoring Well
- Recovery Well
- Destroyed Monitoring Well
- Sewer Line
- Manhole
- Interpreted Limits of the** "Hole/Breach"

Notes:
1. µg/L = micrograms per liter
2. <5.0 U = non-detect

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2020 Imagery 2020 Source: ArcGIS Map Service, image accessed via internet from https://metadata.phila.gov/#home/datasetdetails/569684f4c99154d56b426105/

0 260 520 780 1,040
SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

DEEP GROUNDWATER NAPTHALENE ISOCONCENTRATION CONTOURS - 2023

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FIGURE
N-8

2/12/2024 3:03 PM Last saved by

PATH:

DSCP-MW-20D
< 5.0 U

CSX-DW-5
< 5.0 U

DSCP-DW-4
< 5.0 U

CSX-DW-4
< 5.0 U

DSCP-DW-1
< 5.0 U

DSCP-DW-13
< 5.0 U

STEEN-DW-07
< 5.0 U

STEEN-DW-08
< 5.0 U

DSCP-DW-12
< 5.0 U

STEEN-DW-09
< 5.0 U

PH-DW-10
< 5.0 U

PH-DW-11
< 50 U

PH-DW-2
< 5.0 U

PH-DW-3
< 25 U

NOVA-DW-14
< 5.0 U

FDR-DW-13
< 5.0 U

Legend:

< 5.0 U	1,2,4-TMB Concentration (µg/L)
	Monitoring Well
	Recovery Well
	Destroyed Monitoring Well
	Sewer Line
	Manhole
	Interpreted Limits of the** "Hole/Breach"

Notes:
1. µg/L = micrograms per liter
2. <5.0 U = non-detect

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2020 Imagery 2020 Source: ArcGIS Map Service, image accessed via internet from https://metadata.phila.gov/#home/datasetdetails/569684f4c99154d56b426105/

0 260 520 780 1,040
SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

DEEP GROUNDWATER 1,2,4-TMB ISOCONCENTRATION CONTOURS - 2023

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FIGURE
N-9

2/12/2024 3:09 PM Last saved by:

PATH: T

DSCP-MW-20D
< 1.0 U

CSX-DW-5
< 1.0 UJ

DSCP-DW-9
< 1.0 U

DSCP-DW-1
< 1.0 U

CSX-DW-4
0.39 J

STEEN-DW-07
0.47 J

STEEN-DW-08
0.74 J

STEEN-DW-13
0.36 J

DSCP-DW-12
< 1.0 U

DSCP-DW-13
< 1.0 U

PH-DW-10
< 1.0 U

PH-DW-11
< 1.0 U

PH-DW-2
< 1.0 U

PH-DW-3
< 5.0 U

NOVA-DW-14
< 1.0 UJ

FDR-DW-15
< 1.0 UJ

Legend:

- 0.47 J — 1,2-DCA Concentration (µg/L)
- Monitoring Well
- Recovery Well
- Destroyed Monitoring Well
- Sewer Line
- Manhole
- Interpreted Limits of the** "Hole/Breach"

Notes:
1. µg/L = micrograms per liter
2. <1.0 U = non-detect

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2020 Imagery 2020 Source: ArcGIS Map Service, image accessed via internet from https://metadata.phila.gov/#home/datasetdetails/569684f4c99154d56b426105/

0 260 520 780 1,040
SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER 2023 PROGRESS REPORT

DEEP GROUNDWATER 1,2-DCA ISOCONCENTRATION CONTOURS - 2023

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FIGURE
N-10

2/12/2024 3:16 PM Last saved by:

PATH: T

DATE: 1/31/2025

DIV/GROUP

Legend

0.54 J Benzene Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Interpreted limits of the "hole/breach"
- Manhole
- Sewer Line

Q1 2024 Benzene Concentration Shallow Zone

- 1 - 10 µg/L
- 10 - 100 µg/L
- 100 - 1000 µg/L
- 1000 - 10000 µg/L
- > 10000 µg/L

Notes:

µg/L = micrograms per liter
U = non-detect
B = Analyte detected in both the sample and blank samples
J = Estimated, the analyte was positively identified, the quantitation is an estimation
J1 = Estimated, the quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
Q = One or more quality control criteria failed

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013, meeting with the PADEP, DLA and USACE.

City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 200 400 600 800

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

FOURTH QUARTER OF 2024 PROGRESS REPORT

SHALLOW GROUNDWATER BENZENE ISOCONCENTRATION CONTOURS - 2024

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FIGURE
N-11

Legend:

0.54 J Ethylbenzene Concentration (µg/L)

Monitoring Well
Recovery Well
Manhole

Interpreted Limits of the** "Hole/Breach"
Sewer Line

Q4 2024 Ethylbenzene Concentration Shallow Zone
- 0.1 - 1 µg/L
- 1 - 10 µg/L
- 10 - 100 µg/L
- 100 - 1000 µg/L
- >1000 µg/L

Notes:
µg/L = micrograms per liter
B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estmated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
Q = One or more quality control criteria failed
U = Undetected at the Limit of Detection

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 200 400 600 800

SCALE IN FEET

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FOURTH QUARTER 2024 PROGRESS REPORT

SHALLOW GROUNDWATER ETHYLBENZENE ISOCONCENTRATION CONTOURS - 2024

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FIGURE
N-12

1/31/2025 2:45 PM Last save by:

Legend:

0.54 J Napthalene Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Manhole
- Interpreted Limits of the** "Hole/Breach"
- Sewer Line

Q1 2024 Naphthalene Concentration Shallow Zone

- 1 - 10 µg/L
- 10 - 100 µg/L
- 100 - 1000 µg/L

Notes:
µg/L = micrograms per liter

B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estimated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
Q = One or more quality control criteria failed
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City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 200 400 600 800

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

FOURTH QUARTER 2024 PROGRESS REPORT

SHALLOW GROUNDWATER NAPTHALENE ISOCONCENTRATION CONTOURS - 2024

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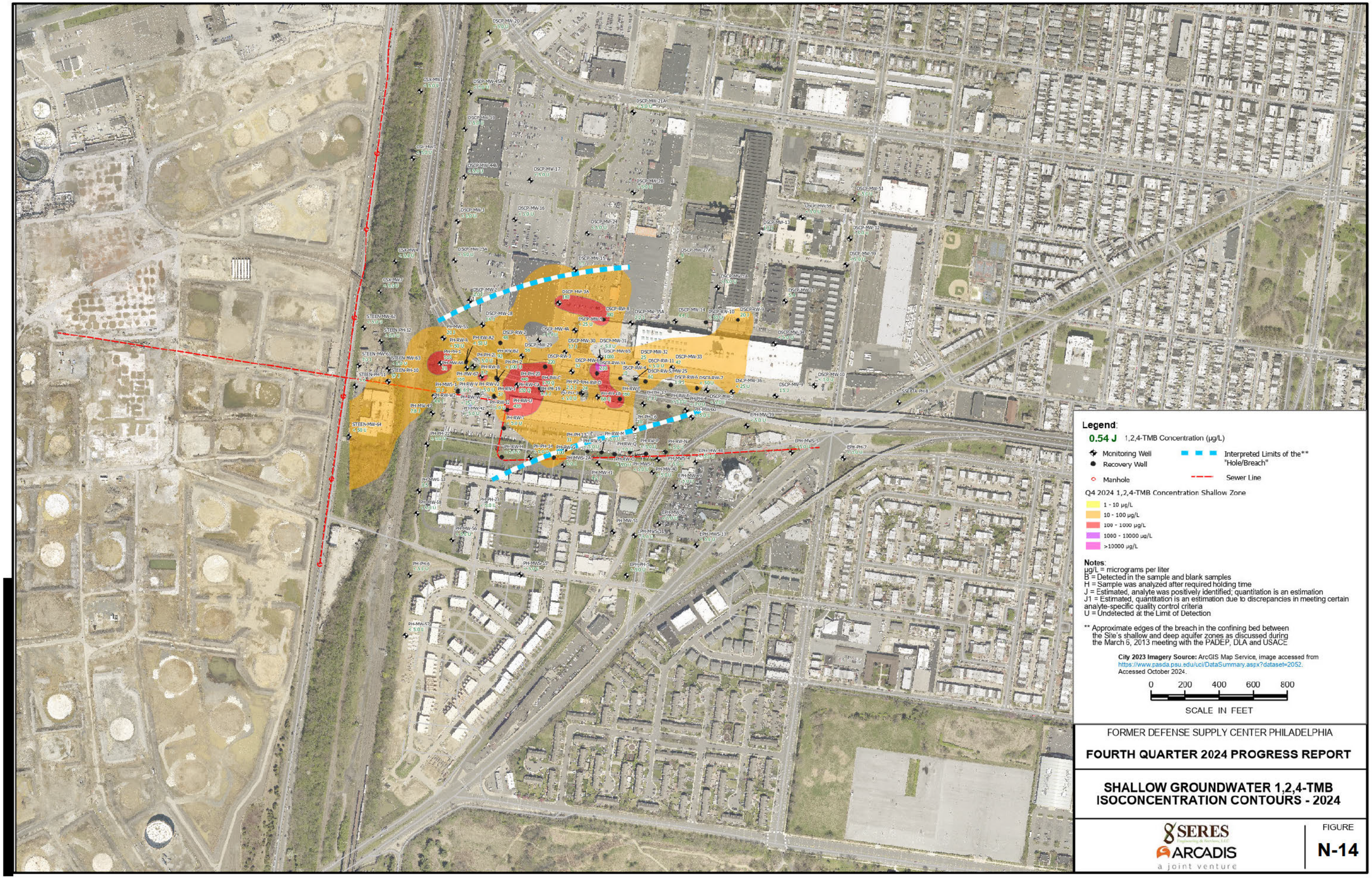
FIGURE
N-13


Legend:
0.54 J 1,2,4-TMB Concentration (µg/L)
Monitoring Well
Recovery Well
Manhole
Interpreted Limits of the** "Hole/Breach"
Sewer Line
Q4 2024 1,2,4-TMB Concentration Shallow Zone
1 - 10 µg/L
10 - 100 µg/L
100 - 1000 µg/L
1000 - 10000 µg/L
>10000 µg/L
Notes:
µg/L = micrograms per liter
B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estimated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
U = Undetected at the Limit of Detection
** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE
City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.
0 200 400 600 800
SCALE IN FEET
FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
FOURTH QUARTER 2024 PROGRESS REPORT
SHALLOW GROUNDWATER 1,2,4-TMB ISOCONCENTRATION CONTOURS - 2024
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ARCADIS
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FIGURE
N-14

Legend:

0.54 J 1,2-DCA Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Manhole
- Sewer Line
- Interpreted Limits of the** "Hole/Breach"

Notes:

µg/L = micrograms per liter
B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estimated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
Q = One or more quality control criteria failed
U = Undetected at the Limit of Detection

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City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 200 400 600 800

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

FOURTH QUARTER 2024 PROGRESS REPORT

SHALLOW GROUNDWATER 1,2-DCA ISOCONCENTRATION CONTOURS - 2024

SERES Consulting & Services, LLC
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FIGURE
N-15

DSCP-MW-20D
< 1.0 U
CSX-DW-5
< 1.0 U
DSCP-DW-6
< 1.0 U
DSCP-DW-1
< 1.0 U
CSX-DW-4
< 1.0 U
DSCP-DW-13
< 1.0 U
DSCP-DW-12
100
STEEN-DW-08
< 1.0 U
STEEN-DW-09
6.8
PH-DW-10
48
PH-DW-11
1800
PH-DW-2
6.5
PH-DW-3
1800

Legend:

0.54 J Benzene Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Manhole
- Sewer Line
- Interpreted Limits of the** "Hole/Breach"

Q4 2024 Benzene Concentration Deep Zone

- 1 - 10 µg/L
- 10 - 100 µg/L
- 100 - 1000 µg/L
- 1000 - 10000 µg/L

Notes:

µg/L = micrograms per liter
U = non-detect

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 270 540 810 1,080

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

FOURTH QUARTER 2024 PROGRESS REPORT

DEEP GROUNDWATER BENZENE ISOCONCENTRATION CONTOURS - 2024

SERES Engineering & Sciences, LLC
ARCADIS
a joint venture

FIGURE
N-16

DSCP-MW-20D
< 1.0 U

GSX-DW-5
< 1.0 U

DSCP-DW-6
< 1.0 U

DSCP-DW-1
< 1.0 U

GSX-DW-4
< 1.0 U

DSCP-DW-13
< 1.0 U

DSCP-DW-12
12

STEEN-DW-08
< 1.0 U

STEEN-DW-09
< 1.0 U

PH-DW-10
< 1.0 U

PH-DW-11
< 1.0 U

PH-DW-9
< 1.0 U

PH-DW-8
25.1

Legend:

0.54 J Ethylbenzene Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Manhole
- Interpreted Limits of the** "Hole/Breach"
- Sewer Line

Notes:
µg/L = micrograms per liter
B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estmated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
Q = One or more quality control criteria failed
U = Undetected at the Limit of Detection

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 200 400 600 800

SCALE IN FEET

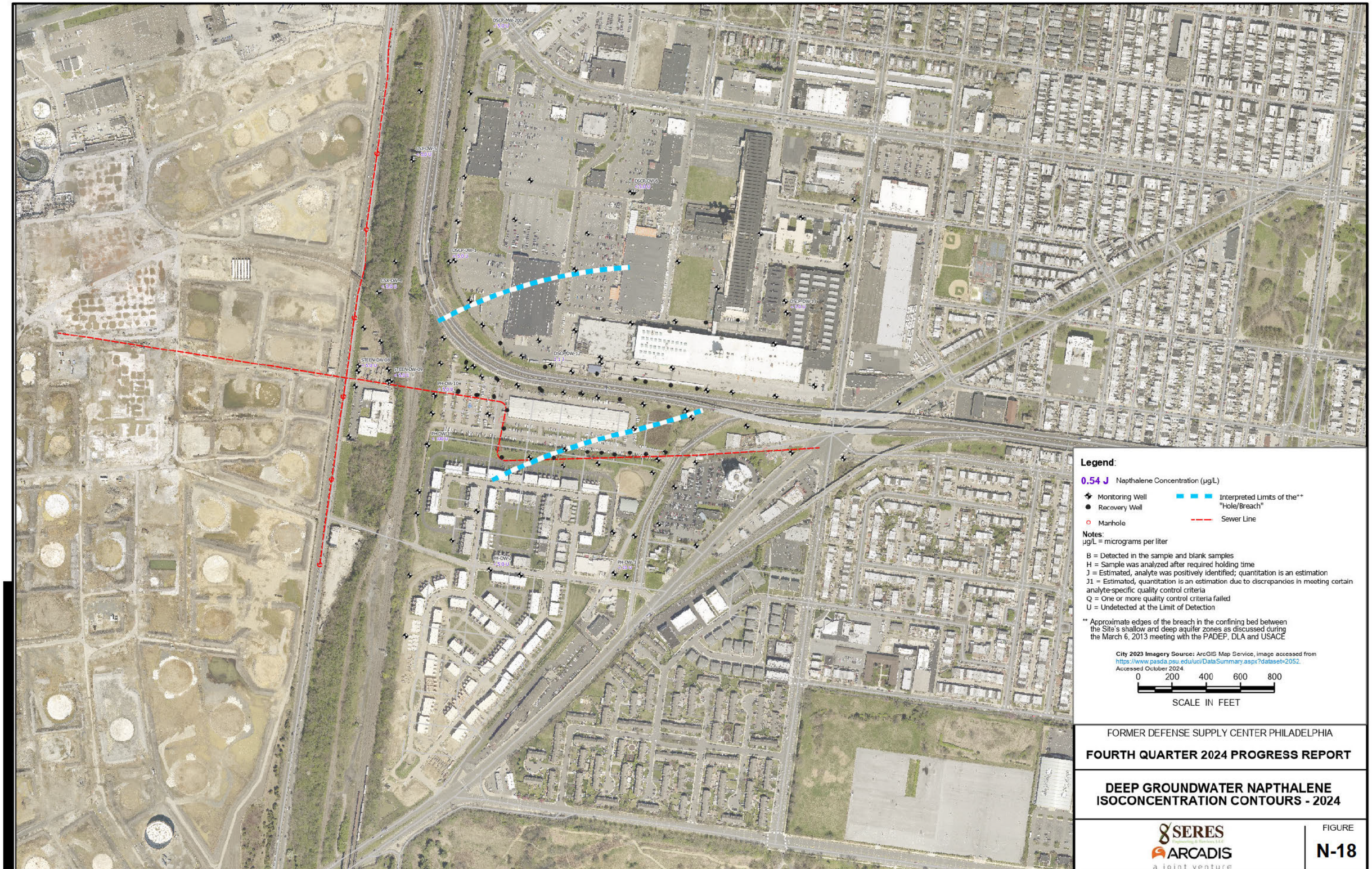
FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

FOURTH QUARTER 2024 PROGRESS REPORT

DEEP GROUNDWATER ETHYLBENZENE ISOCONCENTRATION CONTOURS - 2024

SERES Engineering & Services, LLC
ARCADIS a joint venture

FIGURE
N-17



Legend:

0.54 J Napthalene Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Manhole
- Interpreted Limits of the** "Hole/Breach"
- Sewer Line

Notes:
µg/L = micrograms per liter

B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estimated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
Q = One or more quality control criteria failed
U = Undetected at the Limit of Detection

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024

0 200 400 600 800

SCALE IN FEET

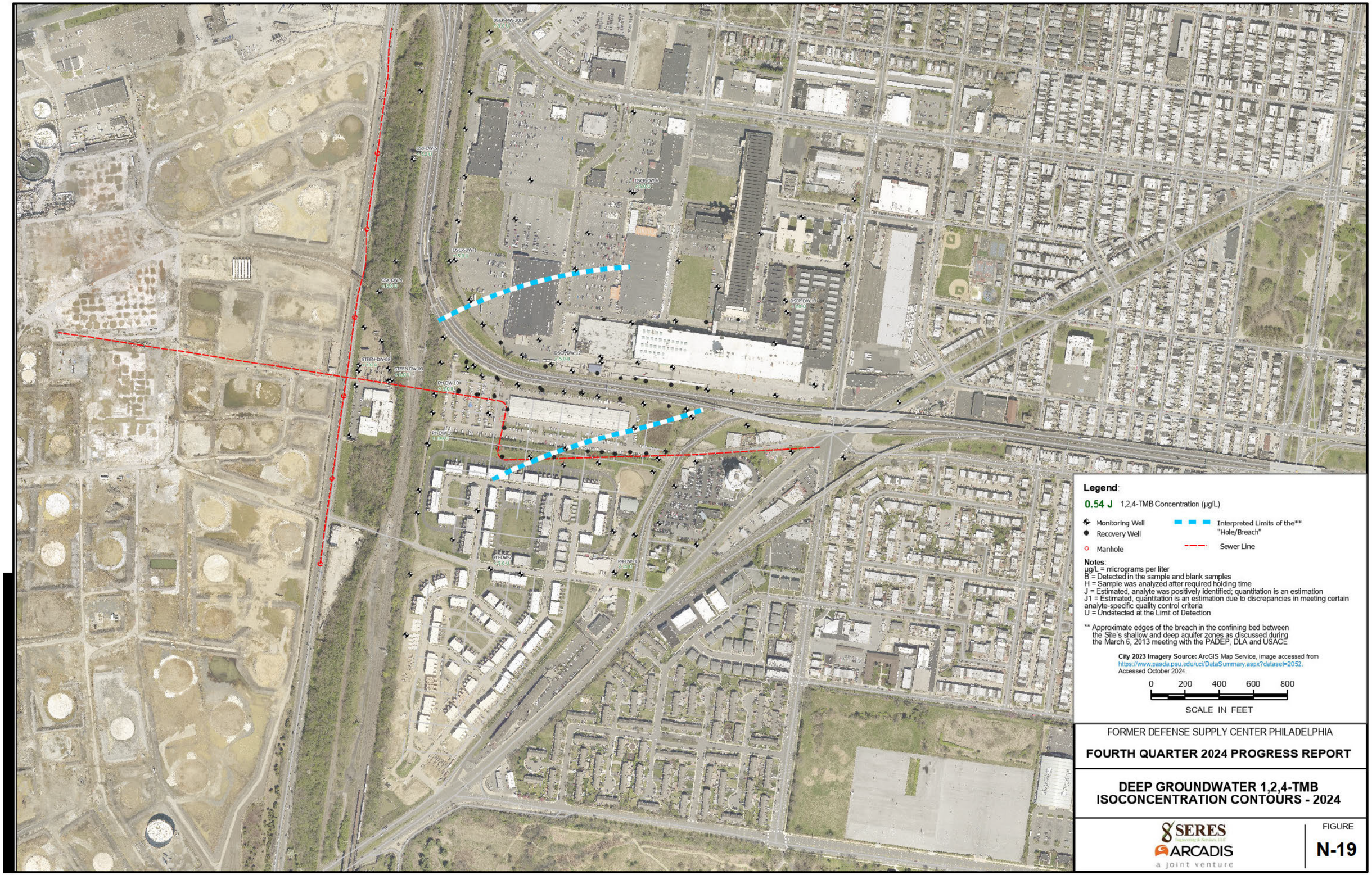
FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

FOURTH QUARTER 2024 PROGRESS REPORT

DEEP GROUNDWATER NAPTHALENE ISOCONCENTRATION CONTOURS - 2024

SERES Engineering & Services, LLC
ARCADIS
a joint venture

FIGURE
N-18



Legend:

0.54 J 1,2,4-TMB Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Manhole
- Interpreted Limits of the** "Hole/Breach"
- Sewer Line

Notes:
µg/L = micrograms per liter
B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estimated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
U = Undetected at the Limit of Detection

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 200 400 600 800

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

FOURTH QUARTER 2024 PROGRESS REPORT

DEEP GROUNDWATER 1,2,4-TMB ISOCONCENTRATION CONTOURS - 2024

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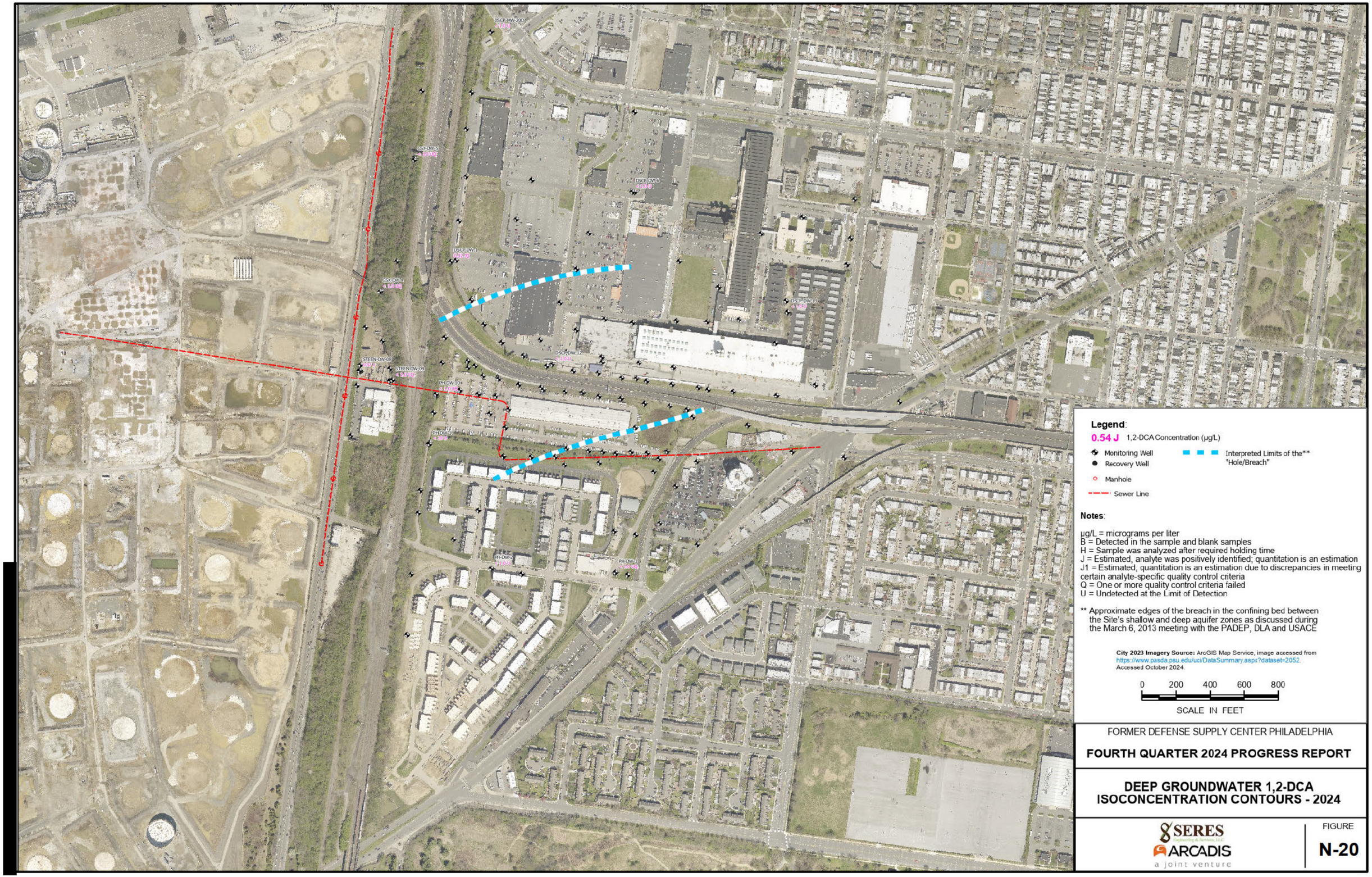
ARCADIS
a joint venture

FIGURE
N-19



Legend:

0.54 J 1,2-DCA Concentration (µg/L)

- Monitoring Well
- Recovery Well
- Manhole
- Sewer Line
- Interpreted Limits of the** "Hole/Breach"

Notes:

µg/L = micrograms per liter
B = Detected in the sample and blank samples
H = Sample was analyzed after required holding time
J = Estimated, analyte was positively identified; quantitation is an estimation
J1 = Estimated, quantitation is an estimation due to discrepancies in meeting certain analyte-specific quality control criteria
Q = One or more quality control criteria failed
U = Undetected at the Limit of Detection

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE

City 2023 Imagery Source: ArcGIS Map Service, image accessed from https://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=2052. Accessed October 2024.

0 200 400 600 800

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

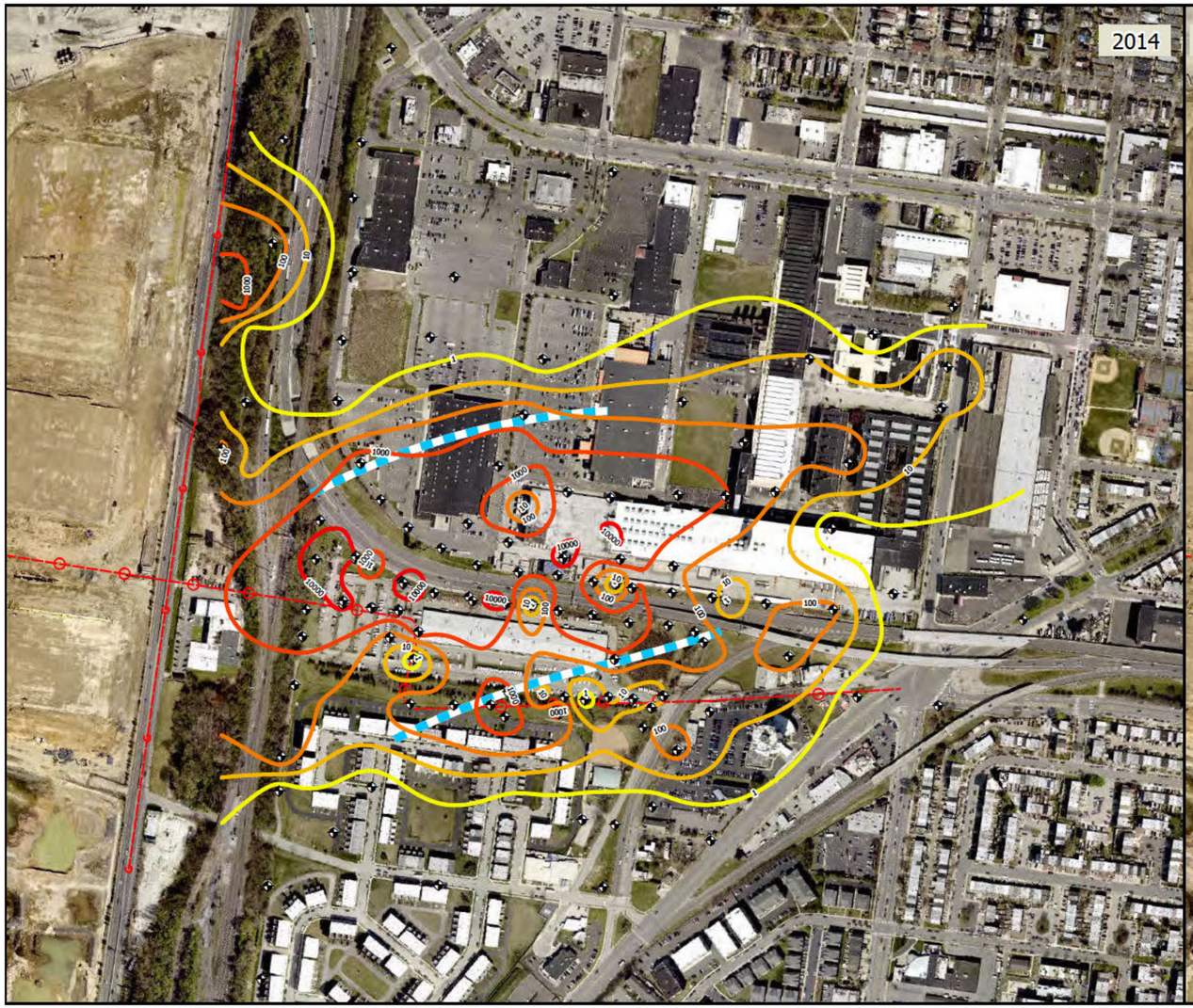
FOURTH QUARTER 2024 PROGRESS REPORT

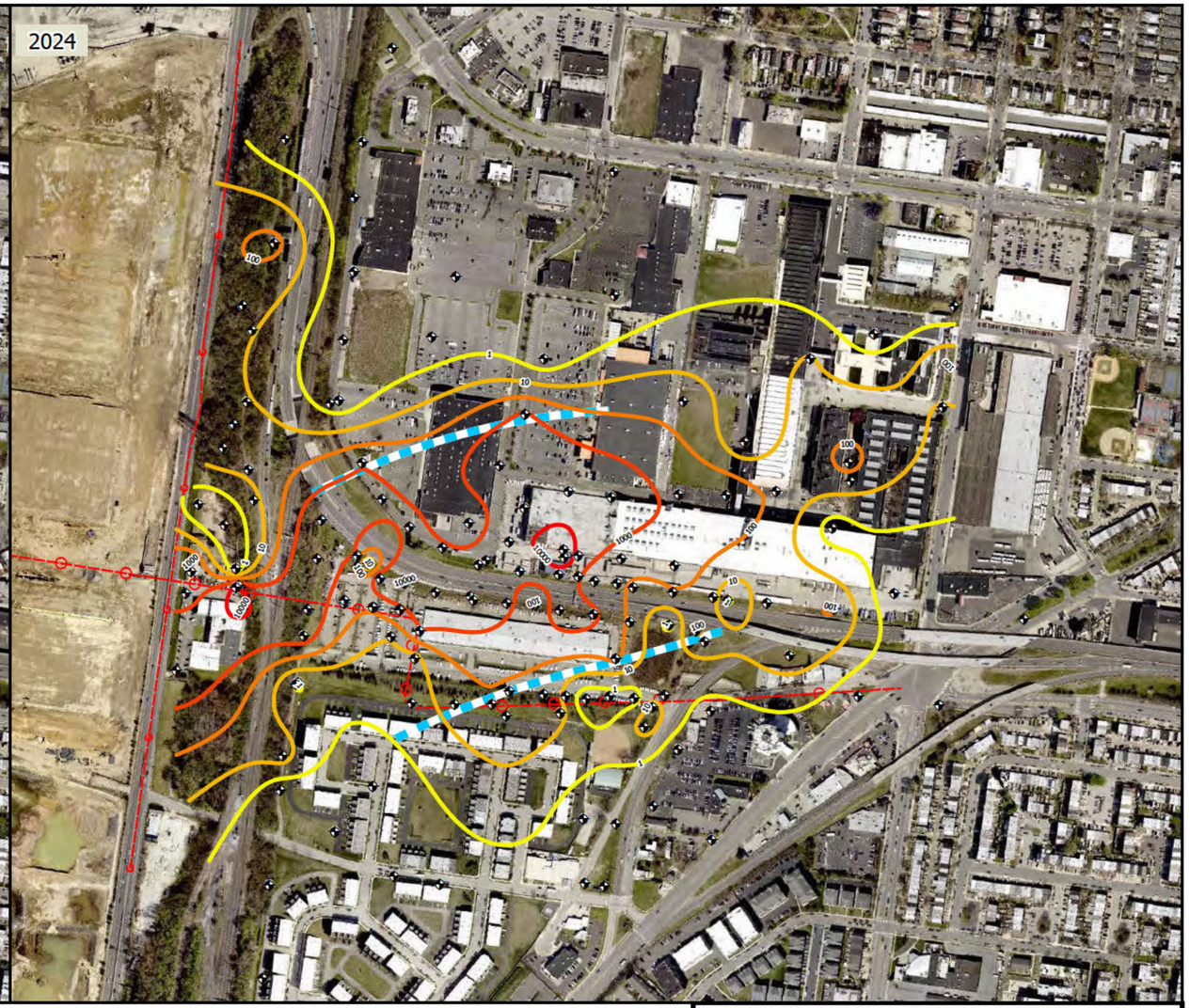
DEEP GROUNDWATER 1,2-DCA ISOCONCENTRATION CONTOURS - 2024

SERES ARCADIS a joint venture

FIGURE

N-20





Legend

- Monitoring Well
- Sewer Line
- Manhole
- Interpreted Limits of Breach or Hole

Benzene Contours (µg/l)

- 1
- 10
- 100
- 1000
- 10000

Notes:

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE.

Imagery Data from City of Philadelphia 2024 Aerial Imagery 1 inch Resolution uploaded to ArcGIS online 12 June 2025.

0 250 500 1,000 1,500 2,000 Feet

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

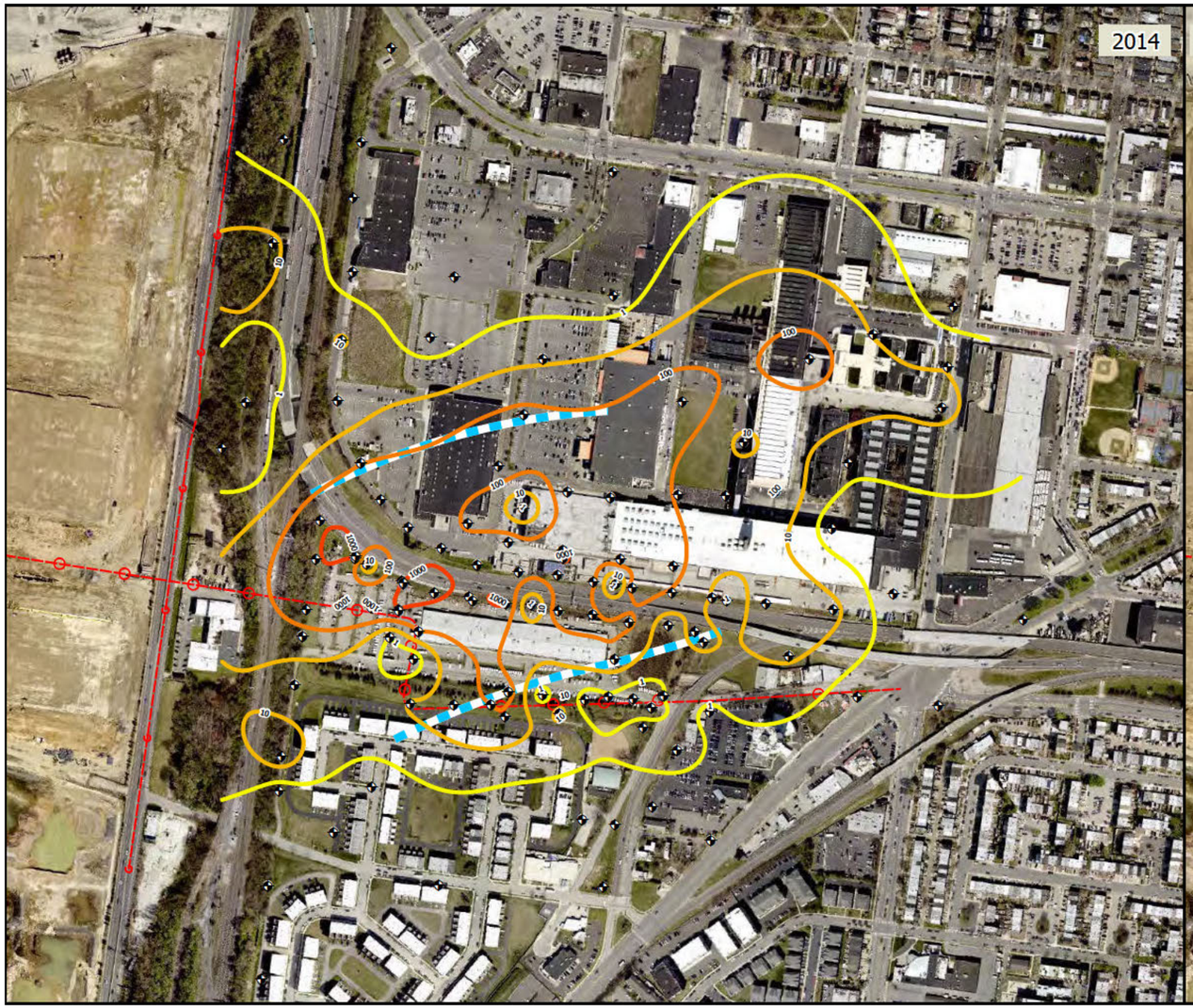
REMEDIAL INVESTIGATION REPORT

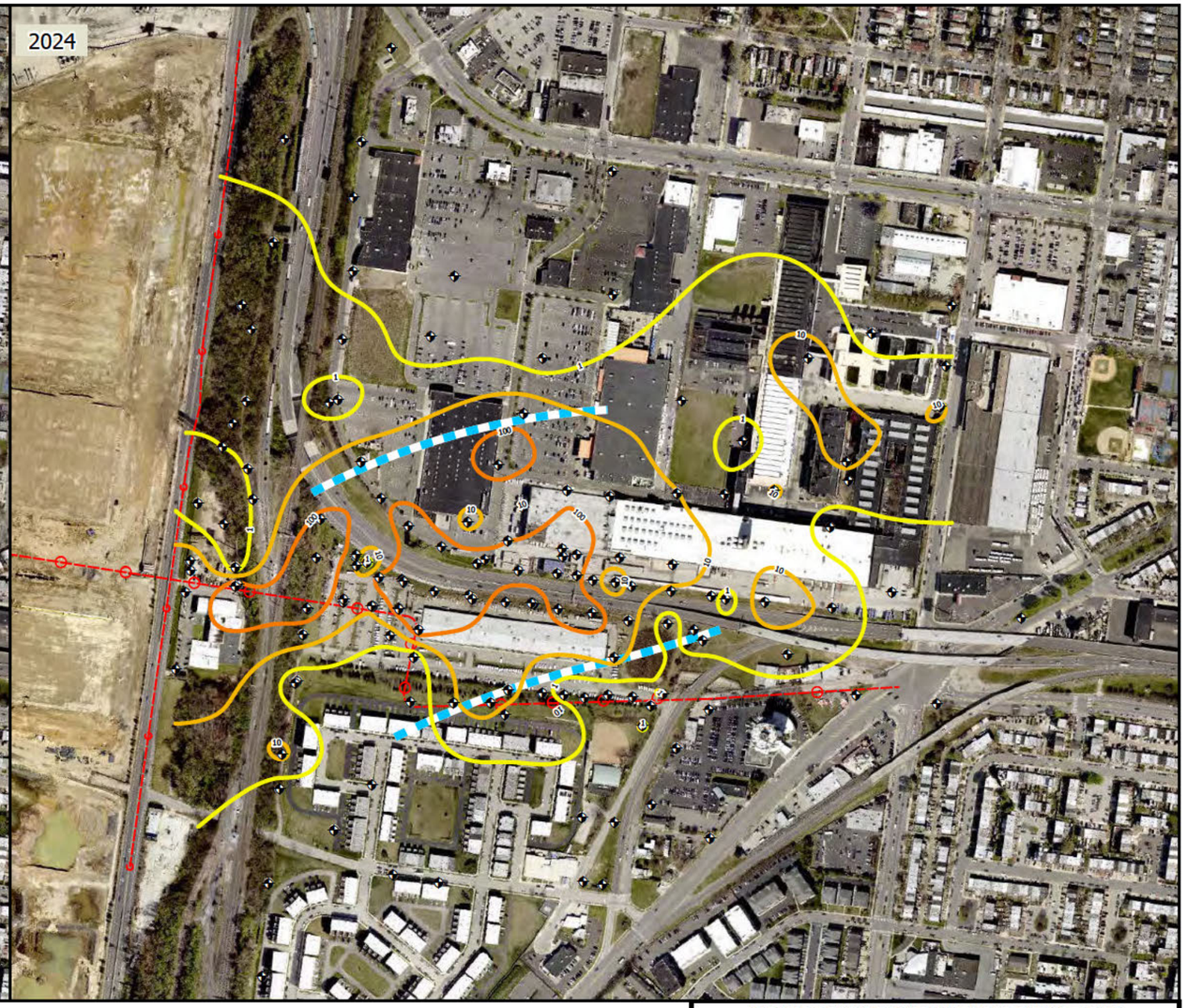
2014 VS 2024 SHALLOW BENZENE ISOCONCENTRATION CONTOURS

SERES ARCADIS a joint venture

FIGURE

N-21





Legend

- Monitoring Well
- Sewer Line
- Manhole
- Interpreted Limits of Breach or Hole

Ethylbenzene Contours (µg/l)

- 1
- 10
- 100
- 1000
- 10000

Notes:

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE.

Imagery Data from City of Philadelphia 2024 Aerial Imagery 1 inch Resolution uploaded to ArcGIS online 12 June 2025.

0 250 500 1,000 1,500 2,000 Feet

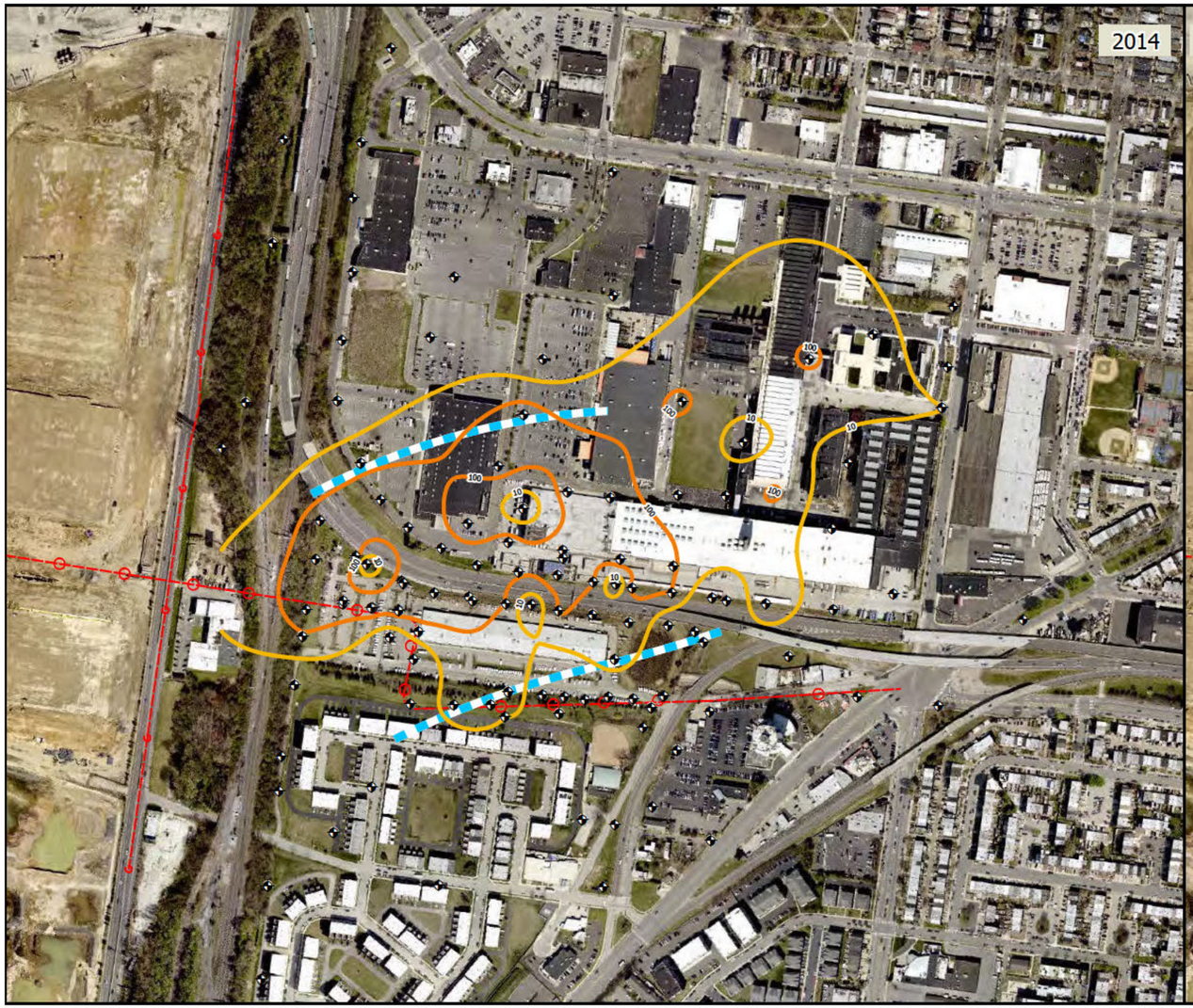
FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

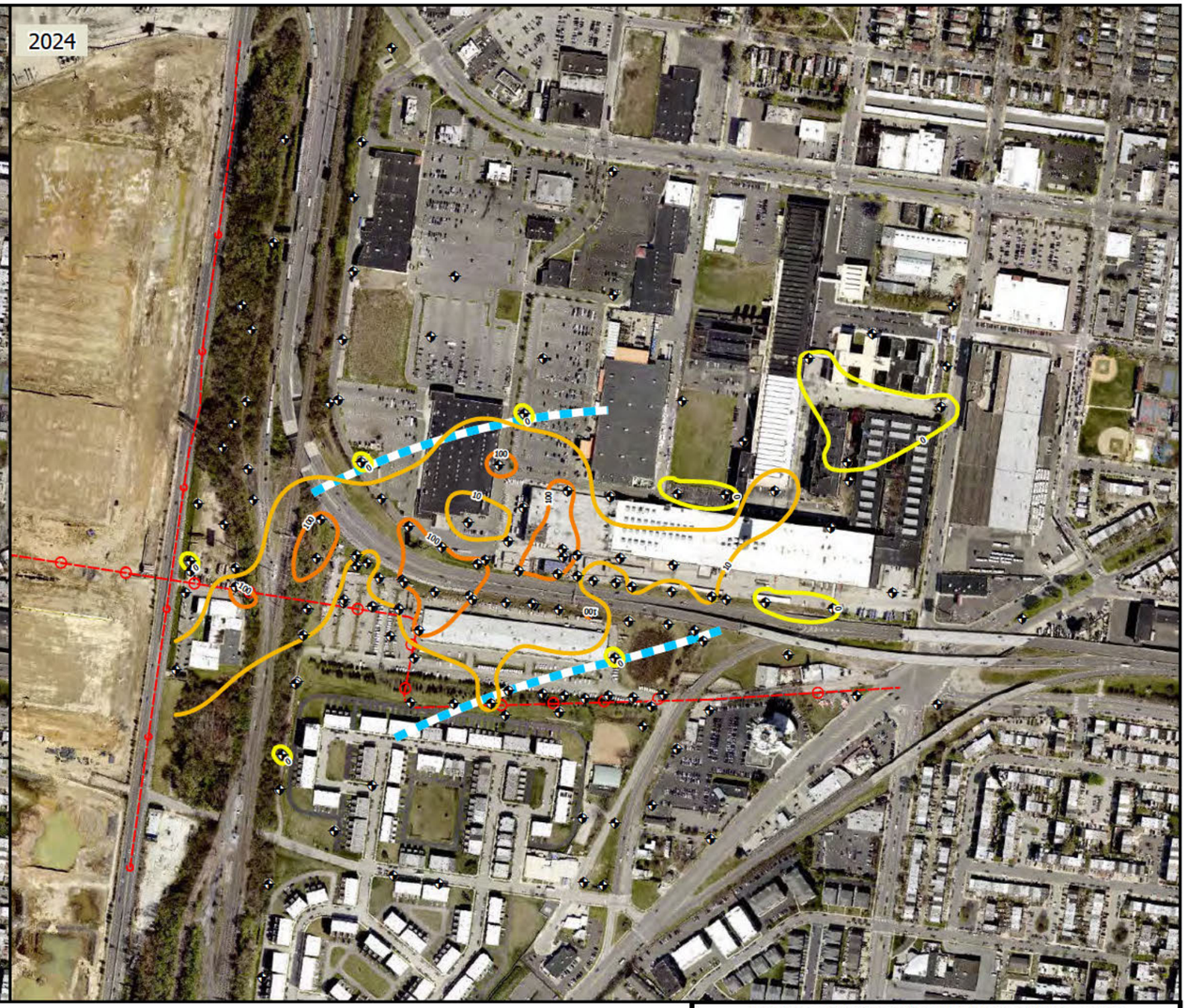
REMEDIAL INVESTIGATION REPORT

2014 VS 2024 SHALLOW ETHYLBENZENE ISOCONCENTRATION CONTOURS

SERES ARCADIS a joint venture

FIGURE **N-22**





Legend

- Monitoring Well
- Sewer Line
- Manhole
- Interpreted Limits of Breach or Hole

Naphthalene Contours (µg/l)

- 1
- 10
- 100
- 1000
- 10000

Notes:

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE.

Imagery Data from City of Philadelphia 2024 Aerial Imagery 1 inch Resolution uploaded to ArcGIS online 12 June 2025.

0 250 500 1,000 1,500 2,000 Feet

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

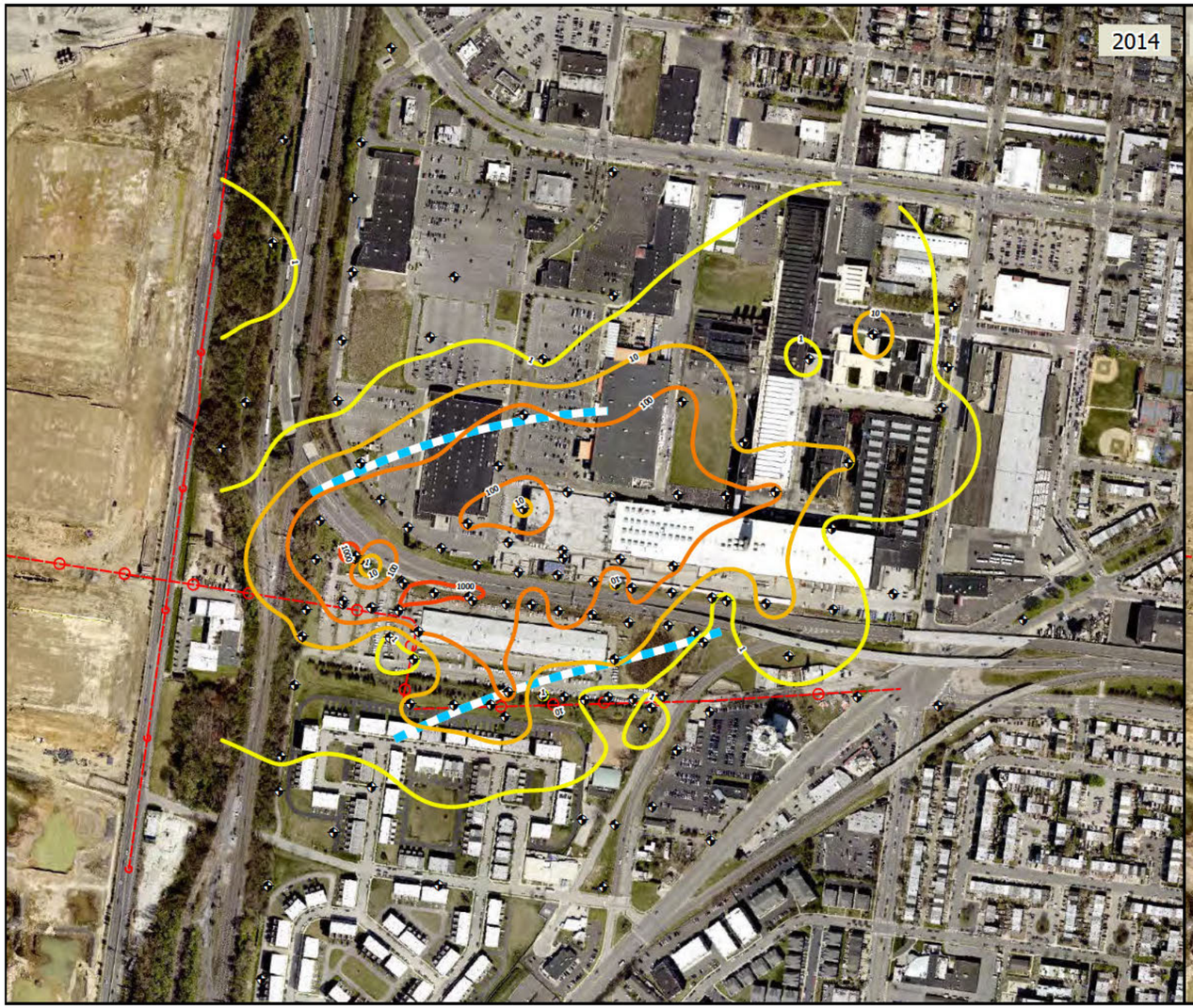
REMEDIAL INVESTIGATION REPORT

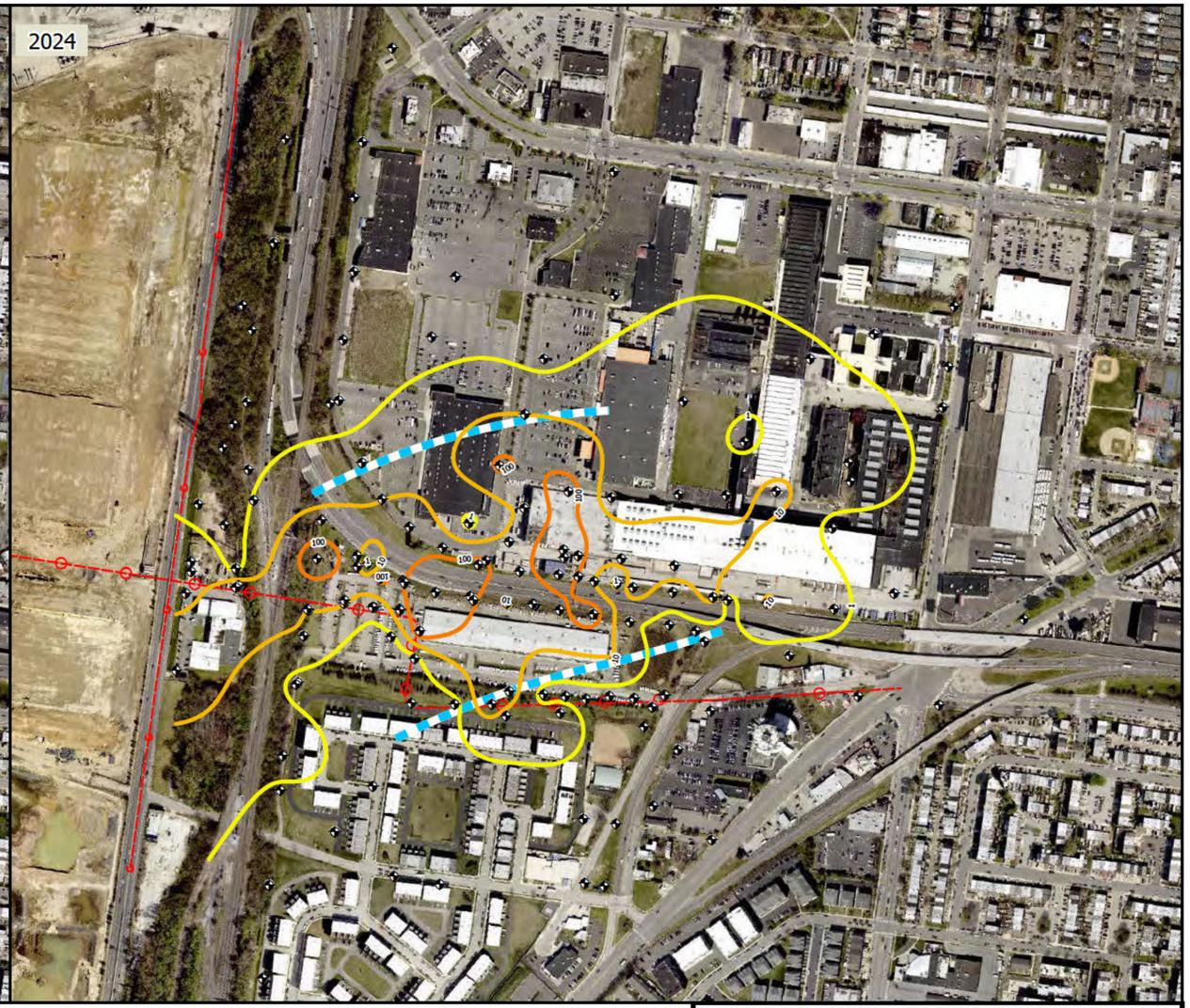
2014 VS 2024 SHALLOW NAPHTHALENE ISOCONCENTRATION CONTOURS

SERES ARCADIS a joint venture

FIGURE

N-23





Legend

- Monitoring Well
- Sewer Line
- Manhole
- Interpreted Limits of Breach or Hole

1,2,4-Trimethylbenzene Contours (µg/l)

- 1
- 10
- 100
- 1000
- 10000

Notes:

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE.

Imagery Data from City of Philadelphia 2024 Aerial Imagery 1 inch Resolution uploaded to ArcGIS online 12 June 2025.

0 250 500 1,000 1,500 2,000 Feet

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

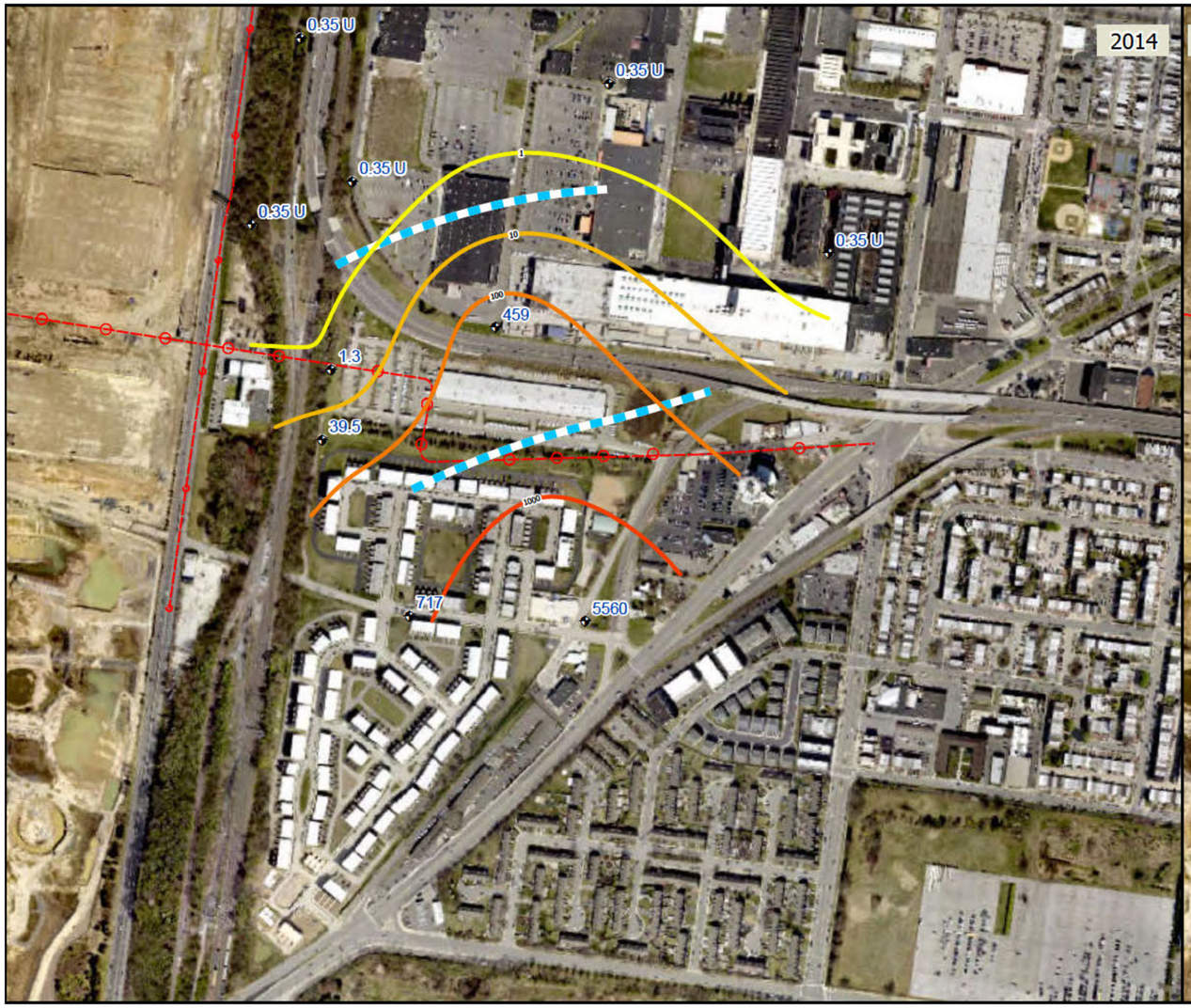
REMEDIAL INVESTIGATION REPORT

2014 VS 2024 SHALLOW 1,2,4-TRIMETHYLBENZENE ISOCONCENTRATION CONTOURS

SERES ARCADIS a joint venture

FIGURE

N-24





Legend

- Monitoring Well
  - Benzene Concentration (µg/l)
- Sewer Line
- Manhole
- Interpreted Limits of Breach or Hole

Benzene Contours (µg/l)

- 1
- 10
- 100
- 1000
- 10000

Notes:

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE.

Imagery Data from City of Philadelphia 2024 Aerial Imagery 1 inch Resolution uploaded to ArcGIS online 12 June 2025.

Abbreviations:
U: Undetected at the limit of detection
D: Reported value from dilution
cn: Refer to case narrative

0 275 550 1,100 1,650 2,200 Feet

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

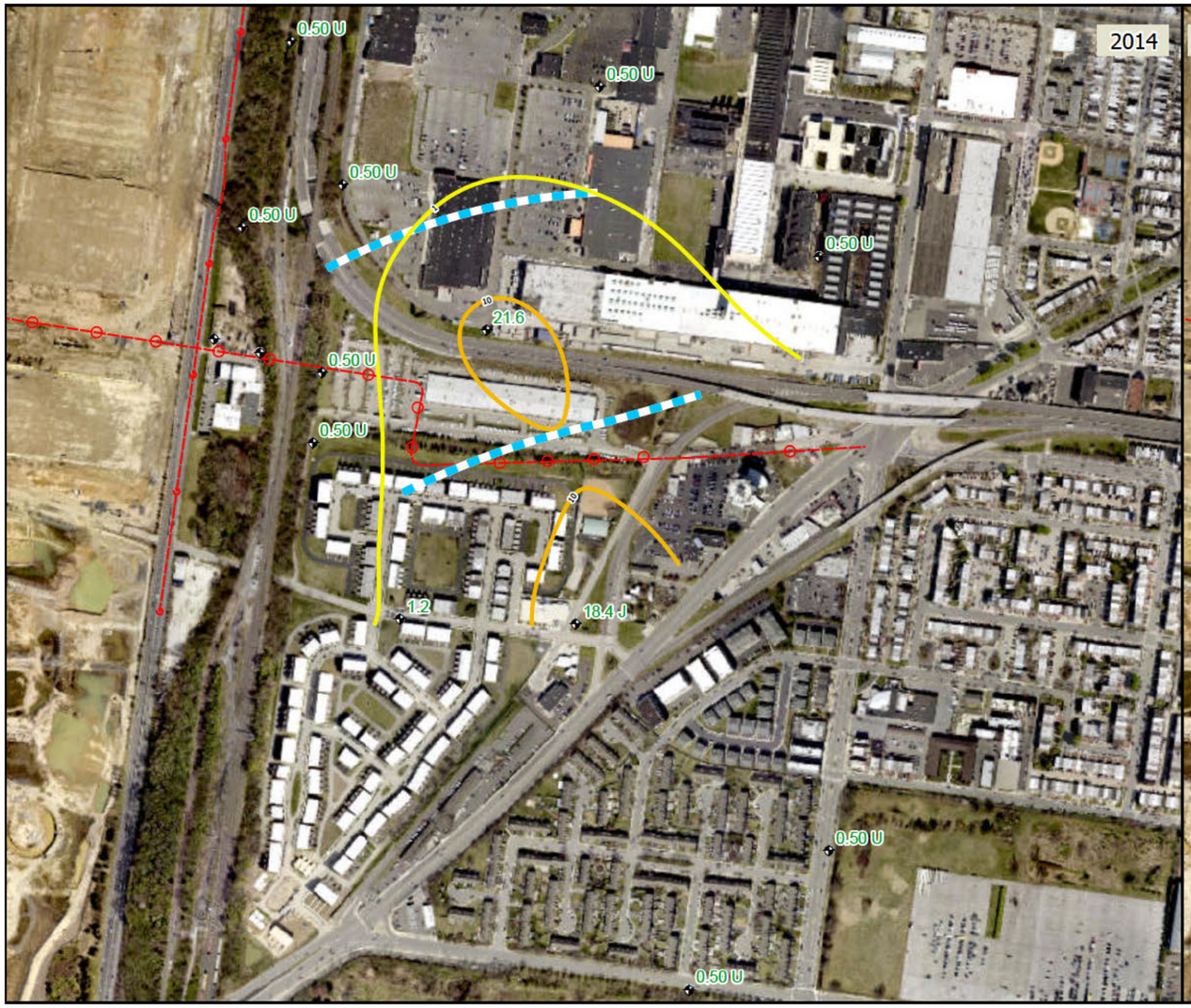
REMEDIAL INVESTIGATION REPORT

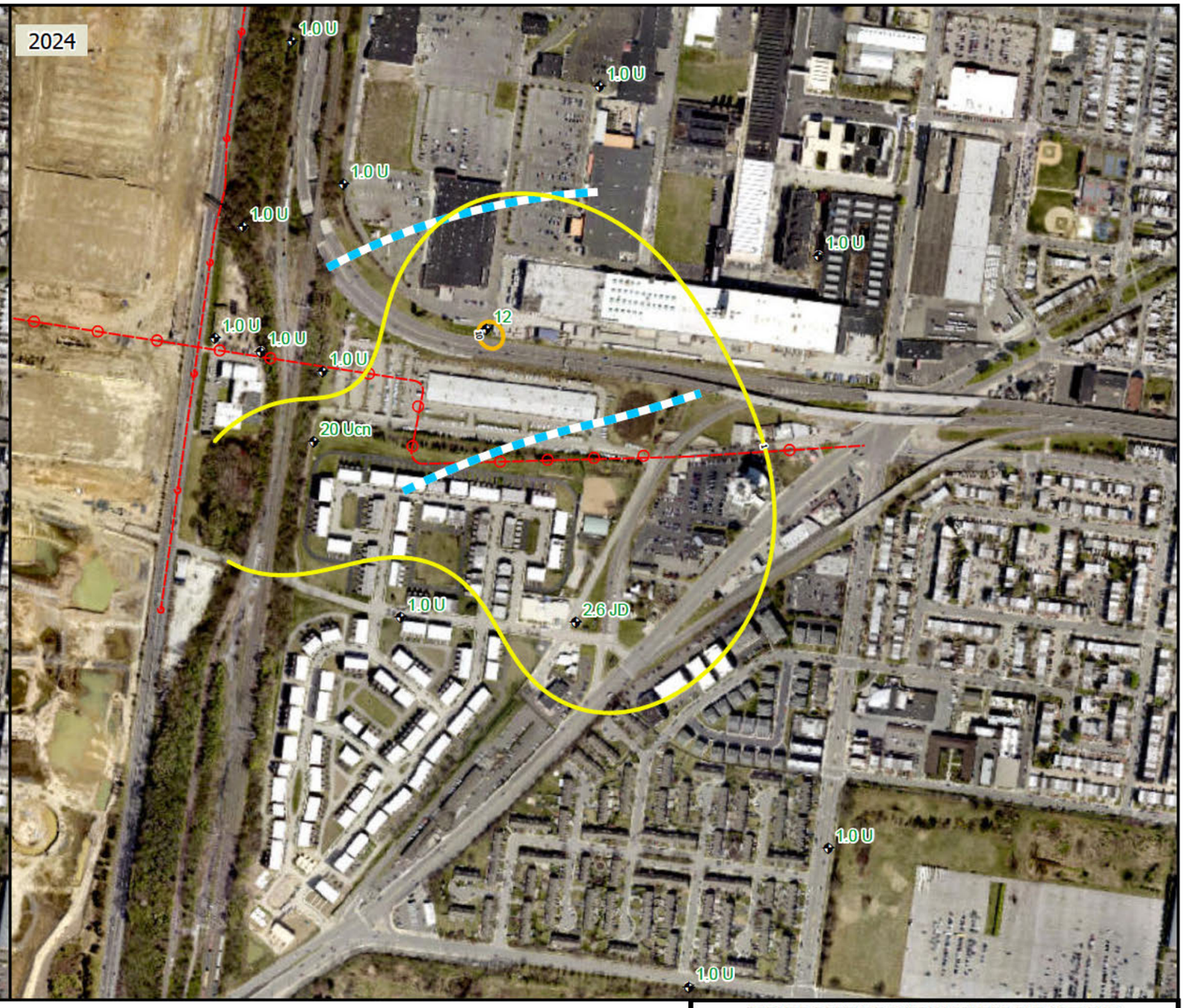
2014 VS 2024 DEEP BENZENE ISOCONCENTRATION CONTOURS

SERES ARCADIS a joint venture

FIGURE

N-25





Legend

- Monitoring Well
  - Ethylbenzene Concentration (µg/l)
- Sewer Line
- Manhole
- Interpreted Limits of Breach or Hole

Ethylbenzene Contours (µg/l)

- 1
- 10
- 100
- 1000
- 10000

Notes:

** Approximate edges of the breach in the confining bed between the Site's shallow and deep aquifer zones as discussed during the March 6, 2013 meeting with the PADEP, DLA and USACE.

Imagery Data from City of Philadelphia 2024 Aerial Imagery 1 inch Resolution uploaded to ArcGIS online 12 June 2025.

Abbreviations:
U: Undetected at the limit of detection
D: Reported value from dilution
cn: Refer to case narrative
J: Estimated

0 275 550 1,100 1,650 2,200 Feet

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA

REMEDIAL INVESTIGATION REPORT

2014 VS 2024 DEEP ETHYLBENZENE ISOCONCENTRATION CONTOURS

SERES Engineering & Services, LLC
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a joint venture

FIGURE
N-26

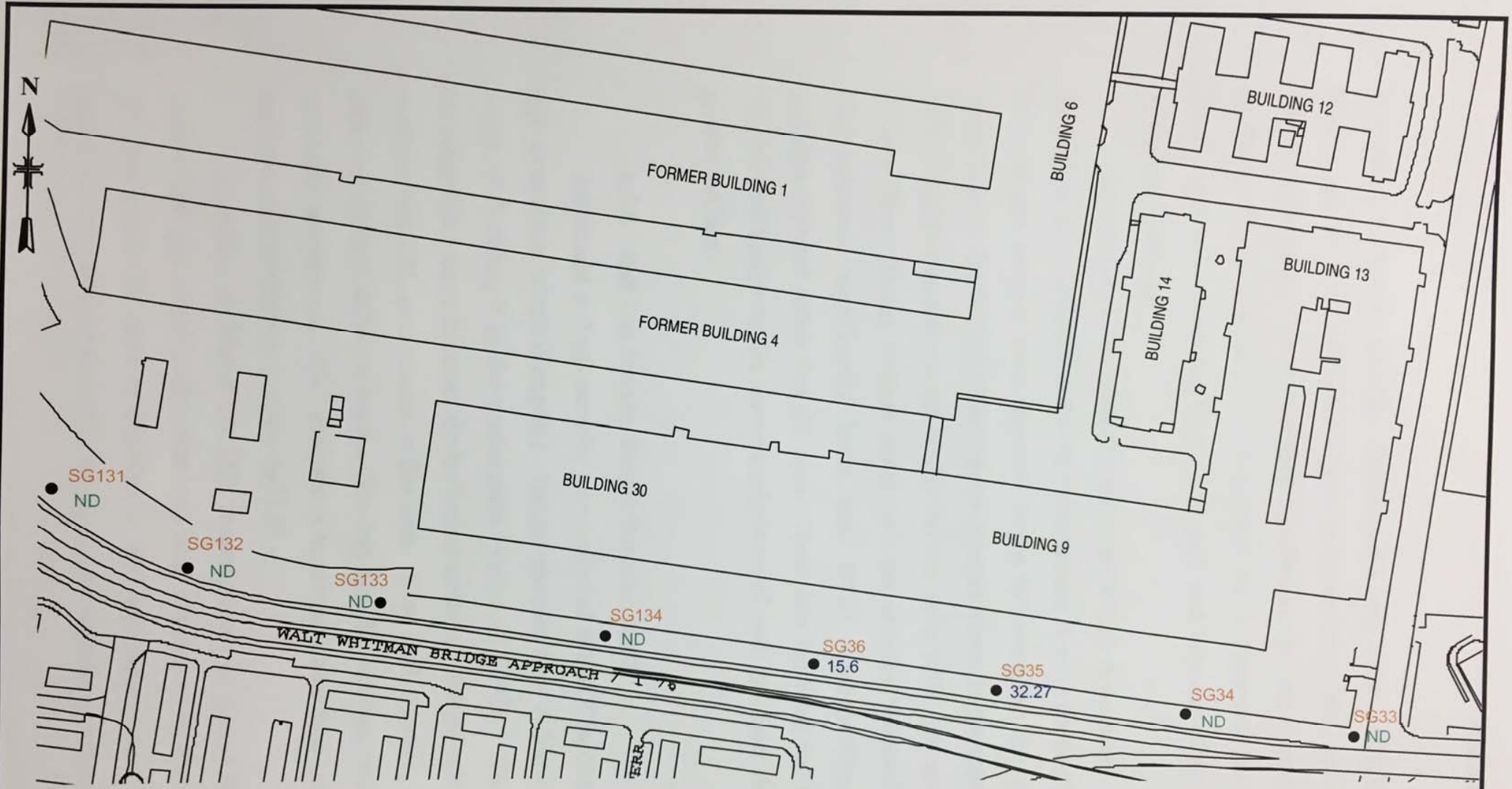
Appendix O

Groundwater MNA
Analytical Results

(upon request)

Appendix P

Malcolm Pirnie Soil Gas Summary
Figures (1995-2001)



LEGEND

SG36 ● SOIL GAS SAMPLE (COLLECTED AT 5 FEET BGS)

15.6 CONCENTRATION IN UG/L OF TOTAL BENZENE, TOLUENE, AND XYLENES (BTX)

ND NOT DETECTED GREATER THAN METHOD DETECTION LIMIT

APPROXIMATE SCALE IN FEET

0 100 200 400

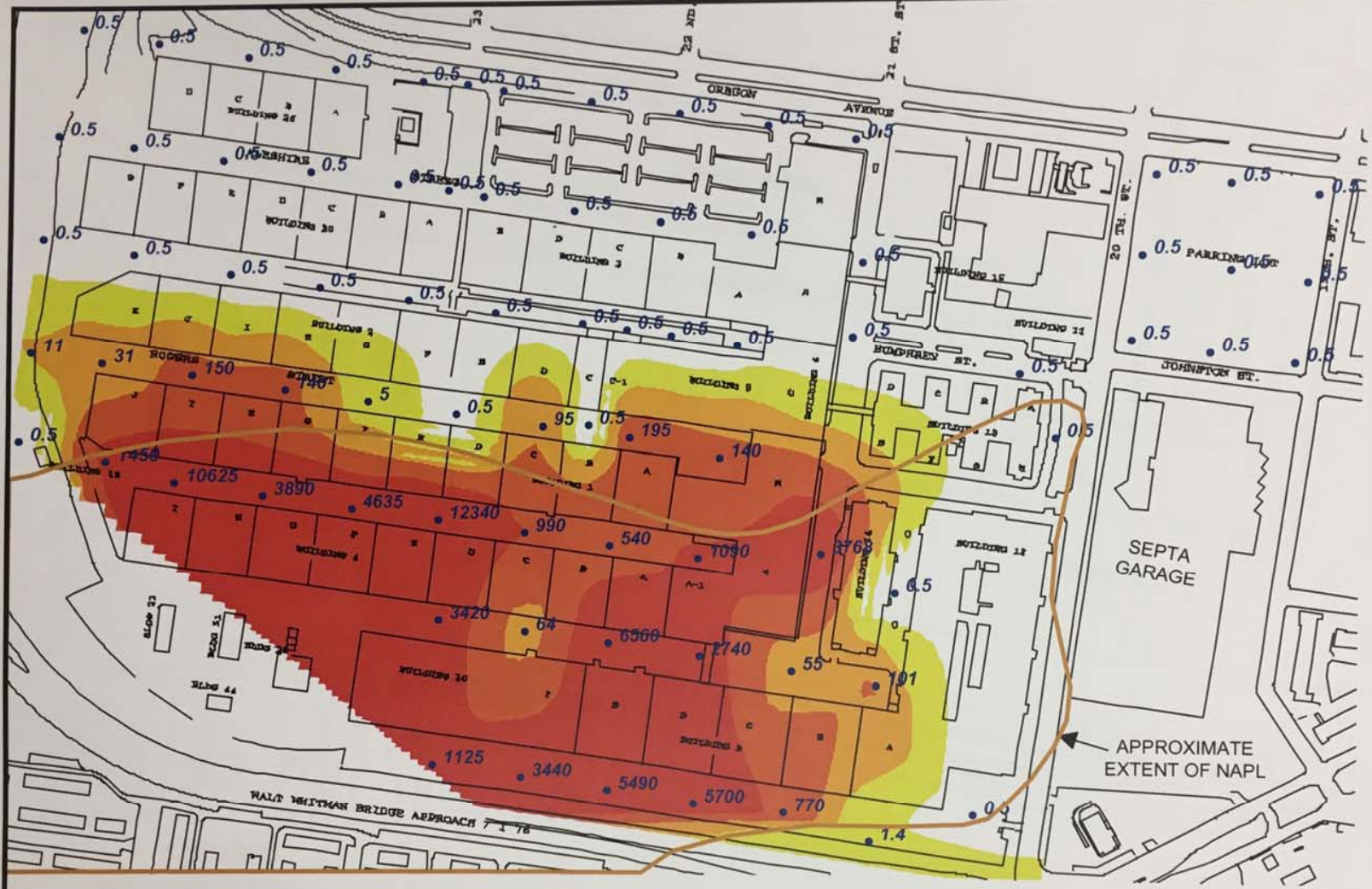
US Army Corps of Engineers
Baltimore District

DEFENSE SUPPLY CENTER PHILADELPHIA
PHILADELPHIA, PENNSYLVANIA

SOIL GAS BTX CONCENTRATIONS - PADEP SOIL GAS SURVEY (1996)

MALCOLM PIRNIE

FIGURE 8



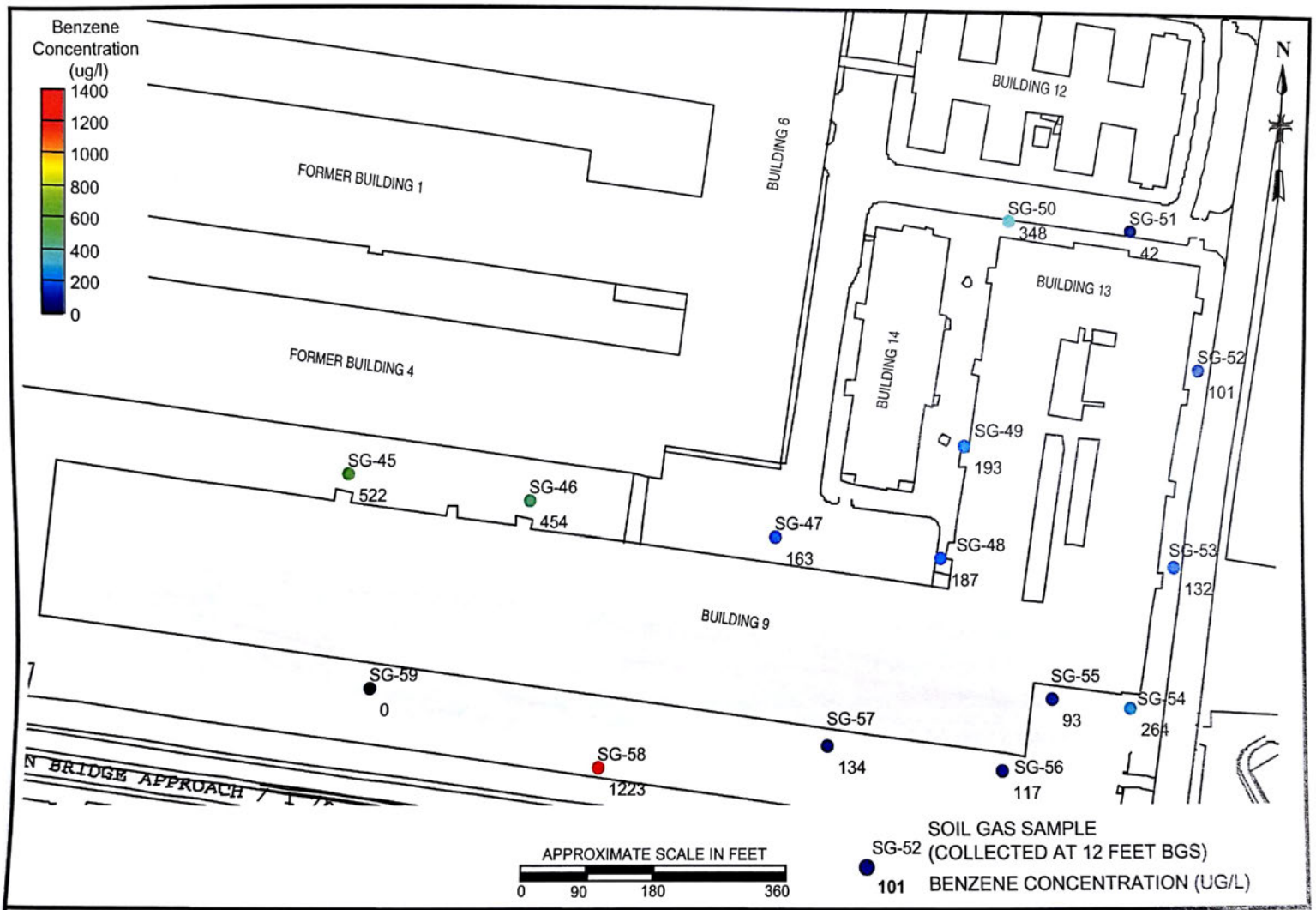
US Army Corps of Engineers
Baltimore District

DEFENSE SUPPLY CENTER PHILADELPHIA
PHILADELPHIA, PENNSYLVANIA

SOIL GAS BTEX CONCENTRATIONS - 12 FEET BELOW GROUND SURFACE (1995)

MALCOLM PIRNIE

FIGURE 7



US Army Corps of Engineers Baltimore District

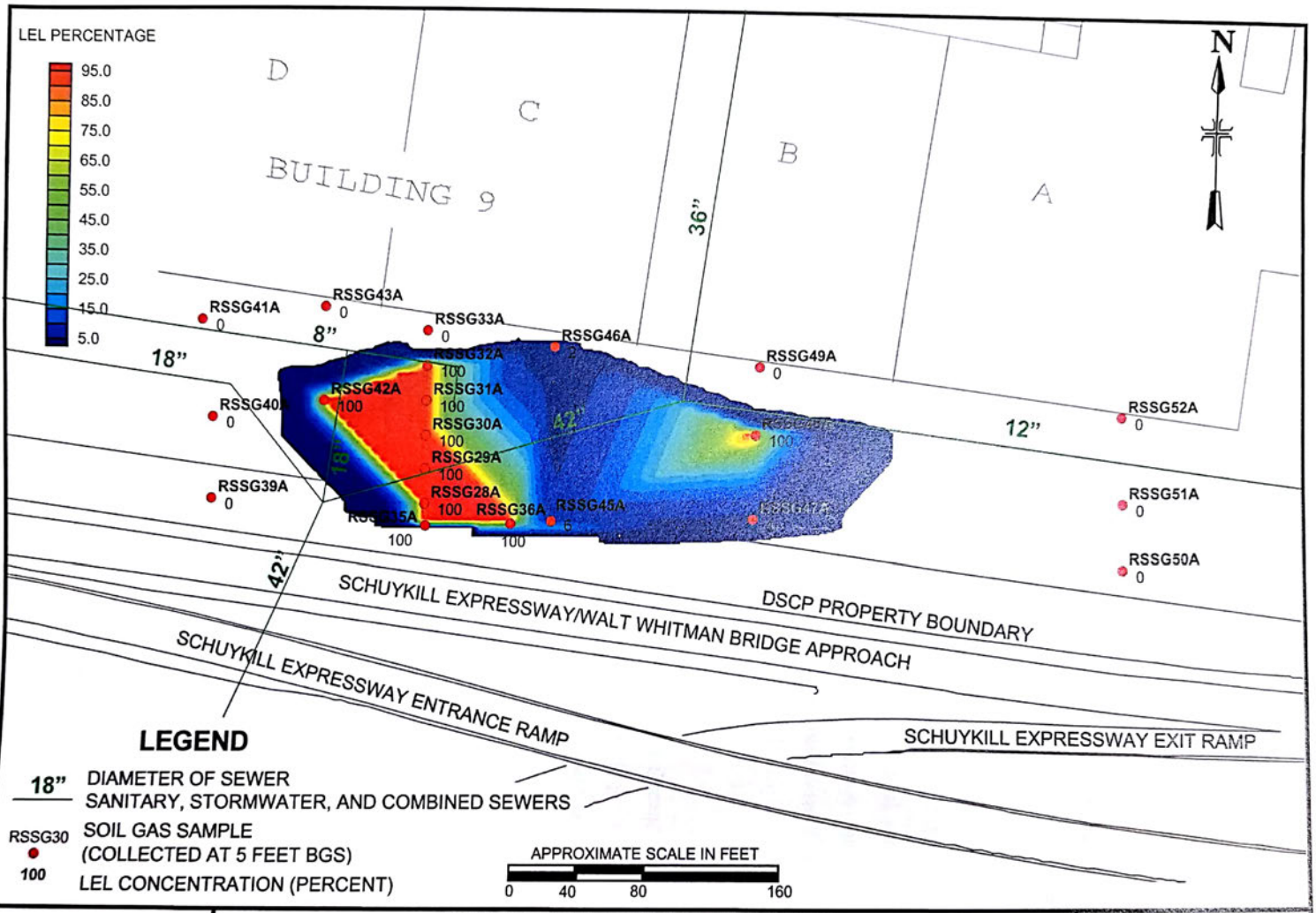
DEFENSE SUPPLY CENTER PHILADELPHIA
PHILADELPHIA, PENNSYLVANIA

PREVIOUS SOIL GAS RESULTS AT DSCP (RISK ASSESSMENT ONLY)

MALCOLM PIRNIE

FIGURE 9

Scanned by CamScanner



US Army Corps of Engineers
Baltimore District

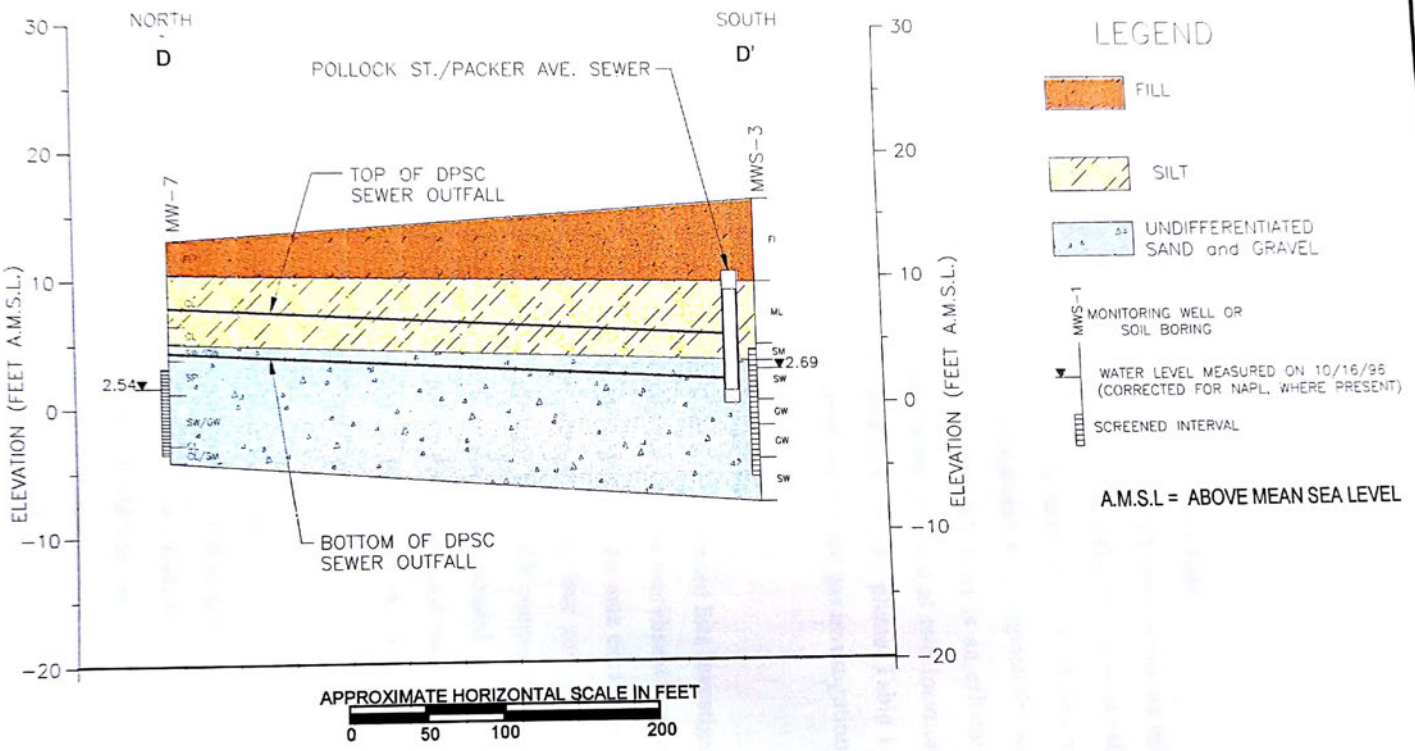
DEFENSE SUPPLY CENTER PHILADELPHIA
PHILADELPHIA, PENNSYLVANIA

RESULTS OF SHALLOW SOIL GAS SAMPLES SOUTH OF BUILDING 9 (2000)

MALCOLM PIRNIE

FIGURE 10

Scanned by CamScanner



US Army Corps of Engineers
Baltimore District

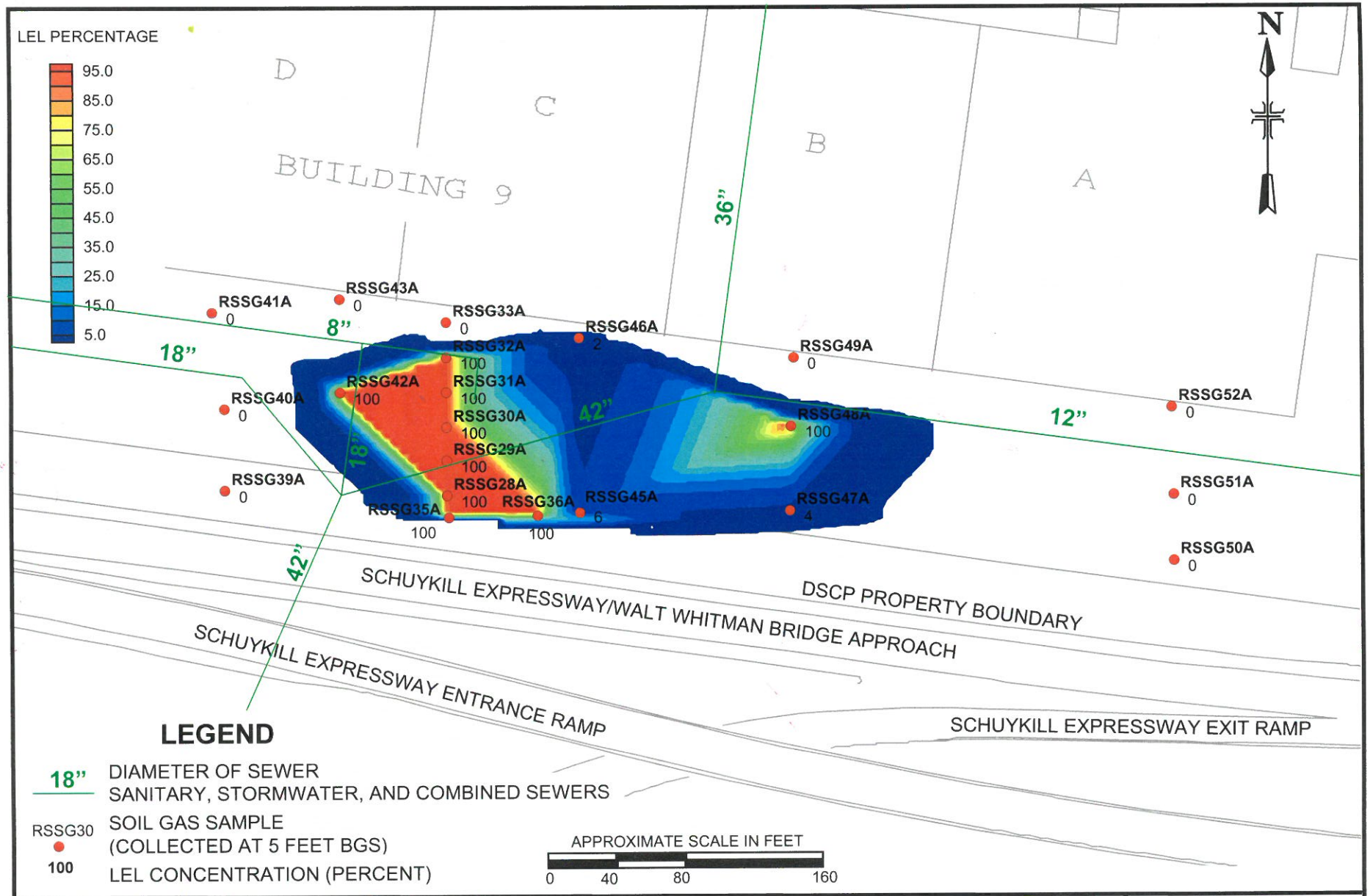
DEFENSE SUPPLY CENTER PHILADELPHIA
PHILADELPHIA, PENNSYLVANIA

CROSS SECTION D-D' - DSCP COMBINED SEWER OUTFALL

MALCOLM PIRNIE

FIGURE 11

Scanned by CamScanner



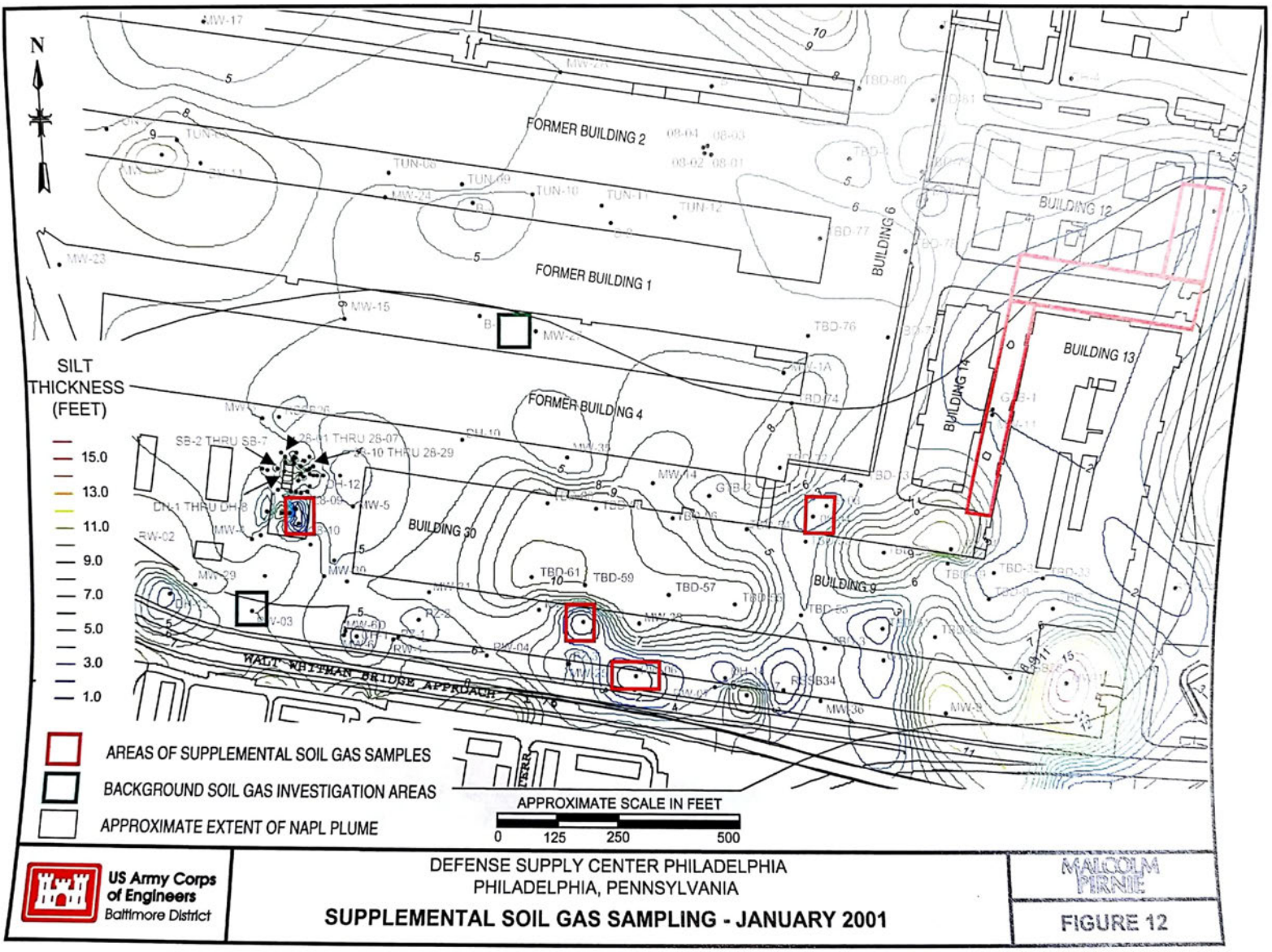
US Army Corps of Engineers
Baltimore District

DEFENSE SUPPLY CENTER PHILADELPHIA
PHILADELPHIA, PENNSYLVANIA

RESULTS OF SHALLOW SOIL GAS SAMPLES SOUTH OF BUILDING 9 (2000)

MALCOLM PIRNIE

FIGURE 10



Scanned by CamScanner

Appendix R

Offsite Sources

Appendix R

Subsection One:
Data Gap Analysis Report Figures

CITY: SF DIV/GROUP: ENV/IM DB: MESTIFANOS LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
TotalVOCsFig18A GW SUN TotalVOCs greater10KShallowZone D-size a.mxd 7/7/2013 10:15:57 PM

SUN-N-57

Date	8/1/1985	1/1/1986	8/3/1988	12/2/1993	12/13/1994	11/20/1996	11/17/1997	11/11/1998	12/1/1999	11/15/2000	11/12/2002	11/14/2003	10/19/2004	11/7/2005
Benzene	330	300	< 50 U/47.2	20	110 J	190	180	82 J	120	110	6	24.1	38	2
Ethylbenzene	2100	1300	< 50 U	4	720	13	< 100 U	< 100 U	< 100 U	< 100 U	2	1.1	< 5 U	1
m,p-Xylenes	--	--	3200	--	--	--	--	--	--	290	140	--	--	--
MTBE	--	--	--	--	--	--	--	--	--	260	< 1 U	< 1 U	< 5 U	< 1 U
m-Xylene	< 15000 U	9600	--	470	--	--	--	--	--	--	--	--	--	--
o,p-Xylenes	< 2100 U	< 1300 U	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	< 50 U	< 500 U	< 50 U/3.9	2	< 250 U	2.8	< 100 U	< 100 U	< 100 U	< 100 U	< 1 U	1.1	< 5 U	< 1 U
Xylenes	--	--	1600	--	4140	2000	1900	1600	660	--	--	32.3	140	57
Total VOCs	2430	11200	3566.1	593	4970 J	2205.8	2080	1682 J	780	810	211	58.6	178	60

SUN-MW-32

Date	4/26/2005	11/10/2005
Benzene	420	801
Ethylbenzene	1100	3160
MTBE	< 250 U	285
Toluene	4600	2430
Xylenes	6200	13100
Total VOCs	12320	20364

SUN-MW-36

Date	4/25/2005
Benzene	150000
Ethylbenzene	< 5000 U
MTBE	< 5000 U
Toluene	< 5000 U
Xylenes	< 5000 U
Total VOCs	150000

SUN-TW-3

Date	10/15/2004	4/25/2005
Benzene	130000	63000
Ethylbenzene	3500	2700
MTBE	170000	56000
Toluene	48000	29000
Xylenes	20000	17000
Total VOCs	371500	167700

SUN-S-81

Date	8/4/1988	11/30/1993	12/13/1994	12/28/1995	11/19/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001
Benzene	13000	20000	9500	21000	130	17000	12000	4000	54000	2100
Ethylbenzene	--	680	70 J	--	3.7	230	120	110	< 100 U	< 100 U
m,p-Xylenes	3000	--	--	--	--	--	--	--	< 100 U	< 100 U
MTBE	--	--	--	--	--	--	--	--	< 100 U	130
Toluene	2100	64	180 J	300	< 0.3 U	92 J	< 100 U	< 100 U	< 100 U	< 100 U
Xylenes	--	600	150 J	470 J	2.6	280	94 J	230	--	--
Total VOCs	18243	21344	9900 J	21770 J	136.3	17602 J	12214 J	4340	54000	2100

SUN-TW-5

Date	10/14/2004	4/25/2005
Benzene	700000	450000
Ethylbenzene	540	< 5000 U
MTBE	< 200 U	< 5000 U
Toluene	12000	8500
Xylenes	2100	< 5000 U
Total VOCs	714640	458500

SUN-S-183

Date	10/13/2004	4/18/2005
Benzene	9900	14000
Ethylbenzene	77	< 130 U
MTBE	< 44 U	140
Toluene	84	130
Xylenes	190	290
Total VOCs	10251	14560

SUN-N-58

Date	8/11/1988	10/19/2004
Benzene	13900	28
Ethylbenzene	--	< 5 U
MTBE	--	< 5 U
Toluene	--	< 5 U
Xylenes	--	130
Total VOCs	13900	158

SUN-N-48

Date	8/13/1985	1/1/1986
Benzene	4200	700
Ethylbenzene	< 500 U	< 25 U
m-Xylene	3600	330
o,p-Xylenes	3300	360
Toluene	4500	220
Total VOCs	15800	1610

SUN-MW-31

Date	4/26/2005
Benzene	2600
Ethylbenzene	290
MTBE	< 250 U
Toluene	510
Xylenes	1000
Total VOCs	4400

SUN-MW-37

Date	4/26/2005
Benzene	370000
Ethylbenzene	12000
MTBE	< 10000 U
Toluene	31000
Xylenes	41000
Total VOCs	454000

SUN-TW-10

Date	4/27/2005
Benzene	9200
Ethylbenzene	3200
MTBE	84000
Toluene	24000
Xylenes	20000
Total VOCs	140400

SUN-PZ-402

Date	10/13/2004	4/20/2005
Benzene	21000	25000
Ethylbenzene	810	2200
MTBE	2800	2300
Toluene	230	300
Xylenes	1500	3700
Total VOCs	26340	33500

SUN-S-82

Date	1/21/1997	11/8/2005
Benzene	18000 E.L/27000	19900
Ethylbenzene	1400/1500	248
m,p-Xylenes	4600 L/5900	--
MTBE	--	3100
Toluene	4900 E/7300	91
Xylenes	--	850
Total VOCs	31000/43800	24482

SUN-N-74

Date	3/10/1994
Benzene	37730
Total VOCs	37730

SUN-S-77P

Date	10/12/2004	4/20/2005
Benzene	16000	17000
Ethylbenzene	270	< 500 U
MTBE	4100	10000
Toluene	68	< 500 U
Xylenes	650	< 500 U
Total VOCs	21088	27000

SUN-S-182

Date	10/13/2004	4/18/2005
Benzene	9500	12000
Ethylbenzene	130	140
MTBE	240	340
Toluene	130	150
Xylenes	250	320
Total VOCs	10250	12950

SUN-S-215

Date	4/19/2005
Benzene	29000
Ethylbenzene	3300
MTBE	51000
Toluene	29000
Xylenes	19000
Total VOCs	131300

SUN-S-204

Date	4/19/2005
Benzene	26000
Ethylbenzene	< 10000 U
MTBE	370000
Toluene	< 10000 U
Xylenes	< 10000 U
Total VOCs	396000

SUN-S-125

Date	10/13/2004	4/19/2005
Benzene	7600	17000
Ethylbenzene	380	250
MTBE	800	11000
Toluene	190	180
Xylenes	1300	920
Total VOCs	10270	29350

SUN-S-226

Date	4/22/2005
Benzene	91000
Ethylbenzene	1200
MTBE	< 1000 U
Toluene	6100
Xylenes	4700
Total VOCs	103000

SUN-S-127

Date	10/19/2004	4/22/2005
Benzene	15000	15000
Ethylbenzene	1400	< 1000 U
MTBE	6400	1700
Toluene	130	< 1000 U
Xylenes	1700	1000
Total VOCs	24630	17700

SUN-S-79

Date	8/13/1985
Benzene	4200
Ethylbenzene	< 500 U
m-Xylene	3600
o,p-Xylenes	3300
Toluene	4500
Total VOCs	15600

SUN-S-203

Date	4/20/2005
Benzene	940
Ethylbenzene	< 100 U
MTBE	17000
Toluene	< 100 U
Xylenes	220
Total VOCs	18160

SUN-W-17

Date	7/30/1985	1/1/1986	10/14/1988	10/27/2004
Benzene	< 4000 U	260	350	8.9
Ethylbenzene	1100	210	680	< 5 U
MTBE	--	--	--	< 5 U
m-Xylene	39000	4900	--	--
o,p-Xylenes	29000	4100	--	--
Toluene	< 4000 U	< 1000 U	< 250 U	< 5 U
Xylenes	--	--	7000	10
Total VOCs	69100	9470	8030	18.9

SUN-S-209

Date	4/22/2005
Benzene	7600
Ethylbenzene	460
MTBE	77
Toluene	91
Xylenes	1800
Total VOCs	10028

SUN-S-49

Date	8/4/1988
Benzene	14300
Total VOCs	14300

SUN-S-68

Date	7/17/1985	1/1/1986
Benzene	110	1300
Ethylbenzene	490	7700
m-Xylene	< 100 U	14000
o,p-Xylenes	690	13000
Toluene	< 100 U	< 625 U
Total VOCs	1290	36000

SUN-S-50

Date	8/6/1985	1/1/1986	8/2/1988	11/30/1993	1/1/1994	12/28/1995	11/19/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/27/2001
Benzene	23000	24000	24000 U/100	290	290	17000	14	21000	18000	28000	47000	53000
Ethylbenzene	5400	2300	< 5000 U	< 25 U	160	98	< 0.4 U	1300	570	< 1000 U	240	9
m,p-Xylenes	--	--	--	--	--	--	--	--	--	--	370	--
MTBE	--	--	--	--	--	--	--	--	--	--	590	5200
m-Xylene	12000	660	--	--	--	--	--	--	--	--	--	--
o,p-Xylenes	11000	860	--	--	--	--	--	--	--	--	--	--
Toluene	< 500 U	< 1000 U	< 5000 U	< 25 U	20	1600	< 0.3 U	210	57 J	< 1000 U	< 100 U	1400
Xylenes	--	--	< 5000 U	< 25 U	40	3000	< 0.6 U	2200	980	< 1000 U	--	1300
Total VOCs	51400	27820	10000/ND	290	510	21698	14	24710	19607 J	28000	48200	60909

SUN-S-43

Date	8/10/1988	12/1/1993	12/13/1994	12/28/1995	11/13/1996	11/19/1997	5/11/1998	11/12/1998	12/2/1999	11/16/2000	11/14/2001	11/12/2002	11/13/2003	10/19/2004	4/21/2005	5/2/2005	11/8/2005
Benzene	15830	12000	17000	12000	2100	13000	2200 L	6700	3600	990	6100	5500	3600	720	940	820	5520
Ethylbenzene	--	1300	250 J	170	120	1200	280 L	720	< 100 U	< 100 U	< 500 U	790	863	150	160	160	1090
m,p-Xylenes	478	--	--	--	--	--	160	--	--	< 100 U	--	460	--	--	--	--	--
MTBE	--	--	--	--	--	--	--	--	--	< 100 U	< 500 U	< 50 U	18.8	< 4.4 U	10	< 20 U	20
Toluene	9410	190	1700	1200	110	210	34	94 J	< 100 U	< 100 U	< 500 U	170	130	31	41	35	212
Xylenes	--	1000	1680	860	110	1000	--	470	250	--	< 1000 U	--	489	90	98	100	716
Total VOCs	25718	14490	20630 J	14230	2440	15410	2685	7984 J	3850	990	6100	6920	5100.8	991	1249	1115	7856

SUN-S-40

Date	8/6/1985	1/1/1986	8/4/1988	10/13/1988	12/1/1993	12/13/1994	12/28/1995	11/13/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001	11/12/2002	11/13/2003	11/8/2005	11/7/2008
1,2-Dibromoethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 2 U
1,2-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 2 U
Benzene	2800	600	4400	2000	78	280	150	12	350	630	1000	600	1200	240	987	436	< 2 U
Ethylbenzene	1200	210	--	2900	12	140 J	29	3.4	< 100 U	< 100 U	< 100 U	< 100 U	68	7	19.5	28	< 2 U
m,p-Xylenes	--	--	400	--	--	--	--	--	--	--	--	< 100 U	< 50 U	8	--	--	< 4 U
MTBE	--	--	--	--	--	--	--	--	--	--	--	< 100 U	1200	< 5 U	< 5 U	< 10 U	< 2 U
m-Xylene	3300	660	--	--	5	--	--	--	--	--	--	--	--	--	--	--	--
o,p-Xylenes	2800	860	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	< 500 U	< 250 U	830	< 1200 U	6	55 J	23	1.8	< 100 U	< 100 U	< 100 U	< 100 U	76	9	36.9	17	< 2 U
Xylenes	--	--	--	4100	--	75 J	51.2	1.9	56 J	< 100 U	< 100 U	--	--	--	20.9	56	--
Total VOCs	10100	2330	5630	9000	112	550 J	253.2	19.1	406 J	630	1000	600	2544	264	1064.3	666	ND

VOCs	Action Level
1,1,2,2-Tetrachloroethane	4.3 µg/L
1,2,4-Trimethylbenzene	62 µg/L
1,2-Dibromoethane	0.05 µg/L
1,2-Dichloroethane	5 µg/L
1,3,5-Trimethylbenzene	53 µg/L
Benzene	5 µg/L
Chloromethane	30 µg/L
Ethylbenzene	700 µg/L
m,p-Xylenes	10000 µg/L
Methylene Chloride	5 µg/L
MTBE	20 µg/L
m-Xylene	10000 µg/L
o,p-Xylenes	10000 µg/L
Tetrachloroethene	5 µg/L
Toluene	1000 µg/L
Trichloroethene	5 µg/L
Vinyl chloride	2 µg/L
Xylenes	10000 µg/L

Notes:

1. VOCs are screened against Action Level of Non-Residential Used aquifer (TDS <2500 mg/L) Groundwater MSCs for VOCs.
2. < indicates non-detects.
3. All units are in micrograms per liter (µg/L).
4. Results shown are for Total VOCs where sample(s) greater than or equal to 10,000 µg/L.
5. MSC - Medium-Specific Concentration
6. VOC - Volatile Organic Compound
7. TDS - Total Dissolved Solids
8. D - The reported value is from a dilution
9. J - The analyte was positively identified; the quantitation is an estimation
10. U - Undetected at the Limit of Detection

Legend

Total VOCs (Intermediate Aquifer Wells)

- ≤ 1,000 ppb
- ≥1000 & < 10,000 ppb
- ≥10,000 & < 20,000 ppb
- ≥ 20,000 ppb
- Well Location Not Sampled

Total VOCs (Shallow Aquifer Wells)

- ≤ 1,000 ppb
- ≥1000 & < 10,000 ppb
- ≥10,000 & < 20,000 ppb
- ≥ 20,000 ppb
- Well Location Not Sampled

- Manhole
- Sewer Line
- Potential Area of Confining Bed Thinning and/or Absence – DW-04, DW-06, DW-10, DW-11, and DW-12
- Value — Exceedes Non-Residential Used aquifer (TDS<2500 mg/L) Groundwater MSCs for VOCs
- Value — Exceedances is due to an elevated detection limit

0 740 1,480 2,220 2,960
SCALE IN FEET

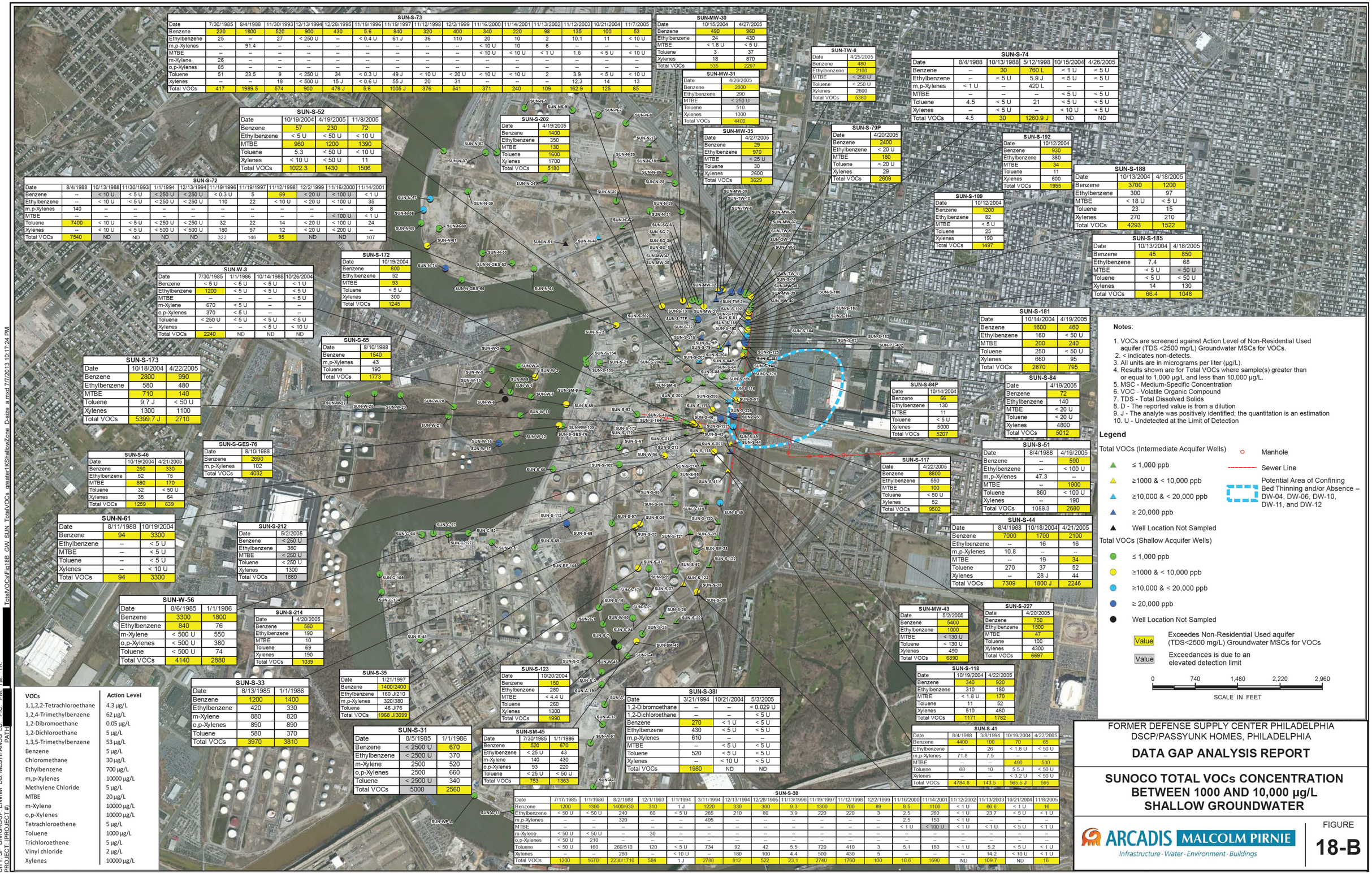
FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

DATA GAP ANALYSIS REPORT

SUNOCO TOTAL VOCs CONCENTRATION GREATER THAN 10,000 µg/LSHALLOW GROUNDWATER

ARCADIS MALCOLM PIRNIE
Infrastructure · Water · Environment · Buildings

FIGURE
18-A



SUN-S-73

Date	7/30/1985	8/4/1988	11/30/1993	12/13/1994	12/28/1995	11/19/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001	11/13/2002	11/12/2003	10/21/2004	11/7/2005
Benzene	230	1800	520	900	430	5.6	840	320	400	340	220	98	135	100	53
Ethylbenzene	25	--	27	< 250 U	--	< 0.4 U	61 J	36	110	20	10	2	10.1	11	< 10 U
m,p-Xylenes	--	91.4	--	--	--	--	--	--	--	< 10 U	10	6	--	--	--
MTBE	--	--	--	--	--	--	--	--	--	< 10 U	< 10 U	< 1 U	1.6	< 5 U	< 10 U
m-Xylene	26	--	--	--	--	--	--	--	--	--	--	--	--	--	--
o,p-Xylenes	85	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	51	23.5	9	< 250 U	34	< 0.3 U	49 J	< 10 U	< 20 U	< 10 U	< 10 U	2	3.9	< 5 U	< 10 U
Xylenes	--	--	18	< 500 U	15 J	< 0.6 U	55 J	20	31	--	--	--	12.3	14	13
Total VOCs	417	1989.5	574	900	479 J	5.6	1005 J	376	541	371	240	109	162.9	125	85

SUN-MW-30

Date	10/15/2004	4/27/2005
Benzene	490	960
Ethylbenzene	24	430
MTBE	< 1.8 U	< 5 U
Toluene	3	37
Xylenes	18	870
Total VOCs	535	2297

SUN-TW-8

Date	4/25/2005
Benzene	480
Ethylbenzene	2100
MTBE	< 250 U
Toluene	< 250 U
Xylenes	2800
Total VOCs	5380

SUN-S-74

Date	8/4/1988	10/13/1988	5/12/1998	10/15/2004	4/26/2005
Benzene	--	30	760 L	< 1 U	< 5 U
Ethylbenzene	--	< 5 U	5.9 J	< 5 U	< 5 U
m,p-Xylenes	< 1 U	--	420 L	--	--
MTBE	--	--	--	< 5 U	< 5 U
Toluene	4.5	< 5 U	21	< 5 U	< 5 U
Xylenes	--	< 5 U	--	< 10 U	< 5 U
Total VOCs	4.5	30	1260.9 J	ND	ND

SUN-S-52

Date	10/19/2004	4/19/2005	11/8/2005
Benzene	57	230	72
Ethylbenzene	< 5 U	< 50 U	< 10 U
MTBE	960	1200	1390
Toluene	5.3	< 50 U	< 10 U
Xylenes	< 10 U	< 50 U	11
Total VOCs	1022.3	1430	1506

SUN-S-202

Date	4/19/2005
Benzene	1400
Ethylbenzene	350
MTBE	130
Toluene	1600
Xylenes	1700
Total VOCs	5180

SUN-MW-31

Date	4/26/2005
Benzene	2600
Ethylbenzene	290
MTBE	< 250 U
Toluene	510
Xylenes	1000
Total VOCs	4400

SUN-MW-35

Date	4/27/2005
Benzene	29
Ethylbenzene	970
MTBE	< 25 U
Toluene	30
Xylenes	2600
Total VOCs	3629

SUN-S-79P

Date	4/20/2005
Benzene	2400
Ethylbenzene	< 20 U
MTBE	180
Toluene	< 20 U
Xylenes	29
Total VOCs	2609

SUN-S-192

Date	10/12/2004
Benzene	930
Ethylbenzene	380
MTBE	34
Toluene	11
Xylenes	600
Total VOCs	1955

SUN-S-72

Date	8/4/1988	10/13/1988	11/30/1993	1/1/1994	12/13/1994	11/19/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001
Benzene	--	< 10 U	< 5 U	< 250 U	< 250 U	< 0.3 U	5	69	< 20 U	< 100 U	< 1 U
Ethylbenzene	--	< 10 U	< 5 U	< 250 U	< 250 U	110	22	< 10 U	< 20 U	< 100 U	35
m,p-Xylenes	140	--	--	--	--	--	--	--	--	--	8
MTBE	--	--	--	--	--	--	--	--	--	< 100 U	< 1 U
Toluene	7400	< 10 U	< 5 U	< 250 U	< 250 U	32	22	14	< 20 U	< 100 U	24
Xylenes	--	< 10 U	< 5 U	< 500 U	< 500 U	180	97	12	< 20 U	< 200 U	--
Total VOCs	7540	ND	ND	ND	ND	322	146	95	ND	ND	107

SUN-S-189

Date	10/12/2004
Benzene	1200
Ethylbenzene	82
MTBE	< 5 U
Toluene	25
Xylenes	190
Total VOCs	1497

SUN-S-188

Date	10/13/2004	4/18/2005
Benzene	3700	1200
Ethylbenzene	300	97
MTBE	< 18 U	< 5 U
Toluene	23	15
Xylenes	270	210
Total VOCs	4293	1522

SUN-S-172

Date	10/19/2004
Benzene	800
Ethylbenzene	52
MTBE	93
Toluene	< 5 U
Xylenes	300
Total VOCs	1245

SUN-W-3

Date	7/30/1985	1/1/1986	10/14/1988	10/26/2004
Benzene	< 5 U	< 5 U	< 5 U	< 1 U
Ethylbenzene	1200	< 5 U	< 5 U	< 5 U
MTBE	--	--	--	< 5 U
m-Xylene	670	< 5 U	--	--
o,p-Xylenes	370	< 5 U	--	--
Toluene	< 250 U	< 5 U	< 5 U	< 5 U
Xylenes	--	--	< 5 U	< 10 U
Total VOCs	2240	ND	ND	ND

SUN-S-65

Date	8/10/1988
Benzene	1540
m,p-Xylenes	43
Toluene	190
Total VOCs	1773

SUN-S-185

Date	10/13/2004	4/18/2005
Benzene	45	850
Ethylbenzene	7.4	68
MTBE	< 5 U	< 50 U
Toluene	< 5 U	< 50 U
Xylenes	14	130
Total VOCs	66.4	1048

SUN-S-181

Date	10/14/2004	4/19/2005
Benzene	1600	460
Ethylbenzene	160	< 50 U
MTBE	200	240
Toluene	250	< 50 U
Xylenes	660	95
Total VOCs	2870	795

SUN-S-173

Date	10/18/2004	4/22/2005
Benzene	2800	990
Ethylbenzene	580	480
MTBE	710	140
Toluene	9.7 J	< 50 U
Xylenes	1300	1100
Total VOCs	5399.7 J	2710

SUN-S-84P

Date	10/14/2004
Benzene	66
Ethylbenzene	130
MTBE	11
Toluene	< 5 U
Xylenes	5000
Total VOCs	5207

SUN-S-84

Date	4/19/2005
Benzene	72
Ethylbenzene	140
MTBE	< 20 U
Toluene	< 20 U
Xylenes	4800
Total VOCs	5012

SUN-S-46

Date	10/19/2004	4/21/2005
Benzene	260	330
Ethylbenzene	52	75
MTBE	880	170
Toluene	32	< 50 U
Xylenes	35	64
Total VOCs	1259	639

SUN-S-GES-76

Date	8/10/1988
Benzene	2690
m,p-Xylenes	102
Total VOCs	4032

SUN-S-117

Date	4/22/2005
Benzene	8800
Ethylbenzene	550
MTBE	100
Toluene	< 50 U
Xylenes	52
Total VOCs	9502

SUN-S-51

Date	8/4/1988	4/19/2005
Benzene	--	590
Ethylbenzene	--	< 100 U
m,p-Xylenes	47.3	--
MTBE	--	1900
Toluene	860	< 100 U
Xylenes	--	190
Total VOCs	1059.3	2680

SUN-S-44

Date	8/4/1988	10/18/2004	4/21/2005
Benzene	7000	1700	2100
Ethylbenzene	--	16	16
m,p-Xylenes	10.8	--	--
MTBE	--	19	34
Toluene	270	37	52
Xylenes	--	28 J	44
Total VOCs	7309	1800 J	2246

SUN-N-61

Date	8/11/1988	10/19/2004
Benzene	94	3300
Ethylbenzene	--	< 5 U
MTBE	--	< 5 U
Toluene	--	< 5 U
Xylenes	--	< 10 U
Total VOCs	94	3300

SUN-S-212

Date	5/2/2005
Benzene	< 250 U
Ethylbenzene	360
MTBE	< 250 U
Toluene	< 250 U
Xylenes	1300
Total VOCs	1660

SUN-MW-43

Date	5/2/2005
Benzene	5400
Ethylbenzene	1000
MTBE	< 130 U
Toluene	< 130 U
Xylenes	490
Total VOCs	6890

SUN-S-227

Date	4/20/2005
Benzene	750
Ethylbenzene	1500
MTBE	47
Toluene	100
Xylenes	4300
Total VOCs	6697

SUN-W-56

Date	8/6/1985	1/1/1986
Benzene	3300	1800
Ethylbenzene	840	76
m-Xylene	< 500 U	550
o,p-Xylenes	< 500 U	380
Toluene	< 500 U	74
Total VOCs	4140	2880

SUN-S-214

Date	4/20/2005
Benzene	580
Ethylbenzene	190
MTBE	10
Toluene	69
Xylenes	190
Total VOCs	1039

SUN-S-123

Date	10/20/2004
Benzene	150
Ethylbenzene	280
MTBE	< 4.4 U
Toluene	260
Xylenes	1300
Total VOCs	1990

SUN-S-118

Date	10/19/2004	4/22/2005
Benzene	340	920
Ethylbenzene	310	180
MTBE	< 1.8 U	170
Toluene	11	52
Xylenes	510	460
Total VOCs	1171	1782

SUN-S-33

Date	8/13/1985	1/1/1986
Benzene	1200	1400
Ethylbenzene	420	330
m-Xylene	880	820
o,p-Xylenes	890	890
Toluene	580	370
Total VOCs	3970	3810

SUN-S-35

Date	1/21/1997
Benzene	1400/2400
Ethylbenzene	160 J/210
m,p-Xylenes	320/380
Toluene	46 J/76
Total VOCs	1968 J/3099

SUN-S-38I

Date	3/21/1994	10/21/2004	5/3/2005
1,2-Dibromoethane	--	--	< 0.029 U
1,2-Dichloroethane	--	--	< 5 U
Benzene	270	< 1 U	< 5 U
Ethylbenzene	430	< 5 U	< 5 U
m,p-Xylenes	610	--	--
MTBE	--	< 5 U	< 5 U
Toluene	520	< 5 U	< 5 U
Xylenes	--	< 10 U	< 5 U
Total VOCs	1980	ND	ND

SUN-S-31

Date	8/5/1985	1/1/1986
Benzene	< 2500 U	670
Ethylbenzene	< 2500 U	370
m-Xylene	2500	520
o,p-Xylenes	2500	660
Toluene	< 2500 U	340
Total VOCs	5000	2560

SUN-SM-45

Date	7/30/1985	1/1/1986
Benzene	520	670
Ethylbenzene	< 25 U	43
m-Xylene	140	430
o,p-Xylenes	93	220
Toluene	< 25 U	< 50 U
Total VOCs	753	1363

SUN-S-38

Date	7/17/1985	1/1/1986	8/2/1988	12/1/1993	1/1/1994	3/11/1994	12/13/1994	12/28/1995	11/13/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001	11/12/2002	11/13/2003	10/21/2004	11/8/2005
Benzene	1200	1300	1400/930	310	1 J	1220	330	300	9.3	1300	700	89	8.5	1100	< 1 U	66.6	< 1 U	16
Ethylbenzene	< 50 U	< 50 U	240	60	< 5 U	285	210	80	3.9	220	220	3	2.5	260	< 1 U	23.7	< 5 U	< 1 U
m,p-Xylenes	--	--	320	--	--	495	--	--	--	--	--	--	2.5	150	< 1 U	--	--	--
MTBE	--	--	--	--	--	--	--	--	--	--	--	--	< 1 U	< 100 U	< 1 U	< 1 U	< 5 U	< 1 U
m-Xylene	< 50 U	< 50 U	--	30	--	--	--	--	--	--	--	--	--	--	--	--	--	--
o,p-Xylenes	< 50 U	210	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	< 50 U	160	260/510	120	< 5 U	734	92	42	5.5	720	410	3	5.1	180	< 1 U	5.2	< 5 U	< 1 U
Xylenes	--	--	280	--	< 10 U	--	180	100	4.4	500	430	5	--	--	--	14.2	< 10 U	< 1 U
Total VOCs	1200	1670	2230/1710	584	1 J	2788	812	522	23.1	2740	1760	100	18.6	1690	ND	109.7	ND	16

Notes:

1. VOCs are screened against Action Level of Non-Residential Used aquifer (TDS <2500 mg/L) Groundwater MSCs for VOCs.
2. < indicates non-detects.
3. All units are in micrograms per liter (µg/L).
4. Results shown are for Total VOCs where sample(s) greater than or equal to 1,000 µg/L and less than 10,000 µg/L.
5. MSC - Medium-Specific Concentration
6. VOC - Volatile Organic Compound
7. TDS - Total Dissolved Solids
8. D - The reported value is from a dilution
9. J - The analyte was positively identified; the quantitation is an estimation
10. U - Undetected at the Limit of Detection

Legend

Total VOCs (Intermediate Acquifer Wells)

- ≤ 1,000 ppb
- ≥1000 & < 10,000 ppb
- ≥10,000 & < 20,000 ppb
- ≥ 20,000 ppb
- Well Location Not Sampled

Total VOCs (Shallow Acquifer Wells)

- ≤ 1,000 ppb
- ≥1000 & < 10,000 ppb
- ≥10,000 & < 20,000 ppb
- ≥ 20,000 ppb
- Well Location Not Sampled

Value — Exceedes Non-Residential Used aquifer (TDS<2500 mg/L) Groundwater MSCs for VOCs

Value — Exceedances is due to an elevated detection limit

- Manhole
- Sewer Line
- Potential Area of Confining Bed Thinning and/or Absence – DW-04, DW-06, DW-10, DW-11, and DW-12

0 740 1,480 2,220 2,960

SCALE IN FEET

VOCs	Action Level
1,1,2,2-Tetrachloroethane	4.3 µg/L
1,2,4-Trimethylbenzene	62 µg/L
1,2-Dibromoethane	0.05 µg/L
1,2-Dichloroethane	5 µg/L
1,3,5-Trimethylbenzene	53 µg/L
Benzene	5 µg/L
Chloromethane	30 µg/L
Ethylbenzene	700 µg/L
m,p-Xylenes	10000 µg/L
Methylene Chloride	5 µg/L
MTBE	20 µg/L
m-Xylene	10000 µg/L
o,p-Xylenes	10000 µg/L
Tetrachloroethene	5 µg/L
Toluene	1000 µg/L
Trichloroethene	5 µg/L
Vinyl chloride	2 µg/L
Xylenes	10000 µg/L

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

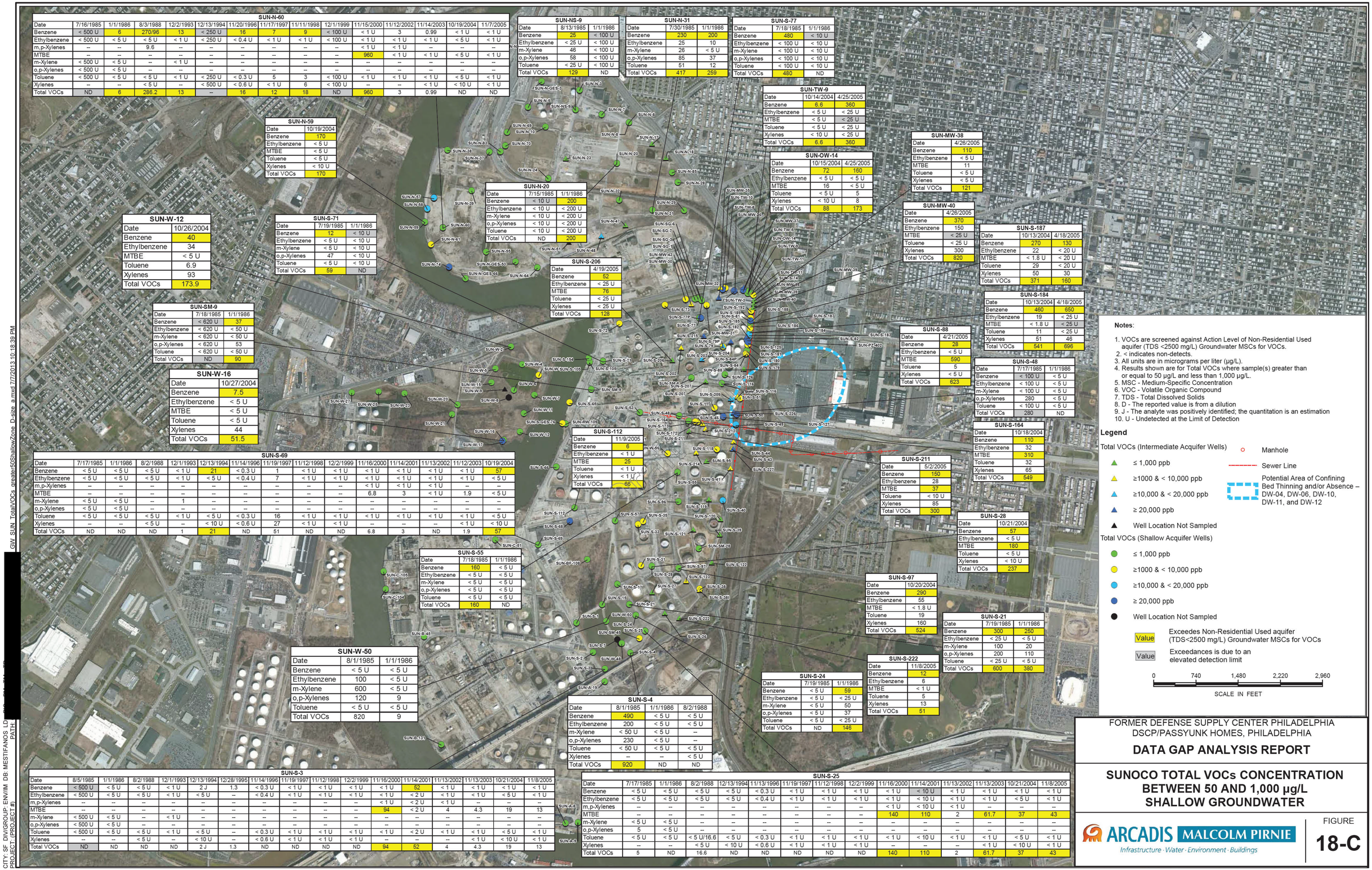
DATA GAP ANALYSIS REPORT

SUNOCO TOTAL VOCs CONCENTRATION BETWEEN 1000 AND 10,000 µg/L SHALLOW GROUNDWATER

ARCADIS MALCOLM PIRNIE
Infrastructure · Water · Environment · Buildings

FIGURE
18-B

CITY: SF DIV/GROUP: ENV/IM DB: MESTIFANOS LD: PIC: PM: TM: TR:
PATH: ...\TotalVOCsFig18B_GW_SUN_TotalVOCs_greaterIKShallowZone_D-size_a.mxd 7/7/2013 10:17:24 PM
PROJECT (PROJECT #)


SUN-N-60
Date | 7/16/1985 | 1/1/1986 | 8/3/1988 | 12/2/1993 | 12/13/1994 | 11/20/1996 | 11/17/1997 | 11/11/1998 | 12/1/1999 | 11/15/2000 | 11/12/2002 | 11/14/2003 | 10/19/2004 | 11/7/2005
Benzene | < 500 U | 6 | 270/96 | 13 | < 250 U | 16 | 7 | 9 | < 100 U | < 1 U | 3 | 0.99 | < 1 U | < 1 U
Ethylbenzene | < 500 U | < 5 U | < 5 U | < 1 U | < 250 U | < 0.4 U | < 1 U | < 1 U | < 100 U | < 1 U | < 1 U | < 1 U | < 5 U | < 1 U
m,p-Xylenes | -- | -- | 9.6 | -- | -- | -- | -- | -- | -- | < 1 U | < 1 U | -- | -- | --
MTBE | -- | -- | -- | -- | -- | -- | -- | -- | -- | 960 | < 1 U | < 1 U | < 5 U | < 1 U
m-Xylene | < 500 U | < 5 U | -- | < 1 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
o,p-Xylenes | < 500 U | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
Toluene | < 500 U | < 5 U | < 5 U | < 1 U | < 250 U | < 0.3 U | 5 | 3 | < 100 U | < 1 U | < 1 U | < 1 U | < 5 U | < 1 U
Xylenes | -- | -- | < 5 U | -- | < 500 U | < 0.6 U | < 1 U | 6 | < 100 U | -- | -- | < 1 U | < 10 U | < 1 U
Total VOCs | ND | 6 | 286.2 | 13 | -- | 16 | 12 | 18 | ND | 960 | 3 | 0.99 | ND | ND
SUN-NS-9
Date | 8/13/1985 | 1/1/1986
Benzene | 25 | < 100 U
Ethylbenzene | < 25 U | < 100 U
m-Xylene | 48 | < 100 U
o,p-Xylenes | 58 | < 100 U
Toluene | < 25 U | < 100 U
Total VOCs | 129 | ND
SUN-N-31
Date | 7/30/1985 | 1/1/1986
Benzene | 230 | 200
Ethylbenzene | 25 | 10
m-Xylene | 26 | < 5 U
o,p-Xylenes | 85 | 37
Toluene | 51 | 12
Total VOCs | 417 | 259
SUN-S-77
Date | 7/18/1985 | 1/1/1986
Benzene | 480 | < 10 U
Ethylbenzene | < 100 U | < 10 U
m-Xylene | < 100 U | < 10 U
o,p-Xylenes | < 100 U | < 10 U
Toluene | < 100 U | < 10 U
Total VOCs | 480 | ND
SUN-TW-9
Date | 10/14/2004 | 4/25/2005
Benzene | 6.6 | 360
Ethylbenzene | < 5 U | < 25 U
MTBE | < 5 U | < 25 U
Toluene | < 5 U | < 25 U
Xylenes | < 10 U | < 25 U
Total VOCs | 6.6 | 360
SUN-MW-38
Date | 4/26/2005
Benzene | 110
Ethylbenzene | < 5 U
MTBE | 11
Toluene | < 5 U
Xylenes | < 5 U
Total VOCs | 121
SUN-N-59
Date | 10/19/2004
Benzene | 170
Ethylbenzene | < 5 U
MTBE | < 5 U
Toluene | < 5 U
Xylenes | < 10 U
Total VOCs | 170
SUN-OW-14
Date | 10/15/2004 | 4/25/2005
Benzene | 72 | 160
Ethylbenzene | < 5 U | < 5 U
MTBE | 16 | < 5 U
Toluene | < 5 U | 5
Xylenes | < 10 U | 8
Total VOCs | 88 | 173
SUN-N-20
Date | 7/15/1985 | 1/1/1986
Benzene | < 10 U | 200
Ethylbenzene | < 10 U | < 200 U
m-Xylene | < 10 U | < 200 U
o,p-Xylenes | < 10 U | < 200 U
Toluene | < 10 U | < 200 U
Total VOCs | ND | 200
SUN-MW-40
Date | 4/26/2005
Benzene | 370
Ethylbenzene | 150
MTBE | < 25 U
Toluene | < 25 U
Xylenes | 300
Total VOCs | 820
SUN-W-12
Date | 10/26/2004
Benzene | 40
Ethylbenzene | 34
MTBE | < 5 U
Toluene | 6.9
Xylenes | 93
Total VOCs | 173.9
SUN-S-71
Date | 7/19/1985 | 1/1/1986
Benzene | 12 | < 10 U
Ethylbenzene | < 5 U | < 10 U
m-Xylene | < 5 U | < 10 U
o,p-Xylenes | 47 | < 10 U
Toluene | < 5 U | < 10 U
Total VOCs | 59 | ND
SUN-S-206
Date | 4/19/2005
Benzene | 52
Ethylbenzene | < 25 U
MTBE | 76
Toluene | < 25 U
Xylenes | < 25 U
Total VOCs | 128
SUN-S-187
Date | 10/13/2004 | 4/18/2005
Benzene | 270 | 130
Ethylbenzene | 22 | < 20 U
MTBE | < 1.8 U | < 20 U
Toluene | 29 | < 20 U
Xylenes | 50 | 30
Total VOCs | 371 | 160
SUN-S-184
Date | 10/13/2004 | 4/18/2005
Benzene | 460 | 650
Ethylbenzene | 19 | < 25 U
MTBE | < 1.8 U | < 25 U
Toluene | 11 | < 25 U
Xylenes | 51 | 46
Total VOCs | 541 | 696
SUN-SM-9
Date | 7/18/1985 | 1/1/1986
Benzene | < 620 U | 37
Ethylbenzene | < 620 U | < 50 U
m-Xylene | < 620 U | < 50 U
o,p-Xylenes | < 620 U | 53
Toluene | < 620 U | < 50 U
Total VOCs | ND | 90
SUN-S-88
Date | 4/21/2005
Benzene | 28
Ethylbenzene | < 5 U
MTBE | 590
Toluene | 5
Xylenes | < 5 U
Total VOCs | 623
SUN-S-48
Date | 7/17/1985 | 1/1/1986
Benzene | < 100 U | < 5 U
Ethylbenzene | < 100 U | < 5 U
m-Xylene | < 100 U | < 5 U
o,p-Xylenes | 280 | < 5 U
Toluene | < 100 U | < 5 U
Total VOCs | 280 | ND
SUN-W-16
Date | 10/27/2004
Benzene | 7.5
Ethylbenzene | < 5 U
MTBE | < 5 U
Toluene | < 5 U
Xylenes | 44
Total VOCs | 51.5
SUN-S-164
Date | 10/18/2004
Benzene | 110
Ethylbenzene | 32
MTBE | 310
Toluene | 32
Xylenes | 65
Total VOCs | 549
SUN-S-69
Date | 7/17/1985 | 1/1/1986 | 8/2/1988 | 12/1/1993 | 12/13/1994 | 11/14/1996 | 11/19/1997 | 11/12/1998 | 12/2/1999 | 11/16/2000 | 11/14/2001 | 11/13/2002 | 11/12/2003 | 10/19/2004
Benzene | < 5 U | < 5 U | < 5 U | < 1 U | 21 | < 0.3 U | 1 | < 1 U | < 1 U | < 1 U | < 1 U | < 1 U | < 1 U | 57
Ethylbenzene | < 5 U | < 5 U | < 5 U | < 1 U | < 5 U | < 0.4 U | 7 | < 1 U | < 1 U | < 1 U | < 1 U | < 1 U | < 1 U | < 5 U
m,p-Xylenes | -- | -- | -- | -- | -- | -- | -- | -- | -- | < 1 U | < 1 U | < 1 U | -- | --
MTBE | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.8 | 3 | < 1 U | 1.9 | < 5 U
m-Xylene | < 5 U | < 5 U | -- | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
o,p-Xylenes | < 5 U | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
Toluene | < 5 U | < 5 U | < 5 U | < 1 U | < 5 U | < 0.3 U | 16 | < 1 U | < 1 U | < 1 U | < 1 U | < 1 U | < 1 U | < 5 U
Xylenes | -- | -- | < 5 U | -- | < 10 U | < 0.6 U | 27 | < 1 U | < 1 U | -- | -- | -- | < 1 U | < 10 U
Total VOCs | ND | ND | ND | 1 | 21 | ND | 51 | ND | ND | 6.8 | 3 | ND | 1.9 | 57
SUN-S-112
Date | 11/9/2005
Benzene | 6
Ethylbenzene | < 1 U
MTBE | 25
Toluene | < 1 U
Xylenes | < 1 U
Total VOCs | 66
SUN-S-28
Date | 10/21/2004
Benzene | 57
Ethylbenzene | < 5 U
MTBE | 180
Toluene | < 5 U
Xylenes | < 10 U
Total VOCs | 237
SUN-S-55
Date | 7/18/1985 | 1/1/1986
Benzene | 160 | < 5 U
Ethylbenzene | < 5 U | < 5 U
m-Xylene | < 5 U | < 5 U
o,p-Xylenes | < 5 U | < 5 U
Toluene | < 5 U | < 5 U
Total VOCs | 160 | ND
SUN-S-97
Date | 10/20/2004
Benzene | 290
Ethylbenzene | 55
MTBE | < 1.8 U
Toluene | 19
Xylenes | 160
Total VOCs | 524
SUN-S-21
Date | 7/19/1985 | 1/1/1986
Benzene | 300 | 250
Ethylbenzene | < 25 U | < 5 U
m-Xylene | 100 | 20
o,p-Xylenes | 200 | 110
Toluene | < 25 U | < 5 U
Total VOCs | 600 | 380
SUN-W-50
Date | 8/1/1985 | 1/1/1986
Benzene | < 5 U | < 5 U
Ethylbenzene | 100 | < 5 U
m-Xylene | 600 | < 5 U
o,p-Xylenes | 120 | 9
Toluene | < 5 U | < 5 U
Total VOCs | 820 | 9
SUN-S-222
Date | 11/8/2005
Benzene | 12
Ethylbenzene | 6
MTBE | < 1 U
Toluene | 5
Xylenes | 13
Total VOCs | 51
SUN-S-24
Date | 7/19/1985 | 1/1/1986
Benzene | < 5 U | 59
Ethylbenzene | < 5 U | < 25 U
m-Xylene | < 5 U | 50
o,p-Xylenes | < 5 U | 37
Toluene | < 5 U | < 25 U
Total VOCs | ND | 146
SUN-S-4
Date | 8/1/1985 | 1/1/1986 | 8/2/1988
Benzene | 490 | < 5 U | < 5 U
Ethylbenzene | 200 | < 5 U | < 5 U
m-Xylene | < 50 U | < 5 U | --
o,p-Xylenes | 230 | < 5 U | --
Toluene | < 50 U | < 5 U | < 5 U
Xylenes | -- | -- | < 5 U
Total VOCs | 920 | ND | ND
SUN-S-211
Date | 5/2/2005
Benzene | 150
Ethylbenzene | 28
MTBE | 37
Toluene | < 10 U
Xylenes | 85
Total VOCs | 300
SUN-S-3
Date | 8/6/1985 | 1/1/1986 | 8/2/1988 | 12/1/1993 | 12/13/1994 | 12/28/1995 | 11/14/1996 | 11/19/1997 | 11/12/1998 | 12/2/1999 | 11/16/2000 | 11/14/2001 | 11/13/2002 | 11/13/2003 | 10/21/2004 | 11/8/2005
Benzene | < 500 U | < 5 U | < 5 U | < 1 U | 2 J | 1.3 | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | 52 | < 1 U | < 1 U | < 1 U | < 1 U
Ethylbenzene | < 500 U | < 5 U | < 5 U | < 1 U | < 5 U | -- | < 0.4 U | < 1 U | < 1 U | < 1 U | < 1 U | < 2 U | < 1 U | < 1 U | < 5 U | < 1 U
m,p-Xylenes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | < 1 U | < 2 U | < 1 U | -- | -- | --
MTBE | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 94 | < 2 U | 4 | 4.3 | 19 | 13
m-Xylene | < 500 U | < 5 U | -- | < 1 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
o,p-Xylenes | < 500 U | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
Toluene | < 500 U | < 5 U | < 5 U | < 1 U | < 5 U | -- | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | < 2 U | < 1 U | < 1 U | < 5 U | < 1 U
Xylenes | -- | -- | < 5 U | -- | < 10 U | -- | < 0.6 U | < 1 U | < 1 U | < 1 U | -- | -- | -- | < 1 U | < 10 U | < 1 U
Total VOCs | ND | ND | ND | ND | 2 J | 1.3 | ND | ND | ND | ND | 94 | 52 | 4 | 4.3 | 19 | 13
SUN-S-25
Date | 7/17/1985 | 1/1/1986 | 8/2/1988 | 12/13/1994 | 11/13/1996 | 11/19/1997 | 11/12/1998 | 12/2/1999 | 11/16/2000 | 11/14/2001 | 11/13/2002 | 11/13/2003 | 10/21/2004 | 11/8/2005
Benzene | < 5 U | < 5 U | < 5 U | < 5 U | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | < 10 U | < 1 U | < 1 U | < 1 U | < 1 U
Ethylbenzene | < 5 U | < 5 U | < 5 U | < 5 U | < 0.4 U | < 1 U | < 1 U | < 1 U | < 1 U | < 10 U | < 1 U | < 1 U | < 5 U | < 1 U
m,p-Xylenes | -- | -- | -- | -- | -- | -- | -- | -- | < 1 U | < 10 U | < 1 U | -- | -- | --
MTBE | -- | -- | -- | -- | -- | -- | -- | -- | 140 | 110 | 2 | 61.7 | 37 | 43
m-Xylene | < 5 U | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
o,p-Xylenes | 5 | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
Toluene | < 5 U | < 5 U | < 5 U/16.6 | < 5 U | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | < 10 U | < 1 U | < 1 U | < 5 U | < 1 U
Xylenes | -- | -- | < 5 U | < 10 U | < 0.6 U | < 1 U | < 1 U | < 1 U | -- | -- | -- | < 1 U | < 10 U | < 1 U
Total VOCs | 5 | ND | 16.6 | ND | ND | ND | ND | ND | 140 | 110 | 2 | 61.7 | 37 | 43
SUN-S-83
Date | 8/6/1985 | 1/1/1986 | 8/2/1988 | 12/1/1993 | 12/13/1994 | 12/28/1995 | 11/14/1996 | 11/19/1997 | 11/12/1998 | 12/2/1999 | 11/16/2000 | 11/14/2001 | 11/13/2002 | 11/13/2003 | 10/21/2004 | 11/8/2005
Benzene | < 500 U | < 5 U | < 5 U | < 1 U | 2 J | 1.3 | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | 52 | < 1 U | < 1 U | < 1 U | < 1 U
Ethylbenzene | < 500 U | < 5 U | < 5 U | < 1 U | < 5 U | -- | < 0.4 U | < 1 U | < 1 U | < 1 U | < 1 U | < 2 U | < 1 U | < 1 U | < 5 U | < 1 U
m,p-Xylenes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | < 1 U | < 2 U | < 1 U | -- | -- | --
MTBE | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 94 | < 2 U | 4 | 4.3 | 19 | 13
m-Xylene | < 500 U | < 5 U | -- | < 1 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
o,p-Xylenes | < 500 U | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
Toluene | < 500 U | < 5 U | < 5 U | < 1 U | < 5 U | -- | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | < 2 U | < 1 U | < 1 U | < 5 U | < 1 U
Xylenes | -- | -- | < 5 U | -- | < 10 U | -- | < 0.6 U | < 1 U | < 1 U | < 1 U | -- | -- | -- | < 1 U | < 10 U | < 1 U
Total VOCs | ND | ND | ND | ND | 2 J | 1.3 | ND | ND | ND | ND | 94 | 52 | 4 | 4.3 | 19 | 13
SUN-S-28
Date | 10/21/2004
Benzene | 57
Ethylbenzene | < 5 U
MTBE | 180
Toluene | < 5 U
Xylenes | < 10 U
Total VOCs | 237
SUN-S-21
Date | 7/19/1985 | 1/1/1986
Benzene | 300 | 250
Ethylbenzene | < 25 U | < 5 U
m-Xylene | 100 | 20
o,p-Xylenes | 200 | 110
Toluene | < 25 U | < 5 U
Total VOCs | 600 | 380
SUN-S-222
Date | 11/8/2005
Benzene | 12
Ethylbenzene | 6
MTBE | < 1 U
Toluene | 5
Xylenes | 13
Total VOCs | 51
SUN-S-24
Date | 7/19/1985 | 1/1/1986
Benzene | < 5 U | 59
Ethylbenzene | < 5 U | < 25 U
m-Xylene | < 5 U | 50
o,p-Xylenes | < 5 U | 37
Toluene | < 5 U | < 25 U
Total VOCs | ND | 146
SUN-S-4
Date | 8/1/1985 | 1/1/1986 | 8/2/1988
Benzene | 490 | < 5 U | < 5 U
Ethylbenzene | 200 | < 5 U | < 5 U
m-Xylene | < 50 U | < 5 U | --
o,p-Xylenes | 230 | < 5 U | --
Toluene | < 50 U | < 5 U | < 5 U
Xylenes | -- | -- | < 5 U
Total VOCs | 920 | ND | ND
SUN-S-211
Date | 5/2/2005
Benzene | 150
Ethylbenzene | 28
MTBE | 37
Toluene | < 10 U
Xylenes | 85
Total VOCs | 300
SUN-S-3
Date | 8/6/1985 | 1/1/1986 | 8/2/1988 | 12/1/1993 | 12/13/1994 | 12/28/1995 | 11/14/1996 | 11/19/1997 | 11/12/1998 | 12/2/1999 | 11/16/2000 | 11/14/2001 | 11/13/2002 | 11/13/2003 | 10/21/2004 | 11/8/2005
Benzene | < 500 U | < 5 U | < 5 U | < 1 U | 2 J | 1.3 | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | 52 | < 1 U | < 1 U | < 1 U | < 1 U
Ethylbenzene | < 500 U | < 5 U | < 5 U | < 1 U | < 5 U | -- | < 0.4 U | < 1 U | < 1 U | < 1 U | < 1 U | < 2 U | < 1 U | < 1 U | < 5 U | < 1 U
m,p-Xylenes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | < 1 U | < 2 U | < 1 U | -- | -- | --
MTBE | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 94 | < 2 U | 4 | 4.3 | 19 | 13
m-Xylene | < 500 U | < 5 U | -- | < 1 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
o,p-Xylenes | < 500 U | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
Toluene | < 500 U | < 5 U | < 5 U | < 1 U | < 5 U | -- | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | < 2 U | < 1 U | < 1 U | < 5 U | < 1 U
Xylenes | -- | -- | < 5 U | -- | < 10 U | -- | < 0.6 U | < 1 U | < 1 U | < 1 U | -- | -- | -- | < 1 U | < 10 U | < 1 U
Total VOCs | ND | ND | ND | ND | 2 J | 1.3 | ND | ND | ND | ND | 94 | 52 | 4 | 4.3 | 19 | 13
SUN-S-25
Date | 7/17/1985 | 1/1/1986 | 8/2/1988 | 12/13/1994 | 11/13/1996 | 11/19/1997 | 11/12/1998 | 12/2/1999 | 11/16/2000 | 11/14/2001 | 11/13/2002 | 11/13/2003 | 10/21/2004 | 11/8/2005
Benzene | < 5 U | < 5 U | < 5 U | < 5 U | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | < 10 U | < 1 U | < 1 U | < 1 U | < 1 U
Ethylbenzene | < 5 U | < 5 U | < 5 U | < 5 U | < 0.4 U | < 1 U | < 1 U | < 1 U | < 1 U | < 10 U | < 1 U | < 1 U | < 5 U | < 1 U
m,p-Xylenes | -- | -- | -- | -- | -- | -- | -- | -- | < 1 U | < 10 U | < 1 U | -- | -- | --
MTBE | -- | -- | -- | -- | -- | -- | -- | -- | 140 | 110 | 2 | 61.7 | 37 | 43
m-Xylene | < 5 U | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
o,p-Xylenes | 5 | < 5 U | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | --
Toluene | < 5 U | < 5 U | < 5 U/16.6 | < 5 U | < 0.3 U | < 1 U | < 1 U | < 1 U | < 1 U | < 10 U | < 1 U | < 1 U | < 5 U | < 1 U
Xylenes | -- | -- | < 5 U | < 10 U | < 0.6 U | < 1 U | < 1 U | < 1 U | -- | -- | -- | < 1 U | < 10 U | < 1 U
Total VOCs | 5 | ND | 16.6 | ND | ND | ND | ND | ND | 140 | 110 | 2 | 61.7 | 37 | 43
Notes:
1. VOCs are screened against Action Level of Non-Residential Used aquifer (TDS <2500 mg/L) Groundwater MSCs for VOCs.
2. < indicates non-detects.
3. All units are in micrograms per liter (µg/L).
4. Results shown are for Total VOCs where sample(s) greater than or equal to 50 µg/L and less than 1,000 µg/L.
5. MSC - Medium-Specific Concentration
6. VOC - Volatile Organic Compound
7. TDS - Total Dissolved Solids
8. D - The reported value is from a dilution
9. J - The analyte was positively identified; the quantitation is an estimation
10. U - Undetected at the Limit of Detection
Legend
Total VOCs (Intermediate Aquifer Wells)
≤ 1,000 ppb
≥1000 & < 10,000 ppb
≥10,000 & < 20,000 ppb
≥ 20,000 ppb
Well Location Not Sampled
Total VOCs (Shallow Acquifer Wells)
≤ 1,000 ppb
≥1000 & < 10,000 ppb
≥10,000 & < 20,000 ppb
≥ 20,000 ppb
Well Location Not Sampled
Manhole
Sewer Line
Potential Area of Confining Bed Thinning and/or Absence – DW-04, DW-06, DW-10, DW-11, and DW-12
Value
Exceeds Non-Residential Used aquifer (TDS<2500 mg/L) Groundwater MSCs for VOCs
Value
Exceedances is due to an elevated detection limit
0
740
1,480
2,220
2,960
SCALE IN FEET
FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA
DATA GAP ANALYSIS REPORT
SUNOCO TOTAL VOCs CONCENTRATION BETWEEN 50 AND 1,000 µg/L SHALLOW GROUNDWATER
ARCADIS MALCOLM PIRNIE
Infrastructure · Water · Environment · Buildings
FIGURE
18-C
VOCs | Action Level
1,1,2,2-Tetrachloroethane | 4.3 µg/L
CITY: SF DIV/GROUP: ENV/IM DB: MESTIFANOS LD PATH:
PROJECT: (PROJECT #)
GW SUN TotalVOCs greater50ShallowZone D-size a.mxd 7/7/2013 10:18:39 PM

SUN-N-64												
Date	8/3/1988	11/30/1993	12/13/1994	11/20/1996	11/17/1997	11/11/1998	12/1/1999	11/15/2000	11/12/2002	11/14/2003	10/19/2004	11/7/2005
Benzene	--	< 5 U	< 250 U	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
Ethylbenzene	--	< 5 U	90 J	< 0.4 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 5 U	< 1 U
m,p-Xylenes	19.4	--	--	--	--	--	--	< 1 U	< 1 U	--	--	--
MTBE	--	--	--	--	--	--	--	< 1 U	< 1 U	< 1 U	< 5 U	< 1 U
Toluene	--	< 5 U	< 250 U	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 5 U	< 1 U
Xylenes	--	< 5 U	< 500 U	< 0.6 U	< 1 U	< 1 U	< 1 U	--	--	< 1 U	< 10 U	1
Total VOCs	28	--	90 J	--	--	--	--	--	--	--	--	--

SUN-N-5		
Date	8/3/1988	10/20/2004
Benzene	1.8	< 1 U
Ethylbenzene	--	< 5 U
MTBE	--	< 5 U
Toluene	< 1 U	< 5 U
Xylenes	--	< 10 U
Total VOCs	1.8	ND

SUN-N-GES-1	
Date	8/3/1988
m,p-Xylenes	4
Total VOCs	4

SUN-N-GES-3	
Date	8/3/1988
Benzene	2.2
m,p-Xylenes	< 1 U
Toluene	< 1 U
Total VOCs	2.2

SUN-N-7											
Date	12/2/1993	12/13/1994	11/20/1996	11/17/1997	11/11/1998	12/1/1999	11/15/2000	11/13/2002	11/13/2003	10/20/2004	11/7/2005
Benzene	< 5 U	< 250 U	< 0.3 U	1	< 10 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
Ethylbenzene	< 2 U	480	< 0.4 U	4	< 10 U	< 1 U	< 1 U	< 1 U	< 1 U	< 5 U	< 1 U
m,p-Xylenes	--	--	--	--	--	--	< 1 U	< 1 U	--	--	--
MTBE	--	--	--	--	--	--	1.2	< 1 U	< 1 U	< 5 U	< 1 U
m-Xylene	5	--	--	--	--	--	--	--	--	--	--
Toluene	< 1 U	< 250 U	< 0.3 U	3	< 10 U	< 1 U	1.7	< 1 U	< 1 U	< 5 U	< 1 U
Xylenes	--	< 500 U	< 0.6 U	3	< 10 U	< 1 U	--	--	< 1 U	< 10 U	2
Total VOCs	8	480	ND	11	ND	ND	2.9	ND	ND	ND	6

SUN-N-GES-53			
Date	7/16/1985	1/1/1986	8/3/1988
Benzene	< 500 U	< 5 U	< 5 U/5.4
Ethylbenzene	< 500 U	< 5 U	< 5 U
m,p-Xylenes	--	--	< 1 U
m-Xylene	< 500 U	< 6 U	--
o,p-Xylenes	< 500 U	< 18 U	--
Toluene	< 500 U	< 5 U	< 1 U/< 5 U
Xylenes	--	--	6.6
Total VOCs	ND	ND	7/6.6

SUN-N-39		
Date	7/16/1985	1/1/1986
Benzene	< 5 U	< 5 U
Ethylbenzene	< 5 U	< 5 U
m-Xylene	< 5 U	< 5 U
o,p-Xylenes	< 5 U	6
Toluene	< 5 U	< 5 U
Total VOCs	ND	6

SUN-N-24		
Date	7/16/1985	1/1/1986
Benzene	< 25 U	5
Ethylbenzene	< 10 U	< 5 U
m-Xylene	< 10 U	< 5 U
o,p-Xylenes	< 10 U	< 5 U
Toluene	< 10 U	< 5 U
Total VOCs	ND	5

SUN-N-18		
Date	8/3/1988	10/20/2004
Benzene	--	4.1
Ethylbenzene	--	< 5 U
m,p-Xylenes	36.1	--
MTBE	--	< 5 U
Toluene	12.3	< 5 U
Xylenes	--	< 10 U
Total VOCs	153.4	4.1

SUN-N-8					
Date	7/15/1985	1/1/1986	8/4/1988	10/13/1988	10/20/2004
Benzene	< 5 U	< 5 U	1	< 5 U	< 1 U
Ethylbenzene	< 5 U	< 5 U	--	< 5 U	< 5 U
MTBE	--	--	--	--	< 5 U
m-Xylene	< 5 U	< 5 U	--	--	--
o,p-Xylenes	< 5 U	< 5 U	--	--	--
Toluene	< 5 U	< 5 U	< 1 U	< 5 U	< 5 U
Xylenes	--	--	--	< 5 U	< 10 U
Total VOCs	ND	ND	1	ND	ND

SUN-N-55	
Date	8/3/1988
m,p-Xylenes	10.4
Total VOCs	29.4

SUN-N-GES-66	
Date	8/10/1988
m,p-Xylenes	20
Total VOCs	101

SUN-S-154	
Date	11/10/2005
Benzene	2
Ethylbenzene	< 1 U
MTBE	5
Toluene	< 1 U
Xylenes	3
Total VOCs	10

SUN-S-105	
Date	10/19/2004
Benzene	4.5
Ethylbenzene	< 5 U
MTBE	30
Toluene	< 5 U
Xylenes	< 10 U
Total VOCs	34.5

SUN-TW-11		
Date	10/14/2004	4/25/2005
Benzene	2.3	< 5 U
Ethylbenzene	< 5 U	< 5 U
MTBE	< 5 U	< 5 U
Toluene	< 5 U	< 5 U
Xylenes	< 10 U	< 5 U
Total VOCs	2.3	ND

SUN-MW-39	
Date	4/26/2005
Benzene	8
Ethylbenzene	< 5 U
MTBE	18
Toluene	< 5 U
Xylenes	8
Total VOCs	34

SUN-S-186		
Date	10/13/2004	4/18/2005
Benzene	32	47
Ethylbenzene	5	< 10 U
MTBE	< 5 U	< 10 U
Toluene	< 5 U	< 10 U
Xylenes	12	< 10 U
Total VOCs	49	47

SUN-S-179		
Date	10/14/2004	4/19/2005
Benzene	2.1	< 5 U
Ethylbenzene	< 5 U	< 5 U
MTBE	< 5 U	< 5 U
Toluene	< 5 U	< 5 U
Xylenes	< 10 U	< 5 U
Total VOCs	2.1	ND

SUN-S-207	
Date	4/19/2005
Benzene	< 5 U
Ethylbenzene	< 5 U
MTBE	10
Toluene	< 5 U
Xylenes	< 5 U
Total VOCs	10

SUN-S-116		
Date	10/12/2004	4/18/2005
Benzene	1.1	< 5 U
Ethylbenzene	< 5 U	< 5 U
MTBE	< 5 U	< 5 U
Toluene	< 5 U	< 5 U
Xylenes	< 10 U	< 5 U
Total VOCs	1.1	ND

SUN-S-53	
Date	1/21/1997
Benzene	< 20 U/2
Ethylbenzene	0.69 J/3
m,p-Xylenes	0.16 J/8
Toluene	< 20 U/2
Total VOCs	1.95 J/19

SUN-S-95			
Date	5/13/1998	10/19/2004	4/15/2005
Benzene	12/14	14	< 5 U
Ethylbenzene	< 1 U/0.9 J	< 5 U	< 5 U
m,p-Xylenes	2/2 J	--	--
MTBE	--	< 5 U	8
Toluene	5/5.9 J	< 5 U	< 5 U
Xylenes	--	< 10 U	< 5 U
Total VOCs	20/23.9 J	14	8

SUN-S-39												
Date	8/4/1988	12/1/1993	12/13/1994	11/13/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001	11/12/2002	11/13/2003	10/20/2004	11/8/2005
Benzene	2.5	< 5 U	1 J	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	3.7	< 1 U	< 1 U
Ethylbenzene	--	< 5 U	< 5 U	< 0.4 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	1.3	< 5 U	< 1 U
m,p-Xylenes	--	--	--	--	--	--	--	< 1 U	< 1 U	--	--	--	--
MTBE	--	--	--	--	--	--	--	1.7	1	< 1 U	< 1 U	< 5 U	< 1 U
Toluene	< 1 U	< 5 U	< 5 U	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 5 U	< 1 U
Xylenes	--	< 5 U	< 10 U	< 0.6 U	< 1 U	< 1 U	< 1 U	--	--	--	1.5	< 10 U	< 1 U
Total VOCs	4.9	ND	1 J	ND	ND	ND	ND	1.7	1	ND	6.5	ND	ND

SUN-W-5	
Date	10/27/2004
Benzene	< 1 U
Ethylbenzene	< 5 U
MTBE	7.7
Toluene	< 5 U
Xylenes	< 10 U
Total VOCs	7.7

SUN-RW-109	
Date	11/8/2005
Benzene	4
Ethylbenzene	< 1 U
MTBE	< 1 U
Toluene	1
Xylenes	3
Total VOCs	9

SUN-S-66													
Date	7/17/1985	1/1/1986	8/2/1988	12/2/1993	12/13/1994	11/14/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001	11/13/2002	11/12/2003	10/19/2004
Benzene	< 5 U	< 5 U	< 5 U/6.3	< 50 U	< 5 U	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
Ethylbenzene	< 5 U	< 5 U	< 5 U	< 1 U	< 5 U	< 0.4 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 5 U
m,p-Xylenes	--	--	--	--	--	--	--	--	--	< 1 U	< 1 U	< 1 U	--	--
MTBE	--	--	--	--	--	--	--	--	--	10	1	< 1 U	< 1 U	< 5 U
m-Xylene	< 5 U	< 5 U	--	< 1 U	--	--	--	--	--	--	--	--	--	--
o,p-Xylenes	< 5 U	< 5 U	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	< 5 U	< 5 U	< 5 U	< 1 U	< 5 U	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 5 U
Xylenes	--	--	< 5 U	--	< 10 U	< 0.6 U	< 1 U	< 1 U	< 1 U	--	--	--	< 1 U	< 10 U
Total VOCs	ND	ND	ND/6.3	ND	ND	ND	ND	ND	ND	10	1	ND	ND	ND

SUN-C-97	
Date	10/21/2004
Benzene	1.4
Ethylbenzene	< 5 U
MTBE	12
Toluene	< 5 U
Xylenes	< 10 U
Total VOCs	13.4

SUN-C-127			
Date	11/13/2002	10/21/2004	11/9/2005
Benzene	< 1 U	< 1 U	< 1 U
Ethylbenzene	< 1 U	< 5 U	< 1 U
m,p-Xylenes	< 1 U	--	--
MTBE	--	23	21
Toluene	< 1 U	< 5 U	< 1 U
Xylenes	--	< 10 U	< 1 U
Total VOCs	ND	23	21

SUN-B-45	
Date	11/10/2005
Benzene	3
Ethylbenzene	1
MTBE	< 1 U
Toluene	< 1 U
Xylenes	8
Total VOCs	26

SUN-S-1															
Date	8/8/1985	1/1/1986	8/2/1988	12/1/1993	12/13/1994	12/28/1995	11/14/1996	11/19/1997	11/12/1998	12/2/1999	11/16/2000	11/14/2001	11/13/2003	10/21/2004	11/8/2005
Benzene	< 5 U	< 5 U	< 5 U	< 1 U	< 50 U	2.7	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U
Ethylbenzene	< 5 U	< 5 U	< 5 U	< 1 U	< 50 U	--	< 0.4 U	< 1 U	< 1 U	< 1 U	< 1 U	1	< 1 U	< 5 U	< 1 U
m,p-Xylenes	--	--	--	--	--	--	--	--	--	--	< 1 U	2	--	--	--
MTBE	--	--	--	--	--	--	--	--	--	--	10	38	< 1 U	< 5 U	23
m-Xylene	< 5 U	< 5 U	--	< 1 U	--	--	--	--	--	--	--	--	--	--	--
o,p-Xylenes	< 5 U	< 5 U	--	--	--	--	--	--	--	--	--	--	--	--	--
Toluene	< 5 U	< 5 U	< 5 U	< 1 U	< 50 U	--	< 0.3 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 1 U	< 5 U	< 1 U
Xylenes	--	--	< 5 U	--	< 100 U	0.8 J	< 0.6 U	2	< 1 U	< 1 U	--	--	< 1 U	< 10 U	< 1 U
Total VOCs	ND	ND	ND	ND	ND	3.5 J	ND	2	ND	ND	10	42	ND	ND	23

SUN-B-131			
Date	11/13/2002	10/21/2004	11/9/2005
Benzene	5	1.1	< 1 U
Ethylbenzene	< 1 U	< 5 U	< 1 U
m,p-Xylenes	2	--	--
MTBE	--	< 5 U	< 1 U
Toluene	1	< 5 U	< 1 U
Xylenes	--	< 10 U	< 1 U
Total VOCs	8	1.1	ND

SUN-WP-A	
Date	11/9/2005
Benzene	< 1 U
Ethylbenzene	< 1 U
MTBE	21
Toluene	< 1 U
Xylenes	< 1 U
Total VOCs	21

SUN-A-4	
Date	10/22/2004
Benzene	1.2
Ethylbenzene	< 5 U
MTBE	< 5 U
Toluene	< 5 U
Xylenes	< 10 U
Total VOCs	1.2

SUN-A-9	
Date	10/22/2004
Benzene	< 1 U
Ethylbenzene	< 5 U
MTBE	12
Toluene	< 5 U
Xylenes	< 10 U
Total VOCs	12

SUN-A-137			
Date	11/13/2002	10/22/2004	11/9/2005
Benzene	< 1 U	< 1 U	< 1 U
Ethylbenzene	< 1 U	< 5 U	< 1 U
m,p-Xylenes	< 1 U	--	--
MTBE	--	< 5 U	4
Toluene	< 1 U	< 5 U	< 1 U
Xylenes	--	< 10 U	< 1 U
Total VOCs	ND	ND	4

SUN-S-17		
Date	7/17/1985	1/1/1986
Benzene	< 5 U	14
Ethylbenzene	< 5 U	< 5 U
m-Xylene	< 5 U	< 5 U
o,p-Xylenes	< 5 U	< 5 U
Toluene	< 5 U	< 5 U
Total VOCs	ND	14

SUN-SM-28		
Date	7/17/1985	1/1/1986
Benzene	< 5 U	11
Ethylbenzene	< 5 U	< 5 U
m-Xylene	< 5 U	< 5 U
o,p-Xylenes	< 5 U	< 5 U
Toluene	< 5 U	< 5 U
Total VOCs	ND	11

SUN-S-26		
Date	8/1/1988	11/21/2004
Benzene	--	< 1 U
Ethylbenzene	--	< 5 U
m,p-Xylenes	4.3	--
MTBE	--	39
Toluene	--	< 5 U
Xylenes	--	< 10 U
Total VOCs	35.3	39

Notes:

1. VOCs are screened against Action Level of Non-Residential Used aquifer (TDS <2500 mg/L) Groundwater MSCs for VOCs.
2. < indicates non-detects.
3. All units are in micrograms per liter (µg/L).
4. Results shown are for Total VOCs where sample(s) greater than 0 µg/L and less than 50 µg/L.
5. MSC - Medium-Specific Concentration
6. VOC - Volatile Organic Compound
7. TDS - Total Dissolved Solids
8. D - The reported value is from a dilution
9. J - The analyte was positively identified; the quantitation is an estimation
10. U - Undetected at the Limit of Detection

VOCs	Action Level
1,1,2,2-Tetrachloroethane	4.3 µg/L
1,2,4-Trimethylbenzene	62 µg/L
1,2-Dibromoethane	0.05 µg/L
1,2-Dichloroethane	5 µg/L
1,3,5-Trimethylbenzene	53 µg/L
Benzene	5 µg/L
Chloromethane	30 µg/L
Ethylbenzene	700 µg/L
m,p-Xylenes	10000 µg/L
Methylene Chloride	5 µg/L
MTBE	20 µg/L
m-Xylene	10000 µg/L
o,p-Xylenes	10000 µg/L
Tetrachloroethene	5 µg/L
Toluene	1000 µg/L
Trichloroethene	5 µg/L
Vinyl chloride	2 µg/L
Xylenes	10000 µg/L

Legend

Total VOCs (Intermediate Aquifer Wells)

- ≤ 1,000 ppb
- ≥1000 & < 10,000 ppb
- ≥10,000 & < 20,000 ppb
- ≥ 20,000 ppb

Total VOCs (Shallow Aquifer Wells)

- ≤ 1,000 ppb
- ≥1000 & < 10,000 ppb
- ≥10,000 & < 20,000 ppb
- ≥ 20,000 ppb

- Well Location Not Sampled
- Well Location Not Sampled
- Manhole
- Sewer Line
- Potential Area of Confining Bed Thinning and/or Absence – DW-04, DW-06, DW-10, DW-11, and DW-12
- Value — Exceedes Non-Residential Used aquifer (TDS<2500 mg/L) Groundwater MSCs for VOCs
- Value — Exceedances is due to an elevated detection limit

0 740 1,480 2,220 2,960

SCALE IN FEET

FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

DATA GAP ANALYSIS REPORT

SUNOCO TOTAL VOCs CONCENTRATION BETWEEN 0 AND 50 µg/L SHALLOW GROUNDWATER

ARCADIS MALCOLM PIRNIE
Infrastructure · Water · Environment · Buildings

FIGURE
18-D

CITY: SF DIV/GROUP: ENV/IM DB: MESTIFANOS LD: PIC: PM: TM: TR:
PROJECT (PROJECT #)
PATH: ...than50ShallowZone_D-size_a.mxd 7/7/2013 10:19:38 PM
...TotalVOCsFirst18D_GW_SUN_TotalVOCs_lessthan50ShallowZone_D-size_a.mxd

Appendix R

Subsection Two:
Sunoco Refinery Figures

AOI-8

AOI -10

AOI-2

AOI-1

LANDS CREEK

AOI-11

SCHUYLKILL RIVER

AOI-3

AOI-4

AOI-7

AOI-6

AOI-9

AOI-5

MINGO CREEK
FLOOD CONTROL BASIN

Draft Only

Notes:
1. Bings Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.

Legend

- AOI -11: Deep (Lower Sand) Aquifer
- AOI-1: Belmont Terminal/No.1 Tank Farm/No.2 Tank Farm
- AOI-2: Point Breeze Processing Area
- AOI-3: Impoundment Area
- AOI-4: No. 4 Tank Farm Area
- AOI-5: Girard Point South Tank Field Area
- AOI-6: Girard Point Chemical Processing Area
- AOI-7: Girard Point Fuels Processing Area
- AOI-8: Point Breeze Process Area North Yard
- AOI-9: Schuylkill River Tank Farm
- AOI -10: Point Breeze Processing Area West Yard

N W E S

Figure 2: Area of Interest Site Plan
AOI-11 Site Characterization/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

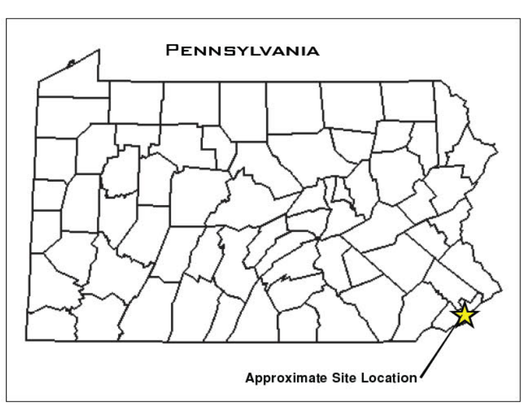
Sunoco, Inc. (R&M)
Philadelphia Refinery
[redacted]

0 250 500 1,000 Feet

SCALE: 1" = 500'
DATE: November 23, 2010
DRN. BY: MH
CKD. BY: DW
JOB#: 2574601



Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.



Legend

- BF-108 — Deep Groundwater Monitoring Well
- S-6 — Abandoned or Damaged Monitoring Well
- Area of Interest (AOI)

Figure 3: Deep Monitoring Well Location Plan
AOI-11 Site Characterization/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
[redacted]

0 250 500 1,000 Feet

SCALE: 1" = 600'
DATE: August 22, 2011
DRN. BY: MH
CKD. BY: DW
JOB#: 2874601

Path: [redacted]Figure 3 - Sitewide Deep Wells.mxd

N
W E
S

AOI-8
AOI -10
AOI-2
AOI-1
AOI-4
AOI-3
AOI-7
AOI-6
AOI-5
AOI-9

SCHUYLKILL RIVER

N-4 7.15
N-9 5.68
N-13 4.88
N-38D 0.85
N-21 3.72
N-19 3.18
N-27 2.51
N-30 3.77
N-44D 4.15
N-46D
N-50D 4.25
S-294D 2.41
S-72D 2.38
S-80D 1.82
S-302D 1.7
S-305D 0.47
S-46D 1.06
S-59D
S-264 0.53
S-280D 0.51
S-119D 0.41
C-129D 0.13
S-284D 0.37
C-65D
C-144D -4.16
S-69D -0.15
BF-108
C-50D -0.16
S-38D -0.52
S-38D2 -0.7
BF-90D -0.44
S-13
S-22 -0.73
S-8 -1.72
S-6
C-134D -1.43
A-19D -1.89
B-48D -1.64
S-76DSRTF -6.4
B-134D -2.91
B-133D -1.59
S-74D2SRTF -5.03
S-74D1SRTF -6.6
B-132D -4.96
A-21D -5.31
A-13D -2.15
S-120DSRTF -7
S-106DSRTF -7.17

1 2 3 4 4 3
4 5 6 7 7 6 5 4
3 2 1
2 2
1 1
0 -1 -2 -3 -4
-5 -6 -7 -7 -6 -5 -5 -4 -3 -2

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Deep groundwater elevations provided by Aquaterra, June/July 2011.

PENNSYLVANIA

Approximate Site Location

Legend

S-119D 0.41 — Deep Groundwater Monitoring Well and Groundwater Elevation

N-46D — Damaged/Abandoned/Unable to Locate

Deep Groundwater Contour

Area of Interest (AOI)

N-30 3.77 — Wells omitted from contouring

Figure 4 - Deep Groundwater Elevation Contour Plan - June/July 2011
AOI-11 Site Characterizaton/ Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
[redacted]

0 250 500 1,000 Feet

SCALE: 1" = 600'
DATE: November 24, 2010
DRN. BY: MH
CKD. BY: DW
JOB#: 2674601

Path: [redacted]Figure 4 - July 2011 Deep GW Contours_9-8-11.mxd

N

W E

S

N-21				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/23/2008 Result (ug/L)	4/6/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Benzene	5	**16**	**20**	**110**

N-4				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/15/2008 Result (ug/L)	4/6/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Benzene	5	**5**	ND	ND

N-9				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/16/2008 Result (ug/L)	4/6/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Benzene	5	**8**	ND	ND

N-44D				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/25/2008 Result (ug/L)	4/5/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Benzene	5	**6**	**10**	**7**

N-50D				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/23/2008 Result (ug/L)	4/5/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Chrysene	1.9	ND	**2**	**5**

S-294D				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/23/2010 Result (ug/L)	4/6/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Semi-Volatile Organic Compounds (SVOCs)				
Naphthalene	100	**140**	ND	ND

BF-108				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/22/2010 Result (ug/L)	4/7/2011 Result (ug/L)	7/5/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Methyl Tertiary Butyl Ether	20	**120**	**55**	ND

S-38D2				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	5/3/2010 Result (ug/L)	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Benzene	5	ND	ND	**110**

S-22				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/16/2010 Result (ug/L)	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Benzene	5	**6**	**20**	**28**
Methyl Tertiary Butyl Ether	20	**48**	**75**	**49**

S-8				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	7/21/2010 Result (ug/L)	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Methyl Tertiary Butyl Ether	20	1	**30**	8

A-19D			
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/11/2011 Result (ug/L)	7/1/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)			
Methyl Tertiary Butyl Ether	20	**43**	**40**

S-120DSRTF				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	8/12/2009 Result (ug/L)	4/8/2011 Result (ug/L)	6/30/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Methyl Tertiary Butyl Ether	20	**21**	**37**	**30**

S-106DSRTF				
Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	8/12/2009 Result (ug/L)	4/8/2011 Result (ug/L)	6/30/2011 Result (ug/L)
Volatile Organic Compounds (VOCs)				
Methyl Tertiary Butyl Ether	20	**98**	**300**	**260**

N-38D, N-44D, N-50D, N-21, N-4, N-9, N-13, N-19, N-27, N-30, N-46D, S-294D, S-72D, S-80D, S-302D, S-305D, S-46D, S-59D, S-264, S-280D, S-119D, S-284D, S-69D, BF-108, C-50D, C-129D, C-65D, C-144D, S-38D, S-38D2, BF-90D, S-13, S-22, S-8, S-6, C-134D, B-48D, A-19D, S-76DSRTF, S-74D2SRTF, S-74D1SRTF, B-134D, B-133D, B-132D, A-21D, A-13D, S-120DSRTF, S-106DSRTF

AOI-8, AOI -10, AOI-2, AOI-1, AOI-4, AOI-3, AOI-7, AOI-6, AOI-9, AOI-5

Draft Only

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.

PENNSYLVANIA

Approximate Site Location

Legend

- BF-108 — Deep Groundwater Monitoring Well with no exceedances of PADEP Non-Res groundwater MSC's
- S-294D — Deep Groundwater Monitoring Well with exceedances of PADEP Non-Res groundwater MSC's
- S-6 — Abandoned or Damaged Monitoring Well
- Deep Groundwater Contours (June/July 2011)
- Area of Interest (AOI)

Figure 5: Summary Volatile and Semi-Volatile Exceedances in Deep Groundwater - 2005-2010, April/June-July 2011
AOI-11 Site Characterization
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
[redacted]

0 275 550 1,100 Feet

SCALE: 1" = 550'
DATE: August 22, 2011
DRN. BY: MH
CKD. BY: DW
JOB#: 2674601

Path: [redacted]Figure 5 - GW VOC SVOC Exceedances with 2011 Contours.mxd

N

W E

S

N-4

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/27/2011 Result (ug/L)
Metals			
Manganese	300	**2850**	**2750**

N-13

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/27/2011 Result (ug/L)
Metals			
Manganese	300	**1370**	**1370**

N-9

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/5/2011 Result (ug/L)	6/27/2011 Result (ug/L)
Metals			
Manganese	300	155	**1810**

N-38D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**356**	**340**

N-19

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/5/2011 Result (ug/L)	6/27/2011 Result (ug/L)
Metals			
Manganese	300	**484**	251

N-21

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Cobalt	31	**36.1**	**228**
Manganese	300	**606**	**4830**
Arsenic	10	4.3	**54**

N-44D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/5/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**486**	**605**
Arsenic	10	**55.1**	**62.2**

N-27

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/5/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**5930**	**5850**

N-50D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/5/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**1000**	**588**

S-294D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**8210**	**8390**

S-72D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**4020**	**3770**

S-302D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**4140**	**3930**

S-80D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**11800**	**11900**

S-46D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**16400**	**20500**
Arsenic	10	**34.6**	**11.1**

S-305D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**1840**	**2160**
Arsenic	10	**39.6**	**51.9**

S-264

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/6/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Cobalt	31	29	**35.7**
Manganese	300	**7420**	**8580**

S-280D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/28/2011 Result (ug/L)
Metals			
Manganese	300	**694**	**661**

S-59D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**2910**	**2440**
Arsenic	10	**13.3**	**13.2**

C-144D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/8/2011 Result (ug/L)	7/5/2011 Result (ug/L)
Metals			
Manganese	300	**2890**	**1490**

S-284D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**979**	**922**

C-50D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/8/2011 Result (ug/L)	7/5/2011 Result (ug/L)
Metals			
Manganese	300	**2890**	**2970**

S-69D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**2940**	**2730**

BF-108

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**1070**	262

B-48D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/8/2011 Result (ug/L)	7/1/2011 Result (ug/L)
Metals			
Manganese	300	**2050**	**1890**

S-38D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	ND	**430**

S-38D2

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**6730**	**6410**

S-8

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	6/29/2011 Result (ug/L)
Metals			
Manganese	300	**1140**	**368**

BF-90D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/7/2011 Result (ug/L)	7/5/2011 Result (ug/L)
Metals			
Manganese	300	167	**351**

A-13D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/11/2011 Result (ug/L)	7/1/2011 Result (ug/L)
Metals			
Manganese	300	**709**	**621**

S-76DSRTF

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/8/2011 Result (ug/L)	6/30/2011 Result (ug/L)
Metals			
Manganese	300	**3900**	**3540**

A-21D

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/11/2011 Result (ug/L)	7/1/2011 Result (ug/L)
Metals			
Manganese	300	**708**	**611**

S-120DSRTF

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/8/2011 Result (ug/L)	6/30/2011 Result (ug/L)
Metals			
Manganese	300	**1720**	**1710**

S-106DSRTF

Chemical Name	PADEP Non-Residential Used Aquifer MSC for Groundwater TDS<2,500	4/8/2011 Result (ug/L)	6/30/2011 Result (ug/L)
Metals			
Manganese	300	**1030**	**913**

N-4 N-13 N-9 N-38D N-19 N-21 N-27 N-30 N-44D N-46D N-50D S-294D S-72D S-80D S-302D S-305D S-264 S-59D S-280D C-129D S-284D C-65D C-144D S-69D BF-108 C-50D S-38D S-38D2 BF-90D S-13 S-22 S-8 C-134D B-48D A-19D S-76DSRTF S-74D2SRTF S-74D1SRTF B-134D B-133D B-132D A-21D A-13D S-120DSRTF S-106DSRTF

AOI-8 AOI-2 AOI-1 AOI -10 AOI-4 AOI-3 AOI-7 AOI-6 AOI-9 AOI-5

SCHUYLKILL RIVER

PENNSYLVANIA

Approximate Site Location

Legend

- BF-108 — Deep Groundwater Monitoring Well with no exceedances of PADEP Non-Res groundwater MSC's
- BF-108 — Deep Groundwater Monitoring Well with exceedances of PADEP Non-Res groundwater MSC's
- S-6 — Abandoned or Damaged Monitoring Well
- Deep Groundwater Contours (June/July 2011)
- Area of Interest (AOI)

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.
2. Results based on dissolved metal values.

Figure 6: Summary Metal Exceedances in Deep Groundwater - April/June-July 2011
AOI-11 Site Characterization/ Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
[redacted]

0 285 570 1,140 Feet

SCALE: 1" = 570'
DATE: August 22, 2011
DRN. BY: MH
CKD. BY: DW
JOB#: 2674801

N
W
E
S

N-38D
N-4
N-9
N-13
N-19
N-21
N-27
N-30
N-44D
N-46D
N-50D
S-294D
S-72D
S-80D
S-302D
S-305D
S-46D
S-59D
S-264
S-280D
S-119D
S-284D
S-69D
BF-108
C-50D
C-129D
C-65D
C-144D
S-38D
S-38D2
BF-90D
S-13
S-22
S-8
S-6
C-134D
B-48D
A-19D
B-134D
B-133D
B-132D
A-21D
A-13D
S-76DSRTF
S-74D2SRTF
S-74D1SRTF
S-120DSRTF
S-106DSRTF

Absent
Absent
Clay
AOI-8
Alluvium
Alluvium
AOI -10
Alluvium
SCHUYLKILL RIVER
AOI-2
AOI-1
Deep Well Data Gap
Clay
Deep Well Data Gap
AOI-4
AOI-3
Absent/ Interfingering
Clay
AOI-7
AOI-6
Clay
AOI-9
Clay
AOI-5

1,000 ug/L
300 ug/L
10,000 ug/L
1,000 ug/L
300 ug/L
300 ug/L
1,000 ug/L
300 ug/L
300 ug/L

1 2 3 4 4 3 4 5 6 7 7 6 5 4 3 2 1
2 2 1 1
0 -1 -2 -3 -4 -5 -5 -6 -7

Notes:
1. Bing Maps aerial imagery provided by © 2010 Microsoft Corporation and its data suppliers and obtained under the licensing agreement with ESRI.

PENNSYLVANIA

Approximate Site Location

BF-108 Deep Groundwater Monitoring Well with no exceedances of PADEP Non-Res groundwater MSC's

S-294D Deep Groundwater Monitoring Well with exceedances of PADEP Non-Res groundwater MSC's

S-6 Abandoned or Damaged Monitoring Well

Deep Groundwater Contours (June/July 2011)

Sheetpile/Bulkhead

Area of Interest (AOI)

Legend

Alluvium Present to Depth No Clay Present

Clay

AOIs

Manganese Isoconcentrations (ug/L)

300

1,000

10,000

Figure 7: AOI-11 Conceptual Model Drawing
AOI-11 Site Characterization/
Remedial Investigation Report
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Sunoco, Inc. (R&M)
Philadelphia Refinery
[redacted]

0 250 500 1,000 Feet

SCALE: 1" = 600'
DATE: August 22, 2011
DRN. BY: MH
CKD. BY: DW
JOB#: 2674601

Path: [redacted] Figure 7 - Conceptual Model Drawing_rev9-8-11.mxd

BELMONT TERMINAL

AOI-1

AOI-2

AOI-4

FORMER DSCP PROPERTY

PASSYUNK AVE

Passyunk Ave Sewer

Shunk Street Sewer

28th Street Sewer

Pollock Street Sewer

Pollock Street / Packer Avenue Sewer

BELMONT WAY

FRONTAGE RD

DOVER ST

NEWARK ST

29TH ST

VARE AVE

16TH STREET

28TH STREET

UNNAMED ROAD

GALLOWS ROAD

P AVENUE

POLLOCK STREET

DEAD END ROAD

ROADWAY

SCHUYLKILL EXP

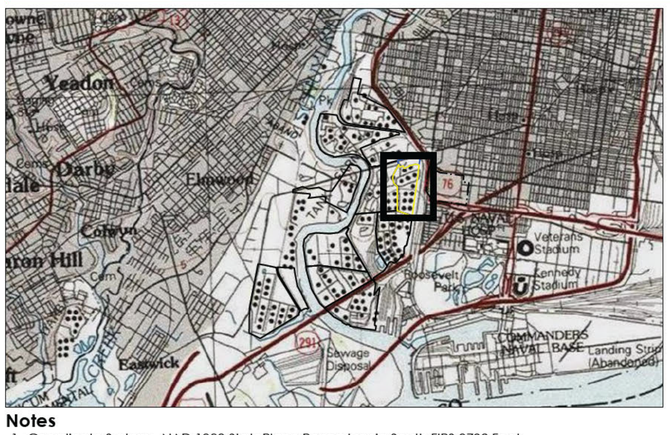
TAYLOR TER

PACKER AVE

HARTRANFT

GEARY TER

MW-35 35.4
TW-8 63
MW-37 236000
S-395 312
MW-44 13000
OW-18 2200
RW-15 2260
MW-36 309000
OW-19 20900
OW-2 26700
TW-5 665000
TW-9 0.33
TW-11 ND
RW-26 7500
OW-17 35.5
TW-3 147000
OW-20 82900
RW-30 983
RW-29 406
RW-27 7230
RW-1 9170
RW-7 16000
OW-13 72700
RW-6 18.7
OW-14 2.4
S-74 3
RW-32 ND
RW-28 7.1
RW-21 183
RW-31 67.8
MW-33 24.5
MW-32 7.6
RW-24 7020
RW-22 1670
MW-38 57.4
S-268 2
S-332 509
S-330 1330
MW-43 1110
MW-31 1040
MW-28 2960
MW-39 0.36
S-351 2
MW-41 169
RW-400 30.9
S-75 9.9
S-196 ND
S-331 117
PZ-400 2.7
S-192 0.85
S-267 ND
S-191 202
S-98 1390
S-200 9590
S-77P 1950
S-190 138
S-193 1350
S-194 38.2
S-189 154
S-188 24.9
S-271 404
S-81 63.3
S-272 2
S-187 167
S-273 376
S-186 107
S-185 0.69
S-80 384
S-275 993
S-184 2660
S-183 831
S-182 1950
S-78 6.6
S-202 573
S-79P 784
RW-402 ND
S-180 0.66
S-84P 1.6
S-179 0.47
RW-403 51.8
S-206 7.8
S-405 5700
S-396 7710
S-85 6.9
S-101 27.8
RW-404 8.7
S-88A 15.2
S-88 15.1
S-404 13
S-403 160
S-397 3.8
S-207 0.42
S-116 ND
S-261 ND
S-99 4
RM 109
RM 108
RM 107
RM 110
RM 111
RM 112
RM 106
RM 104
RM 105
RM-115
RM-90
RM-91
18T1011
S-269 149
S-270 371
S-208 4620
S-209 1390
S-52 0.26
S-51 13.9
S-419 2610
S-418 88300
S-230 8680
S-226 60400
S-117 88.1
S-50 2390
S-127 257
S-231 232
S-232 4.7
S-164 138
RW-110 25.5
S-162 1000
S-47I 0.84
RW-112 3.4
RW-111 4.7
S-46 161
S-262 1430
S-211 3.7
S-212 18.8
S-213 19.9
S-263 1530
S-260 21.3
S-44 575
S-259 502
S-255 0.23
S-258 243
S-228 94.8
S-227 101
S-118 1090
ARCO-3 2430
S-312 ND
S-214 169
S-256 12.8
S-43 50
S-257 48
S-95 2.6
ARCO-1 293
S-41 6
ARCO-2 517



Notes

1. Coordinate System: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet North American Vertical Datum of 1988 (NAVD 88)
2. Sources: Stantec
3. Labels denote well identifier and benzene concentration in micrograms per liter (ug/L). Contour Interval = Logarithmic (3 levels per log cycle)
4. COC analytical data was interpolated using the Natural Neighbor gridding method in Surfer.
5. Belmont Terminal data shown for informational purposes only.
6. Aerial & Topo Copyright:© 2013 National Geographic Society, i-cubed
7. Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation

Legend

- MONITORING/RECOVERY WELL
- POLLOCK STREET HORIZONTAL WELL
- APPROXIMATE LOCATION OF PHILADELPHIA WATER DEPARTMENT SEWER
- AREA OF INTEREST (AOI) 1
- BELMONT TERMINAL
- AREA OF INTEREST (AOI)
- FORMER DSCP PROPERTY
- CROPPED GRID EXTENT

2014/2015 BENZENE MAXIMUM CONCENTRATION (ug/L)

BENZENE CONCENTRATION SCALE (ug/L)

- 100,000+
- 77,500
- 55,000
- 32,500
- 10,000
- 7,750
- 5,500
- 3,250
- 1,000
- 775
- 550
- 325
- 100
- 77.5
- 55
- 32.5
- 10
- 7.75
- 5.5

0 125 250 Feet

1:1,500 (At original document size of 24x36)

N

Figure No.

10-2

Title

UNCONFINED AQUIFER BENZENE MAXIMUM CONCENTRATION - 2014 AND 2015 DATA

Client/Project

EVERGREEN RESOURCES MANAGEMENT OPERATIONS
PHILADELPHIA REFINERY COMPLEX

[redacted]

Project Location

City of Philadelphia, Pennsylvania

213402434

Prepared by GWC on 2/26/2016
Technical Review by ADK on 2/29/2016
Independent Review by JKD on 2/29/2016

Stantec

EVERGREEN

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Appendix R

Subsection Three:
Groundwater Contour Maps



Stantec

EVERGREEN

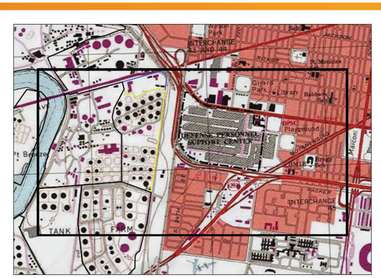
Legend

- WELL UTILIZED IN CONTOURING
- 2015 WATER-TABLE ELEVATION (ft NAVD 88)
- APPROXIMATE LOCATION OF PHILADELPHIA WATER DEPARTMENT SEWER
- LIMITS OF UNCONFINED AQUIFER WELL CONTROL
- AREA OF INTEREST (AOI) 1
- BELMONT TERMINAL
- AREA OF INTEREST (AOI)
- FORMER DSCP PROPERTY

0 250 500 Feet

1:3,000 (At original document size of 24x36)

N



Notes

1. Coordinate System: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet North American Vertical Datum of 1988 (NAVD 88)
2. Sources: Stantec and Defense Logistics Agency (DLA)
3. Labels denote groundwater elevation in feet. Depth to groundwater was measured in each well to the nearest one-hundredth of a foot using an interface probe.
4. Contour Interval = 0.5 feet
5. Gauging data for DSCP property wells obtained from the Defense Logistics Agency. Rigorous evaluation of that data not performed by Stantec.
6. Groundwater elevation data was interpolated using block kriging with a linear variogram model in Surfer.
7. Aerial & Topo: PASDA 2014 & Copyright© 2013 National Geographic Society, i-cubed Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation

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Project Location
City of Philadelphia, Pennsylvania

213402434

Prepared by GWC on 2/9/2016
Technical Review by ADK on 2/16/2016
Independent Review by MN on 2/16/2016

Client/Project
EVERGREEN RESOURCES MANAGEMENT OPERATIONS
PHILADELPHIA REFINERY COMPLEX
[redacted]

Figure No.
5-5

Title
MAY 2015 WATER-TABLE ELEVATION - INCLUDING SYNOPTIC DSCP GAUGING DATA



FORMER DEFENSE SUPPLY CENTER PHILADELPHIA
DSCP/PASSYUNK HOMES, PHILADELPHIA

SECOND QUARTER OF 2015 PROGRESS REPORT

SHALLOW GROUNDWATER POTENTIOMETRIC CONTOURS - MAY 13, 2015

ARCADIS

FIGURE
1

CITY: SF DIV/GROUP: ENV/IM DB: MESTIFANOS LD: PIC: PM: TM: TR:
PROJECT #: 06262046.0003.0002
PATH:
mxd 7/30/2015 9:48:23 AM

Appendix S

Standard Operating Procedures

Appendix S

Subsection One:
Baildown Testing and Manual Skimming Testing

MEMO

ARCADIS Design & Consultancy for natural and built assets

To:
Project and Field Team Personnel

Copies:
File

Arcadis U.S., Inc.
[redacted]

From:
[redacted]

Date:
Revised October 2, 2017

Arcadis Project No.:
[redacted]

Subject:

Defense Supply Center Philadelphia (DSCP) LNAPL Transmissivity Testing
Work Plan- Baildown Testing and Manual Skimming Testing- October 2017

INTRODUCTION

As part of LNAPL stability determination activities, LNAPL baildown and manual skimming tests are scheduled to be conducted at the DSCP site in October 2017. Results will be used to support efforts to determine the stability of Site LNAPL through calculation of recovery rates and/or transmissivity values.

The following documents are provided for reference:

- Arcadis Standard Operating Procedure (SOP) for Baildown Testing (2010)
- Arcadis technical presentation on manual skimming
- Site- and task-specific Activity Hazard Analysis (AHA)
- Site Map

WELL LIST

The below wells are to be tested via either baildown testing or manual skimming testing. An LNAPL thickness of ~0.5 ft or greater is considered acceptable for baildown testing; a manual skimming test should be conducted at a well with an LNAPL thickness of 0.2- 0.5 ft. Tests should not be conducted at wells with LNAPL thicknesses of <0.2 ft.

Well List (October 2017):

- DSCP-RW-9
- DSCP-MW-33
- DSCP-MW-65
- DSCP-RW-2
- PH-RW-A
- PH-RW-G

“DSCP” wells, or those north of the highway, will be tested first, followed by the “PH” wells south of the highway.

SCHEDULE: OCTOBER 2017 (AS OF 9/27/2017)

- 9/25: System shutdown (Chuck onsite)
- 9/28 and/or 9/29: Collect gauging measurements at wells to be tested (Chuck)
- 10/2: Collect gauging measurements at wells to be tested. Notify Joe Righter and others re: RW-9 access (Chuck)
- 10/3: Conduct up to 2 baildown tests at wells with greatest LNAPL thickness (Chuck, Chris). Conduct manual skimming tests at field team’s discretion.
- 10/4-10/6: Conduct remaining baildown tests and manual skimming tests (Chuck [10/4-10/5], Chris [all], Adam [10/6])
- 10/7: Since this is a Friday, only conduct manual skimming tests, if remaining (Chuck, Chris, Adam as needed)

HEALTH AND SAFETY

All field personnel should be familiar with the Site Accident Prevention Plan (APP), which includes a Site Safety and Health Plan (SSHP). Personnel should review the AHA for baildown and manual skimming testing. In addition, a Traffic Control Plan has been developed for activities at DSCP-RW-2, and should be followed during testing at this well.

EQUIPMENT

Baildown tests are to be conducted in accordance with the SOP, and both types of test procedures should follow the AHA for safety considerations. Required equipment includes:

- PPE (nitrile and cut-resistant gloves, safety glasses, hard hat, safety boots, long sleeves, long pants)
- Stopwatch (let’s be honest, cell phone. But a stopwatch is easier to replace if it gets plume-ed. So your choice and at your own risk!)
- Hand tools, safety grate, and crowbar for accessing vaults and wells
- PID (breathing zone action level: >30 ppm, stop work)
- Benzene-specific Draeger tubes and pump (breathing zone action level: > 5 ppm, stop work)
- Site ventilation fan and vehicle battery
- Interface probe
- Decon supplies- Alconox or liquinox and water

- Absorbent pads
- Whale pump for baildown testing
- Peristaltic pump and tubing for manual skimming testing
- Battery (or use battery in field vehicle) for operating pump
- Zip ties
- Graduated cups and bucket for measuring volume of LNAPL removed (gradations should allow measurement of LNAPL recovered within +/- 5-10% of total).
- Poly drum with lid and/or buckets with lids for transporting liquid IDW
- Thick/contractor grade trash bag for containing solid IDW
- Field logs (attached)

ACCESS AND NOTIFICATIONS

Notification of access to DSCP-RW-9 should be provided approximately 1 day in advance to Defense Realty and local contacts in the building next to this well. Chuck Rogers will contact Joe Righter of Defense Realty and indicate that testing is scheduled at DSCP-RW-9 and will take up to 8 hours to complete.

PARTIAL SYSTEM SHUTDOWN AND EQUILIBRATION PROCEDURE

For an accurate baildown or manual skimming test, a well should not be under the influence of the Site VES or skimming systems. For this reason; the VES and skimmer system must be shut down at least in the area where the where the test is being conducted such that there is no impact to liquid levels of the test well. In addition, the well and subsurface should have ample time to equilibrate following shutdown of all or part of the systems.

System Shutdown

The VES system will be shut down approximately 1 week prior to the anticipated test start date, and will remain off for the duration of testing. For the October 2017 testing, the team expects that the entire system may be shut off for the duration of testing while system maintenance is performed simultaneously. However, should the schedule change, the following procedure should be followed:

Portions of the VES system will be shut down in the area of the wells being tested approximately 1 week prior to the anticipated test start date, and will remain off for the duration of testing so as not to influence the water and LNAPL levels. Portions of the VES system further than 200ft from the wells being testing will remain on, so that at least some part system is operating at any point during testing to remain in compliance with the administrative order. The VES will be operated as follows:

- VES system zones A, B, C, F, G will be shut off 1 week prior to testing and during testing of wells DSCP-RW-9, DSCP-MW-33, and DSCP-MW-65. VES system zones D and E will continue to operate during the testing of these wells, however, skimmer pumps will be removed from PH-RW-A and PH-RW-G, and skimming will not take place in any well for at least 1 week prior to, or during testing.
- Following completion of tests at wells DSCP-RW-9, DSCP-MW-33, and DSCP-MW-65, VES system zones A, C, F, G will be restarted, and VES system zones D and E will be shut down. Zone B will stay off. 1 week after zones D and E are shut off, testing will be conducted on wells DSCP-RW-2, PH-RW-A and PH-RW-G

- Upon completion of these tests, the entire VES system will be restarted and skimming can resume.

Equilibration Monitoring

To determine if the well has sufficiently equilibrated for testing, the field team should gauge the wells to be tested several times over the week prior to testing, after the VES system has been shut off. Field team should gauge wells as many days that someone is already onsite this week, and at least the business day prior to testing. If water and product levels are not within 10% of the previous recorded data, the well may not be equilibrated, and the field team should contact the project team (Emily, Carlo, Meredith, and Matt) before proceeding with testing.

TEST SELECTION

The following LNAPL thickness limits will be used to determine which testing procedure to use at a well:

- LNAPL thickness ≥0.5 ft: Baildown test
- LNAPL thickness ≥0.2 ft and ≤0.5 ft: Manual skimming test
- LNAPL thickness <0.2 ft: No test, contact project team

BAILDOWN TESTING PROCEDURE

1. Fill in prelim info on field log.
2. Place absorbent pads on ground next to vault/well.
3. Open vault/well.
4. Continually monitor breathing zone using PID and benzene tubes. Stop work and evacuate area if PID sustains a reading of >30 ppm in the breathing zone or if 5 ppm benzene detected via Draeger tubes. Contact the Site SSHO on duty. SSHO may instruct continued Stop Work, or may instruct use of the fan to reduce breathing zone levels to <30 ppm. Fan may also be used to reduce odors, even if odors do not register high readings on the PID.
5. Monitor well headspace using PID. Record on field log.
6. Gauge depths to LNAPL and water and record to hundredths of a foot, measuring from the survey mark if present or from a field-designated measuring point if not. Do not measure depth to bottom (to avoid removing LNAPL and/or displacing liquid with the probe). If well is of ample diameter, leave probe in well just above level of LNAPL.
7. Set up whale pump next to well. Measure appropriate length of dedicated tubing based on depth to water. Place pump discharge tubing in graduated bucket (to measure volume of LNAPL recovered). Team may zip tie 1 interface probe to the whale pump if desired. Place probe tip just at or just below the pump intake.
8. Connect pump to power source.
9. Carefully lower pump intake tubing until it is just above the LNAPL-water interface.
10. Note exact time (including seconds) when Step 10 is started.
11. Pump LNAPL from the well. Goal is to pump LNAPL as quickly as possible while minimizing water removal. LNAPL removal should take less than 5 minutes for an accurate baildown test. Remove pump as soon as possible (when reading frequency decreases). Team may use second interface probe to take readings.
12. Note exact time when Step 10 is finished.

13. Immediately begin measuring elapsed time.
14. Monitor depth to LNAPL and depth to water and record to hundredths of a foot, noting elapsed time in minutes and seconds. Measurement intervals are at your discretion based on rates observed in the field. Guidelines are:
    a. 30 second intervals for first 5 min
    b. 1 min intervals for next 10 min. Continue 1 or 2 min intervals if recovery rate is high, or switch to 5 to 30 min intervals if recovery rate is low.
    c. When possible, record the volumes of LNAPL and water in the graduated cups and/or bucket. Note appearance of LNAPL and any indication of emulsification with water. 5 min intervals for next 45 min. (concludes first hour of monitoring)
    d. 5 to 30 minute intervals as needed until levels return to 95% of original depth. Usually takes between 2 and 8 hours. For this project, collect readings for at least 8 hours. Can return to well and measure again in 24 hrs for wells with low LNAPL recovery rates. Suggested data collection frequency:
        i. 10 min intervals for second hour of monitoring
        ii. 20 min intervals for remaining 6 hours of monitoring (30 min intervals ok if this helps with testing logistics)
        iii. 1 reading after ~24 hours
15. Note time of end of test, or end of that day's portion of test, and final depths to LNAPL and water.
16. If necessary, transfer LNAPL and water to proper container for transportation. Chuck Rogers (Arcadis, systems operator) will transfer LNAPL to site AST for storage.
17. Decon the interface probe. Clean whale pump as much as possible.
18. Close and secure well/vault and clean area.
19. Return to well after ~24 hours for final reading. Report exact time reading was collected (ok if not exactly 24 hours).
20. Provide field forms to Emily when finished.

MANUAL SKIMMING TESTING PROCEDURE

1. Fill in prelim info on field log.
2. Place absorbent pads on ground next to vault/well.
3. Open vault/well.
4. Continually monitor breathing zone using PID. Stop work and evacuate area if PID sustains a reading of >30 ppm in the breathing zone. Contact the Site SSHO on duty. SSHO may instruct continued Stop Work, or may instruct use of the fan to reduce breathing zone levels to <30 ppm. Fan may also be used to reduce odors, even if odors do not register high readings on the PID.
5. Monitor well headspace using PID. Record on field log.
6. Set up peristaltic pump next to well. Measure appropriate length of dedicated tubing based on depth to water. Place pump discharge tubing in graduated cup or bucket (to measure volume of LNAPL recovered).
7. Attach the intake end of the tubing to the interface probe tip with zip ties to facilitate placement of the intake in LNAPL (and not water) during evacuation. Align the end of the tubing with or just above the probe tip.
8. Connect pump to power source.
9. Gauge depths to LNAPL and water and record to hundredths of a foot, measuring from the survey mark if present or from a field-designated measuring point if not. Do not measure depth to bottom (to avoid removing LNAPL and/or displacing liquid with the probe).
10. Select an LNAPL thickness between 10% and 25% of the initial thickness as the “trigger thickness” for the test. Selection for the first round of testing is largely arbitrary; future tests may select a trigger thickness based on time available for testing (that is, if more time is available and/or the initial LNAPL thickness is small, a value closer to 25% will be used since it will take longer for LNAPL to recharge to this thickness than to 10%). If unsure, call Emily for help with selecting a trigger thickness.
11. Carefully lower pump intake tubing until it is just above the LNAPL-water interface.
12. Note exact time (including seconds) when Step 13 is started.
13. Pump all LNAPL from the well. Note that the interface may actually rise as LNAPL is removed. Goal is to pump LNAPL as quickly as possible while minimizing water removal. LNAPL removal should take less than 5 minutes for an accurate skimming test. Remove tubing as soon as possible, when reading frequency decreases, and do not disengage the pump before raising the tubing (to avoid releasing LNAPL back into the well). Raise the end of the tubing above the top of the water and any remaining LNAPL and pump all liquid from the tubing into the graduated cup/bucket. Note appearance of LNAPL and any indication of emulsification with water. Perform these observations as soon as practicable, then transfer LNAPL and water to another container and/or have other empty graduated cups/buckets for subsequent LNAPL removals (see step 17).
14. Note exact time when Step 10 is finished. Note volumes of LNAPL and water evacuated.
15. Immediately begin measuring elapsed time.
16. Monitor depth to LNAPL and depth to water and record to hundredths of a foot, noting elapsed time in minutes and seconds, until the thickness reaches the “trigger thickness” selected above. Measurement intervals are at your discretion based on LNAPL recharge rates observed in the field with the goal of accurately observing when the trigger thickness is reached. Guidelines are:
    a. 1 min intervals for first 10 min., or fewer if trigger thickness is reached within 10 min.

   b. If the LNAPL recharge rate is high (i.e. LNAPL is rapidly approaching the trigger thickness), continue 1 or 2 minute intervals. Otherwise, monitor at 10 min intervals until trigger thickness reached. Increase to 20 min intervals if recharge is very slow.
17. When the trigger thickness is reached, note time and final depths to LNAPL and water. Immediately pump LNAPL from the well again. Repeat Steps 13-16.
18. Repeat skimming and monitoring until the rate of recharge to the well stabilizes. The rate of recharge will usually slow down over time. If time permits, repeat tests such that 3 consecutive tests are conducted where the times to reach the trigger thickness and the amount of LNAPL removed are each within 25% of the previous tests' readings.
19. If necessary, transfer LNAPL and water to proper container for transportation. Chuck Rogers (Arcadis, systems operator) will transfer LNAPL to site AST for storage.
20. Decon the interface probe. Contain used tubing in contractor-grade trash bag.
21. Close and secure well/vault and clean area.
22. Provide field forms to Emily when finished.

Appendix S

Subsection Two:
LNAPL Baildown Testing

ARCADIS
Infrastructure, environment, facilities

Imagine the result

Standard Operating Procedure for LNAPL Baildown Test

Rev. # 2

Rev. Date: January 14, 2010

oval i natures

Prepared by: [redacted] Date: a 14, 2010

Reviewed by: [redacted] Date: ar 14, 2010

I. Scope and Application

The objective of this Standard Operating Procedure (SOP) is to establish uniform procedures for conducting rising-head light non-aqueous-phase liquid (LNAPL) baildown tests to evaluate LNAPL conductivity (K_n) in the subsurface at a specific well location. The data generated from the LNAPL baildown test can be used, along with other site data, to evaluate LNAPL mobility and recoverability at a site. This SOP describes the equipment, field procedures, materials and documentation procedures necessary to determine LNAPL conductivity. The details within this SOP should be used in conjunction with project work plans.

This SOP applies to task orders and projects associated with ARCADIS. This SOP may be modified, as required, depending on site-specific conditions, equipment limitations or limitations imposed by the procedure. The ultimate procedure employed will be documented in the appropriate project work plans or reports. If changes to the testing procedures are required due to unanticipated field conditions, the changes will be discussed with the project manager as soon as practicable and documented in the project report.

II. Personnel Qualifications

Only qualified ARCADIS-related personnel will conduct LNAPL baildown tests. ARCADIS field sampling personnel will have sufficient “hands-on” experience necessary to successfully complete the LNAPL baildown test field work. Training requirements for conducting LNAPL baildown tests include reviewing this SOP and other applicable SOPs and/or guidance documents, instrument calibration training, and health and safety training.

ARCADIS field sampling personnel will have completed current company-required health and safety training (e.g., 40-hour Hazardous Waste Operations training, site-specific training, first aid and cardiopulmonary resuscitation (CPR) training), as needed.

III. Equipment List

Equipment and materials used for conducting the LNAPL baildown tests may include, but are not limited to, the following:

- appropriate personal protective equipment (PPE), as specified in the site Health and Safety Plan (HASP)
- equipment decontamination supplies
- photoionization detector (PID) (see ARCADIS SOP: Photoionization Detector Air Monitoring and Field Screening)
- plastic sheeting
- oil absorbent pads
- stopwatch
- polypropylene rope
- clean disposable bailers
- oil-specific skimmer pump
- vacuum truck
- plastic bucket with lid
- plastic beakers or graduated cylinders (appropriately sized for anticipated NAPL/water recovery volume)
- Calculator
- appropriate field logs/forms
- oil-water interface probe (see ARCADIS SOP: Water Level Measurement)
- data logger and transducer
- white masking tape

- measuring tape with gradation in hundredths of a foot
- indelible ink pen
- monitoring well keys
- bolt cutters
- monitoring well locks
- field log book or PDA or field (computer) notebook

IV. Cautions and Procedure Considerations

Wells containing LNAPL for baildown testing should be selected based on project-specific objectives and a review of historical site data. It is good practice to select several baildown test wells to bracket the range of observed historical apparent LNAPL thickness measurements and LNAPL mobility/recoverability conditions across a given area. As a rule of thumb, apparent LNAPL thicknesses in wells used for baildown tests should be greater than or equal to the borehole diameter (Lundy and Parcher, 2007). Additional guidelines for selecting appropriate wells for LNAPL baildown testing include:

- Select wells located near the interior and exterior portions of the LNAPL plume(s)
- Select wells located in a variety of geologic materials, as feasible
- Consider the position of wells relative to groundwater and LNAPL flow direction
- Consider the potential of wells to exhibit different equilibrated apparent LNAPL thicknesses
- Select wells which contain different types of LNAPL, if present

In addition, understanding the areas affected by recent remediation efforts should be considered because these areas may not be representative of static subsurface conditions. Also, ARCADIS field sampling personnel must be aware of historical fluid levels as they compare to the conditions at the time of testing (i.e., the smear zone).

If higher LNAPL recovery rates are expected, larger diameter wells (4- to 6-inch-diameter casings) are generally preferred. The increased area of the wellbore

seepage face for larger diameter wells will provide information that is applicable to a larger, more representative volume of aquifer material. However, if the expected recovery rate is low, smaller diameter wells are often preferred because the volume of the borehole is smaller relative to the formation recovery capacity. Further discussion on accounting for the well filter pack is presented in *A Protocol for Performing Field Tasks and Follow-up Analytical Evaluation for LNAPL Transmissivity using Well Baildown Procedures* (Beckett and Lyverse, 2002).

ARCADIS project personnel must confirm that the test wells have been properly developed. This cannot be overemphasized, as incomplete well development results in underestimates of LNAPL transmissivity (T_n) and LNAPL conductivity (K_n). See the ARCADIS SOP titled *Monitoring Well Development* for additional details.

ARCADIS field sampling personnel must verify that the air/LNAPL and LNAPL/groundwater interfaces occur within the screen interval. At a minimum, the piezometric head elevation in the well should occur below the top of the screen.

ARCADIS field sampling personnel will choose the most appropriate technique to evacuate the LNAPL from the well. These techniques include:

- **Manual bailer** — A 1¾-inch-diameter bailer will be used for 2-inch-diameter wells. For 4-inch-diameter wells, a 3-inch-diameter bailer will be used for LNAPL recovery. ARCADIS highly recommends using product recovery cups, which attach to the bottom of the bailer and maximize the surface area for LNAPL recovery (For example, the Superbailer™, manufactured by EON Products, Inc. has this feature built-in). This will allow for more complete LNAPL removal and more accurate recovery measurements.

- **Pumping** — LNAPL removal can be accomplished by using an oil-specific skimmer pump that operates at a pumping rate which exceeds the LNAPL recharge capacity. For shallow wells (< 25 feet below ground surface), a peristaltic pump may also be a useful, effective and appropriate mode of LNAPL removal.

- **Vacuum Truck** — If large LNAPL volumes are to be removed or extremely rapid recovery rates are anticipated, LNAPL removal can be accomplished using a vacuum truck. The vacuum extraction line is to be outfitted with a small-diameter stinger attachment that will be extended down the well and an in-line site glass to observe extracted fluid color for determination of whether LNAPL or groundwater is being extracted. Begin pumping at the LNAPL/air interface and slowly move the stinger tube downward to extract LNAPL. When groundwater recovery is observed indicating that the LNAPL has been evacuated withdraw the stinger tube and begin fluid level measurements.

Follow the sequential steps below for each baildown test well. Data collection is generally manual using an interface probe, although a data logger can also be used as long as it can sense either the fluid interfaces or the head change only with respect to LNAPL. Before performing an LNAPL baildown test, allow monitoring well water and LNAPL levels to equilibrate with atmospheric pressure. Gauge fluid levels periodically for 5 to 10 minutes to monitor changes in head. Monitoring wells without vents (flush mounts) may require more time to equilibrate with atmospheric pressure following well cap removal.

ARCADIS recommends taking LNAPL measurements initially in one-minute intervals and then adjusting the frequency of measurements thereafter, based on site-specific conditions. The rate of LNAPL recovery will usually slow over time unless the zone of interest is highly conductive. Once the rate of recovery is slow enough, a new baildown test can be initiated at another location, returning to take periodic measurements at the initial test well. Continue this process as long as it is viable based on soil characteristics, field logistics, well locations and data collection needs. Real-time examination of the data curves is the best indicator of data sufficiency. A plot of the change in LNAPL thickness over time may exhibit up to three theoretical segments:

1) initial steep segment that could reflect filter pack drainage

2) main production segment where the formation LNAPL gradient to the wells controls recovery

3) third segment where the diminishing formation LNAPL gradient produces a flatter recovery curve

Repeatedly introducing the oil-water interface indicator may alter the fluid-level measurements. Avoid splashing the probe into the water table or lowering the probe too far beyond the LNAPL-water interface depth. To avoid introducing surface soil or other material into the monitoring well, stage downhole equipment on a clean and dry working surface.

Two field personnel are recommended to adequately perform this test, one person to collect the data and one person to record the data.

V. Health and Safety Considerations

Overall, the Loss Prevention System™ (LPS) tools and the site-specific HASP will be used to guide the performance of LNAPL baildown tests in a safe manner without incident. A Job Safety Analysis (JSA) will be prepared for LNAPL baildown tests. The

following specific health and safety issues must be considered when conducting LNAPL baildown tests:

- Monitoring for volatile organic compounds (VOCs) in the monitoring well head space must be conducted with a PID and recorded in the field logbook prior to initiating the LNAPL baildown test. PID readings will be compared to action levels established in the site HASP for appropriate action.

- Appropriate PPE must be worn to avoid contact with LNAPL during the baildown test.

- LNAPL removed from the test well must be managed with caution to avoid igniting the LNAPL material. LNAPL characteristics must be reviewed in the JSA, which will be prepared and reviewed by the project team prior to implementing the baildown test.

- LNAPL generated during the baildown test must be properly managed in accordance with facility and applicable regulatory requirements.

- Well covers must be carefully removed to avoid potential contact with insects or animals nesting in the well casings.

VI. Procedure

Specific procedures for conducting LNAPL baildown tests are presented below:

1. Identify site, well number, date and time on the LNAPL Baildown Test Log and field logbook or PDA, along with other appropriate LNAPL baildown testing information. An example LNAPL Baildown Test Log is provided in Attachment 1 to this SOP.

2. Place clean plastic sheeting and several oil absorbent pads on the ground next to the well.

3. Unlock and open the monitoring well cover while standing upwind from the well.

4. Measure the concentration of detectible organics present in the worker breathing zone immediately after opening the well using a PID. If the PID reading(s) exceed the thresholds provided in the HASP, take appropriate actions per the HASP. After monitoring the worker breathing zone, proceed to

monitor the well head space with the PID and record the PID reading in the field logbook.

5. Prepare a test log to record LNAPL recovery data. Initially, data should be collected very frequently. As time progresses and the LNAPL recovery rate slows, less frequent measurements will be required. In most cases, initial measurement increments of 1 minute are sufficient, with subsequent measurements farther apart as appropriate, based on observed rate of recovery during the first few readings. If LNAPL recovery rates are high, data should be collected more frequently. For lower LNAPL recovery rates, time intervals between measurements can be increased.

6. It is important to monitor rapid LNAPL recovery at a higher frequency, again as indicated by the observed recovery data.

7. Secure one end of the rope to the bailer and the other end to the well casing using a bowline knot.

8. Before beginning the baildown testing, measure and record static fluid levels using the oil/ water interface probe (i.e., depth to LNAPL and depth to groundwater) and document the well construction details. Using the conversion chart at the bottom of the test log, the measured LNAPL thickness and the well diameter, calculate and record the initial LNAPL volume in the well. Gauge fluid levels periodically for 5 to 10 minutes to monitor changes in head. Do not begin the test until the well has equilibrated. Ideally, one person will be responsible for lowering the bailer into the well and recording time intervals in the log, and another person will be responsible for lowering the water-level probe into the well and measuring and communicating water-level depths to the person recording information in the log.

9. To begin baildown testing, slowly lower the bailer or equivalent into the well until it is just below the LNAPL-water interface.

10. Set stopwatch. Wait to start the stopwatch until immediately after LNAPL removal is finished.

11. Evacuate LNAPL from the well by gently bailing, pumping, or vacuum recovery as described in Section IV above while minimizing water production. One of the assumptions employed in the analysis of the baildown test data is that the LNAPL is removed from the well instantaneously. Thus, it is important to avoid spending excessive amounts of time (more than 5 minutes) removing LNAPL from the well.

12. Record the time at which LNAPL removal is complete (or removed to the maximum practical extent) as the test start time. Begin measuring the elapsed time, starting with this point. Monitor depth to LNAPL and depth to water at the appropriate intervals, as discussed above (5). Measure fluid levels to the nearest hundredth of a foot with the oil-water interface probe and record, along with the corresponding time reading in minutes and seconds.

13. Transfer the LNAPL and groundwater evacuated from the well into an appropriately sized beaker or graduated cylinder. Record the volumes of LNAPL and groundwater on the Baildown Test Log (Attachment 1). If an LNAPL/water emulsion was formed during fluid recovery, allow time for LNAPL/water separation and make note of the observed emulsification.

14. Two to eight hours of data collection is usually sufficient. However, faster LNAPL recovery need not be monitored for extended periods, and slow recovering wells may benefit from follow-up readings the next day.

15. Place all LNAPL and groundwater collected during the test into an appropriate container for proper waste management.

16. Decontaminate the oil-water level indicator with a non-phosphate detergent and water scrub, a tap water rinse, a reagent grade methanol rinse, a second tap water rinse, a second methanol rinse, a third tap water rinse, and a triple rinse with distilled water (see SOP titled *Field Equipment Decontamination*).

17. Secure the monitoring well prior to leaving by replacing the well cap and/or cover and locking it.

VII. Waste Management

Rinse water, PPE and other waste materials generated during equipment decontamination must be placed in appropriate containers and labeled. Containerized waste will be disposed of in a manner consistent with appropriate waste management procedures for investigation-derived waste.

VIII. Data Recording and Management

ARCADIS field sampling personnel will record data using the LNAPL Baildown Test Log (Attachment 1). All information relevant to the test data beyond the items identified in the Baildown Test Log will be recorded using the field logbook, PDA or field computer. Field equipment decontamination activities and waste management activities will be recorded in the field logbook. Records generated as a result of

implementing this SOP will be controlled and maintained in the project record files in accordance with client-specific requirements.

IX. Quality Assurance/Quality Control

ARCADIS project personnel will review the data set collected during the LNAPL baildown test in the field to determine whether or not the data are reasonable given site-specific conditions. For example, if the data indicates that LNAPL recovery is very rapid in a very low-permeability soil type, this may indicate that there are problems with the data set. If the data are questionable, the field equipment must be checked to confirm it is working properly and the test will be repeated, if possible. Depending on data quality objectives, a duplicate LNAPL baildown test may be conducted as a quality control check 48 hours after the initial test, assuming water levels and apparent LNAPL thicknesses have returned to static conditions.

Any issues that may affect the data must be recorded in the field log book so that analysts can consider those issues when processing the data.

X. References

Beckett, G.D. and Lyverse, M.A. 2002. *A Protocol for Performing Field Tasks and Follow-up Analytical Evaluation for LNAPL Transmissivity using Well Baildown Procedures, August 2002.*

Lundy, D. and Parcher, M. 2007. *Assessment of LNAPL Volume, Mobility and Recoverability for Recovery Systems: Design and Risk-Based Corrective Action. National Ground Water Association Short Course, November 2007.*

ARCADIS SOPs Referenced Herein:

Field Equipment Decontamination, Revision No.1, April, 2009.

Monitoring Well Development, Revision No.2, March, 2008.

Photoionization Detector Air Monitoring and Field Screening, Revision No. 0, July, 2003.

Water Level Measurement, Revision No. 1, March, 2004.

.

Attachment 1: LNAPL BAILDOWN TEST LOG

LNAPL Baildown Test Standard Operating Procedure

Site Name		Test Well ID	
Date and Time In		Date and Time Out	
Personnel		Weather	

Well Construction Details

Top of Casing Elevation (ft amsl)		Screen Slot Size (in)	
Total Well Depth (ft)		Filter Pack Type	
Depth to Top of Screen (ft)		Depth to Bottom of Screen (ft)	
Well Casing Diameter (in)		Borehole Diameter (in)	

Initial Test Conditions

Static Depth to LNAPL (ft)		Test Date	
Static Depth to Water (ft)		Start Time	
LNAPL Thickness (ft)		Initial LNAPL Volume in Well (gal)	

LNAPL Removal Information

LNAPL Removal Method/Equipment		Time LNAPL Removal Begins	
Volume of LNAPL Removed (gal)		Time LNAPL Removal is Completed	
Volume of Groundwater Removed (gal)			

Baildown Test Data

Elapsed Time (min)	Depth to LNAPL (ft)	Depth to Water (ft)	Observations

(Modified after Beckett and Lyverse, 2002)

Well Casing Volumes	1-¼" = 0.06	2" = 0.16	3" = 0.37	4" = 0.65
(Gal./Ft.)	1-½" = 0.09	2-½" = 0.26	3-½" = 0.50	6" = 1.47

LNAPL Manual Skimming Tests

Quick-Reference Field Guide

A manual skimming test is performed by removing (bailing/purging) LNAPL several times, allowing LNAPL to recharge into the well in between each LNAPL removal event. The goal is to see the rate of LNAPL recharge stabilize over several removal events.

Test wells should have at least ~0.2 feet of LNAPL and be at confirmed equilibrium before starting a test. After removing socks, pumps, etc., perform gauging at least one day and immediately prior to test to confirm <10% variation in DTP, DTW, and LNAPL thickness. Record pre-test gauging data.



Material List

- Peristaltic pump & tubing (or bailer/spill buddy pump)
- Interface Probe
- Graduated bucket or container
- Plastic sheeting
- Decon supplies
- Notebook
- Watch/Stopwatch/timer

For pumping LNAPL out, try fastening tubing to the interface probe with zip-ties, and raise and lower the probe to keep the tubing intake within the LNAPL layer.

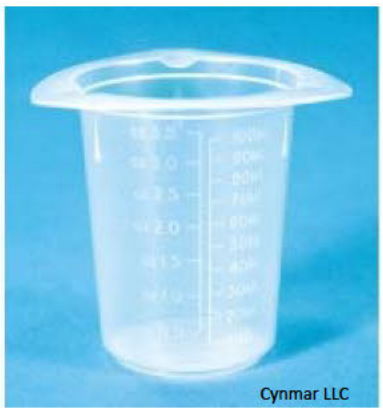
Keep in Mind

- Try to remove LNAPL quickly, and remove as little water as possible (try for 90%+ LNAPL, <10% water).
- Record the LNAPL and water volume removed each time and the times pumping/bailing is started and stopped each time.

Accurate recording of the LNAPL volume removed during each event is important! Beakers or paint mixing containers, like those shown below, are good to use – don't rely on estimating volumes in a bucket.



Grainger/US Plastics



Cynmar LLC



LNAPL Manual Skimming Tests

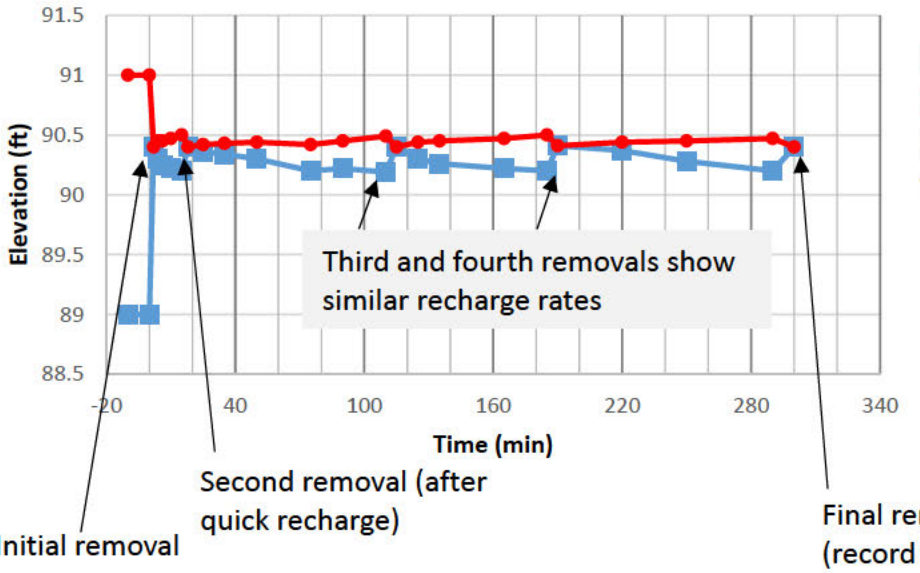
Quick-Reference Field Guide

Document carefully and don't hesitate to reach out for support!

Test Steps

1. Gauge the well and record initial fluid levels (DTP and DTW).
2. Pump NAPL from the well and record volume.
3. Pick an LNAPL thickness between 10% and 25% of the initial thickness (for an initial LNAPL thickness of 0.8 ft, you could pick 0.08 ft or 0.2 ft). This is the "trigger thickness."
4. Monitor LNAPL recovery. When LNAPL thickness recovers to the "trigger thickness," pump LNAPL from the well again.
5. Repeat Step 4 until the rate of LNAPL recharge to the well stabilizes.

Example Skimming Test Hydrograph



Red = DTP
Blue = DTW
Initial LNAPL thickness = 2 ft
Trigger thickness = 0.3 ft

Keep in Mind

- Write down the most accurate time you can for each measurement.
- The trigger thickness can be adjusted if needed, but should always be less than 25% of the initial LNAPL thickness.
- Use a (cheap) watch/stopwatch. It's less expensive to replace than a phone. Set watch(es) to phone time before entering field.

The rate of LNAPL recharge will usually slow down over time.
Try to get three events where the times to reach the "trigger thickness" are within 25% of each other, similar to low-flow stabilization.

The Arcadis LNAPL team is here to help!

[redacted]

Appendix S

Subsection Three:
Synoptic Water Level Measurements and
Groundwater Purging and Sampling

MEMO

ARCADIS Design & Consultancy for natural and built assets

To:
Defense Logistics Agency
United States Army Corps of Engineers

Copies:
ARCADIS Field Team
File

Arcadis U.S., Inc.
[redacted]

From:
[redacted]

Date:
Updated August 23, 2017

Arcadis Project No.:
[redacted]

Subject:
Synoptic Water Level Measurements and Groundwater Purging and Sampling – Standard Operating Procedures (SOP), DSCP, Philadelphia, PA

Note: Please direct public inquiries to DLA Public Affairs Office (or PAO) at 571.767.6200.

Groundwater gauging and sampling activities will be completed on a quarterly basis at the former DCSP Site located at 2990 B South 20th Street, Philadelphia, Pennsylvania. This document describes the SOP for low-flow groundwater sampling techniques which will be utilized for this sampling event.

General Health and Safety Notes

The product that will be gauged is a light non-aqueous phase liquid (LNAPL) and is most closely associated with the PADEP Short List for Petroleum Compounds. Personnel will likely encounter strong odors in and around wells and well vaults. PID's should be with personnel and on at all times. Due to the nature of the product, Tyvek suits will be provided by ARCADIS and will need to be worn at all times when in contact with product-bearing wells. Please wear gloves when handling equipment at all times and be sure to decontaminate and clean all equipment that comes in contact with a well (water or product). Personnel should refer to the Accident Prevention Plan (APP) for specific health and safety information and personal protective equipment (PPE) requirements.

Sampling personnel are expected to provide their own safety vest, hard hat, safety glasses, and steel toe boots. These items are to be worn at all times while gauging and sampling the wells, along with other field appropriate attire (old t-shirts and jeans that properly cover skin, i.e., no holes).

Some of these wells will be located in high traffic areas, such as parking lots or driveways in strip malls. Refer to the Arcadis Traffic Control Plan/Site Traffic Awareness and Response (TCP/STAR) Plan for

detailed traffic control information. Please use the truck to block the flow of traffic (i.e., park truck behind well, in the direction of the flow of traffic and work in front of the truck) and place cones as markers to direct traffic around the truck. One person per team will be responsible for watching and directing traffic.

Out of respect for client confidentiality, field personnel should refrain from extensive responses to outside inquiries related to the Site and remediation activities. Responses should be limited to who the field personnel are working for (Defense Logistics Agency and United States Army Corps of Engineers) and that the field personnel are completing "environmental work." Anyone with additional questions or who is from the press (radio station, newspaper, TV) should be referred directly to the DLA Public Affairs Office (or PAO) at 703.767.6200.

Equipment required

- 4 rented or company pool Pick-up Trucks
- At least 16 – 5 gallon buckets with lids
- 4 Solinst Interface Probes or similar
- 4 PIDs
- Nitrile Gloves (XL, L, M if requested)
- Oil-Absorbent Pads
- Tyvek suits (XL, L, M, S if requested)
- Alconox/Liquinox
- Cleaning Brushes
- Shop Towels
- Measuring cups (to find purging rate)
- Stop watch or other timing device (to find purging rate) (aka cell phone, because we are modern)
- Poly tubing
- 2" PVC piping with male and female fittings
- 5 QED Bladder Pumps (request 4 regular and 1 backup, request 3/8" discharge)
- QED Bladders (Quantity determined by number of samples)
- 5 QED Control Boxes (request 4 regular and 1 backup) AND
- 5 QED Air Compressors (request 4 regular and 1 backup) OR
- 5 QED MP-50 combined control box/compressor units (request 4 regular and 1 backup)
- 5 Horiba U-52 Water Quality Meters (request 4 regular and 1 backup)
- Individual Tools, including 9/16" wrench, 15/16" wrench, well keys
- 4 Tablets programmed using pLog with DSCP Site data
- 4 poly drums for temporary purge water containerization during the day

Data Record Materials

- pLog-configured tablet
- Site Figures
- Master Sampling Table
- Labels and bottles
- Pens for writing sample labels

SYNOPTIC DATA COLLECTION

Prior to groundwater sampling activities, a groundwater synoptic event will be conducted by the project team. Water levels will be measured using a Solinst Model 101 water level meter or similar and will be recorded in the field using pLog software. Data from pLog will be uploaded and compiled shortly after gauging so that a table of LNAPL-bearing wells can be generated.

Four teams of two people each will collect water levels measurements from all accessible wells (approximately 163 wells) located on or around the Former DSCP Site, which include the CSX Property, the Former Passyunk Homes Property (currently the Siena Place Homes and Philadelphia Housing Authority Property), and the Former DSCP Property (currently Quartermaster Plaza, Defense Realty and Kindy's). Well depth to bottom will be recorded at least once per year, during the Third Quarter. Accessible wells are those that the project team is able to locate, and for which well access is not obstructed and/or access to a given property is permitted. When access is not available, an explanation will be noted in pLog. The project team will follow previous gauging strategies when not impeded by access requirements, starting on the western edge of all accessible properties (CSX and/or Steen wells), gauging them first, followed by Former Passyunk Homes wells and Former DSCP wells that are not impacted with product. Impacted wells will be gauged last.

SYNOPTIC PROCEDURE FOR WELLS

- Open Well.
- Record headspace reading with PID by placing PID influent tip into the well and covering the well with the well lid or your hand.
- NOTE: Please keep the PID on while the well is open to ensure safe working environment.
- Using interface probe, measure the depth to product, if any, and the depth to water, from the surveyed mark on the well. If the survey mark is not shown on the well, note this in the notes section of the data sheet/tablet and record depth to product from the north side of the well. End depth will automatically populate when you enter the Depth to Water.
- If necessary, use the interface probe to measure the depth to bottom from the surveyed mark on the well.
- Remove probe from the well, using absorbent pads to check for small amounts of LNAPL that may not have been measurable via probe, and to soak up excess LNAPL when known to be present.
- Record sheens (LNAPL present but not measurable thickness) in pLog and/or on paper to ensure these are documented.
- Decontaminate the probe using distilled water and Liquinox between each well.
- Replace well cap and lock.

SYNOPTIC PROCEDURE FOR VAULTED WELLS

- **NOTE: Only Confined Space Entry (CSE) trained individuals are permitted to access the interiors of Vaulted Wells.** Please be sure that all CSE certifications are on file at the Site prior to beginning this phase of work.
- Open Vault.
- Place a catwalk grate over the vault.
- Using a 3' crow bar, remove the well seal by latching onto looped rope on top of lid.
- Record headspace reading by lowering the PID into the vault with the 3' crowbar near the well opening. Be careful not to drop PID down well while doing this.
- NOTE: Please keep the PID on while the vault is open to ensure safe working environment.
- Using interface probe, measure the depth to product, if any, from the surveyed mark on the well. If the survey mark is not shown on the well, note this in the notes section of the data sheet/tablet and record depth to product from the north side of the well. .
- Remove probe from the well, using absorbent pads to check for small amounts of LNAPL that may not have been measurable via probe, and to soak up excess LNAPL when known to be present.
- Record sheens (LNAPL present but not measurable thickness) in pLog and/or on paper to ensure these are documented.
- Replace well lid with the 3' crowbar, remove catwalk and close vault lid.
- Decontaminate the probe using distilled water and Liquinox between each well.
- Below is the list of a vaulted wells that need to have the preceding procedure followed:

FORMER DSCP PROPERTY:

- Zone A: MW-5, MW-11, MW-14, MW-34, MW-35A, RW-8, RW-9, RW-10
- Zone B: MW-28, MW-29, MW-31, MW-32, RW-2, RW-3
- Zone C: MW-33, RW-1A, RW-4, RW-5, RW-6, RW-7, RW-11

Former Passyunk Homes property

- Zone D: RW-A, RW-B, RW-CA, RW-I, RW-T, RW-U, RW-V, RW-W
- Zone E: PH-13, PH-14, MWS-2A, RW-D, RW-G, RW-H, RW-S
- Zone F: MW-41, RW-E, RW-M, RW-Q
- Zone G: PH-16, MWS-3, RW-F, RW-N, RW-P, RW-O

Gauging Notes

Please note any abnormality on the field data sheets/tablet such as broken well caps, etc. Please be aware that if the water level measure is not stable, this indicated the vacuum seal on the well was strong and that the well needs to equilibrate. This well should NOT be gauged right away. Please contact Chuck Rogers for details on how to proceed.

SOP FOR LOW-FLOW GROUNDWATER SAMPLING VIA BLADDER PUMP TECHNIQUE

Groundwater samples will be collected from monitoring wells via low-flow sampling techniques; QED bladder pumps will be utilized for purging and sampling of the monitoring wells.

Every morning, prior to sampling wells, the Horiba U-52 Water Quality Meters will be calibrated according to the manufacturer's procedures for calibration. The PID's will also be calibrated every morning prior to sampling to ensure accurate volatile readings are being collected.

Each well will be re-gauged prior to sampling for depth to product (if any) and depth to water using the interface probe and will be recorded on purge logs in the pLog program on the tablet.

To prepare and install the pump into the well, the airline tubing will be attached to the airport and the sample discharge tubing will be attached to the water port on the top of the bladder pump. Then, depending on the well, one of the two following procedures will be followed for setting the pump at the proper depth.

Wells with Free Phase Product

If during the synoptic round the well was determined to have free phase product (LNAPL) present, a 2" PVC drop tube will be used to lower the pump through the product layer. A 10' section of 2" PVC will have the end capped off with a layer of aluminum foil then attached to subsequent sections of 2" PVC. **Note: no glued sections will be lowered into the water column.** All sections of 2" PVC will be tied off with individual ropes to secure objects above the ground surface to ensure that pipe sections do not break loose and fall down the well. The 2" drop tube will be slowly lowered so that the capped foil end is through the product layer and into the water column. The PVC will be attached to the well vault or other secure object using a fray resistant rope. The pump will be slowly lowered through the drop tube and using the weight of the pump will break through the capped foil end into the water column keeping the pump clear of free phase product. If the product bearing well is 2" in diameter and the drop tube cannot be used, a 2" x 3' Absorbent sock will be lowered into the well to absorb as much LNAPL as possible, minimizing the amount

of product the pump will have to go through and lowered to the middle of the screened interval (as shown in the attached table) and/or is based on the initial water level and total depth of the well.

Wells with No Free Phase Product

The pump will be slowly lowered into the well to a depth that corresponds to the middle of the screened interval (as shown in the attached table) and/or is based on the initial water level and total depth of the well.

Well Sampling Procedure

After the QED pump is set at the correct depth, the air line will be connected to the output port on the QED pump controller and the discharge line will be connected to the Horiba U-52 Water Quality Meter flow-through cell. The QED pump controller will be connected to a supply line from an air compressor using an appropriate regulator and air hose. The water level will be recorded once more and then the pump will be turned on via the controller and purging will begin. **Purge rate and sample rates should remain the same; the target purge rate is 250 mL/min but not to exceed 750 mL/min.**

During purging, field parameters will be recorded in pLog every 5 minutes including turbidity, temperature, dissolved oxygen, specific conductance, pH, oxygen reduction potential (ORP), depth to water (DTW) and volume purged. If the DTW is dropping during the purging process the bladder pump will have the mL/min purge rate lowered via the QED control box. **The wells will be allowed to purge until all parameters are stable, for a minimum of 30 minutes, or until one hour has elapsed.** If after one hour the well has not stabilized, a note will be made on the purge log that the well has not stabilized and a sample was collected. A final field parameter reading will be collected for parameters listed. After this point, groundwater samples will be collected by disconnecting the Horiba U-52 Water Quality Meter and filling the appropriate sample containers with water from the tubing connected directly to the pump (e.g. not through the U-52). Please confirm sampling containers and analyses on the quarter-specific Master Well Sampling Table. All samples collected for dissolved metals analysis are to be field filtered.

After sampling, the QED bladder pump will be removed from the well, using caution not to contaminate the surrounding area. The well will be secured, and personal protective equipment (PPE), tubing, and disposable pump equipment will be disposed of properly. Additionally, all groundwater sampling equipment will be decontaminated before the first well has been sampled and after each subsequent well using procedures for equipment decontamination. Purge water will be drummed in a poly drum provided onsite. Drum is to be closed, latched, and secured while vehicle is in motion.

Decon Procedure

After the well has been sampled, the QED bladder pump will be removed from the well. Absorbent pads can be used during the removal of the pump to capture any product or water that may spill on the ground and the tubing and PPE will be stored in large trash bags to be disposed of in a roll off container at the end of the day for proper disposal. The QED Bladder Pump then will be taken apart, removing and disposing of the QED bladder with the tubing and PPE. The various components of the QED bladder pump will be decontaminated in a solution of DI water and Liquinox or Alconox, brushed with the provided brushes to remove any accumulated material. Then the materials will be rinsed with new DI water. A new unused bladder will be placed in the pump and the pump will be reassembled for use in the next well.

INVESTIGATIVE DERIVED WASTE (IDW)

Liquid IDW, which consists of purge and decon water, will be transferred from the poly drums referred to above into appropriate storage tanks onsite at the end of each workday. No LNAPL should be transferred

in this manner. If LNAPL has been collected for any reason, consult the project team regarding handling and disposal. Water will be transferred using an electric sump pump and a hose. Personnel are responsible for ensuring that the open end of the hose is placed and secured appropriately in the storage tank so that 1) water does not spill and 2) a siphon effect is not induced that would cause water to backflow out of the tank (i.e. keep the open end of the hose from being submerged in the storage tank, especially if the water level in the storage tank is higher than the level of the pump end of the hose).

Solid IDW, which consists of spent gloves, tubing, absorbent pads, and other disposable field items, will be stored onsite in a roll-off container. The roll-off will be removed from the site by the subcontractor following the event.

Appendix T

Transmissivity Results, API Guide,

Baildown Test Result Spreadsheets

Appendix T
LNAPL Baildown Testing and Analysis Results

Well ID	Date	Initial LNAPL Thickness (ft)	Test Duration (min)	Final LNAPL Thickness (ft)	Percent LNAPL Recovered	LNAPL Transmissivity, T_n (ft^2/day)				Notes/Comments
						B&R	C&J	CB&P	Mean	
MW-33	3/21/2017	1.09	85	0.33	30%	NA	NA	NA	NA	Data could not be analyzed quantitatively. Very little LNAPL recharge observed, and no change in LNAPL drawdown after first 7 minutes of test. LNAPL discharge likely attributed to filter pack drainage.
	10/3/2017	0.43	420	0.41	95%	NA	NA	NA	NA	Negative LNAPL drawdown after only 15 minutes likely due to fluctuating water table during testing.
DSCP-MW-65	3/20/2017	0.97	1,320	0.67	69%	0.21	0.36	0.33	0.30	
DSCP-RW-2	3/21/2017	1.43	100	0.41	29%	0.23	**1.82**	**0.83**	**0.96**	Majority of LNAPl recharge occurred during early stages of testing and are likely resprentative of filterpack drainage. The reported value(s) should thus be regarded as an upper limit estimate of LNAPL transmissivity.
DSCP-RW-9	3/22/2017	1.36	50	0.62	46%	**2.47**	**3.45**	**4.96**	**3.63**	
	10/4/2017	0.81	360	0.39	48%	**0.86**	**1.35**	**6.12**	**2.78**	High variability observed between methods
DSCP-PH-RW-A	3/22/2017	0.81	55	0.05	6%	NA	NA	NA	NA	Very little LNAPL recharge observed. Any LNAPL recharge likely from filter pack drainage based on LNAPL volume removed.
DSCP-MW-3A	9/15/2017	0.9	400	0.63	70%	0.10	0.11	0.26	0.16	Less than half of the initial LNAPL contained in the well was removed prior to testing.
RW-6	9/15/2017	0.54	340	0.21	39%	0.13	0.37	NA	0.25	Early test data from 5 to 100 minutes could not be utilized due to negative LNAPL discharge.
PH-PH-18	9/14/2017	0.7	301	0.24	34%	0.003	0.06	0.04	0.03	The LNAPL discharged during the test was likely filter pack drainage based on initial casing and filter pack LNAPL volume estimates.
RW-C	9/14/2017	0.8	400	0.25	31%	0.19	0.40	0.84	0.48	
RW-G	10/5/2017	0.68	480	0.21	31%	0.03	0.03	0.21	0.09	

General Notes:
All analyses completed using American Petroleum Institute (API) LNAPL Transmissivity Workbook (API 2012).
Bold - Exceeds 0.1 to 0.8 ft^2/day lower criterion range to produce sufficient LNAPL recoverability (ITRC 2009).

Acronyms and Abbreviations:
ft = feet
LNAPL = light non-aqueous phase liquid
min = minute
NA = not analyzed
B&R = Method based on Bouwer & Rice (1976) method for analysis of groundwater slug tests in unconfined aquifers.
C&J = Method based on Cooper & Jacob (1946)/Jacob & Lohman (1952) methods for groundwater flow to a well under constant drawdown or constant discharge conditions
CB&P = Method based on Cooper, Bredehoeft and Papadopulos (1967) method for analysis of groundwater slug tests in confined aquifers.

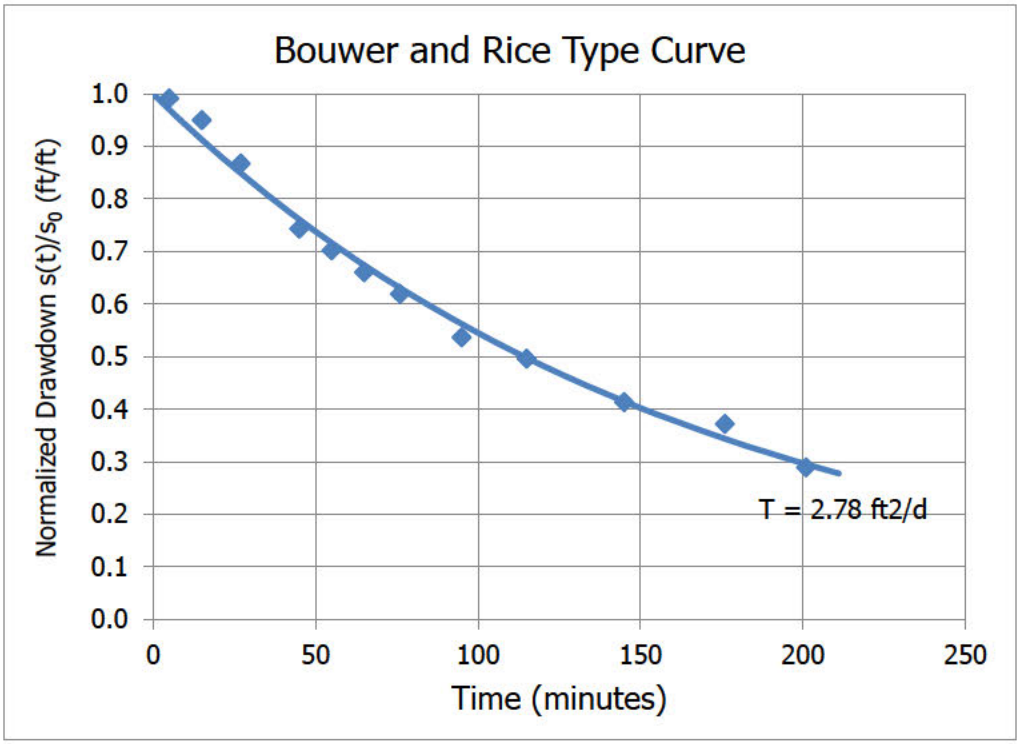
User Guide for the

API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis

API Regulatory and Scientific Affairs Department

API Publication 46xx (pre-publication draft)
SEPTEMBER 2012

NOTE: This is a 'pre-publication' version of the API LNAPL Transmissivity Workbook that is provided to allow early access to this report. Minor formatting changes may occur prior to its formal publication.



User Guide for

API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis

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PREFACE

LNAPL transmissivity provides a useful measure of potential hydrocarbon liquid mobility within the subsurface environment. The magnitude of LNAPL transmissivity is being accepted as a metric for hydrocarbon recovery system performance and determination of technology-specific endpoints. Baildown tests are a simple method for estimating LNAPL transmissivity. This manuscript describes a spreadsheet tool that can be used to analyze results from baildown tests.

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LIST OF SYMBOLS

b_n	LNAPL thickness in well
b_{nR}	initial LNAPL thickness in well (same as at radius of influence)
b_{nW}	limiting effective LNAPL thickness in well (see Appendix F)
DZ_{12}	depth to top of perching layer
$F( )$	Cooper, Bredehoeft and Papadopulos slug test function
$G( )$	Jacob-Lohman free-flowing discharge function
h_n	LNAPL head
J	Kirkman J-ratio (see Appendix B)
L_e	initial LNAPL column height (contacting screen) in well
N	number of increments
Q_n	LNAPL discharge
Q_{ni}	LNAPL discharge at time t_i
R	radius of influence
r_c	radius of casing
r_e	effective well radius
$r_{e(i)}$	effective well radius at time t_i (varies with LNAPL column location in well)
r_w	well borehole radius
S	coefficient of storage
s_n	LNAPL drawdown
S_n	LNAPL storage parameter
s_{ni}	LNAPL drawdown at time t_i
S_y	LNAPL specific yield
T	transmissivity
t_i	time epoch
T_n	LNAPL transmissivity
V_n	LNAPL volume
$W( )$	Theis well function
z_{an}	elevation of air-LNAPL interface in well
z_{nw}	elevation of LNAPL-water interface in well
Δs_n	LNAPL drawdown correction
Δt_a	time adjustment factor
ρ_r	LNAPL-to-water density ratio

ACRONYMS

BOS	Bottom of Screen
B&R:	(generalized) Bouwer and Rice method
CSM:	Conceptual Site Model
C&J:	Cooper and Jacob method
CB&P:	Cooper, Bredehoeft and Papadopulos method
CV:	Coefficient of Variation
DTP:	Depth to Product
DTW:	Depth to Water
ITRC:	Interstate Technology Regulatory Council
LNAPL:	Light Non-Aqueous Phase Liquid
SOP:	Standard Operating Procedure
SSD:	Sum-Square-Difference
TOS	Top of Screen

1. Introduction

LNAPL transmissivity is a measure of lateral mobility of free-product hydrocarbon liquid within the groundwater environment. The magnitude of LNAPL transmissivity has been suggested as a possible endpoint criterion for LNAPL mass removal using LNAPL hydraulic recovery systems (ASTM E 2531-06 [Tbl X5.1], 2006; ITRC, 2009). Such hydraulic recovery systems include skimmer wells, single-pump wells, dual-pump wells, and trenches. Coupled with the LNAPL CSM, the magnitude of LNAPL transmissivity will assist in the choice of recovery system. As such, methods and their consistent application for estimating LNAPL transmissivity are significant. Perhaps the simplest methods for estimating LNAPL transmissivity are borehole slug test methods, or baildown tests, where a volume of LNAPL is rapidly removed from a well and the rate of fluid-level recovery (water and LNAPL) is measured and analyzed. Several analytical methods are available to analyze the data from baildown tests to estimate LNAPL transmissivity and described herein. A more general discussion of LNAPL transmissivity measurement is provided by ASTM (2011).

Following a brief description of suggested well configuration, pre-test and test measurements and methods, application of the spreadsheet tool is discussed. Subsequent sections provide a more detailed discussion of significant parameters and basis for the various analysis procedures. A number of example applications are presented. Further details on the different methods are provided in the appendices. Noteworthy is the introduction of the J-ratio (J) described in Appendix B, which appears to render discussions over preference between Lundy and Zimmerman (1996) versus Huntley (2000) methods moot.

2. Well Configuration Data

The following well configuration data should be gathered for baildown test analysis:

1. Elevation of ground surface. This generally serves as the datum with elevations specified as depth below ground surface, bgs. Elevations presented with the geologic log are generally expressed as depth bgs. If data are not conveniently available (or necessary), enter 0 on the spreadsheet.
2. Elevation of top of casing (depths to fluid levels are usually measured from top of casing). If data are not conveniently available (or necessary), enter 0 on the spreadsheet.
3. Well casing radius, r_c (ft).
4. Well borehole radius, r_w (ft).
5. Depth of top of screen (ft bgs). The top of screen can be interpreted to be the top of screen or filter pack, depending on the well construction and gauged fluid levels, and it is up to professional judgment to correctly select between these. If data are not conveniently available (or necessary), enter 0 on the spreadsheet.

6. Depth of bottom of screen (ft bgs). If data are not conveniently available (or necessary), enter 0 on the spreadsheet.

3. Pre-Test Data

Certain data should be gathered before performance of the baildown test, in order to establish and verify initial conditions. The depth to product (DTP) and depth to water (DTW) should be measured over a period equal to the expected test length; if the test length is unknown then use of historic hydrograph data and gauging 8 hours before the test would provide a basic level of understanding for equilibrium conditions. The DTP and DTW should then be measured immediately before start of the test to confirm that fluid levels are stable and in equilibrium. The best practice to confirm equilibrium fluid levels is to gauge the well until it fully recovers as discussed in ASTM E2856-11, Section 6.1.4.16 (2011). Additionally, when conditions allow, it is useful to remove LNAPL from the well during a period before the test (say within one month) to confirm equilibrium contact between formation and well hydrocarbon liquid. This is necessary especially if standing LNAPL is observed or LNAPL has not been recovered from a well for a while. Baildown tests are analyzed by slug test methods modified for two fluids, and it is important that formation and well fluids are in equilibrium. If tidal fluctuations are present the DTP and DTW must be measured regularly for at least a week leading up to the test. In any case it is imperative that the LNAPL/water interface should be positioned across the well screen for confined LNAPL conditions, or the air/LNAPL interface for perched LNAPL conditions, if not both the interfaces.

4. Baildown Test Procedures and Data

In performance of a baildown test a volume of hydrocarbon liquid is rapidly removed from the well and the DTP and DTW are measured as a function of time during the fluid recovery period. Fluid recovery rates generally vary logarithmically, so measurements should be taken more frequently during the initial period following hydrocarbon removal, and the measurement frequency decreases during the later period of the test. The ASTM standard E2856-11 provides a thorough procedure for conducting baildown tests, however, a brief description of significant features are provided below:

- Initial hydrocarbon liquid removal should be rapid. Commercial peristaltic pumps (such as Spill Buddy ™) are preferred since the pump intake can be located to remove only hydrocarbon liquid during the baildown stage. If a bailer is used then additional precautions are necessary to minimize fluid disturbance during LNAPL removal. If removal of larger LNAPL volumes is required, then vacuum trucks can be used, recognizing that significant volumes of water may be removed in addition to LNAPL.

- Following the baildown stage of hydrocarbon liquid removal, the DTP and DTW are measured as a function of time. Measurements can be taken using interface probes (optical and electrical resistivity), and data are recorded as depth (feet) below top of casing.
- In general, the interface depth measurements are taken more frequently during the initial recovery period, and the frequency decreases as recovery time proceeds. If recovery rates are too rapid for (near) simultaneous measurement of DTP and DTW, then a pressure transducer can be placed below the LNAPL-water interface and connected to a data-logger. In this case only the DTP need be measured, and such measurements combined with the data-logger record and LNAPL density can be used to calculate the DTW at desired time intervals.
- When possible, recovery monitoring should continue until essentially complete LNAPL recovery is achieved. In low LNAPL transmissivity locations, time requirements might be excessive and early termination will be necessary. Nearly full recovery is especially important for confined and perched LNAPL conditions, to help verify the site conceptual model for the test.
- A record of 20 to 30 measurements (each for DTP and DTW) is generally adequate for data analysis. When possible, these data should be evenly spread in terms of recovery volume. [For example, if the initial LNAPL thickness in a well is 4 ft and the LNAPL thickness after baildown is 0.5 ft, then measurements might be taken when the LNAPL thickness roughly has the following sequence of values: 0.50, 0.52, 0.54, … 3.90, .. ft.]

5. Post-Test Data

LNAPL transmissivity value from a baildown test is estimated based on measurement of LNAPL drawdown and recharge to the well as a function of time, along with a site conceptual model that can include geologic log and well configuration data to identify possible unconfined, confined, or perched LNAPL conditions. Estimation of formation discharge (well recharge) is based on changes in DTP and DTW values. Changes in fluid levels in the well compared with screen elevations determine the effective storage associated with the well. This storage can include only the casing volume or the casing volume plus some fraction of the pore space of the filter pack that has been drained of LNAPL during the baildown stage of the test. This latter case becomes more complicated, depending on the fluid levels versus the well screen interval, since only part of the LNAPL column in the well may be in contact with the screened interval of the well. These issues are discussed in more detail in Appendix A with regard to estimation of the effective well radius, r_e.

The post-test data that must be calculated includes estimation of LNAPL drawdown (s_n) and well discharge (Q_n) as a function of time, and this in turn depends on the effective well radius value along with DTP and DTW measurements.

The LNAPL drawdown is measured based on the DTP, along with any correction that is applied to account for initial non-equilibrium between formation and wellbore LNAPL. Specifically, the drawdown corresponding to time t_i is calculated using

(5.1) $$s_{ni} = DTP_i - DTP_0 - \Delta s_n$$

In Eq. (5.1) DTP_0 is the initial (pre-test) depth to product and Δs_n is a possible LNAPL drawdown correction that is applied as discussed below.

The LNAPL discharge from the formation to the well is calculated based on the effective well radius ($r_{e(i)}$) and changes in DTP and DTW over time. Once the effective well radius has been determined, the well discharge from time t_i to time t_{i+1} is calculated using the following equation:

(5.2) $$Q_{ni} = \pi r_{e(i)}^2 \left(DTP_i - DTP_{i+1} + DTW_{i+1} - DTW_i\right) \Big/ \left(t_{i+1} - t_i\right)$$

This equation accounts for the increase in LNAPL storage volume over the time interval, and specifically identifies that the effective well radius might not be constant (such as a change from well casing storage to casing/screen plus filter pack storage).

6. Overview and General Discussion: Analysis of LNAPL Transmissivity Baildown Test Data

This section briefly summarizes methods for analysis of LNAPL transmissivity baildown test data. Additionally, use of time cutoff and time adjustment to eliminate early-time data influenced by filter pack drainage or other factors is discussed, and a default method for estimation of LNAPL storage coefficient is described. Finally, a flowchart that outlines the LNAPL transmissivity estimation process using this workbook is presented.

6.1. Methods for Estimating LNAPL Transmissivity

Among the variety of methods suggested in the literature for analysis of slug test data, three different methods are presented here for analysis of unconfined LNAPL transmissivity baildown tests. These three methods are designated through their original presentation in the literature as follows:

- B&R - Bouwer and Rice (1976)
- C&J - Cooper and Jacob (1946)
- CB&P - Cooper, Bredehoeft and Papadopulos (1967)

LNAPL baildown tests are inherently transient, meaning that fluid levels and flow rates change with time. Experience with transient aquifer tests suggests that at least two parameters are necessary to describe system performance. With a conventional pumping test one estimates the aquifer transmissivity and storage coefficient. For LNAPL baildown test analysis, both parameters are also necessary, though only the LNAPL transmissivity is of direct interest.

The Bouwer and Rice (B&R) method is conceptually the simplest. The method uses a linear model (Thiem equation) to relate LNAPL discharge to LNAPL drawdown, and is based on continuity of LNAPL volume within the well. LNAPL drawdown versus time data are used to determine the LNAPL transmissivity, based on an estimate of the well radius of influence provided through the empirical analysis presented by Bouwer and Rice (1976). Interesting questions remain in the literature between the applications of the B&R method for LNAPL baildown testing as presented by Lundy and Zimmerman (1996) and Huntley (2000). These approaches differ in terms of assumed fluid levels in the well during recovery. The Huntley method assumes that the water table elevation remains constant during the recovery period. The Lundy method, which proposes removal of a small slug of LNAPL from the well, assumes that the depth to water remains constant during the recovery period. This difference in assumptions results in the Huntley method including an additional factor $1/(1 - \rho_r)$ in the calculation of LNAPL transmissivity, where ρ_r is the LNAPL-water density ratio. For many LNAPL transmissivity baildown tests, neither assumption is observed. For the general case, Andrew Kirkman (personal communication) suggests introduction of the J-ratio parameter that is directly based on measured data to address this issue. The Kirkman J-ratio is described in Appendix B and the J-ratio method is used herein for both the B&R method of analysis, and for the CB&J analysis. The magnitude of the J-ratio is determined by the user using Fig. 4 on the "Figures" worksheet. The B&R method is developed in Appendix C.

The Cooper and Jacob (C&J) method provides an estimate of the LNAPL transmissivity based on the LNAPL discharge to the well and LNAPL drawdown, as a function of time. The method also requires estimation of an LNAPL storage coefficient. Guidance on suggested magnitudes of the LNAPL storage coefficient is provided for the user. The C&J method is developed in Appendix D.

The Cooper, Bredehoeft and Papadopulos (CB&J) method provides an estimate of the LNAPL transmissivity based on measurements of LNAPL drawdown versus time. The method also requires an estimate of the LNAPL storage coefficient. The CB&P method does not directly use the LNAPL discharge to the well, and it does require an estimate of the effective initial LNAPL drawdown. The CB&P method is developed in Appendix E.

LNAPL can also be found under confined or perched conditions. Methods based on the Bouwer and Rice method of analysis are developed for confined and perched LNAPL in Appendices F and G, respectively.

Discussion

There is no *a priori* preferred method for analysis of LNAPL baildown test data. The B&R method is good for long well purging events, whereas relatively instantaneous events are used with the C&J and CB&P methods because they incorporate transient storage effects. The B&R method is independent of absolute time; rather, just the slope of the log-normalized drawdown versus change in linear time is important. However, if a straight line is not observed with B&R and it concaves upward (as a result of storage effects), then C&J or CB&P are more able to account for the effects attributed to storage. Absolute time is critical for both C&J and CB&P, and thus it is necessary to adjust the effective time origin when early-time data is eliminated because of filter pack drainage. With the B&R method, the well radius of influence is estimated using well configuration data based on analog simulation analysis described by Bouwer and Rice (1976) for flow of groundwater to a well in an unconfined aquifer. This relationship is assumed to hold for LNAPL. The C&J method is based on an approximate solution describing flow of groundwater to a well under conditions of constant discharge and variable drawdown, and constant drawdown and variable discharge. The relationship is also assumed to apply to flow of LNAPL to a well when both the LNAPL discharge and LNAPL drawdown vary with time. The CB&P method is based on an analytical solution for a slug test in a confined aquifer, and is assumed to apply for LNAPL under unconfined conditions. With the CB&P method, both the effective initial drawdown and LNAPL storage coefficient must be estimated along with the LNAPL transmissivity. Because the CB&P method does not directly consider data regarding LNAPL discharge to the well, it is possibly the most uncertain method of analysis. Nevertheless, when properly applied, the user can often estimate LNAPL transmissivity value with coefficient of variation (ratio of the standard deviation to mean value) of twenty percent or less when considering analyses using all three methods.

6.2. Time Cutoff and Time Adjustment

Early-time data from baildown testing may be significantly impacted by filter-pack drainage or other effects that do not reflect LNAPL flow from the formation to the well during recovery. Such data does not contribute to analysis of LNAPL transmissivity, and may be eliminated by specifying a cutoff time. Data from times earlier than the cutoff time are not considered in estimation of LNAPL transmissivity. The cut-off time may be used with the B&R, C&J, and CB&P methods. The B&R method does not depend on the time origin, so no further adjustments are necessary. However, both the C&J and CB&P methods include an LNAPL storage coefficient as a parameter, which represents a capacitance factor, and time origin is significant to the theoretical model. For the C&J method a time adjustment of the apparent time origin may be applied. One may think of the Time Adjustment as accounting for the delay in LNAPL flow from the formation to the well associated with the duration of significant filter-pack drainage. Limited experience suggests that the Time Adjustment and $Time_{cut}$ may be related through the

following: Time Adjustment = (0.6 or 2/3) * $Time_{cut}$. The effects of $Time_{cut}$ and Time Adjustment are shown in Figure 6.1. In this figure, it is desired to eliminate data earlier than 25 minutes because of effects from filter-pack drainage ($Time_{cut}$ = 25 minutes); for a discussion of how this 25-minute time-cut was selected, see discussion leading to Fig. 7.4 below. A Time Adjustment = 15 minutes is applied for analysis of LNAPL transmissivity using the C&J method, meaning that the apparent time origin for data later than 15 minutes is shifted as shown. For the CB&P method, one simply uses the estimated drawdown at the time-cut as the initial drawdown value.

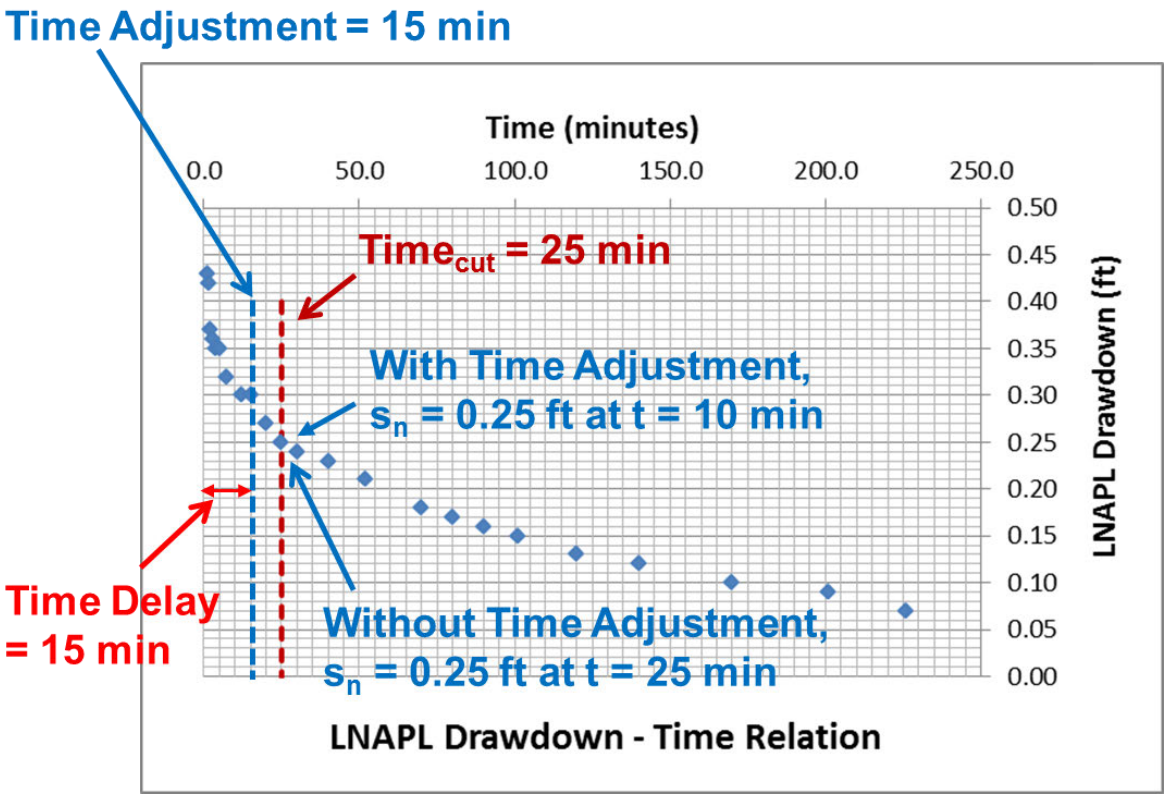


Figure 6.1. Application of $Time_{cut}$ and Time Adjustment to eliminate early-time data influenced by filter-pack drainage or other effects

6.3. Analysis of LNAPL Storage Coefficient

The storage parameter S_n is used in the C&J and CB&P methods. The maximum value should equal a reasonable drainable porosity value for the formation. An upper bound estimate would be 0.15 for coarse sands, 0.06 for fine sands, 0.004 to 0.025 for silts. Clays would be on the low end of silts or lower unless LNAPL exists in secondary porosity. These values assume that the recoverable fraction of LNAPL is up to 50% saturation for coarse sands and 5% for silts and clays. These values will be lower (i.e., a factor of 10 to 50) for wells with minimal LNAPL

recovery. Results are relatively insensitive to this parameter if realistic values are used. The table below provides general guidance on appropriate values.

Table 6.1: Recommended Relationship between LNAPL Transmissivity and LNAPL Storage Coefficient (from ASTM, 2011)

LNAPL Transmissivity (ft^2/d)	LNAPLStorage (vol/vol)
50	0.175
20	0.122
10	0.070
5	0.053
1	0.035
0.1	0.008

A "Default" option is available for estimating the LNAPL storage coefficient for the C&J and CB&P methods. An approximate model is fit to the data in Table 6.1, as shown in Figure 6.2.

(6.3.1) $$S_n = 0.025\sqrt{T_n}$$

In Eq. (6.3.1) the units of T_n are ft^2/d. The default option is selected by entering the letter d in the S_n entry cell. With the default option selected, the LNAPL storage coefficient is estimated implicitly as part of determining the LNAPL transmissivity.

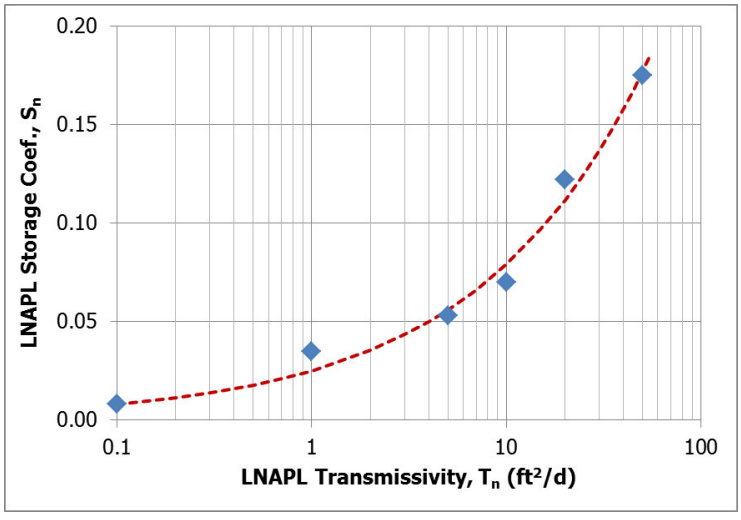


Figure 6.2. LNAPL storage coefficient vs. LNAPL transmissivity

6.4. General overview of LNAPL transmissivity estimation process

The process for estimating LNAPL transmissivity from LNAPL baildown test data using the API LNAPL Transmissivity Workbook is outlined in the flowchart shown in Figure 6.3. Further details are provided in ASTM (2011).

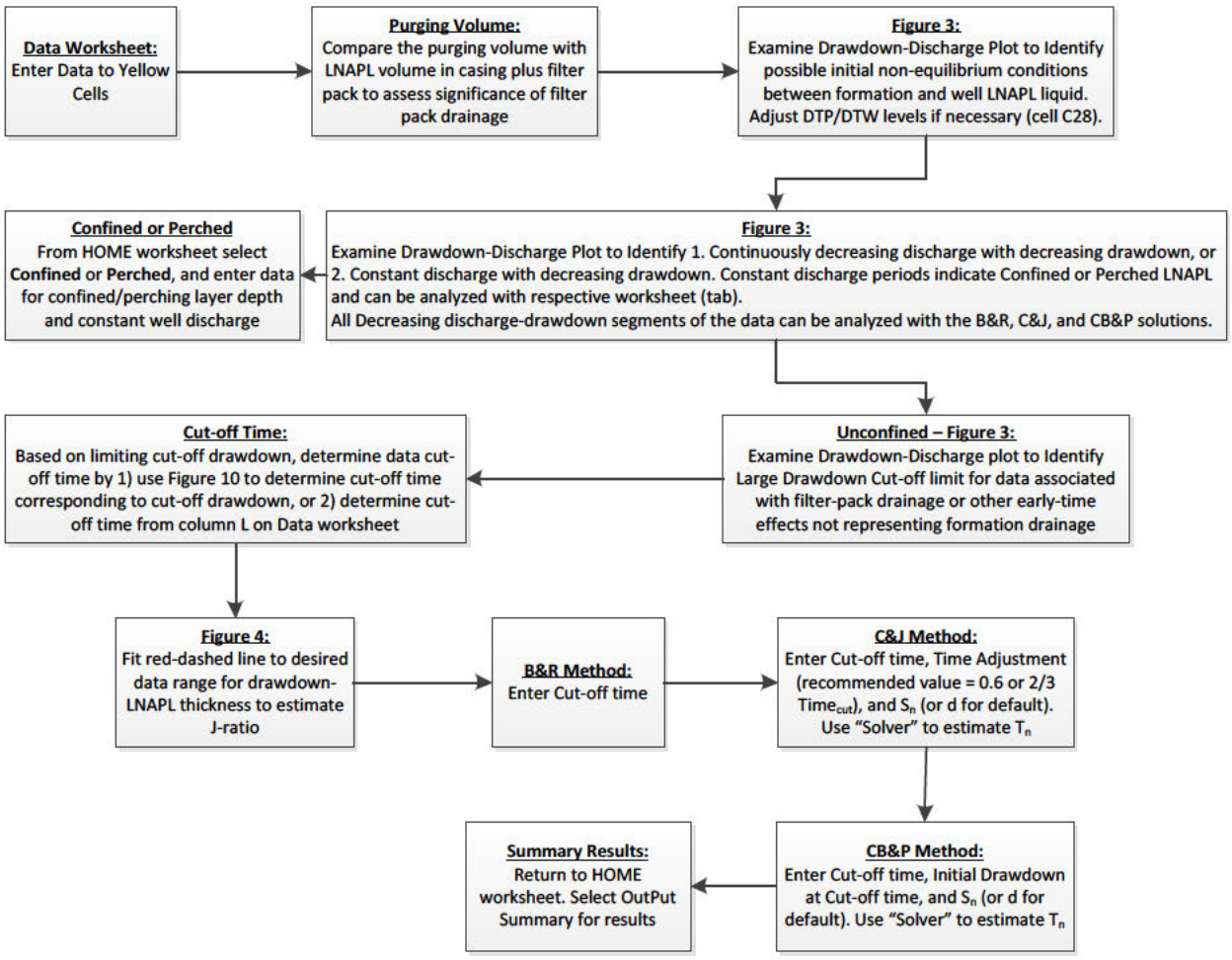


Figure 6.3. Flowchart outlining steps in LNAPL baildown test analysis

7. LNAPL Transmissivity Workbook

The *API LNAPL Transmissivity Workbook* tool is a Microsoft Excel ™ spreadsheet that can be used to estimate LNAPL transmissivity values from baildown test data under unconfined, confined and perched conditions. For unconfined conditions, three methods are used to calculate LNAPL transmissivity, and the results are averaged. The Kirkman J-ratio is required for two of these methods, and the magnitude of the J-ratio is determined by the User with Fig. 4 on the "Figures" worksheet. For both confined and perched LNAPL conditions, only a single estimate of LNAPL transmissivity is made based on the constant LNAPL discharge rate during part of the recovery period of the test.

The application tool has ten different worksheets that are designated as follows:

- HOME - Control and output worksheet
- Data - Entry of well configuration and fluid level data
- Figures - Basic figures showing data
- B&R - Bouwer and Rice method worksheet
- C&J - Cooper and Jacob method worksheet
- CB&P - Cooper, Bredehoeft and Papadopulos method worksheet
- B&R Type Curve - Set of type curves provided as aid to field work
- Confined - Confined LNAPL worksheet
- Perched - Perched LNAPL worksheet
- Flowchart - Flowchart outlining steps in LNAPL baildown test analysis

As discussed below, not all worksheets are visible at any time, though the first three worksheets and the last worksheet are always available.

7.1 "HOME" Worksheet

An example "HOME" worksheet is shown in Figure 7.1. This is the primary worksheet that outlines the steps in data analysis as follows:

1. Reset Output Summary
2. Enter Data & View Figures
3. Choose Well Conditions
4. LNAPL Transmissivity Summary

Step 1 hides the method-specific worksheets. The "Data", "Figures", and "Flowchart" worksheets remain visible and accessible. No existing data are cleared when the RESET button is selected. Step 2 requires entry of data on the "Data" worksheet and review of data on the "Figures" worksheet. Step 2 provides preliminary information to guide in selecting LNAPL

condition (unconfined, confined, or perched) for analysis. If unconfined conditions are observed, then the J-ratio MUST be determined using Fig. 4 on the "Figures" worksheet. Based on Step 2 assessment, Step 3 is selection of LNAPL condition which makes visible either the worksheets appropriate for unconfined conditions, or individually, the worksheets for confined or perched conditions. Step 4, selection of the OUTPUT SUMMARY button copies results from the method-specific worksheets to summary output.

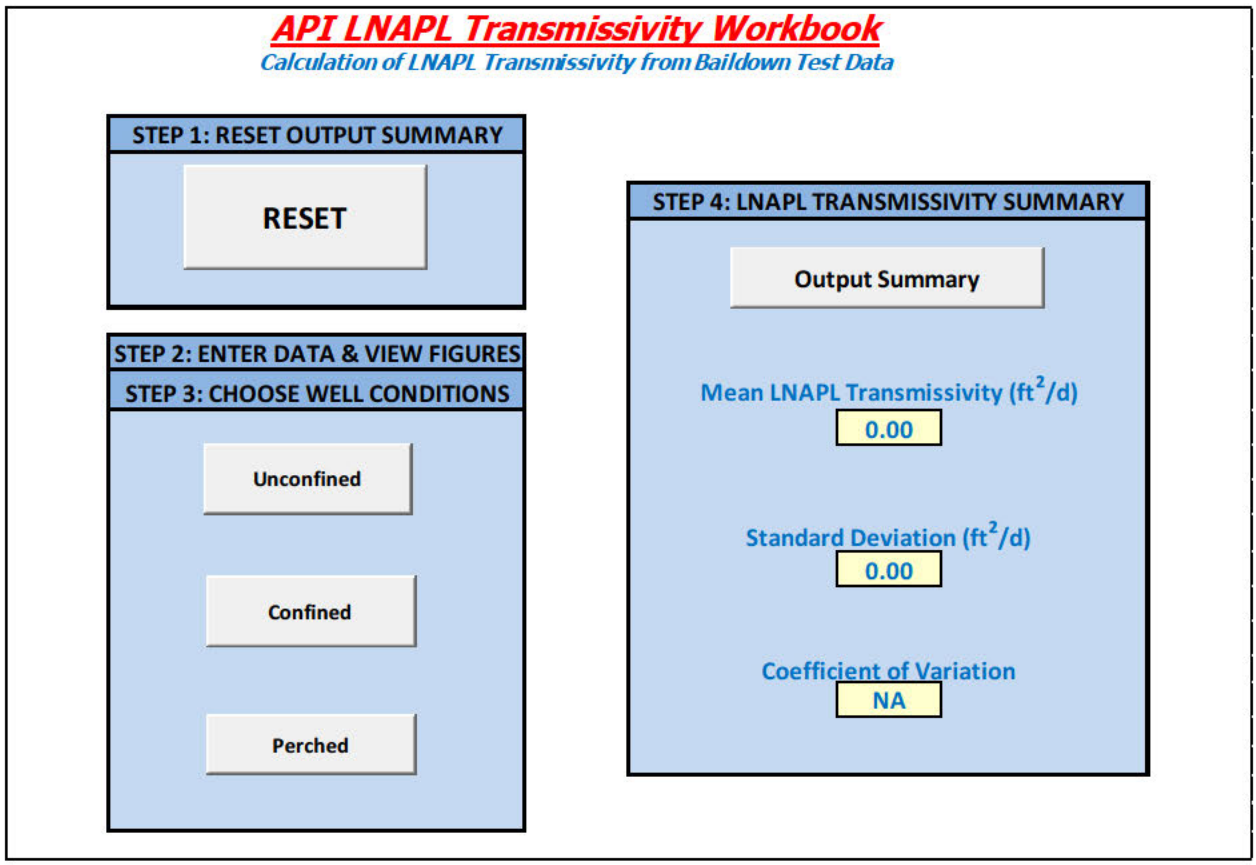


Figure 7.1. "HOME" worksheet

7.2 "Data" Worksheet

An example "Data" worksheet page is shown in Figure 7.2. The cells for data entry are shown in light yellow color and user must input the data in the units indicated. Other cells are locked to help protect against inadvertent modification to the worksheet. This worksheet includes the well configuration data listed in Section 3, along with records of depth to product (DTP) and depth to water (DTW) as a function of time, as measured from the top of casing. The initial values of DTP and DTW are also entered. The LNAPL Specific Yield, S_y, on this worksheet refers to the filter pack. A default value 0.175 is recommended, though the value can be modified by the user. The default value is based on an assumed filter-pack porosity = 0.35, and an assumed

specific yield equal to 50-percent of the void space. The LNAPL Density Ratio, ρ_r, is estimated from field data on product type. The LNAPL Baildown Volume is entered for comparison purposes only; it is not used elsewhere in the workbook. The "Drawdown Adjustment" value is read from the data entry for Fig. 3 on the "Figures" worksheet. Calculations performed on this worksheet include adjustment of fluid levels to give depth bgs, estimation of the water table depth based on DTP and DTW along with LNAPL-water density ratio, LNAPL drawdown using Eq. (5.1) and LNAPL discharge using Eq. (5.2), and the effective well radius as outlined in Appendix B. If both the ground surface elevation and top of casing elevation are entered as zero, then no adjustment is made to DTP and DTW fluid levels. For unconfined conditions with the LNAPL column within the screened interval of the well, these data are not necessary.

Well Designation:	YYY	Beckett and Lyverse (2002)											
Date:	date												
Ground Surface Elev (ft msl)	0.0	Enter These Data		Drawdown									
Top of Casing Elev (ft msl)	0.0			Adjustment									
Well Casing Radius, r_c (ft):	0.170	r_{e1}		(ft)									
Well Radius, r_w (ft):	0.500			0.08									
LNAPL Specific Yield, S_y:	0.175												
LNAPL Density Ratio, ρ_r:	0.780												
Top of Screen (ft bgs):	0.0												
Bottom of Screen (ft bgs):	0.0												
LNAPL Baildown Vol. (gal.):													
Effective Radius, r_{e3} (ft):	0.260	Calculated Parameters											
Effective Radius, r_{e2} (ft):	0.245												
Initial Casing LNAPL Vol. (gal.):	2.10												
Initial Filter LNAPL Vol. (gal.):	2.81												
		Enter Data Here					Water Table	LNAPL		LNAPL			
							Depth	Drawdown	Average	Discharge	s_n	b_n	r_e
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)		(ft)	s_n (ft)	Time (min)	Q_n (ft^3/d)	(ft)	(ft)	(ft)
Initial Fluid Levels:	0	22.29	25.38	22.29	25.38		22.97					3.09	
Enter Test Data:	1.0	22.80	23.30	22.80	23.30		22.91	0.43				0.50	
	1.5	22.79	23.38	22.79	23.38		22.92	0.42	1.3	55.041	0.43	0.59	0.260
	2.0	22.74	23.41	22.74	23.41		22.89	0.37	1.8	48.925	0.40	0.67	0.260
	3.0	22.73	23.50	22.73	23.50		22.90	0.36	2.5	30.578	0.37	0.77	0.260
	4.0	22.72	23.54	22.72	23.54		22.90	0.35	3.5	15.289	0.36	0.82	0.260
	5.0	22.72	23.59	22.72	23.59		22.91	0.35	4.5	15.289	0.35	0.87	0.260
	7.5	22.69	23.66	22.69	23.66		22.90	0.32	6.3	12.231	0.34	0.97	0.260
	12.0	22.67	23.89	22.67	23.89		22.94	0.30	9.8	16.988	0.31	1.22	0.260
	15.0	22.67	23.90	22.67	23.90		22.94	0.30	13.5	1.019	0.30	1.23	0.260
	20.0	22.64	23.98	22.64	23.98		22.93	0.27	17.5	6.727	0.29	1.34	0.260
	25.0	22.62	24.04	22.62	24.04		22.93	0.25	22.5	4.893	0.26	1.42	0.260
	30.0	22.61	24.07	22.61	24.07		22.93	0.24	27.5	2.446	0.25	1.46	0.260
	40.0	22.6	24.15	22.60	24.15		22.94	0.23	35.0	2.752	0.24	1.55	0.260
	52.0	22.58	24.22	22.58	24.22		22.94	0.21	46.0	2.293	0.22	1.64	0.260
	70.0	22.55	24.31	22.55	24.31		22.94	0.18	61.0	2.039	0.20	1.76	0.260
	80.0	22.54	24.36	22.54	24.36		22.94	0.17	75.0	1.835	0.18	1.82	0.260
	90.0	22.53	24.39	22.53	24.39		22.94	0.16	85.0	1.223	0.17	1.86	0.260
	101.0	22.52	24.44	22.52	24.44		22.94	0.15	95.5	1.668	0.16	1.92	0.260
	120.0	22.5	24.50	22.50	24.50		22.94	0.13	110.5	1.288	0.14	2.00	0.260
	140.0	22.49	24.57	22.49	24.57		22.95	0.12	130.0	1.223	0.13	2.08	0.260
	170.0	22.47	24.65	22.47	24.65		22.95	0.10	155.0	1.019	0.11	2.18	0.260
	201.0	22.46	24.74	22.46	24.74		22.96	0.09	185.5	0.986	0.10	2.28	0.260
	226.0	22.44	24.79	22.44	24.79		22.96	0.07	213.5	0.856	0.08	2.35	0.260

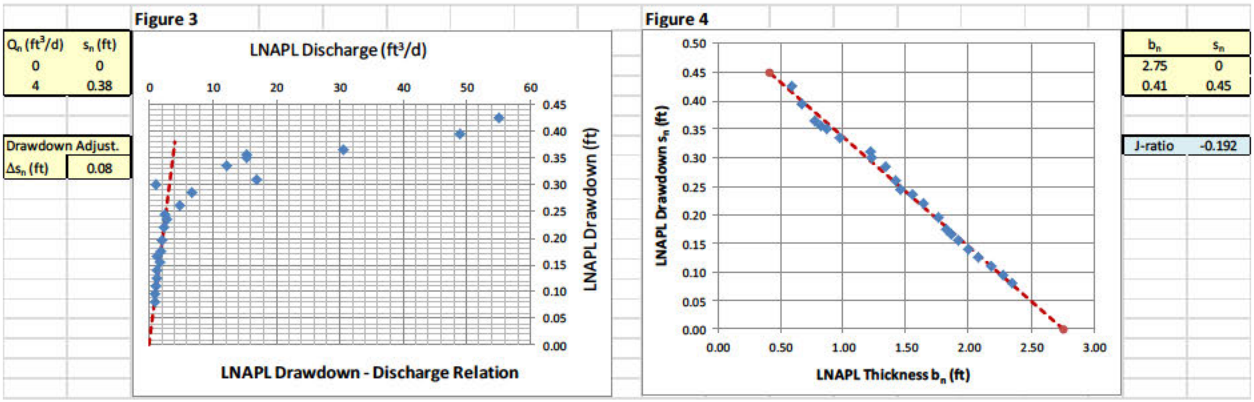
Figure 7.2. "Data" entry worksheet

7.3 "Figures" Worksheet

This worksheet contains ten miscellaneous figures showing the input and the output data. As discussed below, the most important diagnostic tools include the plot of LNAPL drawdown versus discharge, and the plot of LNAPL drawdown versus LNAPL thickness (J-Ratio). The

figures (objects) are not protected to allow edits (i.e., axis scales, etc.). The figures are numbered one through ten and are described as follows:

- Fig 1: Depth to Fluid Interface vs. Time (arithmetic time scale). This figure also shows the initial DTP and DTW. Depending on the screen interval data entered on the "Data" worksheet, the screened interval of the LNAPL column is also shown. The entire screen length is not shown. Instead, only the screened interval extending one foot above and/or below the initial LNAPL well thickness is shown. Fig. 1 is useful for evaluating how the potentiometric surface varied over the test duration. Looking for trends of water-table fluctuation will help identify any significant deviations from the assumed constant background conditions.
- Fig 2: Depth to Fluid Interface vs. Time (logarithmic time scale). This figure also shows the initial DTP and DTW. Depending on the screen interval data entered on the "Data" worksheet, the screened interval of the LNAPL column is also shown. The entire screen length is not shown. Instead, only the screened interval extending one foot above and/or below the initial LNAPL well thickness is shown. Similar to Fig. 1, however the early portion of the test can be better viewed for longer term tests.
- Fig 3: LNAPL Drawdown vs. LNAPL Discharge. This is an important diagnostic tool used to determine Drawdown Adjustment that is copied to the "Data" worksheet and other worksheets to account for initial non-equilibrium between formation and well fluids. The LNAPL Drawdown-LNAPL Discharge data should extrapolate to the origin (zero value) for small values. To aid analysis, a linear model is added with data entry in the yellow-fill box adjacent to the figure, as shown in Figure 7.3(a). LNAPL drawdown-discharge should exhibit a direct relationship. Deviations from this indicate the baildown test may be significantly affected by outside factors (e.g., nearby changes in pumping) or confined or perched conditions (where constant discharge is observed).
- Fig 4: LNAPL Drawdown vs. LNAPL Thickness. This is an <u>essential</u> diagnostic tool that is used to estimate the J-ratio magnitude, as described in Appendix A, and used with the "B&R" worksheet and "CB&P" worksheet. A linear model is provided with data entry in the yellow-fill box adjacent to the figure, and with estimated J-ratio value shown in the blue-fill box adjacent, as shown in Figure 7.3(b).



(a) (b)

Figure 7.3. Fig. 3 and Fig. 4 from the "Figures" worksheet showing data entry boxes for estimation of drawdown adjustment and J-ratio

- Fig. 5: Depth to Product (DTP) vs. LNAPL Discharge. This figure may be helpful as a diagnostic tool to identify soil stratigraphic influences.
- Fig 6: Depth to Water (DTW) vs. LNAPL Discharge. This figure may be helpful as a diagnostic tool to identify soil stratigraphic influences.
- Fig 7: LNAPL Thickness vs. Time. This figure may be useful for evaluating if the fluid levels reach equilibrium at the end of the test.
- Fig 8: LNAPL Discharge vs. Time. This figure represents an alternative method for evaluating if the baildown test has completed and the well reaches equilibrium conditions.
- Fig 9: LNAPL Well Inflow Volume vs. Time. Fig. 9 is analogous to Fig. 7 except provided in terms of the total well volume. In addition for being useful to evaluate test completion, this figure is useful for design of future baildown tests in terms of volume to remove from the well and filter pack.
- Fig 10: LNAPL Drawdown vs. Time. Linear model tool is also added with data entry in the yellow-fill box adjacent to the figure. In combination with Fig. 3, this figure is useful in identifying cut-off time for early-time data.

7.4 "B&R" Worksheet

The "B&R", or Bouwer and Rice worksheet calculates the LNAPL transmissivity and standard deviation based on the Bouwer and Rice (Bouwer and Rice, 1976; Bouwer, 1989) method using the method of linear least squares. As shown in Eq. (C.3), according to this method, the logarithm of the drawdown varies as a linear function of time. A straight line is automatically fit to the log-drawdown vs. time data and the slope of this line is used to determine the LNAPL transmissivity. The variance of the slope of the line is used to estimate the LNAPL

transmissivity standard deviation. The ratio of the radius of influence to the effective radius is calculated using the polynomial approximation presented by Butler (2000). The user may eliminate early time data from the analysis by entering a non-zero value for the cutoff time (yellow cell). An example worksheet is shown in Figure 7.5. The only active cell on this worksheet is the cut-off time, and the LNAPL transmissivity value is automatically calculated. The lower figure on the worksheet shows the fit of the model data to the B&R Type Curve (see discussion below).

For the example shown in Figure 7.5 the cut-off time is set at 25 minutes. This cut-off time is based on eliminating early-time data associated with large filter pack drainage to the well. The drawdown-discharge curve for this example (Fig. 3 on the "Figures" worksheet) is shown in Figure 8.1 (c) and Figure 8.1 (d) (expanded scale after drawdown correction). In particular, Figure 8.1 (d) shows that the linear relationship between drawdown and discharge is reached once the LNAPL drawdown is about 0.25 ft. The LNAPL drawdown vs. time curve (Fig. 10 from the "Figures" worksheet) is shown in Figure 7.4, which gives the corresponding cut-off time 25 minutes for an LNAPL drawdown of 0.25 ft.

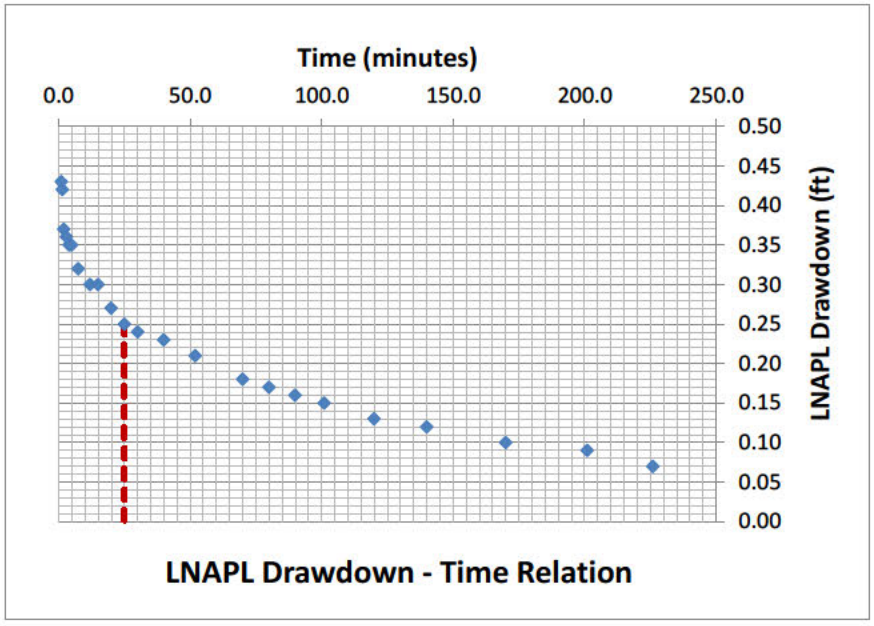


Figure 7.4. LNAPL Drawdown vs. Time Curve (Fig. 10 from "Figures" Worksheet)

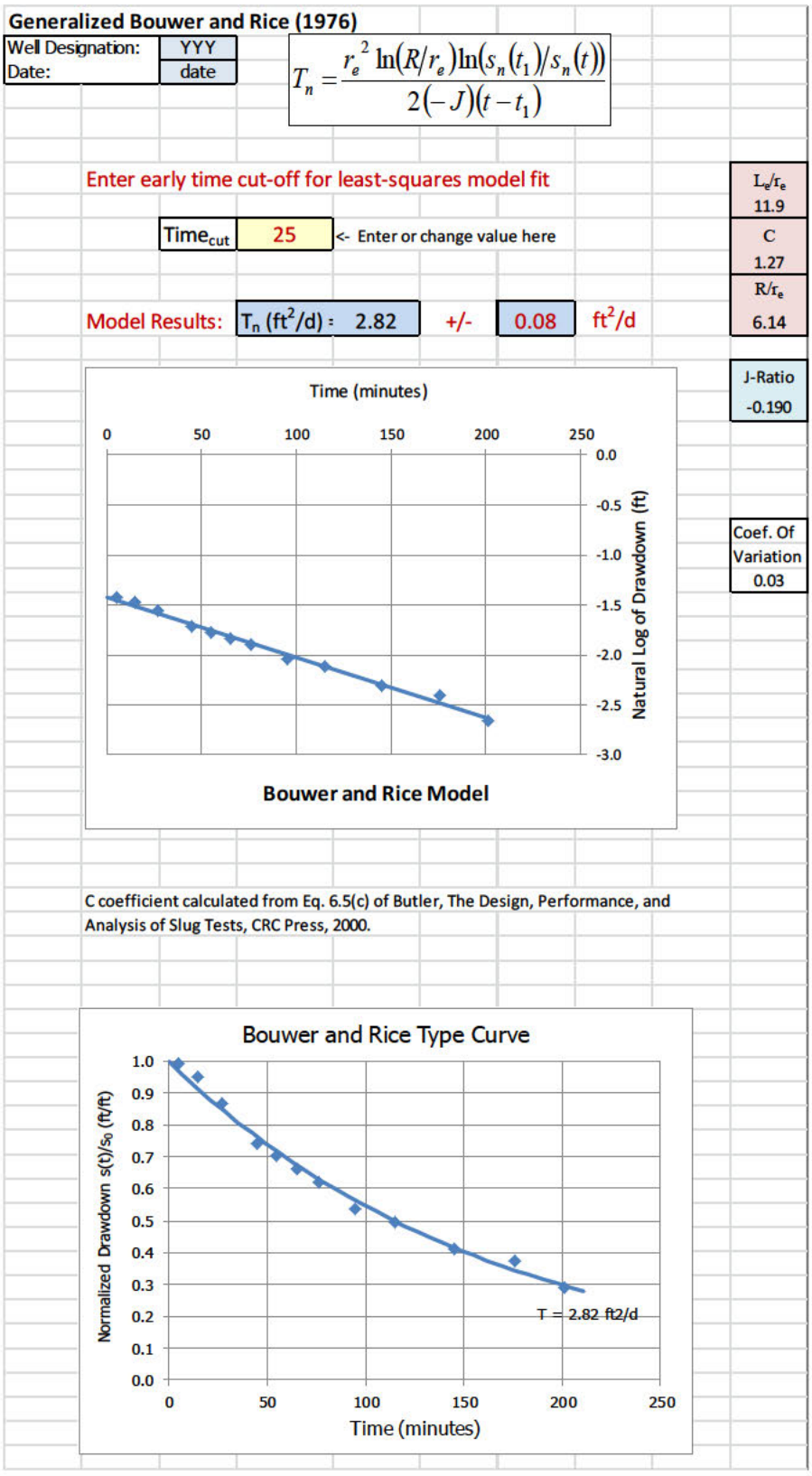


Figure 7.5. "B&R" worksheet

7.5 "C&J" Worksheet

The Cooper and Jacob (C&J) worksheet is used to calculate the LNAPL transmissivity value based on the Cooper and Jacob (1946) equation. [As described in Appendix D, the Theis equation is actually used in calculations, though the more commonly used Cooper and Jacob designation has been retained here.] The method used is modified from that presented as method three of Huntley (2000). The method is outline in Appendix D. Unlike the B&R method, both the C&J method and the CB&P method use a storage parameter (S_n) in addition to LNAPL transmissivity (T_n) to fit the model and data. Use of the storage parameter implies that the time origin is critical to data analysis for both methods. Yet, it is recognized that early-time data can be impacted by filter-pack drainage and not reflect natural LNAPL flow from the formation to the well. Thus the user may specify a cutoff time to eliminate early-time data from the analysis. To provide consistency with the model basis, the user may also adjust the time origin to a fraction of the cut-off time. There is little guidance towards an appropriate fraction, though the range 50% to 80% appears reasonable. Recommended values are 0.6 or 2/3, whichever is more convenient. Both the cut-off time and time adjustment values are specified by the user (light yellow cells). For further discussion, see Section 6.2. In some cases, repeating the test with alternative field methods that reduce the removal time or reduce the filter pack recharge may help reduce the need for the time adjustment.

The estimate of LNAPL transmissivity is found by minimizing the root-mean-square error between model prediction and data by varying the storage coefficient and LNAPL transmissivity. An example worksheet is shown in Figure 7.6. The Adjusted Time = 6 minutes, which is 60% of the cut-off time. The Excel "Solver" function is used to find the root-mean-square error specified by Eq. (D.8). Instead of using "Solver" to find both S_n and T_n, it is recommended that the user select a trial value of S_n and use "Solver" to find T_n. Alternatively, the letter d may be entered as the Trial S_n value to select the default option described in Section 6.3.

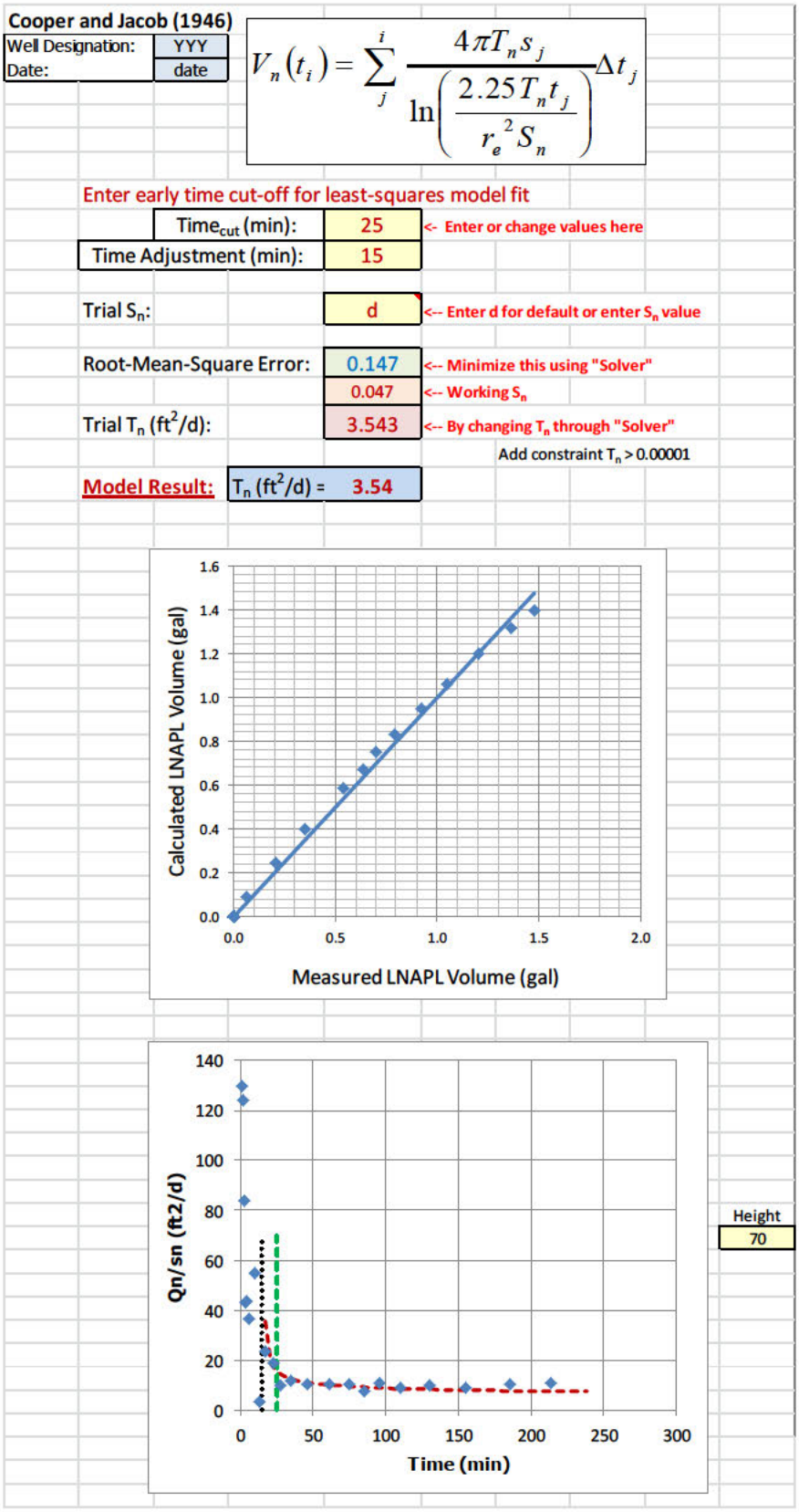


Figure 7.6. "C&J" worksheet

7.6 "CB&P" Worksheet

The Cooper, Bredehoeft and Papadopulos (CB&P) worksheet is used to calculate the LNAPL transmissivity value based on the Cooper, Bredehoeft and Papadopulos (1967) slug test model. Application of this model for an LNAPL baildown test is described in Appendix E, and an example worksheet is shown in Figure 7.7. For application of this method, there are three unknown parameters: initial LNAPL drawdown $s_n(0)$, LNAPL transmissivity T_n, and LNAPL storage coefficient S_n. Trial estimates of these quantities are entered on the worksheet, and the Excel "Solver" function is used to minimize the Root-Mean-Square Error given by the square-root of Eq. (E.7). An estimate of the initial drawdown is provided by the extrapolated drawdown at the cutoff time. Alternatively, the initial drawdown is selected so that the drawdown ratio s_n/s_{n0} extrapolates to 1 at time = 0 (which includes the cutoff time adjustment). The algorithm used to evaluate the model equations is derived from Charbeneau (2000).

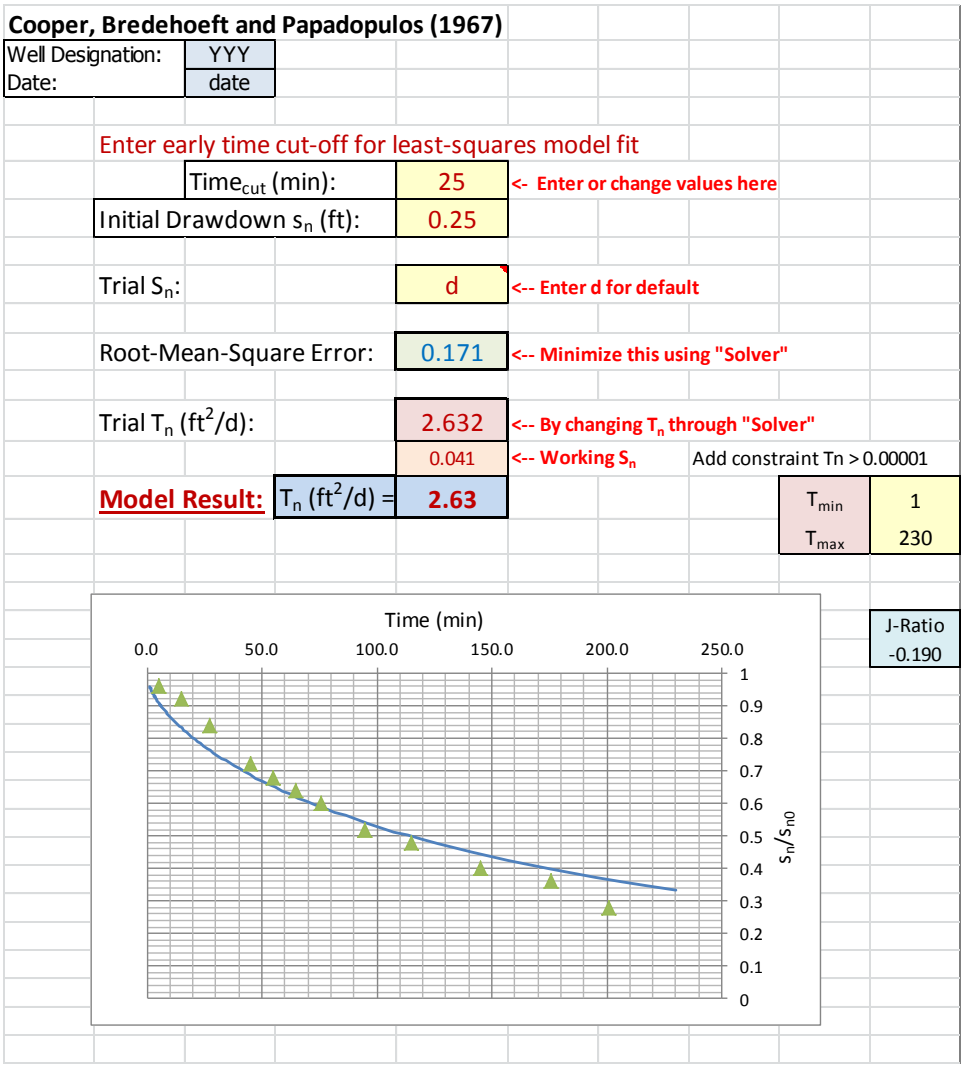
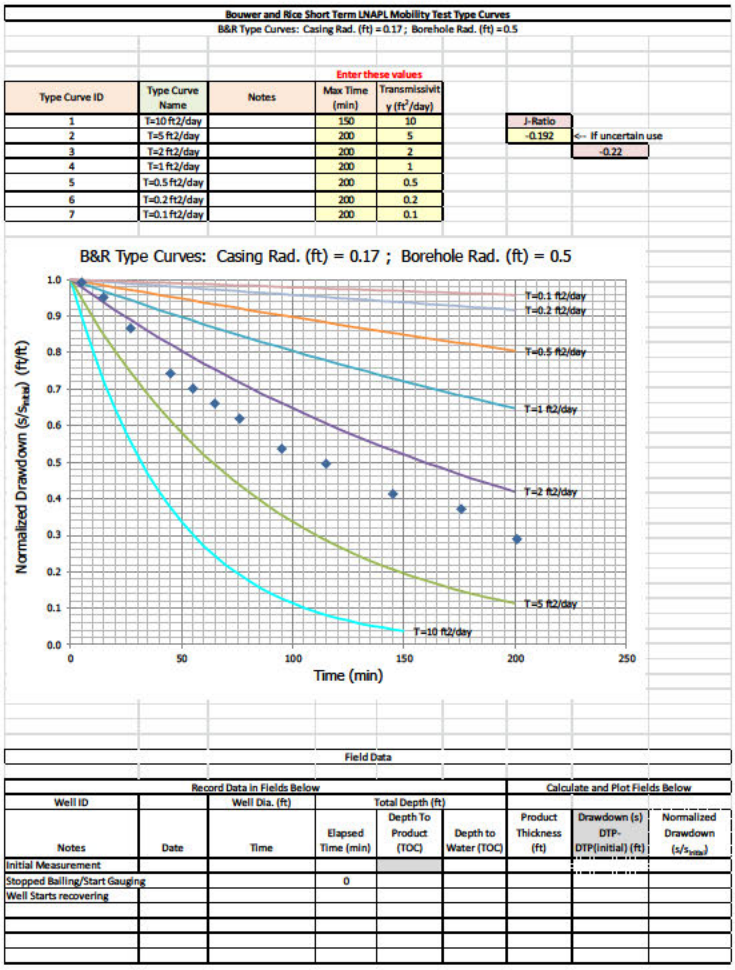


Figure 7.7. "CB&P" worksheet

7.7 "B&R Type Curve" Worksheet

This worksheet presents a type curve based on the Bouwer and Rice method along with a supporting data sheet. The type curve was developed to support rapid field evaluation of LNAPL baildown tests when the user is primarily interested in 'order-of-magnitude' estimates of LNAPL transmissivity and possible early termination of a field test of a particular well. The type curve is a normalized plot of the Bouwer and Rice solution present at the top of the B&R worksheet, where the type curve shows normalized drawdown as a function of time for selected values of LNAPL transmissivity. The use of the type curve requires that the well-specific construction and specific yield data be entered into the "Data" worksheet in order to generate the correct type curves. A J-ratio of $(\rho_r - 1)$ is recommended unless well-specific behavior is available. The user may change the range of LNAPL transmissivity curves shown on the curve and associated maximum times (which may correspond to the test time) (light yellow cells). The lower part of the worksheet provides a data sheet that may be copied for field use. The type curve application was suggested by Andrew Kirkman. Figure 7.8 shows an example worksheet.



Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.17 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio: -0.192 <-- If uncertain use -0.22

Field Data

Record Data in Fields Below						Calculate and Plot Fields Below		
Well ID		Well Dia. (ft)	Total Depth (ft)					
Notes	Date	Time	Elapsed Time (min)	Depth To Product (TOC)	Depth to Water (TOC)	Product Thickness (ft)	Drawdown (s) DTP-DTP(initial) (ft)	Normalized Drawdown (s/s$_{max}$)
Initial Measurement								
Stopped Bailing/Start Gauging			0					
Well Starts recovering								

Figure 7.8. "B&R Type Curve" worksheet

7.8 "Confined" Worksheet

The "Confined" worksheet is used to estimate LNAPL transmissivity under confined LNAPL conditions. This worksheet is visible and available when the CONFINED button is selected under Step 3 Conditions on the "Selection and Results" worksheet. The basic equations are presented in Appendix F, and an example worksheet is shown in Figure 7.9. The depth to base of confining bed is entered to determine the effective limiting thickness of LNAPL in the well b_{nW} (see Eq. F.2). The constant discharge from the steady discharge portion of the test is then entered and used to calculate the LNAPL transmissivity. The radius of influence term for the skimmer well equation is determined from the Bouwer and Rice (B&R) worksheet.

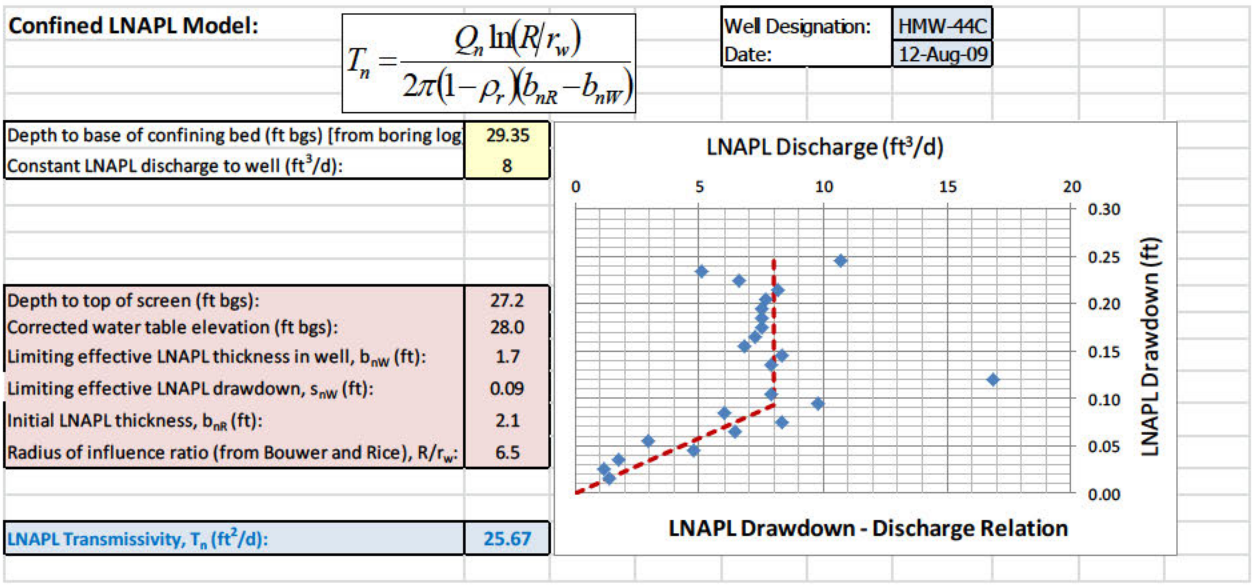


Figure 7.9. "Confined" worksheet

7.9 "Perched" Worksheet

The "Perched" worksheet is used to estimate LNAPL transmissivity under perched LNAPL conditions. The basic equations are presented in Appendix G. The depth (bgs) to the top of the perching layer, DZ_{12}, is entered to determine the effective limiting drawdown of LNAPL in the well based on the initial depth to product DTP_0. The constant discharge from the steady discharge portion of the test is then entered and used to calculate the LNAPL transmissivity. The radius of influence term for the skimmer well equation is determined from the Bouwer and Rice (B&R) worksheet. The worksheet mirrors the "Confined" worksheet and is not repeated here.

8. Examples and Important Diagnostic Tools

An important diagnostic tool is a plot of the well drawdown versus well discharge. The general shape of this relationship can be used to identify conditions with significant borehole recharge from the filter pack, screen for perched or confined LNAPL conditions, and help identify whether formation LNAPL was initially in equilibrium with well-bore LNAPL (and whether drawdown adjustment might be necessary). Some example curves are discussed below.

Figure 8.1 shows a number of drawdown-discharge curves. Figure 8.1(a) shows an example for unconfined LNAPL where significant borehole recharge from the filter pack is not an issue. While the initial calculated data (point with large Q_n, large s_n) is not consistent with other data on this figure, it is based on measurements taken at 0.5 and 1 minute into the test and could be associated with measurement uncertainty. Figure 8.1(b) gives an example where borehole recharge from the filter pack is significant. The initial data show large discharge which is primarily associated with filter pack drainage. Once the drawdown falls below 0.35 feet, consistent linear drawdown-discharge behavior is observed.

Figures 8.1(c) and (d) show the same data set. First, Figure 8.1(c) shows that significant borehole recharge does occur. Also, significantly, the linear part of the curve does not approach zero drawdown at zero discharge. Instead, it appears that the extrapolated limit has zero discharge with s_n = 0.08 ft. Such behavior suggests that the formation and wellbore LNAPL fluids were not initially in equilibrium, and that a drawdown correction of Δs_n = 0.08 ft should be applied to the data before LNAPL transmissivity analysis. Figure 8.1(d) shows an expanded view of this data after the correction has been applied. Such a correction does affect the resulting LNAPL transmissivity value that is calculated. With the correction Δs_n = 0.08 ft, the average LNAPL transmissivity T_n = 2.99 ft^2/d with CV = 0.16. For the same data and analysis without the 0.08 ft correction, the drawdowns are larger and the estimated LNAPL transmissivity is smaller with an average value T_n = 1.89 ft^2/d and coefficient of variation = 0.19.

Figure 8.1(e) shows behavior that suggests confined (or perched) LNAPL conditions. In this case it represents confined conditions with the water table initially located at an elevation above the confined LNAPL and with resulting exaggerated LNAPL thickness in the well. Immediately following LNAPL removal from the well, there is no LNAPL within the wellbore to "push" back against LNAPL inflow from the formation, and LNAPL discharge from the formation occurs at a constant rate while the LNAPL drawdown is declining. Once the LNAPL column within the wellbore increases in thickness to contact the mobile formation LNAPL, the inflow rate is retarded and decreases at a linear rate along with the LNAPL drawdown. One may analyze LNAPL transmissivity from the constant inflow rate along with limiting LNAPL drawdown value (about 0.1 ft in this example), or one can use standard (unconfined) equations on the data from the linear drawdown-discharge part of the curve. Figure 8.1(f) shows large initial LNAPL inflow, which in this case is likely associated with aggressive purging in addition to filter pack drainage (this corresponds to Figure B.1(c)).

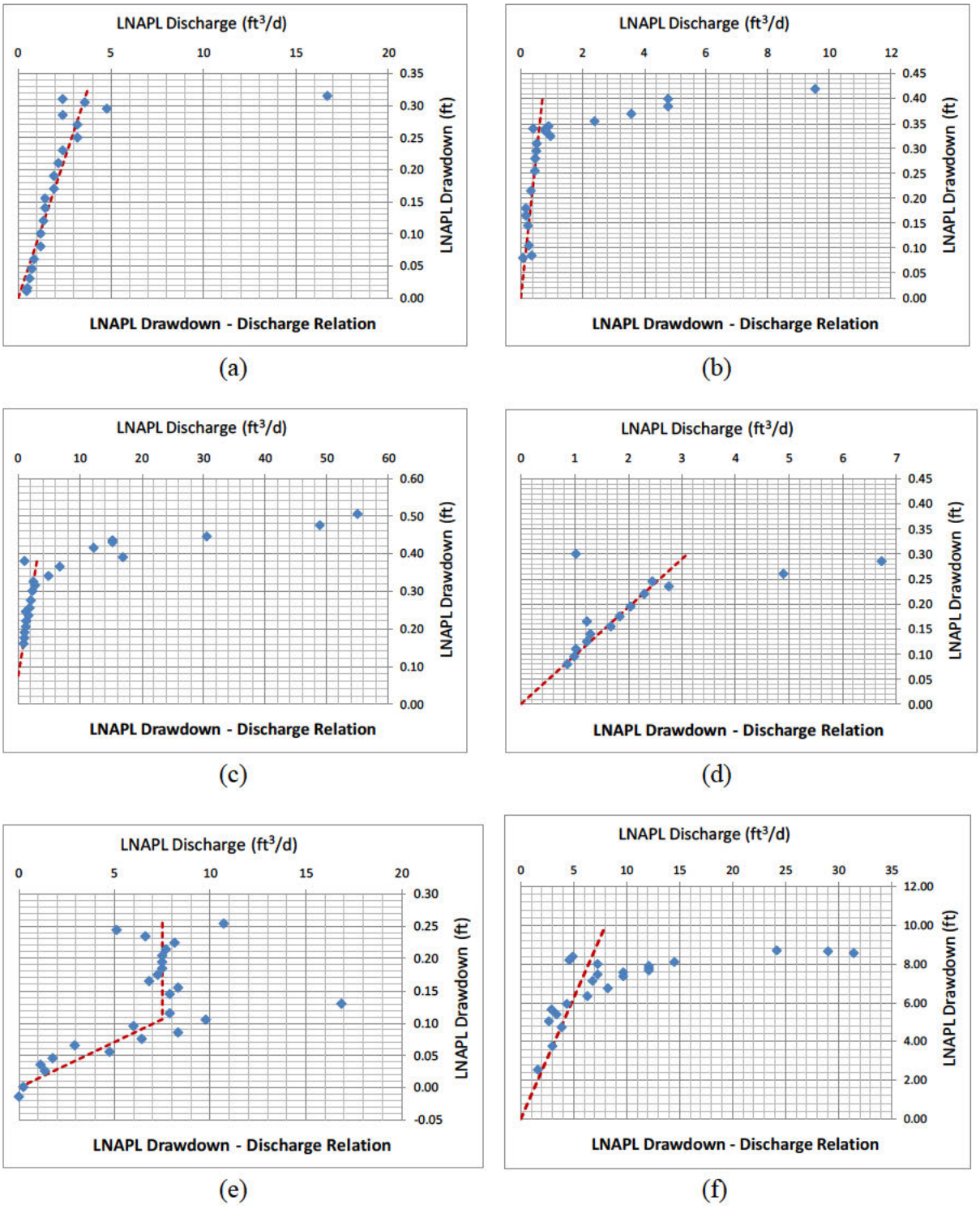


Figure 8.1. Example LNAPL drawdown-discharge curves

A couple of examples are considered in a little more detail. The first example, Figure 8.2, shows results from a baildown test with initial LNAPL thickness approximately 1.5 ft. During fluid removal from the wellbore both LNAPL and water were removed, and there is significant fluid recovery during approximately the first 6 minutes of the test, after which the calculated water table elevation remains stable. While there is significant scatter in the early-time data (larger drawdown values), the latter-time data shows a nearly linear relationship between discharge and drawdown. It also appears that the drawdown intercept with the $Q_n = 0$ axis has a residual value of about s_n = 0.02 ft (0.24 inch). While this magnitude correction appears small, it does represent nearly twenty percent of the drawdown being analyzed during the test analysis. A drawdown correction of magnitude 0.018 ft is applied (larger corrections would result in negative drawdown and require further individual data adjustment or use of an alternative model for analysis). A cut-off of 10 minutes is assumed, and the data gives J = -0.179. The calculated LNAPL transmissivity is T_n = 10.45 ft^2/d, and the coefficient of variation (ratio of standard deviation to mean transmissivity value based on the three methods of data analysis that are discussed below) is CV = 0.13. [If drawdown correction is not applied the model provides a LNAPL transmissivity estimate T_n = 5.34 ft^2/d with CV = 0.28.]

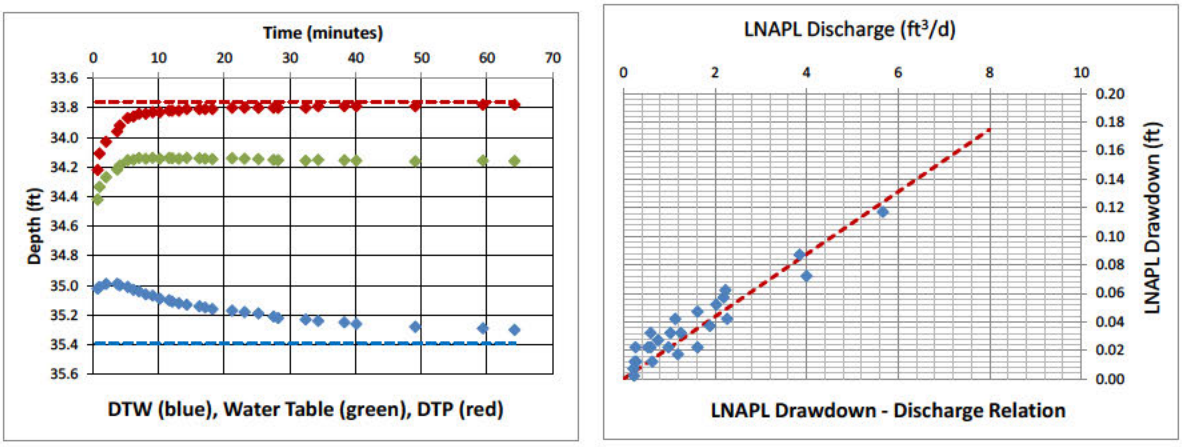


Figure 8.2. Example E1: T_n = 10.4 ft^2/d; CV = 0.13

The second example shown in Figure 8.3 represents a test where purging resulted in significant removal of both LNAPL and groundwater. The bottom of screen is located at a depth 27 ft, and this is the initial elevation for fluid interfaces in the well. Figure 8.3(b) shows the LNAPL drawdown-discharge graph. The expected linear relationship between LNAPL drawdown and discharge is not observed until the drawdown reaches approximately 4.2 ft. Figure 8.3(c) shows that the J-ratio is J = -1.18. This is consistent with a rising water table and LNAPL-water interface elevation throughout the test. Figure 8.3(d) is the graph of LNAPL drawdown versus time (Fig. 10 on the "Figures" worksheet). The LNAPL drawdown is 4.2 ft at a time of 24

minutes. A cut-off time of 25 minutes is assumed, with an Adjustment Time Δt_a = 15 minutes for the C&J and CB&P methods. Results from the three analysis methods give T_n = 3.08 ft^2/d with CV = 0.07.

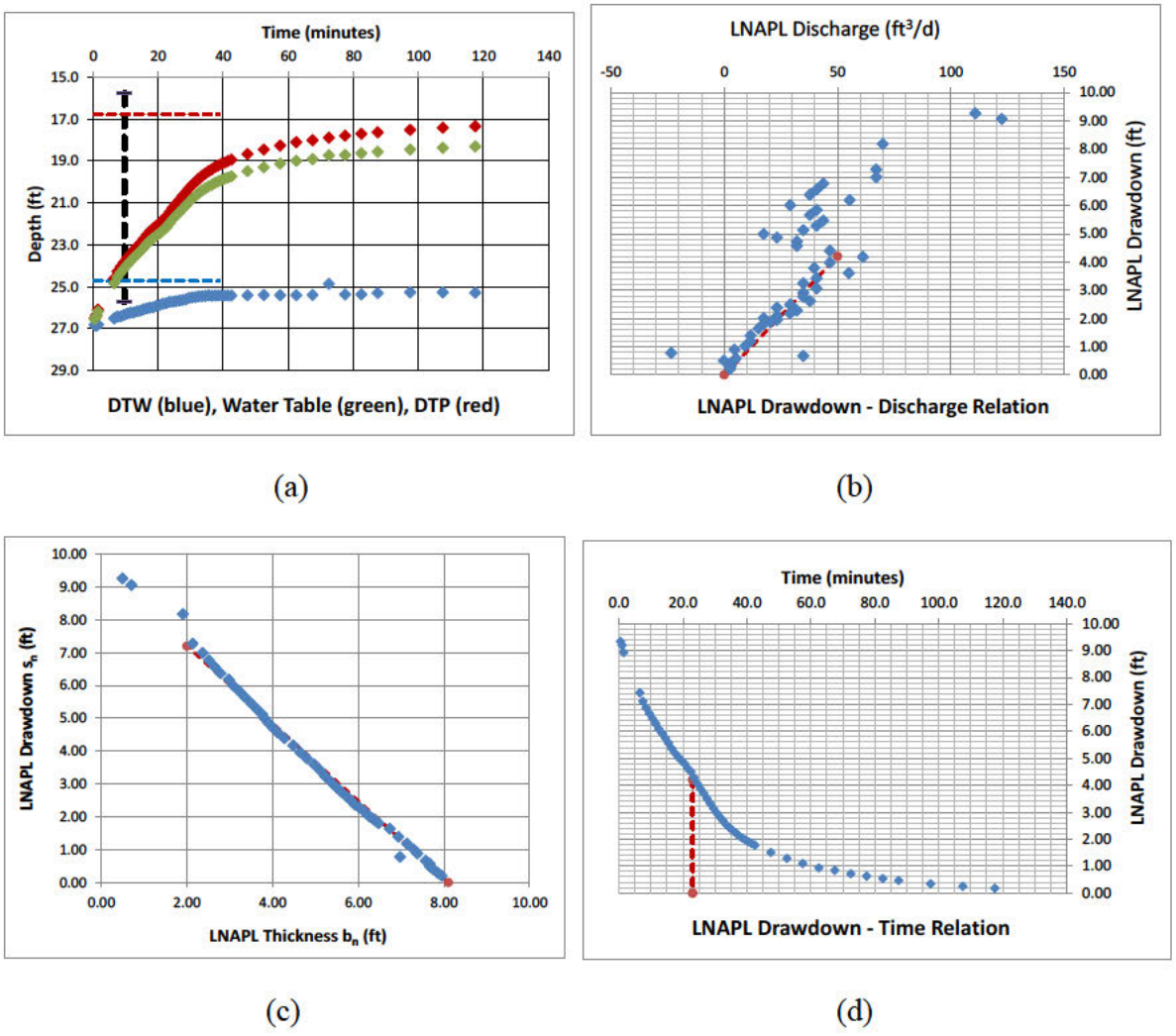


Figure 8.3. Example E2: T_n = 3.08 ft^2/d; CV = 0.07

A third example shown in Figure 8.4 corresponds to the confined LNAPL test shown in Figure 7.9. The LNAPL transmissivity value calculated in Figure 7.9 is based on a single data corresponding to the drawdown and discharge at the end of the "constant discharge" segment. The following example shows that consistent results can be achieved if only the late-time data is used. The drawdown-discharge curve of Figure 8.4(b) shows that the linear relationship is observed starting at a drawdown of about 0.1 ft. Figure 8.4(c) shows that J = -0.257, which is close to the values that would be used with the Huntley method of analysis (for this well, ρ_r = 0.764). Figure 8.4(d) shows that a drawdown of 0.1 ft is observed at a time 12 minutes, which

serves as the cut-off for the three methods of analysis. A time adjustment $\Delta t_a = 8$ minutes is used for the C&J method. Results from the three methods give $T_n = 23.56$ ft^2/d with $CV = 0.14$. This LNAPL transmissivity estimate compares favorably with the estimate $T_n = 25.67$ ft^2/d from Figure 7.9.

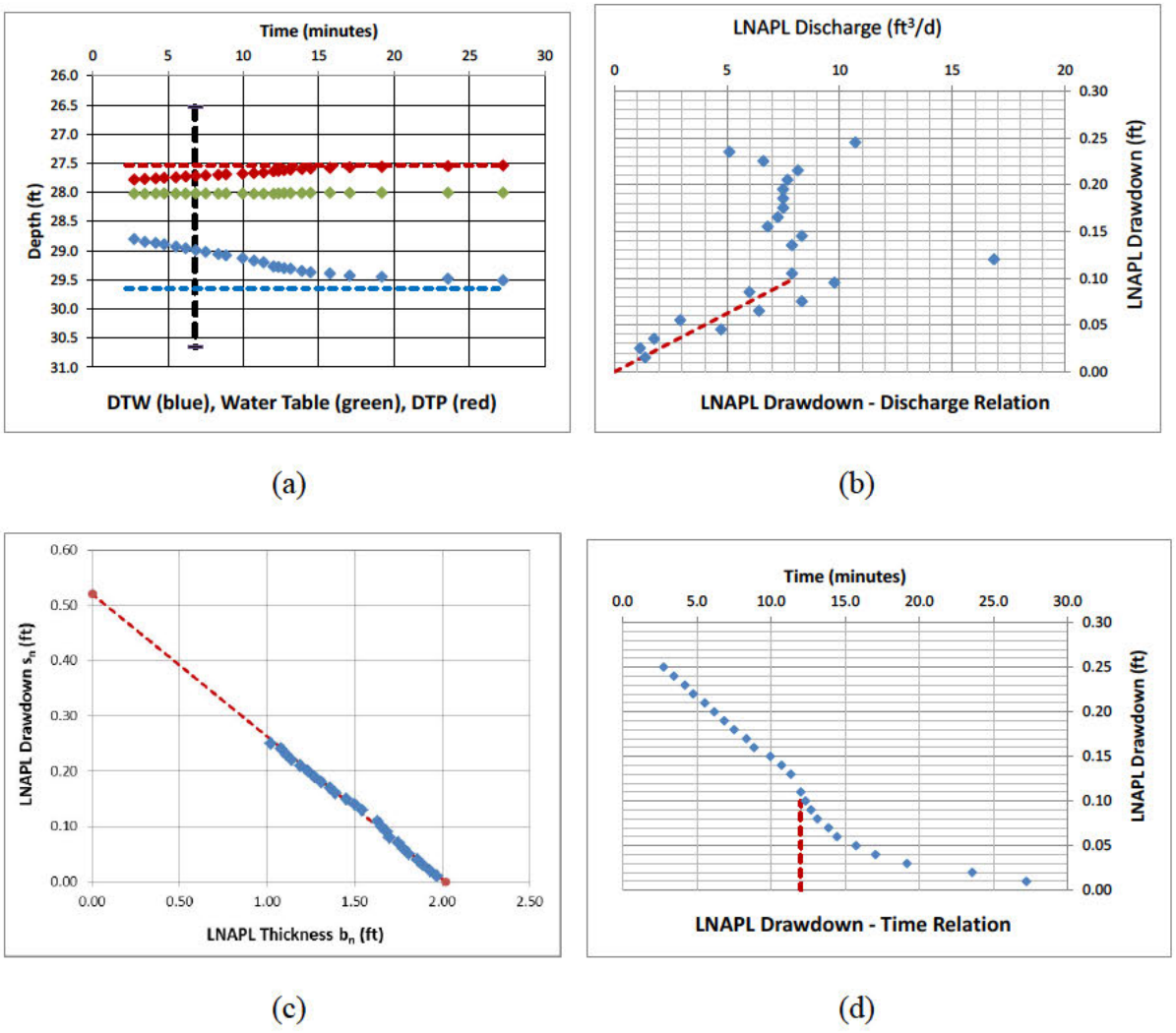


Figure 8.4. Example E3: $T_n = 23.56$ ft^2/d; CV = 0.14

8. Bibliography

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Appendix A: Kirkman J-Ratio

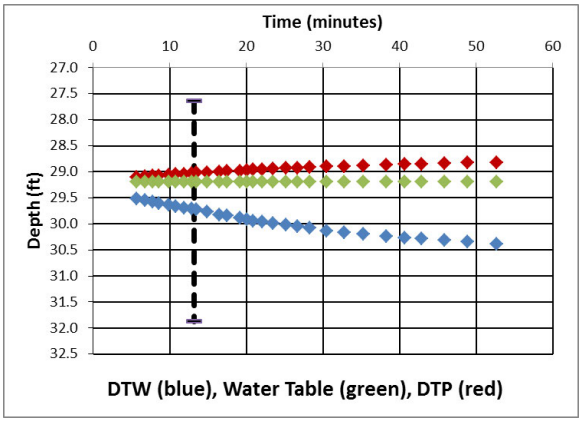
The LNAPL discharge from the formation to the well is also related to changes in LNAPL drawdown. This relationship is critical to the generalized Bouwer and Rice method and Cooper, Bredehoeft and Papadopulos method discussed herein. With the effective well radius (see Appendix B), the relationship is written

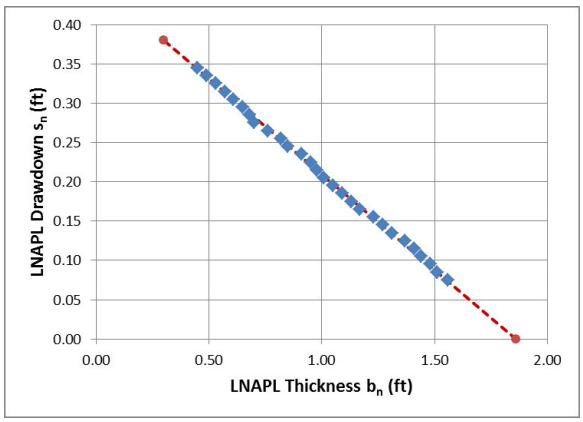
$$(A.1) \quad Q_n = \pi r_e^{\,2} \frac{db_n}{dt} = \frac{\pi r_e^{\,2}}{J} \frac{ds_n}{dt}$$

Equation (A.1) states that the LNAPL discharge is equal to the rate of LNAPL accumulation within the well. Andrew Kirkman (personal communication) has suggested that this rate can be generally related to the change in LNAPL drawdown through introduction of a J-ratio parameter. The J-ratio is the slope of the linear relationship between LNAPL drawdown and LNAPL well thickness:

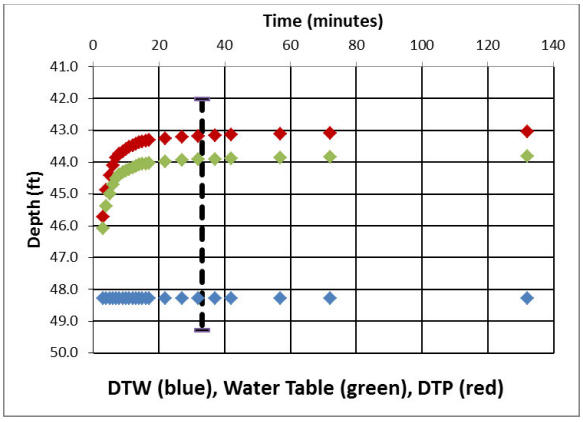
$$(A.2) \quad J = \frac{\Delta s_n}{\Delta b_n}$$

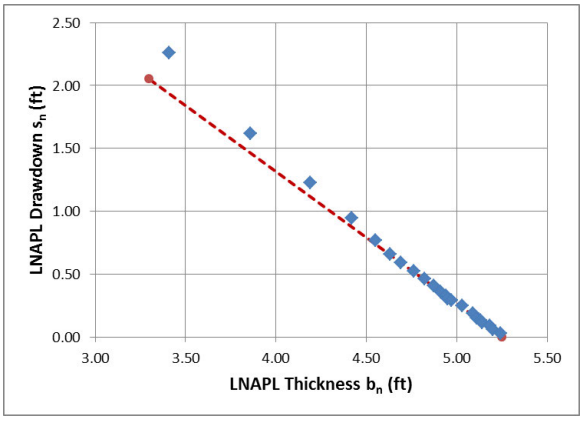
The magnitude of the J-ratio varies with the nature of LNAPL recharge to the well. If, during a baildown test, LNAPL is removed from the well using a peristaltic pump with no removal of water and the water recovers quickly (i.e., water transmissivity is much greater than LNAPL transmissivity through the well screen), then the water table elevation should remain constant and $J = -(1 - \rho_r)$. If both LNAPL and water are removed during a baildown test, and if the LNAPL transmissivity greatly exceeds the water transmissivity for recharge to the well, then the elevation of the LNAPL-water interface can remain constant and $J = -1$. Values outside of this range are also observed. Three examples are shown in Figure A.1. In case (a) the water table elevation remains constant, and the value $J = -0.244$ is close to $J = -(1 - \rho_r)$ [for this well, $\rho_r = 0.764$]. For case (b), the LNAPL-water interface elevation remains constant and $J = -1.051$. For case (c) the interface elevations increase throughout the recovery period and $J = -2.400$.



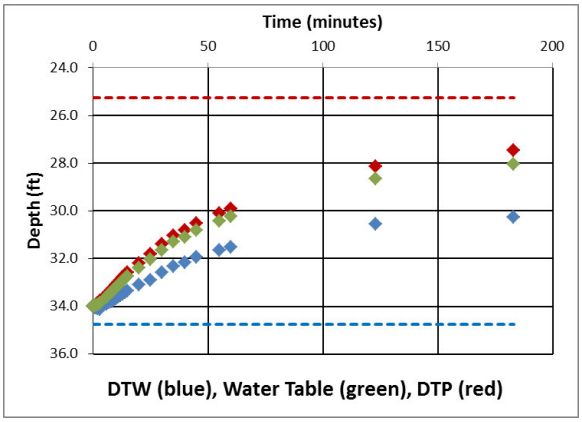


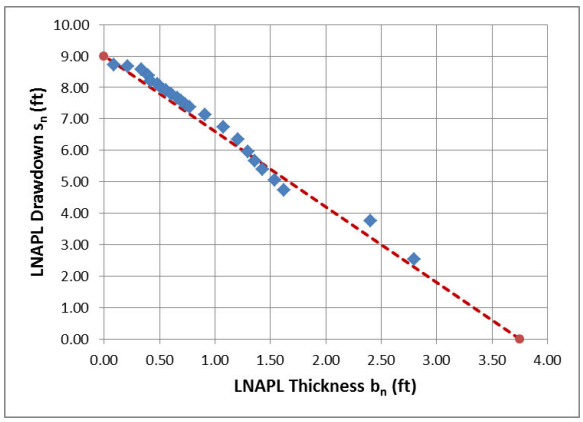
(a)





(b)





(c)

Figure A.1. Variation of J-ratio with nature of recharge to the well. (a) J = -0.244; (b) J = -1.051; (c) J = -2.400

Appendix B: Effective Well Radius

During a baildown test the fluid levels in a well are monitored, and it is necessary to relate the LNAPL volume flux, dV_n, into the well to the increase in LNAPL thickness, db_n, or equivalently to the increase in LNAPL head, dh_n, or decrease in LNAPL drawdown, $-ds_n$. By definition of the J-ratio (see Eq. A.2), $ds_n = J\, db_n$. Clearly,

(B.1) $$dh_n = dz_{an} = - ds_n = - J\, db_n$$

(B.2) $$db_n = dz_{an} - dz_{nw} \rightarrow dz_{nw} = dz_{an} - db_n = - (J + 1)\, db_n$$

In general during a baildown test, after removal of LNAPL from the well, the air-LNAPL interface elevation increases ($dz_{an} > 0$). However, depending on test conditions, the elevation of the LNAPL-water interface can either increase or decrease. This is accounted for through the magnitude of the J-ratio. If the J-ratio magnitude is less than -1, then the elevation of the LNAPL-water interface increases ($dz_{nw} > 0$). Otherwise, if the magnitude of the J-ratio is greater than -1, then the elevation of the LNAPL-water interface decreases ($dz_{nw} < 0$). Finally, if $J = -1$, then the elevation of the LNAPL-water interface remains constant ($dz_{nw} = 0$).

The increase in LNAPL volume within the well (well casing plus filter pack) depends on the location of the LNAPL column within the well. Three cases are shown in Figure B.1. In the first case both z_{an} and z_{nw} are located within the casing. In the second case z_{an} is located within the casing while z_{nw} is located within the screen section of the well with filter pack. Finally, in the third case both z_{an} and z_{nw} are located within the screened section with filter pack. The elevation of top of screen (TOS) and bottom of screen (BOS) are also shown.

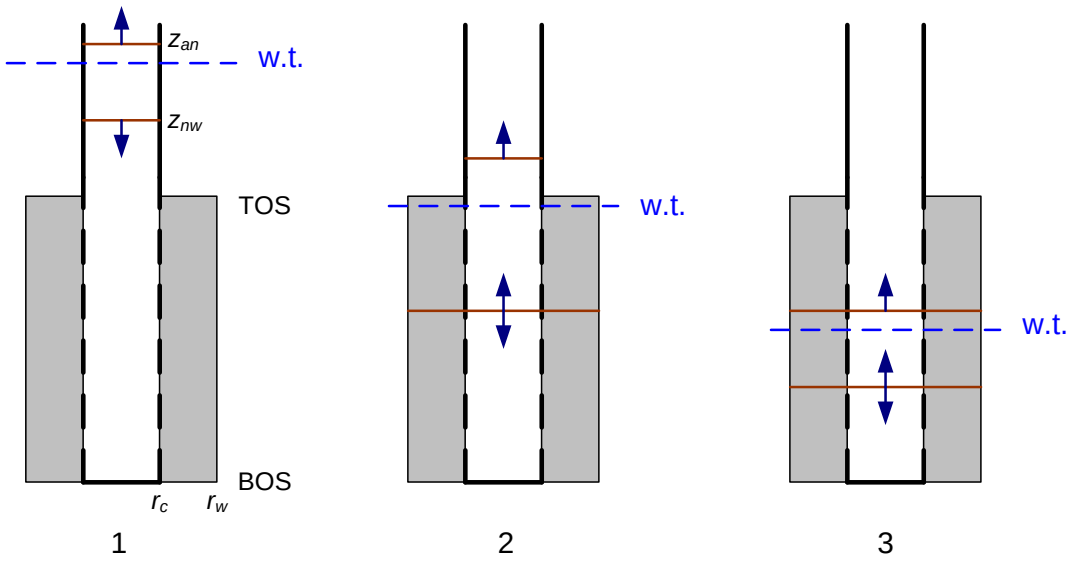


Figure B.1. Three cases showing configuration of LNAPL column in a well

To simplify analysis, it is useful to handle the three cases shown in Figure A.1 with a consistent notation by introducing the effective well radius, r_e. Then for all three cases one has

(B.3) $$dV_n = \pi r_e^{\,2}\, db_n$$

For Case 1 one clearly has

(B.4) $$r_{e1} = r_c$$

Similarly, for Case 3 one has

(B.5) $$r_{e3} = \sqrt{r_c^{\,2} + S_y\left(r_w^{\,2} - r_c^{\,2}\right)}$$

Case 2 is a little more subtle. One has

$$dV_n = \pi r_{e1}^{\,2}\left(dz_{an}\right) + \pi r_{e3}^{\,2}\left(-dz_{nw}\right)$$

Using Eqs. (B.1) and (B.2) this may be written

$$dV_n = \pi r_{e1}^{\,2}\left(-J\, db_a\right) + \pi r_{e3}^{\,2}\left(\left(J+1\right) db_n\right)$$

Comparing this result with Eq. (B.3) gives

(B.6) $$r_{e2} = \sqrt{-J\, r_{e1}^{\,2} + \left(J+1\right) r_{e3}^{\,2}}$$

Appendix C: Generalized Bouwer and Rice Method

The Bouwer and Rice (1976) method for slug test analysis is based on combining a simple representation for flow to the well from the Thiem equation (steady state radial flow to a well) and continuity of fluids within the well. The flow equation takes the form

(C.1) $$Q_n = \frac{2\pi T_n s_n}{\ln\left(R/r_w\right)}$$

Importantly, in Eq. (C.1) it is assumed that the effective radius of influence R is constant, so that there is a linear relation between the discharge Q_n into the well and the LNAPL drawdown s_n. The continuity equation for fluids in the well is problematic only in terms of determining an appropriate effective well radius r_e, as discussed above. With the effective well radius determined and with use of the Kirkman J-ratio, the continuity equation takes the form

(C.2) $$Q_n = \pi r_e^{\,2} \frac{db_n}{dt} = \frac{\pi r_e^{\,2}}{J} \frac{ds_n}{dt}$$

Combining Eqs. (C.1) and (C.2) and integrating gives the generalized Bouwer and Rice formula for determining the LNAPL transmissivity

(C.3) $$\frac{ds_n}{s_n} = \frac{2\,J\,T_n}{r_e^{\,2}\ln\left(R/r_w\right)}dt \quad \rightarrow \quad T_n = \frac{r_e^{\,2}\ln\left(R/r_w\right)\ln\left(s_n(0)/s_n(t)\right)}{2\left(-J\right)t}$$

Appendix D: Cooper and Jacob/Jacob and Lohman Method

Jacob and Lohman (1952) investigated the non-steady flow to a free-flowing well with constant drawdown in an extensive confined aquifer. The model assumes that the well drawdown s_w is constant (= difference between the static head measured during shut-in of the well and the outflow opening of the well). The discharge to the well is given by the following expression

(D.1) $$Q = 2\pi T s_w G(u_w)$$

The function G( ) is the Jacob-Lohman free-flowing discharge function and

(D.2) $$u_w = \frac{r_e^{\,2} S}{4Tt}$$

For all but extremely small values of t, Jacob and Lohman state that the function G( ) can be approximated by G ( ) = 2/W( ), where W( ) is the Theis well function. If, in addition, $u_w < 0.01$, the Theis well function may be approximated as follows:

(D.3) $$W(u_w) \cong \ln\left(\frac{0.561}{u_w}\right)$$

Thus Eq. (D.1) becomes

(D.4) $$Q = \frac{4\pi T s_w}{\ln\left(2.25Tt/r_e^{\,2}S\right)}$$

Equation (D.4) is the Cooper and Jacob (1946) approximation for the Theis well function for transient flow to a well in a confined aquifer with constant discharge and variable drawdown. Thus we find that Eq. (D.4) approximately applies both for constant drawdown and variable discharge, and for constant discharge and variable drawdown. During a baildown test both the LNAPL drawdown and discharge vary with time. With the C&J method, it is assumed that this relationship holds throughout the recovery period following baildown.

In application for baildown test analysis, Eq. (D.4) can be integrated between times t_i and t_{i+1} to give the volume inflow to the well as follows:

(D.5) $$V(t_i, t_{i+1}) = \int_{t_i}^{t_{i+1}} Q_n \, dt = \int_{t_i}^{t_{i+1}} \frac{4\pi T_n s_n}{\ln\left(2.25T_n t/r_e^{\,2}S_n\right)} \, dt$$

The volume inflow to the well is separately measured (see Eq. 5.2). The calculated inflow volume from the right of Eq. (D.5) depends on the drawdown, which is also separately measured (see Eq. 5.1) and the parameters T_n and S_n. By comparing the measured and calculated

cumulative inflow volumes for each time increment, the parameters T_n (and S_n) can be estimated using the method of least squares. The sum-square-difference (SSD) is calculated using

(D.6)
$$SSD = \sum_{J=1}^{N}\left[\sum_{i=1}^{J} Q_{ni}\Delta t_i - \sum_{i=1}^{J}\frac{4\pi T_n s_i}{\ln\left(2.25T_n\left(t_{i+1/2}-\Delta t_a\right)/r_e^{\,2}S_n\right)}\Delta t_i\right]^2$$

In Eq. (D.6), N = number of time increments during the baildown test, $\Delta t_i = t_{i+1} - t_i$, $t_{i+1/2} = (t_i + t_{i+1})/2$, and Δt_a = time adjustment factor that may be applied (see discussion in Section 6.2). The LNAPL transmissivity is estimated by minimizing the SSD in Eq. (D.6).

Fitting of data and estimation of LNAPL transmissivity is based on comparing the measured volume inflow to the well versus the calculated inflow using the Cooper and Jacob equation. It is of some interest to see how the data compares directly with the Cooper and Jacob equation. For this purpose, the ratio Q_n/s_n is plotted as a function of time, as shown in Figure D.1. The red-dashed curve shown in this figure is calculated using the following:

(D.7)
$$\frac{Q_n}{s_n} = \frac{4\pi T_n}{\ln(2.25T_n\left(t-\Delta t_a\right)/r_e^{\,2}S_n)}$$

In Figure D.1, the vertical dotted and dashed lines show the Time Adjustment Δt_a and cut-off time, respectively. This figure is produced in the lower part of the C&J worksheet.

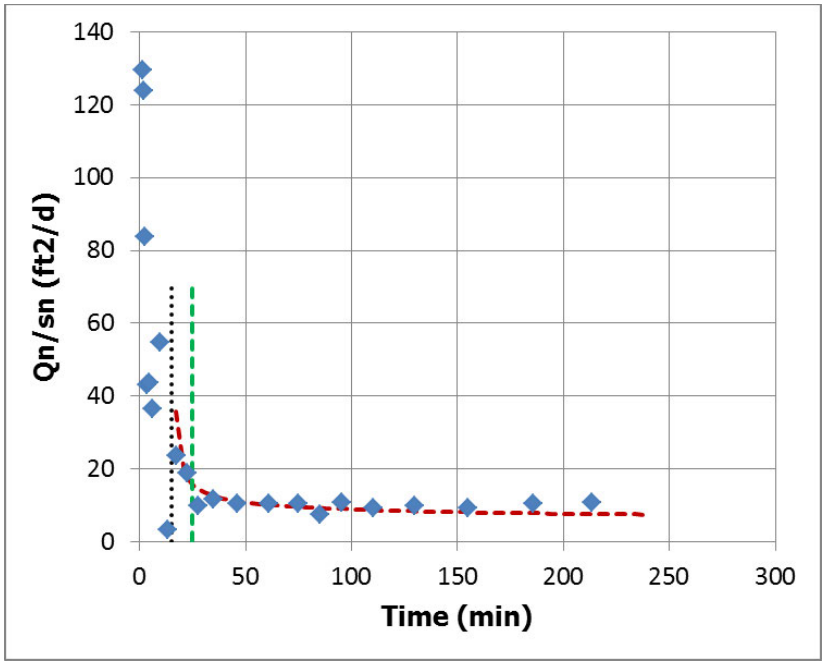


Figure D.1. Comparison of Cooper&Jacob equation with baildown test data. Red-dashed curve = C&J equation; green-dashed line (vertical) = cutoff time; black-dotted line (vertical) = time adjustment

Appendix E: Cooper, Bredehoeft and Papadopulos Method

A third model that can be used to estimate LNAPL transmissivity is based on the work of Cooper, Bredehoeft and Papadopulos (1967). The model assumes that a slug of fluid is added to the casing of a well in a confined aquifer, and the change in fluid levels is monitored. The configuration is shown in Figure E.1. The initial height of the water column above equilibrium, H_0, is related to the volume of water, V_w, added through

(E.1) $$H_0 = \frac{V_w}{\pi r_c^{\,2}}$$

The boundary conditions at the well are specified as

(E.2) $$h\left(r_s^{+}, t\right) = H(t)$$

(E.3) $$2\pi r_s T \frac{\partial h\left(r_s^{+}, t\right)}{\partial r} = \pi r_c^{\,2} \frac{dH(t)}{dt}$$

The first of these equations states that the formation head just outside of the well screen is equal to the water column head above equilibrium within the well. The second of these equations equates the water volume flux into the formation to the change in water volume storage within the well casing. The following solution is presented by Cooper et al. (1967):

(E.4) $$\frac{H(t)}{H_0} = F\left(\frac{r_s^{\,2} S}{r_c^{\,2}}, \frac{Tt}{r_c^{\,2}}\right)$$

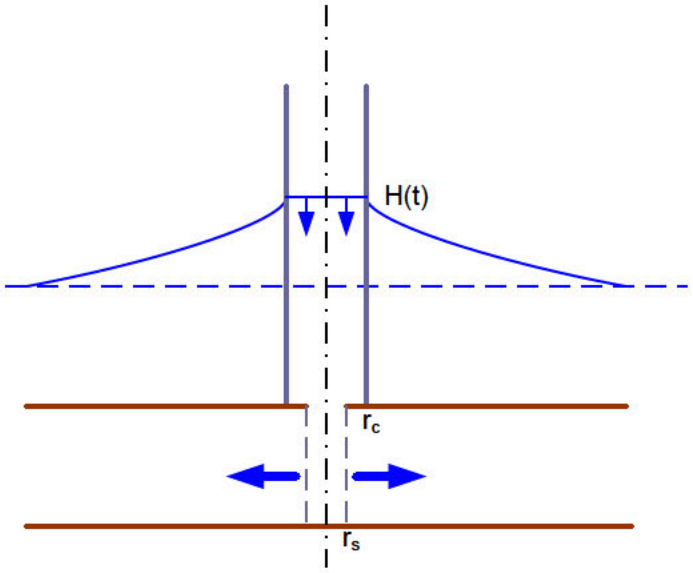


Figure E.1. Configuration for the Cooper et al. (1967) slug test

When applied to LNAPL in a well, the form of Eq. (E.4) and the boundary conditions specified by Eqs. (E.2) and (E.3) must be modified. Cooper et al. (1967) use the casing radius r_c in calculation of changes in well-bore storage. The screen radius r_s is used to designate the (radial) location where the LNAPL head (or drawdown) in the well-bore is equal to that in the formation. In analysis of LNAPL bail-down tests the effective radius r_e plays the same role as r_c. The presence of the filter pack in a bail-down test makes identification of an equivalent radius to r_s less obvious. A simple assumption is that r_e plays an equivalent role to r_s as well. Furthermore, the solution is written in term of the LNAPL drawdown, s_n. With Eq. (A.1), the boundary condition Eq. (E.3) can be written

(E.5) $$Q_n = -2\pi r_e T_n \frac{\partial s_n}{\partial r} = \pi r_e^{\,2} \frac{db_n}{dt} = \frac{\pi r_e^{\,2}}{J} \frac{ds_n}{dt}$$

These changes imply that Eq. (E.4) must be modified to

(E.6) $$\frac{s_n(t)}{s_n(0)} = F\left(S_n, \frac{(-J)T_n\, t}{r_e^{\,2}} \right)$$

Using the LNAPL drawdown (s_{ni}) versus time (t_i) data, a measure of how well the model fits the data is provided by the sum-square error specified by

(E.7) $$\sum_{i=1}^{N} \left[\frac{s_{ni}(t_i)}{s_n(0)} - F\left(S_n, \frac{(-J)T_n\, t_i}{r_e^{\,2}} \right) \right]^2$$

In Eq. (E.7), the summation is over all data included in the analysis.

Appendix F: Confined LNAPL

Figure F.1 (a) shows LNAPL confined beneath a fine-grain soil layer. The initial LNAPL thickness in an observation well, b_{nR}, depends on the water table elevation, z_{aw}, the LNAPL/water density ratio, ρ_r, and the initial elevation of the confined LNAPL-water interface in the formation and well, z_{nw}. During a baildown test the LNAPL discharge from the formation to the well is expected to initially be large, associated with rapid drainage of the filter pack and immediate well vicinity, and then the discharge should reach a constant magnitude that is determined by the radial LNAPL head difference experienced by the confined LNAPL. This head difference is equal to $(1 - \rho_r)(b_{nR} - b_{nW})$, and remains constant until the LNAPL column thickness in the well $b_n = b_{nW}$. For $b_n > b_{nW}$, the LNAPL head difference equals $(1 - \rho_r)(b_{nR} - b_n)$, and this magnitude decreases to zero ($b_n \rightarrow b_{nR}$) with further LNAPL inflow to the well. For this analysis it is assumed that the water table elevation remains constant and $J = -(1 - \rho_r)$. This is reasonable because for LNAPL under confined conditions, it is expected that the water transmissivity of the well will be much greater than the LNAPL transmissivity.

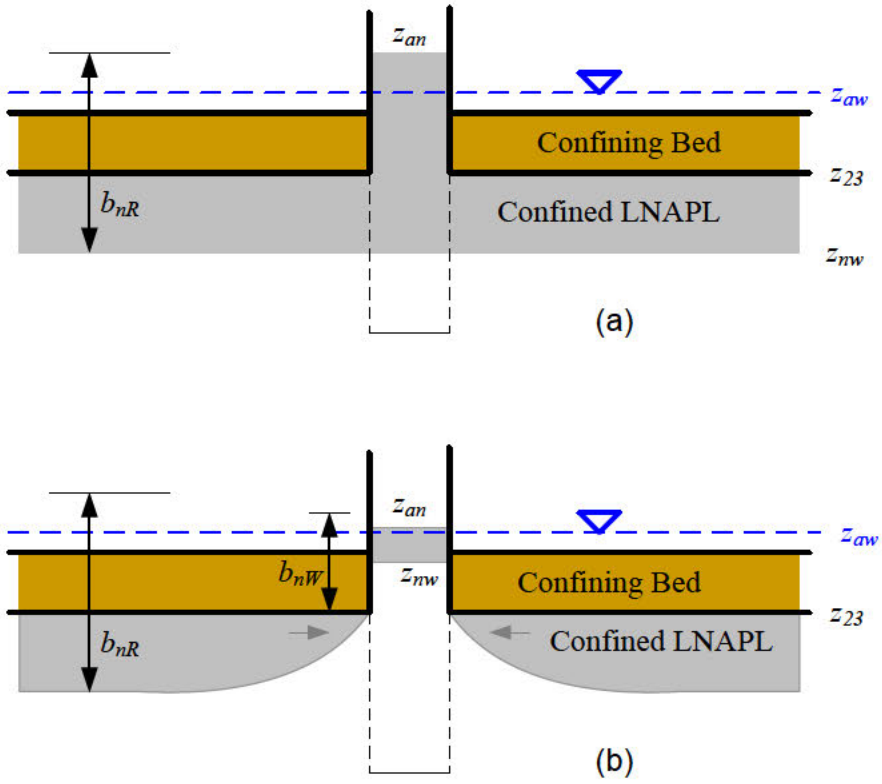


Figure F.1 Confined LNAPL conditions

The constant LNAPL discharge magnitude Q_n for the period with $b_n < b_{nW}$ can be used to estimate the LNAPL transmissivity:

(F.1) $$T_n = \frac{Q_n \ln(R/r_w)}{2\pi(1-\rho_r)(b_{nR} - b_{nW})}$$

With the configuration shown in Figure E.1, the limiting effective well thickness is

(F.2) $$b_{nW} = \frac{z_{aw} - z_{23}}{\rho_r}$$

The corresponding LNAPL drawdown is

(F.3) $$s_{nW} = (1-\rho_r)\left(b_{nR} - \left(\frac{z_{aw} - z_{23}}{\rho_r}\right)\right)$$

Figure F.1 (b) shows the well and LNAPL configuration under conditions with $b_n < b_{nW}$, and suggests that the effective LNAPL thickness at the well is equal to b_{nW}. Actually, under these cut-off conditions for the LNAPL column in the well, there will be a seepage face extending downward from the facies contact at elevation z_{23}. The thickness of the seepage face is unknown, but it may be anticipated that the limiting effective LNAPL thickness at the well might be greater than calculated using Eq. (F.2). Correspondingly, the effective elevation z_{23} as determined from the plot of z_{nw} (DTW) vs. LNAPL discharge (Fig. 6 on the "Figures" worksheet) might have a lower elevation from that estimated using a geologic log.

Appendix G: Perched LNAPL

Figure G.1 shows LNAPL perched upon a low-permeability unit. Analysis of perched LNAPL is essentially the same as that for confined LNAPL. The initial depth to product is DTP_0 and the depth to the top of the perching layer is DZ_{12} (the top of the perching layer is at elevation z_{12}). During a baildown test the LNAPL discharge from the formation to the well is expected to initially be large, associated with rapid drainage of the filter pack and immediate well vicinity, and then the discharge should reach a constant magnitude that is determined by the radial LNAPL head difference experienced by the confined LNAPL. This head difference is equal to $DZ_{12} - DTP_0$, and remains constant until the LNAPL column thickness in the well, b_n, increases in magnitude because of LNAPL inflow from the formation, until $z_{an} = z_{12}$. For $z_{an} > z_{12}$, the LNAPL head difference equals $DTP - DTP_0$, and this magnitude decreases to zero ($DTP \rightarrow DTP_0$) with further LNAPL inflow to the well.

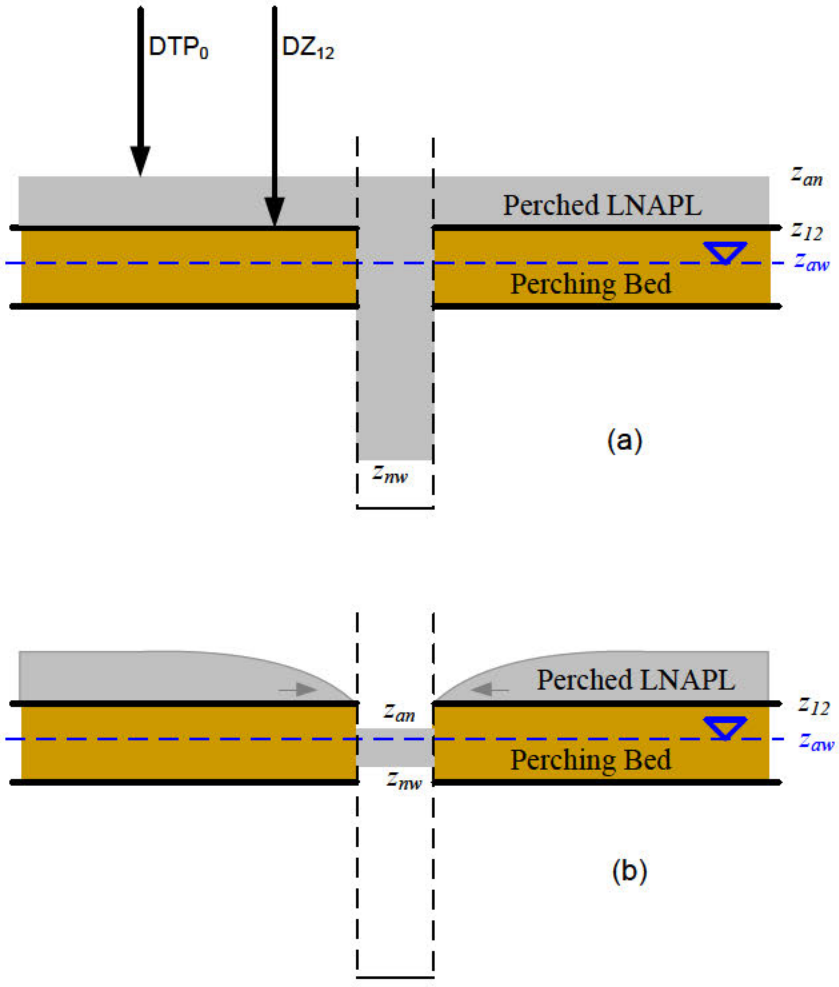


Figure G.1. Perched LNAPL conditions

The constant LNAPL discharge magnitude Q_n for the period with $DTP > DZ_{12}$ can be used to estimate the LNAPL transmissivity:

(G.1) $$T_n = \frac{Q_n \ln\left(R/r_w\right)}{2\pi\left(DZ_{12} - DTP_0\right)}$$

Baildown Test Result Spreadsheets

API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

1.05

Standard Deviation (ft^2/d)

1.63

Coefficient of Variation

1.56

Well Designation:	DSCP-MW-33	Beckett and Lyverse (2002)
Date:	21-Mar-17	

Ground Surface Elev (ft msl)	18.5	Enter These Data	**Drawdown Adjustment (ft)**
Top of Casing Elev (ft msl)	17.5		
Well Casing Radius, r_c (ft):	0.250	r_{e1}	
Well Radius, r_w (ft):	0.500		0
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.840		
Top of Screen (ft bgs):	15.0		
Bottom of Screen (ft bgs):	35.0		
LNAPL Baildown Vol. (gal.):	2.0		
Effective Radius, r_{e3} (ft):	0.309	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.224		
Initial Casing LNAPL Vol. (gal.):	1.60		
Initial Filter LNAPL Vol. (gal.):	0.84		

	Enter Data Here										
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	17.23	18.32	18.24	19.33	18.41					1.09	
Enter Test Data:	0.5	17.43	17.57	18.44	18.58	18.46	0.20				0.14	
	1.0	17.40	17.53	18.41	18.54	18.43	0.17	0.8	-8.624	0.18	0.13	0.309
	1.5	17.37	17.52	18.38	18.53	18.40	0.14	1.3	17.247	0.15	0.15	0.309
	2.5	17.34	17.50	18.35	18.51	18.38	0.11	2.0	4.312	0.13	0.16	0.309
	3.0	17.34	17.50	18.35	18.51	18.38	0.11	2.8	0.000	0.11	0.16	0.309
	3.5	17.33	17.50	18.34	18.51	18.37	0.10	3.3	8.624	0.10	0.17	0.309
	4.0	17.33	17.50	18.34	18.51	18.37	0.10	3.8	0.000	0.10	0.17	0.309
	4.5	17.32	17.50	18.33	18.51	18.36	0.09	4.3	8.624	0.09	0.18	0.309
	5.0	17.32	17.50	18.33	18.51	18.36	0.09	4.8	0.000	0.09	0.18	0.309
	6.0	17.32	17.51	18.33	18.52	18.36	0.09	5.5	4.312	0.09	0.19	0.309
	7.0	17.30	17.51	18.31	18.52	18.34	0.07	6.5	8.624	0.08	0.21	0.309
	8.0	17.3	17.51	18.31	18.52	18.34	0.07	7.5	0.000	0.07	0.21	0.309
	9.0	17.3	17.51	18.31	18.52	18.34	0.07	8.5	0.000	0.07	0.21	0.309
	10.0	17.3	17.51	18.31	18.52	18.34	0.07	9.5	0.000	0.07	0.21	0.309
	15.0	17.3	17.53	18.31	18.54	18.35	0.07	12.5	1.725	0.07	0.23	0.309
	20.0	17.3	17.55	18.31	18.56	18.35	0.07	17.5	1.725	0.07	0.25	0.309
	25.0	17.3	17.57	18.31	18.58	18.35	0.07	22.5	1.725	0.07	0.27	0.309
	30.0	17.3	17.58	18.31	18.59	18.35	0.07	27.5	0.862	0.07	0.28	0.309
	35.0	17.3	17.58	18.31	18.59	18.35	0.07	32.5	0.000	0.07	0.28	0.309
	40.0	17.3	17.60	18.31	18.61	18.36	0.07	37.5	1.725	0.07	0.30	0.309
	55.0	17.3	17.62	18.31	18.63	18.36	0.07	47.5	0.575	0.07	0.32	0.309
	70.0	17.3	17.62	18.31	18.63	18.36	0.07	62.5	0.000	0.07	0.32	0.309
	85.00	17.3	17.63	18.31	18.64	18.36	0.07	77.5	0.287	0.07	0.33	0.309

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-MW-33
Date:	21-Mar-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t - t_1)}$$

Enter early time cut-off for least-squares model fit

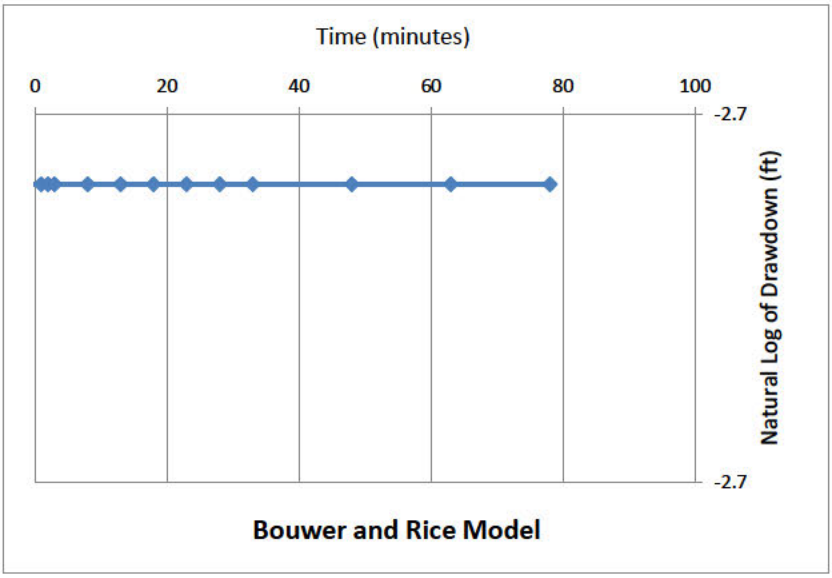
$Time_{cut}$	7	<- Enter or change value here

Model Results: T_n (ft^2/d) = 0.00 +/- 0.00 ft^2/d

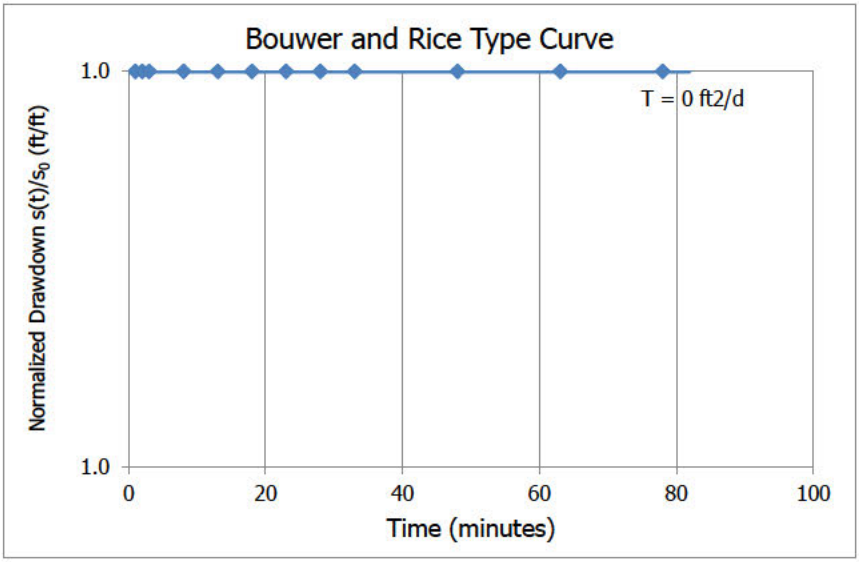
L_e/r_e
3.5
C
0.93
R/r_e
2.41

J-Ratio
-1.378

Coef. Of Variation
0.55



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-MW-33
Date:	21-Mar-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

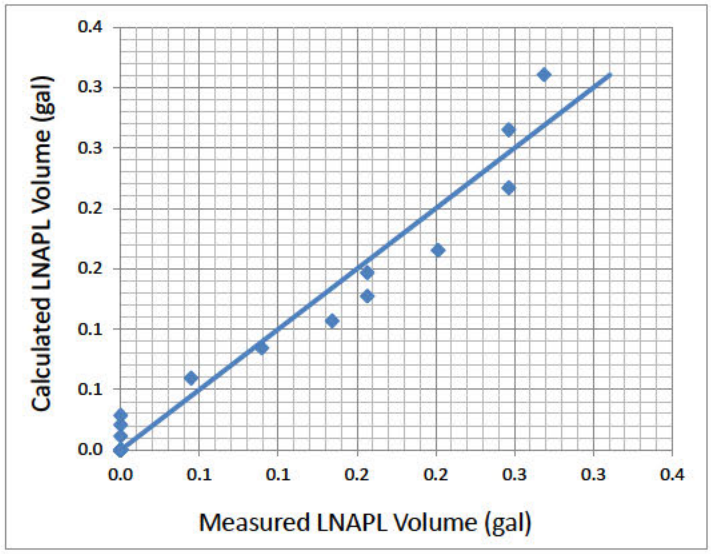
Enter early time cut-off for least-squares model fit

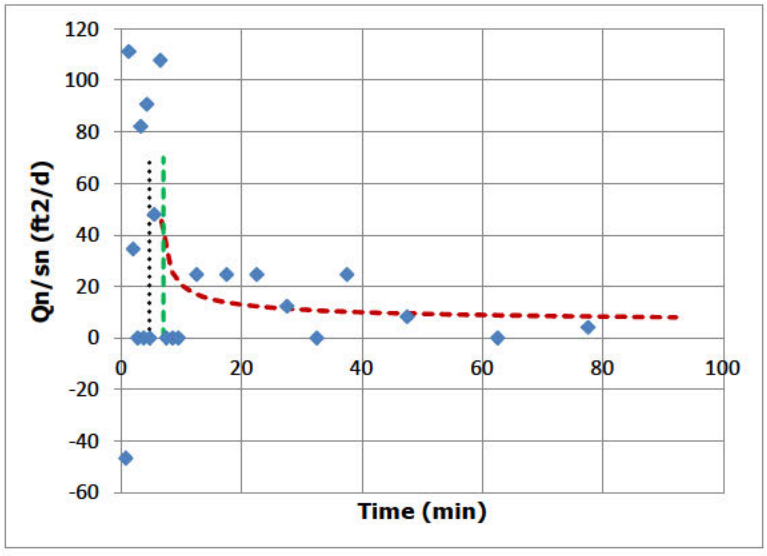
$Time_{cut}$ (min):	7	<- Enter or change values here
Time Adjustment (min):	4.666667	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.087	<-- Minimize this using "Solver"
	0.043	<-- Working S_n
Trial T_n (ft^2/d):	2.924	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **2.92**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-MW-33
Date:	21-Mar-17

Enter early time cut-off for least-squares model fit

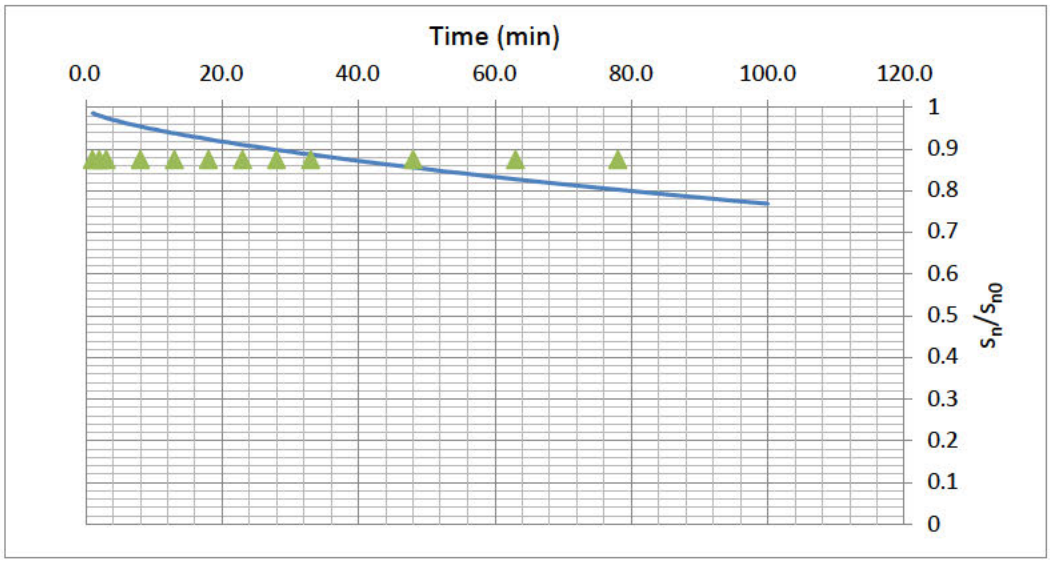
$Time_{cut}$ (min):	7	<- Enter or change values here
Initial Drawdown s_n (ft):	0.08	
Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.236	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.218	<-- By changing T_n through "Solver"
	0.012	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	1
T_{max}	100

Model Result: T_n (ft^2/d) = **0.22**

J-Ratio
-1.378



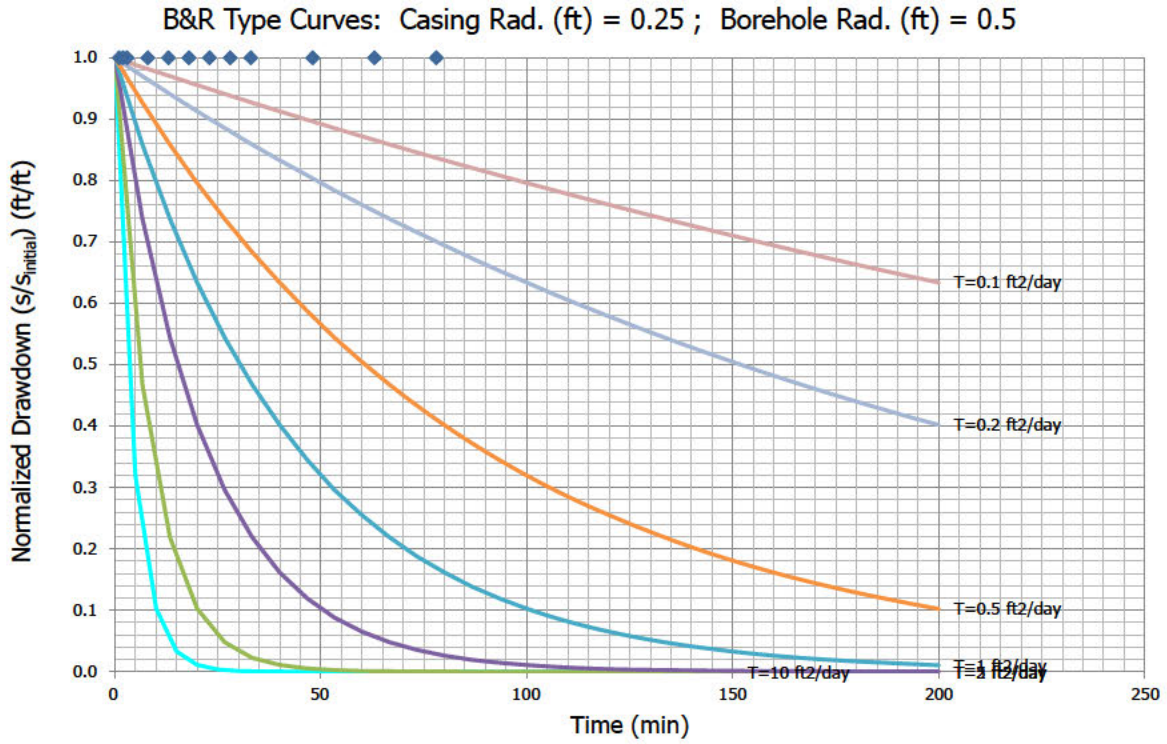
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-1.378	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.00

Standard Deviation (ft^2/d)

0.00

Coefficient of Variation

NA

Well Designation:	DSCP-MW-33	Beckett and Lyverse (2002)
Date:	3-Oct-17	

Ground Surface Elev (ft msl)	18.5	Enter These Data	Drawdown Adjustment (ft)
Top of Casing Elev (ft msl)	17.5		
Well Casing Radius, r_c (ft):	0.250	r_{e1}	0
Well Radius, r_w (ft):	0.500		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.840		
Top of Screen (ft bgs):	15.0		
Bottom of Screen (ft bgs):	35.0		
LNAPL Baildown Vol. (gal.):	1.0		
Effective Radius, r_{e1} (ft):	0.309	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.227		
Initial Casing LNAPL Vol. (gal.):	0.63		
Initial Filter LNAPL Vol. (gal.):	0.33		

	Enter Data Here					Water Table Depth	LNAPL Drawdown	Average	LNAPL Discharge	s_n	b_n	r_e
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	(ft)	s_n (ft)	Time (min)	Q_n (ft^3/d)	(ft)	(ft)	(ft)
Initial Fluid Levels:	0	16.76	17.19	17.77	18.2	17.84					0.43	
Enter Test Data:	0.5	16.67	16.70	17.68	17.71	17.68	-0.09				0.03	
	1.5	16.92	16.97	17.93	17.98	17.94	0.16	1.0	8.624	0.03	0.05	0.309
	2.0	16.88	16.93	17.89	17.94	17.90	0.12	1.8	0.000	0.14	0.05	0.309
	2.5	16.90	16.95	17.91	17.96	17.92	0.14	2.3	0.000	0.13	0.05	0.309
	3.0	16.85	16.90	17.86	17.91	17.87	0.09	2.8	0.000	0.11	0.05	0.309
	3.5	16.86	16.93	17.87	17.94	17.88	0.10	3.3	17.247	0.09	0.07	0.309
	4.0	16.85	16.93	17.86	17.94	17.87	0.09	3.8	8.624	0.09	0.08	0.309
	4.5	16.84	16.92	17.85	17.93	17.86	0.08	4.3	0.000	0.08	0.08	0.309
	5.0	16.85	16.94	17.86	17.95	17.87	0.09	4.8	8.624	0.08	0.09	0.309
	7.0	16.83	16.92	17.84	17.93	17.85	0.07	6.0	0.000	0.08	0.09	0.309
	9.0	16.81	16.91	17.82	17.92	17.84	0.05	8.0	2.156	0.06	0.10	0.309
	10.0	16.81	16.92	17.82	17.93	17.84	0.05	9.5	4.312	0.05	0.11	0.309
	13.0	16.8	16.91	17.81	17.92	17.83	0.04	11.5	0.000	0.04	0.11	0.309
	15.0	16.8	16.92	17.81	17.93	17.83	0.04	14.0	2.156	0.04	0.12	0.309
	25.0	16.75	16.90	17.76	17.91	17.78	-0.01	20.0	1.294	0.01	0.15	0.309
	30.0	16.76	16.92	17.77	17.93	17.80	0.00	27.5	0.862	-0.01	0.16	0.309
	35.00	16.76	16.91	17.77	17.92	17.79	0.00	32.5	-0.862	0.00	0.15	0.309
	40.00	16.75	16.94	17.76	17.95	17.79	-0.01	37.5	3.449	-0.01	0.19	0.309
	45.00	16.75	16.96	17.76	17.97	17.79	-0.01	42.5	1.725	-0.01	0.21	0.309
	50.00	16.75	16.97	17.76	17.98	17.80	-0.01	47.5	0.862	-0.01	0.22	0.309
	55.00	16.75	17.02	17.76	18.03	17.80	-0.01	52.5	4.312	-0.01	0.27	0.309
	70.00	16.75	17.02	17.76	18.03	17.80	-0.01	62.5	0.000	-0.01	0.27	0.309
	90.00	16.75	17.04	17.76	18.05	17.81	-0.01	80.0	0.431	-0.01	0.29	0.309
	100.00	16.75	17.05	17.76	18.06	17.81	-0.01	95.0	0.431	-0.01	0.30	0.309
	110.00	16.75	17.05	17.76	18.06	17.81	-0.01	105.0	0.000	-0.01	0.30	0.309
	120.00	16.75	17.05	17.76	18.06	17.81	-0.01	115.0	0.000	-0.01	0.30	0.309
	140.00	16.75	17.05	17.76	18.06	17.81	-0.01	130.0	0.000	-0.01	0.30	0.309
	160.00	16.75	17.06	17.76	18.07	17.81	-0.01	150.0	0.216	-0.01	0.31	0.309
	180.00	16.75	17.07	17.76	18.08	17.81	-0.01	170.0	0.216	-0.01	0.32	0.309
	200	16.75	17.08	17.76	18.09	17.81	-0.01	190.0	0.216	-0.01	0.33	0.309
	220	16.75	17.08	17.76	18.09	17.81	-0.01	210.0	0.000	-0.01	0.33	0.309
	240	16.75	17.10	17.76	18.11	17.82	-0.01	230.0	0.431	-0.01	0.35	0.309
	260	16.75	17.10	17.76	18.11	17.82	-0.01	250.0	0.000	-0.01	0.35	0.309
	300	16.73	17.10	17.74	18.11	17.80	-0.03	280.0	0.216	-0.02	0.37	0.309
	320	16.73	17.10	17.74	18.11	17.80	-0.03	310.0	0.000	-0.03	0.37	0.309
	340	16.71	17.09	17.72	18.10	17.78	-0.05	330.0	0.216	-0.04	0.38	0.309
	360	16.70	17.09	17.71	18.10	17.77	-0.06	350.0	0.216	-0.06	0.39	0.309
	400	16.70	17.10	17.71	18.11	17.77	-0.06	380.0	0.108	-0.06	0.40	0.309
	420	16.69	17.10	17.70	18.11	17.77	-0.07	410.0	0.216	-0.07	0.41	0.309

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-MW-33
Date:	3-Oct-17

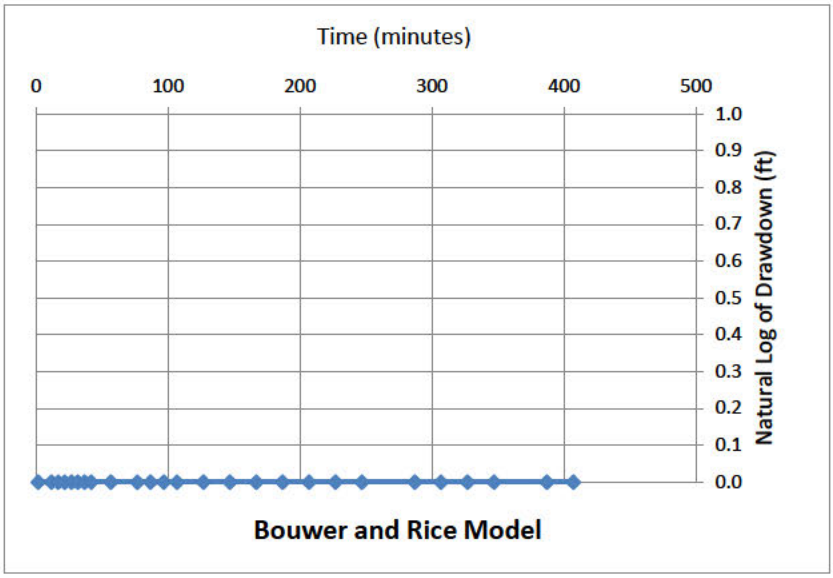
$$T_n = \frac{r_e^{\,2}\ln(R/r_e)\ln(s_n(t_1)/s_n(t))}{2(-J)(t-t_1)}$$

Enter early time cut-off for least-squares model fit

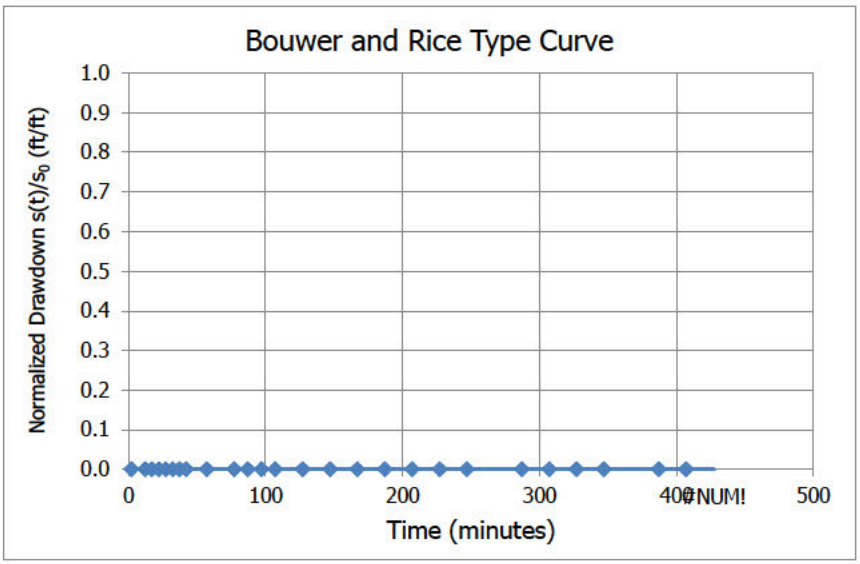
$Time_{cut}$	13	<- Enter or change value here

Model Results: T_n (ft^2/d) = #NUM! +/- #NUM! ft^2/d

L_e/r_e	1.4
C	0.85
R/r_e	1.29
J-Ratio	-1.334
Coef. Of Variation	#NUM!



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-MW-33
Date:	3-Oct-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	13	<- Enter or change values here
Time Adjustment (min):	8.666667	

Trial S_n: d <-- Enter d for default or enter S_n value

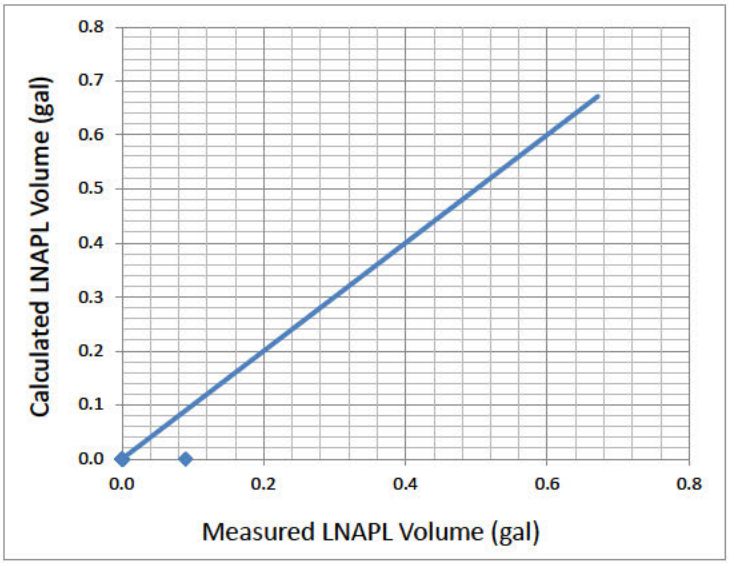
Root-Mean-Square Error: 2.274 <-- Minimize this using "Solver"

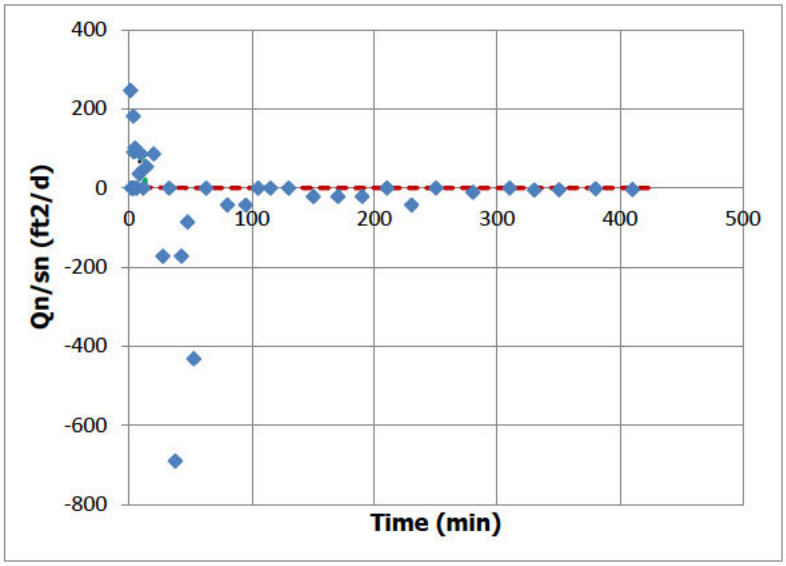
0.005 <-- Working S_n

Trial T_n (ft^2/d): 0.048 <-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = 0.05





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-MW-33
Date:	3-Oct-17

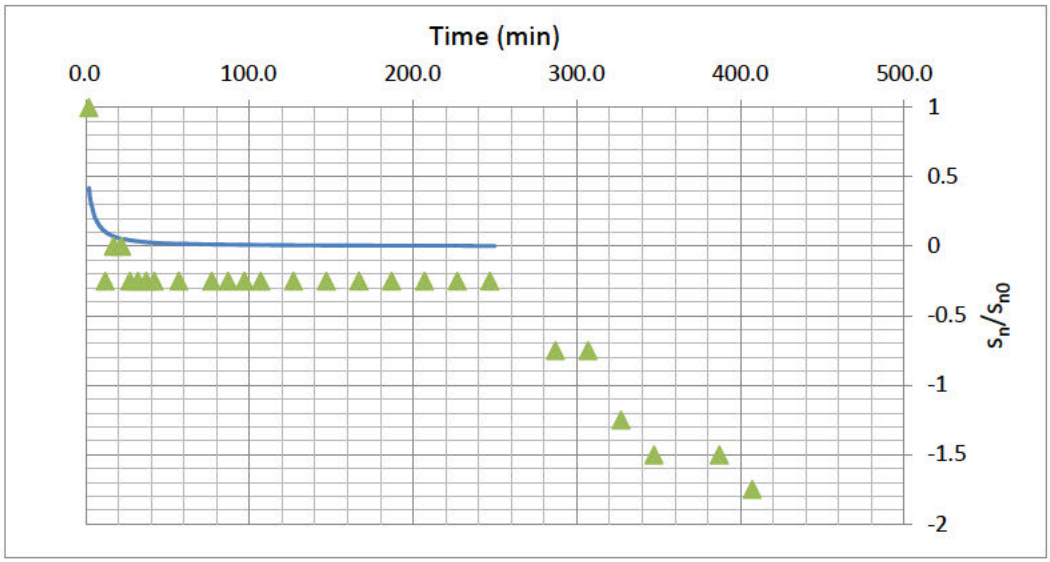
Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	13	<- Enter or change values here
Initial Drawdown s_n (ft):	0.04	
Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	3.447	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	27.551	<-- By changing T_n through "Solver"
	0.131	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	2
T_{max}	250

Model Result: T_n (ft^2/d) = **27.55**



J-Ratio
-1.334

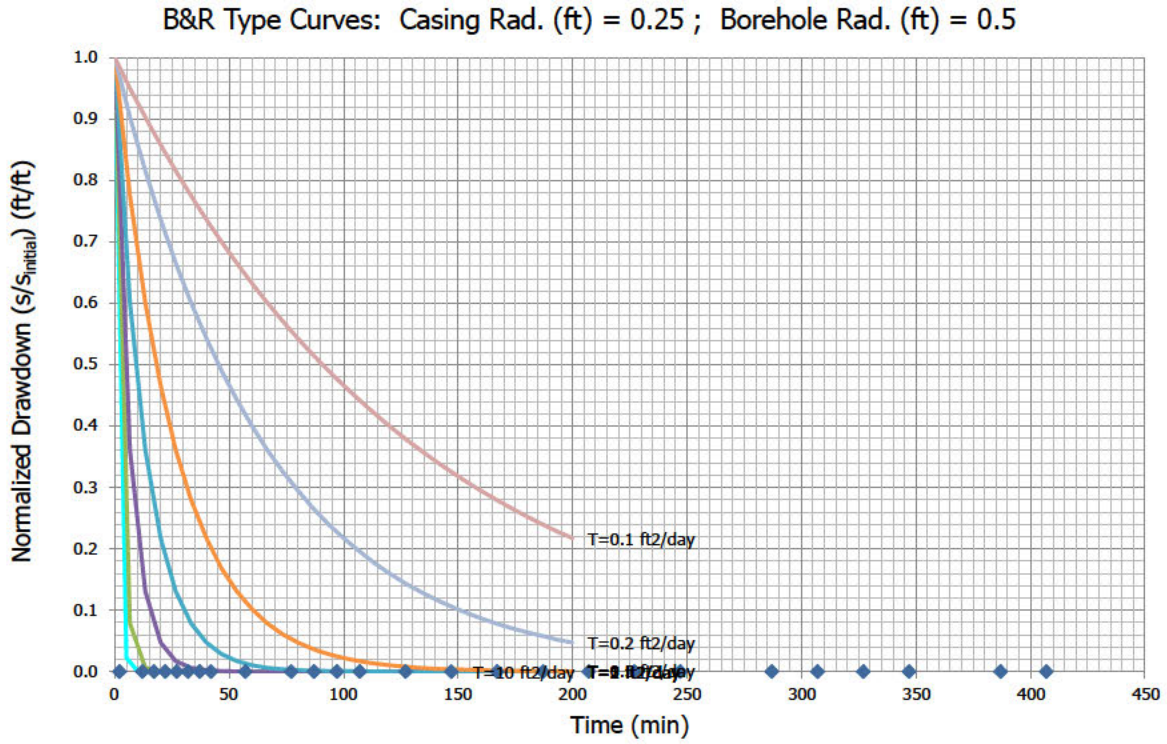
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-1.334	<-- If uncertain use
-0.16	



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.30

Standard Deviation (ft^2/d)

0.08

Coefficient of Variation

0.28

Well Designation:	DSCP-MW-65	Beckett and Lyverse (2002)
Date:	20-Mar-17	

Ground Surface Elev (ft msl)	19.9	Enter These Data	**Drawdown Adjustment (ft)**
Top of Casing Elev (ft msl)	20.2		
Well Casing Radius, r_c (ft):	0.167	r_{e1}	0
Well Radius, r_w (ft):	0.354		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.840		
Top of Screen (ft bgs):	15.0		
Bottom of Screen (ft bgs):	45.0		
LNAPL Baildown Vol. (gal.):	1.3		
Effective Radius, r_{e3} (ft):	0.212	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.199		
Initial Casing LNAPL Vol. (gal.):	0.63		
Initial Filter LNAPL Vol. (gal.):	0.39		

	Enter Data Here					Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	LNAPL Average Time (min)	LNAPL Discharge Q_n (ft³/d)	s_n (ft)	b_n (ft)	r_e (ft)
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)							
Initial Fluid Levels:	0	19.80	20.77	19.50	20.47	19.66					0.97	
Enter Test Data:	0.5	20.05	20.07	19.75	19.77	19.75	0.25				0.02	
	1.0	20.03	20.07	19.73	19.77	19.74	0.23	0.8	#NAME?	0.24	0.04	#NAME?
	1.5	20.02	20.07	19.72	19.77	19.73	0.22	1.3	#NAME?	0.22	0.05	#NAME?
	2.5	20.02	20.07	19.72	19.77	19.73	0.22	2.0	#NAME?	0.22	0.05	#NAME?
	3.0	20.02	20.07	19.72	19.77	19.73	0.22	2.8	#NAME?	0.22	0.05	#NAME?
	3.5	20.02	20.07	19.72	19.77	19.73	0.22	3.3	#NAME?	0.22	0.05	#NAME?
	4.0	20.02	20.08	19.72	19.78	19.73	0.22	3.8	#NAME?	0.22	0.06	#NAME?
	4.5	20.01	20.08	19.71	19.78	19.72	0.21	4.3	#NAME?	0.22	0.07	#NAME?
	7.0	20.02	20.09	19.72	19.79	19.73	0.22	5.8	#NAME?	0.22	0.07	#NAME?
	8.0	20.01	20.10	19.71	19.80	19.72	0.21	7.5	#NAME?	0.22	0.09	#NAME?
	9.0	20.01	20.10	19.71	19.80	19.72	0.21	8.5	#NAME?	0.21	0.09	#NAME?
	10.0	20.01	20.10	19.71	19.80	19.72	0.21	9.5	#NAME?	0.21	0.09	#NAME?
	15.0	20.01	20.12	19.71	19.82	19.73	0.21	12.5	#NAME?	0.21	0.11	#NAME?
	25.0	20	20.11	19.70	19.81	19.72	0.20	20.0	#NAME?	0.20	0.11	#NAME?
	30.0	20	20.14	19.70	19.84	19.72	0.20	27.5	#NAME?	0.20	0.14	#NAME?
	35.0	20	20.14	19.70	19.84	19.72	0.20	32.5	#NAME?	0.20	0.14	#NAME?
	40.0	20	20.14	19.70	19.84	19.72	0.20	37.5	#NAME?	0.20	0.14	#NAME?
	60.0	20	20.16	19.70	19.86	19.73	0.20	50.0	#NAME?	0.20	0.16	#NAME?
	120.0	19.99	20.22	19.69	19.92	19.73	0.19	90.0	#NAME?	0.19	0.23	#NAME?
	135.0	19.99	20.25	19.69	19.95	19.73	0.19	127.5	#NAME?	0.19	0.26	#NAME?
	150.00	19.96	20.27	19.66	19.97	19.71	0.16	142.5	#NAME?	0.18	0.31	#NAME?
	1320.00	19.82	20.49	19.52	20.19	19.63	0.02	735.0	#NAME?	0.09	0.67	#NAME?

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-MW-65
Date:	20-Mar-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t - t_1)}$$

Enter early time cut-off for least-squares model fit

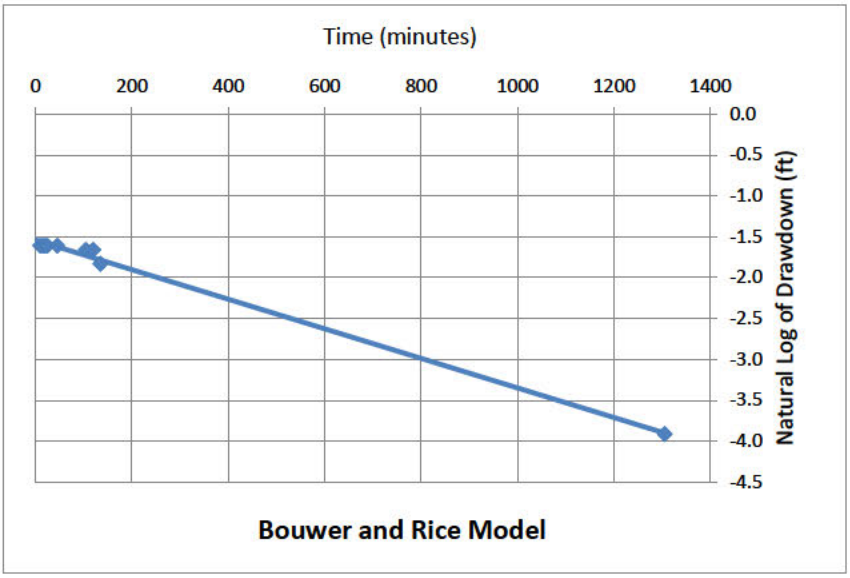
$Time_{cut}$	15

<- Enter or change value here

L_e/r_e
4.6
C
0.97
R/r_e
2.91

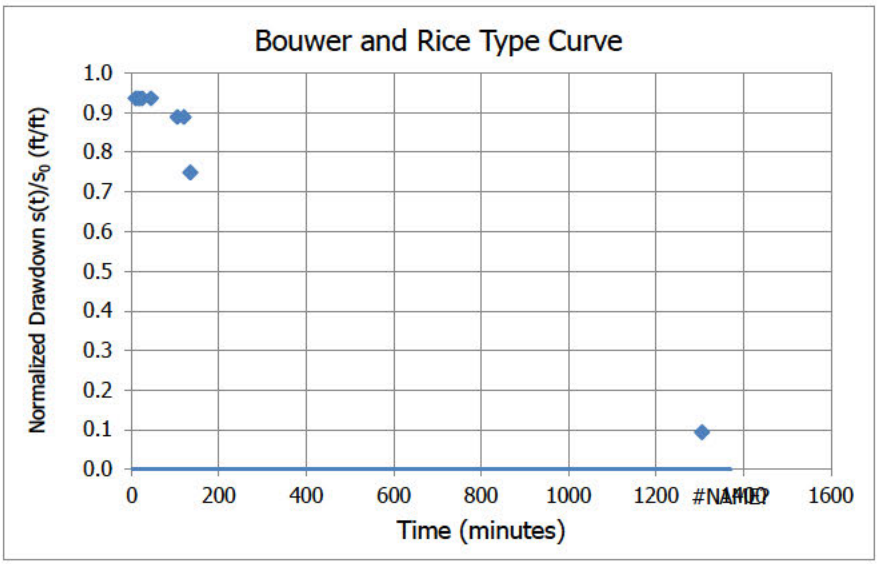
Model Results: T_n (ft^2/d) = #NAME? +/- #NAME? ft^2/d

J-Ratio
-0.304



Coef. Of Variation
#NAME?

C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-MW-65
Date:	20-Mar-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

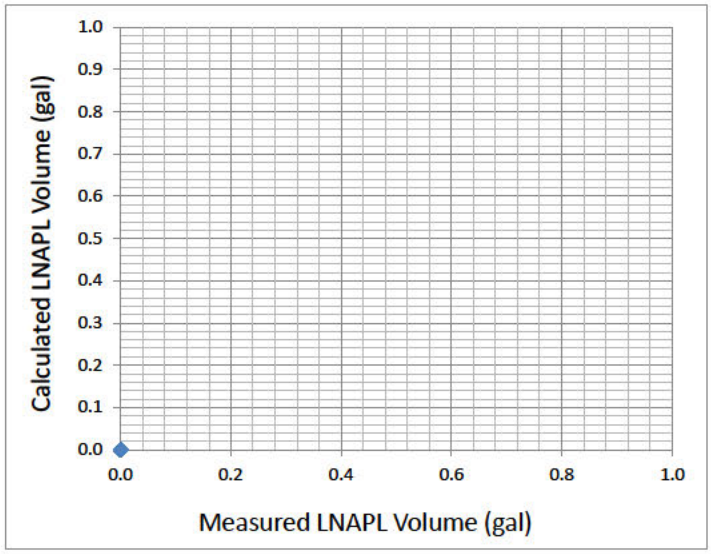
Enter early time cut-off for least-squares model fit

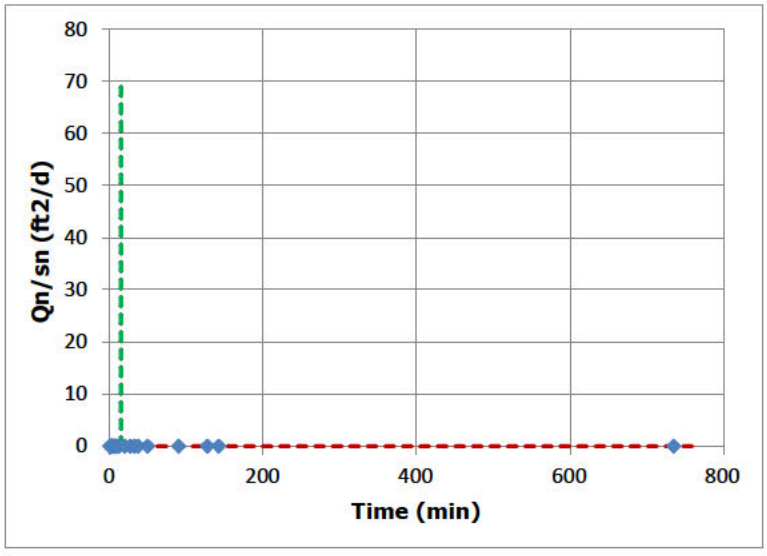
$Time_{cut}$ (min):	15	<- Enter or change values here
Time Adjustment (min):	15	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	#NAME?	<-- Minimize this using "Solver"
	0.015	<-- Working S_n
Trial T_n (ft^2/d):	0.365	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.36**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-MW-65
Date:	20-Mar-17

Enter early time cut-off for least-squares model fit

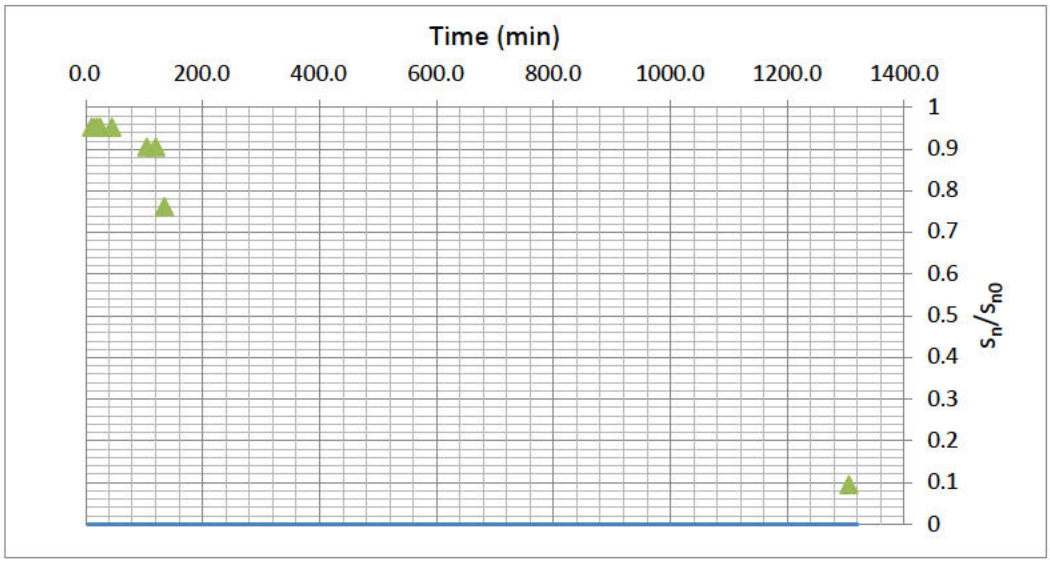
$Time_{cut}$ (min):	15	<- Enter or change values here
Initial Drawdown s_n (ft):	0.21	

Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	#NAME?	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.326	<-- By changing T_n through "Solver"
	0.014	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	3
T_{max}	1320

Model Result: T_n (ft^2/d) = **0.33**



J-Ratio
-0.304

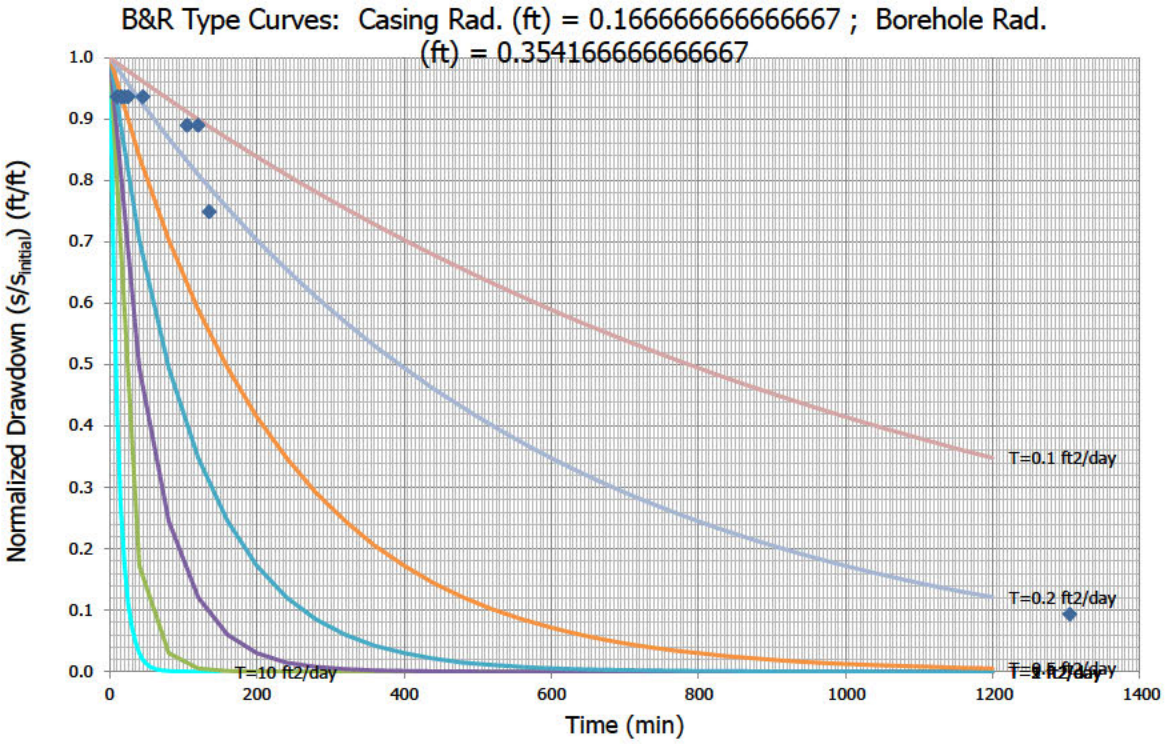
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.166666666666667 ; Borehole Rad. (ft) = 0.354166666666667

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		1200	5
3	T=2 ft2/day		1200	2
4	T=1 ft2/day		1200	1
5	T=0.5 ft2/day		1200	0.5
6	T=0.2 ft2/day		1200	0.2
7	T=0.1 ft2/day		1200	0.1

J-Ratio	
-0.304	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

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STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.96

Standard Deviation (ft^2/d)

0.80

Coefficient of Variation

0.84

Well Designation:	DSCP-RW-2	Beckett and Lyverse (2002)
Date:	21-Mar-17	

Ground Surface Elev (ft msl)	20.1	Enter These Data	Drawdown Adjustment (ft)
Top of Casing Elev (ft msl)	19.1		
Well Casing Radius, r_c (ft):	0.250	r_{e1}	0
Well Radius, r_w (ft):	0.500		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.840		
Top of Screen (ft bgs):	13.0		
Bottom of Screen (ft bgs):	33.0		
LNAPL Baildown Vol. (gal.):	2.8		
Effective Radius, r_{e3} (ft):	0.309	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.246		
Initial Casing LNAPL Vol. (gal.):	2.10		
Initial Filter LNAPL Vol. (gal.):	1.10		

	Enter Data Here										
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	18.41	19.84	19.41	20.84	19.64					1.43	
Enter Test Data:	0.5	18.75	18.96	19.75	19.96	19.78	0.34				0.21	
	1.0	18.75	18.96	19.75	19.96	19.78	0.34	0.8	0.000	0.34	0.21	0.309
	1.5	18.73	18.96	19.73	19.96	19.77	0.32	1.3	17.247	0.33	0.23	0.309
	2.0	18.71	18.96	19.71	19.96	19.75	0.30	1.8	17.247	0.31	0.25	0.309
	2.5	18.70	18.95	19.70	19.95	19.74	0.29	2.3	0.000	0.30	0.25	0.309
	3.0	18.70	18.95	19.70	19.95	19.74	0.29	2.8	0.000	0.29	0.25	0.309
	6.0	18.65	18.90	19.65	19.90	19.69	0.24	4.5	0.000	0.27	0.25	0.309
	7.0	18.65	18.90	19.65	19.90	19.69	0.24	6.5	0.000	0.24	0.25	0.309
	8.0	18.64	18.90	19.64	19.90	19.68	0.23	7.5	4.312	0.24	0.26	0.309
	9.0	18.63	18.89	19.63	19.89	19.67	0.22	8.5	0.000	0.23	0.26	0.309
	10.0	18.62	18.89	19.62	19.89	19.66	0.21	9.5	4.312	0.22	0.27	0.309
	15.0	18.6	18.87	19.60	19.87	19.64	0.19	12.5	0.000	0.20	0.27	0.309
	20.0	18.57	18.87	19.57	19.87	19.62	0.16	17.5	2.587	0.18	0.30	0.309
	25.0	18.57	18.88	19.57	19.88	19.62	0.16	22.5	0.862	0.16	0.31	0.309
	30.0	18.55	18.90	19.55	19.90	19.61	0.14	27.5	3.449	0.15	0.35	0.309
	35.0	18.54	18.93	19.54	19.93	19.60	0.13	32.5	3.449	0.14	0.39	0.309
	40.0	18.55	18.93	19.55	19.93	19.61	0.14	37.5	-0.862	0.14	0.38	0.309
	55.0	18.55	18.95	19.55	19.95	19.61	0.14	47.5	0.575	0.14	0.40	0.309
	70.0	18.53	18.94	19.53	19.94	19.60	0.12	62.5	0.287	0.13	0.41	0.309
	85.00	18.55	18.97	19.55	19.97	19.62	0.14	77.5	0.287	0.13	0.42	0.309
	100.00	18.52	18.93	19.52	19.93	19.59	0.11	92.5	-0.287	0.13	0.41	0.309

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-RW-2
Date:	21-Mar-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t-t_1)}$$

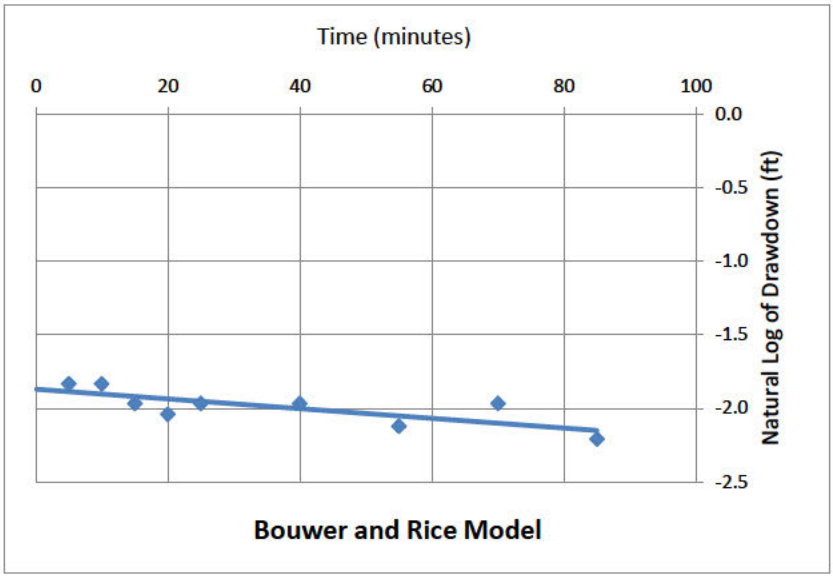
Enter early time cut-off for least-squares model fit

$Time_{cut}$	15	<- Enter or change value here

L_e/r_e
4.6
C
0.98
R/r_e
2.94

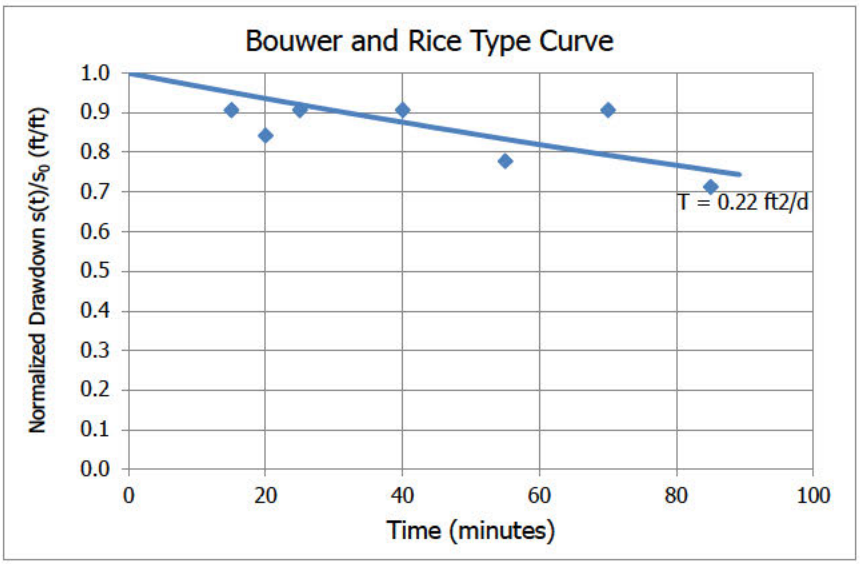
Model Results: T_n (ft^2/d) = 0.23 +/- 0.07 ft^2/d

J-Ratio
-1.067



Coef. Of Variation
0.31

C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-RW-2
Date:	21-Mar-17

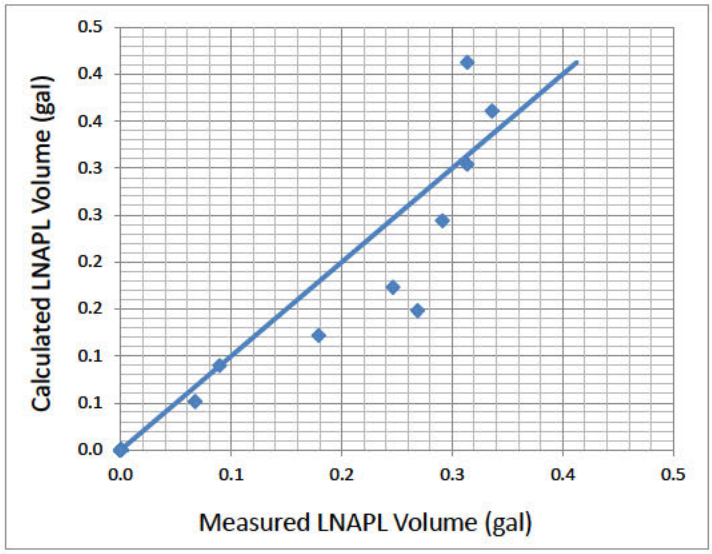
$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

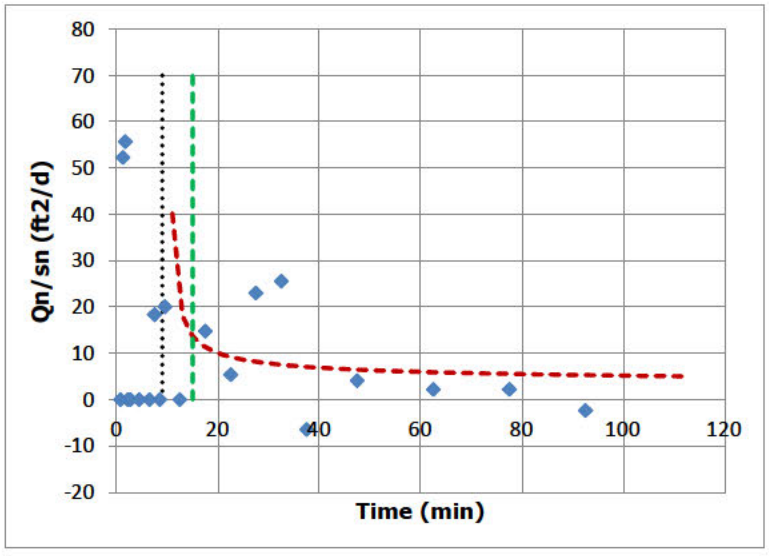
Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	15	<- Enter or change values here
Time Adjustment (min):	9	
Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.190	<-- Minimize this using "Solver"
	0.034	<-- Working S_n
Trial T_n (ft^2/d):	1.823	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **1.82**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-RW-2
Date:	21-Mar-17

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	15	<- Enter or change values here
Initial Drawdown s_n (ft):	0.19	

Trial S_n: d <-- Enter d for default

Root-Mean-Square Error: 0.232 <-- Minimize this using "Solver"

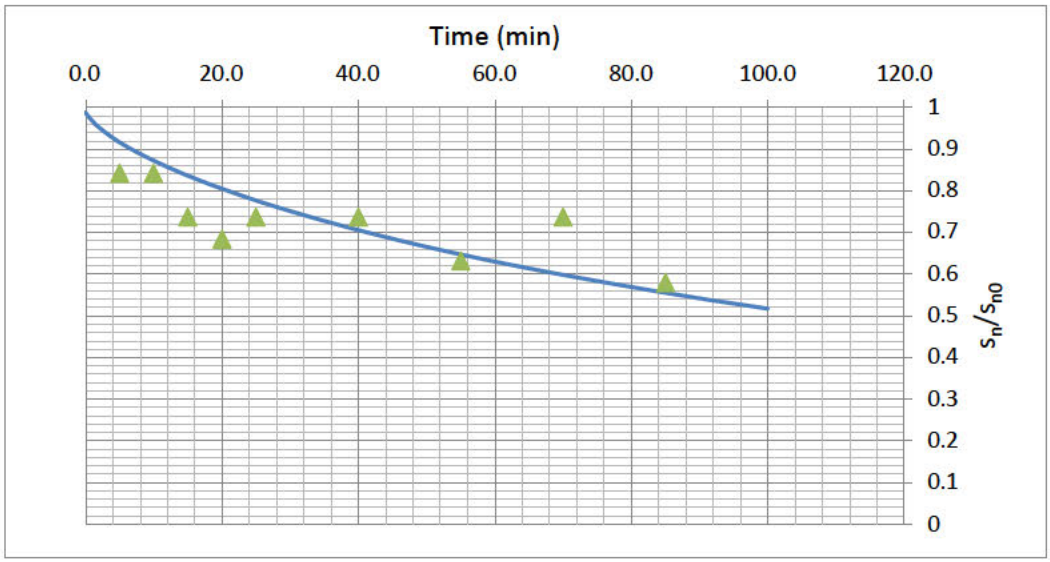
Trial T_n (ft^2/d): 0.833 <-- By changing T_n through "Solver"

0.023 <-- Working S_n

Add constraint Tn > 0.00001

T_{min}	0.01
T_{max}	100

Model Result: T_n (ft^2/d) = **0.83**



J-Ratio
-1.067

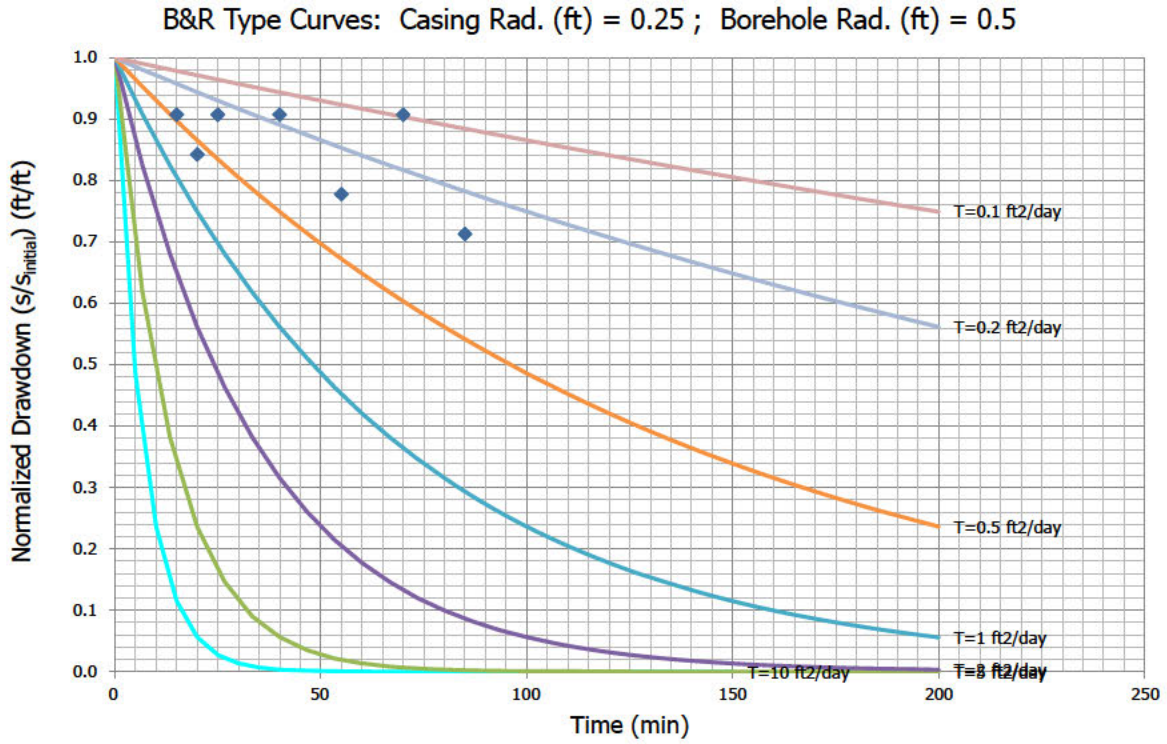
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-1.067	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

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STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

3.63

Standard Deviation (ft^2/d)

1.26

Coefficient of Variation

0.35

Well Designation:	DSCP-RW-9	Beckett and Lyverse (2002)
Date:	22-Mar-17	

Ground Surface Elev (ft msl)	19.0	Enter These Data	**Drawdown Adjustment (ft)**
Top of Casing Elev (ft msl)	17.0		
Well Casing Radius, r_c (ft):	0.250	r_{e1}	0
Well Radius, r_w (ft):	0.583		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.840		
Top of Screen (ft bgs):	15.0		
Bottom of Screen (ft bgs):	35.0		
LNAPL Baildown Vol. (gal.):	4.3		
Effective Radius, r_{e3} (ft):	0.333	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.276		
Initial Casing LNAPL Vol. (gal.):	2.00		
Initial Filter LNAPL Vol. (gal.):	1.55		

	Enter Data Here										
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	16.23	17.59	18.23	19.59	18.45					1.36	
Enter Test Data:	0.5	16.85	16.95	18.85	18.95	18.87	0.62				0.10	
	1.0	16.79	16.94	18.79	18.94	18.81	0.56	0.8	50.265	0.59	0.15	0.333
	1.5	16.76	16.95	18.76	18.95	18.79	0.53	1.3	40.212	0.54	0.19	0.333
	2.0	16.72	16.95	18.72	18.95	18.76	0.49	1.8	40.212	0.51	0.23	0.333
	2.5	16.70	16.95	18.70	18.95	18.74	0.47	2.3	20.106	0.48	0.25	0.333
	3.0	16.66	16.95	18.66	18.95	18.71	0.43	2.8	40.212	0.45	0.29	0.333
	3.5	16.64	16.95	18.64	18.95	18.69	0.41	3.3	20.106	0.42	0.31	0.333
	4.0	16.63	16.94	18.63	18.94	18.68	0.40	3.8	0.000	0.40	0.31	0.333
	4.5	16.60	16.92	18.60	18.92	18.65	0.37	4.3	10.053	0.38	0.32	0.333
	7.0	16.53	16.85	18.53	18.85	18.58	0.30	5.8	0.000	0.33	0.32	0.333
	8.0	16.53	16.85	18.53	18.85	18.58	0.30	7.5	0.000	0.30	0.32	0.333
	9.0	16.52	16.85	18.52	18.85	18.57	0.29	8.5	5.027	0.29	0.33	0.333
	10.0	16.5	16.85	18.50	18.85	18.56	0.27	9.5	10.053	0.28	0.35	0.333
	15.0	16.45	16.85	18.45	18.85	18.51	0.22	12.5	5.027	0.24	0.40	0.333
	20.0	16.42	16.85	18.42	18.85	18.49	0.19	17.5	3.016	0.20	0.43	0.333
	25.0	16.4	16.85	18.40	18.85	18.47	0.17	22.5	2.011	0.18	0.45	0.333
	30.0	16.38	16.86	18.38	18.86	18.46	0.15	27.5	3.016	0.16	0.48	0.333
	45.0	16.35	16.90	18.35	18.90	18.44	0.12	37.5	2.346	0.13	0.55	0.333
	50.0	16.33	16.95	18.33	18.95	18.43	0.10	47.5	7.037	0.11	0.62	0.333

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-RW-9
Date:	22-Mar-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t-t_1)}$$

Enter early time cut-off for least-squares model fit

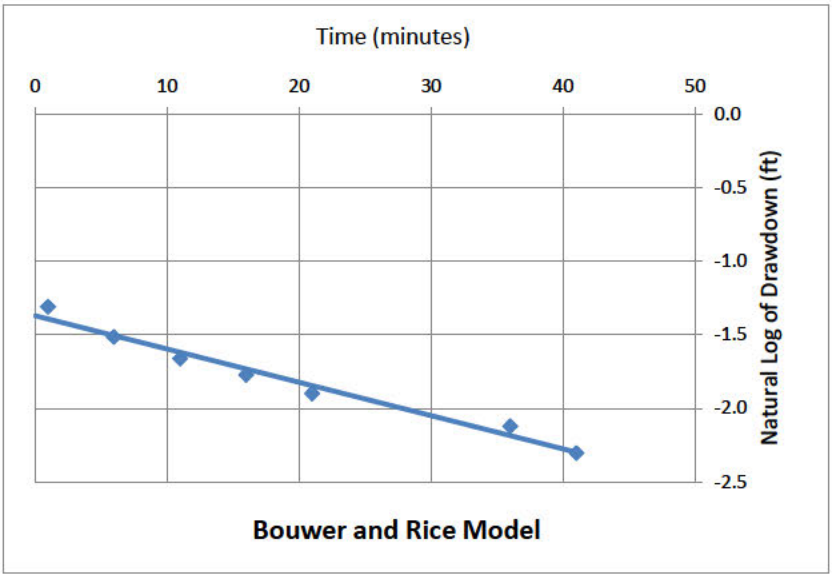
$Time_{cut}$	9	<- Enter or change value here

Model Results: T_n (ft^2/d) = 2.47 +/- 0.17 ft^2/d

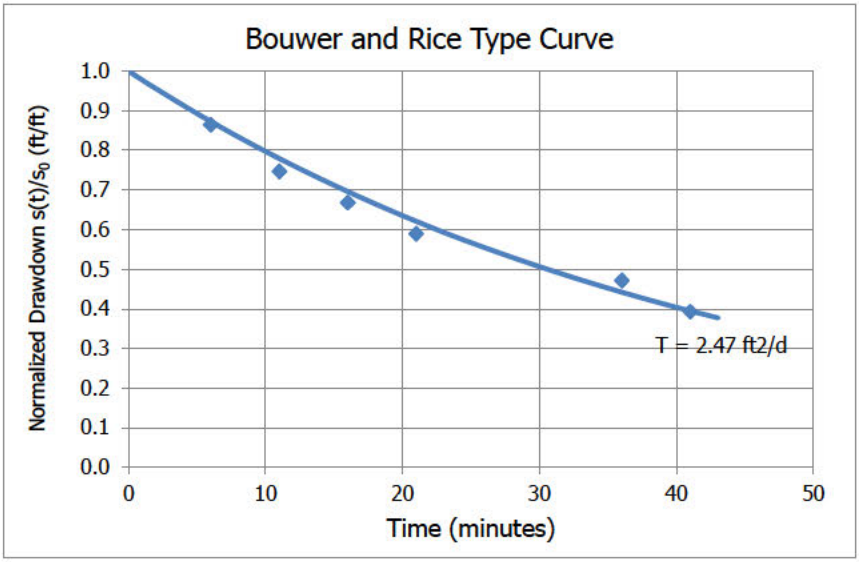
L_e/r_e
4.1
C
0.95
R/r_e
2.67

J-Ratio
-0.722

Coef. Of Variation
0.07



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-RW-9
Date:	22-Mar-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

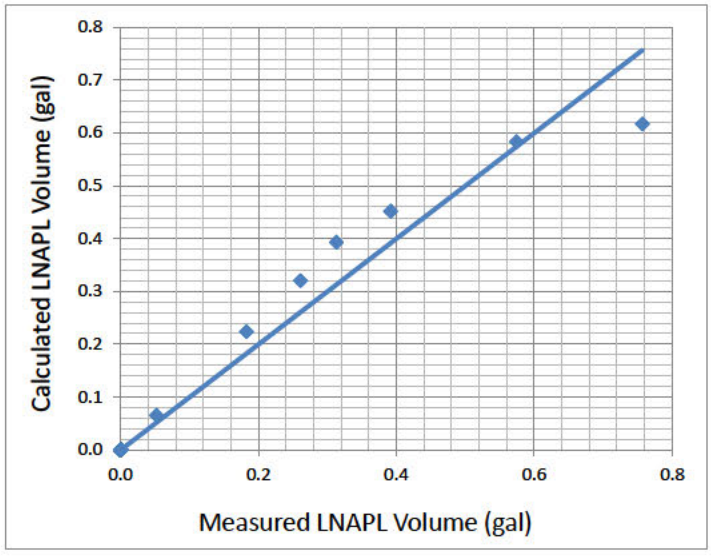
Enter early time cut-off for least-squares model fit

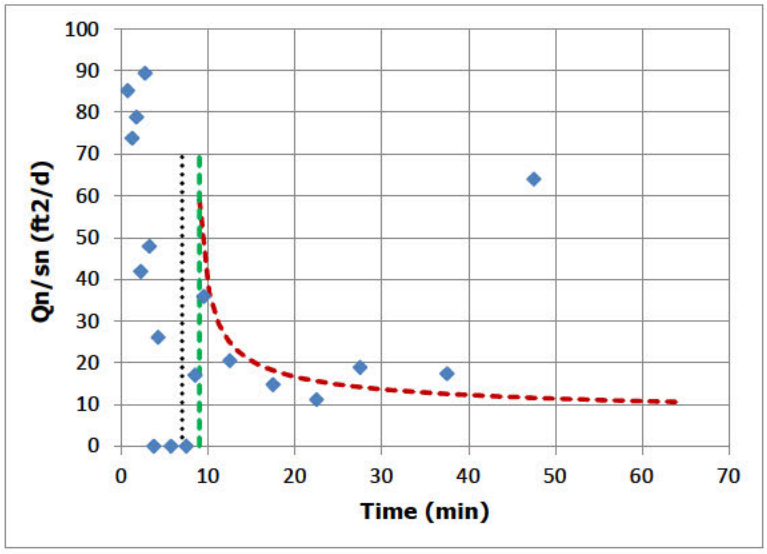
$Time_{cut}$ (min):	9	<- Enter or change values here
Time Adjustment (min):	7	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.187	<-- Minimize this using "Solver"
	0.046	<-- Working S_n
Trial T_n (ft^2/d):	3.453	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **3.45**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-RW-9
Date:	22-Mar-17

Enter early time cut-off for least-squares model fit

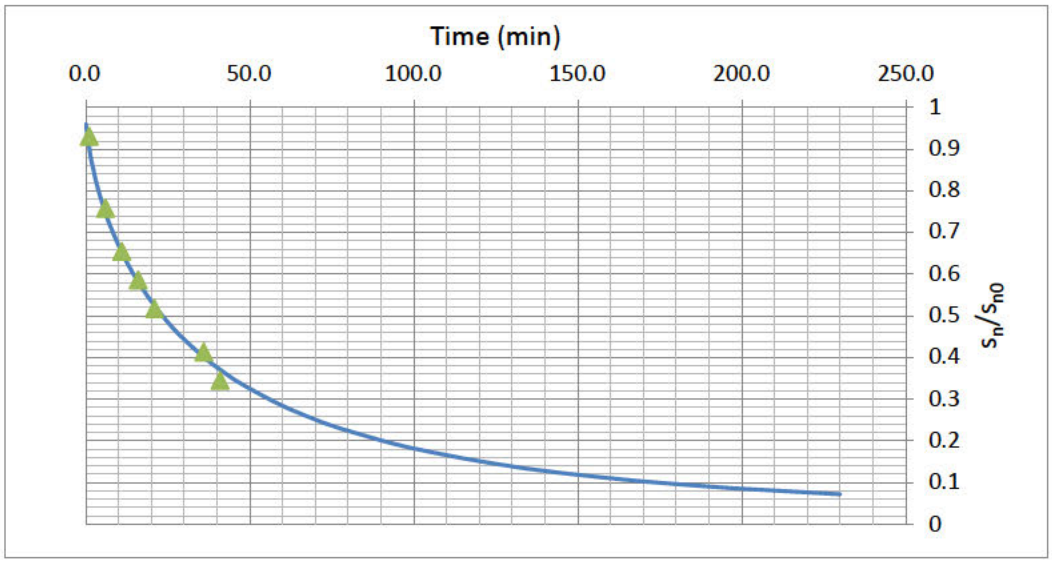
$Time_{cut}$ (min):	9	<- Enter or change values here
Initial Drawdown s_n (ft):	0.29	

Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.040	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	4.965	<-- By changing T_n through "Solver"
	0.056	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	0.1
T_{max}	230

Model Result: T_n (ft^2/d) = **4.96**



J-Ratio
-0.722

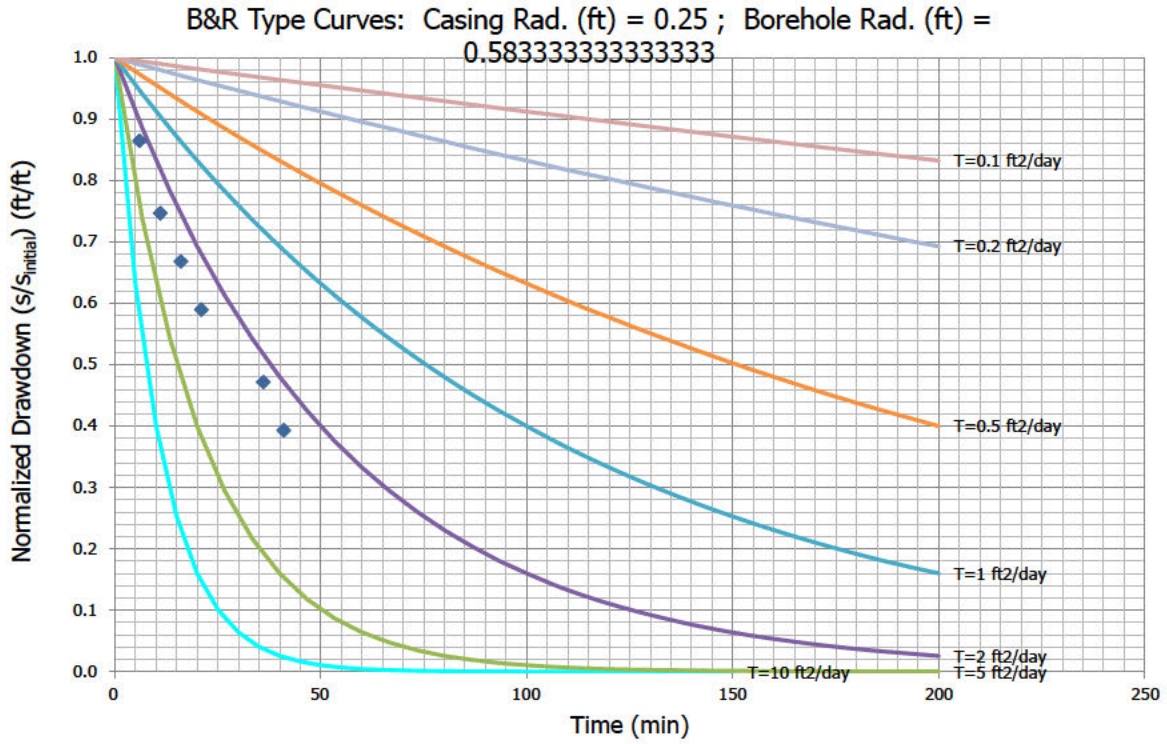
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.583333333333333

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-0.722	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

2.78

Standard Deviation (ft^2/d)

2.91

Coefficient of Variation

1.05

Well Designation:	DSCP-RW-9	Beckett and Lyverse (2002)
Date:	4-Oct-17	

Ground Surface Elev (ft msl)	19.0	Enter These Data	Drawdown Adjustment (ft)
Top of Casing Elev (ft msl)	17.0		
Well Casing Radius, r_c (ft):	0.250	r_{e1}	0
Well Radius, r_w (ft):	0.583		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.840		
Top of Screen (ft bgs):	15.0		
Bottom of Screen (ft bgs):	35.0		
LNAPL Baildown Vol. (gal.):	1.1		
Effective Radius, r_{e3} (ft):	0.333	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.307		
Initial Casing LNAPL Vol. (gal.):	1.19		
Initial Filter LNAPL Vol. (gal.):	0.93		

	Enter Data Here					Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)							
Initial Fluid Levels:	0	15.56	16.37	17.56	18.37	17.69					0.81	
Enter Test Data:	0.5	16.20	16.24	18.20	18.24	18.21	0.64				0.04	
	1.0	16.10	16.18	18.10	18.18	18.11	0.54	0.8	40.212	0.59	0.08	0.333
	1.5	16.07	16.16	18.07	18.16	18.08	0.51	1.3	10.053	0.52	0.09	0.333
	2.0	16.03	16.13	18.03	18.13	18.05	0.47	1.8	10.053	0.49	0.10	0.333
	3.0	15.98	16.09	17.98	18.09	18.00	0.42	2.5	5.027	0.45	0.11	0.333
	3.5	15.96	16.07	17.96	18.07	17.98	0.40	3.3	0.000	0.41	0.11	0.333
	4.0	15.95	16.06	17.95	18.06	17.97	0.39	3.8	0.000	0.40	0.11	0.333
	4.5	15.93	16.04	17.93	18.04	17.95	0.37	4.3	0.000	0.38	0.11	0.333
	5.0	15.92	16.03	17.92	18.03	17.94	0.36	4.8	0.000	0.36	0.11	0.333
	6.0	15.89	16.01	17.89	18.01	17.91	0.33	5.5	5.027	0.34	0.12	0.333
	7.0	15.87	16.00	17.87	18.00	17.89	0.31	6.5	5.027	0.32	0.13	0.333
	8.0	15.87	16.00	17.87	18.00	17.89	0.31	7.5	0.000	0.31	0.13	0.333
	12.0	15.82	15.95	17.82	17.95	17.84	0.26	10.0	0.000	0.28	0.13	0.333
	13.0	15.8	15.95	17.80	17.95	17.82	0.24	12.5	10.053	0.25	0.15	0.333
	14.0	15.78	15.94	17.78	17.94	17.81	0.22	13.5	5.027	0.23	0.16	0.333
	15.0	15.78	15.94	17.78	17.94	17.81	0.22	14.5	0.000	0.22	0.16	0.333
	25.00	15.72	15.88	17.72	17.88	17.75	0.16	20.0	0.000	0.19	0.16	0.333
	30.00	15.69	15.86	17.69	17.86	17.72	0.13	27.5	1.005	0.14	0.17	0.333
	35.00	15.68	15.85	17.68	17.85	17.71	0.12	32.5	0.000	0.12	0.17	0.333
	40.00	15.68	15.85	17.68	17.85	17.71	0.12	37.5	0.000	0.12	0.17	0.333
	45.00	15.67	15.85	17.67	17.85	17.70	0.11	42.5	1.005	0.11	0.18	0.333
	50.00	15.63	15.83	17.63	17.83	17.66	0.07	47.5	2.011	0.09	0.20	0.333
	55.00	15.63	15.83	17.63	17.83	17.66	0.07	52.5	0.000	0.07	0.20	0.333
	60.00	15.63	15.83	17.63	17.83	17.66	0.07	57.5	0.000	0.07	0.20	0.333
	70.00	15.63	15.83	17.63	17.83	17.66	0.07	65.0	0.000	0.07	0.20	0.333
	80.00	15.63	15.85	17.63	17.85	17.67	0.07	75.0	1.005	0.07	0.22	0.333
	90.00	15.63	15.86	17.63	17.86	17.67	0.07	85.0	0.503	0.07	0.23	0.333
	100.00	15.63	15.88	17.63	17.88	17.67	0.07	95.0	1.005	0.07	0.25	0.333
	110.00	15.63	15.88	17.63	17.88	17.67	0.07	105.0	0.000	0.07	0.25	0.333
	120	15.63	15.89	17.63	17.89	17.67	0.07	115.0	0.503	0.07	0.26	0.333
	140	15.63	15.90	17.63	17.90	17.67	0.07	130.0	0.251	0.07	0.27	0.333
	160	15.63	15.93	17.63	17.93	17.68	0.07	150.0	0.754	0.07	0.30	0.333
	180	15.62	15.92	17.62	17.92	17.67	0.06	170.0	0.000	0.06	0.30	0.333
	200	15.61	15.92	17.61	17.92	17.66	0.05	190.0	0.251	0.05	0.31	0.333
	220	15.60	15.93	17.60	17.93	17.65	0.04	210.0	0.503	0.04	0.33	0.333
	240	15.60	15.93	17.60	17.93	17.65	0.04	230.0	0.000	0.04	0.33	0.333
	260	15.60	15.93	17.60	17.93	17.65	0.04	250.0	0.000	0.04	0.33	0.333
	280	15.60	15.95	17.60	17.95	17.66	0.04	270.0	0.503	0.04	0.35	0.333
	300	15.59	15.95	17.59	17.95	17.65	0.03	290.0	0.251	0.04	0.36	0.333
	320	15.57	15.95	17.57	17.95	17.63	0.01	310.0	0.503	0.02	0.38	0.333
	340	15.57	15.95	17.57	17.95	17.63	0.01	330.0	0.000	0.01	0.38	0.333
	360	15.56	15.95	17.56	17.95	17.62	0.00	350.0	0.251	0.00	0.39	0.333

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-RW-9
Date:	4-Oct-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t - t_1)}$$

Enter early time cut-off for least-squares model fit

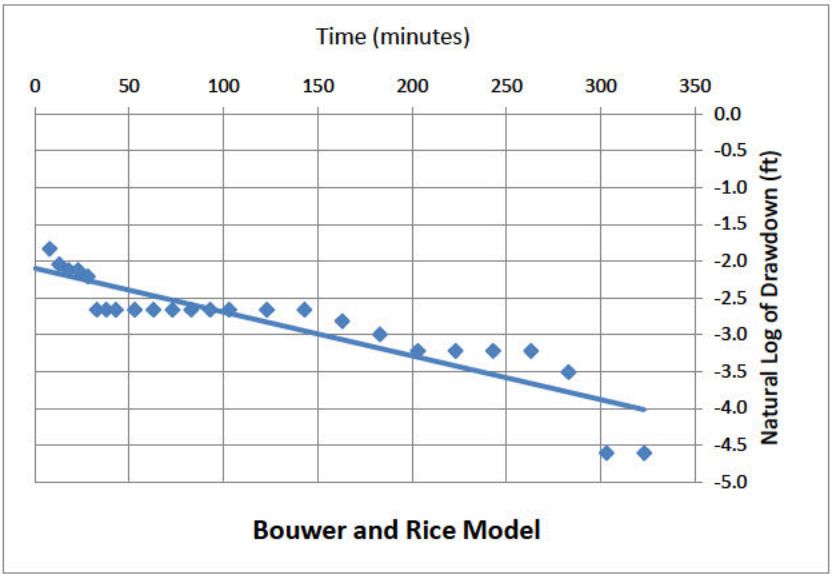
$Time_{cut}$	17	<- Enter or change value here

Model Results: T_n (ft^2/d) = 0.86 +/- 0.09 ft^2/d

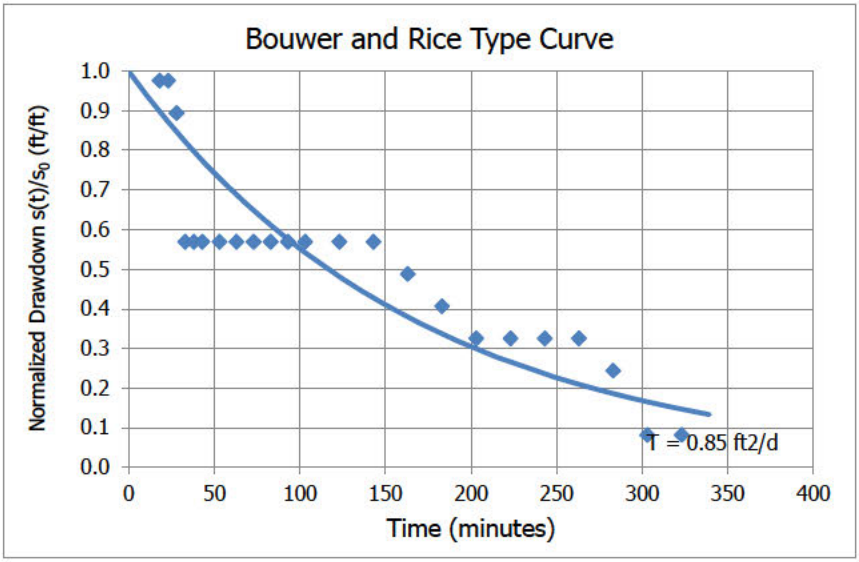
L_e/r_e
2.4
C
0.89
R/r_e
1.86

J-Ratio
-0.346

Coef. Of Variation
0.10



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-RW-9
Date:	4-Oct-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^{\,2} S_n}\right)} \Delta t_j$$

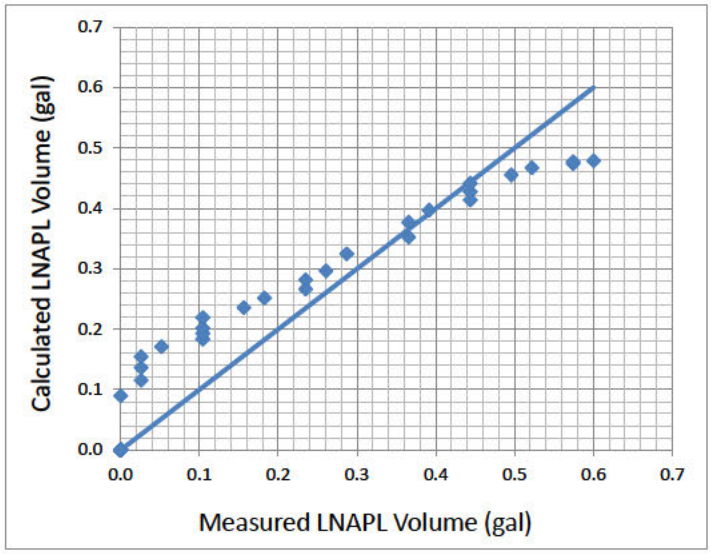
Enter early time cut-off for least-squares model fit

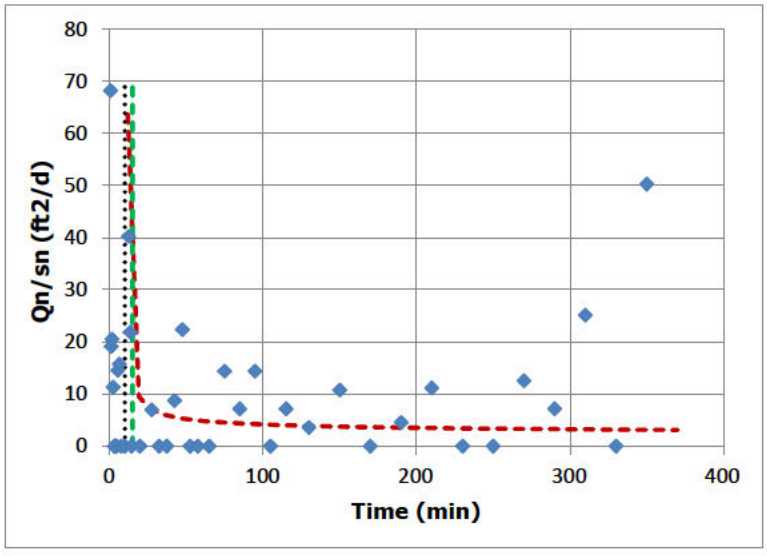
$Time_{cut}$ (min):	15	<- Enter or change values here
Time Adjustment (min):	10	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.391	<-- Minimize this using "Solver"
	0.029	<-- Working S_n
Trial T_n (ft^2/d):	1.353	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **1.35**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-RW-9
Date:	4-Oct-17

Enter early time cut-off for least-squares model fit

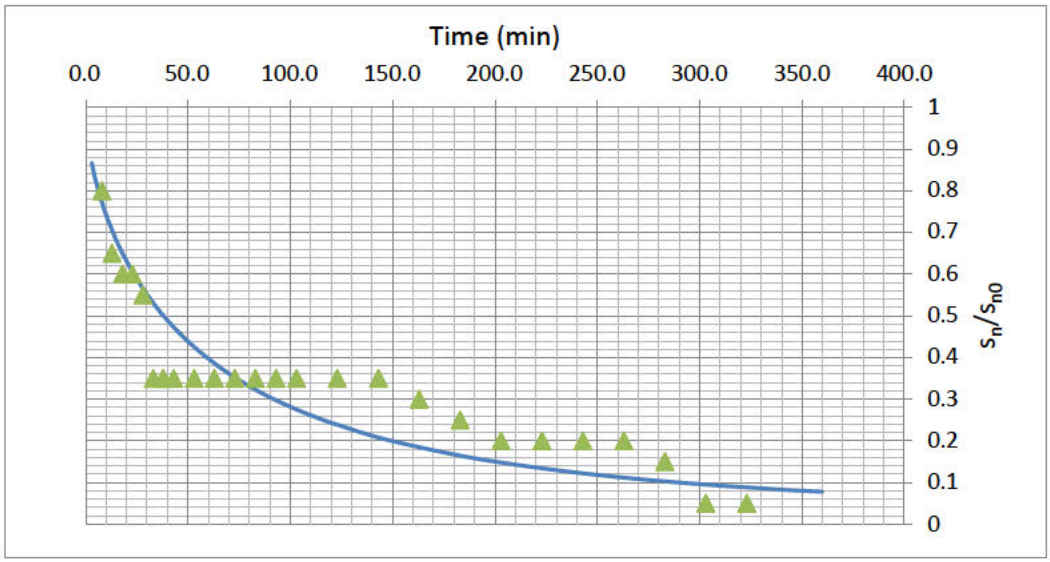
$Time_{cut}$ (min):	17	<- Enter or change values here
Initial Drawdown s_n (ft):	0.2	

Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.416	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	6.118	<-- By changing T_n through "Solver"
	0.062	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	3
T_{max}	360

Model Result: T_n (ft^2/d) = **6.12**



J-Ratio
-0.346

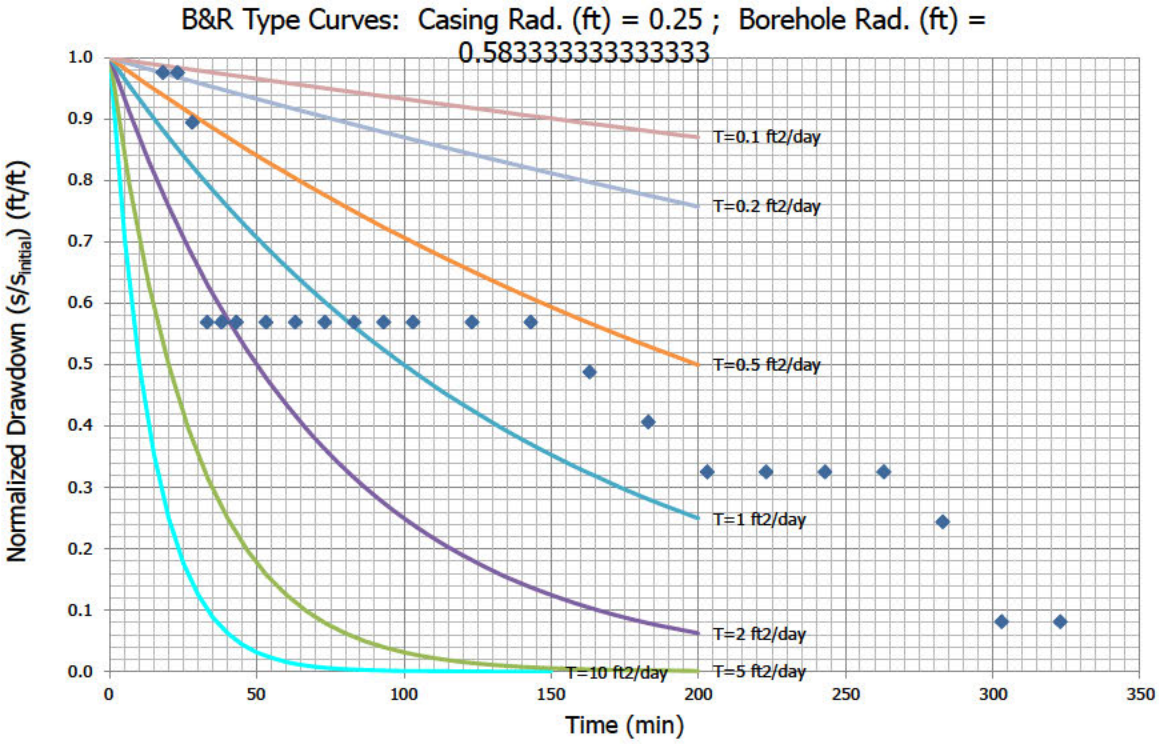
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.583333333333333

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-0.346	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.12

Standard Deviation (ft^2/d)

0.16

Coefficient of Variation

1.36

Well Designation:	PH-RW-A	Beckett and Lyverse (2002)
Date:	22-Mar-17	

Ground Surface Elev (ft msl)	19.5	Enter These Data
Top of Casing Elev (ft msl)	20.5	
Well Casing Radius, r_c (ft):	0.250	r_{e1}
Well Radius, r_w (ft):	0.500	
LNAPL Specific Yield, S_y:	0.175	
LNAPL Density Ratio, ρ_r:	0.840	
Top of Screen (ft bgs):	15.0	
Bottom of Screen (ft bgs):	35.0	
LNAPL Baildown Vol. (gal.):	1.3	
Effective Radius, r_{e3} (ft):	0.309	Calculated Parameters
Effective Radius, r_{e2} (ft):	#NUM!	
Initial Casing LNAPL Vol. (gal.):	1.19	
Initial Filter LNAPL Vol. (gal.):	0.62	

Drawdown Adjustment (ft)
0

	Enter Data Here										
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	18.54	19.35	17.54	18.35	17.67					0.81	
Enter Test Data:	0.5	19.09	19.12	18.09	18.12	18.09	0.55				0.03	
	1.0	18.97	19.03	17.97	18.03	17.98	0.43	0.8	25.871	0.49	0.06	0.309
	1.5	18.92	18.97	17.92	17.97	17.93	0.38	1.3	-8.624	0.41	0.05	0.309
	2.0	18.88	18.94	17.88	17.94	17.89	0.34	1.8	8.624	0.36	0.06	0.309
	2.5	18.85	18.90	17.85	17.90	17.86	0.31	2.3	-8.624	0.33	0.05	0.309
	3.0	18.83	18.89	17.83	17.89	17.84	0.29	2.8	8.624	0.30	0.06	0.309
	3.5	18.82	18.88	17.82	17.88	17.83	0.28	3.3	0.000	0.29	0.06	0.309
	4.0	18.81	18.87	17.81	17.87	17.82	0.27	3.8	0.000	0.28	0.06	0.309
	4.5	18.81	18.86	17.81	17.86	17.82	0.27	4.3	-8.624	0.27	0.05	0.309
	5.0	18.80	18.85	17.80	17.85	17.81	0.26	4.8	0.000	0.27	0.05	0.309
	6.0	18.77	18.82	17.77	17.82	17.78	0.23	5.5	0.000	0.25	0.05	0.309
	7.0	18.76	18.81	17.76	17.81	17.77	0.22	6.5	0.000	0.23	0.05	0.309
	8.0	18.75	18.80	17.75	17.80	17.76	0.21	7.5	0.000	0.22	0.05	0.309
	9.0	18.73	18.80	17.73	17.80	17.74	0.19	8.5	8.624	0.20	0.07	0.309
	10.0	18.72	18.79	17.72	17.79	17.73	0.18	9.5	0.000	0.19	0.07	0.309
	15.0	18.7	18.75	17.70	17.75	17.71	0.16	12.5	-1.725	0.17	0.05	0.309
	20.0	18.68	18.74	17.68	17.74	17.69	0.14	17.5	0.862	0.15	0.06	0.309
	25.0	18.68	18.73	17.68	17.73	17.69	0.14	22.5	-0.862	0.14	0.05	0.309
	30.0	18.68	18.73	17.68	17.73	17.69	0.14	27.5	0.000	0.14	0.05	0.309
	35.0	18.67	18.73	17.67	17.73	17.68	0.13	32.5	0.862	0.14	0.06	0.309
	40.0	18.67	18.73	17.67	17.73	17.68	0.13	37.5	0.000	0.13	0.06	0.309
	55.0	18.66	18.71	17.66	17.71	17.67	0.12	47.5	-0.287	0.13	0.05	0.309

Generalized Bouwer and Rice (1976)

Well Designation:	PH-RW-A
Date:	22-Mar-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t - t_1)}$$

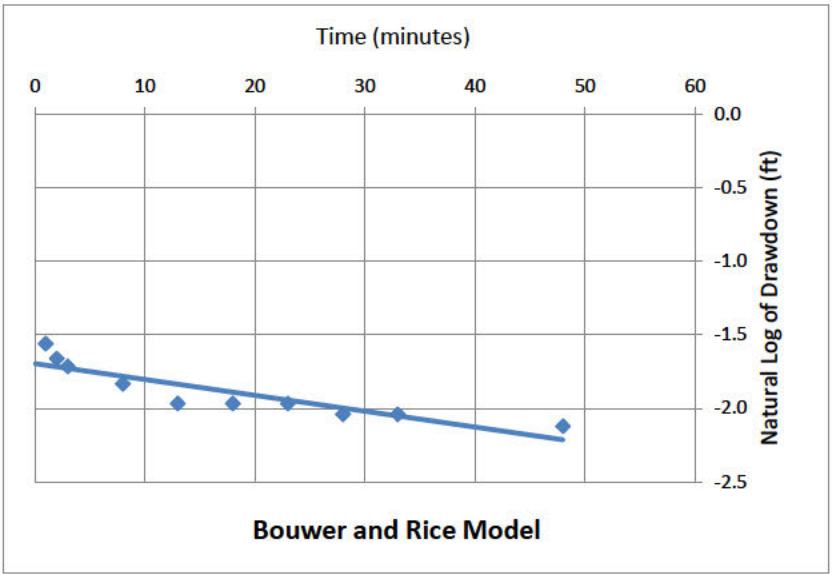
Enter early time cut-off for least-squares model fit

$Time_{cut}$	7	<- Enter or change value here

L_e/r_e
2.6
C
0.90
R/r_e
1.96

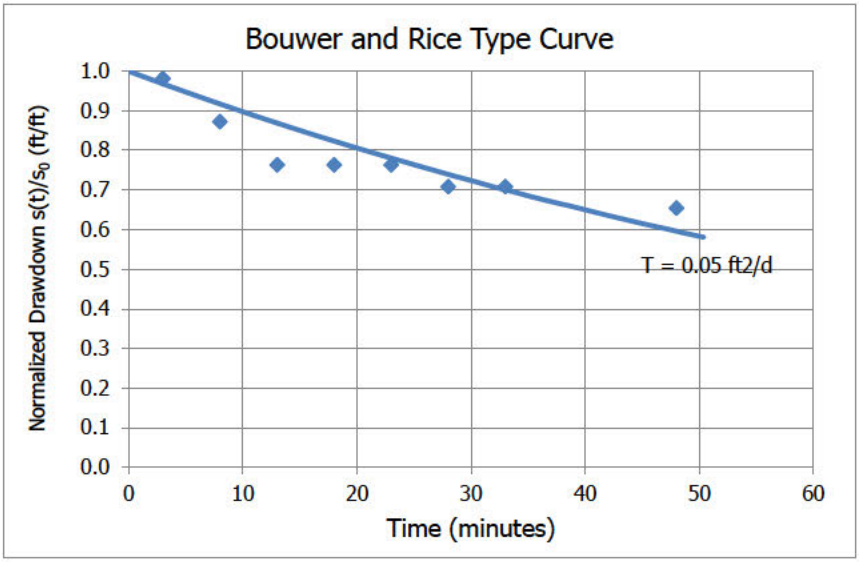
Model Results: T_n (ft^2/d) = 0.06 +/- 0.01 ft^2/d

J-Ratio
-9.000



Coef. Of Variation
0.17

C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	PH-RW-A
Date:	22-Mar-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^{\,2} S_n}\right)} \Delta t_j$$

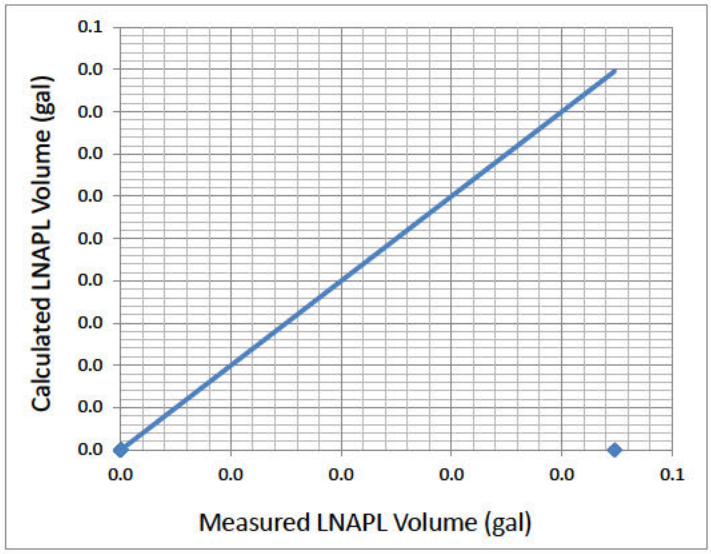
Enter early time cut-off for least-squares model fit

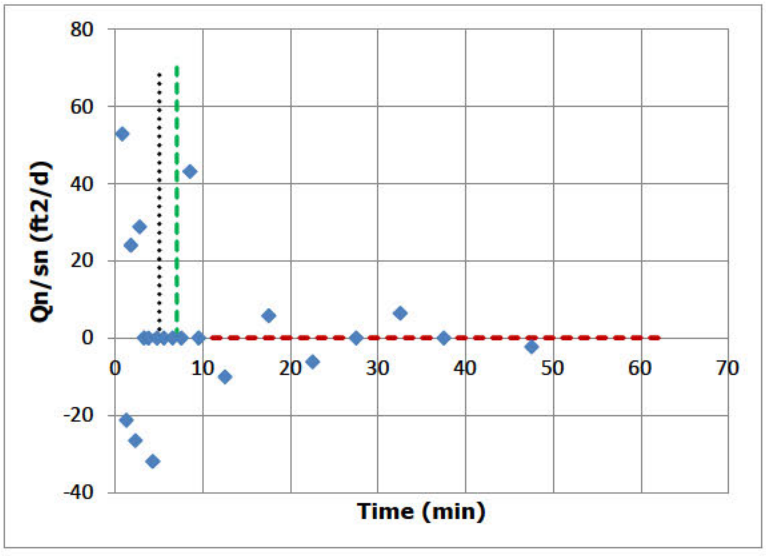
$Time_{cut}$ (min):	7	<- Enter or change values here
Time Adjustment (min):	5	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.074	<-- Minimize this using "Solver"
	0.000	<-- Working S_n
Trial T_n (ft^2/d):	0.000	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.00**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	PH-RW-A
Date:	22-Mar-17

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	7	<- Enter or change values here
Initial Drawdown s_n (ft):	0.22	

Trial S_n: d <-- Enter d for default

Root-Mean-Square Error: 0.192 <-- Minimize this using "Solver"

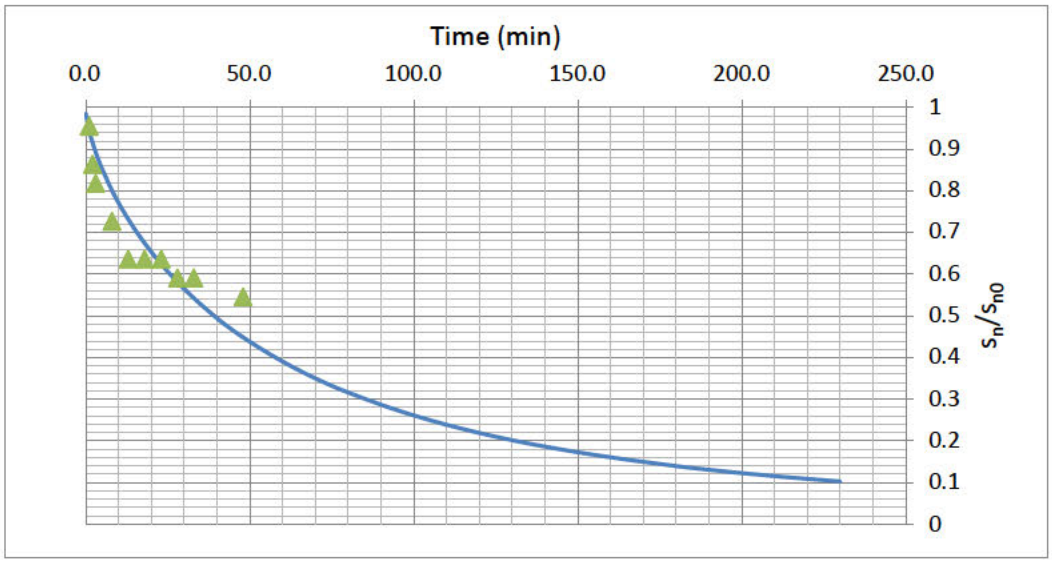
Trial T_n (ft^2/d): 0.308 <-- By changing T_n through "Solver"

0.014 <-- Working S_n

Add constraint Tn > 0.00001

Model Result: T_n (ft^2/d) = **0.31**

T_{min}	0.1
T_{max}	230



J-Ratio
-9.000

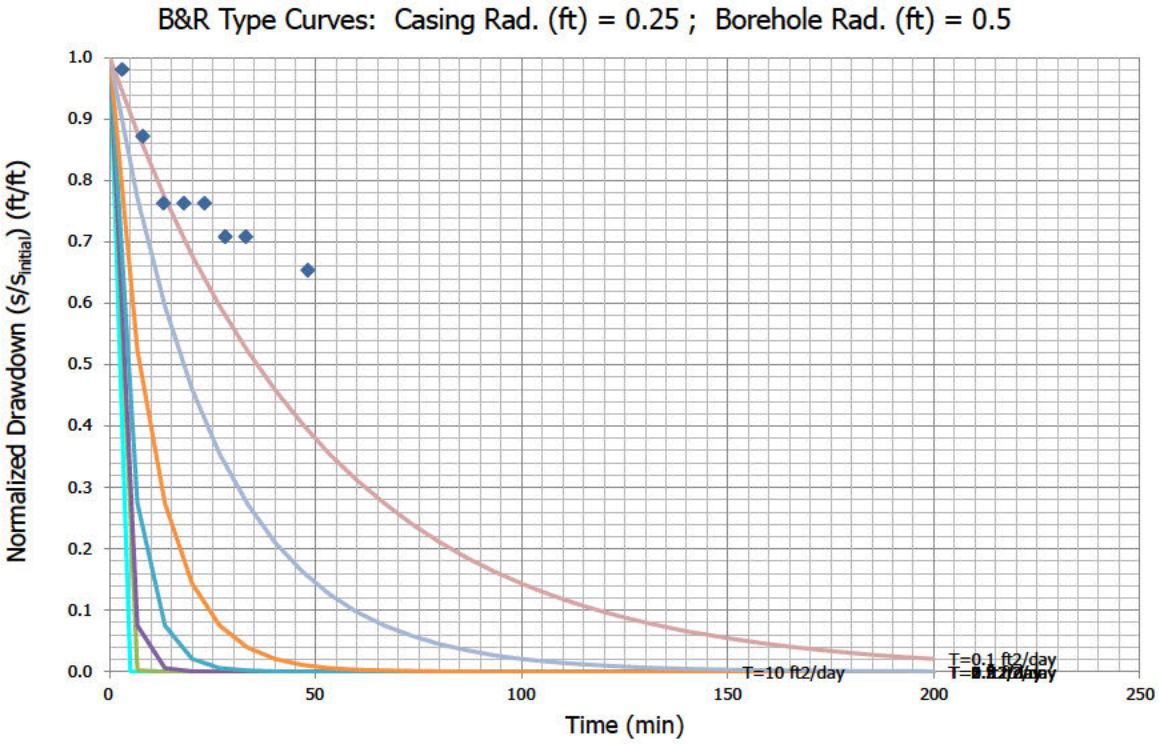
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-9.000	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.16

Standard Deviation (ft^2/d)

0.09

Coefficient of Variation

0.57

Well Designation:	DSCP-MW-3A	Beckett and Lyverse (2002)
Date:	15-Sep-17	

Ground Surface Elev (ft msl)	21.3	Enter These Data
Top of Casing Elev (ft msl)	21.0	
Well Casing Radius, r_c (ft):	0.167	r_{e1}
Well Radius, r_w (ft):	0.333	
LNAPL Specific Yield, S_y:	0.175	
LNAPL Density Ratio, ρ_r:	0.840	
Top of Screen (ft bgs):	15.0	
Bottom of Screen (ft bgs):	35.0	
LNAPL Baildown Vol. (gal.):	0.3	
Effective Radius, r_{e3} (ft):	0.206	Calculated Parameters
Effective Radius, r_{e2} (ft):	0.140	
Initial Casing LNAPL Vol. (gal.):	0.59	
Initial Filter LNAPL Vol. (gal.):	0.31	

Drawdown Adjustment (ft)
0

	Enter Data Here											
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	19.69	20.59	19.99	20.89	20.13					0.90	
Enter Test Data:	1.0	19.88	20.45	20.18	20.75	20.27	0.19				0.57	
	1.5	19.88	20.45	20.18	20.75	20.27	0.19	1.3	0.000	0.19	0.57	0.206
	2.0	19.87	20.44	20.17	20.74	20.26	0.18	1.8	0.000	0.19	0.57	0.206
	3.5	19.89	20.46	20.19	20.76	20.28	0.20	2.8	0.000	0.19	0.57	0.206
	5.0	19.88	20.46	20.18	20.76	20.27	0.19	4.3	1.278	0.20	0.58	0.206
	6.0	19.85	20.44	20.15	20.74	20.24	0.16	5.5	1.916	0.18	0.59	0.206
	9.0	19.85	20.45	20.15	20.75	20.25	0.16	7.5	0.639	0.16	0.60	0.206
	10.0	19.86	20.45	20.16	20.75	20.25	0.17	9.5	-1.916	0.17	0.59	0.206
	11.0	19.85	20.45	20.15	20.75	20.25	0.16	10.5	1.916	0.17	0.60	0.206
	12.0	19.84	20.44	20.14	20.74	20.24	0.15	11.5	0.000	0.16	0.60	0.206
	14.0	19.84	20.44	20.14	20.74	20.24	0.15	13.0	0.000	0.15	0.60	0.206
	30.0	19.85	20.45	20.15	20.75	20.25	0.16	22.0	0.000	0.16	0.60	0.206
	40.00	19.84	20.44	20.14	20.74	20.24	0.15	35.0	0.000	0.16	0.60	0.206
	50.00	19.84	20.45	20.14	20.75	20.24	0.15	45.0	0.192	0.15	0.61	0.206
	70.00	19.79	20.42	20.09	20.72	20.19	0.10	60.0	0.192	0.13	0.63	0.206
	80.00	19.8	20.43	20.10	20.73	20.20	0.11	75.0	0.000	0.11	0.63	0.206
	90.00	19.8	20.42	20.10	20.72	20.20	0.11	85.0	-0.192	0.11	0.62	0.206
	110.00	19.79	20.42	20.09	20.72	20.19	0.10	100.0	0.096	0.11	0.63	0.206
	200	19.76	20.39	20.06	20.69	20.16	0.07	155.0	0.000	0.09	0.63	0.206
	240	19.75	20.41	20.05	20.71	20.16	0.06	220.0	0.144	0.07	0.66	0.206
	400	19.71	20.34	20.01	20.64	20.11	0.02	320.0	-0.036	0.04	0.63	0.206

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-MW-3A
Date:	15-Sep-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t - t_1)}$$

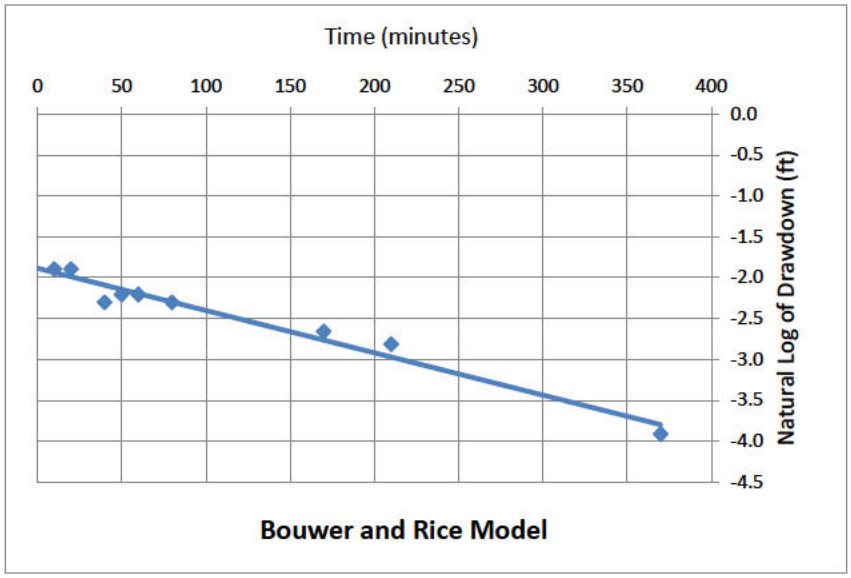
Enter early time cut-off for least-squares model fit

$Time_{cut}$	30	<- Enter or change value here

L_e/r_e	4.4
C	0.97
R/r_e	2.81

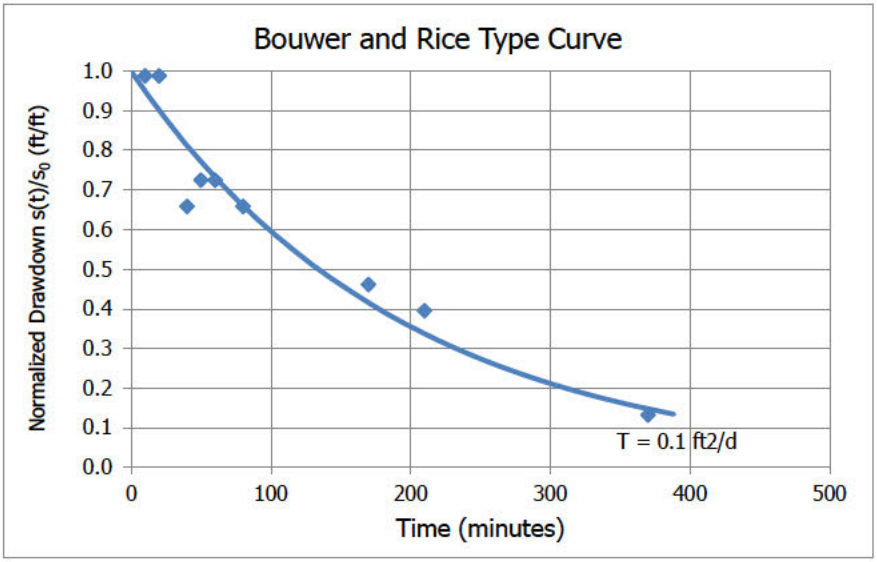
Model Results: T_n (ft^2/d) = 0.10 +/- 0.01 ft^2/d

J-Ratio	-1.569



Coef. Of Variation	0.07

C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-MW-3A
Date:	15-Sep-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

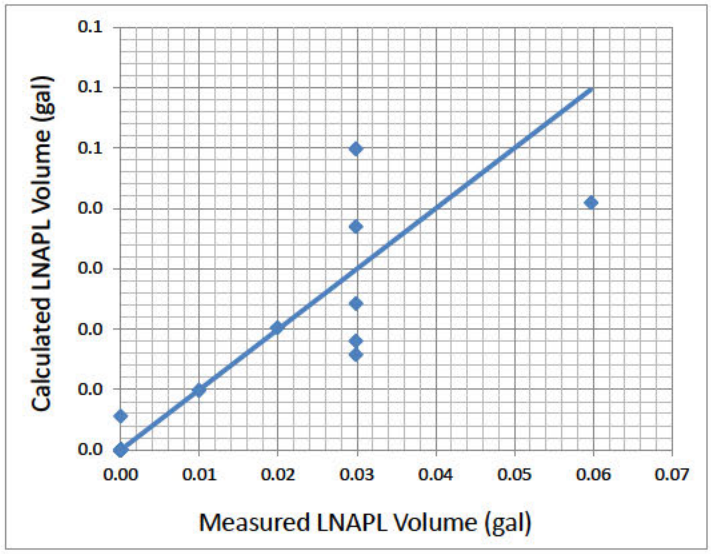
Enter early time cut-off for least-squares model fit

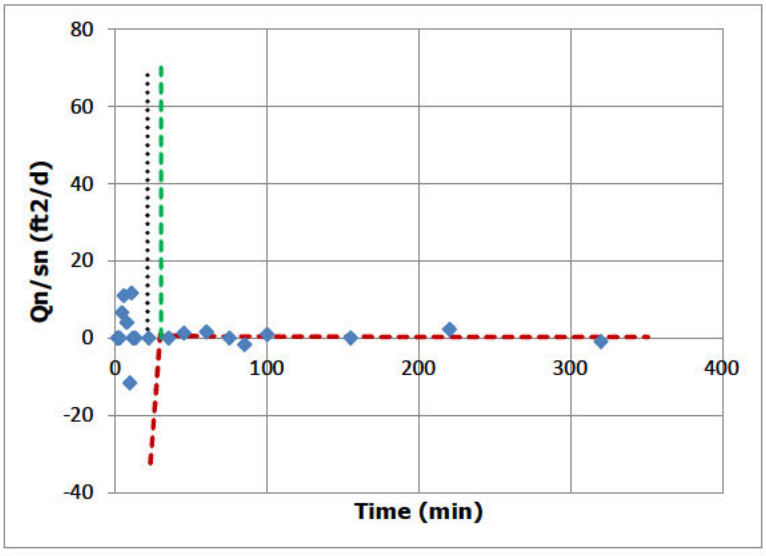
$Time_{cut}$ (min):	30	<- Enter or change values here
Time Adjustment (min):	21	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.035	<-- Minimize this using "Solver"
	0.008	<-- Working S_n
Trial T_n (ft^2/d):	0.106	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.11**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-MW-3A
Date:	15-Sep-17

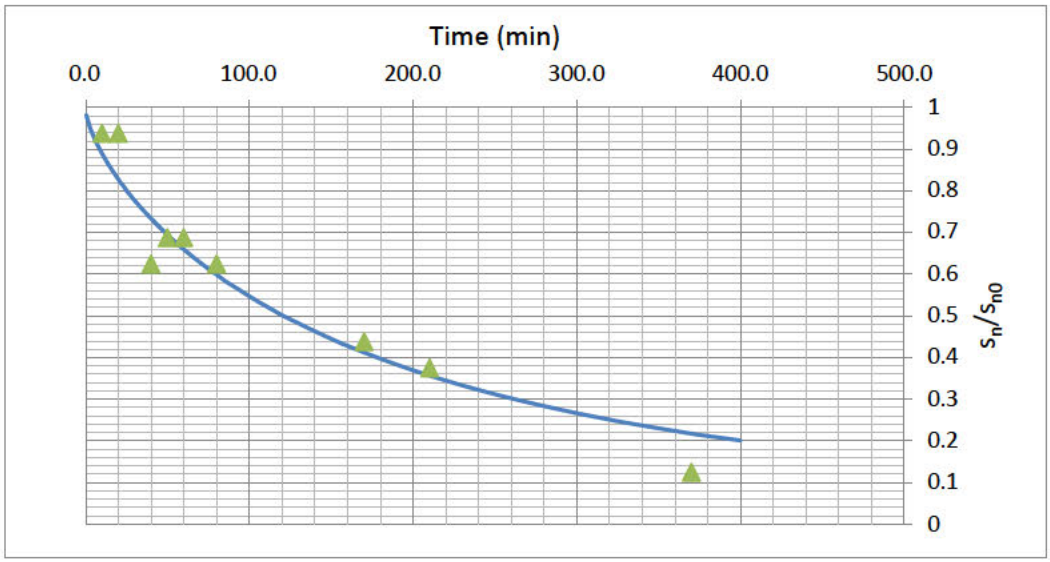
Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	30	<- Enter or change values here
Initial Drawdown s_n (ft):	0.16	
Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.193	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.260	<-- By changing T_n through "Solver"
	0.013	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	0.5
T_{max}	400

Model Result: T_n (ft^2/d) = **0.26**



J-Ratio
-1.569

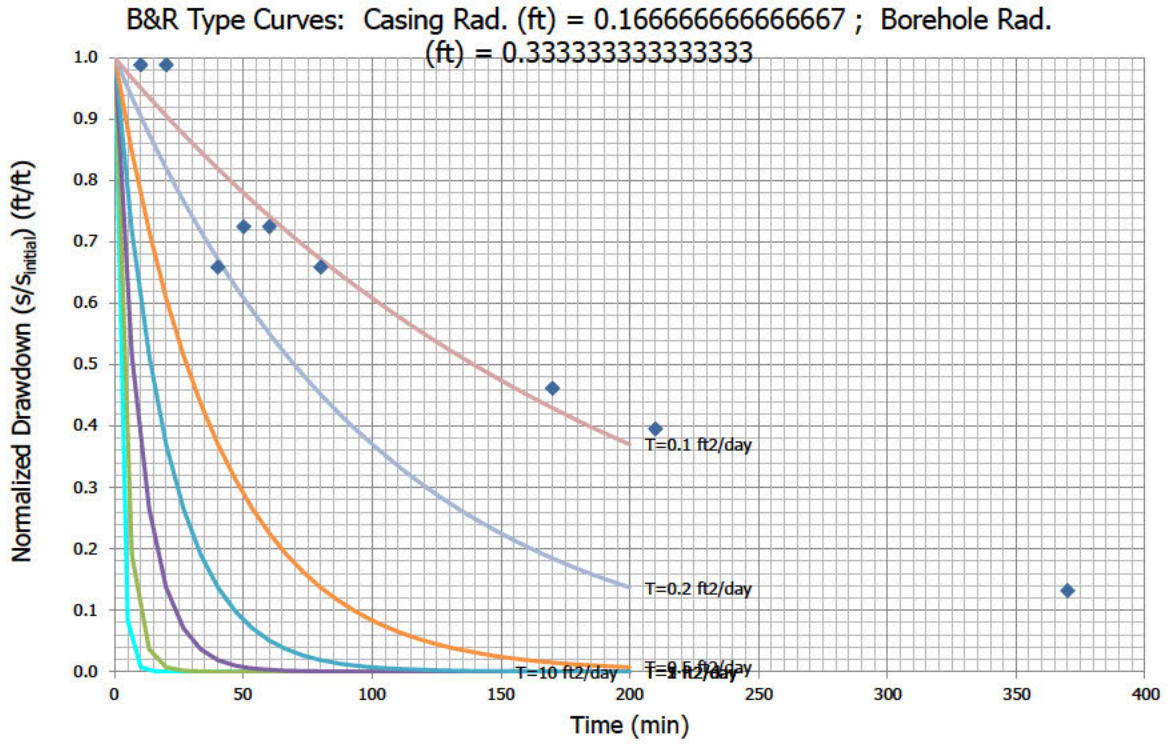
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.166666666666667 ; Borehole Rad. (ft) = 0.333333333333333

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-1.569	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

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STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.17

Standard Deviation (ft^2/d)

0.19

Coefficient of Variation

1.10

Well Designation:	DSCP-RW-6	Beckett and Lyverse (2002)
Date:	15-Sep-17	

Ground Surface Elev (ft msl)	18.6	Enter These Data
Top of Casing Elev (ft msl)	16.6	
Well Casing Radius, r_c (ft):	0.250	r_{e1}
Well Radius, r_w (ft):	0.500	
LNAPL Specific Yield, S_y:	0.175	
LNAPL Density Ratio, ρ_r:	0.840	
Top of Screen (ft bgs):	15.0	
Bottom of Screen (ft bgs):	35.0	
LNAPL Baildown Vol. (gal.):	1.5	
Effective Radius, r_{e3} (ft):	0.309	Calculated Parameters
Effective Radius, r_{e2} (ft):	0.266	
Initial Casing LNAPL Vol. (gal.):	0.79	
Initial Filter LNAPL Vol. (gal.):	0.42	

Drawdown Adjustment (ft)
0

Enter Data Here

	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	15.44	15.98	17.44	17.98	17.53					0.54	
Enter Test Data:	0.5	15.84	15.92	17.84	17.92	17.85	0.40				0.08	
	1.0	15.73	15.82	17.73	17.82	17.74	0.29	0.8	8.624	0.35	0.09	0.309
	1.5	15.70	15.80	17.70	17.80	17.72	0.26	1.3	8.624	0.28	0.10	0.309
	2.0	15.62	15.73	17.62	17.73	17.64	0.18	1.8	8.624	0.22	0.11	0.309
	5.0	15.52	15.63	17.52	17.63	17.54	0.08	3.5	0.000	0.13	0.11	0.309
	100.00	15.55	15.68	17.55	17.68	17.57	0.11	52.5	0.091	0.09	0.13	0.309
	120.00	15.56	15.69	17.56	17.69	17.58	0.12	110.0	0.000	0.12	0.13	0.309
	140.00	15.54	15.68	17.54	17.68	17.56	0.10	130.0	0.216	0.11	0.14	0.309
	160.00	15.53	15.69	17.53	17.69	17.56	0.09	150.0	0.431	0.10	0.16	0.309
	200	15.53	15.69	17.53	17.69	17.56	0.09	180.0	0.000	0.09	0.16	0.309
	220	15.52	15.68	17.52	17.68	17.55	0.08	210.0	0.000	0.09	0.16	0.309
	240	15.52	15.69	17.52	17.69	17.55	0.08	230.0	0.216	0.08	0.17	0.309
	260	15.51	15.70	17.51	17.70	17.54	0.07	250.0	0.431	0.07	0.19	0.309
	300	15.51	15.72	17.51	17.72	17.54	0.07	280.0	0.216	0.07	0.21	0.309
	340	15.48	15.69	17.48	17.69	17.51	0.04	320.0	0.000	0.06	0.21	0.309
	1461	15.55	15.80	17.55	17.80	17.59	0.11	900.5	0.015	0.08	0.25	0.309

Generalized Bouwer and Rice (1976)

Well Designation:	DSCP-RW-6
Date:	15-Sep-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t-t_1)}$$

Enter early time cut-off for least-squares model fit

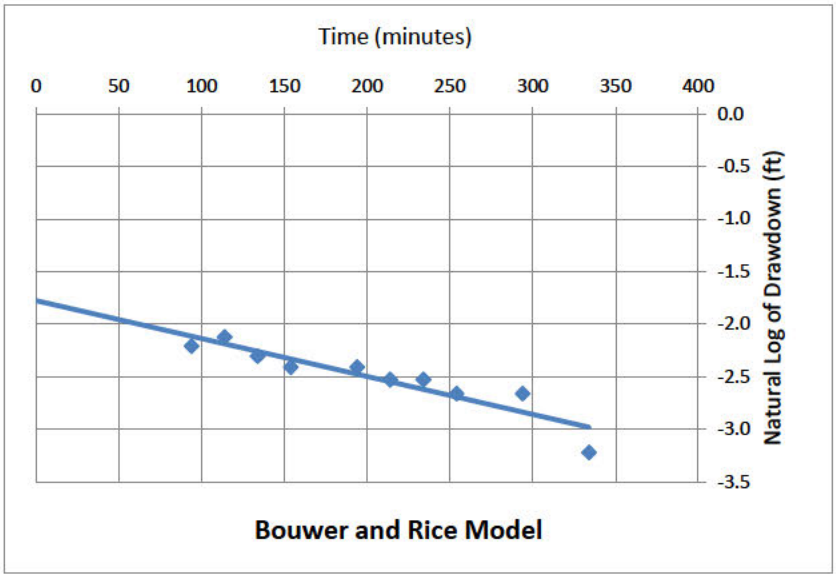
$Time_{cut}$	6	<- Enter or change value here

L_e/r_e	C	R/r_e
1.7	0.86	1.50

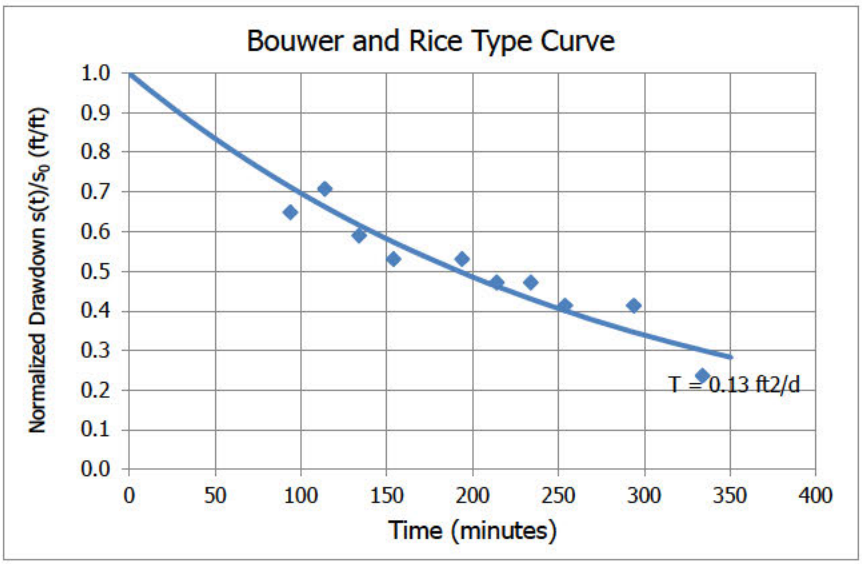
Model Results: T_n (ft^2/d) = 0.13 +/- 0.02 ft^2/d

J-Ratio: -0.750

Coef. Of Variation: 0.15



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	DSCP-RW-6
Date:	15-Sep-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

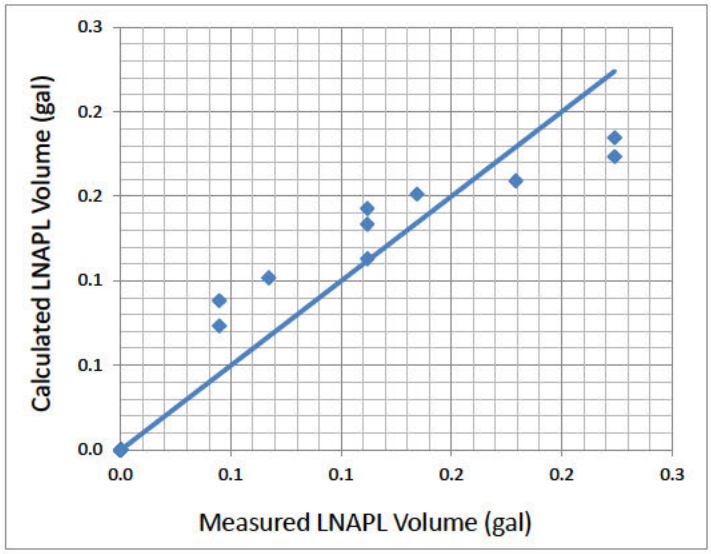
Enter early time cut-off for least-squares model fit

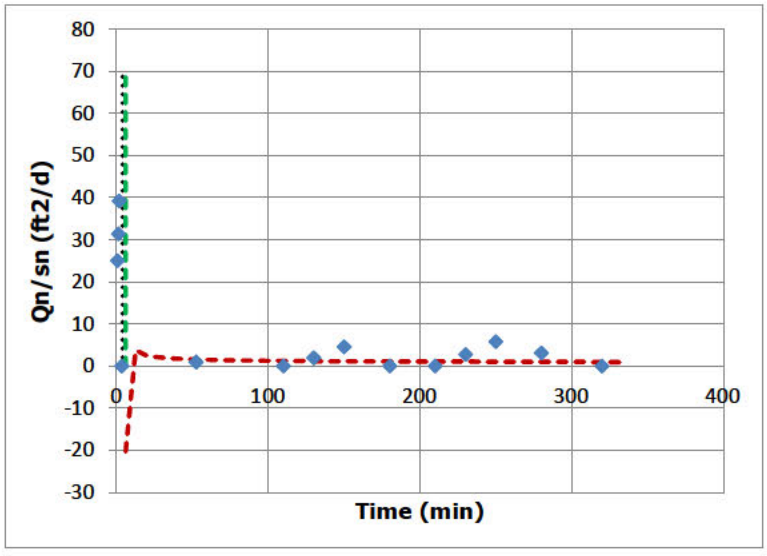
$Time_{cut}$ (min):	6	<- Enter or change values here
Time Adjustment (min):	4	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.100	<-- Minimize this using "Solver"
	0.015	<-- Working S_n
Trial T_n (ft^2/d):	0.369	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.37**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	DSCP-RW-6
Date:	15-Sep-17

Enter early time cut-off for least-squares model fit

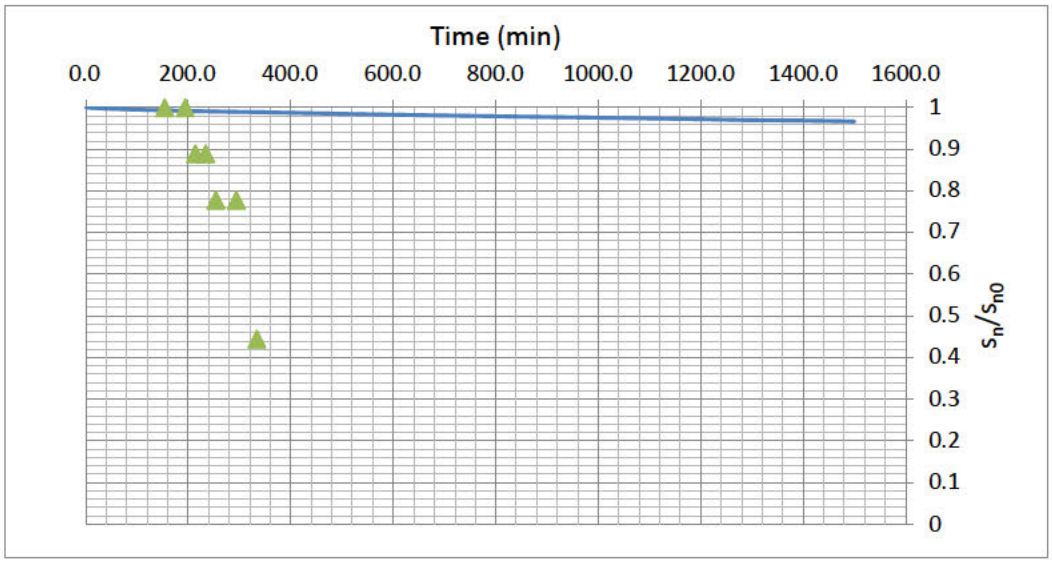
$Time_{cut}$ (min):	6	<- Enter or change values here
Initial Drawdown s_n (ft):	0.09	

Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.808	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.003	<-- By changing T_n through "Solver"
	0.001	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	1
T_{max}	1500

Model Result: T_n (ft^2/d) = **0.00**



J-Ratio
-0.750

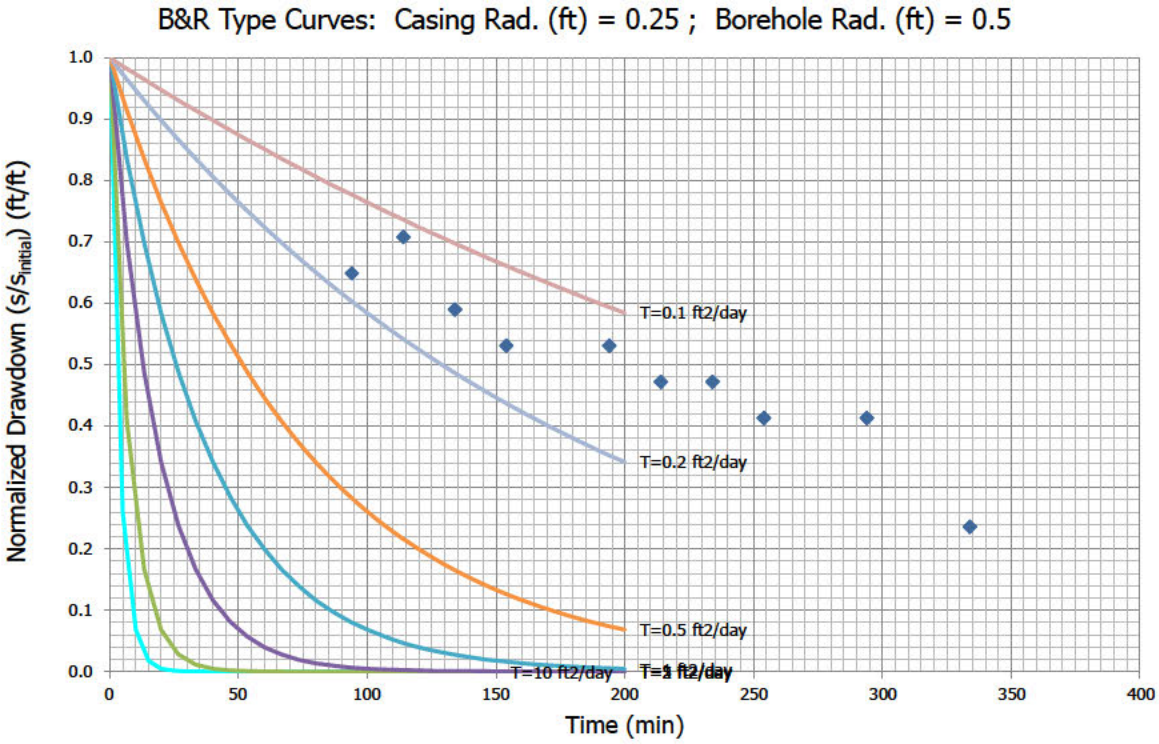
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-0.750	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

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STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.03

Standard Deviation (ft^2/d)

0.03

Coefficient of Variation

0.81

Well Designation:	PH-PH-18	Beckett and Lyverse (2002)
Date:	14-Sep-17	

Ground Surface Elev (ft msl)	16.0	Enter These Data
Top of Casing Elev (ft msl)	18.0	
Well Casing Radius, r_c (ft):	0.250	r_{e1}
Well Radius, r_w (ft):	0.583	
LNAPL Specific Yield, S_y:	0.175	
LNAPL Density Ratio, ρ_r:	0.840	
Top of Screen (ft bgs):	15.0	
Bottom of Screen (ft bgs):	0.0	
LNAPL Baildown Vol. (gal.):	1.0	
Effective Radius, r_{e1} (ft):	0.333	Calculated Parameters
Effective Radius, r_{e2} (ft):	0.198	
Initial Casing LNAPL Vol. (gal.):	1.03	
Initial Filter LNAPL Vol. (gal.):	0.48	

Drawdown Adjustment (ft)
0

	Enter Data Here					Water Table Depth	LNAPL Drawdown		LNAPL			
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	(ft)	s_n (ft)	Average Time (min)	Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	16.72	17.42	14.72	15.42	14.83					0.70	
Enter Test Data:	1.0	17.25	17.38	15.25	15.38	15.27	0.53				0.13	
	1.5	17.25	17.38	15.25	15.38	15.27	0.53	1.3	0.000	0.53	0.13	0.333
	2.0	17.25	17.38	15.25	15.38	15.27	0.53	1.8	0.000	0.53	0.13	0.333
	2.5	17.20	17.35	15.20	15.35	15.22	0.48	2.3	20.106	0.51	0.15	0.333
	7.0	17.14	17.29	15.14	15.29	15.16	0.42	4.8	0.000	0.45	0.15	0.333
	8.0	17.14	17.29	15.14	15.29	15.16	0.42	7.5	0.000	0.42	0.15	0.333
	9.0	17.14	17.30	15.14	15.30	15.17	0.42	8.5	5.027	0.42	0.16	0.333
	10.0	17.15	17.30	15.15	15.30	15.17	0.43	9.5	-5.027	0.43	0.15	0.333
	12.0	17.13	17.28	15.13	15.28	15.15	0.41	11.0	0.000	0.42	0.15	0.333
	14.0	17.11	17.28	15.11	15.28	15.14	0.39	13.0	5.027	0.40	0.17	0.333
	15.0	17.11	17.28	15.11	15.28	15.14	0.39	14.5	0.000	0.39	0.17	0.333
	16.0	17.10	17.26	15.10	15.26	15.13	0.38	15.5	-5.027	0.39	0.16	0.333
	18.0	17.1	17.25	15.10	15.25	15.12	0.38	17.0	-2.513	0.38	0.15	0.333
	20.0	17.08	17.23	15.08	15.23	15.10	0.36	19.0	0.000	0.37	0.15	0.333
	22.0	17.06	17.24	15.06	15.24	15.09	0.34	21.0	7.540	0.35	0.18	0.333
	24.0	17.03	17.21	15.03	15.21	15.06	0.31	23.0	0.000	0.33	0.18	0.333
	26.0	17.01	17.21	15.01	15.21	15.04	0.29	25.0	5.027	0.30	0.20	0.333
	28.0	17.02	17.22	15.02	15.22	15.05	0.30	27.0	0.000	0.30	0.20	0.333
	30.0	17.02	17.22	15.02	15.22	15.05	0.30	29.0	0.000	0.30	0.20	0.333
	32.0	17.02	17.21	15.02	15.21	15.05	0.30	31.0	-2.513	0.30	0.19	0.333
	71.0	16.99	17.18	14.99	15.18	15.02	0.27	51.5	0.000	0.28	0.19	0.198
	81.0	16.98	17.18	14.98	15.18	15.01	0.26	76.0	0.178	0.27	0.20	0.198
	91.0	16.98	17.18	14.98	15.18	15.01	0.26	86.0	0.000	0.26	0.20	0.198
	121.00	17.01	17.21	15.01	15.21	15.04	0.29	106.0	0.000	0.28	0.20	0.333
	141.00	17	17.22	15.00	15.22	15.04	0.28	131.0	0.503	0.29	0.22	0.333
	181.00	17	17.22	15.00	15.22	15.04	0.28	161.0	0.000	0.28	0.22	0.333
	221.00	16.99	17.21	14.99	15.21	15.03	0.27	201.0	0.000	0.27	0.22	0.198
	281.00	16.98	17.20	14.98	15.20	15.02	0.26	251.0	0.000	0.27	0.22	0.198
	301.00	16.95	17.19	14.95	15.19	14.99	0.23	291.0	0.178	0.25	0.24	0.198

Generalized Bouwer and Rice (1976)

Well Designation:	PH-PH-18
Date:	14-Sep-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t - t_1)}$$

Enter early time cut-off for least-squares model fit

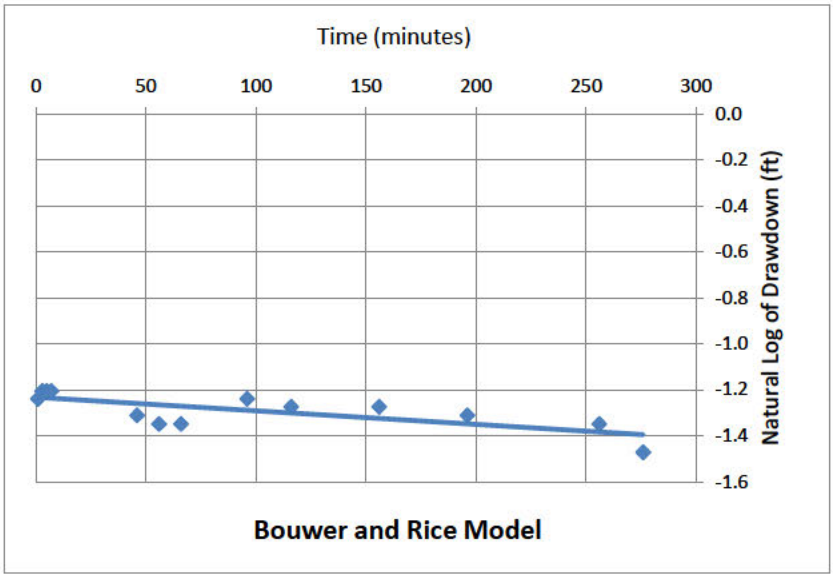
$Time_{cut}$	25	<- Enter or change value here

Model Results: T_n (ft^2/d) = 0.003 +/- 0.00 ft^2/d

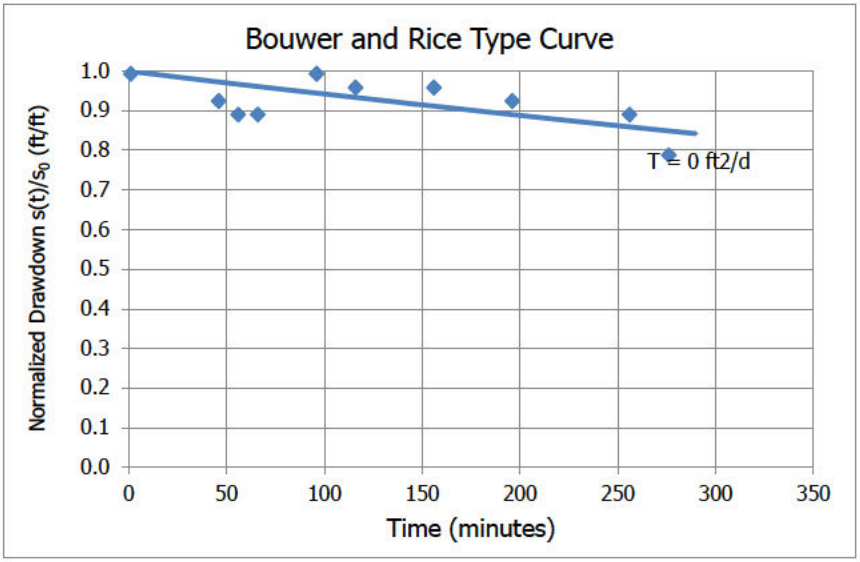
L_e/r_e
1.3
C
0.84
R/r_e
1.20

J-Ratio
-1.476

Coef. Of Variation
0.28



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	PH-PH-18
Date:	14-Sep-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

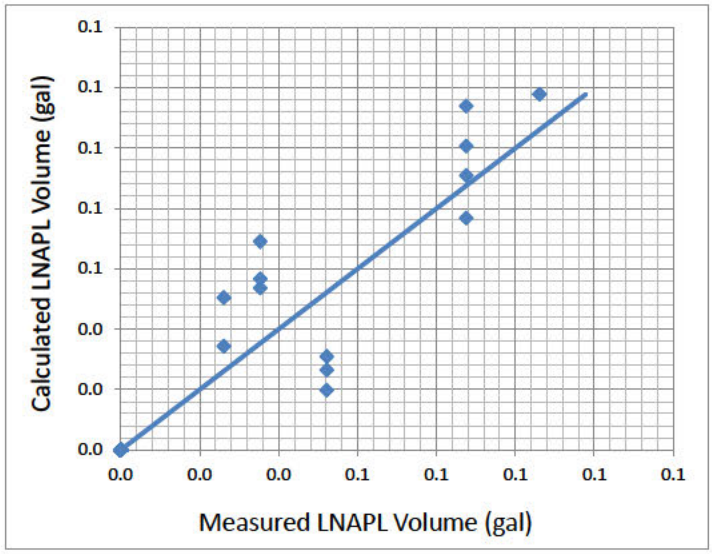
Enter early time cut-off for least-squares model fit

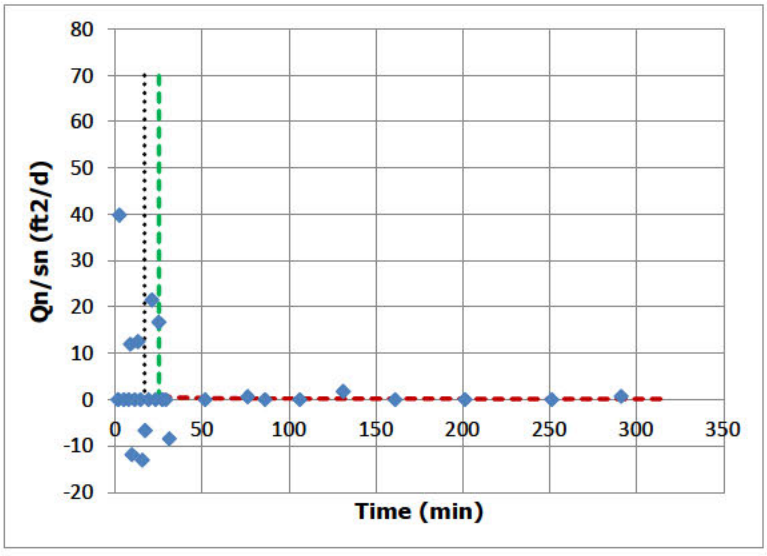
$Time_{cut}$ (min):	25	<- Enter or change values here
Time Adjustment (min):	16.66667	

Trial S_n:	d	<-- Enter d for default or enter S_n value
Root-Mean-Square Error:	0.077	<-- Minimize this using "Solver"
	0.006	<-- Working S_n
Trial T_n (ft^2/d):	0.057	<-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.06**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	PH-PH-18
Date:	14-Sep-17

Enter early time cut-off for least-squares model fit

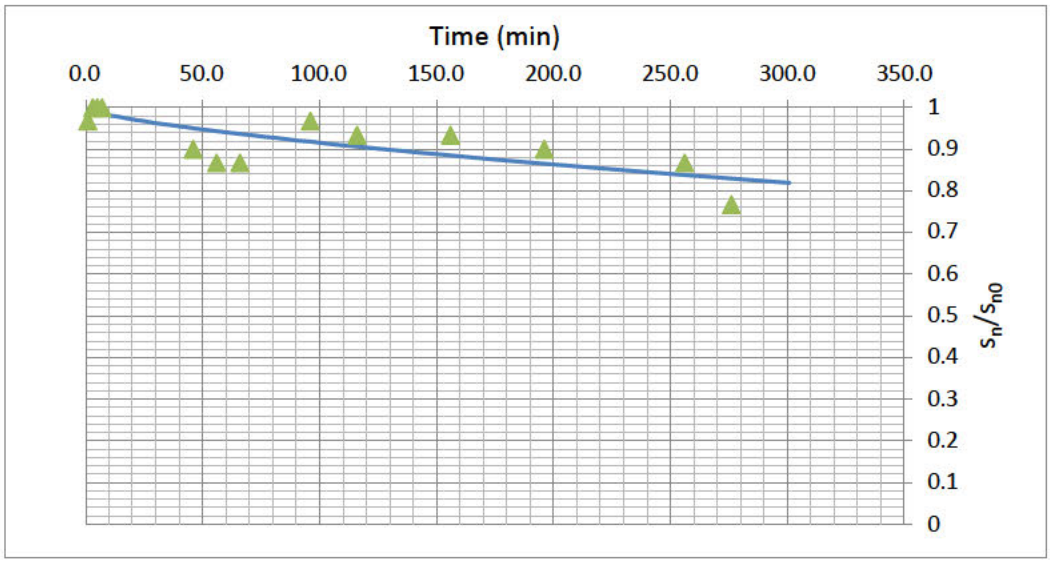
$Time_{cut}$ (min):	25	<- Enter or change values here
Initial Drawdown s_n (ft):	0.3	

Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.161	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.042	<-- By changing T_n through "Solver"
	0.005	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	1
T_{max}	301

Model Result: T_n (ft^2/d) = **0.04**



J-Ratio
-1.476

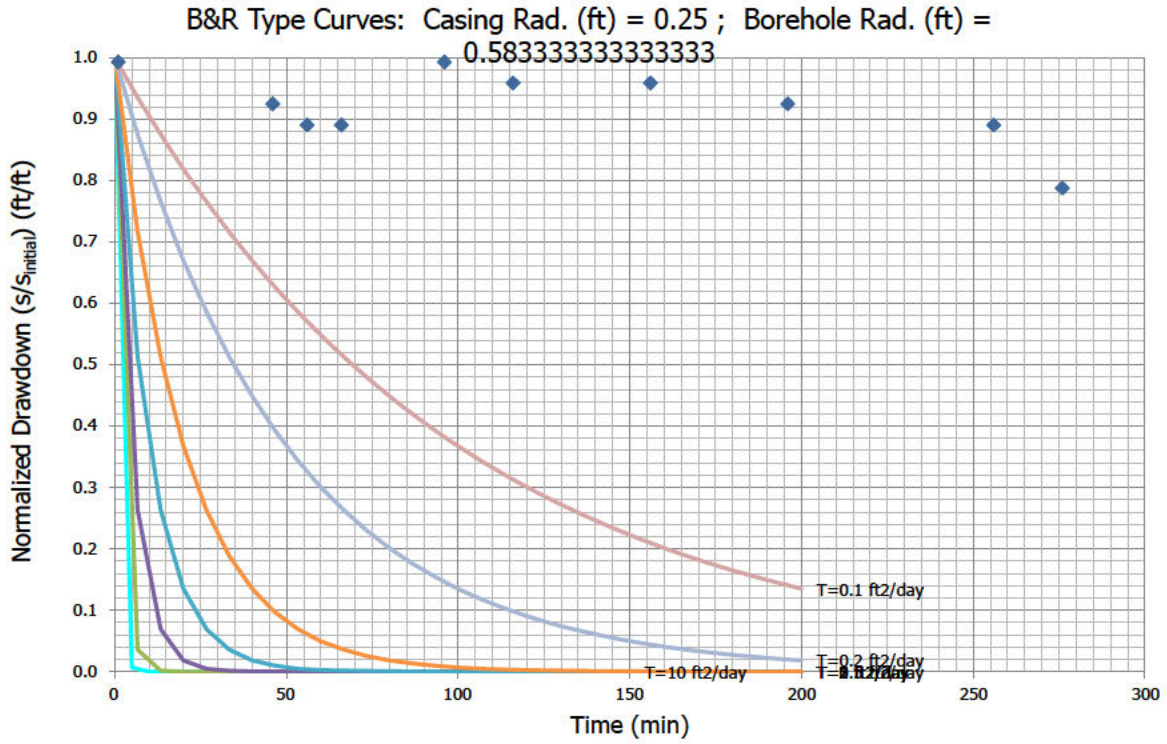
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.583333333333333

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-1.476	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.47

Standard Deviation (ft^2/d)

0.33

Coefficient of Variation

0.70

Well Designation:	PH-RW-C	Beckett and Lyverse (2002)
Date:	14-Sep-17	

Ground Surface Elev (ft msl)	23.0	Enter These Data
Top of Casing Elev (ft msl)	21.0	
Well Casing Radius, r_c (ft):	0.250	r_{e1}
Well Radius, r_w (ft):	0.500	
LNAPL Specific Yield, S_y:	0.175	
LNAPL Density Ratio, ρ_r:	0.840	
Top of Screen (ft bgs):	15.0	
Bottom of Screen (ft bgs):	35.0	
LNAPL Baildown Vol. (gal.):	1.9	
Effective Radius, r_{e3} (ft):	0.309	Calculated Parameters
Effective Radius, r_{e2} (ft):	0.280	
Initial Casing LNAPL Vol. (gal.):	1.17	
Initial Filter LNAPL Vol. (gal.):	0.62	

Drawdown Adjustment (ft)
0

	Enter Data Here					Water Table Depth	LNAPL Drawdown	Average	LNAPL Discharge	s_n	b_n	r_e
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	(ft)	s_n (ft)	Time (min)	Q_n (ft^3/d)	(ft)	(ft)	(ft)
Initial Fluid Levels:	0	18.82	19.62	20.82	21.62	20.95					0.80	
Enter Test Data:	9.0	19.12	19.19	21.12	21.19	21.13	0.30				0.07	
	10.0	19.11	19.18	21.11	21.18	21.12	0.29	9.5	0.000	0.30	0.07	0.309
	11.0	19.11	19.18	21.11	21.18	21.12	0.29	10.5	0.000	0.29	0.07	0.309
	12.0	19.1	19.17	21.10	21.17	21.11	0.28	11.5	0.000	0.29	0.07	0.309
	13.0	19.09	19.16	21.09	21.16	21.10	0.27	12.5	0.000	0.28	0.07	0.309
	15.0	19.08	19.15	21.08	21.15	21.09	0.26	14.0	0.000	0.27	0.07	0.309
	45.00	18.99	19.06	20.99	21.06	21.00	0.17	30.0	0.000	0.21	0.07	0.309
	50.00	18.98	19.07	20.98	21.07	20.99	0.16	47.5	1.725	0.16	0.09	0.309
	55.00	18.97	19.08	20.97	21.08	20.99	0.15	52.5	1.725	0.16	0.11	0.309
	60.00	18.97	19.08	20.97	21.08	20.99	0.15	57.5	0.000	0.15	0.11	0.309
	70.00	18.97	19.09	20.97	21.09	20.99	0.15	65.0	0.431	0.15	0.12	0.309
	80.00	18.96	19.09	20.96	21.09	20.98	0.14	75.0	0.431	0.15	0.13	0.309
	90.00	18.96	19.09	20.96	21.09	20.98	0.14	85.0	0.000	0.14	0.13	0.309
	110.00	18.96	19.09	20.96	21.09	20.98	0.14	100.0	0.000	0.14	0.13	0.309
	120.00	18.95	19.10	20.95	21.10	20.97	0.13	115.0	0.862	0.14	0.15	0.309
	140.00	18.95	19.09	20.95	21.09	20.97	0.13	130.0	-0.216	0.13	0.14	0.309
	160.00	18.94	19.11	20.94	21.11	20.97	0.12	150.0	0.647	0.13	0.17	0.309
	200	18.94	19.12	20.94	21.12	20.97	0.12	180.0	0.108	0.12	0.18	0.309
	240	18.94	19.13	20.94	21.13	20.97	0.12	220.0	0.108	0.12	0.19	0.309
	260	18.93	19.14	20.93	21.14	20.96	0.11	250.0	0.431	0.11	0.21	0.309
	280	18.92	19.14	20.92	21.14	20.96	0.10	270.0	0.216	0.11	0.22	0.309
	300	18.91	19.13	20.91	21.13	20.95	0.09	290.0	0.000	0.09	0.22	0.309
	360	18.90	19.13	20.90	21.13	20.94	0.08	330.0	0.072	0.08	0.23	0.309
	400	18.89	19.14	20.89	21.14	20.93	0.07	380.0	0.216	0.07	0.25	0.309

Generalized Bouwer and Rice (1976)

Well Designation:	PH-RW-C
Date:	14-Sep-17

$$T_n = \frac{r_e^{\,2}\ln(R/r_e)\ln(s_n(t_1)/s_n(t))}{2(-J)(t-t_1)}$$

Enter early time cut-off for least-squares model fit

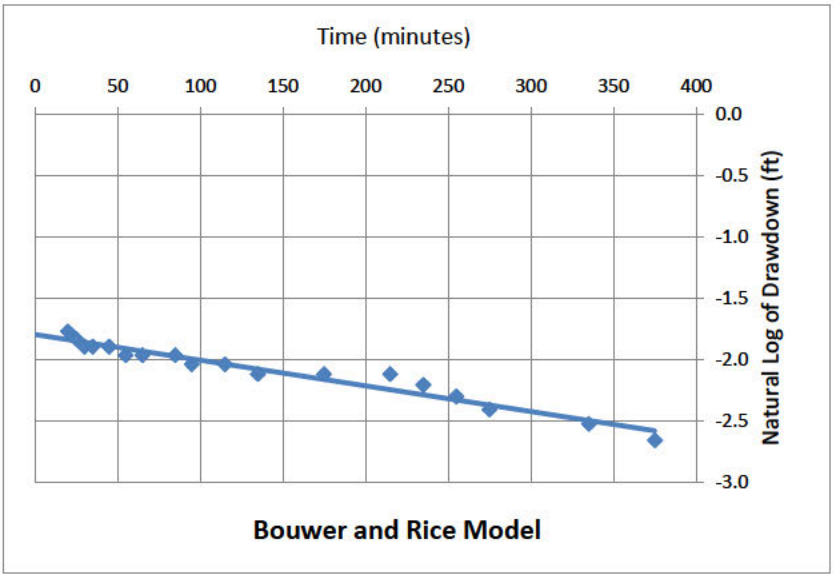
$Time_{cut}$	25	<- Enter or change value here

Model Results: T_n (ft^2/d) = 0.19 +/- 0.01 ft^2/d

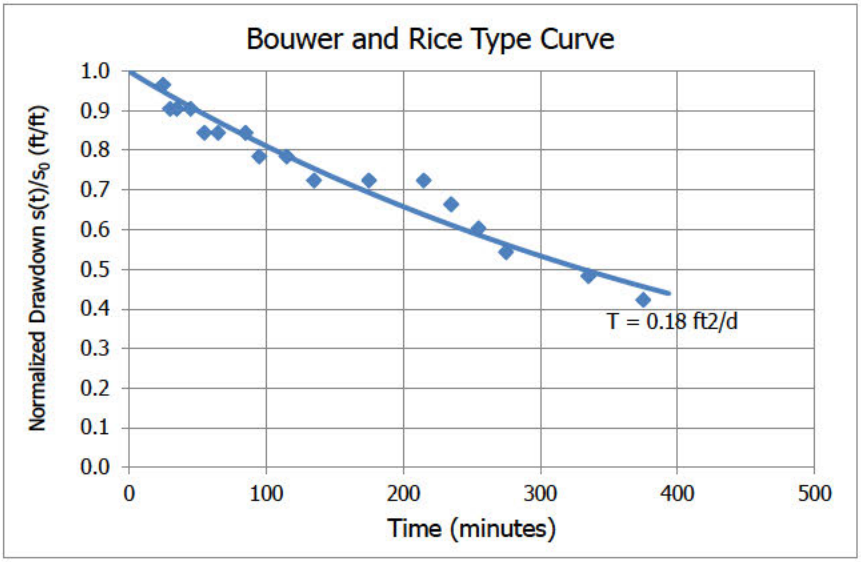
L_e/r_e
2.6
C
0.90
R/r_e
1.95

J-Ratio
-0.517

Coef. Of Variation
0.06



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	PH-RW-C
Date:	14-Sep-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	25	<- Enter or change values here
Time Adjustment (min):	16.66667	

Trial S_n: d <-- Enter d for default or enter S_n value

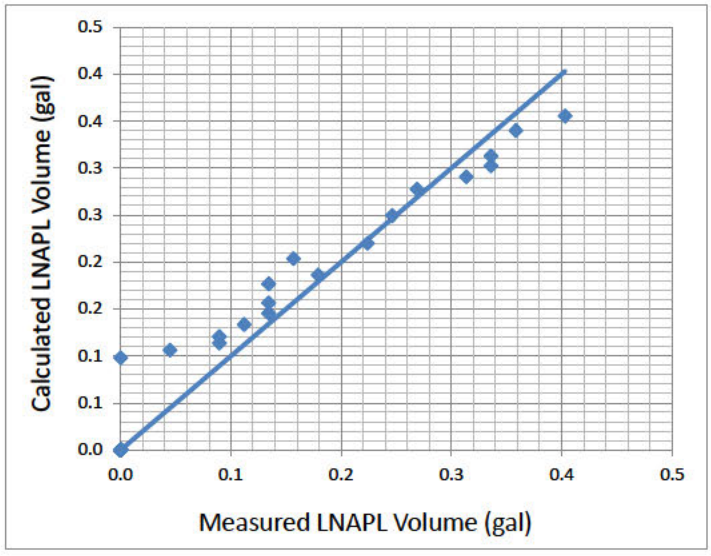
Root-Mean-Square Error: 0.158 <-- Minimize this using "Solver"

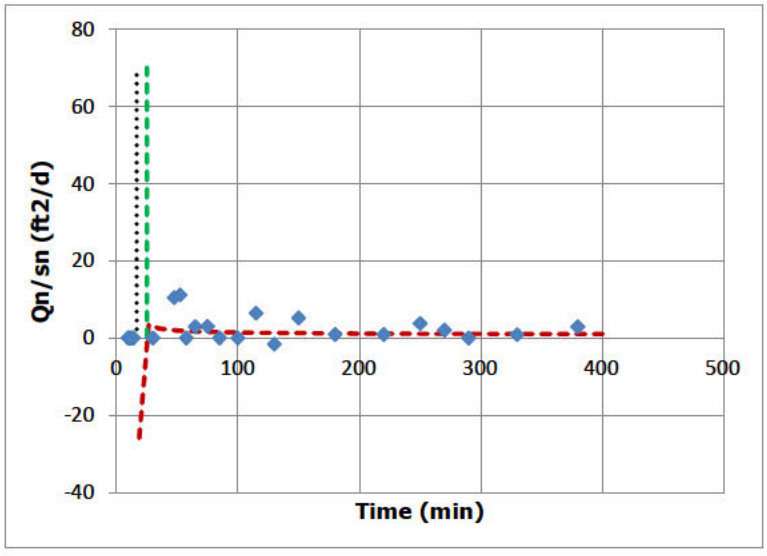
0.016 <-- Working S_n

Trial T_n (ft^2/d): 0.397 <-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.40**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	PH-RW-C
Date:	14-Sep-17

Enter early time cut-off for least-squares model fit

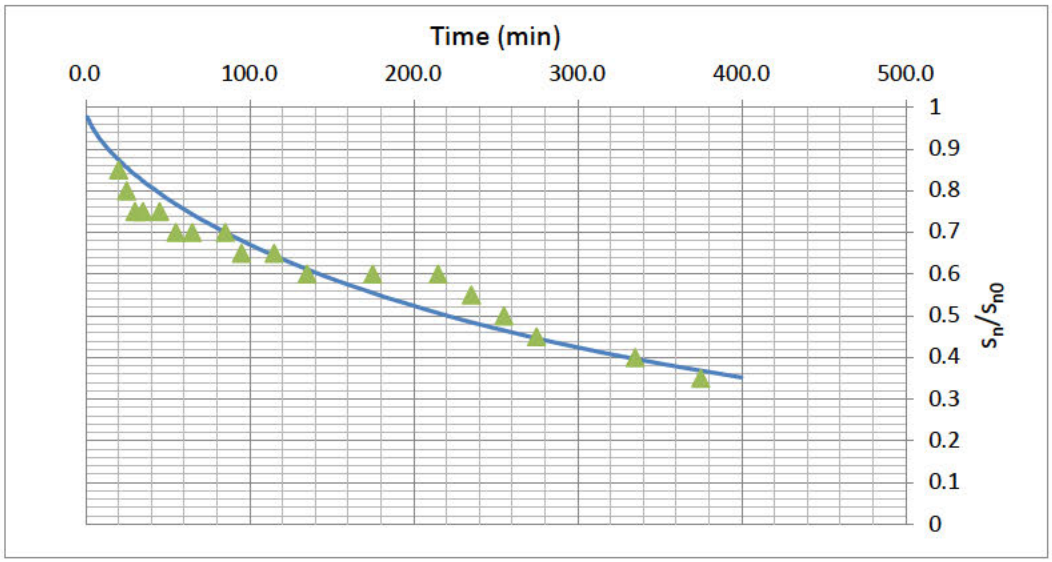
$Time_{cut}$ (min):	25	<- Enter or change values here
Initial Drawdown s_n (ft):	0.2	

Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.208	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.835	<-- By changing T_n through "Solver"
	0.023	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	1
T_{max}	400

Model Result: T_n (ft^2/d) = **0.84**



J-Ratio
-0.517

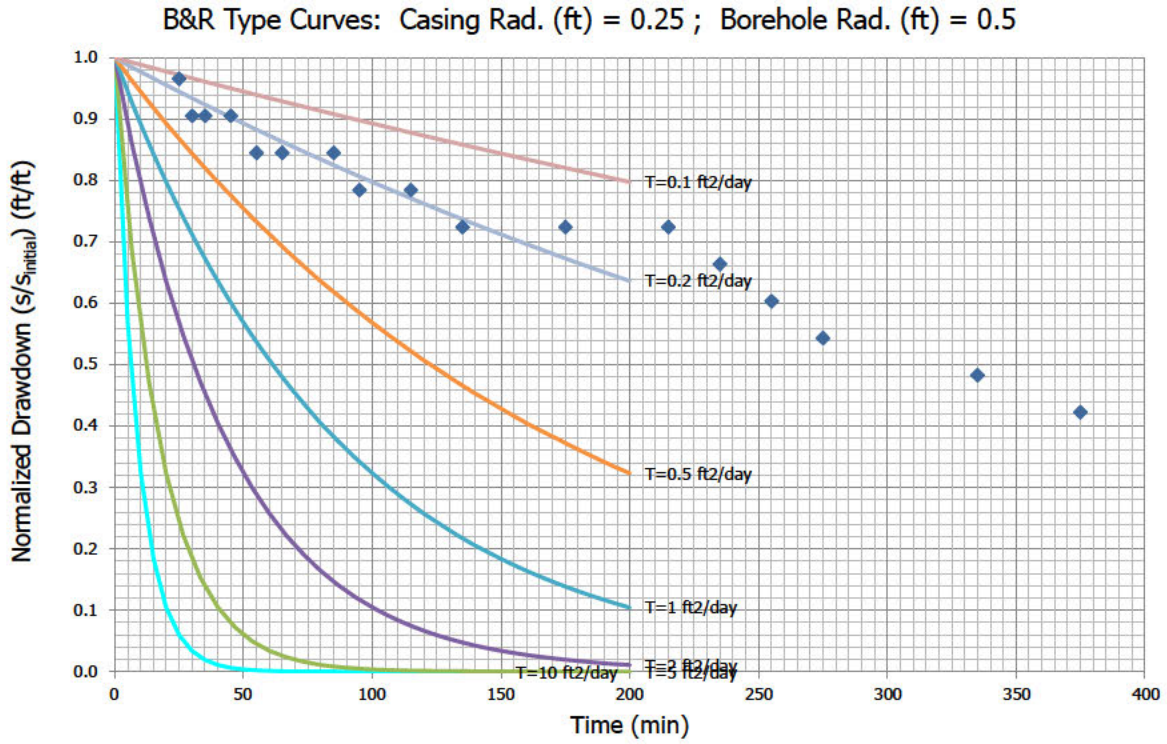
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-0.517	<-- If uncertain use
	-0.16



API LNAPL Transmissivity Workbook

Calculation of LNAPL Transmissivity from Baildown Test Data

STEP 1: RESET OUTPUT SUMMARY

STEP 2: ENTER DATA & VIEW FIGURES

STEP 3: CHOOSE WELL CONDITIONS

STEP 4: LNAPL TRANSMISSIVITY SUMMARY

Mean LNAPL Transmissivity (ft^2/d)

0.09

Standard Deviation (ft^2/d)

0.10

Coefficient of Variation

1.16

Well Designation:	PH-RW-G	Beckett and Lyverse (2002)
Date:	5-Oct-17	

Ground Surface Elev (ft msl)	33.1	Enter These Data
Top of Casing Elev (ft msl)	31.1	
Well Casing Radius, r_c (ft):	0.250	r_{e1}
Well Radius, r_w (ft):	0.500	
LNAPL Specific Yield, S_y:	0.175	
LNAPL Density Ratio, ρ_r:	0.840	
Top of Screen (ft bgs):	15.0	
Bottom of Screen (ft bgs):	35.0	
LNAPL Baildown Vol. (gal.):	1.1	
Effective Radius, r_{e1} (ft):	0.309	Calculated Parameters
Effective Radius, r_{e2} (ft):	#NUM!	
Initial Casing LNAPL Vol. (gal.):	1.00	
Initial Filter LNAPL Vol. (gal.):	0.52	

Drawdown Adjustment (ft)
0

	Enter Data Here											
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	28.65	29.33	30.65	31.33	30.76					0.68	
Enter Test Data:	0.5	29.70	29.71	31.70	31.71	31.70	1.05				0.01	
	1.0	29.75	29.79	31.75	31.79	31.76	1.10	0.8	25.871	1.08	0.04	0.309
	1.5	29.45	29.50	31.45	31.50	31.46	0.80	1.3	8.624	0.95	0.05	0.309
	2.0	29.47	29.52	31.47	31.52	31.48	0.82	1.8	0.000	0.81	0.05	0.309
	2.5	29.46	29.53	31.46	31.53	31.47	0.81	2.3	17.247	0.82	0.07	0.309
	3.0	29.46	29.54	31.46	31.54	31.47	0.81	2.8	8.624	0.81	0.08	0.309
	3.5	29.46	29.55	31.46	31.55	31.47	0.81	3.3	8.624	0.81	0.09	0.309
	5.0	29.45	29.55	31.45	31.55	31.47	0.80	4.3	2.875	0.81	0.10	0.309
	7.0	29.46	29.56	31.46	31.56	31.48	0.81	6.0	0.000	0.81	0.10	0.309
	8.0	29.44	29.55	31.44	31.55	31.46	0.79	7.5	4.312	0.80	0.11	0.309
	9.0	29.45	29.57	31.45	31.57	31.47	0.80	8.5	4.312	0.80	0.12	0.309
	10.0	29.43	29.55	31.43	31.55	31.45	0.78	9.5	0.000	0.79	0.12	0.309
	11.0	29.43	29.58	31.43	31.58	31.45	0.78	10.5	12.936	0.78	0.15	0.309
	25.0	29.35	29.50	31.35	31.50	31.37	0.70	18.0	0.000	0.74	0.15	0.309
	70.00	29.15	29.30	31.15	31.30	31.17	0.50	47.5	0.000	0.60	0.15	0.309
	110.00	29.05	29.20	31.05	31.20	31.07	0.40	90.0	0.000	0.45	0.15	0.309
	180.00	28.94	29.10	30.94	31.10	30.97	0.29	145.0	0.062	0.35	0.16	0.309
	200	28.90	29.07	30.90	31.07	30.93	0.25	190.0	0.216	0.27	0.17	0.309
	260	28.85	29.04	30.85	31.04	30.88	0.20	230.0	0.144	0.23	0.19	0.309
	280	28.84	29.03	30.84	31.03	30.87	0.19	270.0	0.000	0.20	0.19	0.309
	300	28.83	29.02	30.83	31.02	30.86	0.18	290.0	0.000	0.18	0.19	0.309
	320	28.83	29.03	30.83	31.03	30.86	0.18	310.0	0.216	0.18	0.20	0.309
	340	28.80	29.00	30.80	31.00	30.83	0.15	330.0	0.000	0.17	0.20	0.309
	480	28.73	28.94	30.73	30.94	30.76	0.08	410.0	0.031	0.12	0.21	0.309

Generalized Bouwer and Rice (1976)

Well Designation:	PH-RW-G
Date:	5-Oct-17

$$T_n = \frac{r_e^{\,2} \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(-J)(t - t_1)}$$

Enter early time cut-off for least-squares model fit

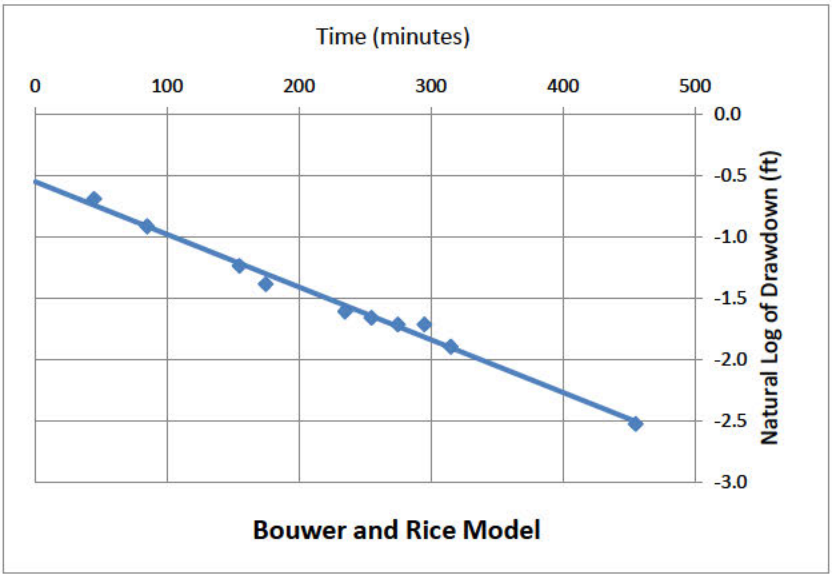
$Time_{cut}$	25	<- Enter or change value here

Model Results: T_n (ft^2/d) = 0.03 +/- 0.00 ft^2/d

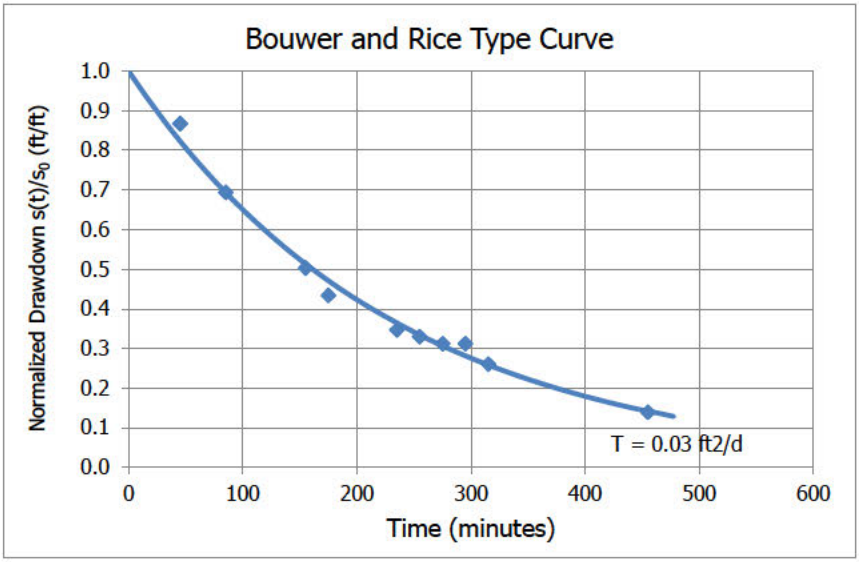
L_e/r_e
2.2
C
0.88
R/r_e
1.75

J-Ratio
-5.045

Coef. Of Variation
0.04



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



Cooper and Jacob (1946)

Well Designation:	PH-RW-G
Date:	5-Oct-17

$$V_n(t_i) = \sum_j^i \frac{4\pi T_n s_j}{\ln\left(\frac{2.25 T_n t_j}{r_e^2 S_n}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	25	<- Enter or change values here
Time Adjustment (min):	16.66667	

Trial S_n: d <-- Enter d for default or enter S_n value

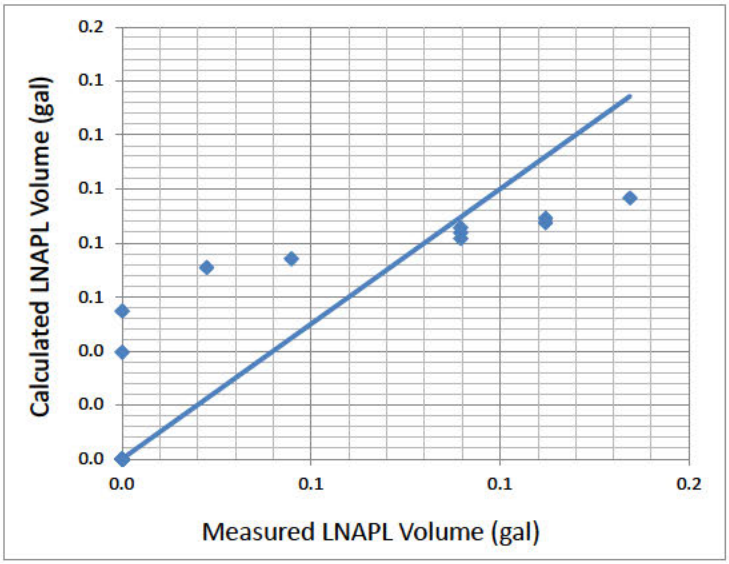
Root-Mean-Square Error: 0.102 <-- Minimize this using "Solver"

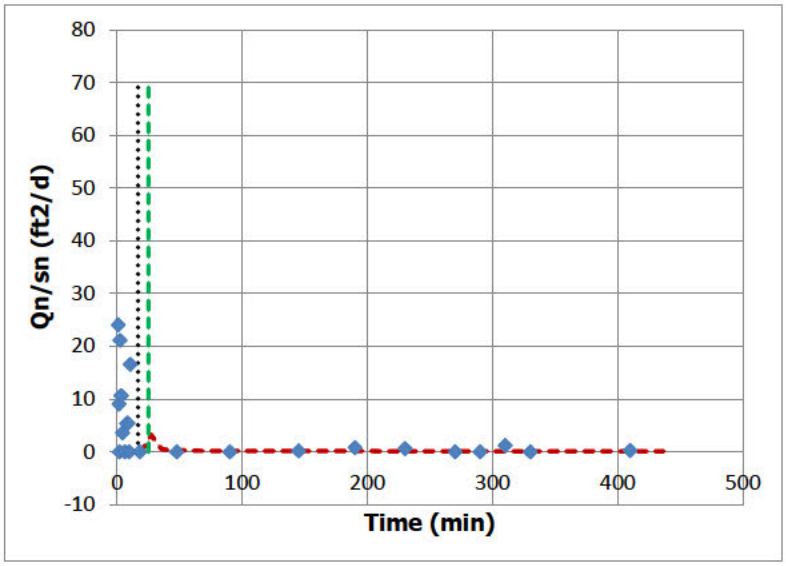
0.004 <-- Working S_n

Trial T_n (ft^2/d): 0.027 <-- By changing T_n through "Solver"

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.03**





Height
70

Cooper, Bredehoeft and Papadopulos (1967)

Well Designation:	PH-RW-G
Date:	5-Oct-17

Enter early time cut-off for least-squares model fit

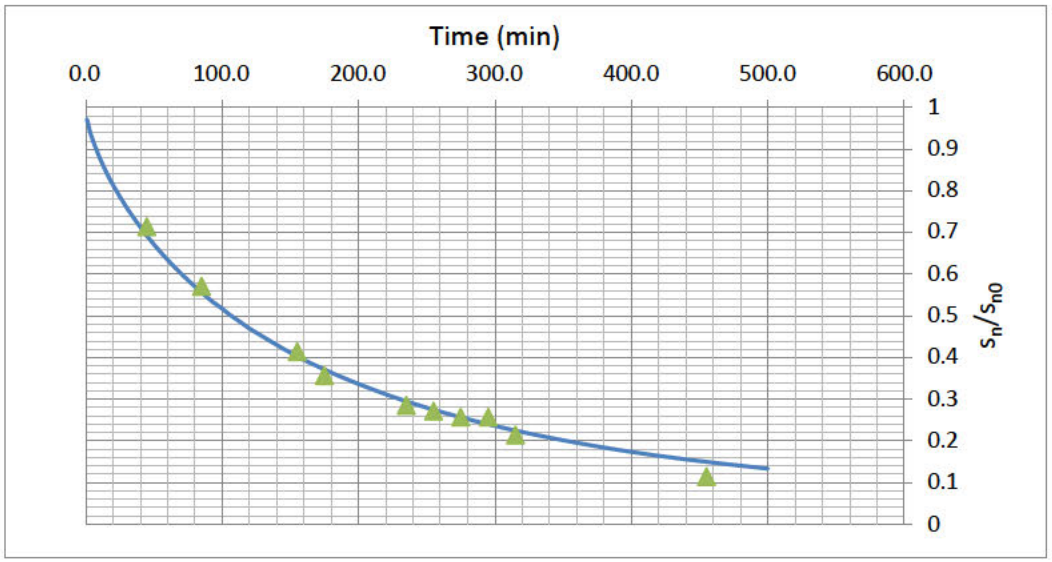
$Time_{cut}$ (min):	25	<- Enter or change values here
Initial Drawdown s_n (ft):	0.7	

Trial S_n:	d	<-- Enter d for default
Root-Mean-Square Error:	0.053	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.211	<-- By changing T_n through "Solver"
	0.011	<-- Working S_n

Add constraint Tn > 0.00001

T_{min}	1
T_{max}	500

Model Result: T_n (ft^2/d) = **0.21**



J-Ratio
-5.045

Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Rad. (ft) = 0.25 ; Borehole Rad. (ft) = 0.5

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=10 ft2/day		150	10
2	T=5 ft2/day		200	5
3	T=2 ft2/day		200	2
4	T=1 ft2/day		200	1
5	T=0.5 ft2/day		200	0.5
6	T=0.2 ft2/day		200	0.2
7	T=0.1 ft2/day		200	0.1

J-Ratio	
-5.045	<-- If uncertain use
-0.16	

