Successful Remediation of a Chlorinated Ethane Plume in Groundwater

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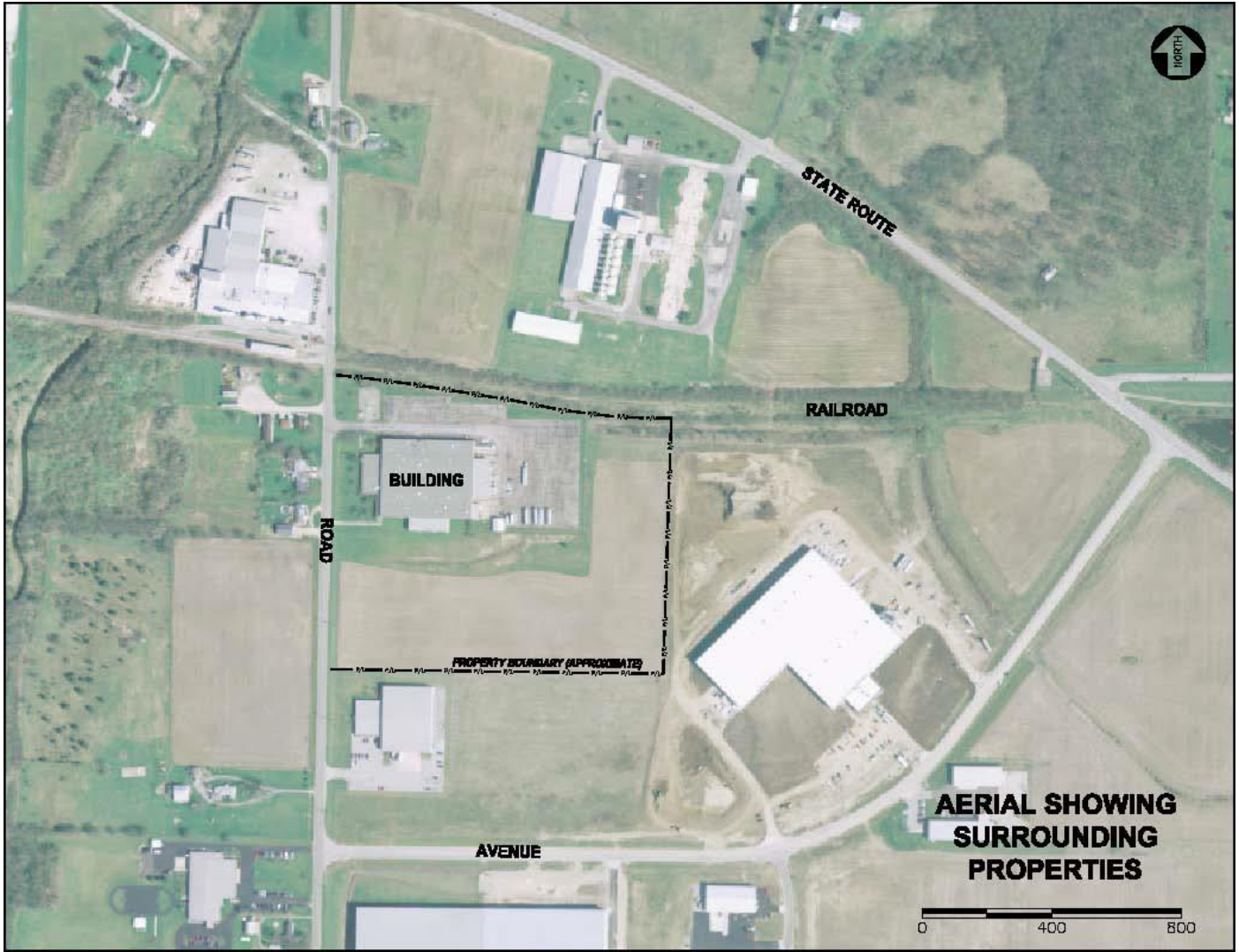
Overview

- **Pragmatic approach to Site remediation**
- **One must work with Site hydrogeology for successful remediation**
- **Adjust approach to fit budget and schedule**
- **Rebound is good in basketball but unwelcomed in remediation**
- **Persistence pays off to obtain Site closure**

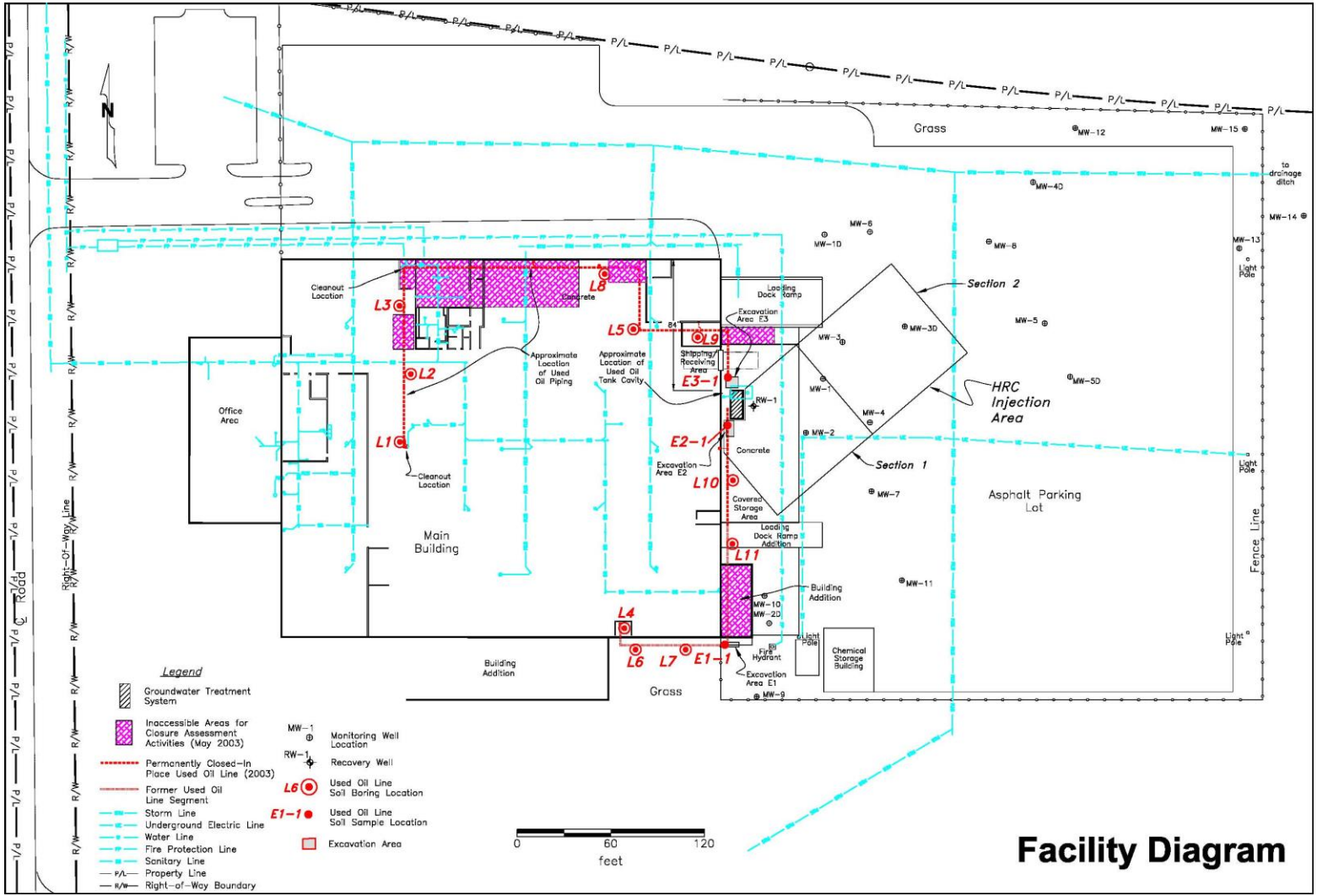
Use of Laboratory Data

- Guided Project
- Over 1000 samples were analyzed
- The analytical laboratory was an integral team member on this project
- Laboratory QA/QC matters


NORTH
STATE ROUTE
RAILROAD
BUILDING
ROAD
PROPERTY BOUNDARY (APPROXIMATE)
AVENUE
AERIAL SHOWING
SURROUNDING
PROPERTIES
0
400
800

Origin of Release

- A 5,000 gallon capacity underground storage tank containing used oil was removed in 1991
- The UST closure assessment documented 1,1,1-trichloroethane (1,1,1-TCA) in the closure samples ranging from 20 milligrams per kilogram (mg/Kg) to 160 mg/Kg
- The 1,1,1-TCA was an additive in the cutting oil used at the Site

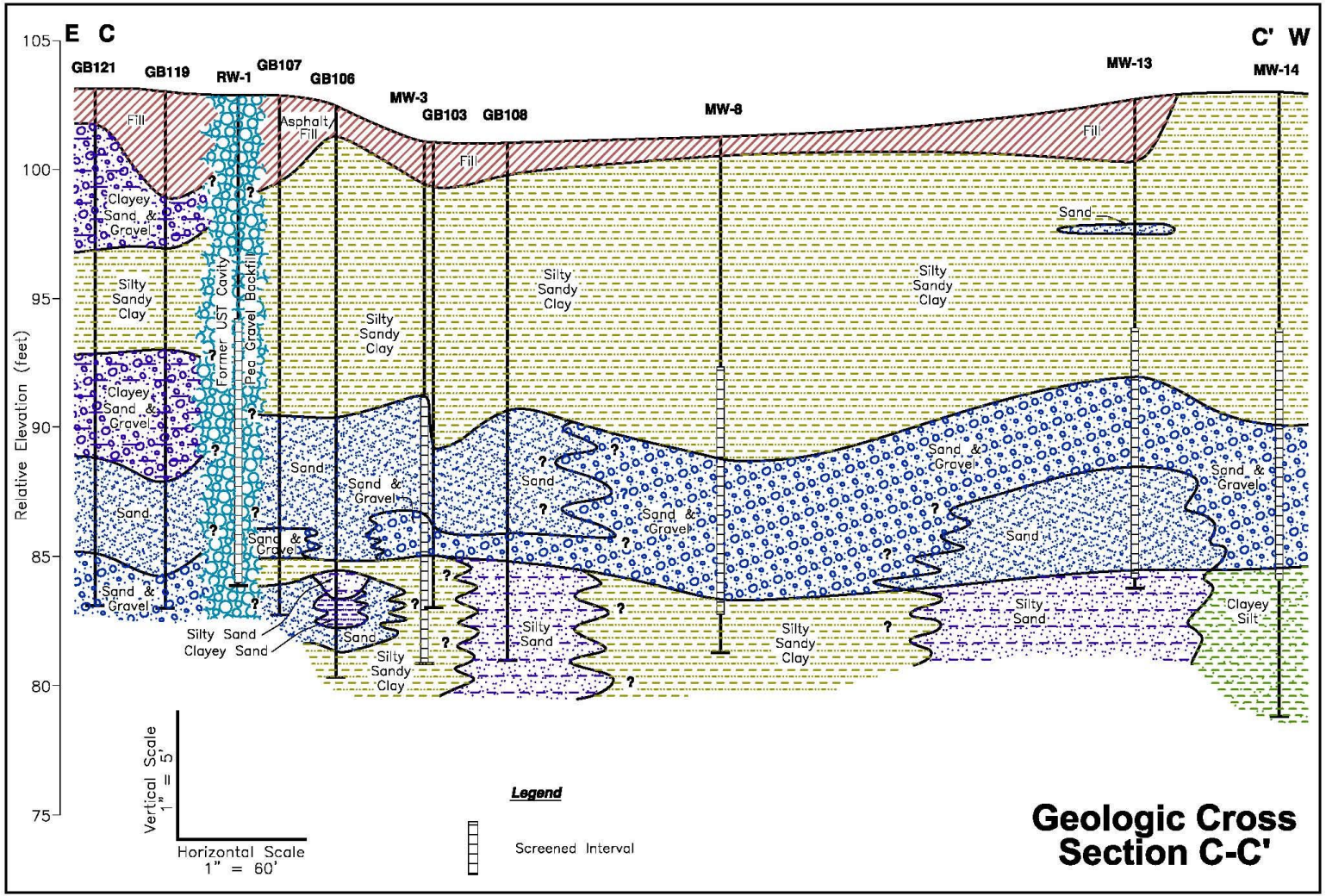

Facility Diagram
Legend
Groundwater Treatment System
Inaccessible Areas for Closure Assessment Activities (May 2003)
Permanently Closed-In Place Used Oil Line (2003)
Former Used Oil Line Segment
Storm Line
Underground Electric Line
Water Line
Fire Protection Line
Sanitary Line
Property Line
Right-of-Way Boundary
Monitoring Well Location
Recovery Well
Used Oil Line Soil Boring Location
Used Oil Line Soil Sample Location
Excavation Area
0
60
120
feet
Main Building
Office Area
Building Addition
Loading Dock Ramp
Loading Dock Ramp Addition
Shipping/Receiving Area
Covered Storage Area
Chemical Storage Building
Asphalt Parking Lot
Grass
Concrete
Cleanout Location
Approximate Location of Used Oil Piping
Approximate Location of Used Oil Tank Cavity
Excavation Area E1
Excavation Area E2
Excavation Area E3
HRC Injection Area
Section 1
Section 2
Fence Line
Right-of-Way Line
to drainage ditch
Light Pole
Fire Hydrant
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
L11
E1-1
E2-1
E3-1
RW-1
MW-1
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-8
MW-9
MW-10
MW-11
MW-12
MW-13
MW-14
MW-15
MW-1D
MW-2D
MW-3D
MW-4D
MW-5D

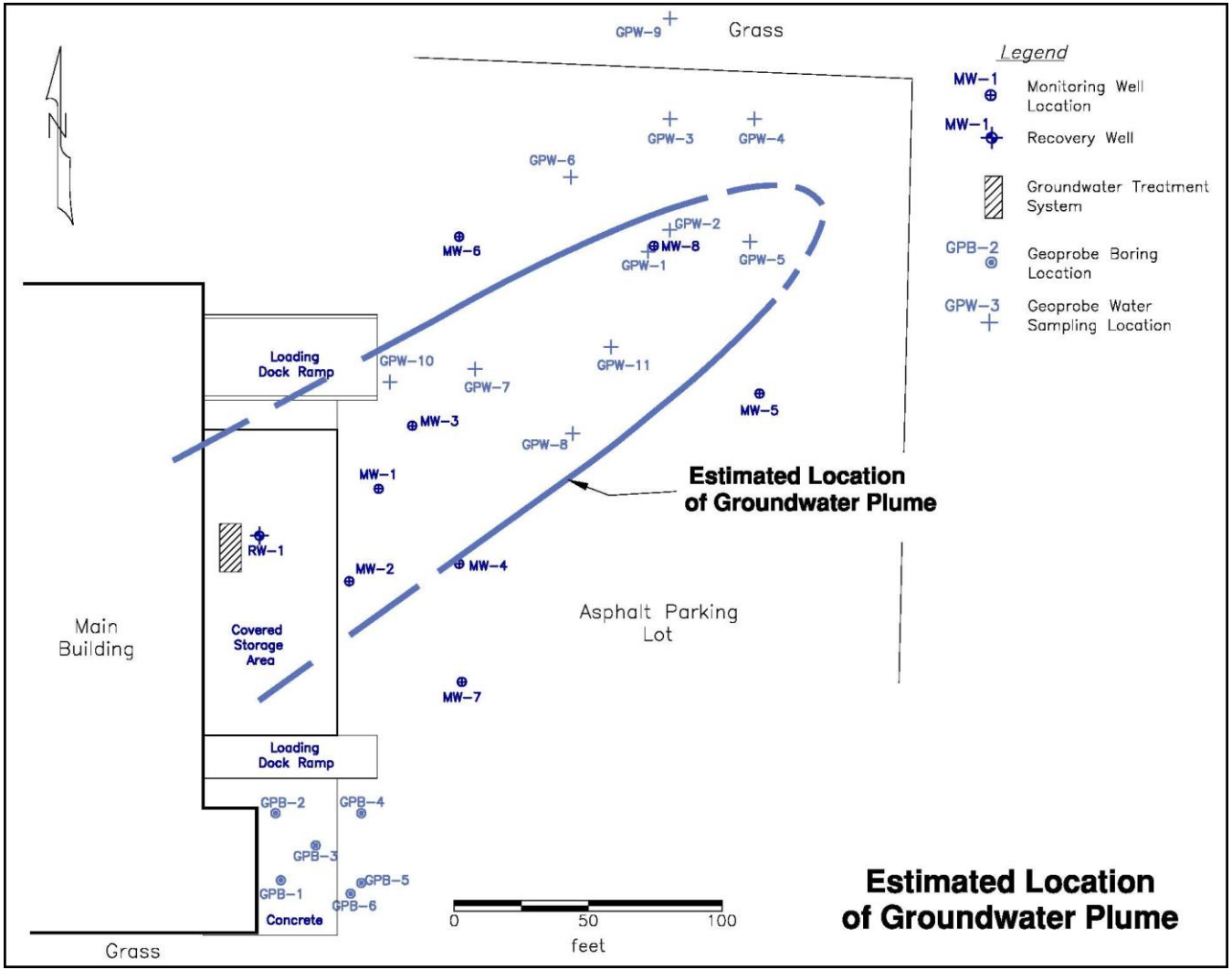
Initial Assessment - 5 Years

- Alarm
- Denial
- Budget impacts
- Additional opinions
- Delayed decisions

Site Hydrogeology

- After three environmental consultants rendered their opinion on the site stratigraphy we have:
  - 12 feet silty sandy clay overlaying
  - 4 - 8 feet sand or sand and gravel overlying
  - Silty sand to approximately 25 feet below ground level

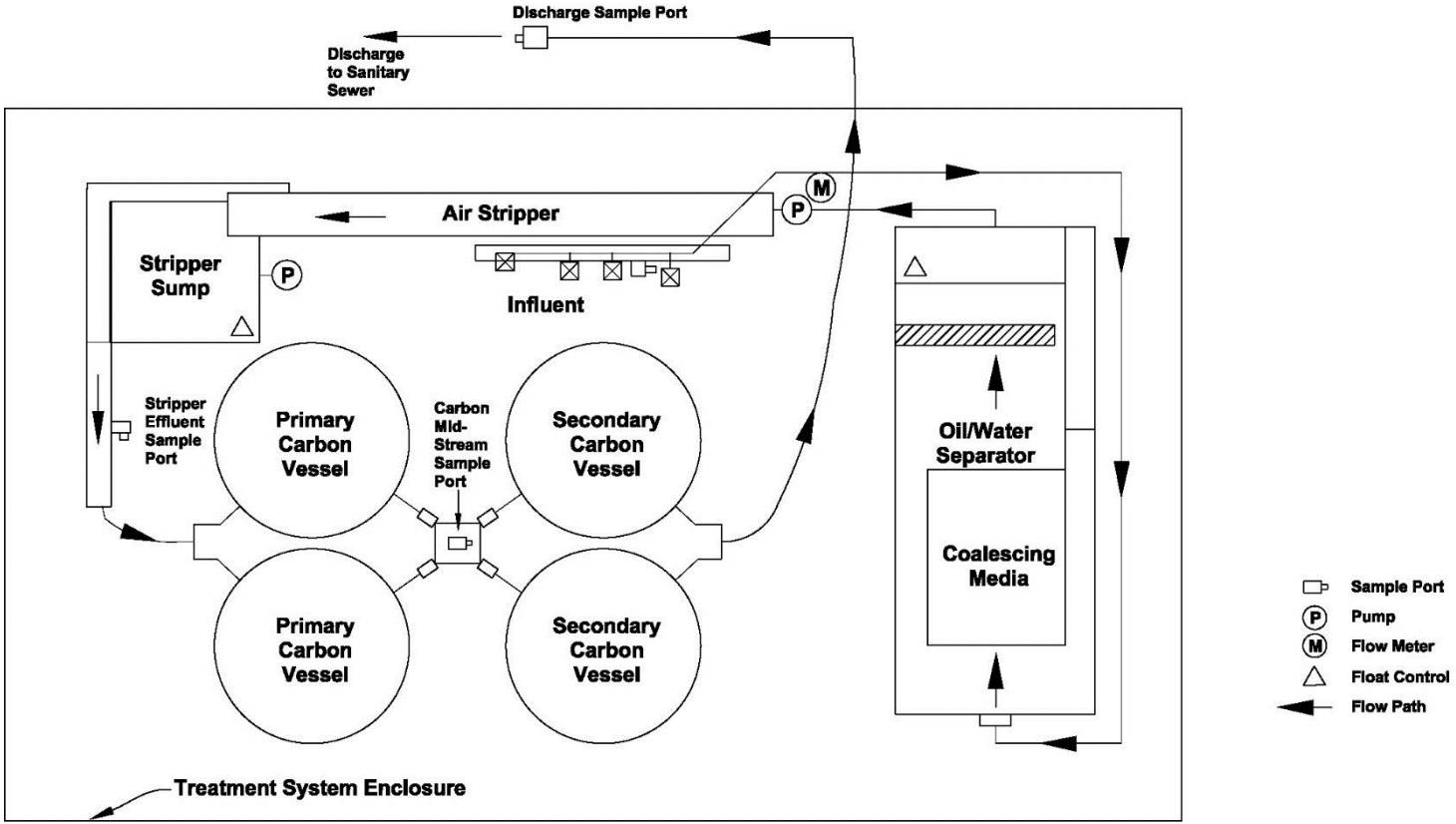

E C
C' W
GB121
GB119
RW-1
GB107
GB106
MW-3
GB103
GB108
MW-8
MW-13
MW-14
105
100
95
90
85
80
75
Relative Elevation (feet)
Fill
Asphalt Fill
Clayey Sand & Gravel
Silty Sandy Clay
Former UST Cavity
Pea Gravel Backfill
Sand
Sand & Gravel
Silty Sand
Clayey Sand
Clayey Silt
Vertical Scale 1" = 5'
Horizontal Scale 1" = 60'
Legend
Screened Interval
Geologic Cross Section C-C'


GPW-9
Grass
Legend
MW-1
Monitoring Well Location
MW-1
Recovery Well
Groundwater Treatment System
GPB-2
Geoprobe Boring Location
GPW-3
Geoprobe Water Sampling Location
GPW-3
GPW-4
GPW-6
GPW-2
MW-6
MW-8
GPW-1
GPW-5
Loading Dock Ramp
GPW-10
GPW-7
GPW-11
MW-5
MW-3
GPW-8
MW-1
Estimated Location of Groundwater Plume
RW-1
MW-2
MW-4
Main Building
Covered Storage Area
Asphalt Parking Lot
MW-7
Loading Dock Ramp
GPB-2
GPB-4
GPB-3
GPB-5
GPB-1
GPB-6
Concrete
0
50
100
feet
Grass
Estimated Location of Groundwater Plume

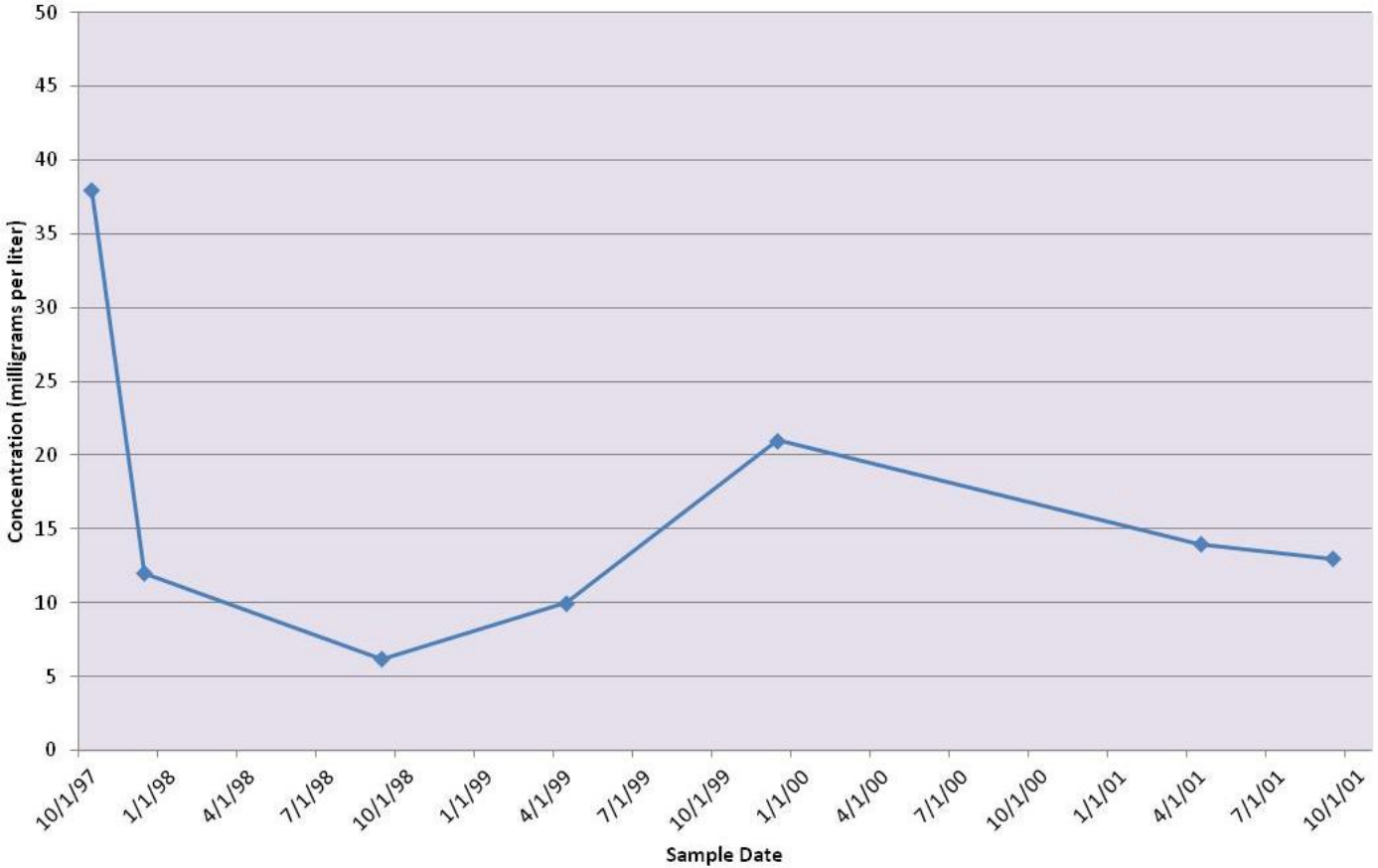
Vacuum-Enhanced Groundwater Recovery

- The first remediation system installed consisted of a vacuum-enhanced groundwater recovery system
- Included one recovery well located in the UST cavity
- The remediation system began operation in 1996
- The groundwater was processed through an oil/water separator, shallow tray air stripper, then primary and secondary granular activated carbon filters
- The remediation system operated from 1996 through 2001

Remediation System Schematic Diagram

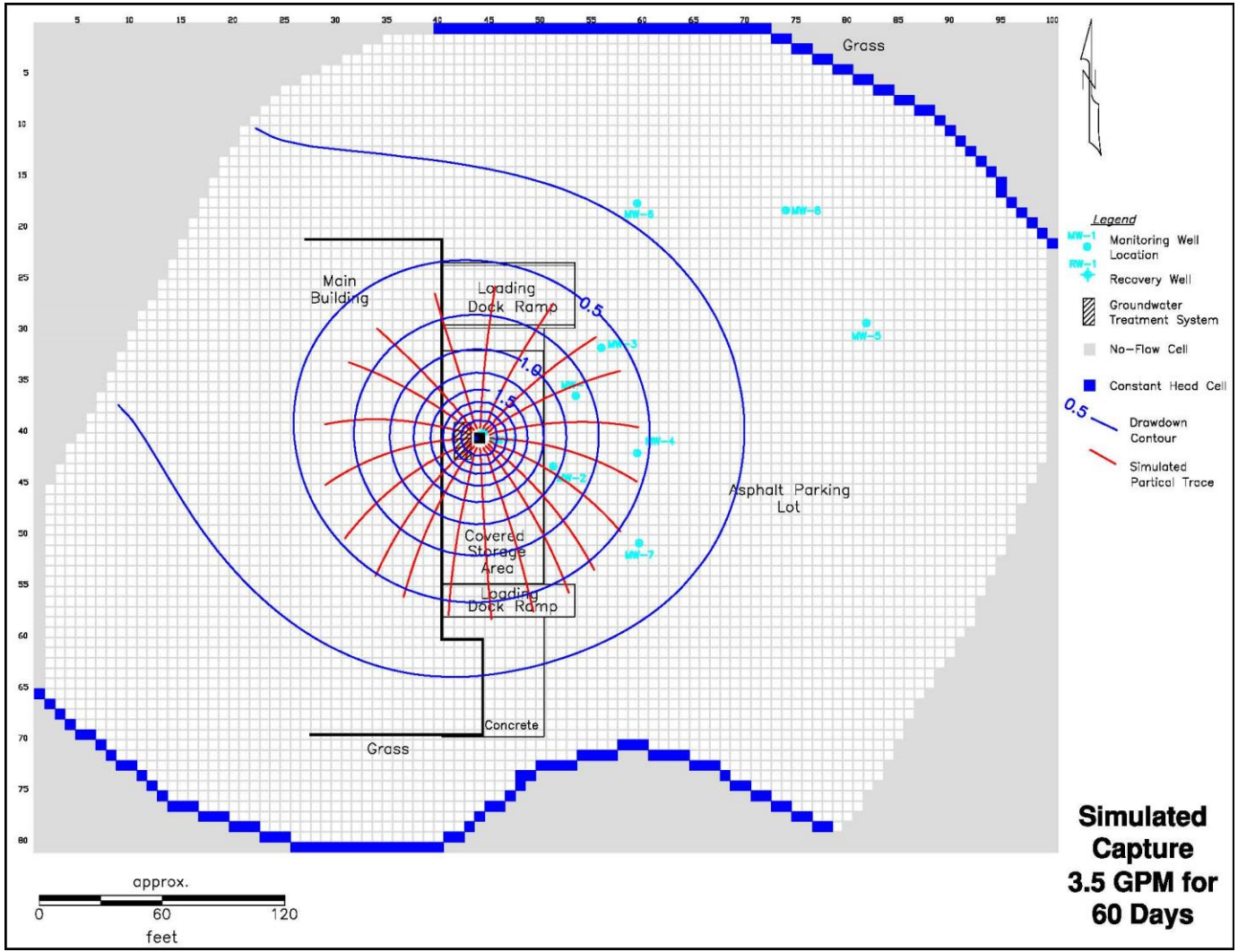


1,1,1-Trichloroethane vs Time MW-3



Remediation System Performance

- VOC plume at MW-3 was not decreasing
- Pump and Treat systems are expensive to operate
- The remedial approach at the Site was reevaluated


Grass
Main Building
Loading Dock Ramp
0.5
1.0
1.5
MW-1
MW-2
MW-3
MW-4
MW-5
MW-6
MW-7
MW-8
Asphalt Parking Lot
Covered Storage Area
Loading Dock Ramp
Concrete
Grass
Legend
Monitoring Well Location
Recovery Well
Groundwater Treatment System
No-Flow Cell
Constant Head Cell
Drawdown Contour
Simulated Partical Trace
approx.
0
60
120
feet
Simulated Capture 3.5 GPM for 60 Days

Insitu-Bioremediation

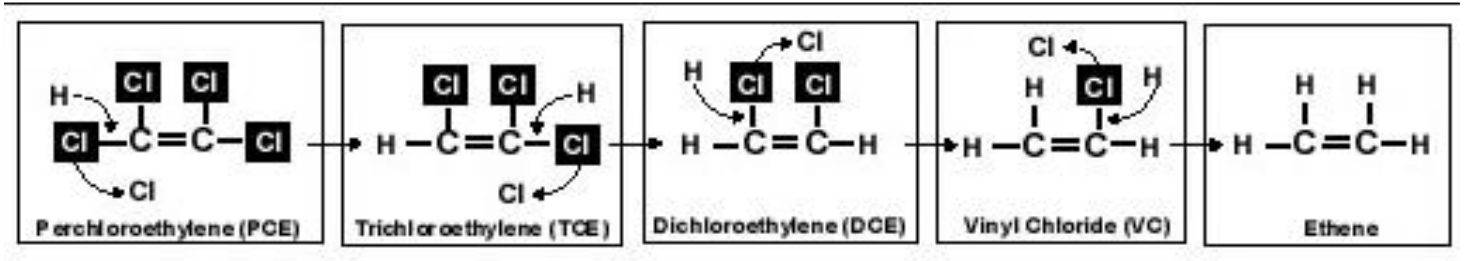
- A new remedial approach was implemented at the Site
- Reductive dechlorination
- A lactate-based carbon substrate (HRC) manufactured by Regenesis was utilize as a carbon source
- 9100 pounds of HRC was injected into 94 injection points in 2001

What is Reductive Dechlorination?

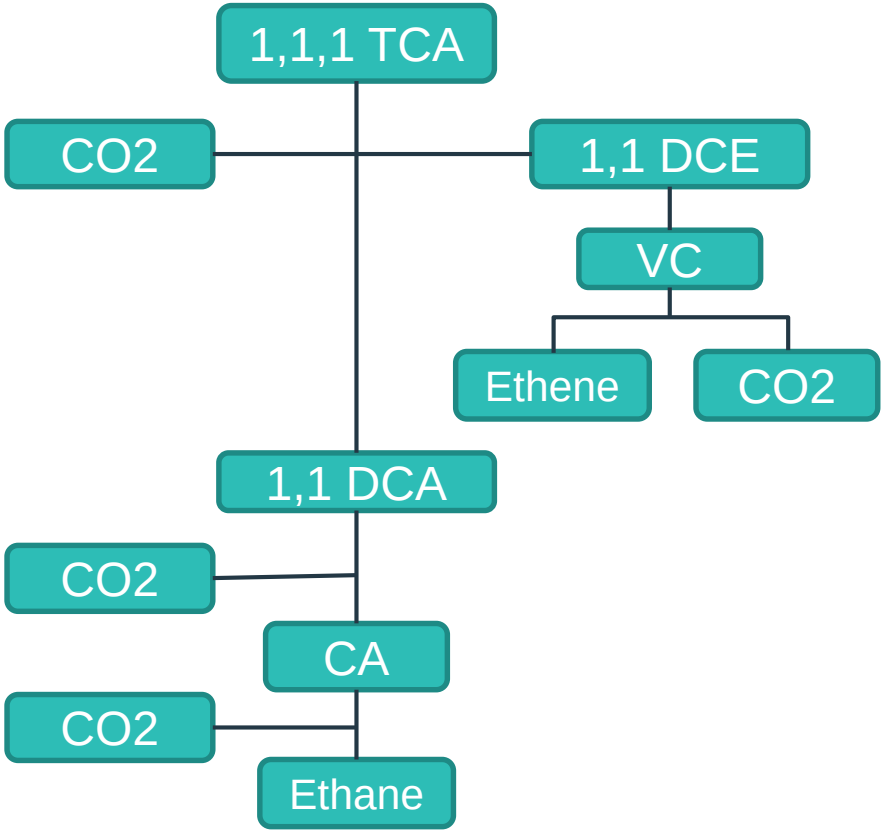
Natural metabolic process where microbes use halogenated compound as an electron acceptor:

- Microbes called “reductive dechlorinators” replace chlorine with hydrogen atoms on CHs
- PCE is biodegraded via the following sequence:

PCE ⟶ TCE ⟶ DCE ⟶ VC ⟶ Ethene



TCA Degradation Pathway



Reductive Dechlorination Geochemistry

- Drive aquifer anaerobic to support RD
- Reduce electron acceptor “interferences”
  - DO – drop
  - Nitrates – drop
  - Iron/manganese – increase
  - Sulfate –drop
- Keep aquifer reduced
  - Allows for complete dechlorination
  - Allows for desorption

Reductive Dechlorination Reaction

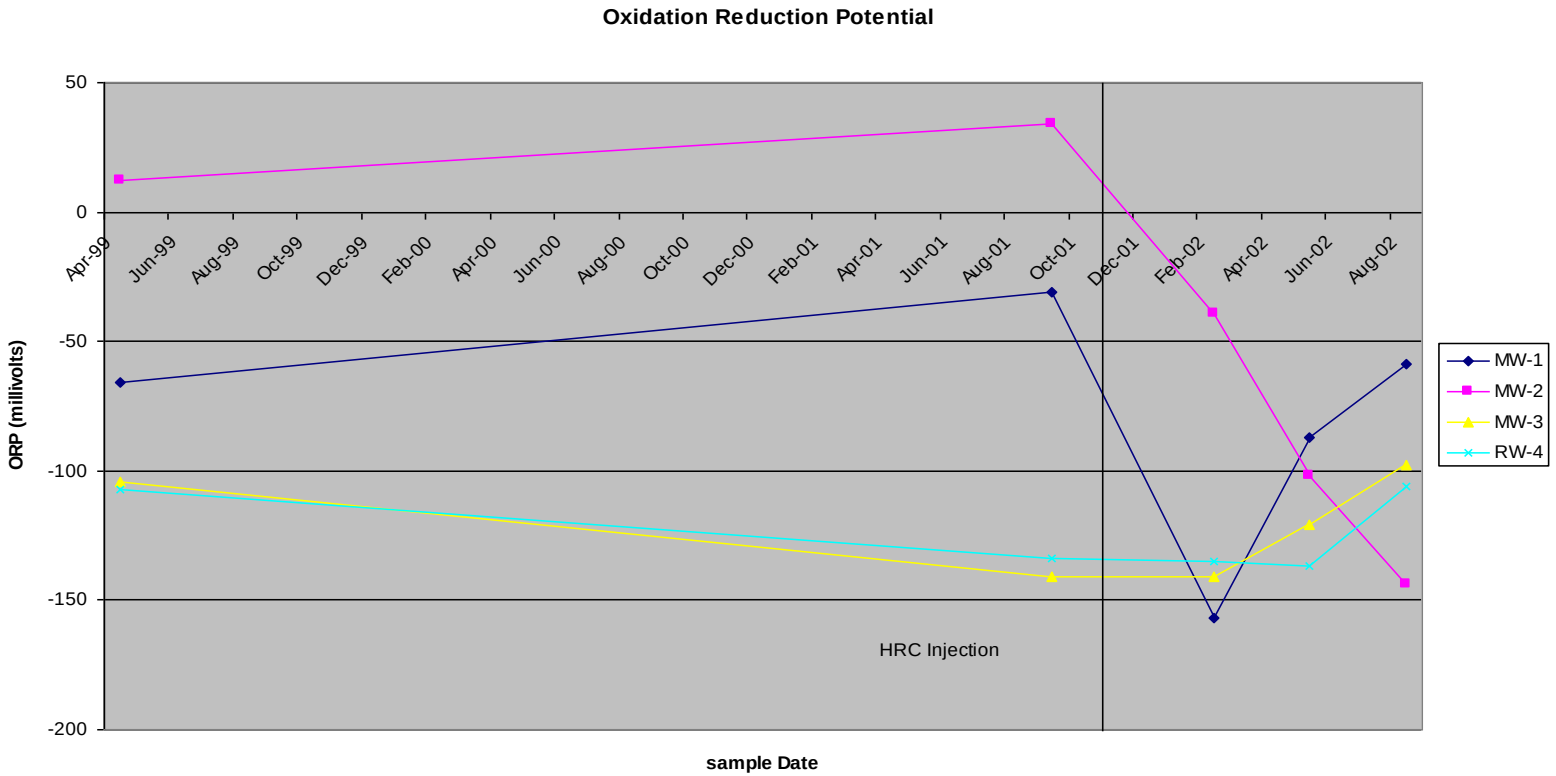
- Gradually release lactic acid to the groundwater
- Converted by bacteria to pyruvic acid, then to acetic acid, with hydrogen being the byproduct
- Chlorine atoms in the contaminant molecules are progressively substituted with hydrogen atoms

Reductive Dechlorination Reaction (continued)

- Excess Hydrogen causes
  - Lactic acid to convert to butyric acid
  - Pyruvic acid coverts to propionic acid

- The excess butyric acid and pyruvic acid can act as hydrogen reservoirs for future reductive dechlorination reactions

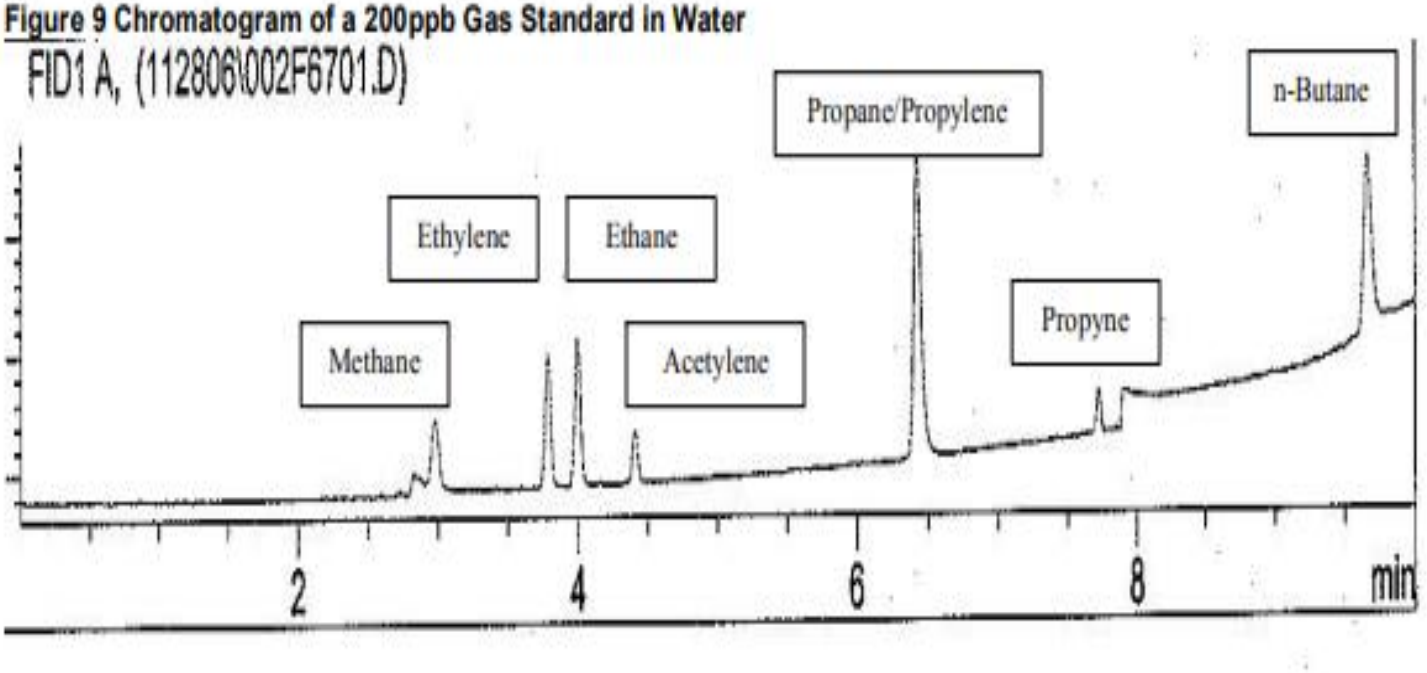
Field Parameters - ORP



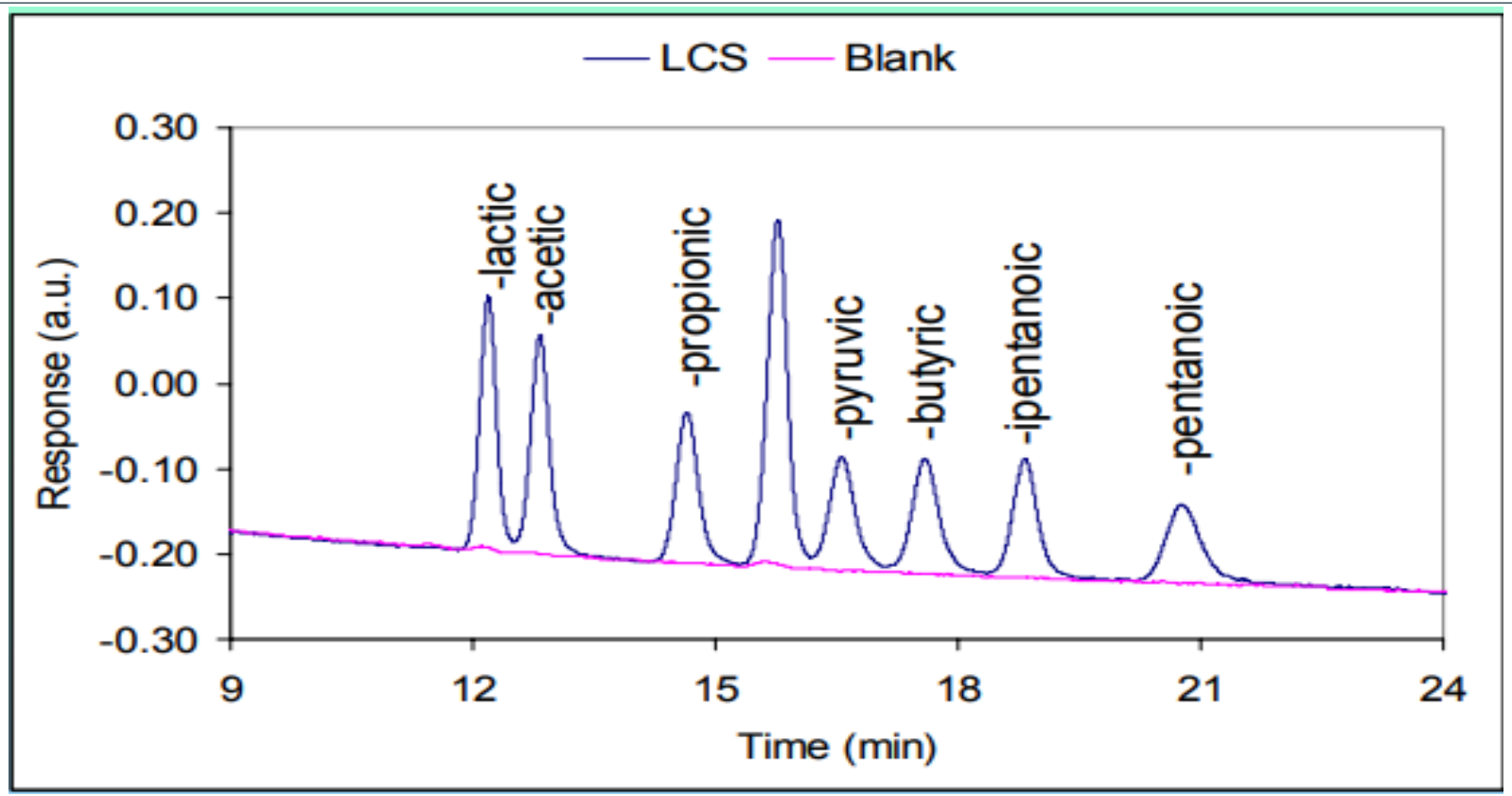
Analytical Methods to Support Reductive Dechlorination

- Dissolved gases method AM20GAX
- Volatile fatty acids method AM23G
- Volatile Organic Compounds method SW 846 8260B
- Anions method SW 846 9056A
- Metals method SW 846 6010B
- Alkalinity method E310.1
- Total Organic Carbon method SW 846 9060A

Dissolved Gases Method AM20GAX

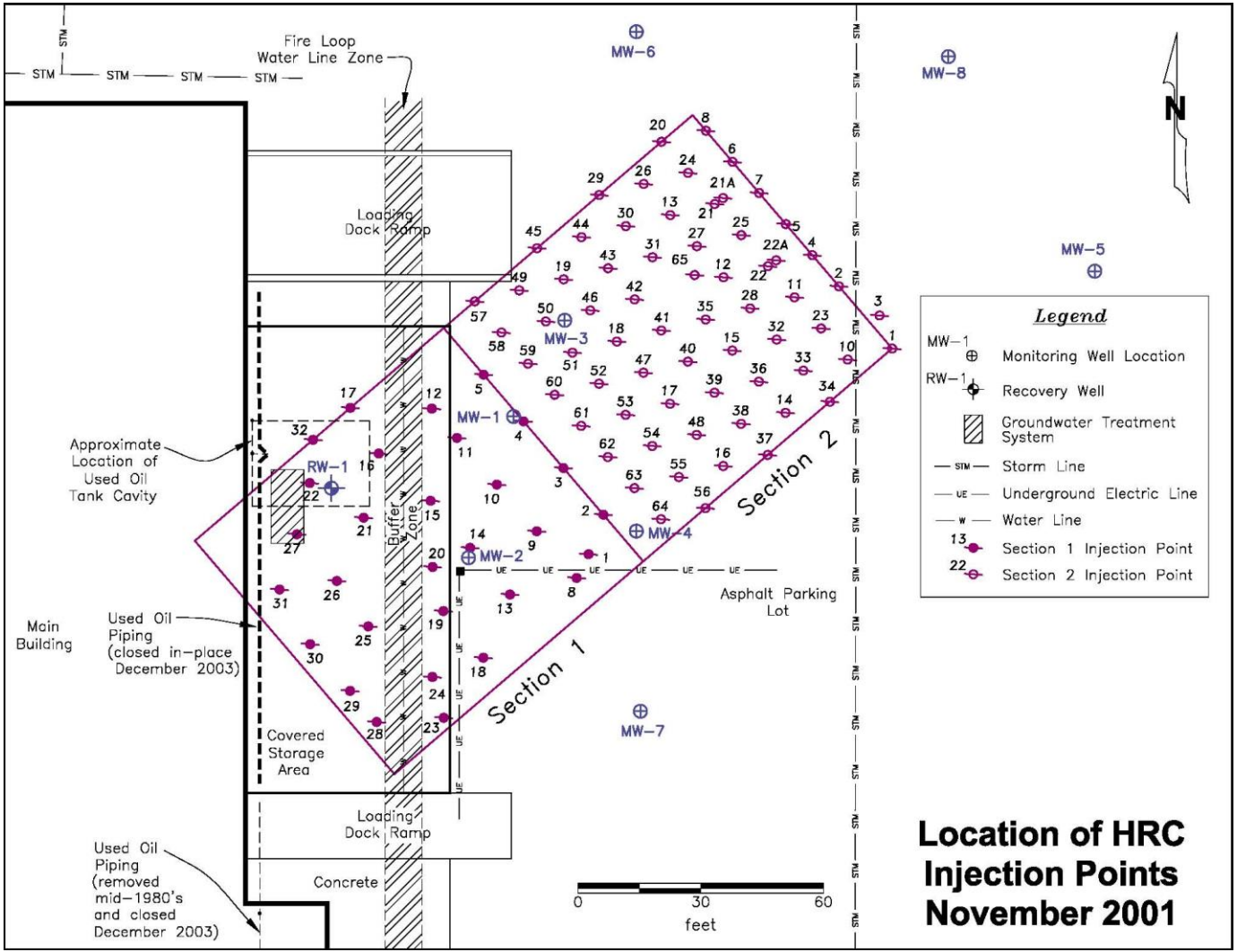


Volatile Fatty Acids Method AM23G - ion chromatography

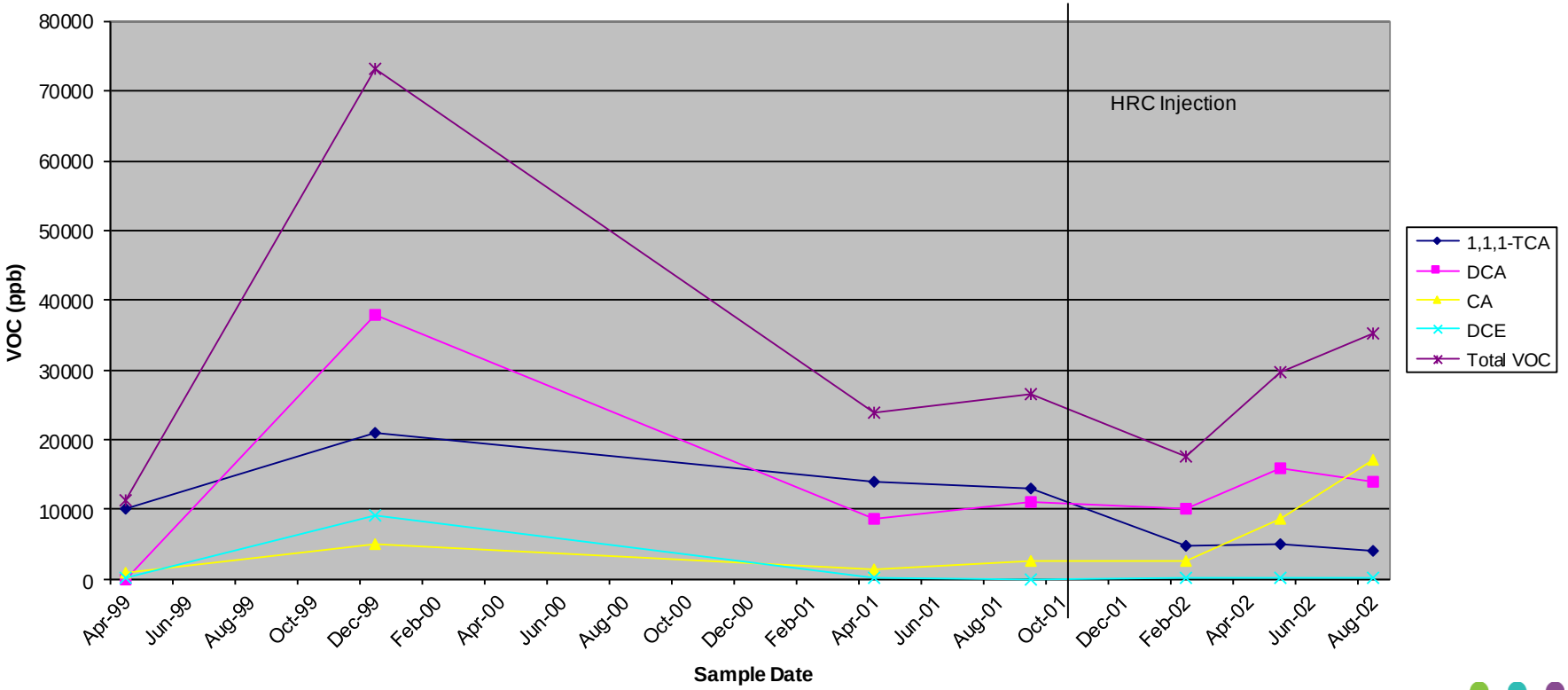


Volatile Fatty Acids Method AM23G

Volatile Fatty Acid Reporting Limits									
Compound Name	Acetic Acid	Propionic Acid	Butyric Acid	Pyruvic Acid	Lactic Acid	n-Pentanoic Acid	i-Pentnaoic Acid	n-Hexanoic Acid	i-Hexanoic Acid
Low Level PQL (ppm)	0.10	0.10	0.10	0.10	0.20	0.10	0.10	0.20	0.20

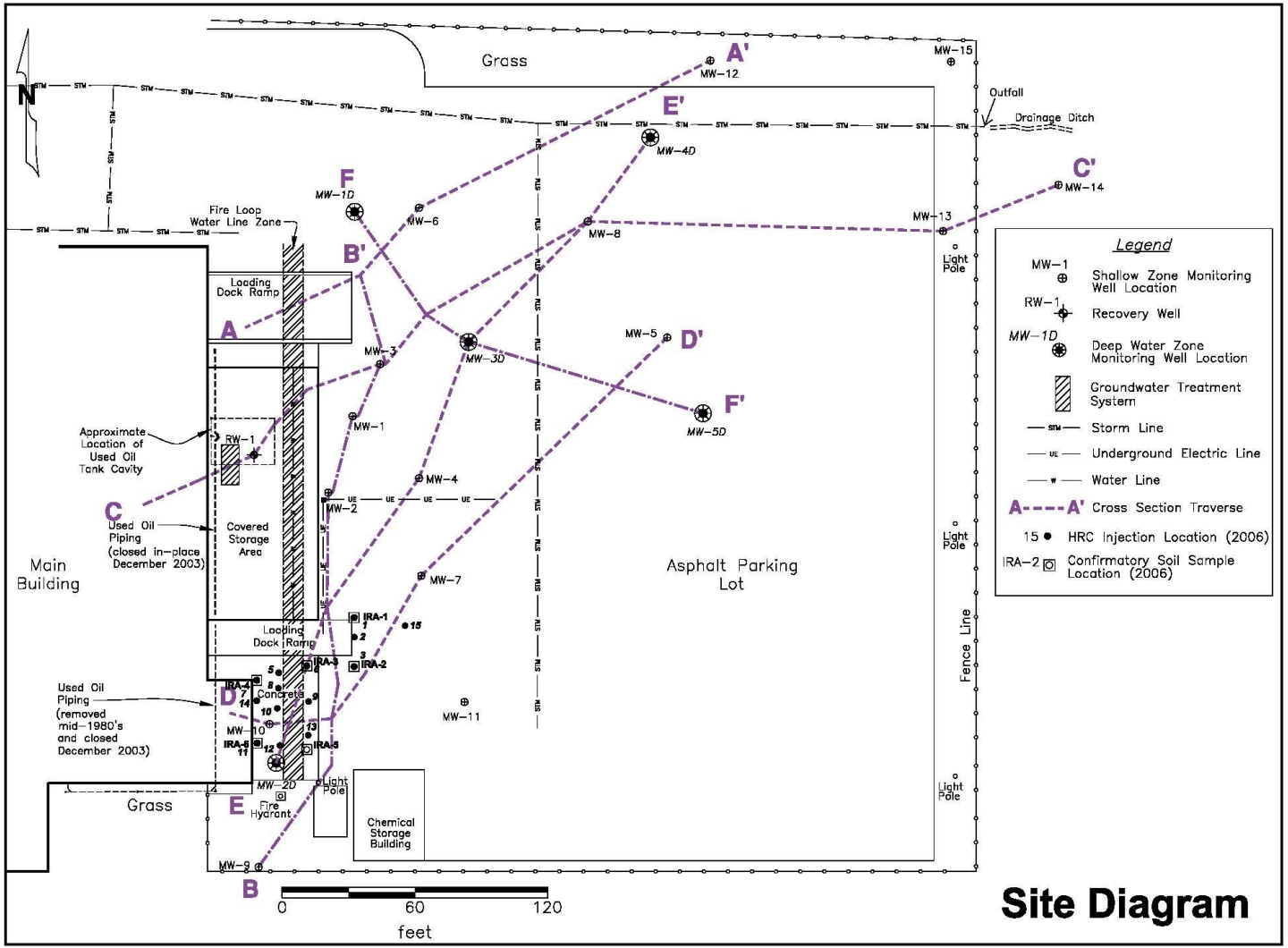

Fire Loop
Water Line Zone
STM
Loading
Dock Ramp
MW-6
MW-8
MW-5
MW-3
MW-1
MW-2
MW-4
MW-7
RW-1
Approximate
Location of
Used Oil
Tank Cavity
Buffer
Zone
Section 1
Section 2
Asphalt Parking
Lot
Main
Building
Used Oil
Piping
(closed in-place
December 2003)
Covered
Storage
Area
Loading
Dock Ramp
Used Oil
Piping
(removed
mid-1980's
and closed
December 2003)
Concrete
N
Legend
MW-1
Monitoring Well Location
RW-1
Recovery Well
Groundwater Treatment
System
STM
Storm Line
UE
Underground Electric Line
W
Water Line
13
Section 1 Injection Point
22
Section 2 Injection Point
0
30
60
feet
Location of HRC
Injection Points
November 2001

VOCs vs Time MW-3

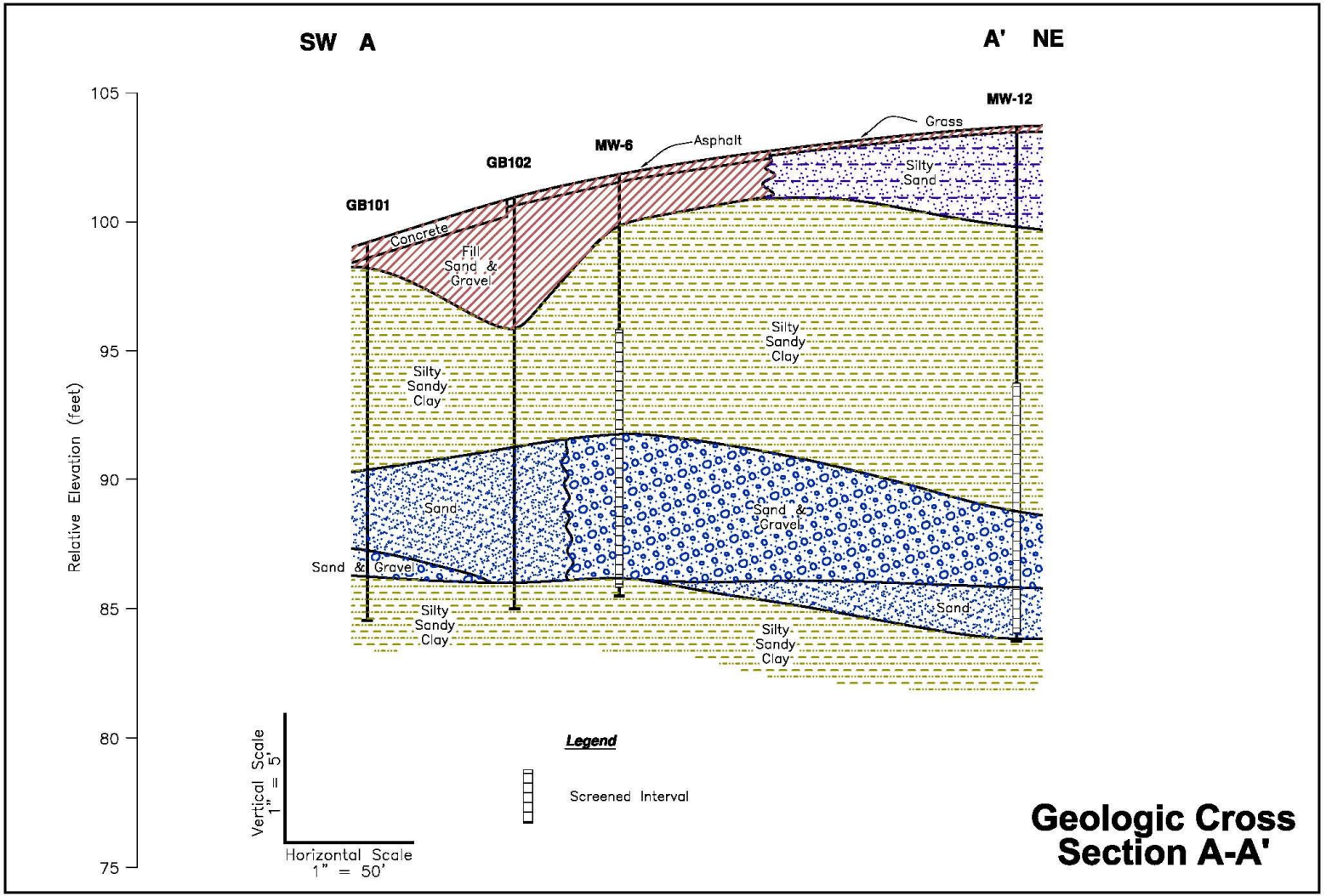


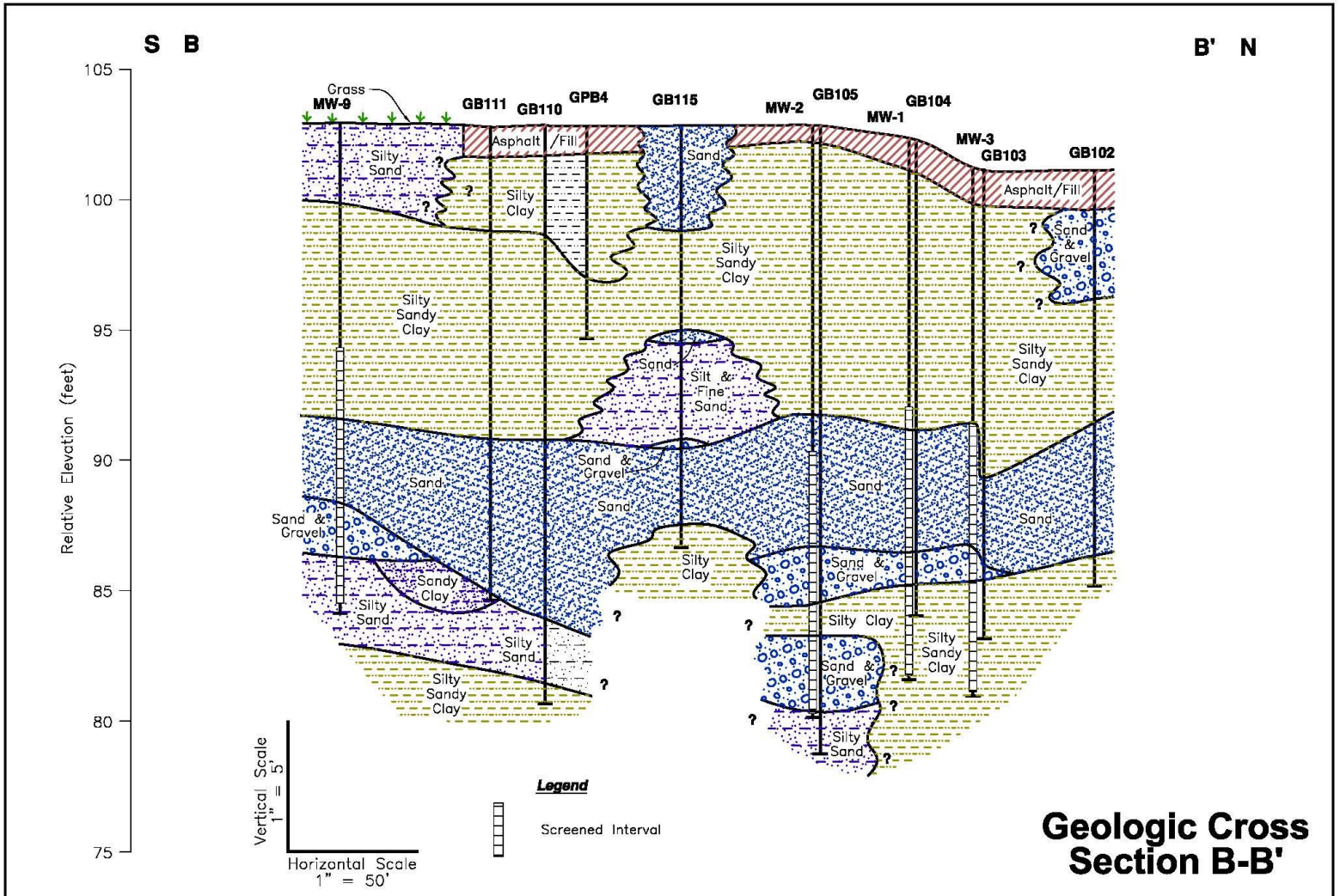
Site Divesture

- The manufacturing Site was closed in 2002 and put up for sale
- Recommended that the up-gradient source of 1,1,1-TCA be evaluated
- Comprehensive investigation was performed
- 320 mg/L of 1,1,1-TCA was identified in monitoring well MW-10 screened in the shallow aquifer

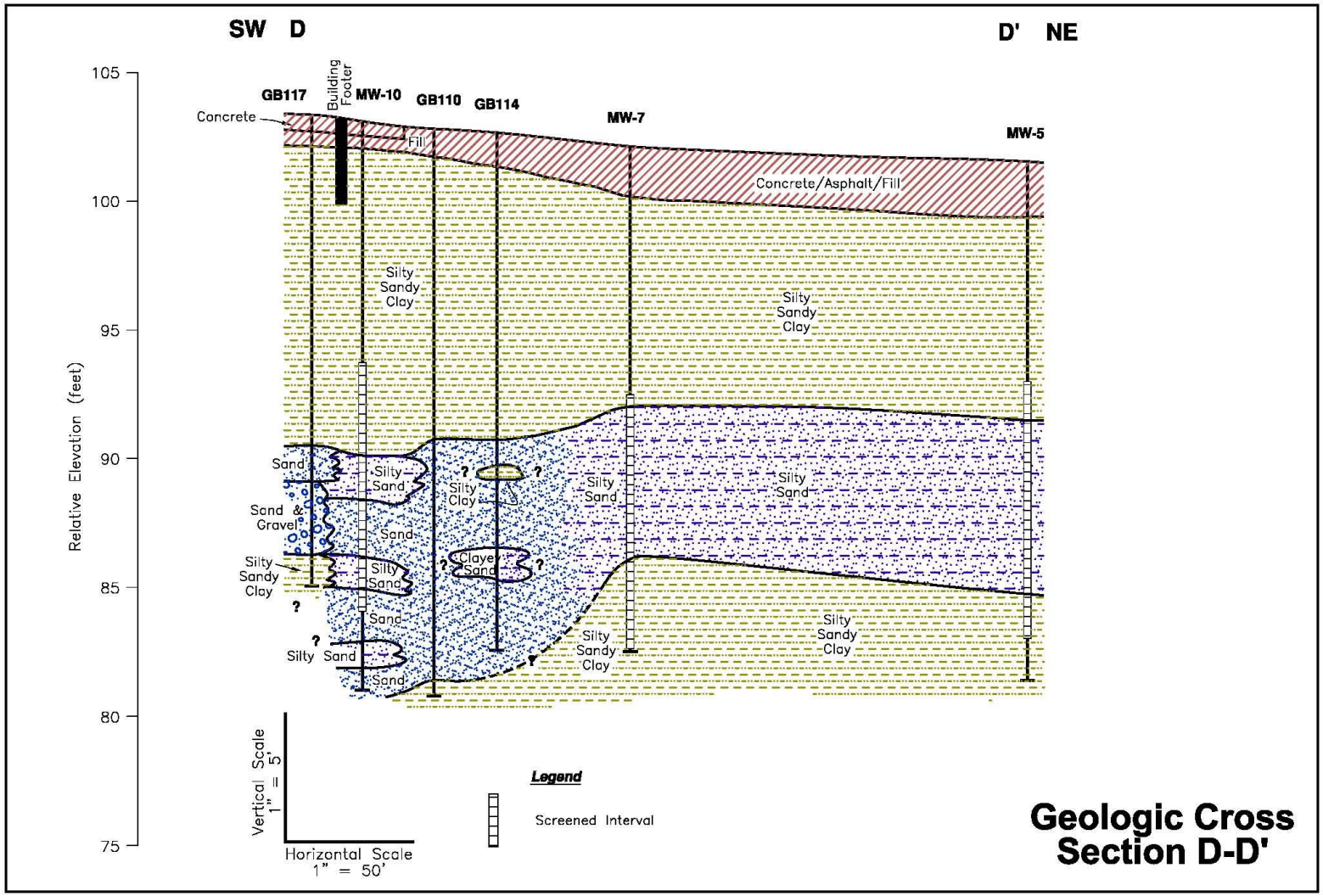


Site Diagram

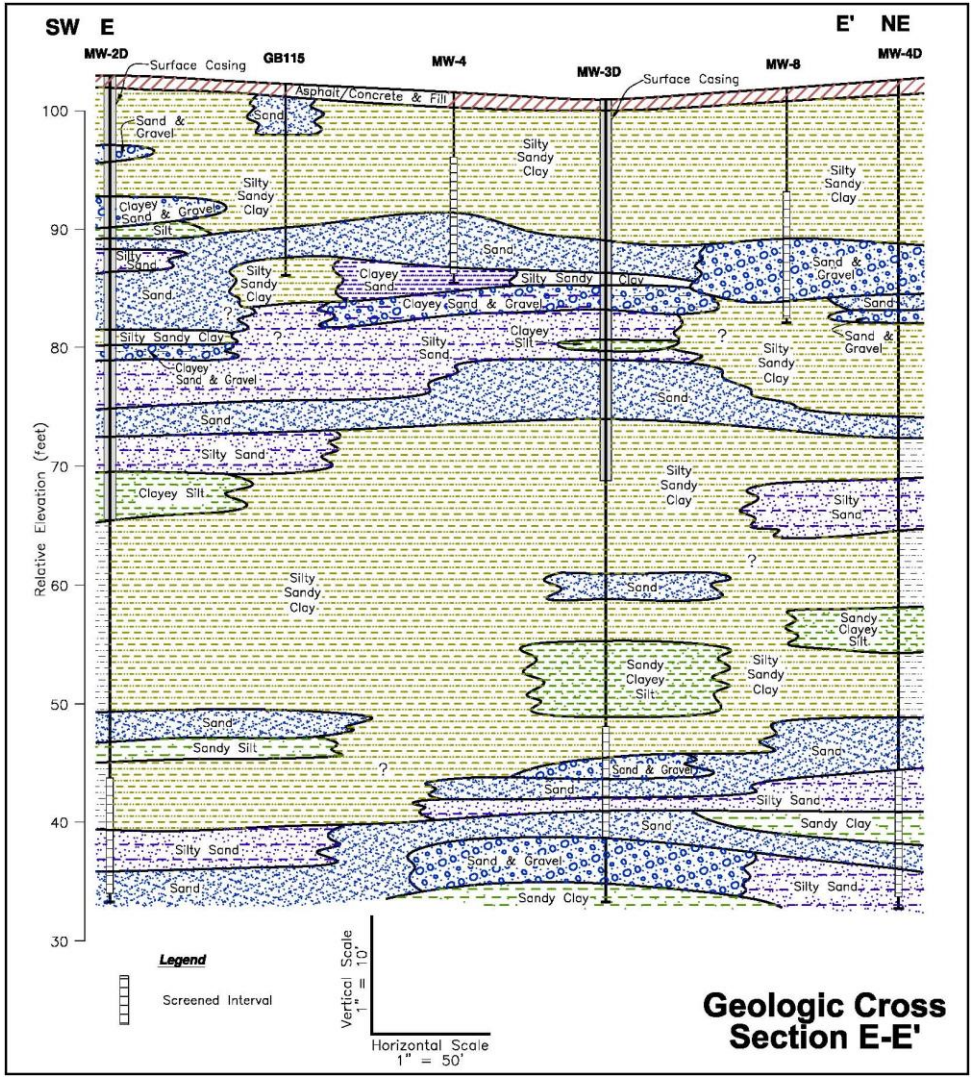

SW A
A' NE
105
100
95
90
85
80
75
Relative Elevation (feet)
GB101
GB102
MW-6
MW-12
Concrete
Asphalt
Grass
Fill
Sand &
Gravel
Silty
Sand
Silty
Sandy
Clay
Sand
Sand & Gravel
Legend
Screened Interval
Vertical Scale
1" = 5'
Horizontal Scale
1" = 50'
Geologic Cross
Section A-A'

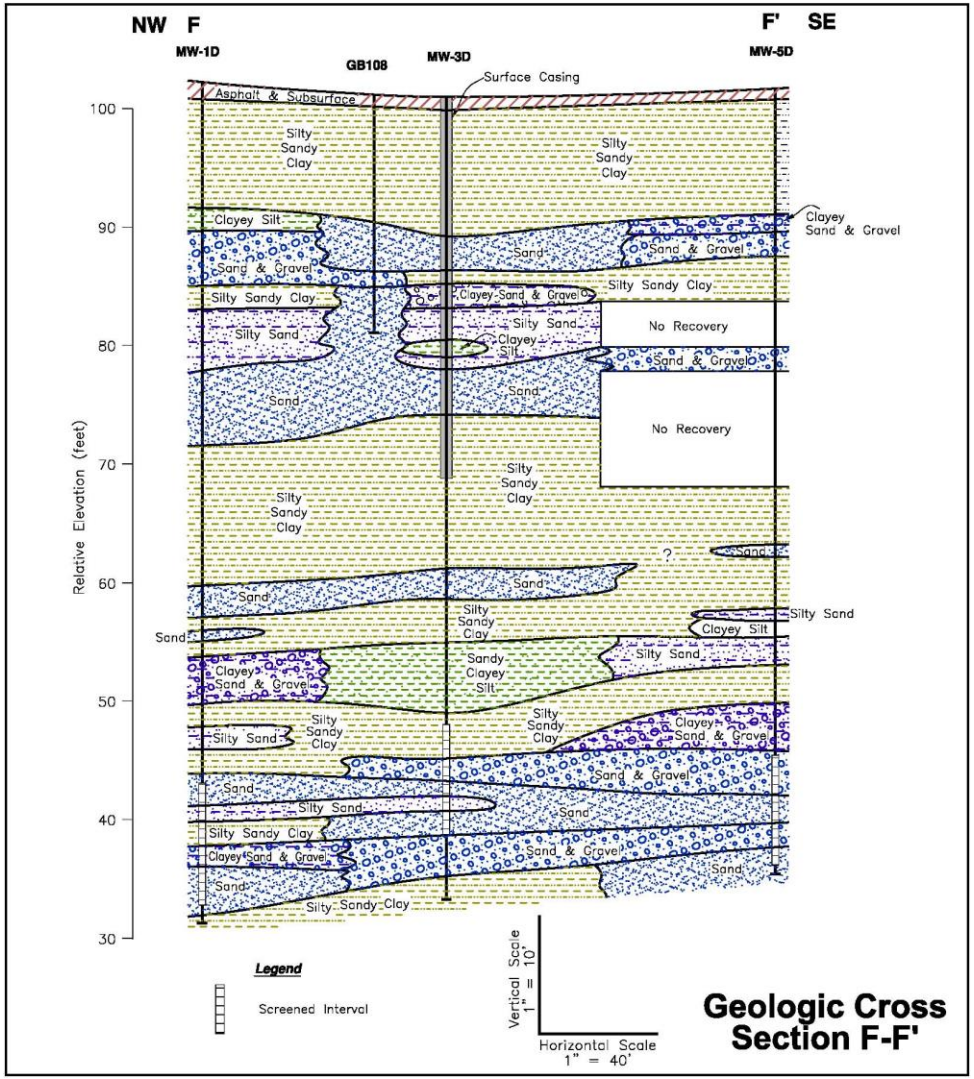


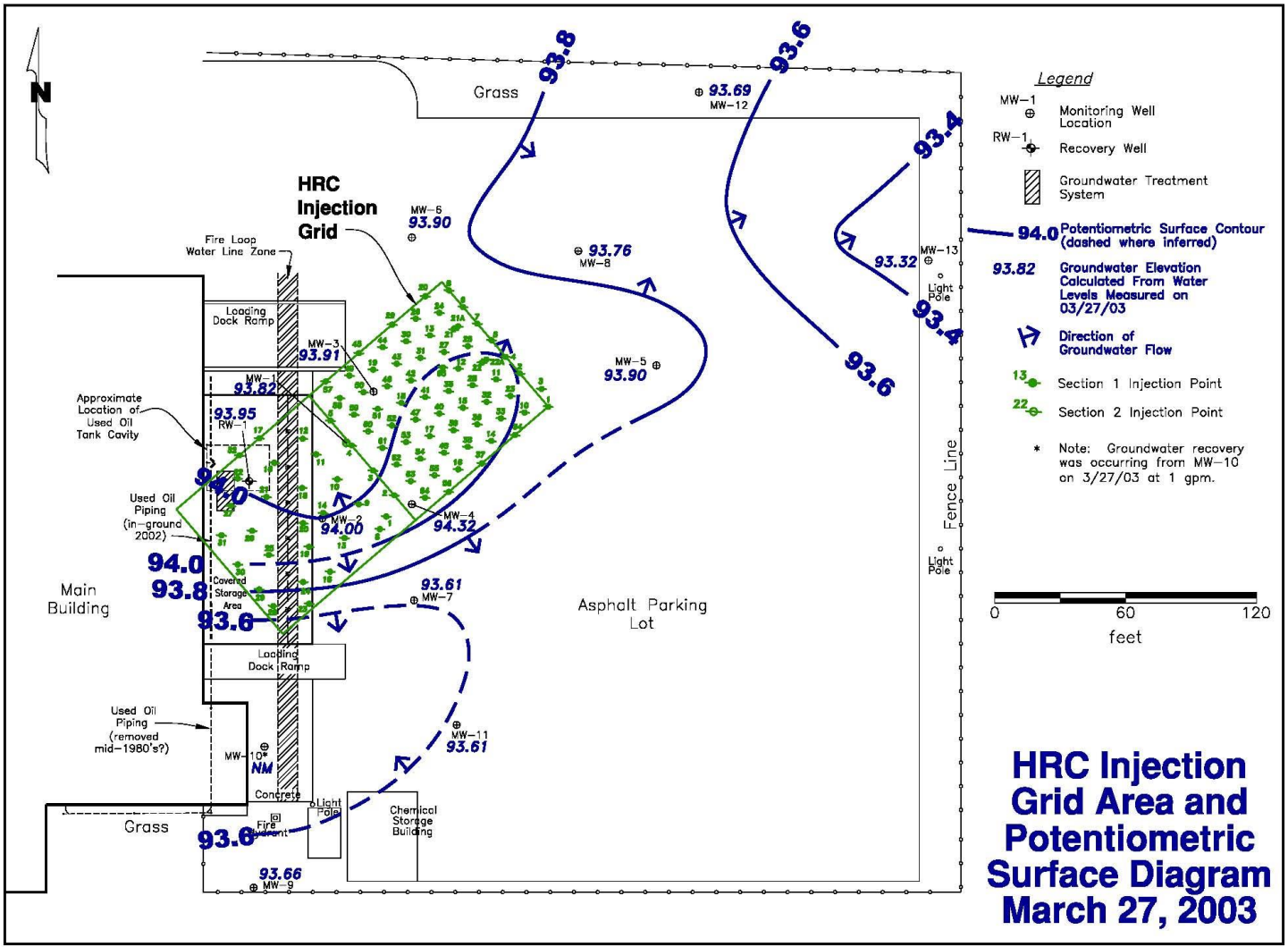
Geologic Cross Section B-B'

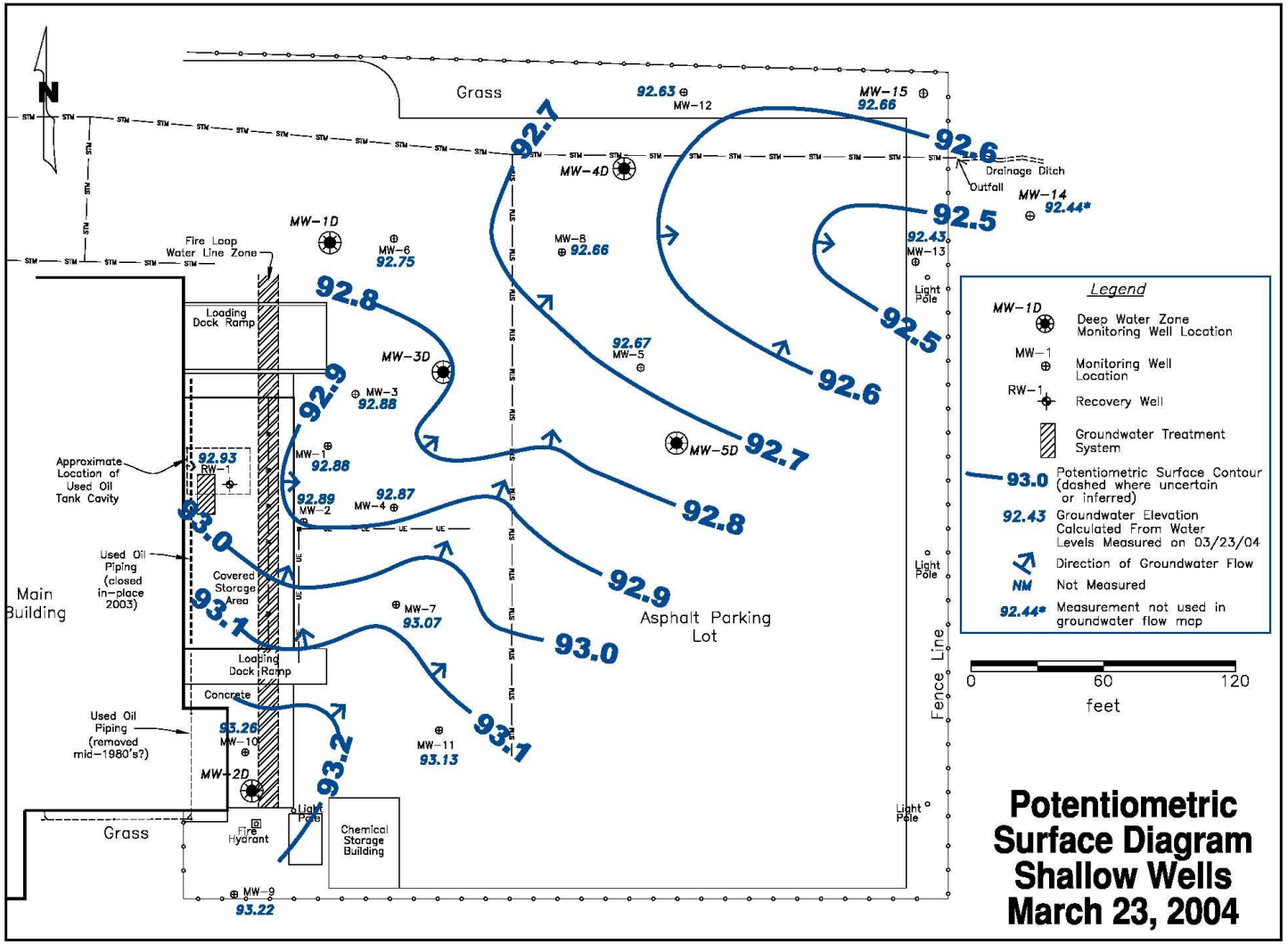


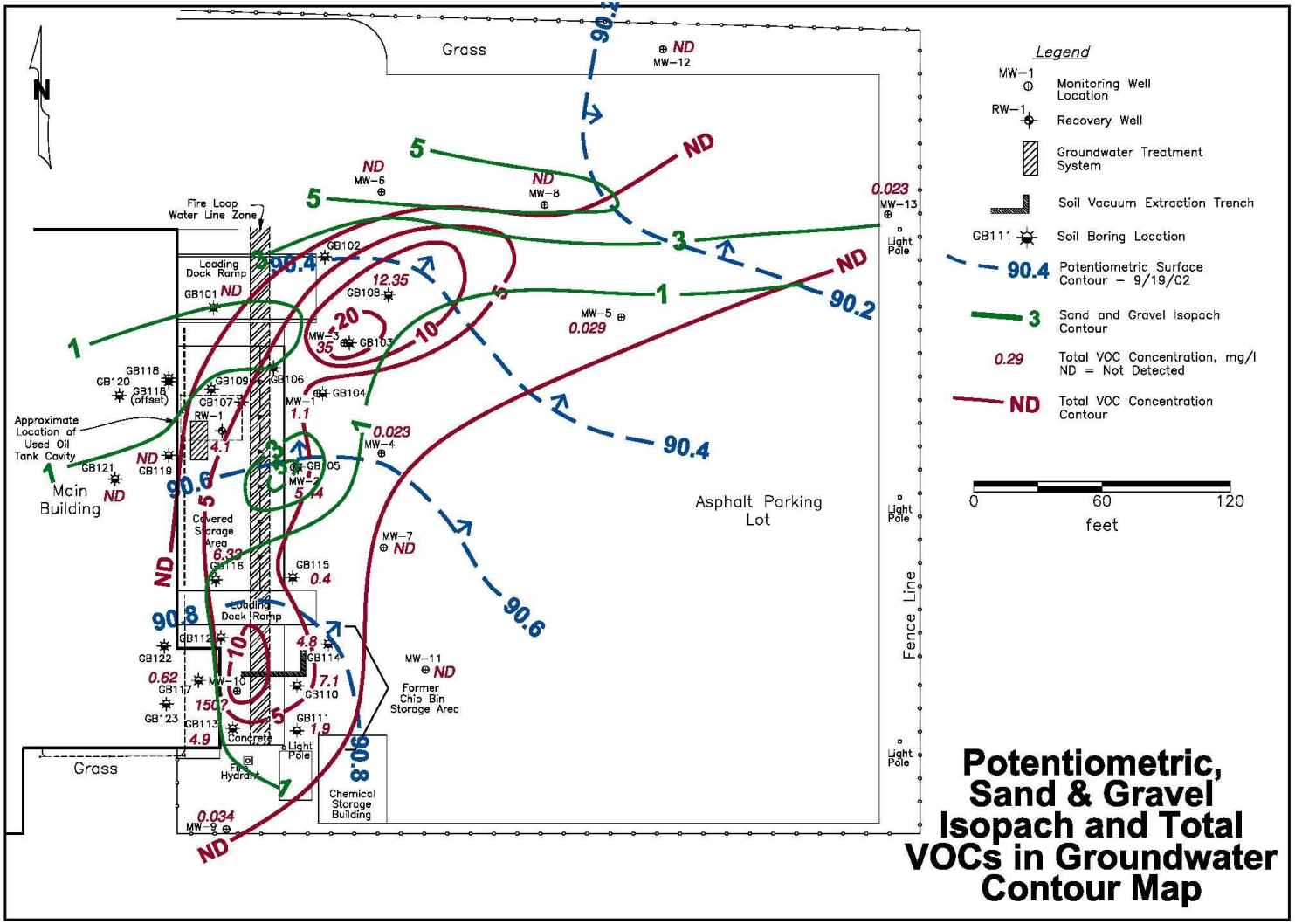
Geologic Cross Section D-D'


SW E
E' NE
MW-2D
GB115
MW-4
MW-3D
MW-8
MW-4D
Surface Casing
Surface Casing
Asphalt/Concrete & Fill
Relative Elevation (feet)
100
90
80
70
60
50
40
30
Sand & Gravel
Sand
Silty Sandy Clay
Clayey Sand & Gravel
Silt
Silty Sand
Clayey Silt
Sandy Clayey Silt
Sandy Silt
Sandy Clay
Legend
Screened Interval
Vertical Scale 1" = 10'
Horizontal Scale 1" = 50'
Geologic Cross Section E-E'


NW F
F' SE
MW-1D
GB108
MW-3D
MW-5D
Surface Casing
Asphalt & Subsurface
Relative Elevation (feet)
100
90
80
70
60
50
40
30
Silty Sandy Clay
Clayey Silt
Sand & Gravel
Clayey Sand & Gravel
Silty Sand
Sand
No Recovery
Legend
Screened Interval
Vertical Scale 1" = 10'
Horizontal Scale 1" = 40'
Geologic Cross Section F-F'


N
Grass
93.8
93.6
93.69
MW-12
93.4
HRC Injection Grid
MW-6
93.90
Fire Loop Water Line Zone
93.76
MW-8
93.32
MW-13
Light Pole
93.4
Loading Dock Ramp
MW-3
93.91
MW-5
93.90
93.6
MW-1
93.82
Approximate Location of Used Oil Tank Cavity
93.95
RW-1
94.0
Used Oil Piping (in-ground 2002)
MW-2
94.00
MW-4
94.32
94.0
93.8
Covered Storage Area
93.61
MW-7
93.6
Main Building
Asphalt Parking Lot
Fence Line
Light Pole
Loading Dock Ramp
Used Oil Piping (removed mid-1980's?)
MW-10
NM
MW-11
93.61
Concrete
Light Pole
Chemical Storage Building
Grass
Fire Hydrant
93.6
93.66
MW-9
Legend
MW-1
Monitoring Well Location
RW-1
Recovery Well
Groundwater Treatment System
94.0
Potentiometric Surface Contour (dashed where inferred)
93.82
Groundwater Elevation Calculated From Water Levels Measured on 03/27/03
Direction of Groundwater Flow
13
Section 1 Injection Point
22
Section 2 Injection Point
* Note: Groundwater recovery was occurring from MW-10 on 3/27/03 at 1 gpm.
0
60
120
feet
HRC Injection Grid Area and Potentiometric Surface Diagram March 27, 2003

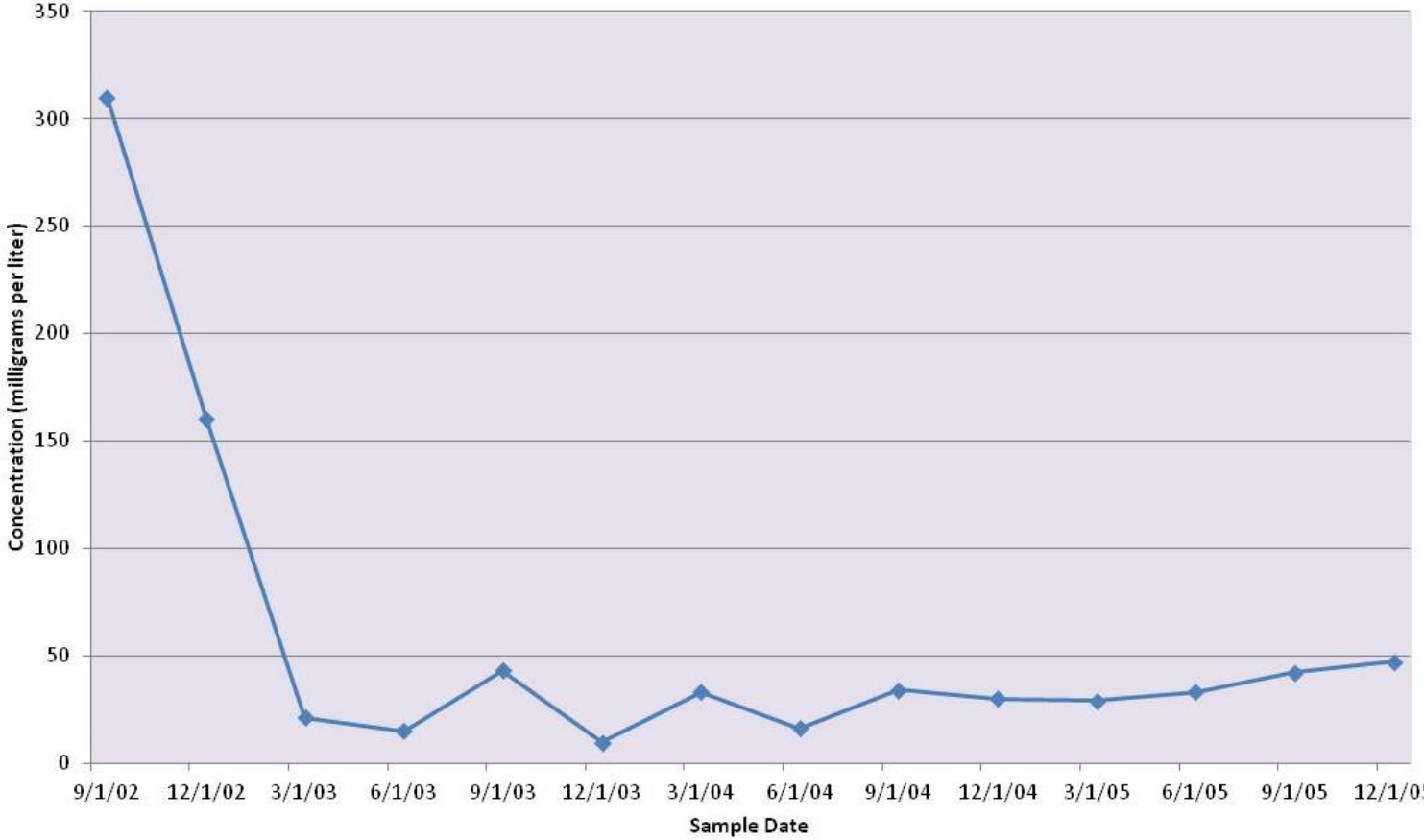

N
Grass
92.63
MW-12
MW-15
92.66
92.6
Drainage Ditch
Outfall
MW-14
92.44*
92.5
92.43
MW-13
Light Pole
MW-4D
MW-1D
MW-6
92.75
Fire Loop Water Line Zone
MW-8
92.66
92.7
92.8
Loading Dock Ramp
MW-3D
92.67
MW-5
92.5
92.6
MW-3
92.88
92.9
MW-1
92.88
MW-5D
92.7
Approximate Location of Used Oil Tank Cavity
92.93
RW-1
92.89
MW-2
92.87
MW-4
92.8
93.0
Used Oil Piping (closed in-place 2003)
Covered Storage Area
Main Building
92.9
Asphalt Parking Lot
MW-7
93.07
93.1
93.0
Loading Dock Ramp
Concrete
Used Oil Piping (removed mid-1980's?)
93.26
MW-10
MW-11
93.13
93.1
MW-2D
93.2
Light Pole
Fire Hydrant
Chemical Storage Building
Grass
Fence Line
Light Pole
MW-9
93.22
Legend
MW-1D
Deep Water Zone Monitoring Well Location
MW-1
Monitoring Well Location
RW-1
Recovery Well
Groundwater Treatment System
93.0
Potentiometric Surface Contour (dashed where uncertain or inferred)
92.43
Groundwater Elevation Calculated From Water Levels Measured on 03/23/04
Direction of Groundwater Flow
NM
Not Measured
92.44*
Measurement not used in groundwater flow map
0
60
120
feet
Potentiometric Surface Diagram Shallow Wells March 23, 2004


Grass
MW-12
ND
MW-6
ND
MW-8
ND
0.023
MW-13
Light Pole
Fire Loop Water Line Zone
Loading Dock Ramp
GB101
ND
GB102
90.4
12.35
GB108
MW-5
0.029
MW-3
35
GB103
20
10
5
1
90.2
GB118
GB120
GB119 (offset)
GB109
GB106
GB107
GB104
MW-1
1.1
RW-1
4.1
Approximate Location of Used Oil Tank Cavity
GB121
ND
GB119
90.6
Main Building
ND
MW-2
5.4
GB105
0.023
MW-4
90.4
Asphalt Parking Lot
Covered Storage Area
6.33
GB116
MW-7
ND
GB115
0.4
Loading Dock Ramp
90.8
GB112
GB122
4.8
GB114
MW-11
ND
0.62
GB117
MW-10
7.1
GB110
Former Chip Bin Storage Area
150?
GB123
GB113
4.9
GB111
1.9
Concrete
Light Pole
Fire Hydrant
Grass
90.8
Chemical Storage Building
0.034
MW-9
ND
Fence Line
Legend
MW-1
Monitoring Well Location
RW-1
Recovery Well
Groundwater Treatment System
Soil Vacuum Extraction Trench
GB111
Soil Boring Location
90.4
Potentiometric Surface Contour – 9/19/02
3
Sand and Gravel Isopach Contour
0.29
Total VOC Concentration, mg/l
ND = Not Detected
ND
Total VOC Concentration Contour
0
60
120
feet
Potentiometric, Sand & Gravel Isopach and Total VOCs in Groundwater Contour Map

MW-10 Source Area Removal

- 1,1,1-TCA concentrations in MW-10 were too great to cost effectively implement reductive dechlorination
- A dual-phase extraction (DPE) system was installed on MW-10 utilizing the existing remediation system components
- The DPE system operated on MW-10 for 9 months
- A total of 350,000 gallons of groundwater and 90 pounds of VOCs were recovered during the 9 months
- The DPE system was shut down and a rebound monitoring program was implemented

1,1,1-Trichloroethane vs Time MW-10

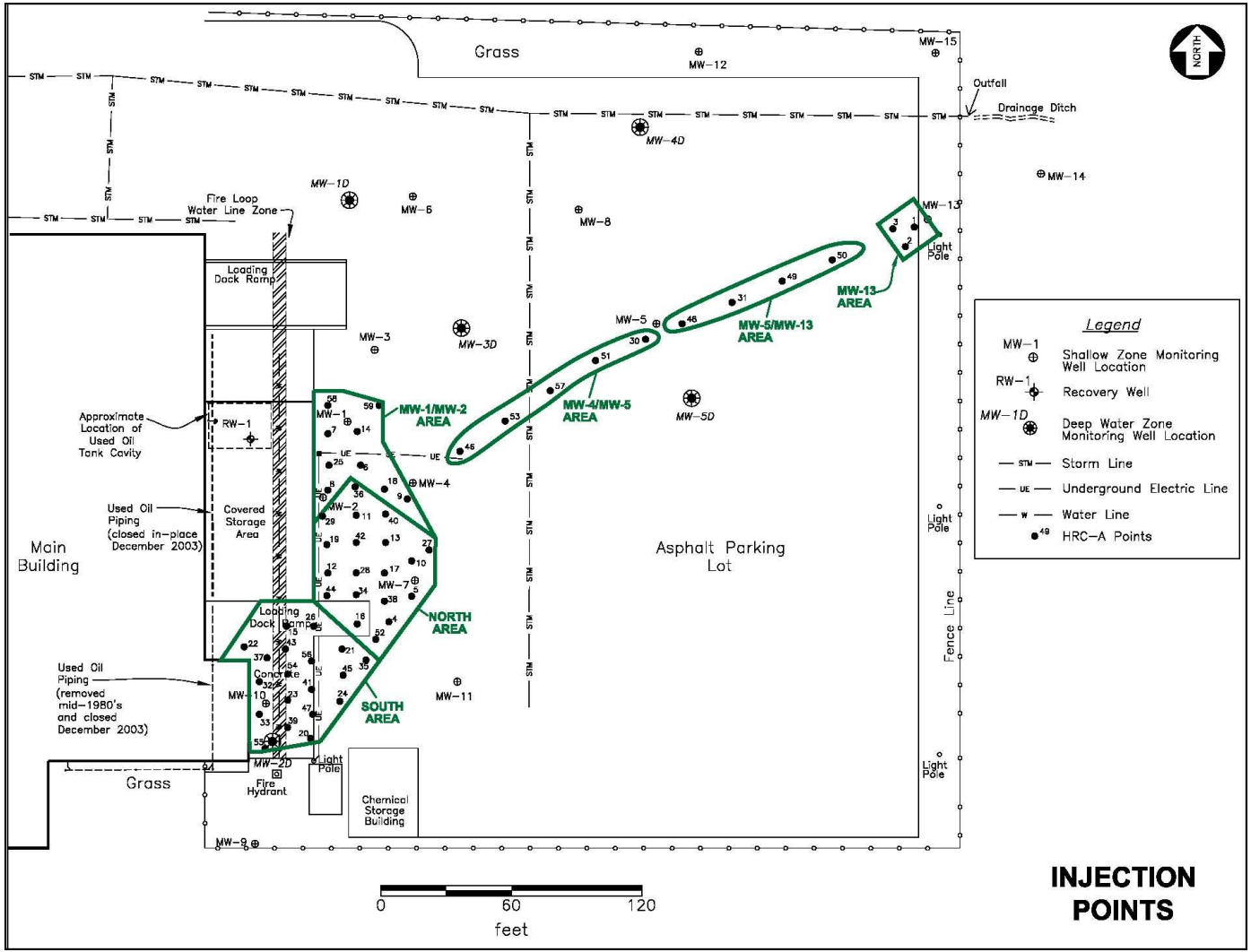


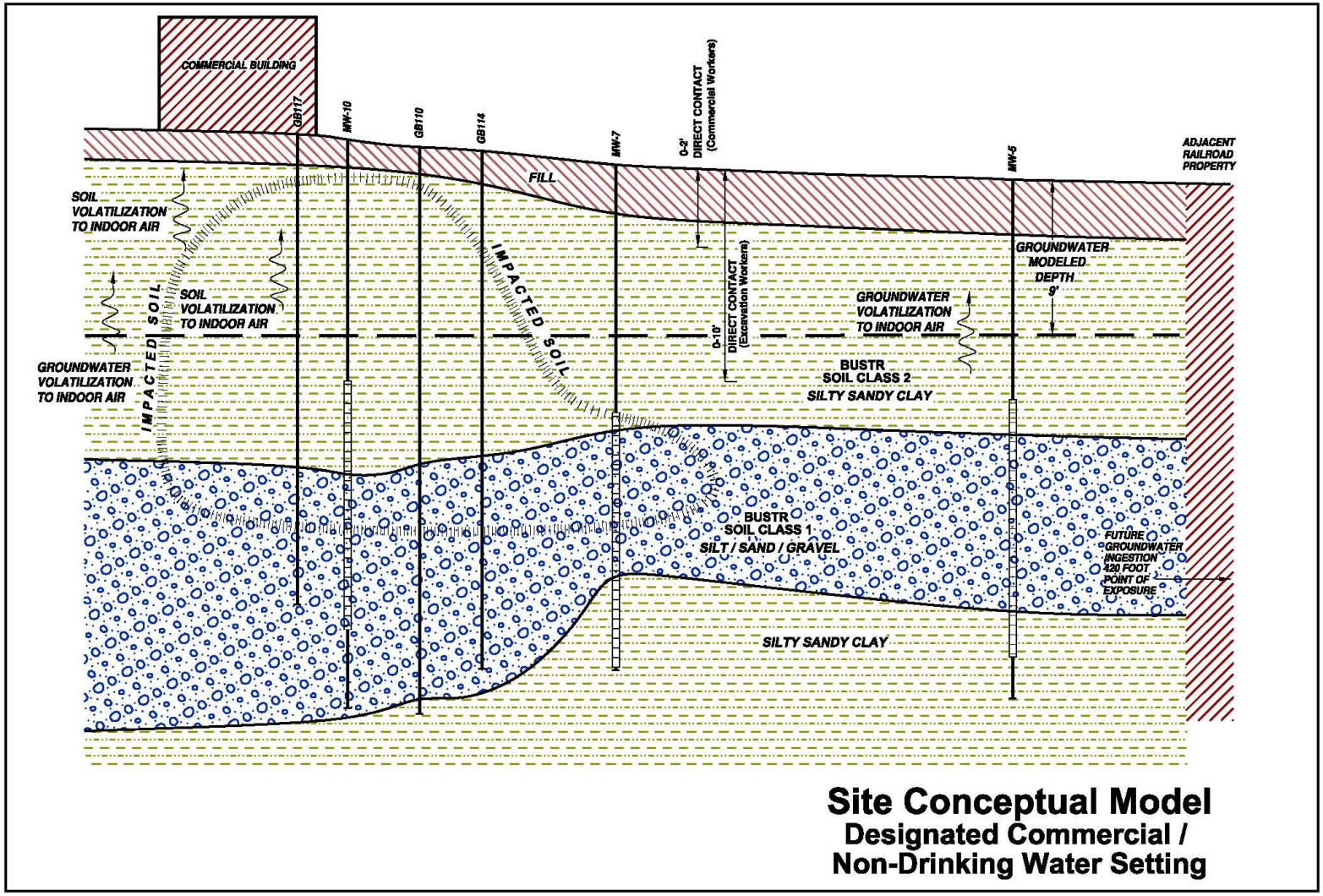
MW-10 Remedial Action

- Due to rebound observed in the groundwater from MW-10, additional remedial actions were required
- Risk based corrective actions were utilized that included institutional controls (deed restriction preventing groundwater consumption and industrial property use only)
- Site specific targets levels (SSTLs) were derived for soil and groundwater clean-up levels
- Even though SSTLs were developed through the risk-based process, the 1,1,1-TCA concentration (50 mg/L) in MW-10 exceeded the SSTL

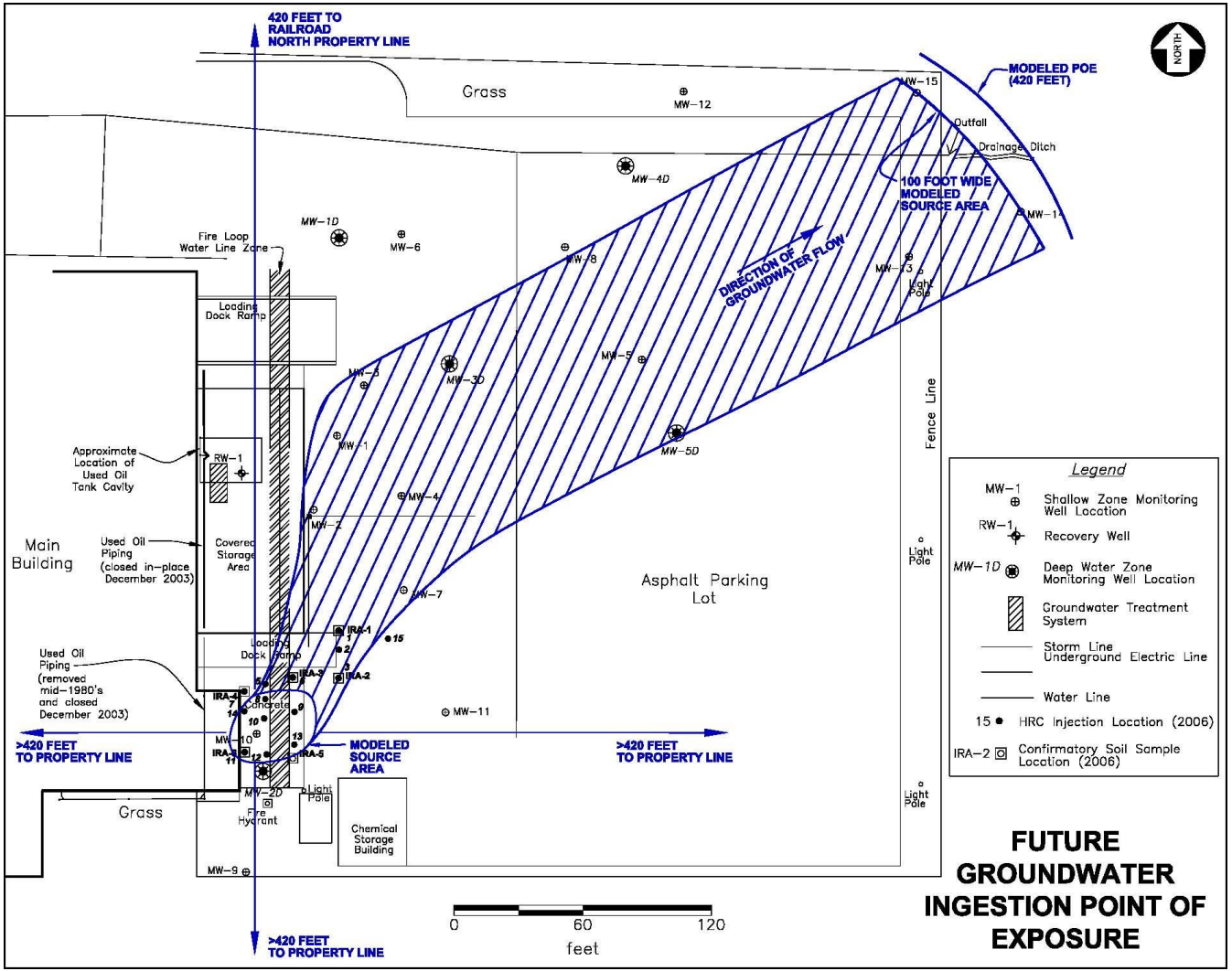
MW-10 Remedial Action (continued)

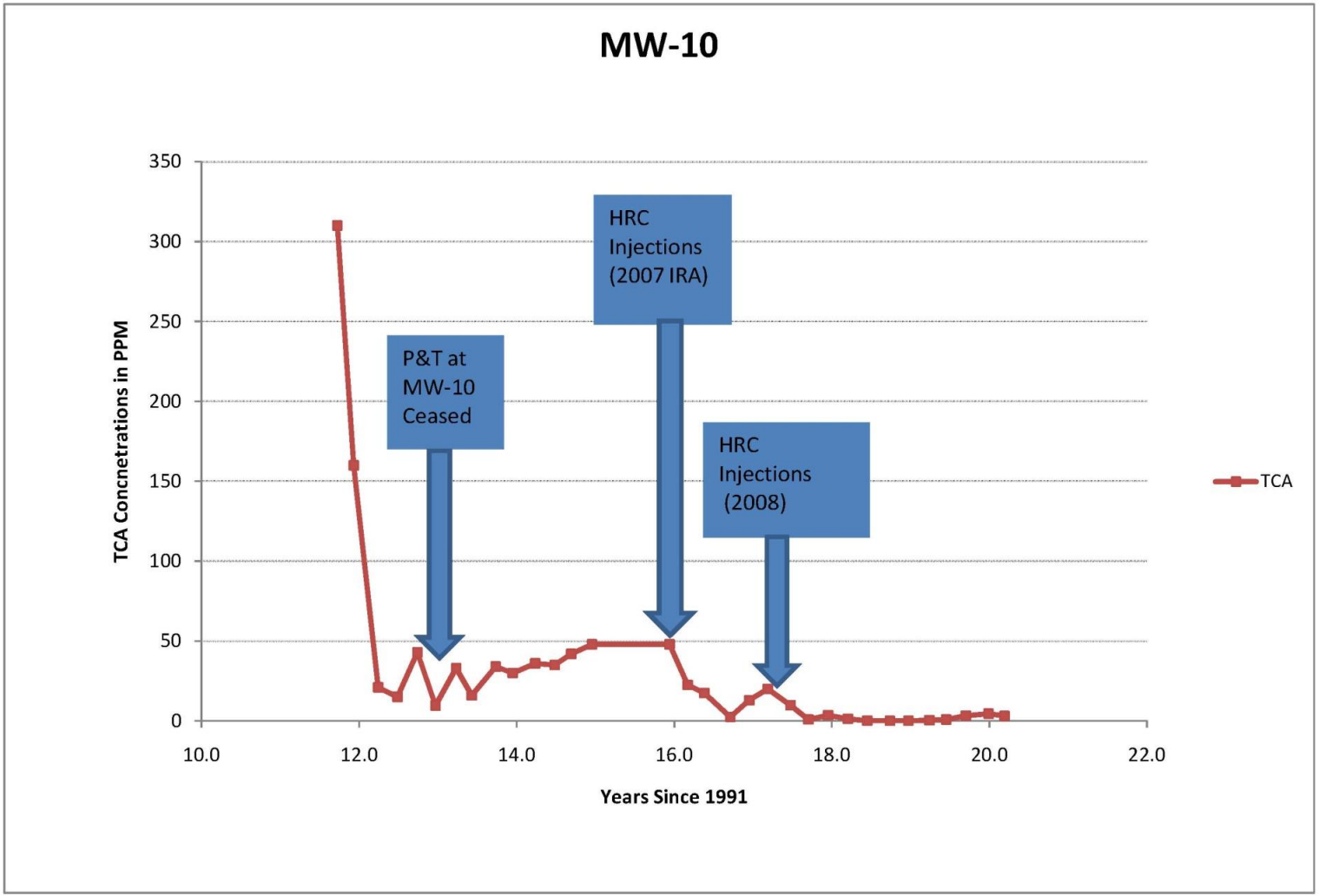
- Reductive dechlorination was selected for the remedial approach to address the groundwater plume emanating from the MW-10 source area
- 1400 pounds of HRC was injected into 20 points in December 2006
- Due to rebound an additional 3200 pounds of a lactate-based carbon substrate (3DME) was injected into 55 points in March 2008

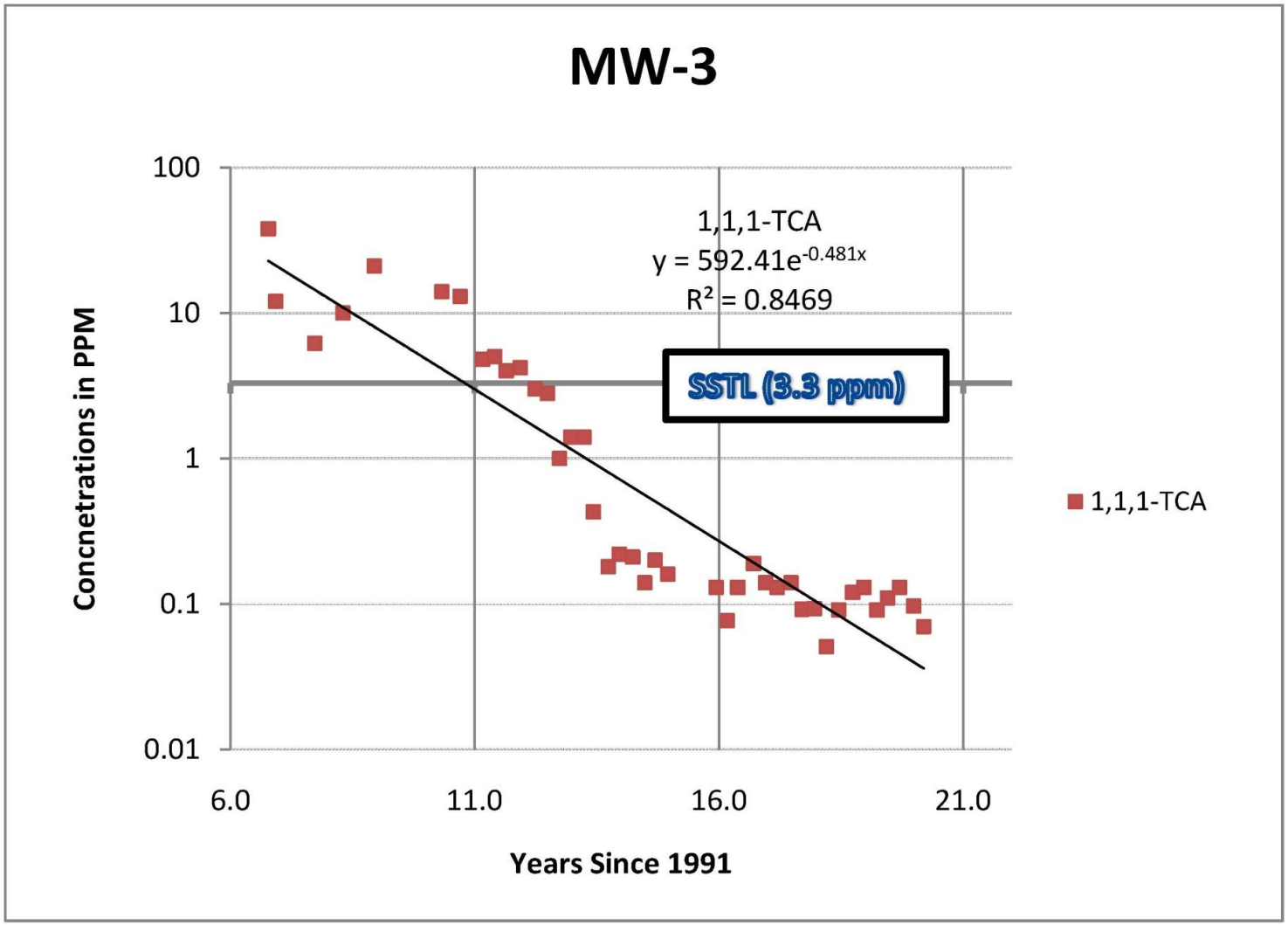

Grass
MW-12
MW-15
NORTH
Outfall
Drainage Ditch
MW-4D
MW-14
MW-1D
MW-6
MW-8
MW-13
Fire Loop
Water Line Zone
Light Pole
Loading Dock Ramp
MW-3
MW-3D
MW-5
MW-13 AREA
MW-5/MW-13 AREA
MW-1/MW-2 AREA
MW-4/MW-5 AREA
MW-5D
Approximate Location of Used Oil Tank Cavity
RW-1
MW-4
Used Oil Piping (closed in-place December 2003)
Covered Storage Area
MW-2
Main Building
Asphalt Parking Lot
MW-7
NORTH AREA
Loading Dock Ramp
Used Oil Piping (removed mid-1980's and closed December 2003)
Concrete
MW-10
SOUTH AREA
MW-11
Fence Line
MW-2D
Fire Hydrant
Grass
Chemical Storage Building
MW-9
Legend
MW-1 Shallow Zone Monitoring Well Location
RW-1 Recovery Well
MW-1D Deep Water Zone Monitoring Well Location
STM Storm Line
UE Underground Electric Line
W Water Line
HRC-A Points
0
60
120
feet
INJECTION POINTS



Site Conceptual Model
Designated Commercial / Non-Drinking Water Setting


420 FEET TO RAILROAD NORTH PROPERTY LINE
NORTH
MODELED POE (420 FEET)
Grass
MW-12
MW-15
Outfall
Drainage Ditch
MW-4D
100 FOOT WIDE MODELED SOURCE AREA
MW-1D
MW-6
MW-8
MW-13
Light Pole
Fire Loop Water Line Zone
DIRECTION OF GROUNDWATER FLOW
Loading Dock Ramp
MW-3
MW-3D
MW-5
MW-1
MW-5D
Fence Line
Approximate Location of Used Oil Tank Cavity
RW-1
MW-4
MW-2
Main Building
Used Oil Piping (closed in-place December 2003)
Covered Storage Area
Asphalt Parking Lot
MW-7
IRA-1
IRA-3
IRA-2
Used Oil Piping (removed mid-1980's and closed December 2003)
Loading Dock Ramp
Concrete
MW-11
>420 FEET TO PROPERTY LINE
MW-10
IRA-4
IRA-5
MODELED SOURCE AREA
>420 FEET TO PROPERTY LINE
MW-2D
Light Pole
Grass
Fire Hydrant
Chemical Storage Building
MW-9
>420 FEET TO PROPERTY LINE
0
60
120
feet
Legend
MW-1 Shallow Zone Monitoring Well Location
RW-1 Recovery Well
MW-1D Deep Water Zone Monitoring Well Location
Groundwater Treatment System
Storm Line
Underground Electric Line
Water Line
15 HRC Injection Location (2006)
IRA-2 Confirmatory Soil Sample Location (2006)
FUTURE GROUNDWATER INGESTION POINT OF EXPOSURE


MW-10
TCA Concnetrations in PPM
350
300
250
200
150
100
50
0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
Years Since 1991
P&T at MW-10 Ceased
HRC Injections (2007 IRA)
HRC Injections (2008)
TCA


MW-3
100
10
1
0.1
0.01
Concnetrations in PPM
1,1,1-TCA
y = 592.41e-0.481x
R² = 0.8469
SSTL (3.3 ppm)
1,1,1-TCA
6.0
11.0
16.0
21.0
Years Since 1991

Summary

- Laboratory Data Guided the Remediation Project
- Work with Site hydrogeology
- Avoid rebound issues by proper dosing (amount and frequency)
- Be persistent with recommendations