Case Study: *In-situ* Chemical Oxidation of TCE using Potassium Permanganate

for the

Minnesota Ground Water Association

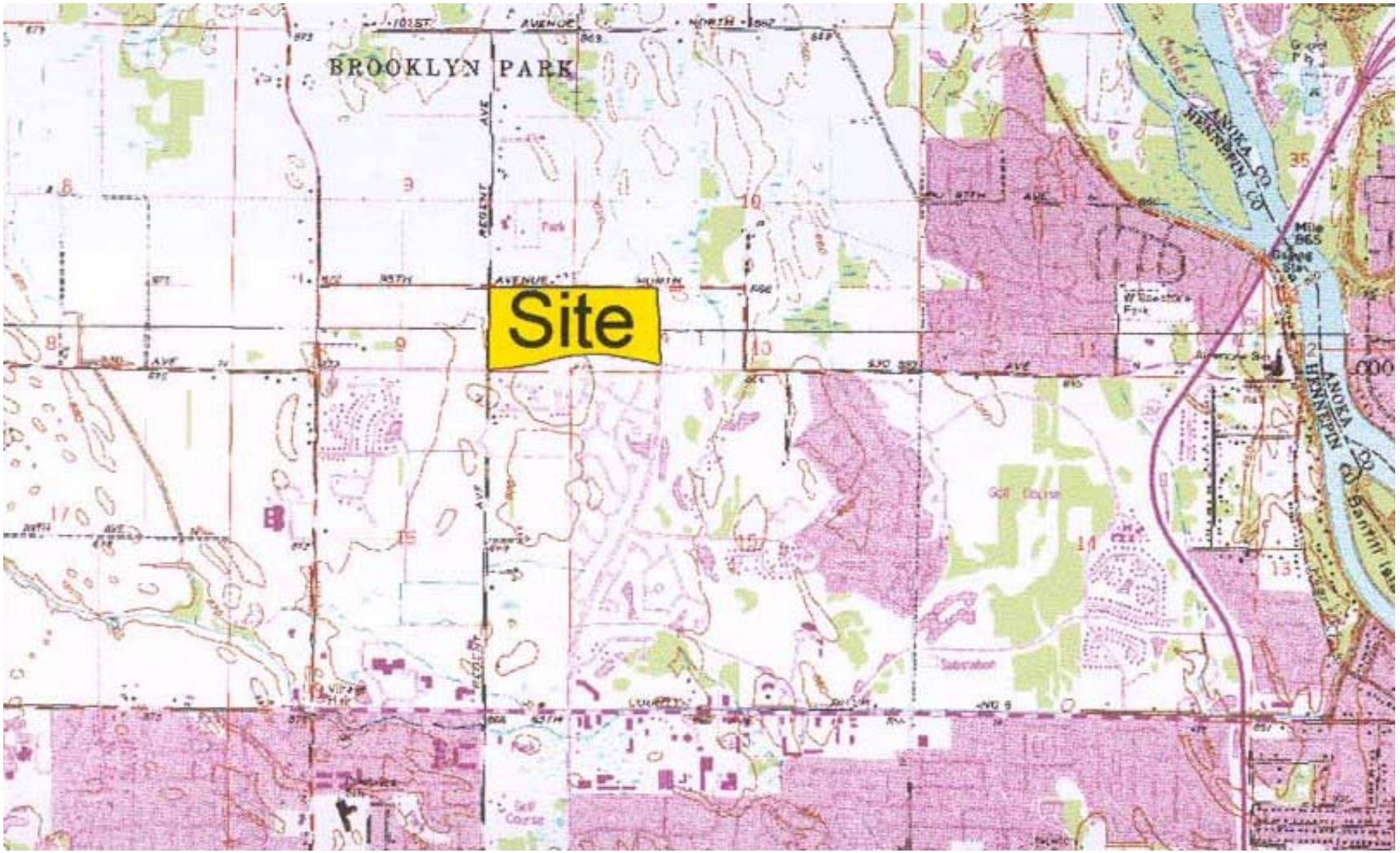
by

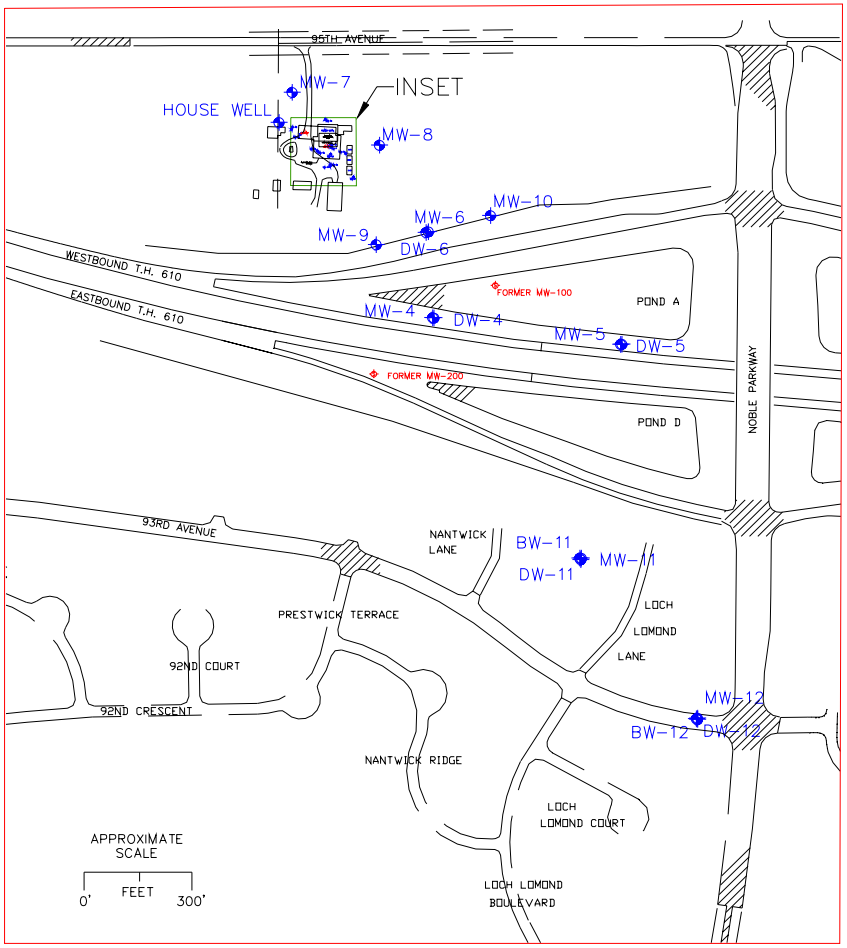
Mark D. Millsop, P.G., Millsop Associates, Inc.

Richard W. Pennings, P.E., GME Consultants, Inc.

Overview of Presentation

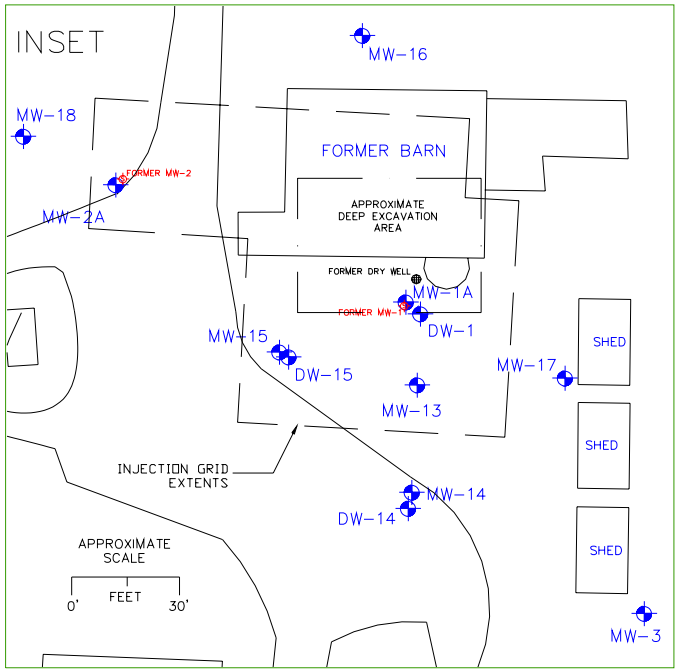
- Site Description
  - History
  - Setting
  - TCE Plume Geometry
  - Hydrogeology
  - Potential Receptors
- Assessed Remedial Alternatives
  - Natural Attenuation
  - Air Sparging/Soil Vapor Extraction (SVE)
  - Pump and Treat
  - Source Reduction
- Source Reduction via Excavation and Oxidation
  - Procedures
  - Results
  - Conclusions


BROOKLYN PARK
Site



LEGEND

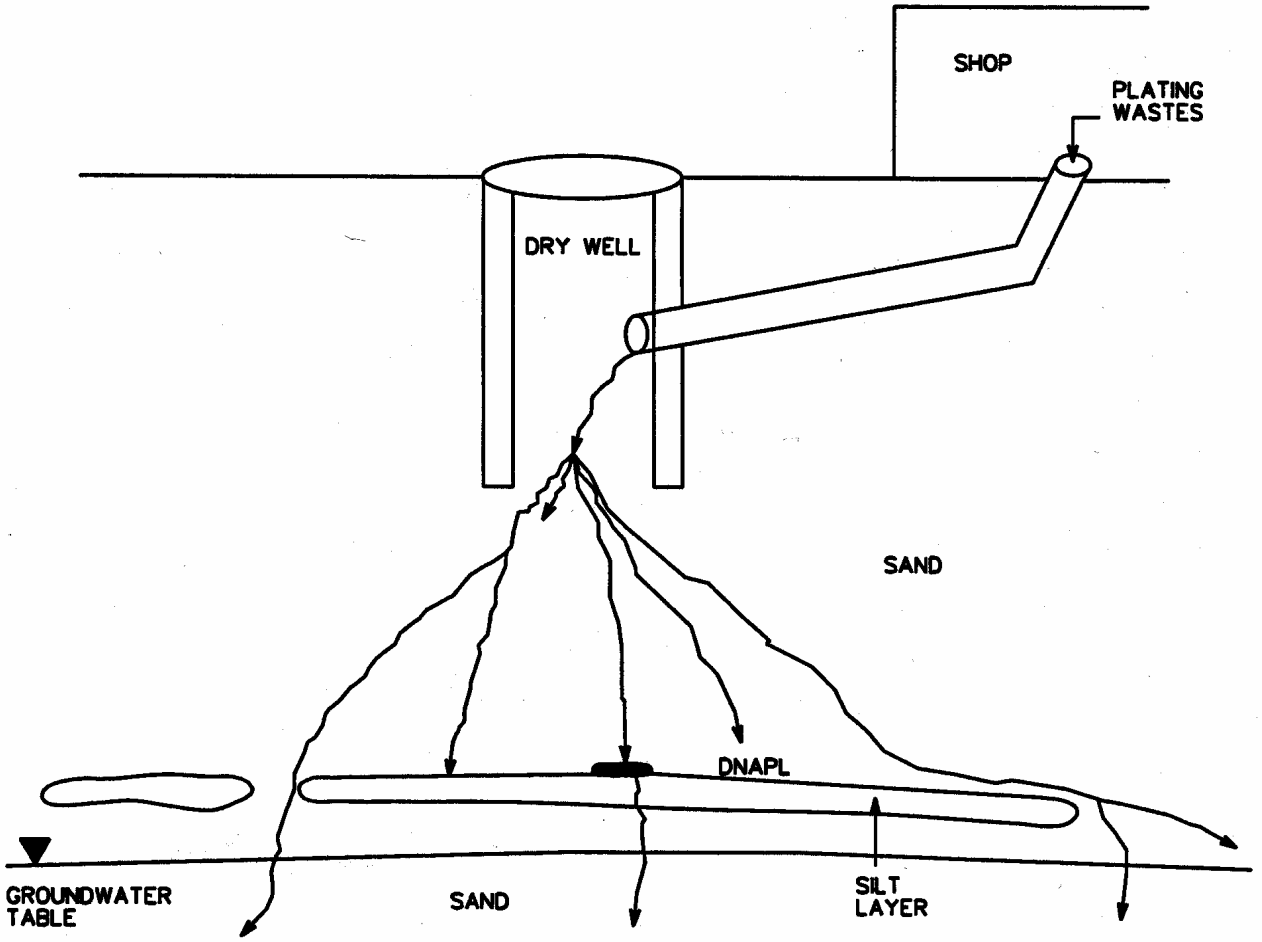
- MONITORING WELL
- SEALED MONITORING WELL
- MW – SHALLOW MONITORING WELL
- DW – DEEP MONITORING WELL
- BW – BASAL WELL

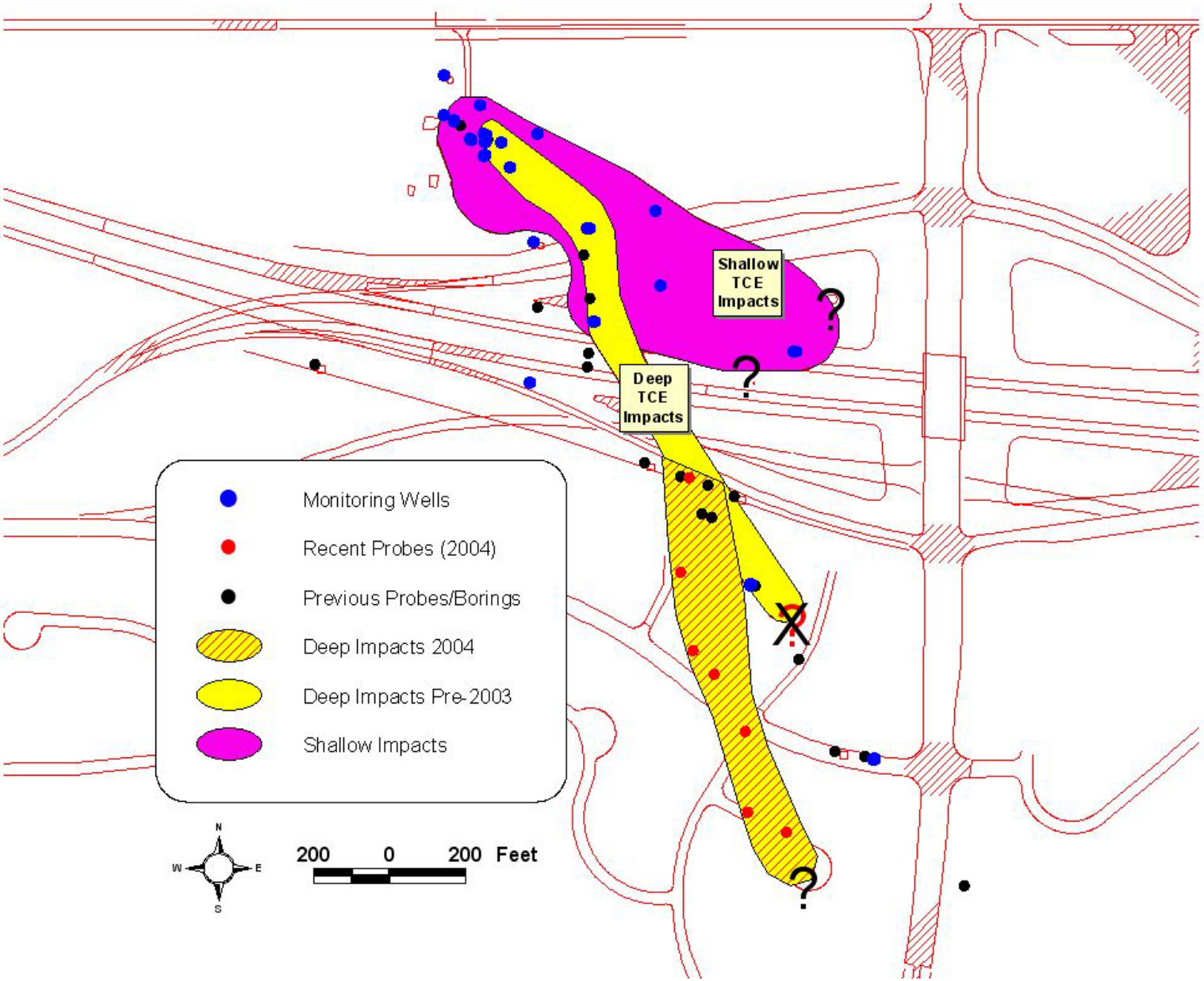


SITE DIAGRAMS

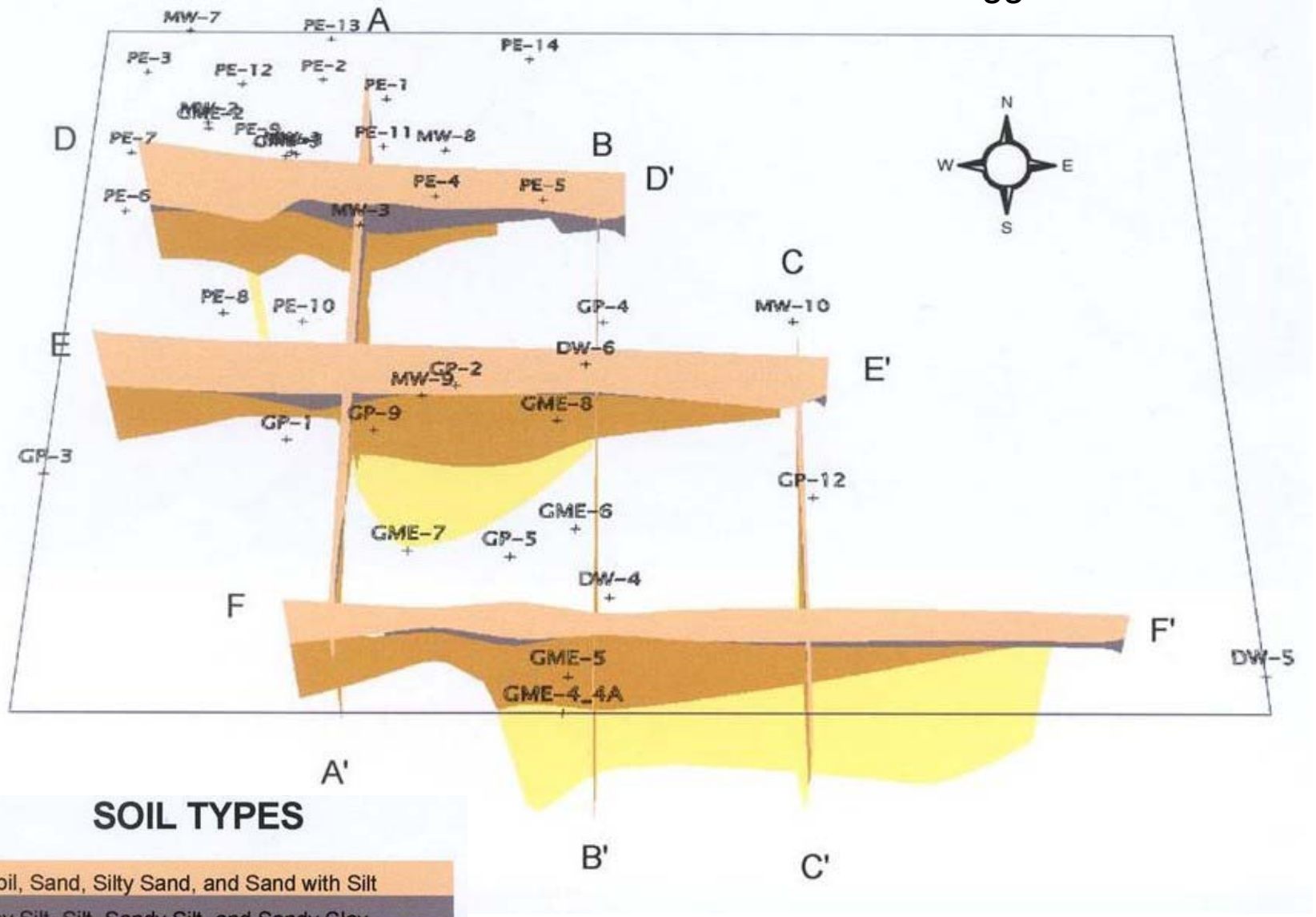

Treflan

CONCEPTUAL DNAPL MIGRATION



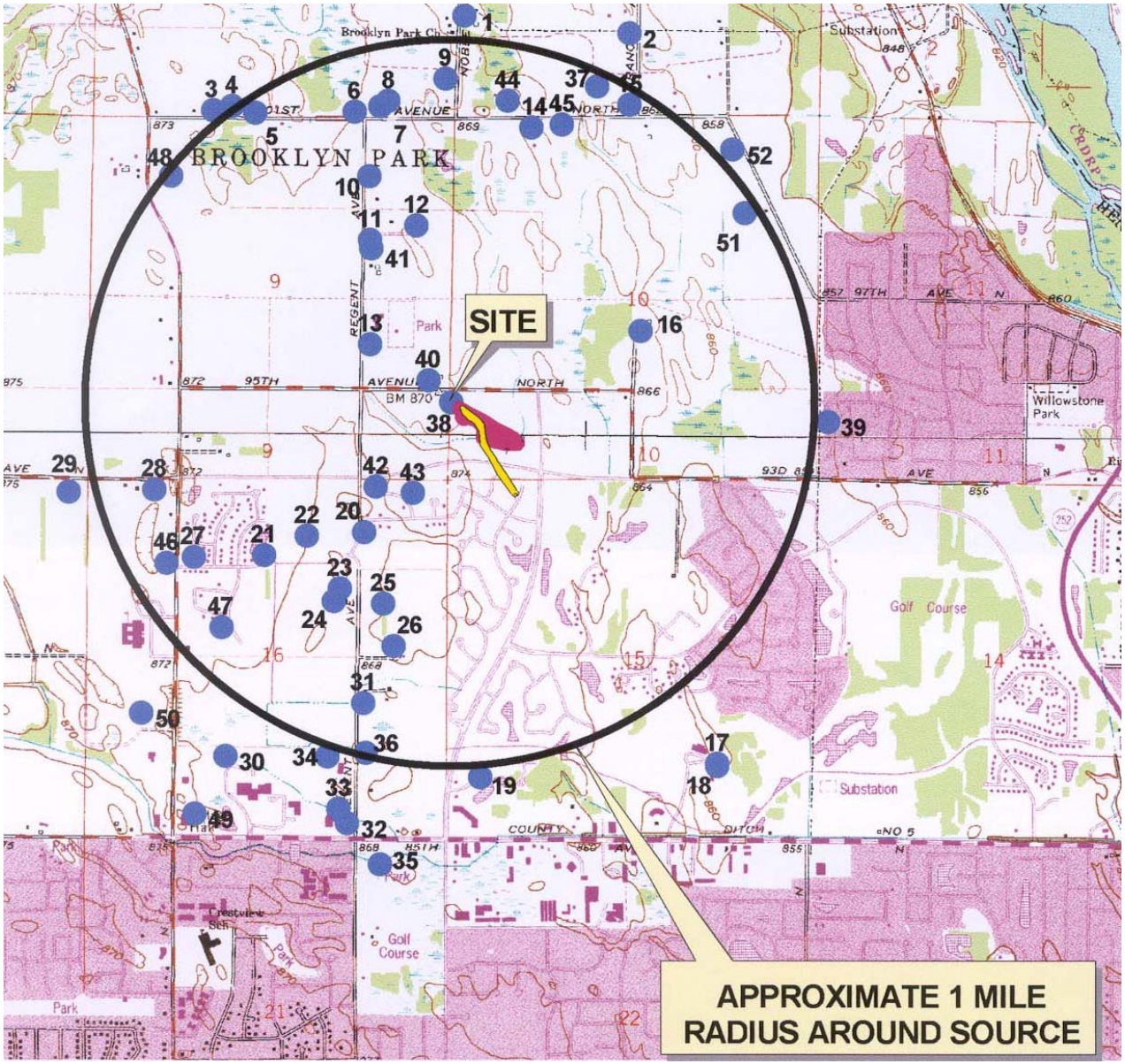

Shallow TCE Impacts
Deep TCE Impacts
Monitoring Wells
Recent Probes (2004)
Previous Probes/Borings
Deep Impacts 2004
Deep Impacts Pre-2003
Shallow Impacts
N
W
E
S
200 0 200 Feet

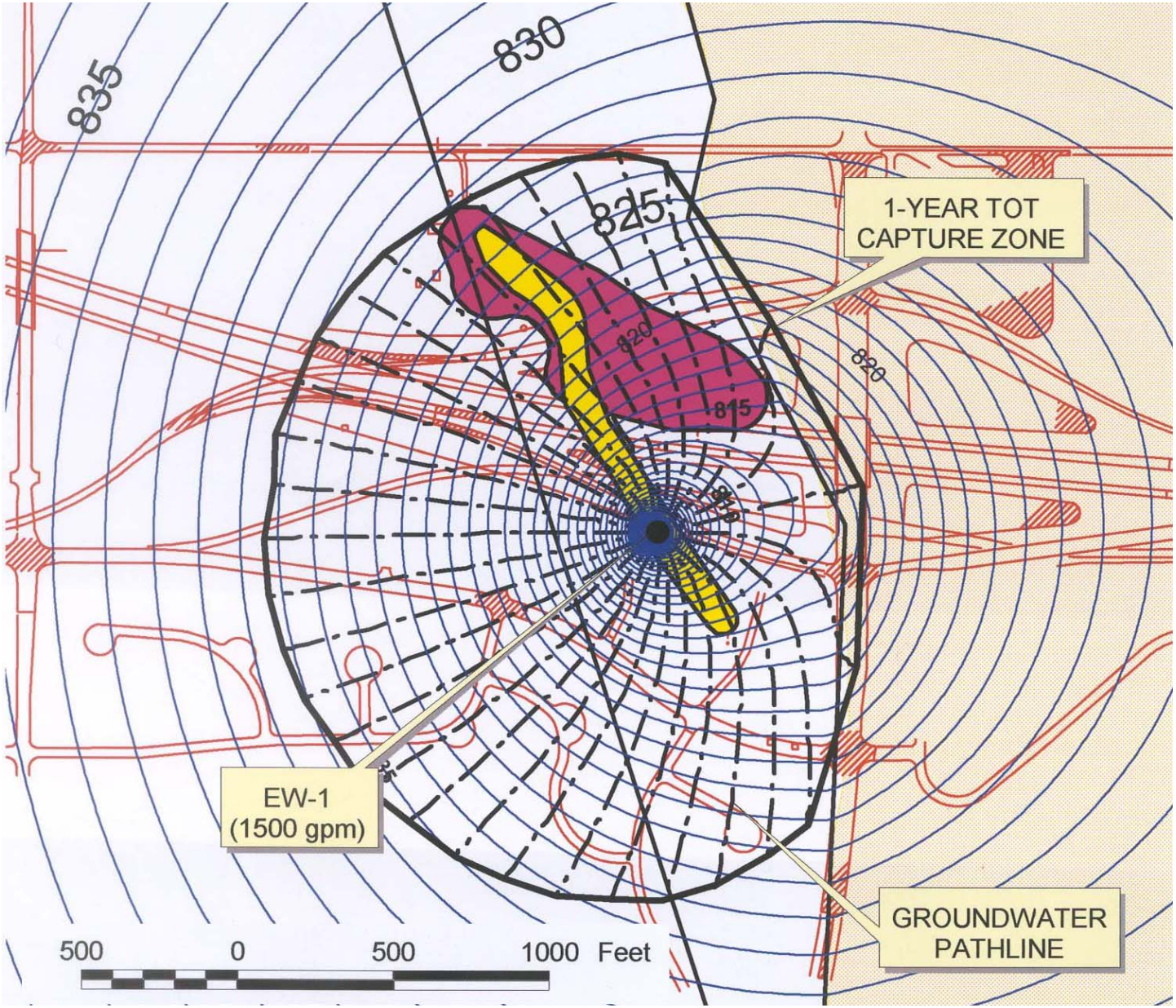
Vertical Exaggeration: 5x

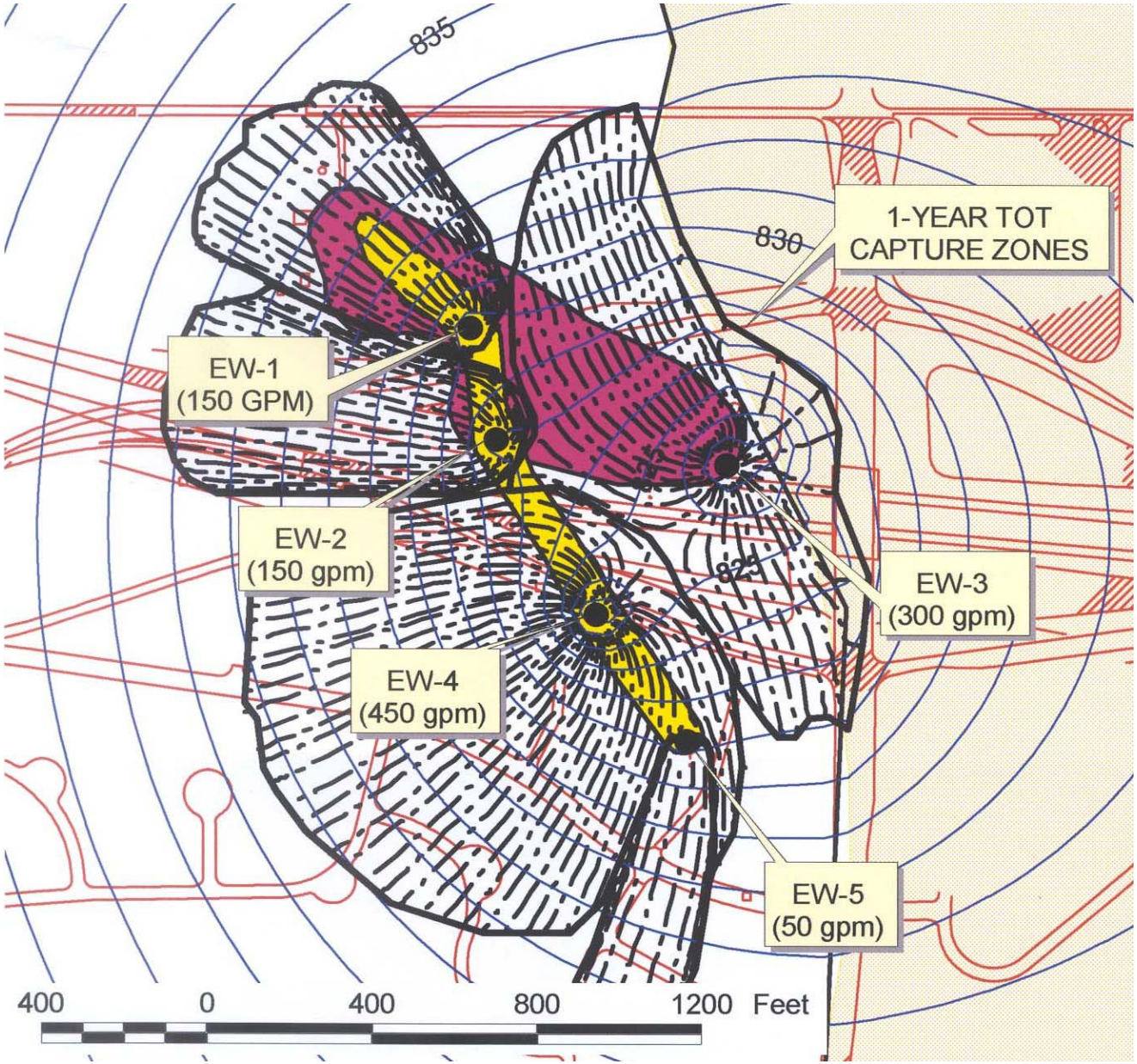


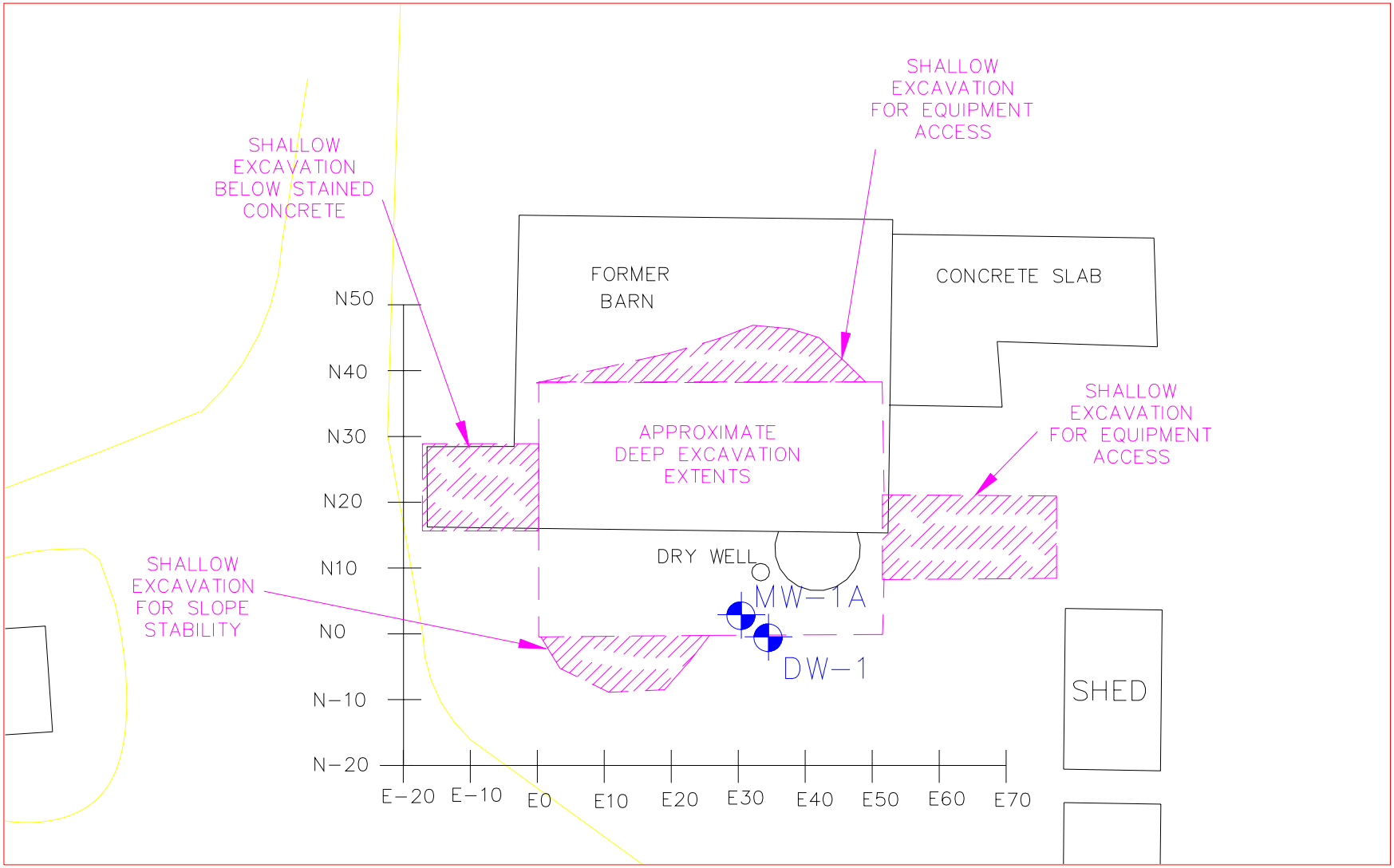
SOIL TYPES

- Topsoil, Sand, Silty Sand, and Sand with Silt
- Clayey Silt, Silt, Sandy Silt, and Sandy Clay
- Silty Sand, Clayey Silty Sand, and Sitly Clayey Sand
- Sand and Sand with Silt


BROOKLYN PARK
SITE
APPROXIMATE 1 MILE
RADIUS AROUND SOURCE
Substation
Willowstone Park
Golf Course
Substation
Golf Course
Park
Park
Crestview Sch
95TH AVENUE NORTH
97TH AVE N
93D AVE
BM 870
REGENT AVE
COUNTY DITCH NO 5

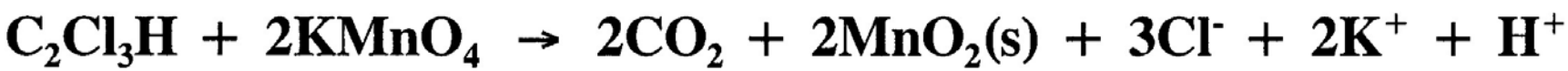

835
830
825
820
815
820
1-YEAR TOT
CAPTURE ZONE
EW-1
(1500 gpm)
GROUNDWATER
PATHLINE
500
0
500
1000 Feet

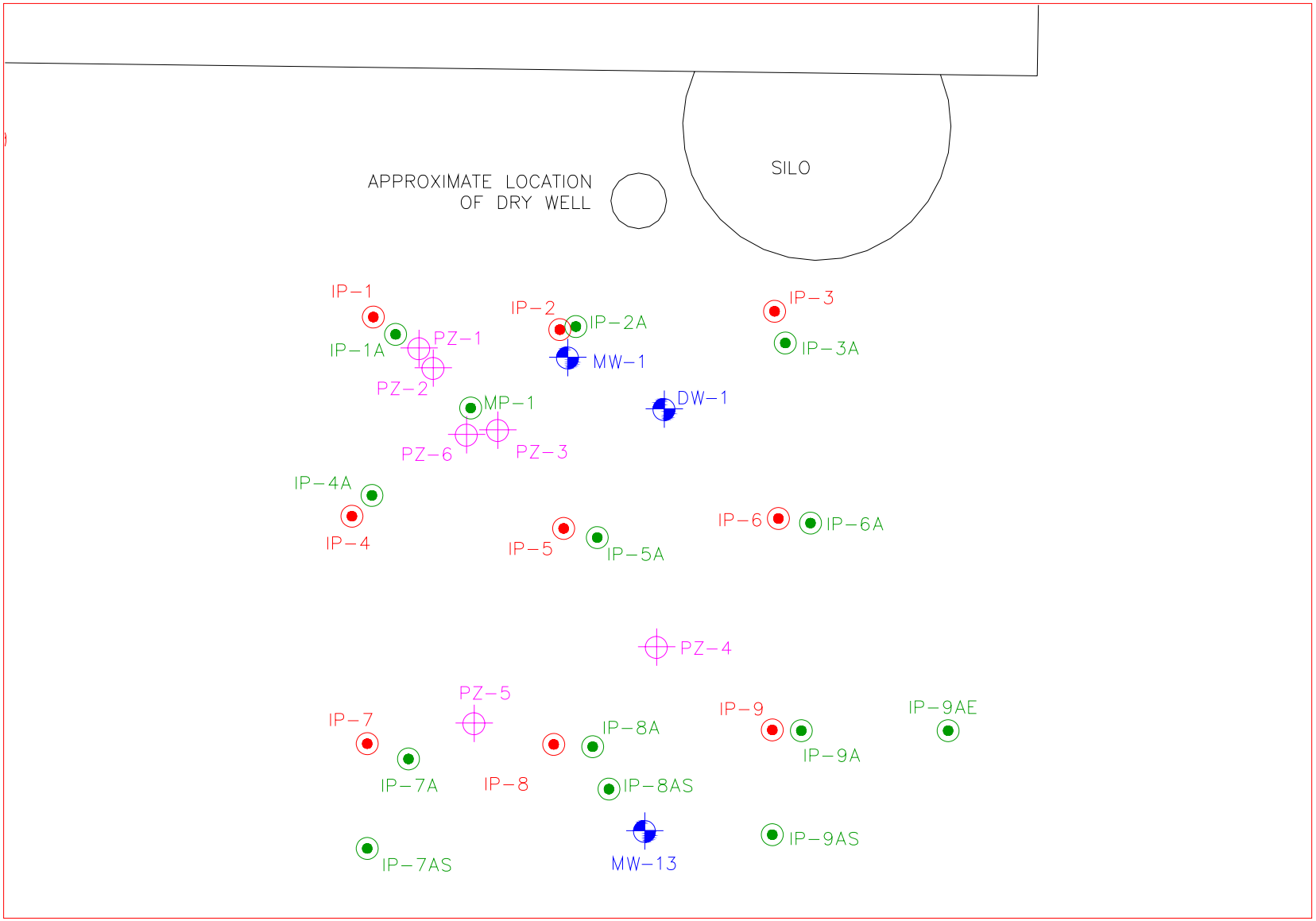

835
830
825
1-YEAR TOT
CAPTURE ZONES
EW-1
(150 GPM)
EW-2
(150 gpm)
EW-3
(300 gpm)
EW-4
(450 gpm)
EW-5
(50 gpm)
400
0
400
800
1200
Feet


SHALLOW EXCAVATION FOR EQUIPMENT ACCESS
SHALLOW EXCAVATION BELOW STAINED CONCRETE
FORMER BARN
CONCRETE SLAB
N50
N40
N30
N20
N10
N0
N-10
N-20
APPROXIMATE DEEP EXCAVATION EXTENTS
SHALLOW EXCAVATION FOR EQUIPMENT ACCESS
DRY WELL
MW-1A
DW-1
SHALLOW EXCAVATION FOR SLOPE STABILITY
SHED
E-20
E-10
E0
E10
E20
E30
E40
E50
E60
E70
0'
FEET
20'
APPROXIMATE EXCAVATION EXTENT
N

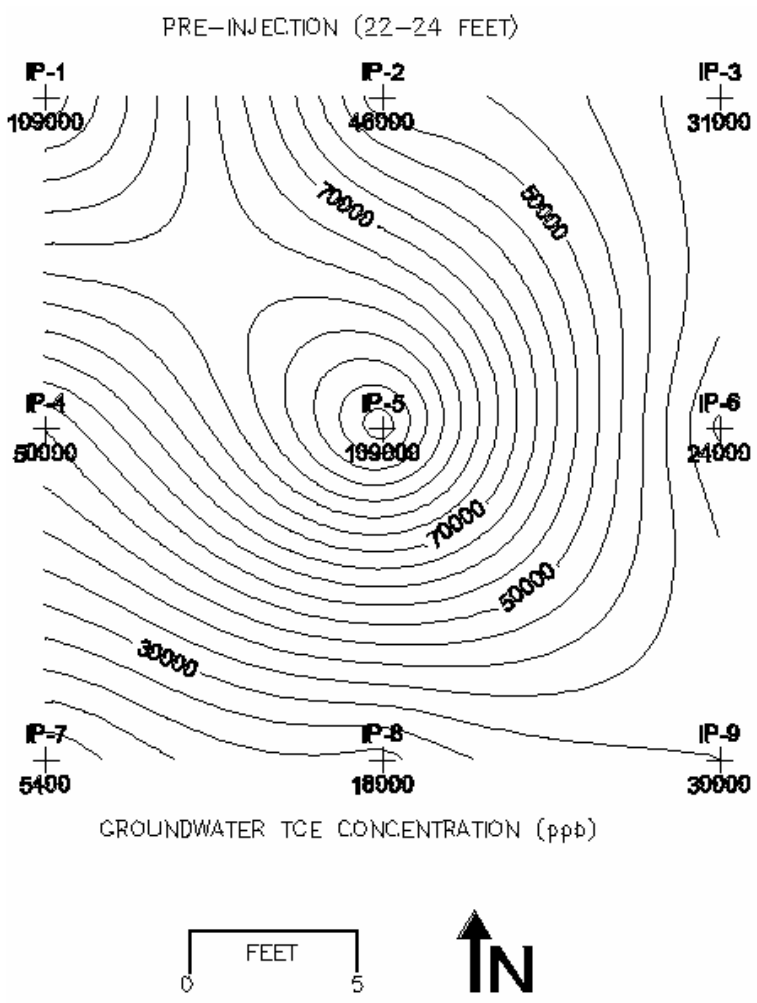
$KMnO_4$ Oxidation of Chlorinated Ethenes

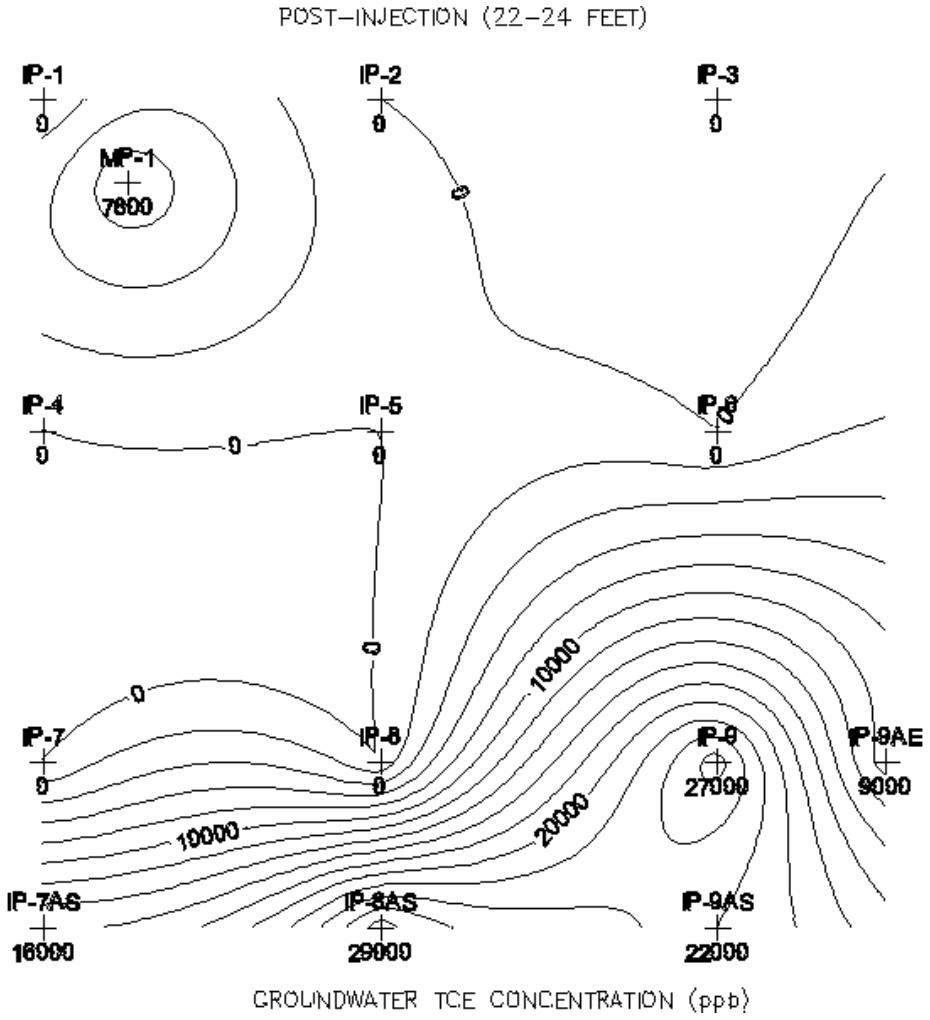
For TCE:

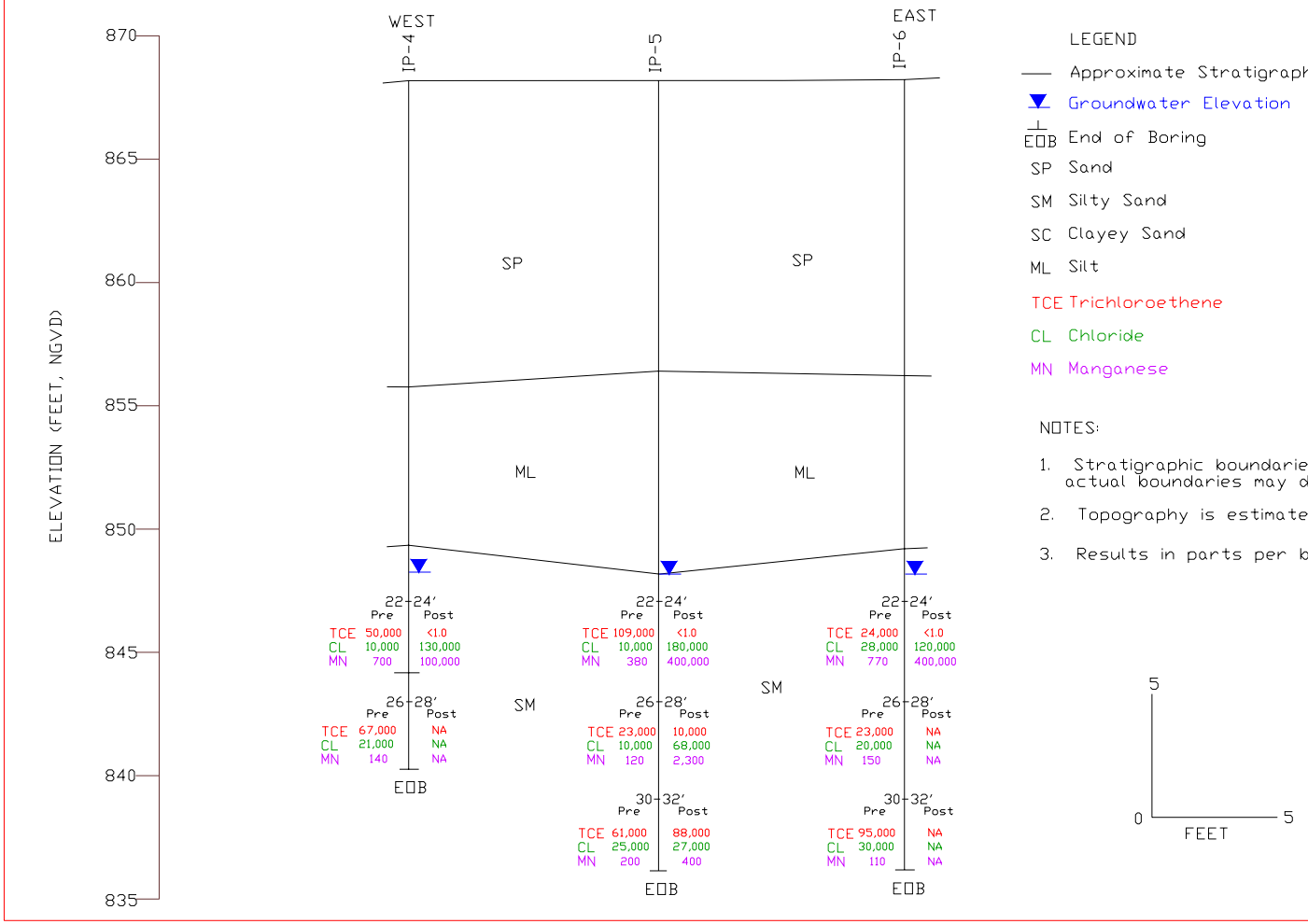




PILOT STUDY SUMMARY


PRE-INJECTION (22-24 FEET)
IP-1
109000
IP-2
46000
IP-3
31000
70000
50000
IP-4
50000
IP-5
109000
IP-6
24000
70000
50000
30000
IP-7
5400
IP-8
18000
IP-9
30000
GROUNDWATER TCE CONCENTRATION (ppb)
FEET
0
5
N


POST-INJECTION (22-24 FEET)
IP-1
0
IP-2
0
IP-3
0
MP-1
7800
0
IP-4
0
0
IP-5
0
IP-6
0
0
0
10000
IP-7
0
0
IP-8
0
IP-9
27000
IP-9AE
9000
10000
20000
IP-7AS
16000
IP-8AS
29000
IP-9AS
22000
GROUNDWATER TCE CONCENTRATION (ppb)

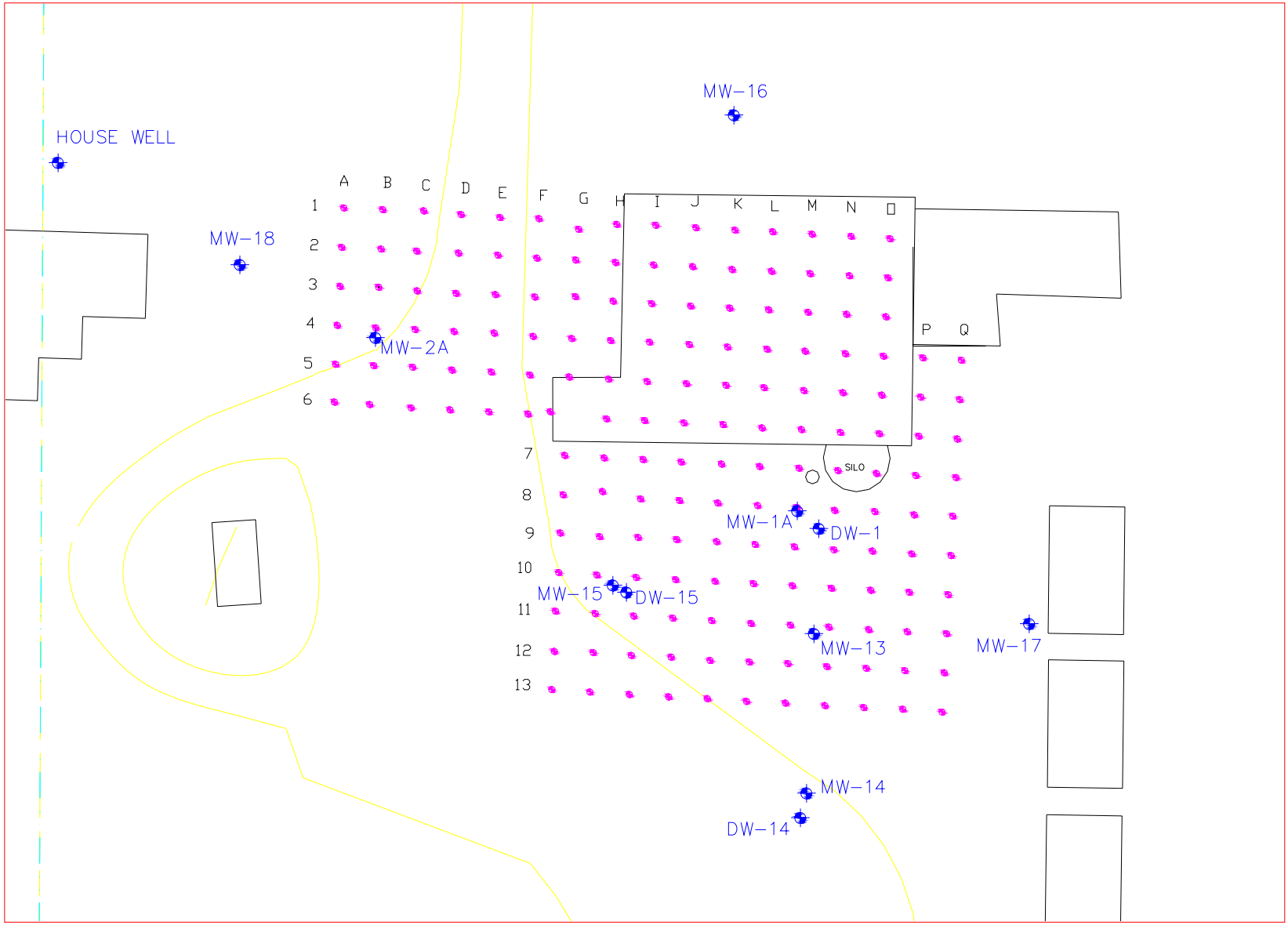


PILOT STUDY RESULTS IN CROSS-SECTION


12 11'01


12'11'01


13 11'01

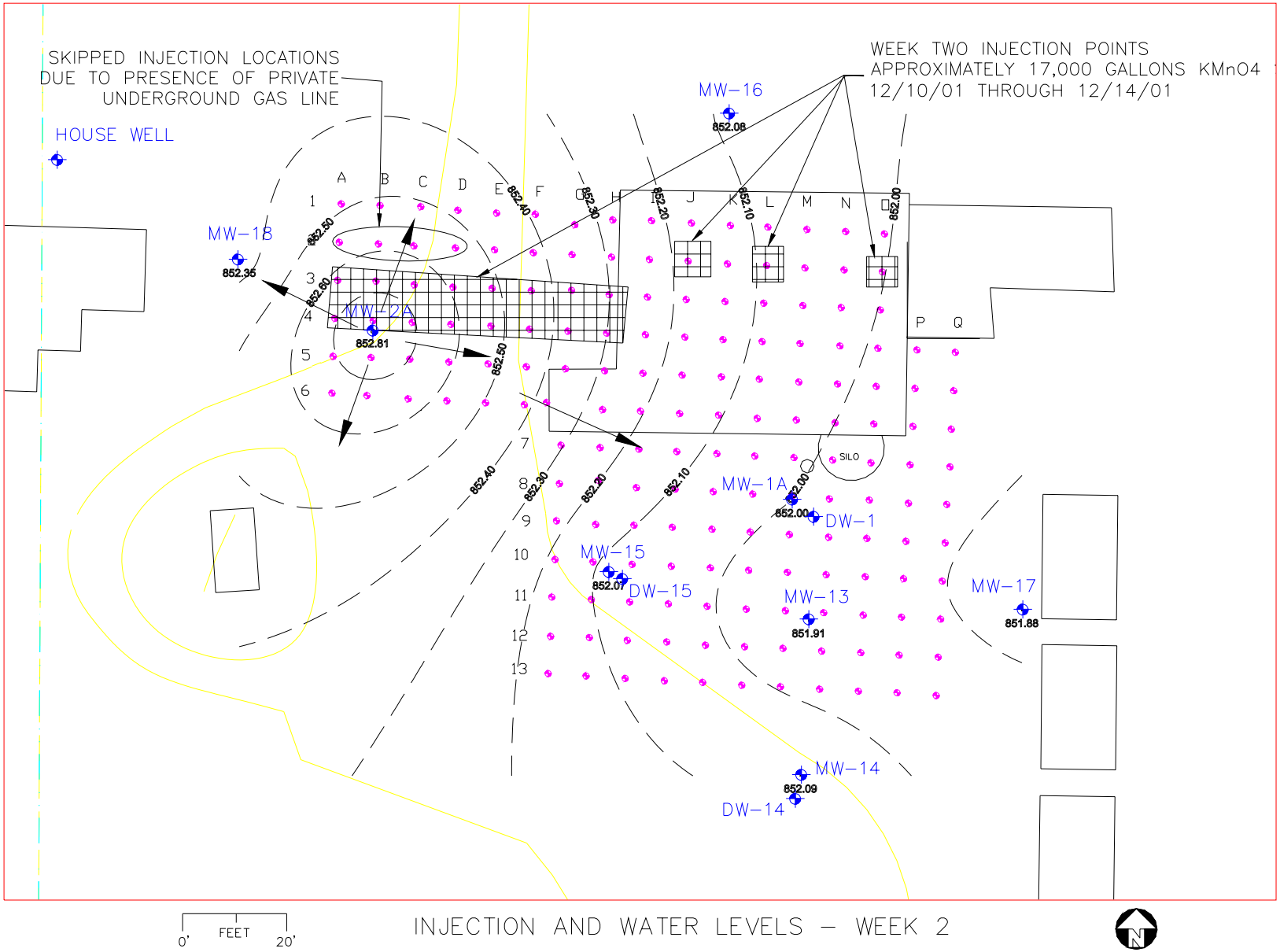


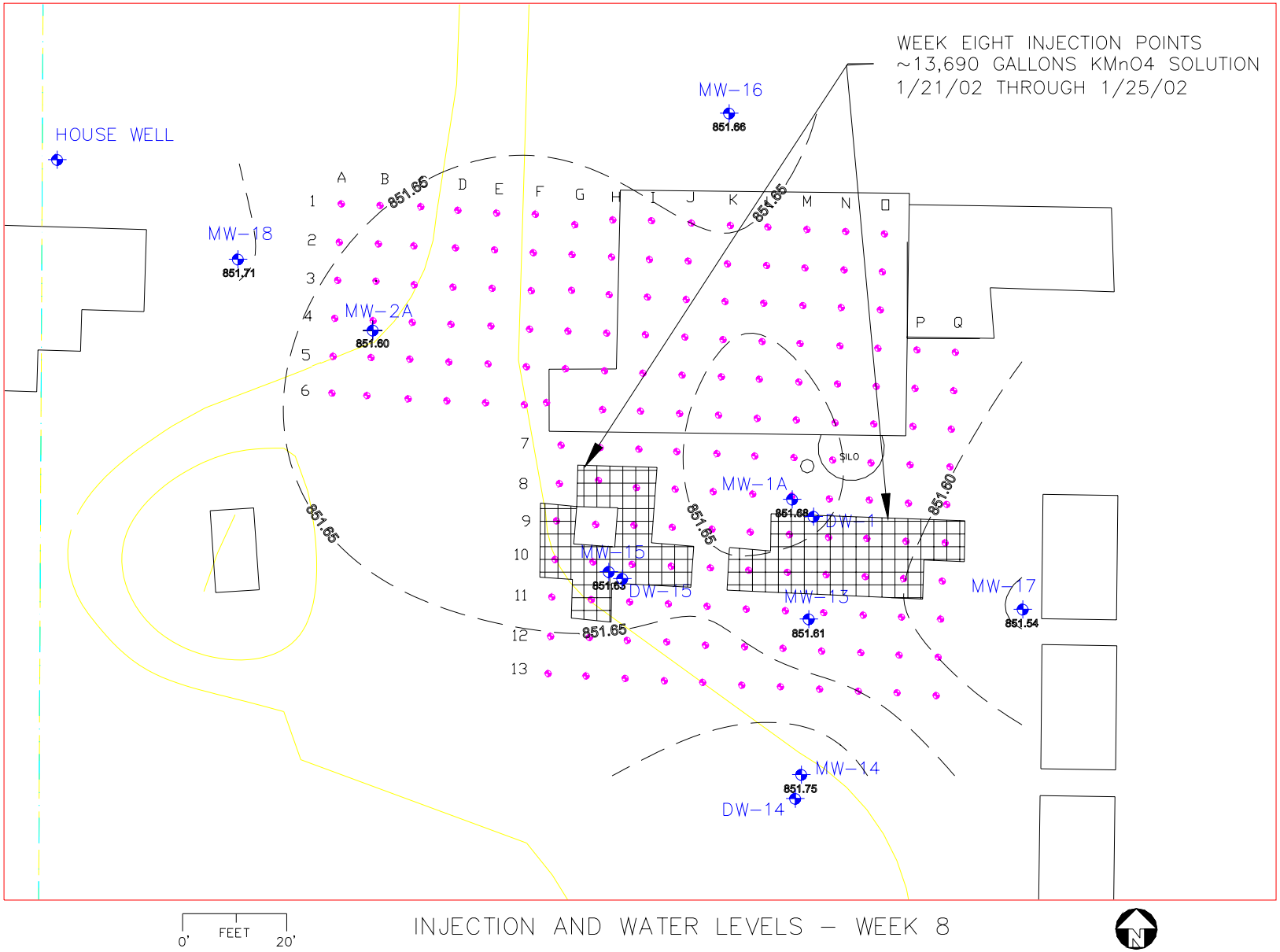
INJECTION AREA DIAGRAM


550
500
450
400
350
300
250
200
FELLING

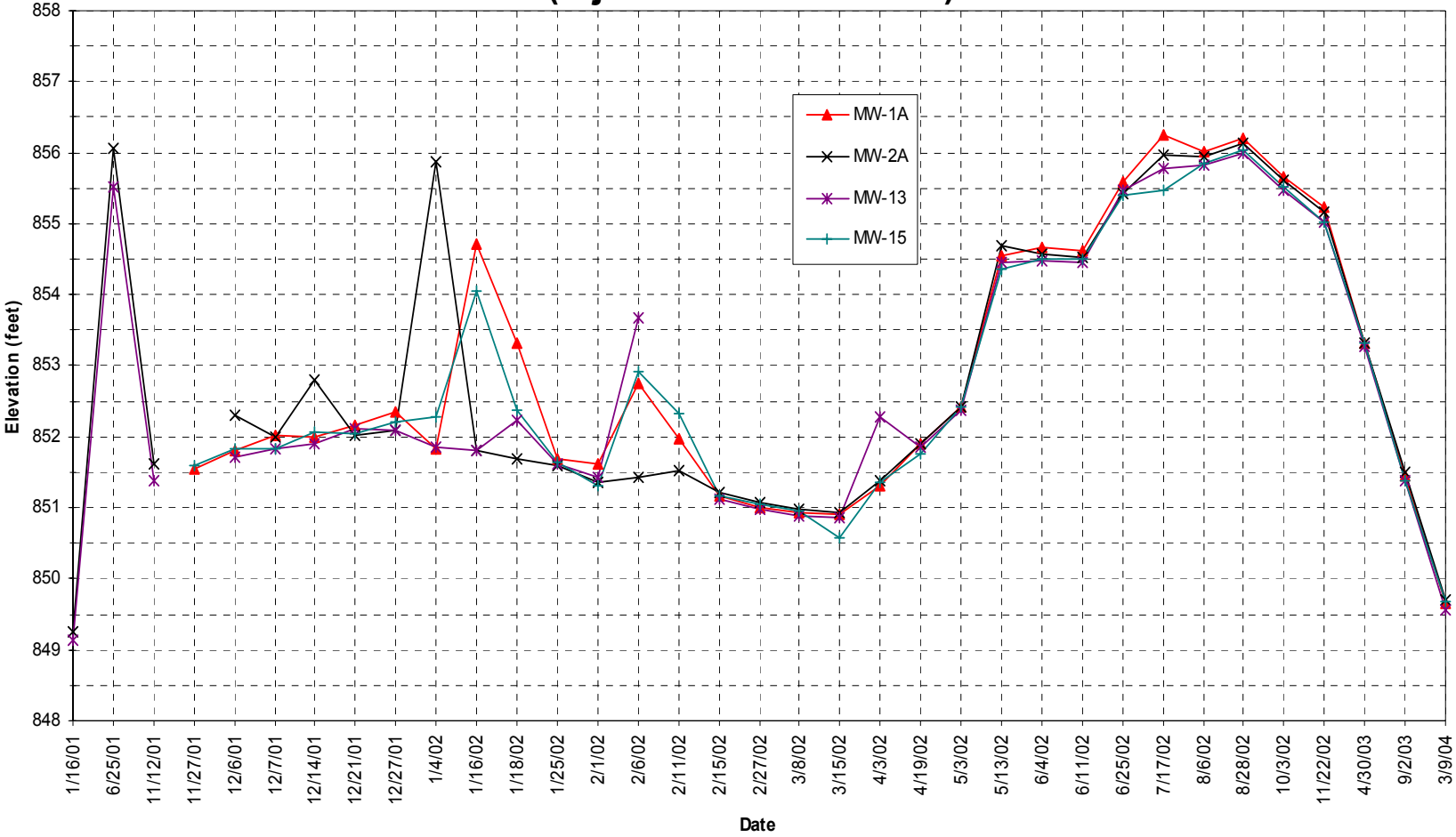

DP800 Injection System

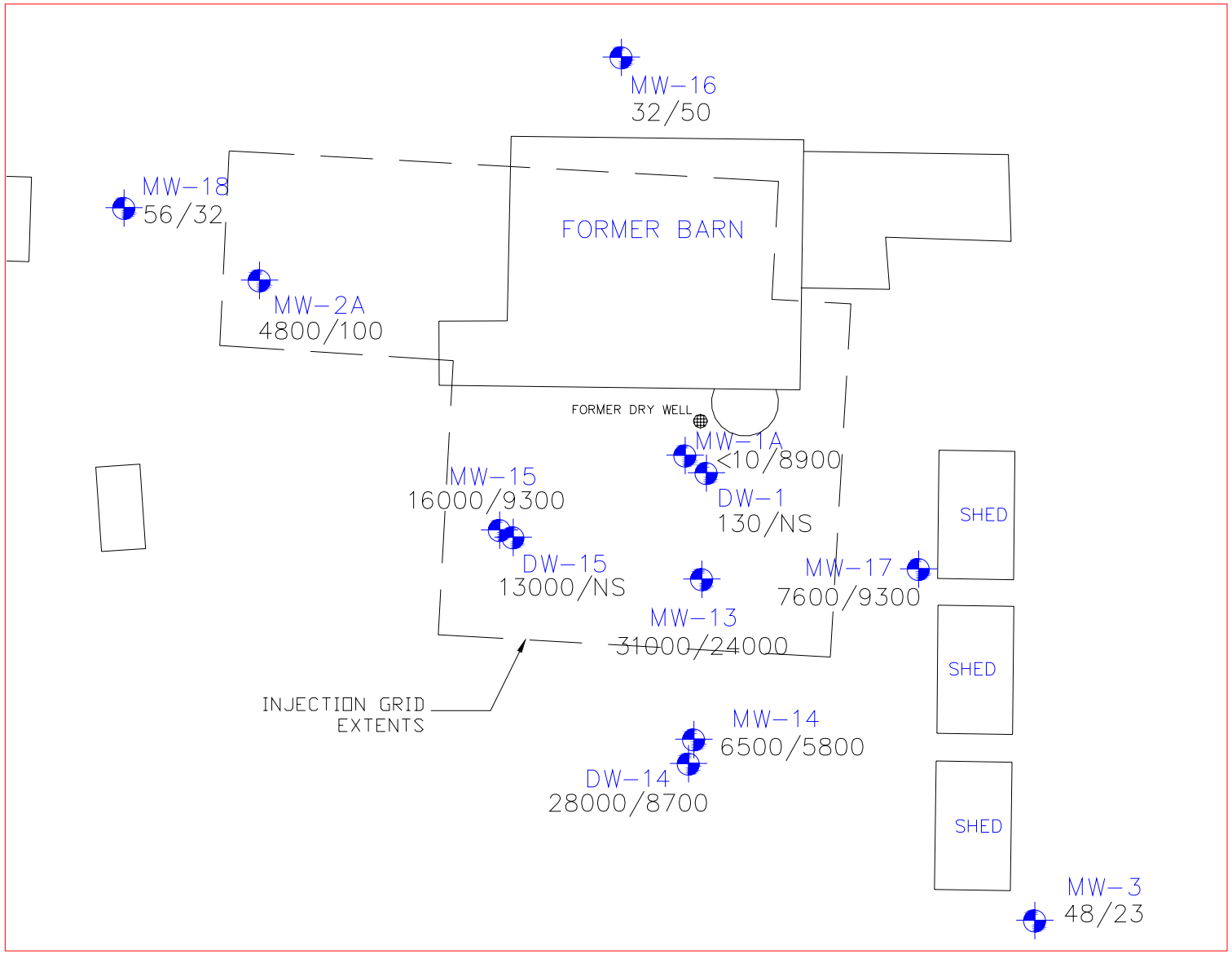

M0175-4

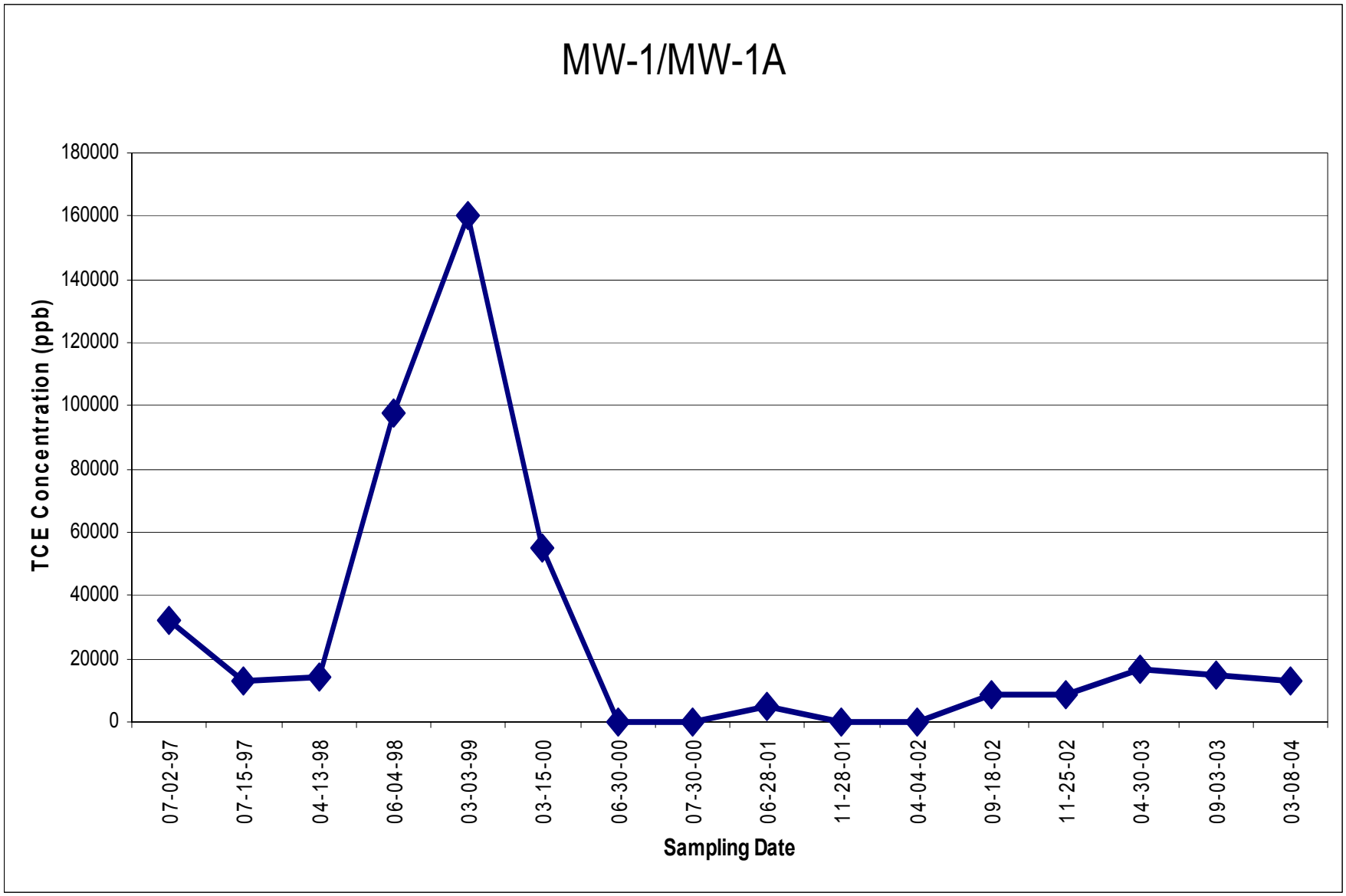

SKIPPED INJECTION LOCATIONS
DUE TO PRESENCE OF PRIVATE
UNDERGROUND GAS LINE
HOUSE WELL
WEEK TWO INJECTION POINTS
APPROXIMATELY 17,000 GALLONS KMnO4
12/10/01 THROUGH 12/14/01
MW-16
852.08
MW-18
852.35
MW-2A
852.81
MW-1A
852.00
DW-1
MW-15
852.07
DW-15
MW-13
851.91
MW-17
851.88
MW-14
852.09
DW-14
SILO
A B C D E F G H J K L M N O P Q
1 3 4 5 6 7 8 9 10 11 12 13
852.50
852.60
852.40
852.30
852.20
852.10
852.00
0' FEET 20'
INJECTION AND WATER LEVELS – WEEK 2
N

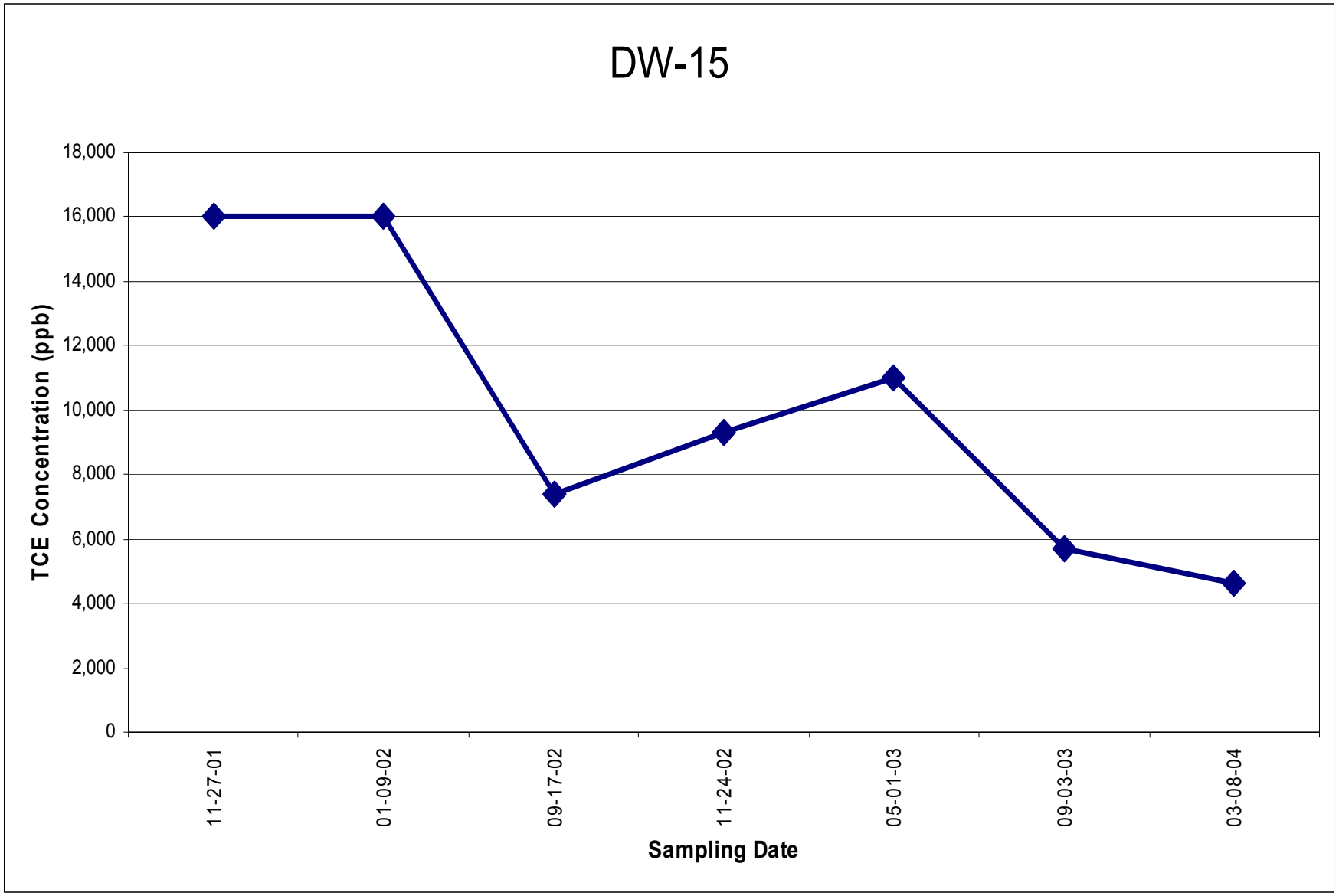

WEEK EIGHT INJECTION POINTS
~13,690 GALLONS KMnO4 SOLUTION
1/21/02 THROUGH 1/25/02
HOUSE WELL
MW-16
851.66
MW-18
851.71
MW-2A
851.60
MW-1A
851.68
DW-1
MW-15
851.63
DW-15
MW-13
851.61
MW-17
851.54
MW-14
851.75
DW-14
SILO
851.65
851.60
A B D E F G H I J K M N O P Q
1 2 3 4 5 6 7 8 9 10 11 12 13
0' FEET 20'
INJECTION AND WATER LEVELS – WEEK 8
N

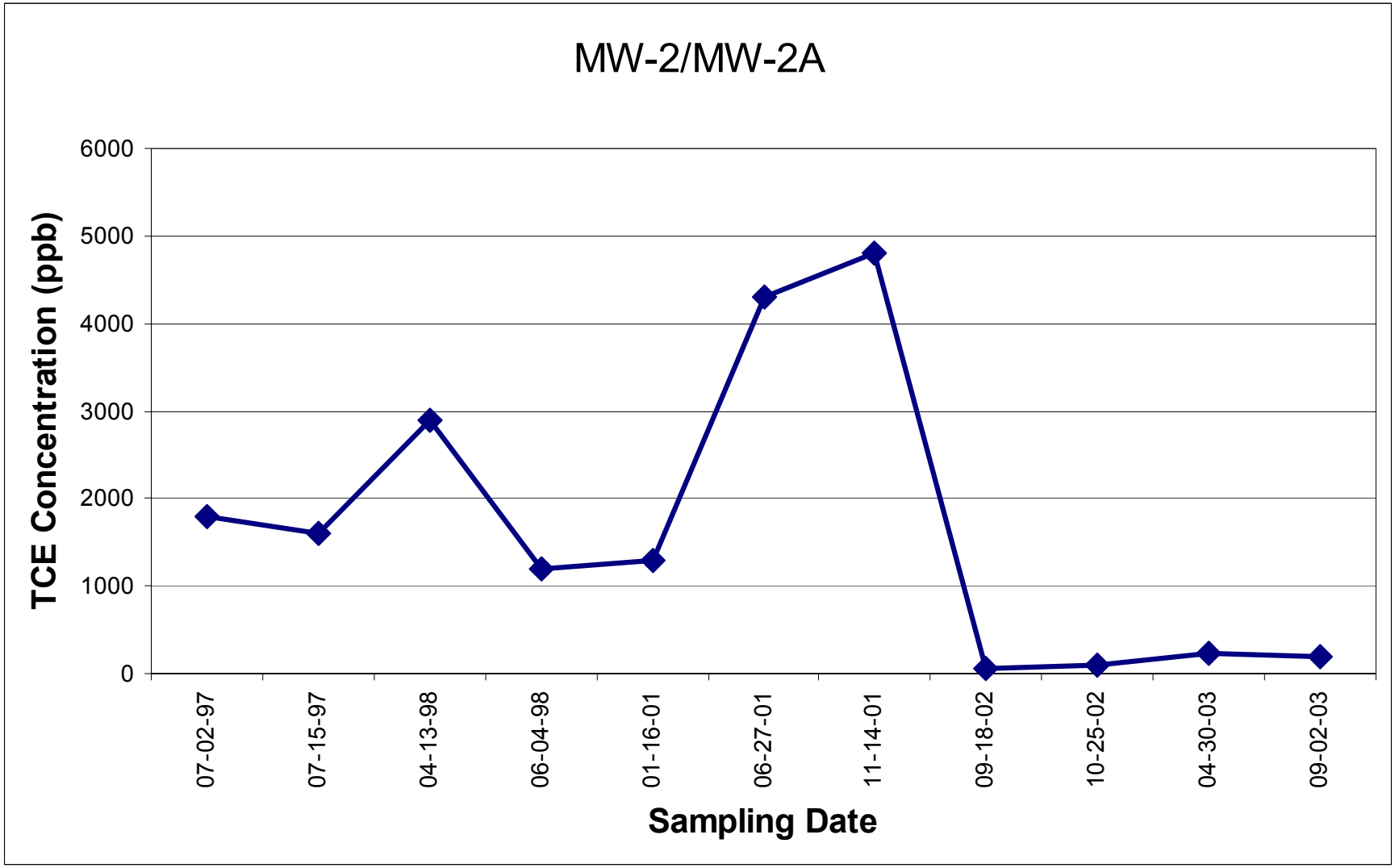
Shallow Monitoring Well Hydrograph
(Injection Grid Interior)

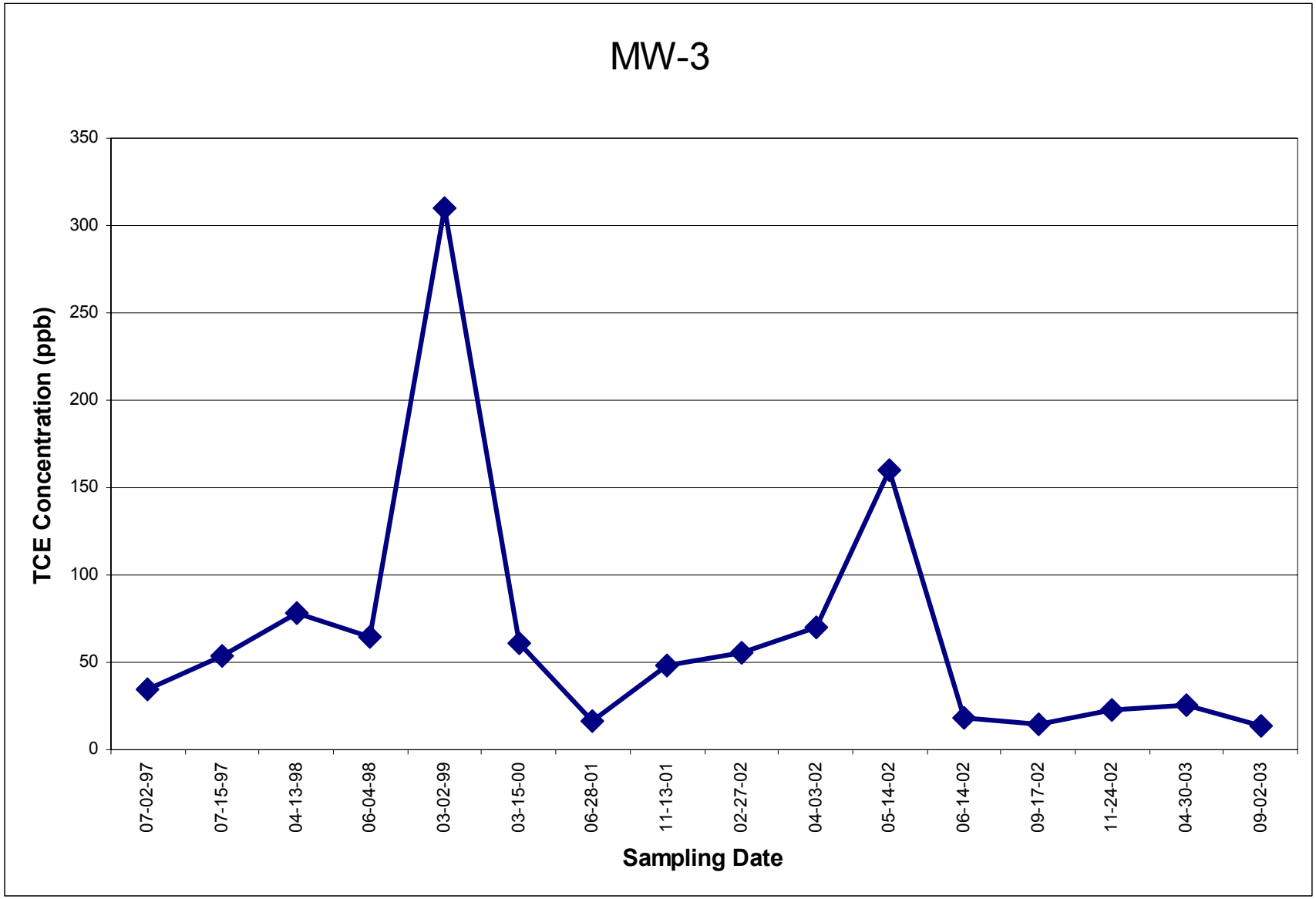


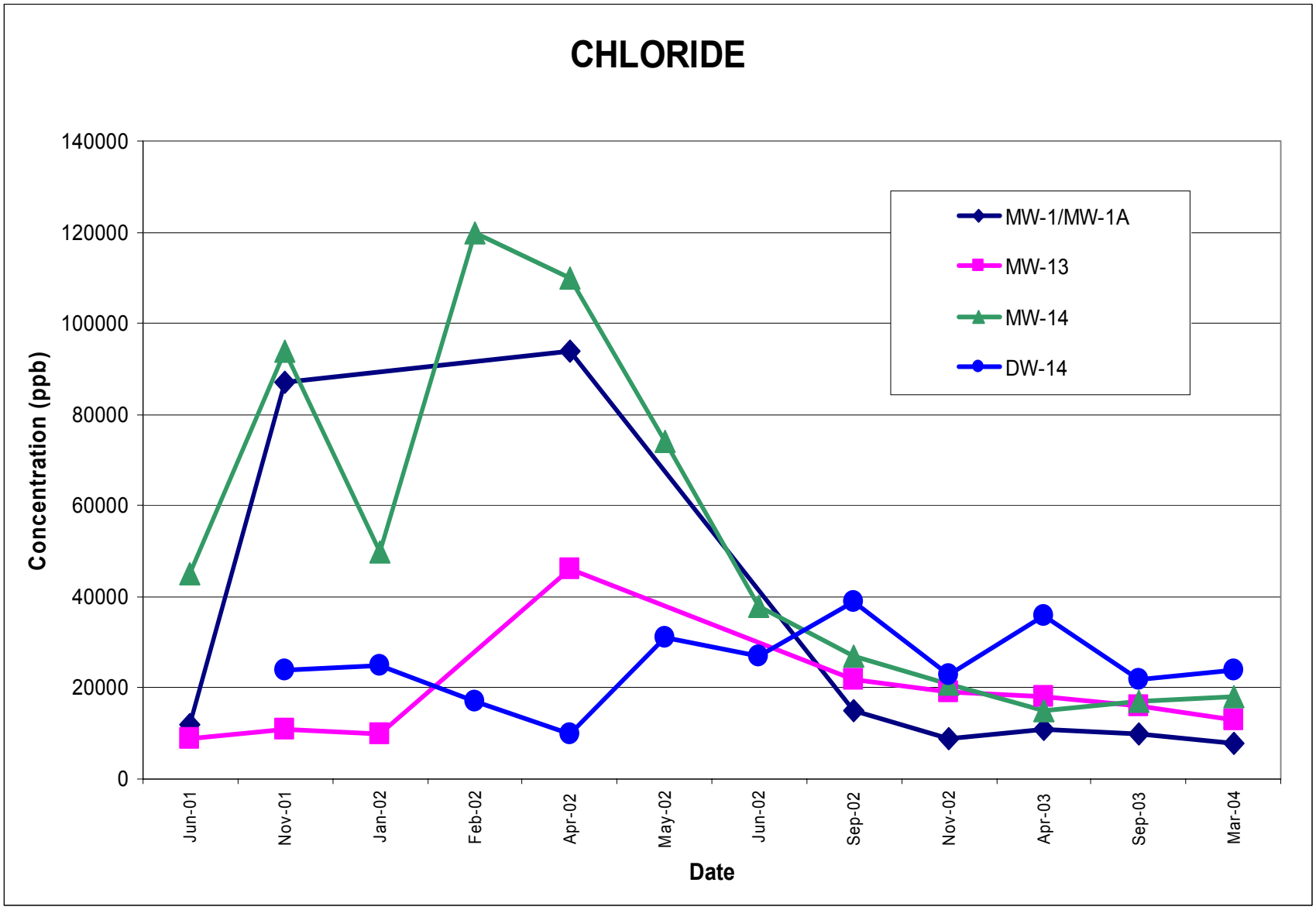

MW-16
32/50
MW-18
56/32
FORMER BARN
MW-2A
4800/100
FORMER DRY WELL
MW-1A
<10/8900
DW-1
130/NS
MW-15
16000/9300
DW-15
13000/NS
MW-17
7600/9300
SHED
MW-13
31000/24000
SHED
INJECTION GRID
EXTENTS
MW-14
6500/5800
DW-14
28000/8700
SHED
MW-3
48/23
0'
FEET
20'
TCE (ppb) - Nov. '01 / Nov. '02
N

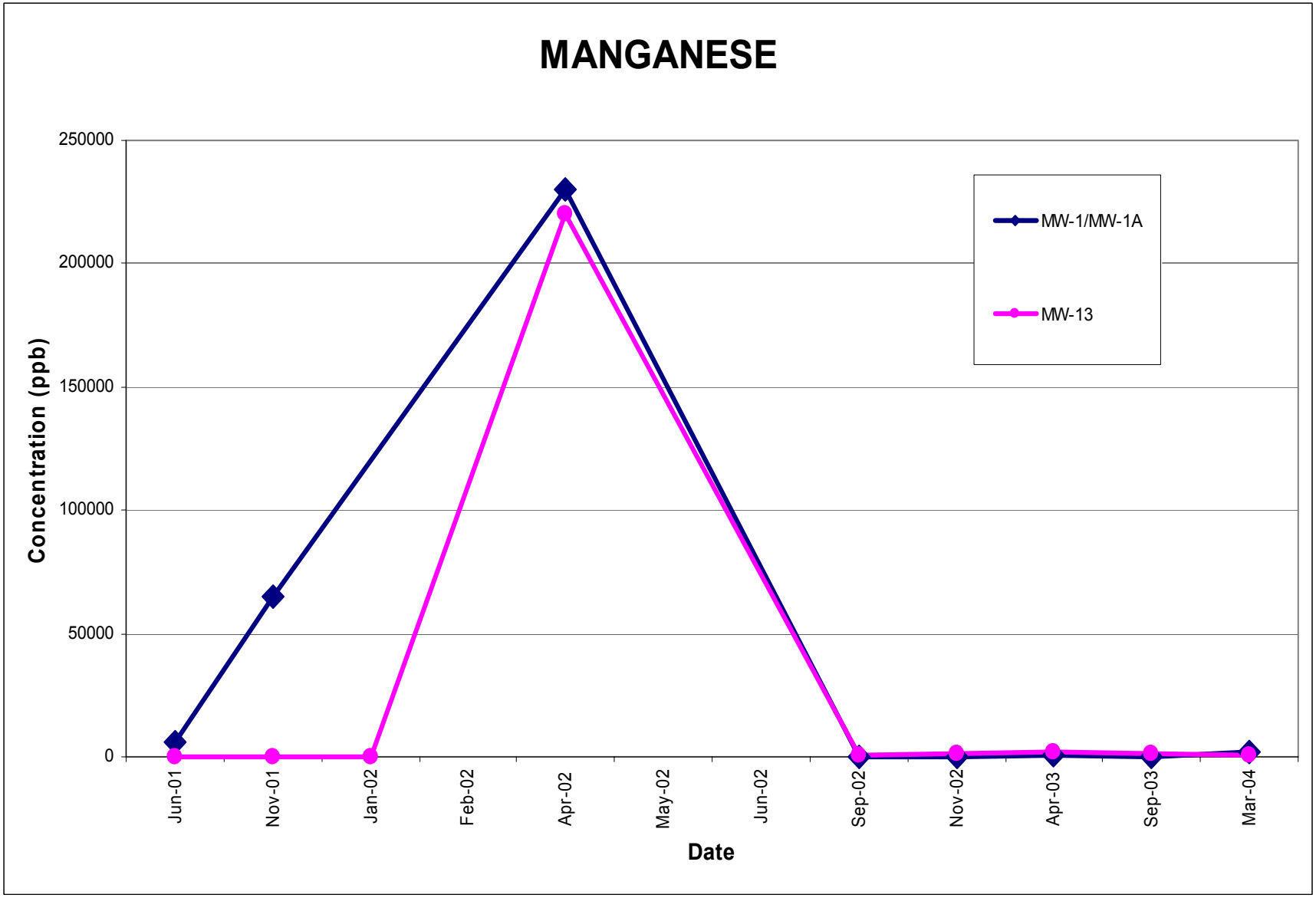

MW-1/MW-1A
TCE Concentration (ppb)
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
07-02-97
07-15-97
04-13-98
06-04-98
03-03-99
03-15-00
06-30-00
07-30-00
06-28-01
11-28-01
04-04-02
09-18-02
11-25-02
04-30-03
09-03-03
03-08-04
Sampling Date


DW-15
TCE Concentration (ppb)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
11-27-01
01-09-02
09-17-02
11-24-02
05-01-03
09-03-03
03-08-04
Sampling Date


MW-2/MW-2A
TCE Concentration (ppb)
6000
5000
4000
3000
2000
1000
0
07-02-97
07-15-97
04-13-98
06-04-98
01-16-01
06-27-01
11-14-01
09-18-02
10-25-02
04-30-03
09-02-03
Sampling Date


MW-3
TCE Concentration (ppb)
350
300
250
200
150
100
50
0
07-02-97
07-15-97
04-13-98
06-04-98
03-02-99
03-15-00
06-28-01
11-13-01
02-27-02
04-03-02
05-14-02
06-14-02
09-17-02
11-24-02
04-30-03
09-02-03
Sampling Date


CHLORIDE
140000
120000
100000
80000
60000
40000
20000
0
Concentration (ppb)
MW-1/MW-1A
MW-13
MW-14
DW-14
Jun-01
Nov-01
Jan-02
Feb-02
Apr-02
May-02
Jun-02
Sep-02
Nov-02
Apr-03
Sep-03
Mar-04
Date


MANGANESE
250000
200000
150000
100000
50000
0
Concentration (ppb)
MW-1/MW-1A
MW-13
Jun-01
Nov-01
Jan-02
Feb-02
Apr-02
May-02
Jun-02
Sep-02
Nov-02
Apr-03
Sep-03
Mar-04
Date

Conclusions

- Potassium Permanganate Oxidizes TCE Soil and Groundwater Impacts *ON CONTACT*
  - Mass Destruction
  - No Daughter Products
  - Limited Diffusion

Conclusions (cont.)

- Geologic and Anthropogenic Heterogeneities are Key Factors
  - Fractures
  - Fine-grained and Cohesive Soils
  - Utility Trenches
  - Old boreholes

Conclusions (cont.)

- Method of Delivery is a Key Factor
  - Injection Pressures
  - Rate of Injection
  - Multi-injection
  - Pattern of Injection
  - Recirculation

Conclusions (cont.)

- Other Factors:
  - Groundwater level fluctuation
  - Depth of delivery
  - Strength of the solution
  - Groundwater mounding
  - Clogging of soil pore spaces
  - Aquifer chemistry
  - Other contaminants


JUL 9 2002