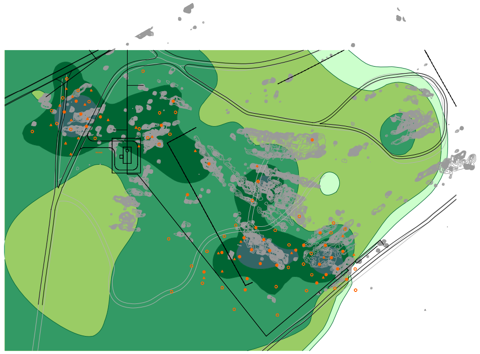


Lessons Learned from In-Situ Resistive Heating of TCE

East Gate Disposal Yard

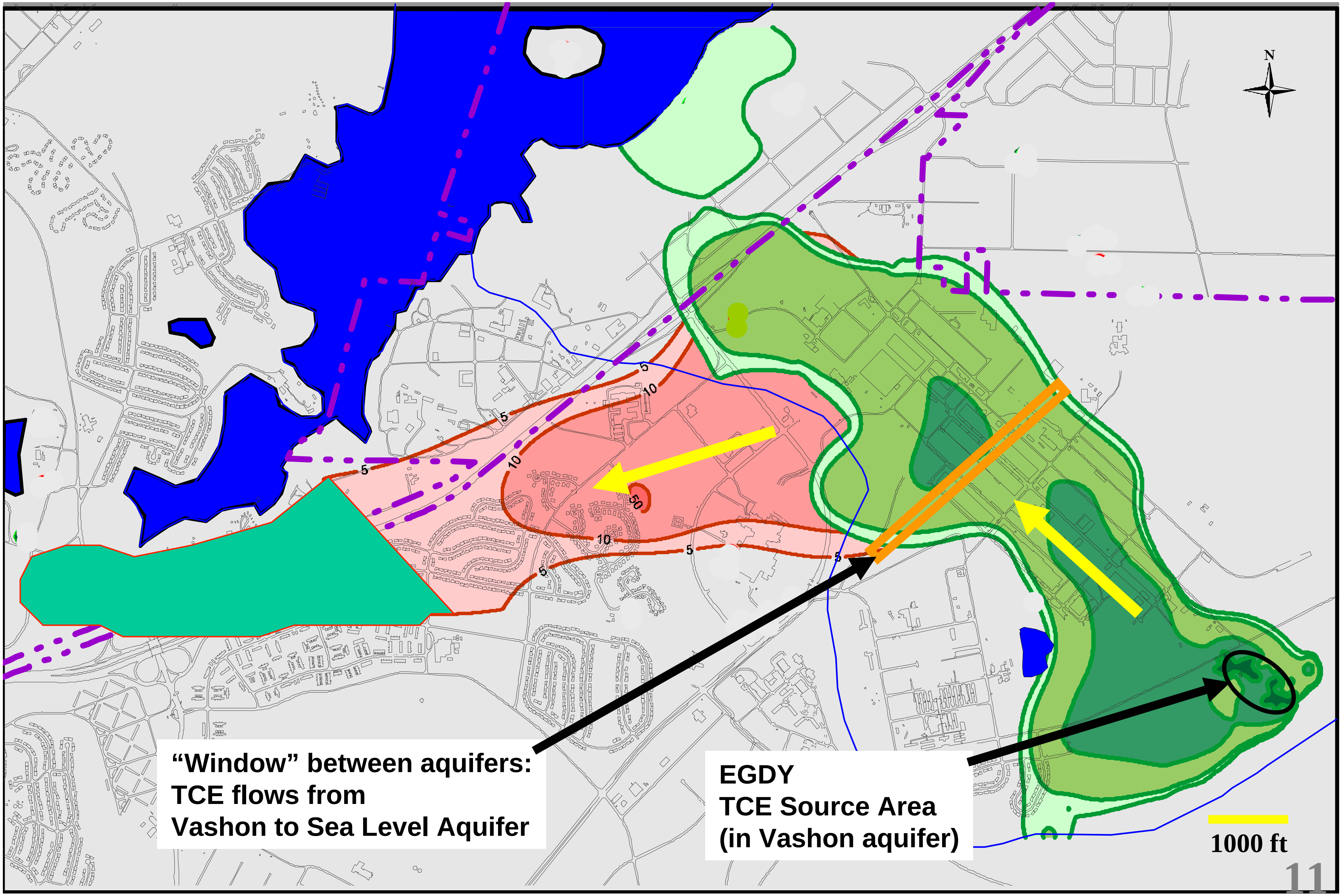
Fort Lewis

Washington

US Army Corps of Engineers

Fort Lewis Washington

TCE Plumes


N
5
10
5
10
50
10
5
5
5
5
"Window" between aquifers:
TCE flows from
Vashon to Sea Level Aquifer
EGDY
TCE Source Area
(in Vashon aquifer)
1000 ft

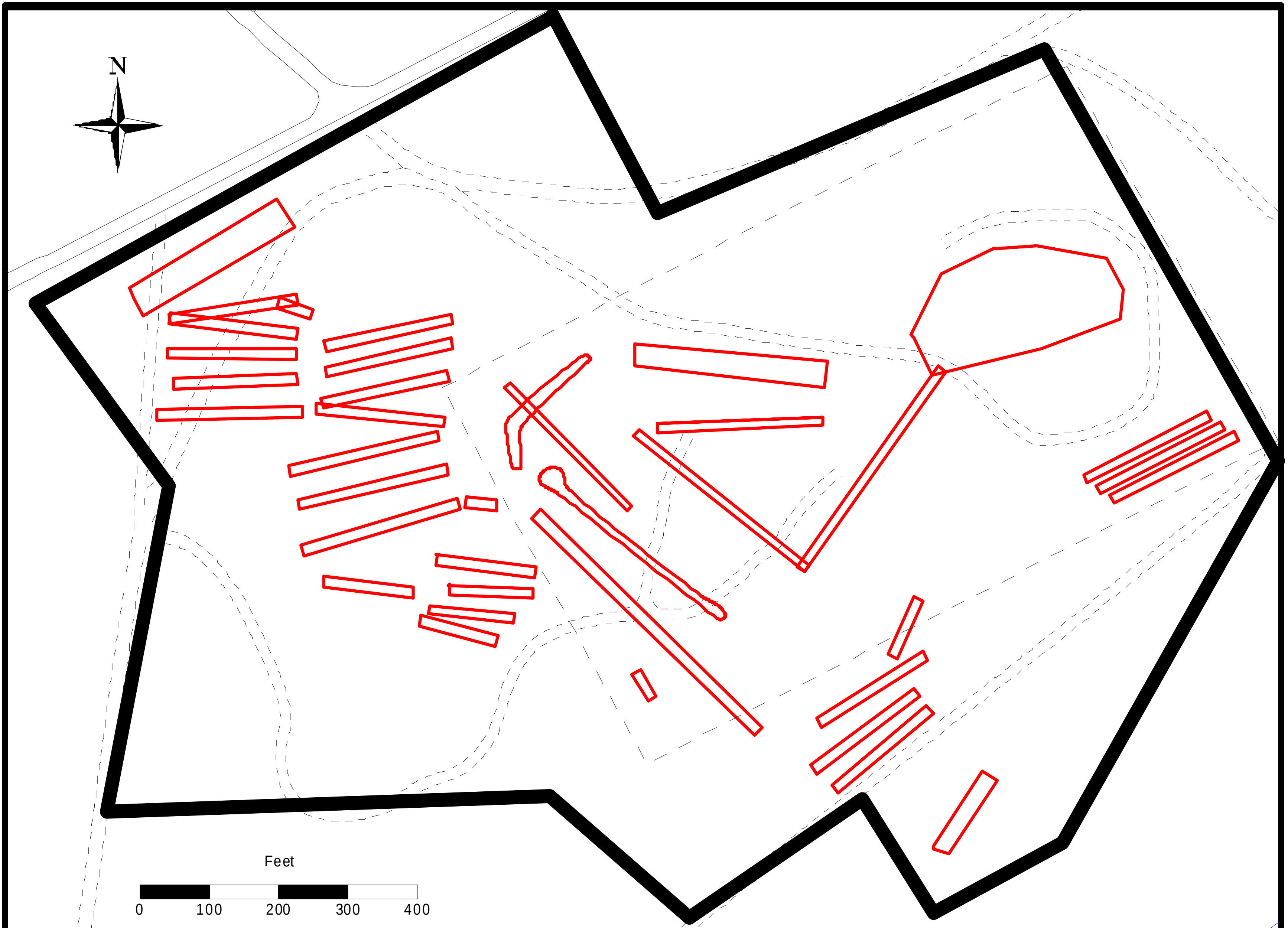
Site History

1989	• Fort Lewis Log Center placed on NPL • RI/FS Performed

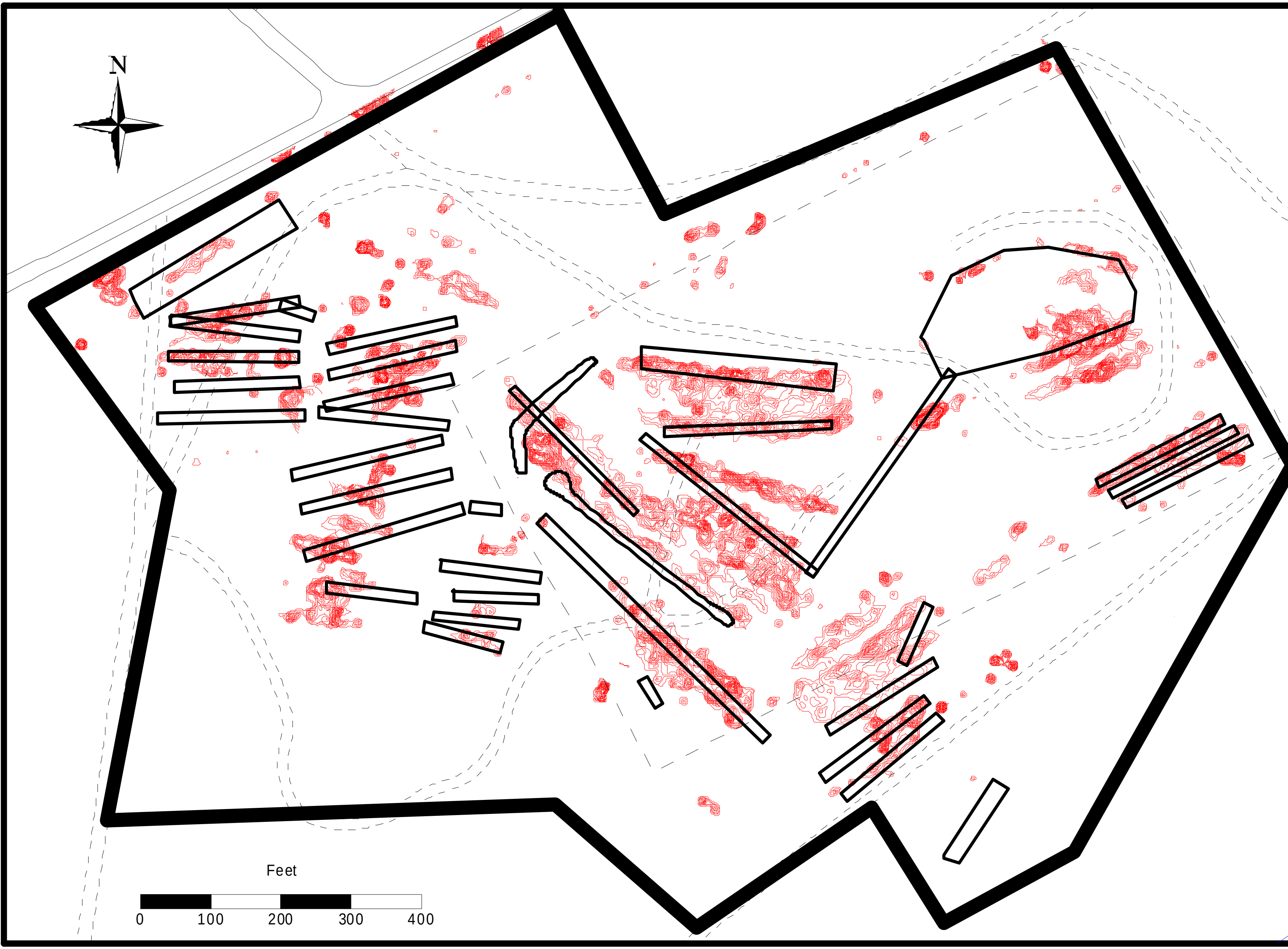
1990	• ROD signed
	  • construction of 2 GW P&T systems
	  • additional investigation into contamination of lower (Sea Level) aquifer

1995	• GW P&T system began operating for hydraulic control of lower aquifer
1998	• ESD prepared that resulted in ESI to evaluate presence of NAPL • Results: GW P&T alone will not remediate shallow Vashon aquifer to beneficial use within ROD 30-year timeframe
2001	• EE/CA prepared to address NAPL source removal • Results: Removal action of shallow partially intact containers and selection of *in situ* thermal remediation • Removal Action performed of over 2,000 containers in various conditions
2002	• Performance-based specs for bid /selection of *in situ* thermal remediation • ERSH Selected
2004	• Treatment completed for NAPL area 1
2005	• Treatment complete for NAPL area 2

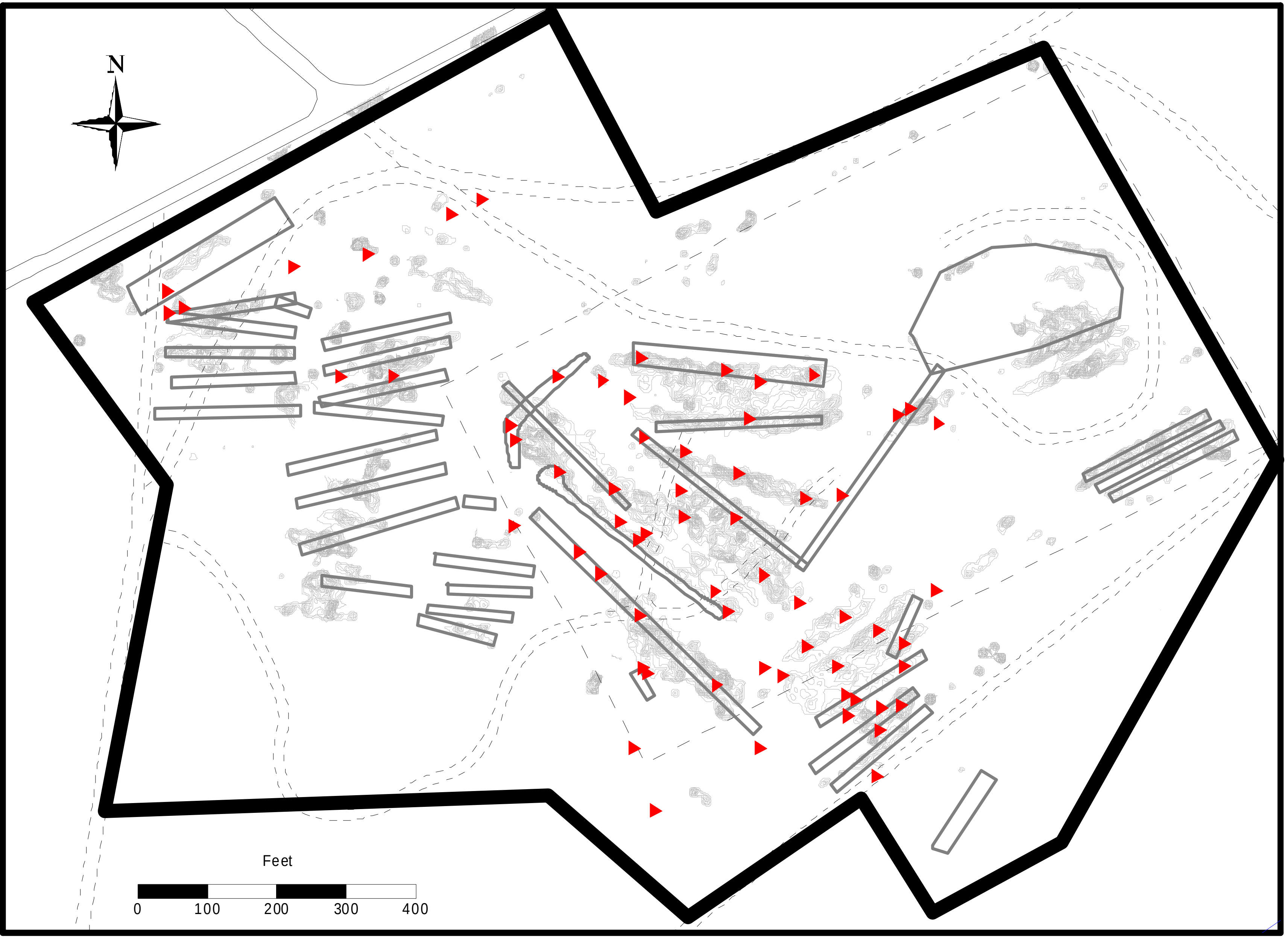
Aerial Photo Analysis Results



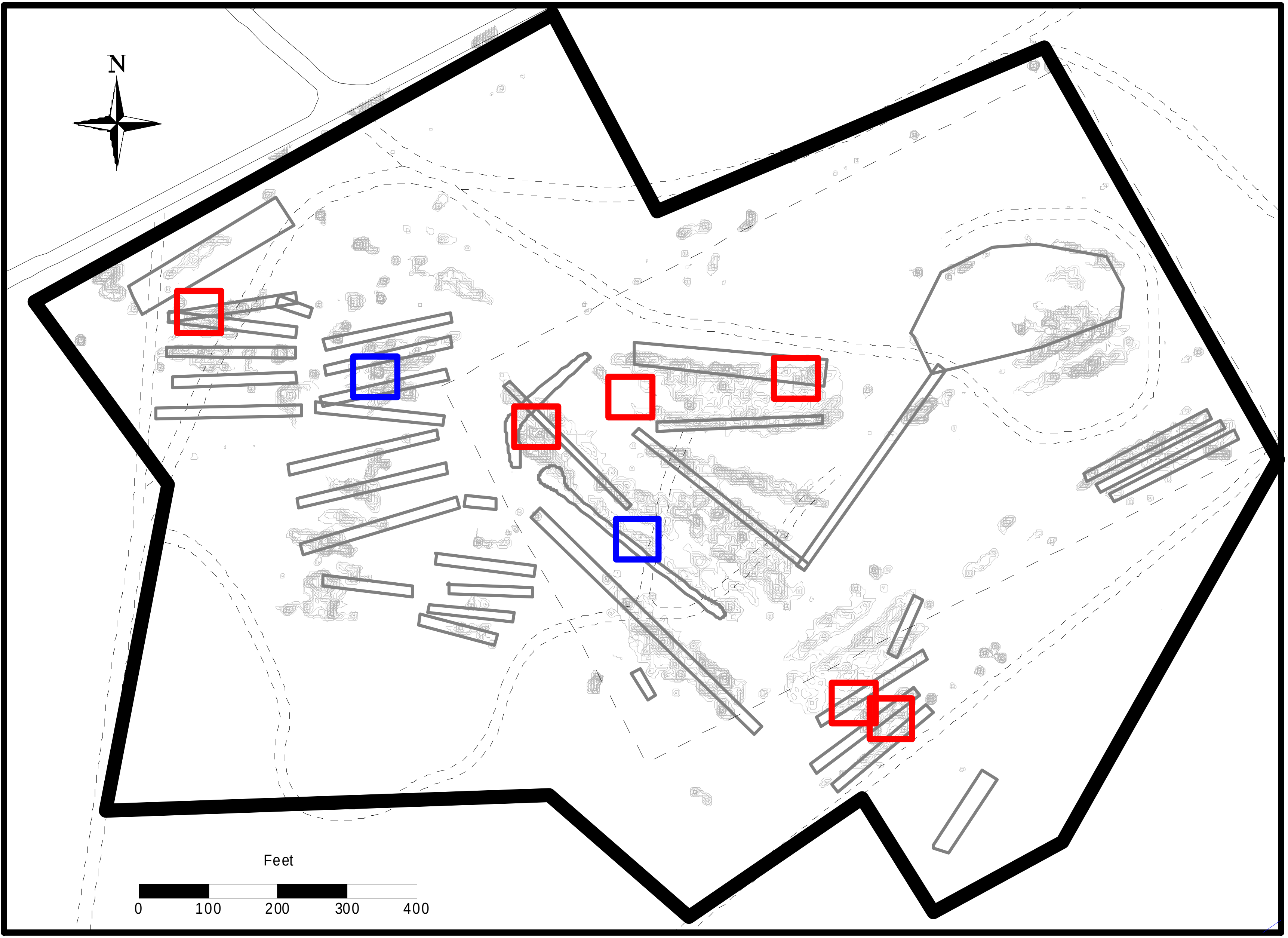
EM-61 Survey Results



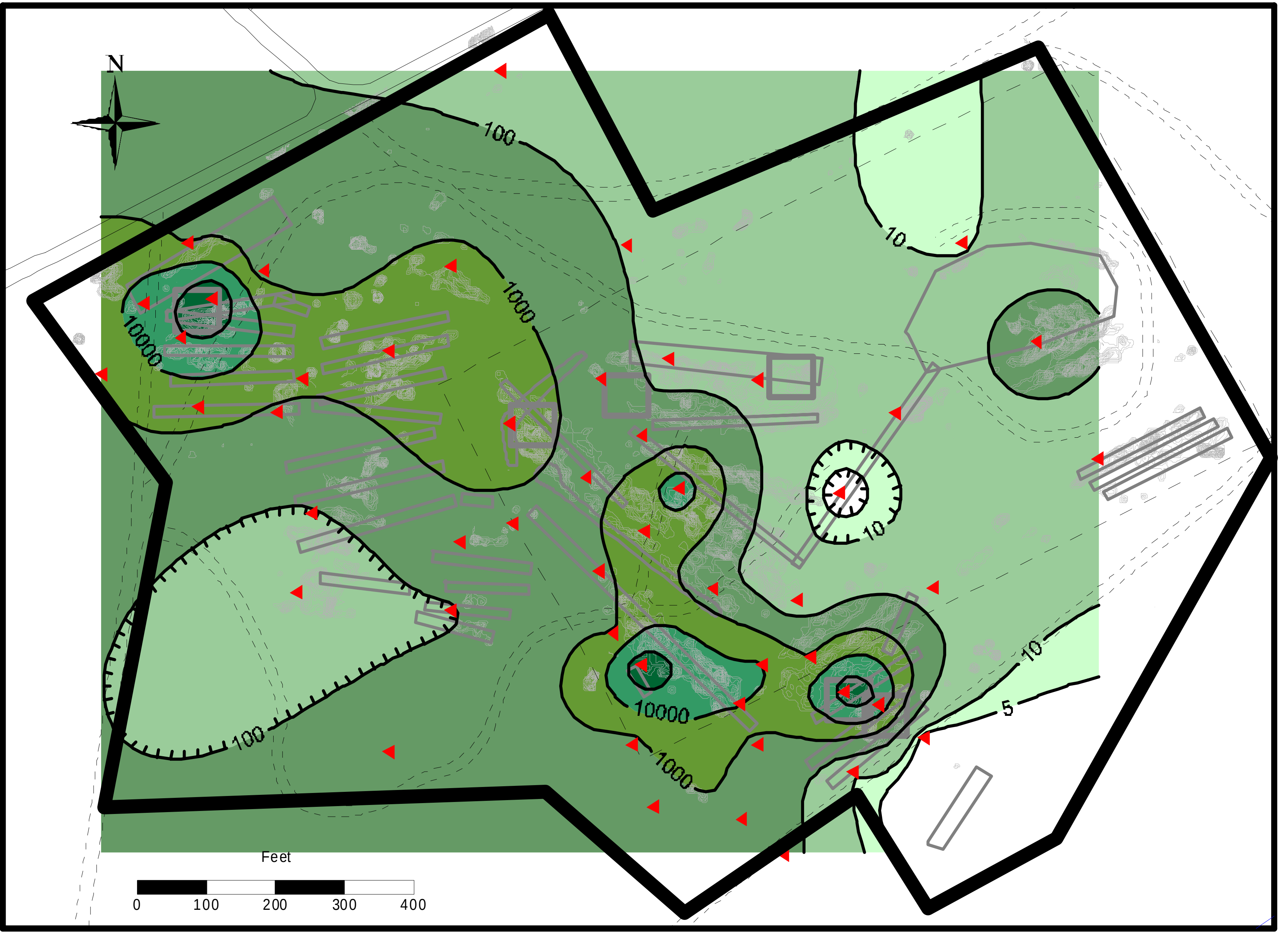
Soil Gas Sampling



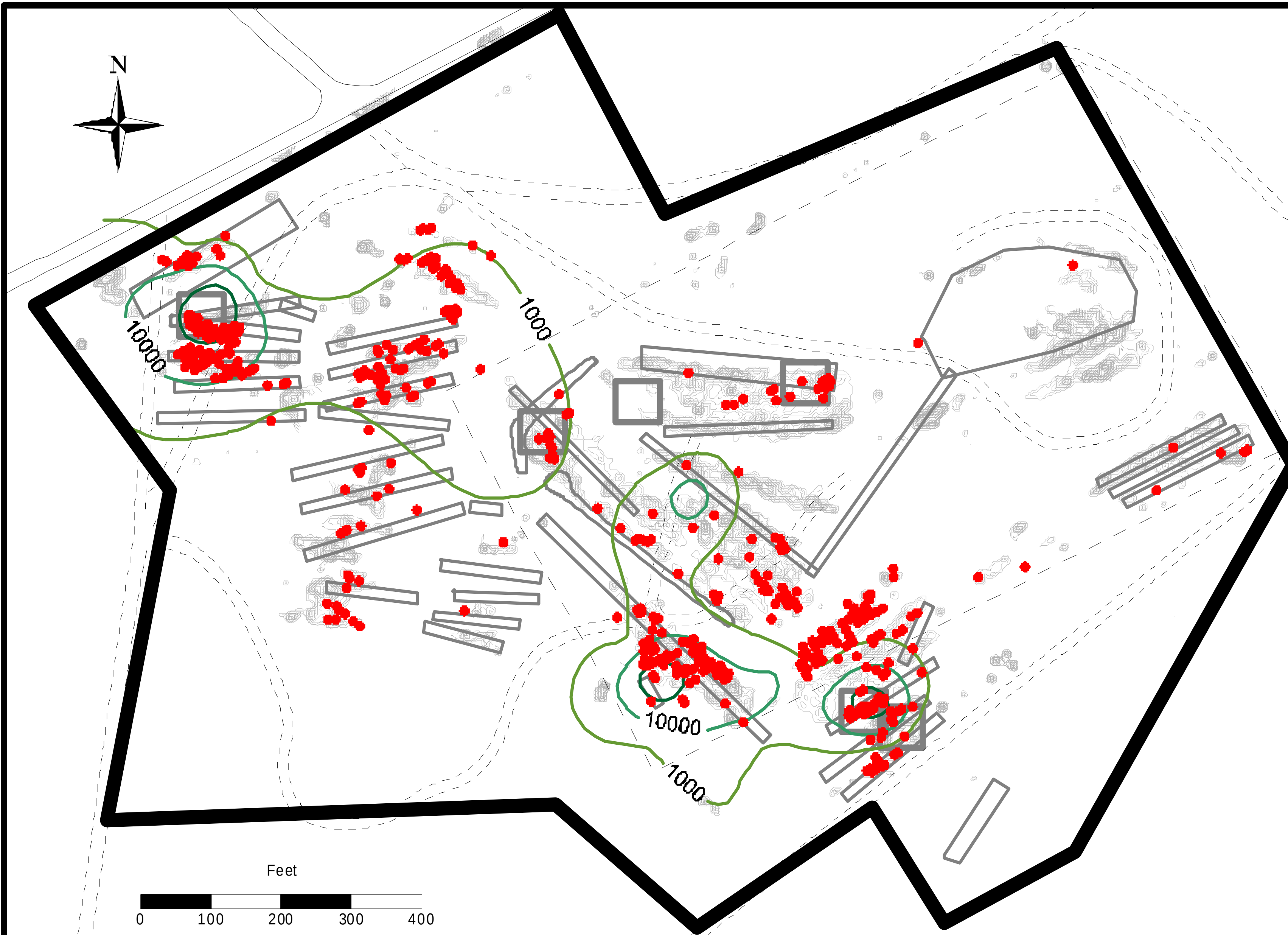
Exploratory Trenching Results



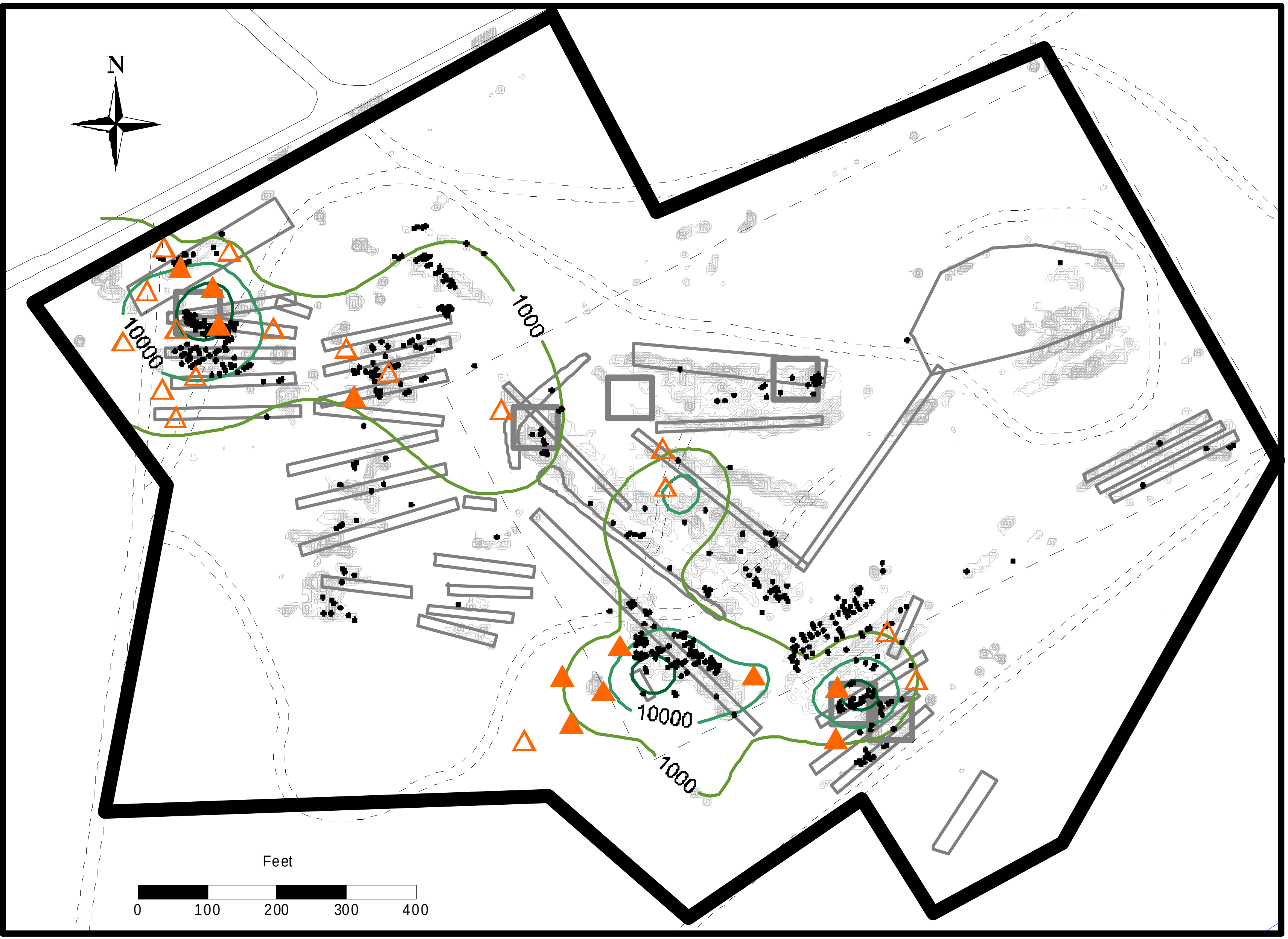
Drive Point Groundwater Results



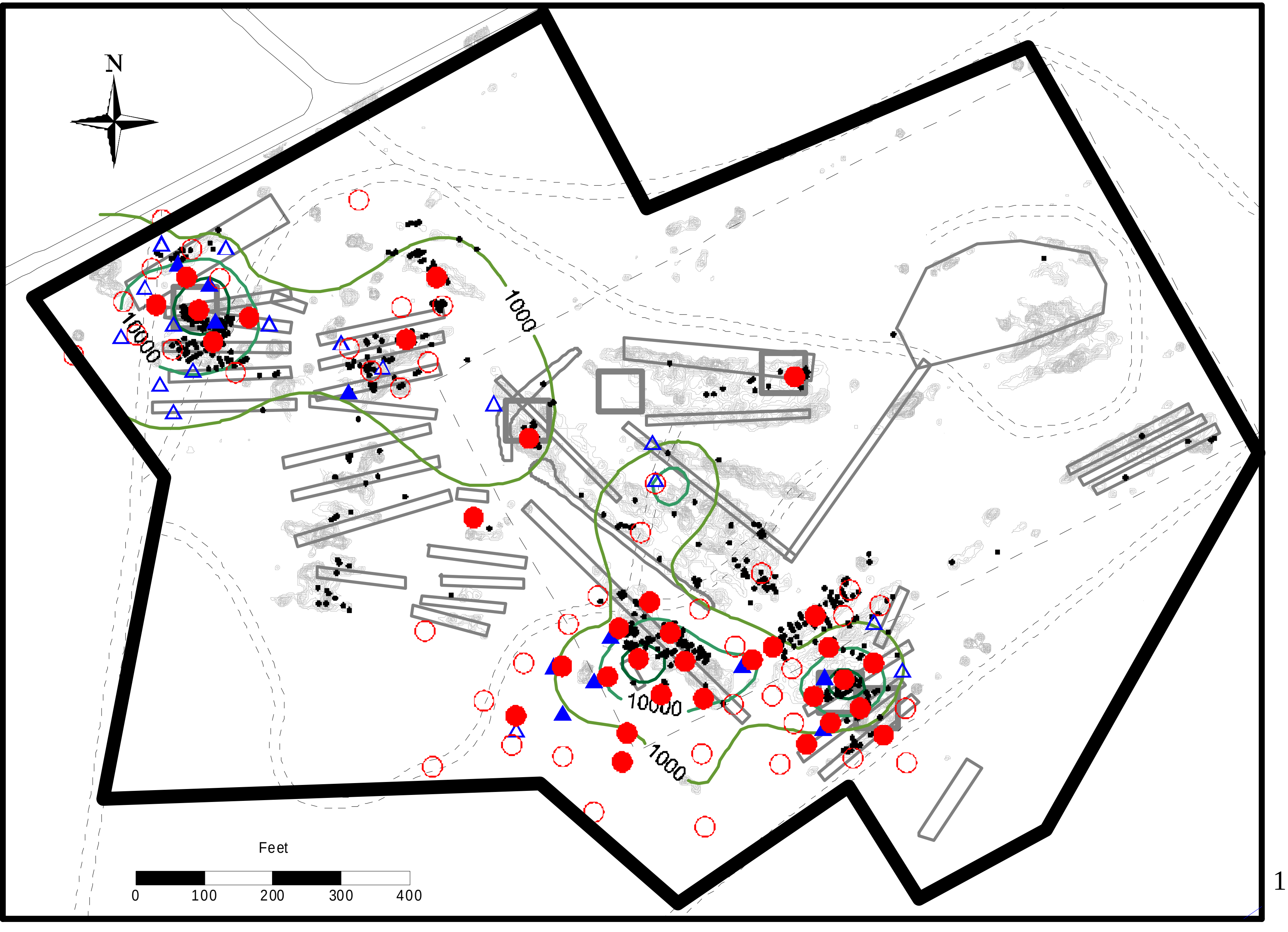
Drum Removal Results



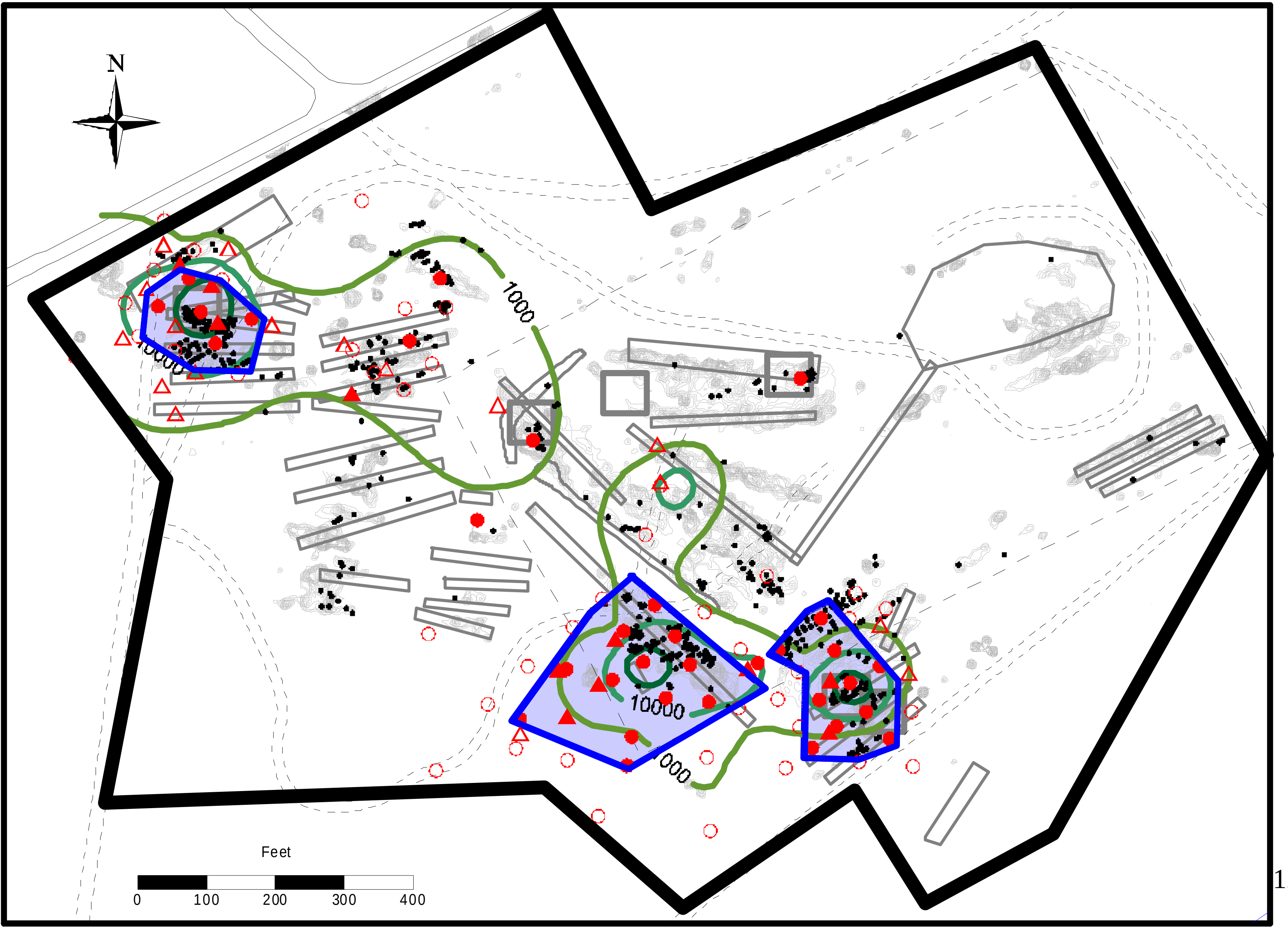
MIP Results



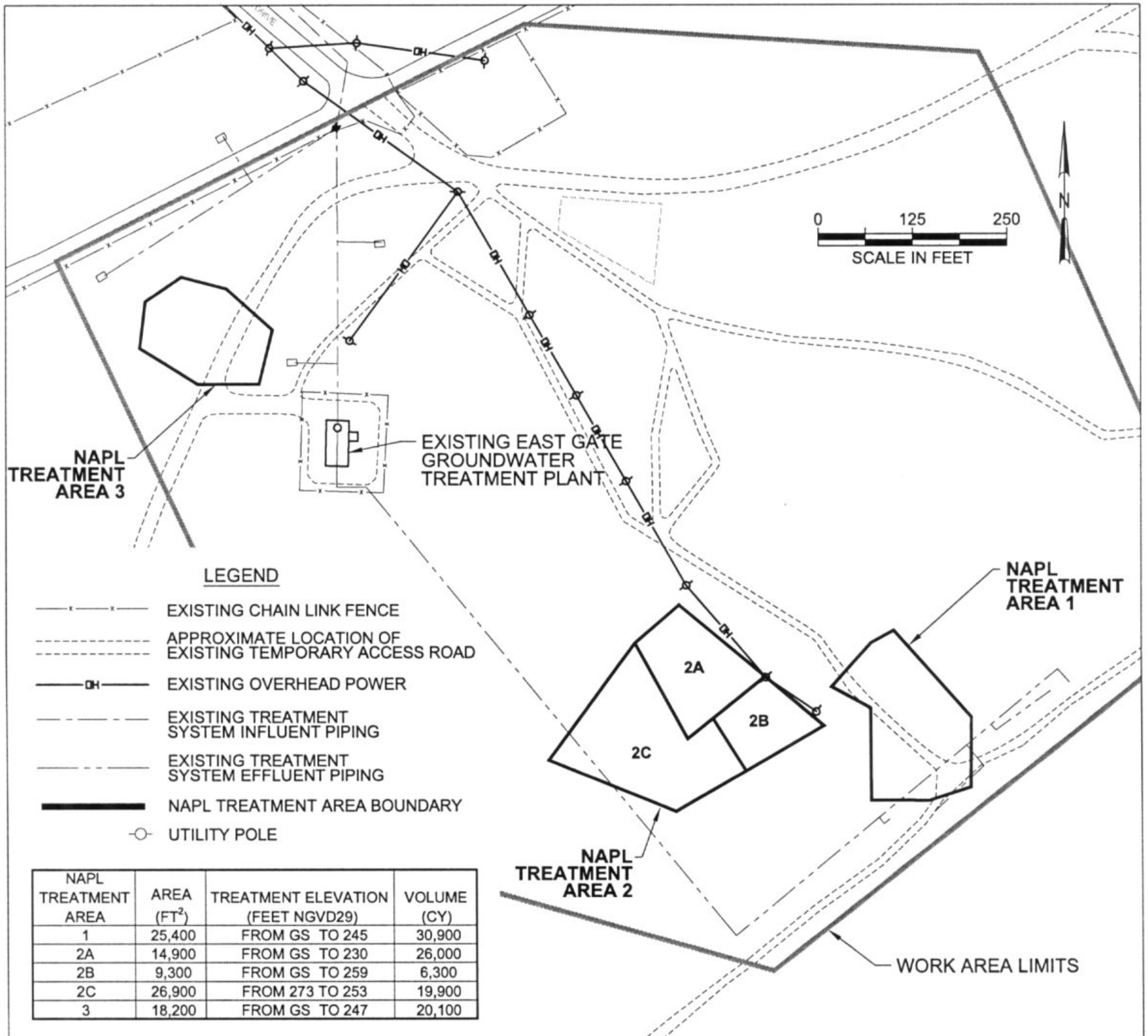
Sonic Drilling Results



Selection of Treatment Volumes



EGDY NAPL TREATMENT AREAS



NAPL TREATMENT AREA	AREA (FT^2)	TREATMENT ELEVATION (FEET NGVD29)	VOLUME (CY)
1	25,400	FROM GS TO 245	30,900
2A	14,900	FROM GS TO 230	26,000
2B	9,300	FROM GS TO 259	6,300
2C	26,900	FROM 273 TO 253	19,900
3	18,200	FROM GS TO 247	20,100

Source Treatment Goals

- Maximize NAPL removal and destruction in source areas defined to contain the majority of NAPL mass
- Reduce risk to potential groundwater receptors
- Reduce timeframe within which pump and treat of groundwater dissolved phase plume is required
- When do we stop heating?
  - Criteria must be adopted that balances the cost of the remediation with the potential for adequate mass removal – heavily dependent on system monitoring data
  - Requires “social capital”

Project Management Approach

- Adaptive site management/Triad
- Performance based contract
- Challenges to bid schedule design:
  - Flexibility was desired to discontinue treatment based on performance
  - It needed to account for area expansion and/or extension of treatment time
  - It needed to encourage the Contractor to optimize the system

Contract Performance Monitoring

- Establish, maintain, and verify subsurface temperatures of 90 C and 100 C for the vadose zone and saturated zones respectively
  - Thermocouples 1 per 100 yd^3
- Hydraulic and vapor control
- Electrical consumption rates
- Water reinjection standards
- Limitations on CVOC mass discharge to atmosphere
  - < 639 kg of TCE per year

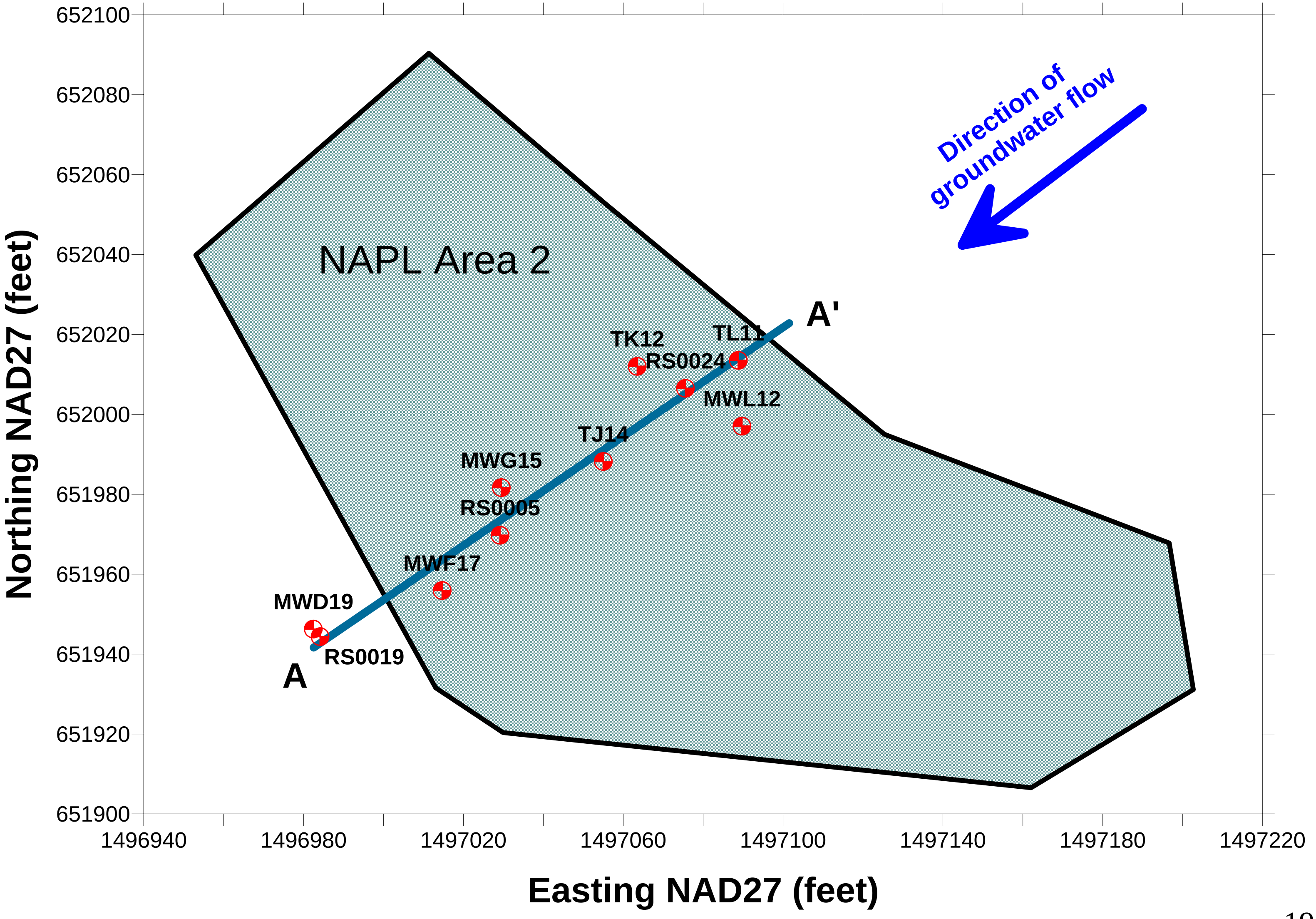
Contracting Lessons Learned

- Use of performance based design build contract facilitated system modification during construction
  - Additional hydraulic control wells
  - Second power control unit
  - Installation of additional electrodes
- Multiple line of evidence approach required to reach consensus on termination decision
  - Communication and data management critical
- Contract performance metrics required modifications to optimize operations to meet overall treatment performance goals
  - Initial contract expectation for consistent heat-up proved unrealistic

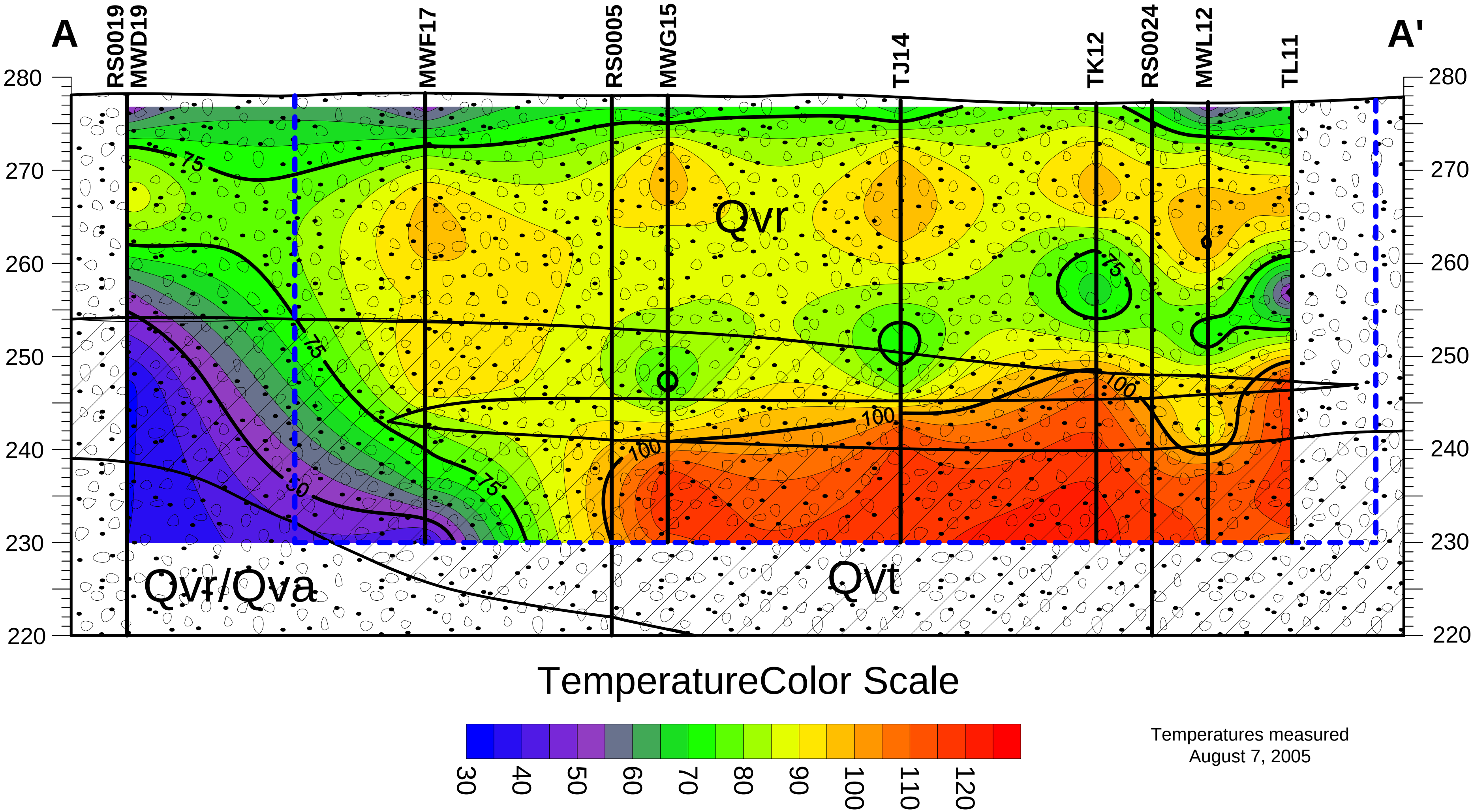
CSM Heterogeneity Impacts

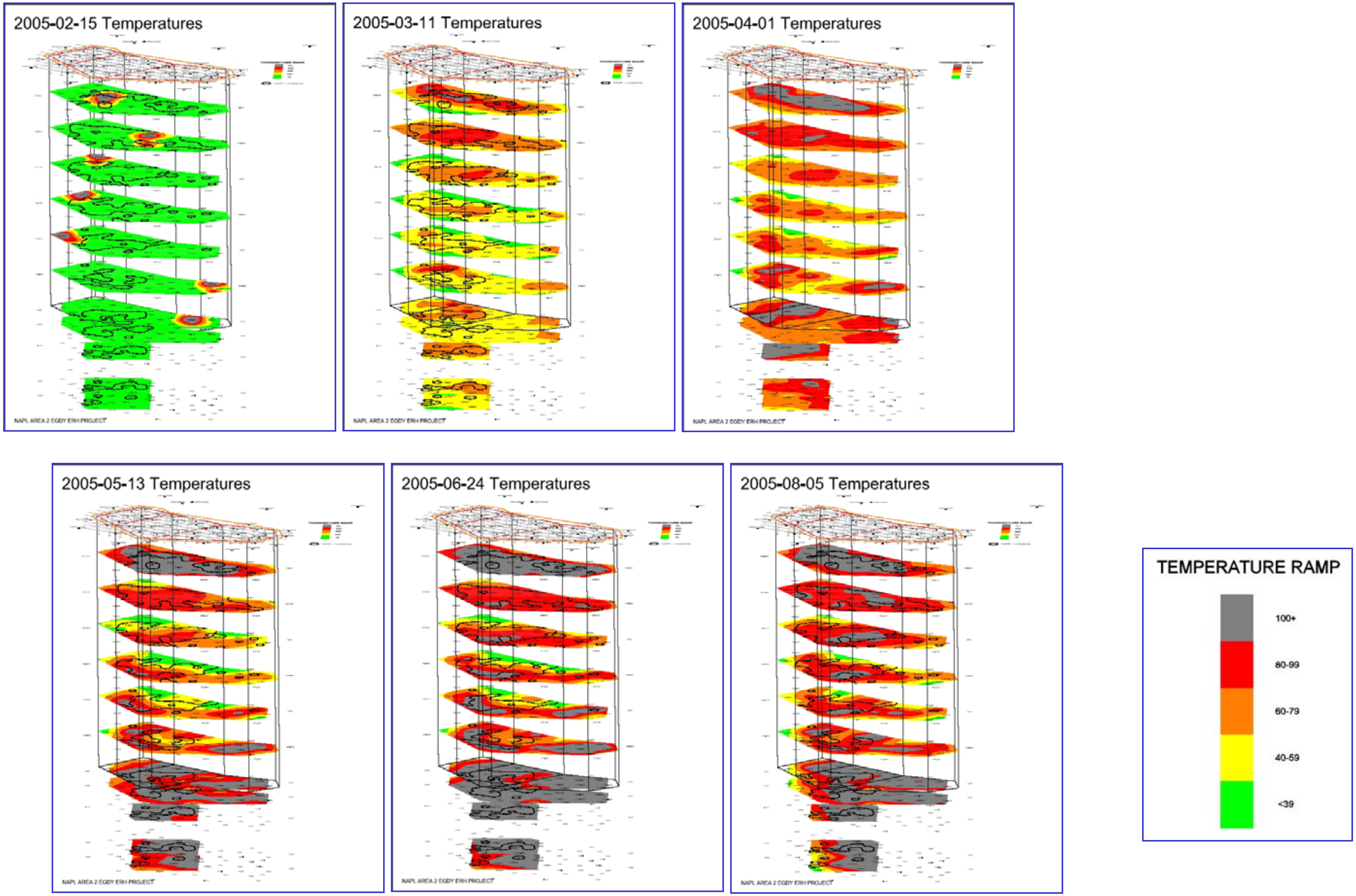
- Heat up of subsurface highly variable and controlled by complex stratigraphy and hydraulic gradients
  - Horizontal hydraulic conductivity values range 850-16 ft/day
  - Vertical hydraulic conductivity values range 590-.9 ft/day
- Hydraulic control difficult to measure
  - Differences in head that are relatively small difficult to measure
  - Pressure transducers measure average vertical head

NAPL Area 2 Cross-Section A-A' Plan View



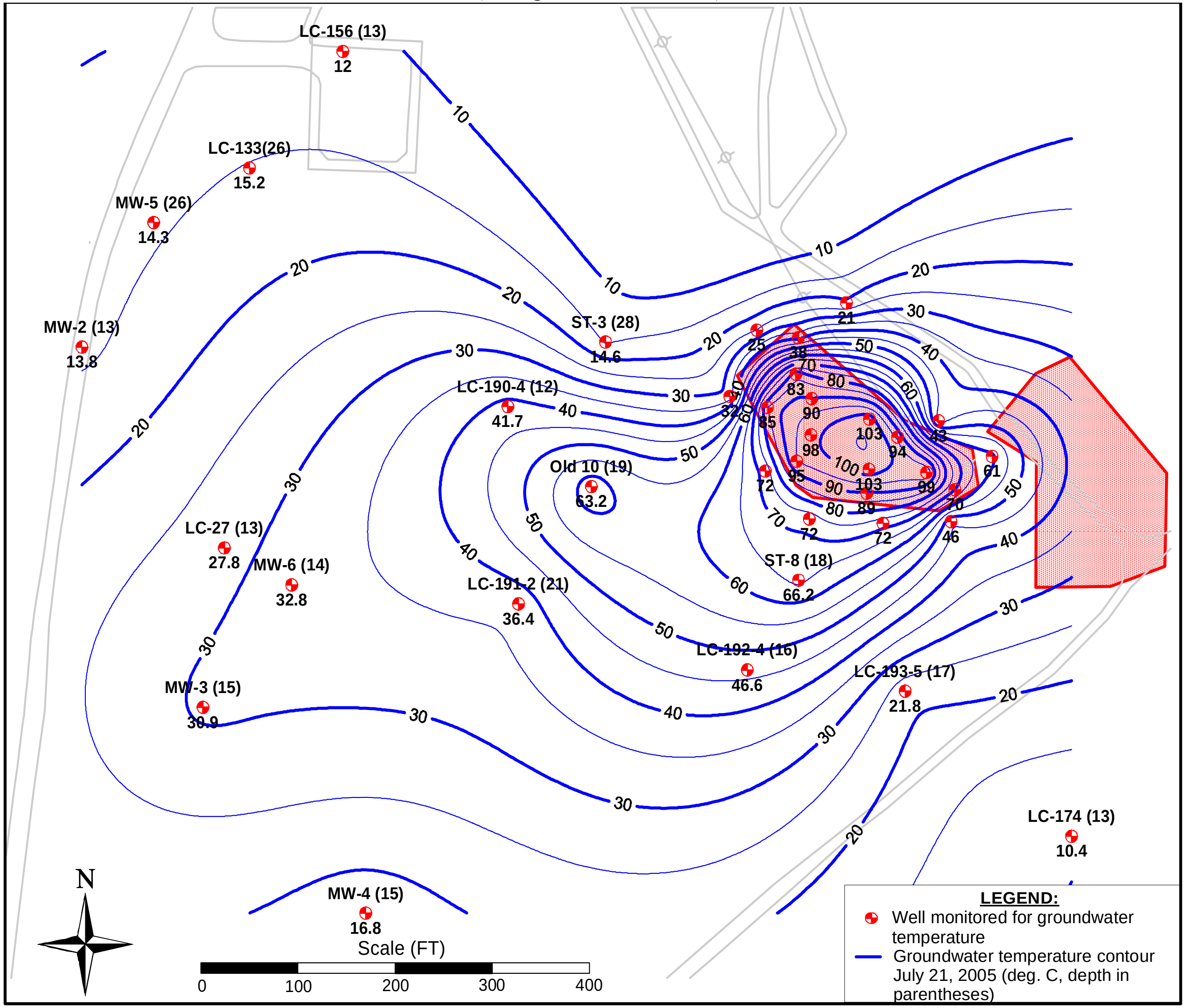
NAPL Area 2 Cross-Section and Isotherm Plot



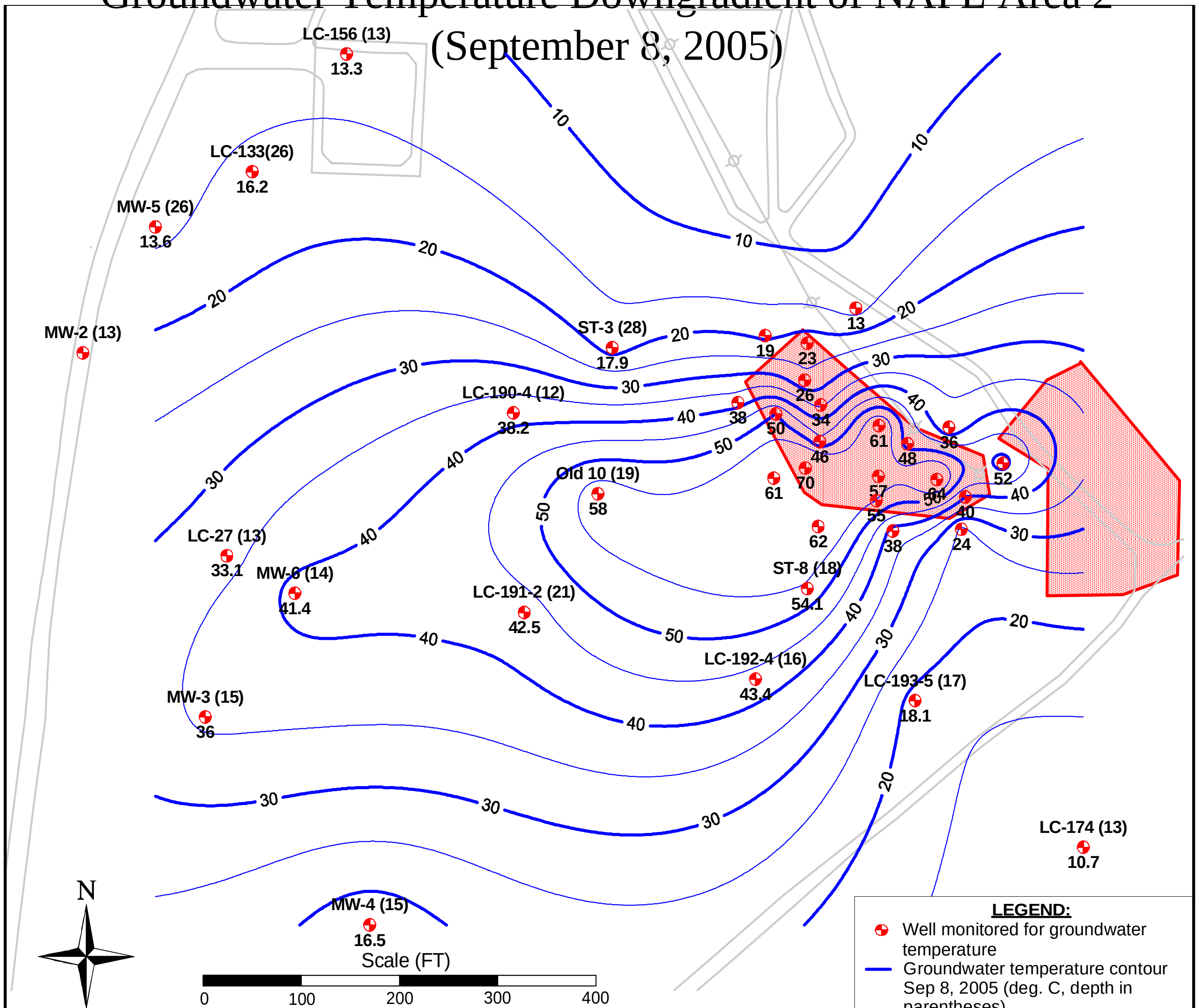


Temperatures

Groundwater Temperature Downgradient of NAPL Area 2
(July 21, 2005)



Groundwater Temperature Downgradient of NAPL Area 2
(September 8, 2005)



NAPL Mass Estimates

- Data Used:
  - Visual observations of NAPL in sonic core and air rotary cuttings.
  - Sonic soil core samples VOC and TPH analytical data.
  - Laboratory porosity.
  - Laboratory NAPL saturation.

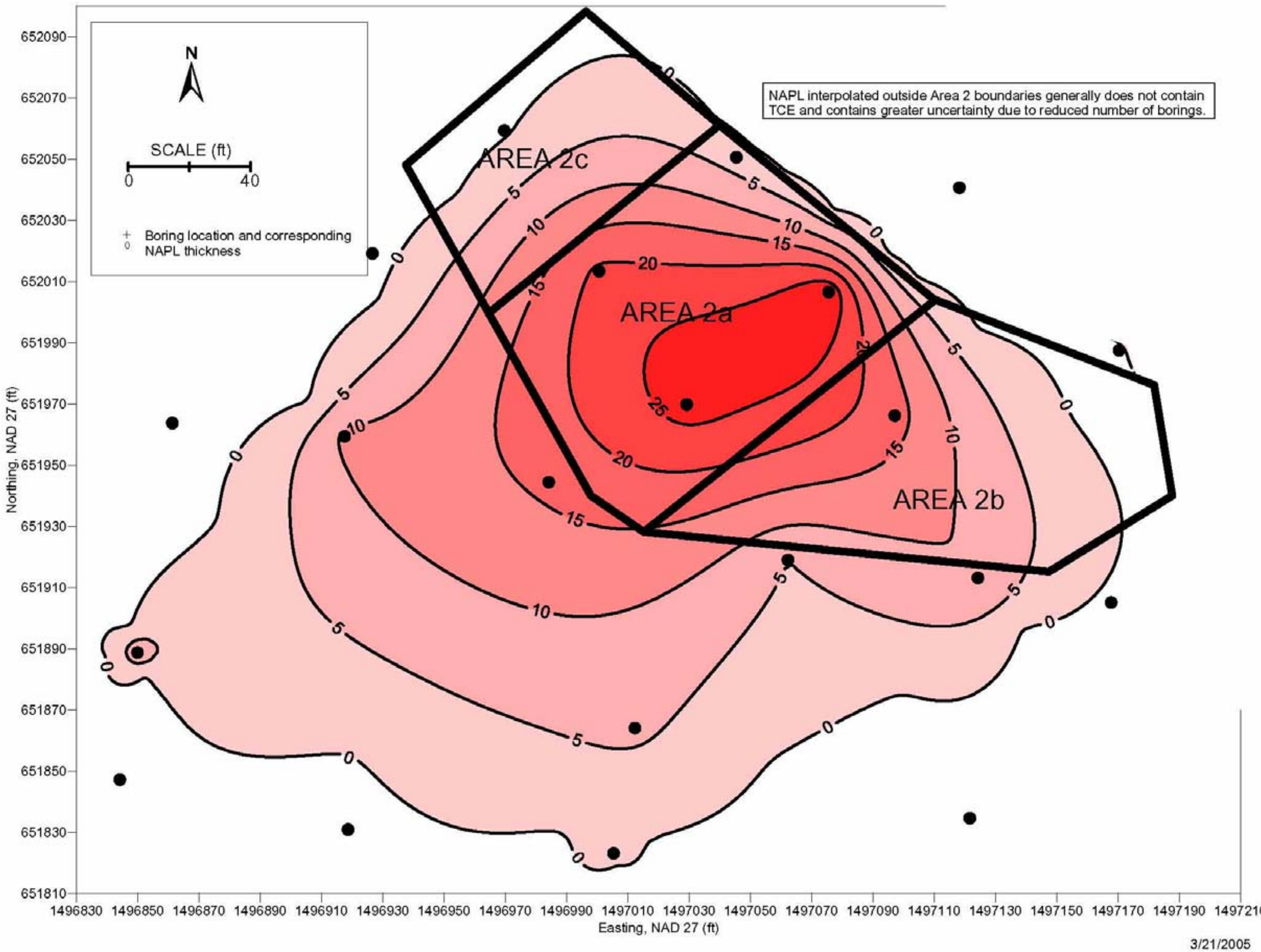
Primary Sources of Uncertainty

- Volume of subsurface contaminated with NAPL.
- NAPL saturation.
- Analyte mass fractions in NAPL.

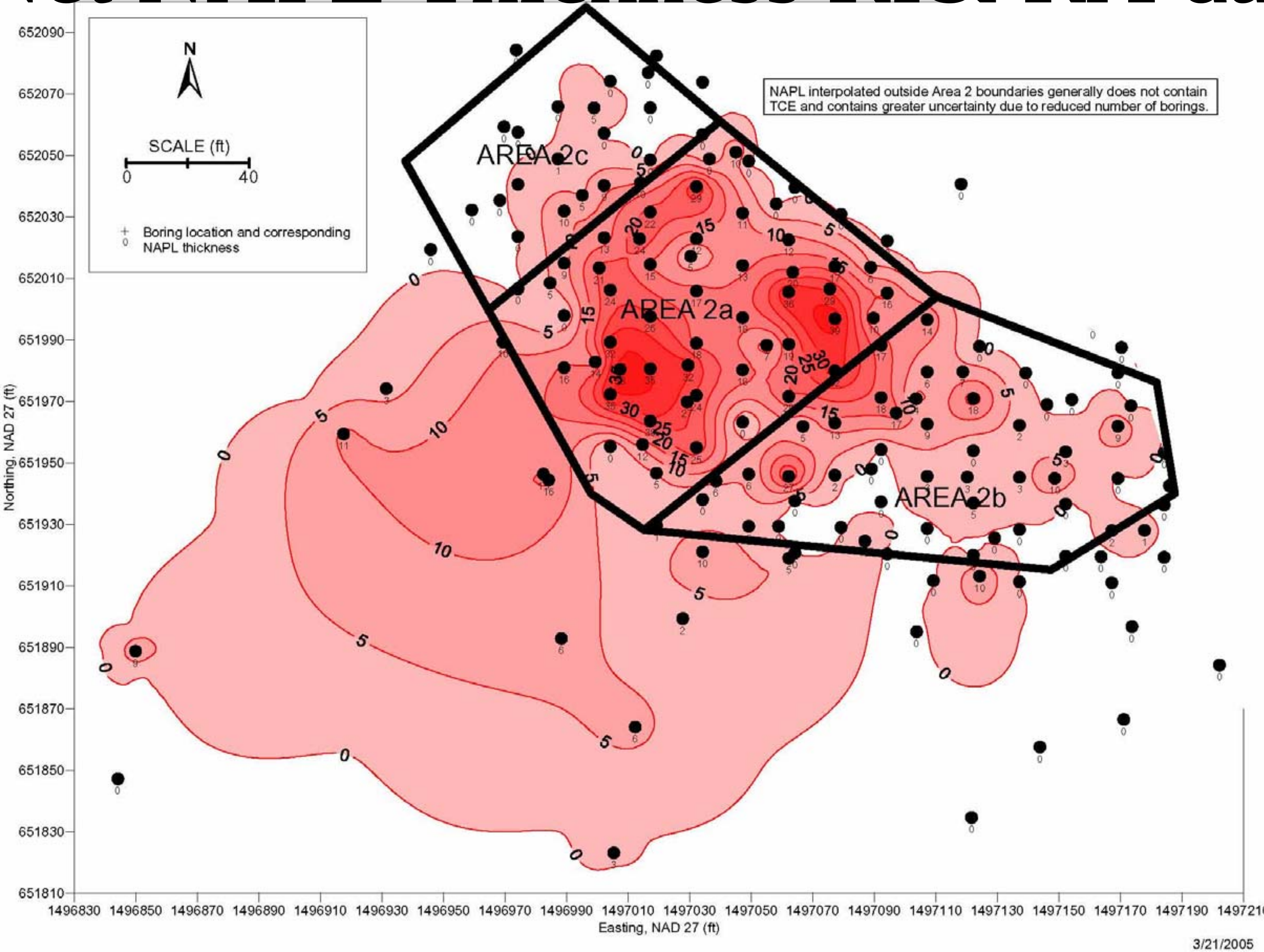
Estimated Initial Mass by Constituent & Area

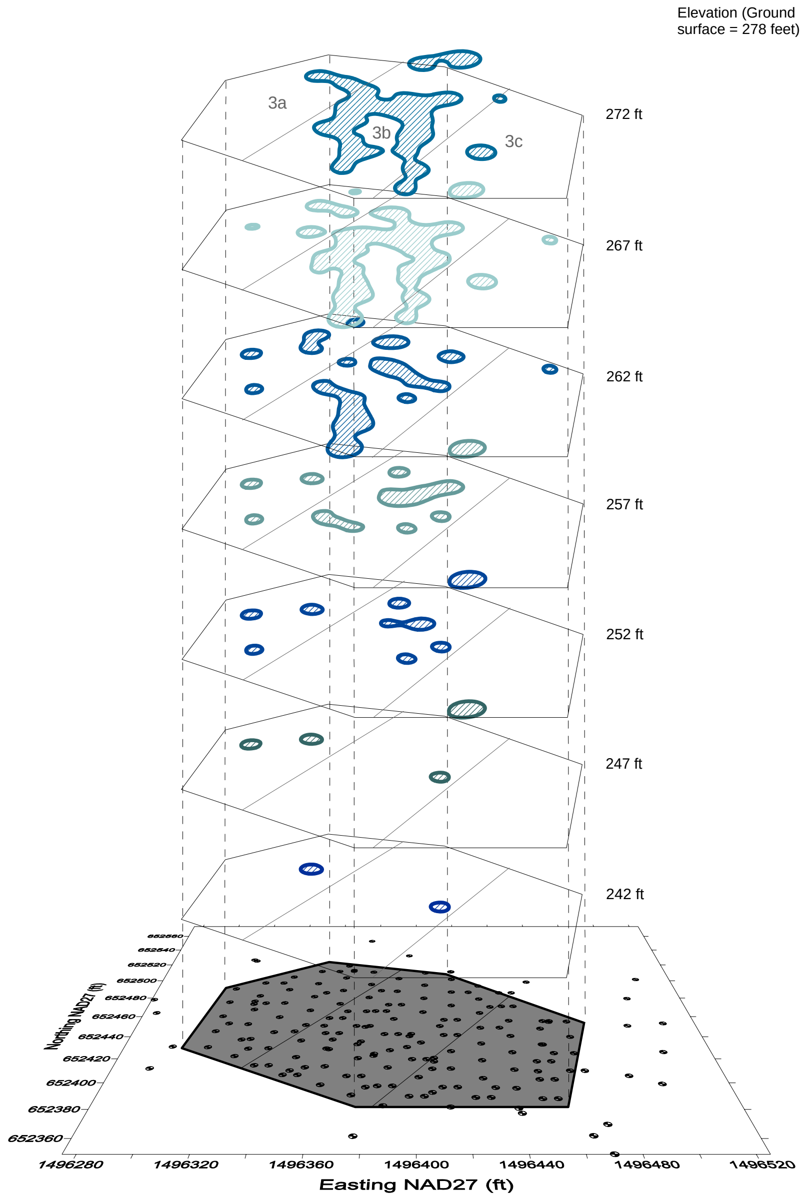
	TCE (Kg)	c-DCE (Kg)	TPH (Kg)
AREA 1			
Initial Mass Estimate	11,800	5,300	79,100
Revised Initial Mass Est. (range)	3,800-13,400	1,700-6,000	25,000-89,700
AREA 2			
Initial Mass Estimate	13,400	600	102,100
Revised Initial Mass Est. (range)	3,400-10,900	200-500	22,400-70,300
AREA 3			
Initial Mass Estimate	43,000	2,400	19,100
Revised Initial Mass Est. (range)	4,200-13,700	200-800	2,300-7,400

Net NAPL Thickness RI data



Net NAPL Thickness RI& RA data





Revised NAPL Extents in Area 3

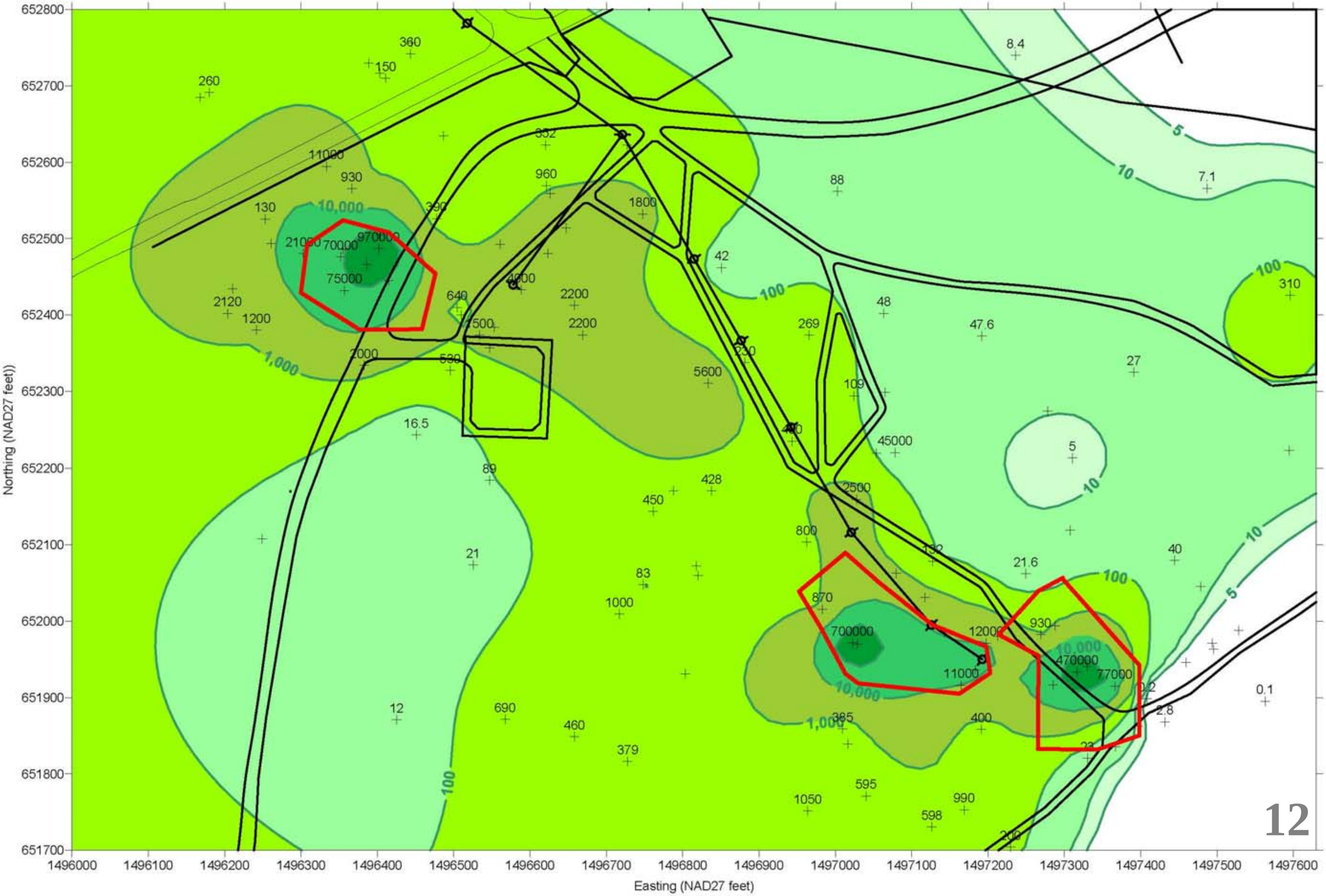
Based on interpretation of TRS infrastructure borings (June-July 2006), soil core drill-back borings (April 2006), North Wind bioremediation cell borings (2003), and Phase II RI borings (2001-2002).

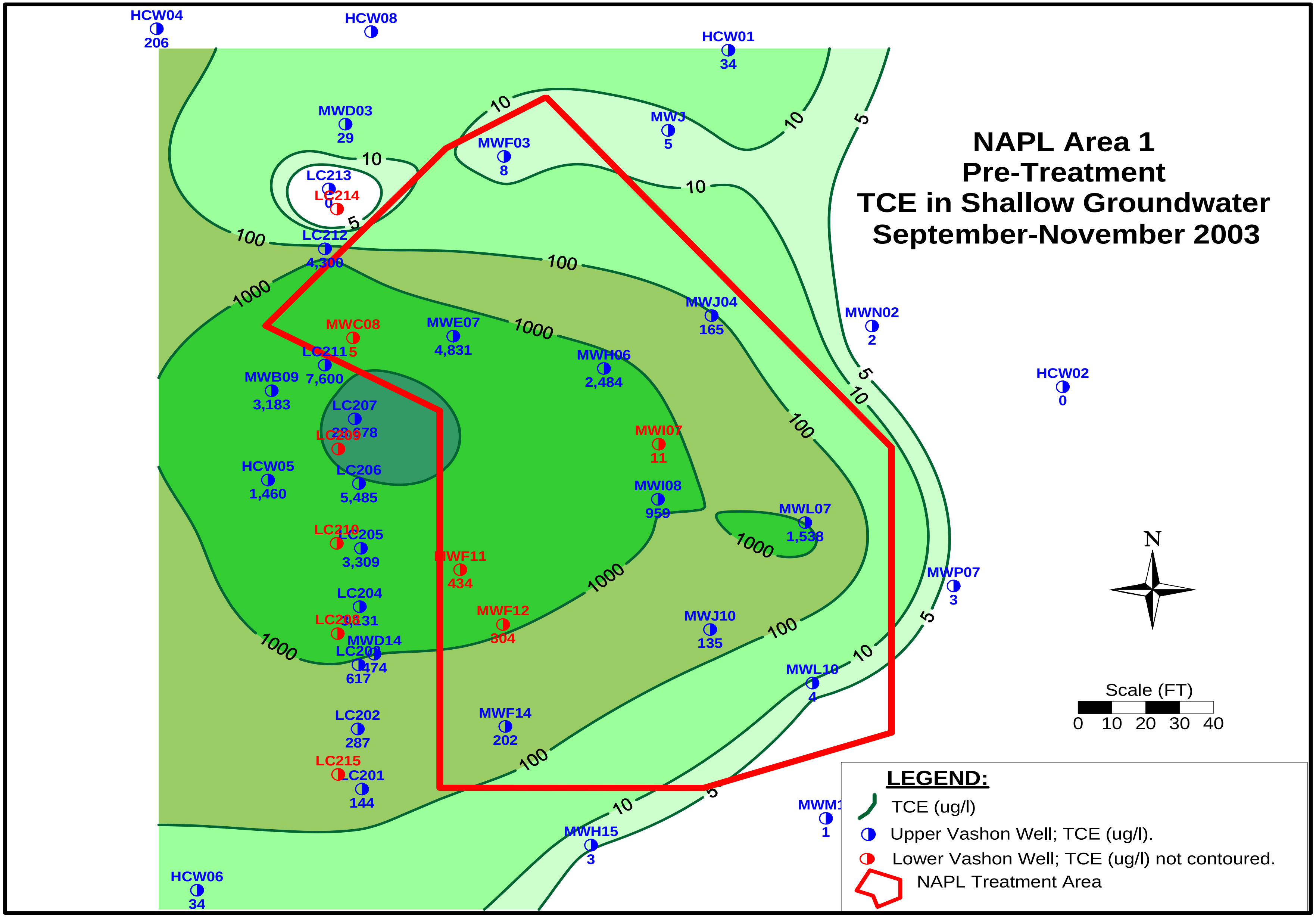
Drawing created 7/20/06

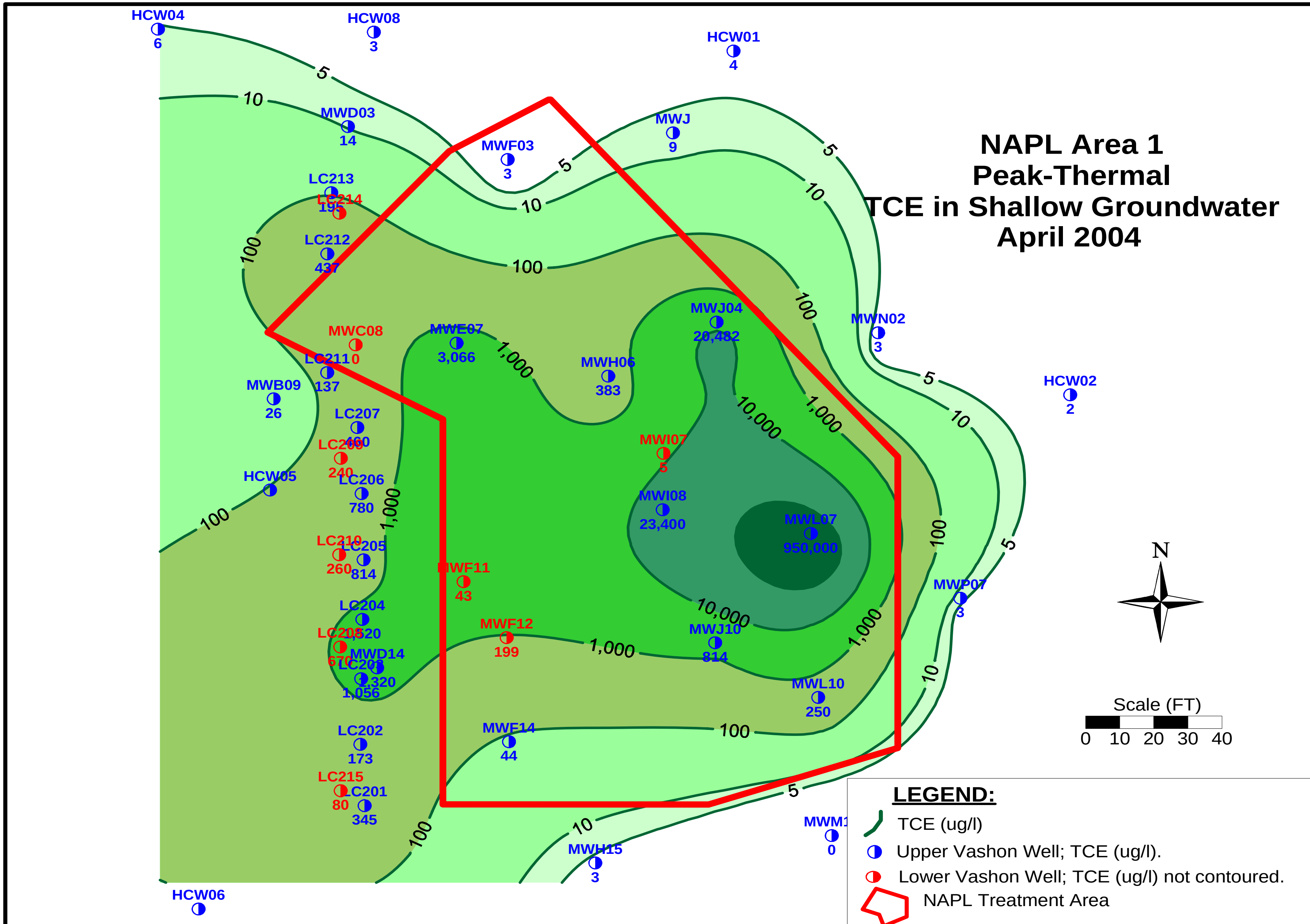
Thermal Treatment Performance Lessons Learned

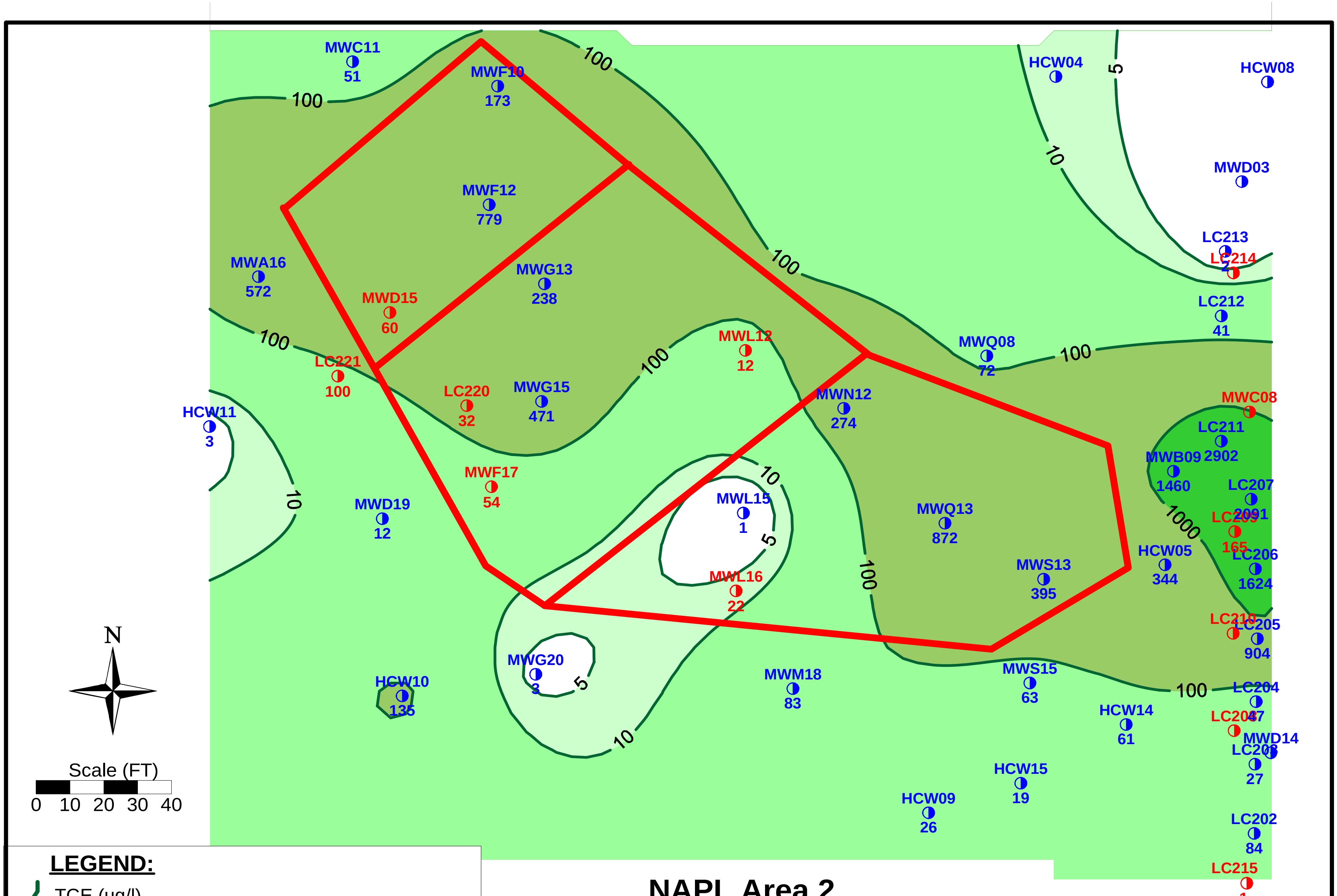
- Groundwater concentration reductions significant
- All soil TCE concentrations reduced to < 1261 ppb in Area 1 and < 544 ppb in Area 2 ug/kg
- > 50% of soil samples ND at 100 ppb TCE
- Groundwater data indicates surgical treatment
- Data suggest potentially significant in situ destruction of contaminants
- No foreseeable rebound

EGDY Contamination




NAPL Area 1
Pre-Treatment
TCE in Shallow Groundwater
September-November 2003
HCW04 206
HCW08
HCW01 34
MWD03 29
MWF03 8
MWJ 5
LC213 0
LC214
LC212 4,300
MWC08
MWE07 4,831
LC211 7,600
MWB09 3,183
LC207 28,678
LC209
MWH06 2,484
MWJ04 165
MWN02 2
HCW02 0
MWI07 11
MWI08 959
HCW05 1,460
LC206 5,485
LC210
LC205 3,309
MWF11 434
MWL07 1,538
MWP07 3
LC204 3,131
LC203
MWD14 474
LC201 617
MWF12 304
MWJ10 135
MWL10 4
LC202 287
MWF14 202
LC215
LC201 144
MWH15 3
HCW06 34
N
Scale (FT)
0 10 20 30 40
LEGEND:
TCE (ug/l)
Upper Vashon Well; TCE (ug/l).
Lower Vashon Well; TCE (ug/l) not contoured.
NAPL Treatment Area


NAPL Area 1
Peak-Thermal
TCE in Shallow Groundwater
April 2004
HCW04 6
HCW08 3
HCW01 4
MWD03 14
MWF03 3
MWJ 9
LC213 195
LC214
LC212 437
MWC08 0
MWE07 3,066
MWJ04 20,482
MWN02 3
HCW02 2
LC211 137
MWB09 26
MWH06 383
LC207 460
LC209 240
MWI07 5
HCW05
LC206 780
MWI08 23,400
MWL07 950,000
LC210 260
LC205 814
MWF11 43
MWP07 3
LC204 1,520
LC208 670
MWF12 199
MWJ10 814
MWD14 1,320
LC203 1,056
MWL10 250
LC202 173
MWF14 44
LC215 80
LC201 345
MWM1 0
MWH15 3
HCW06
N
Scale (FT)
0 10 20 30 40
LEGEND:
TCE (ug/l)
Upper Vashon Well; TCE (ug/l).
Lower Vashon Well; TCE (ug/l) not contoured.
NAPL Treatment Area



LEGEND:

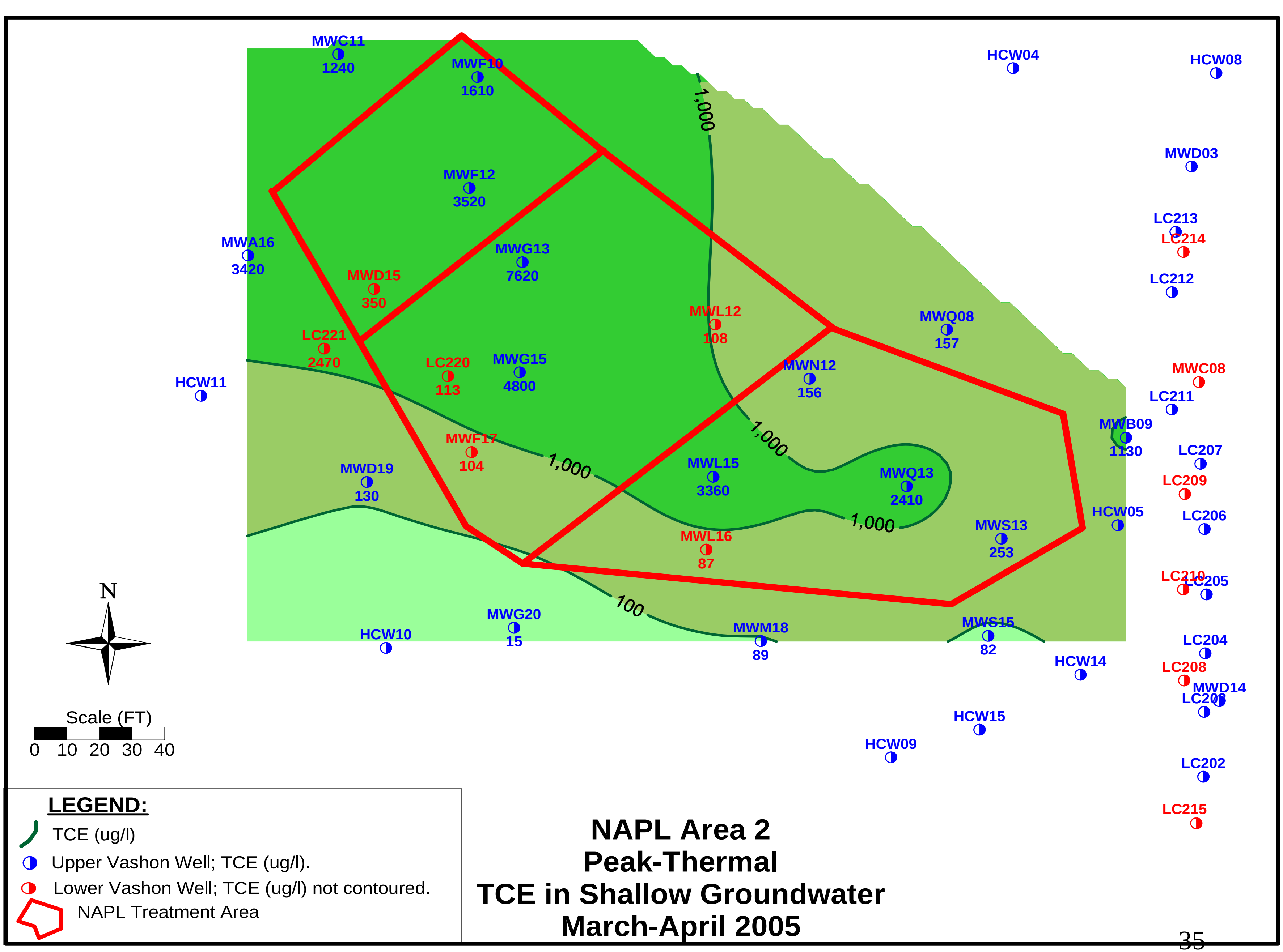
TCE (ug/l)

Upper Vashon Well; TCE (ug/l).

Lower Vashon Well; TCE (ug/l) not contoured.

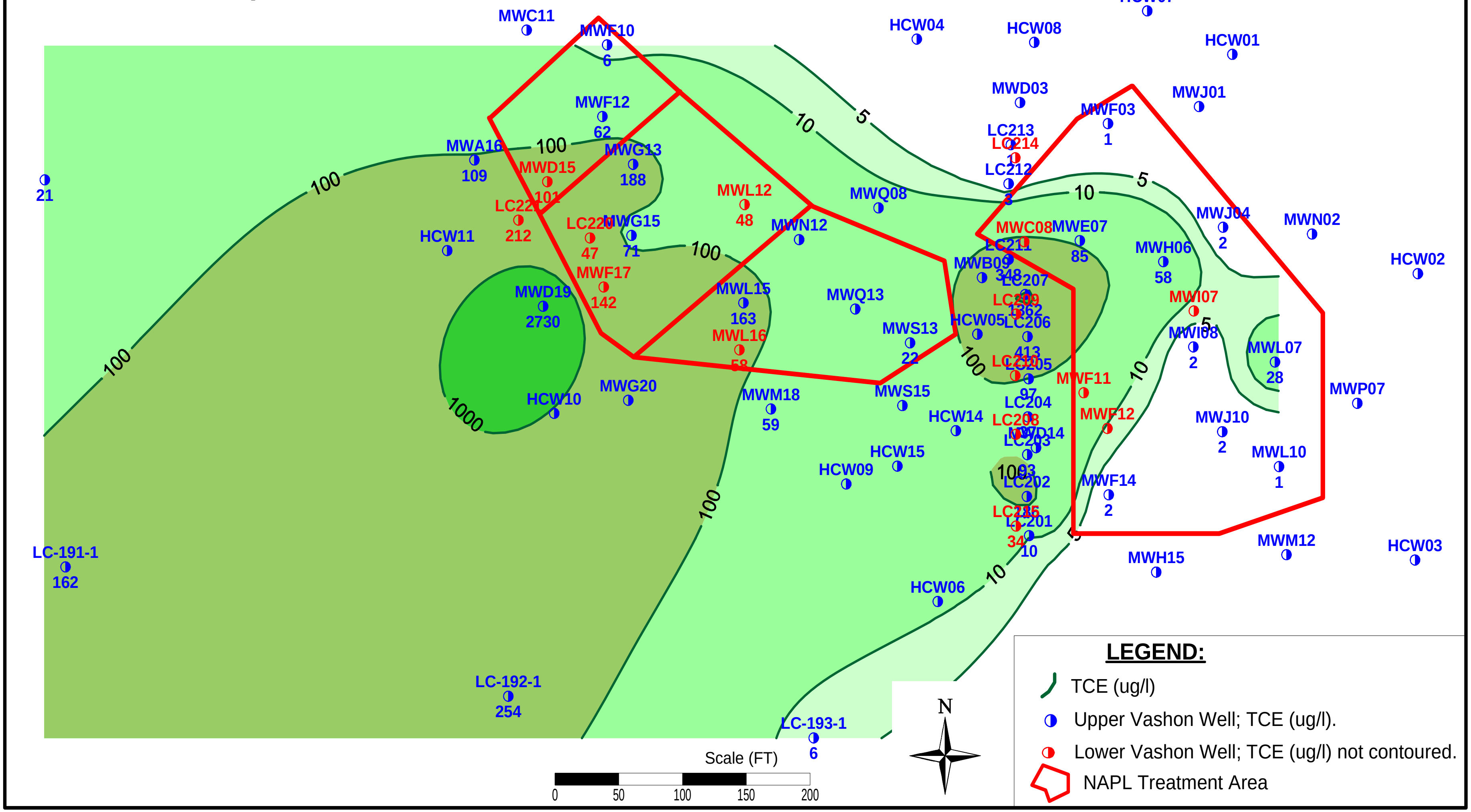
NAPL Treatment Area

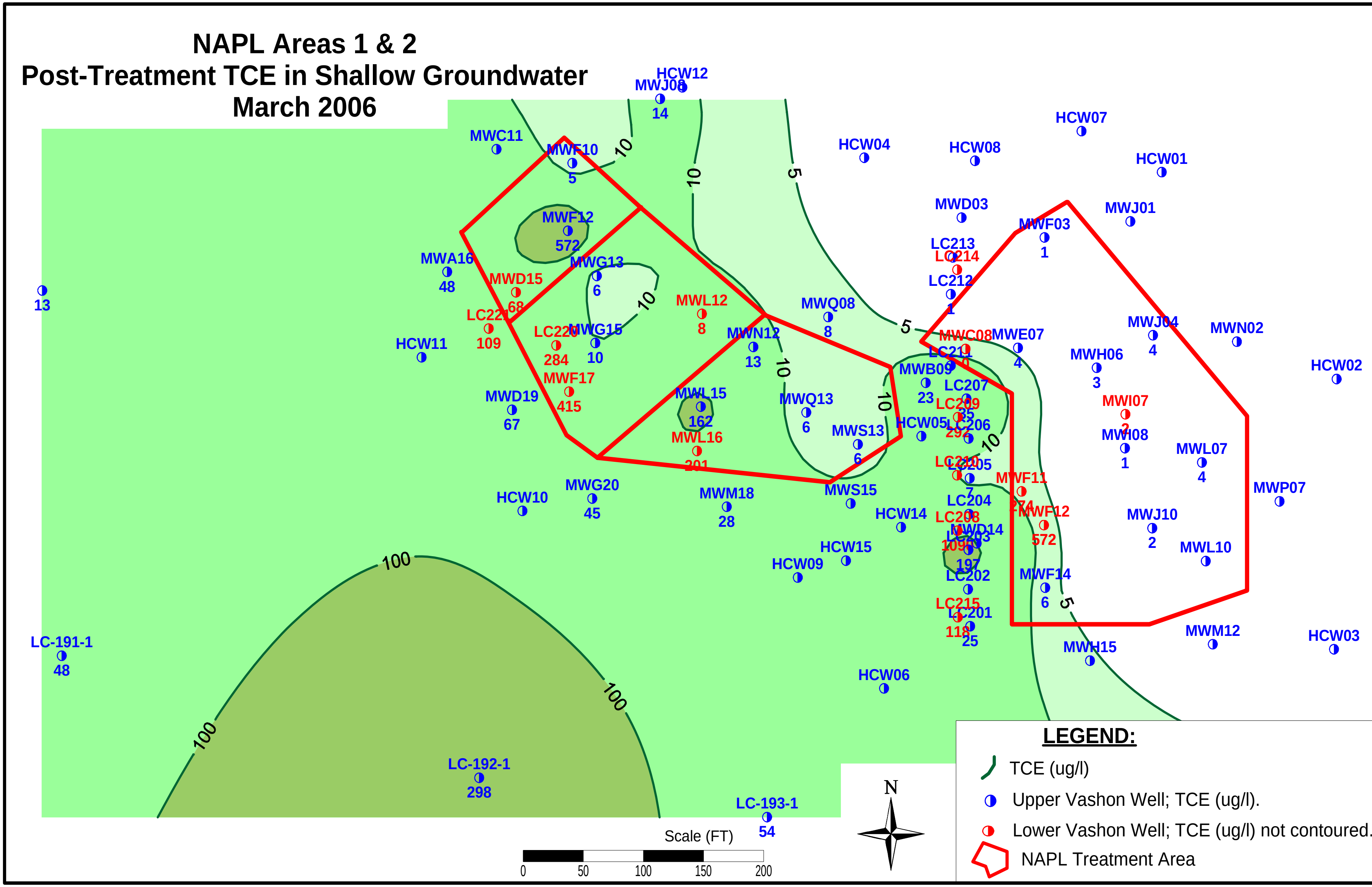
NAPL Area 2
Pre-Treatment
TCE in Shallow Groundwater
January 2005



NAPL Area 2
Peak-Thermal
TCE in Shallow Groundwater
March-April 2005

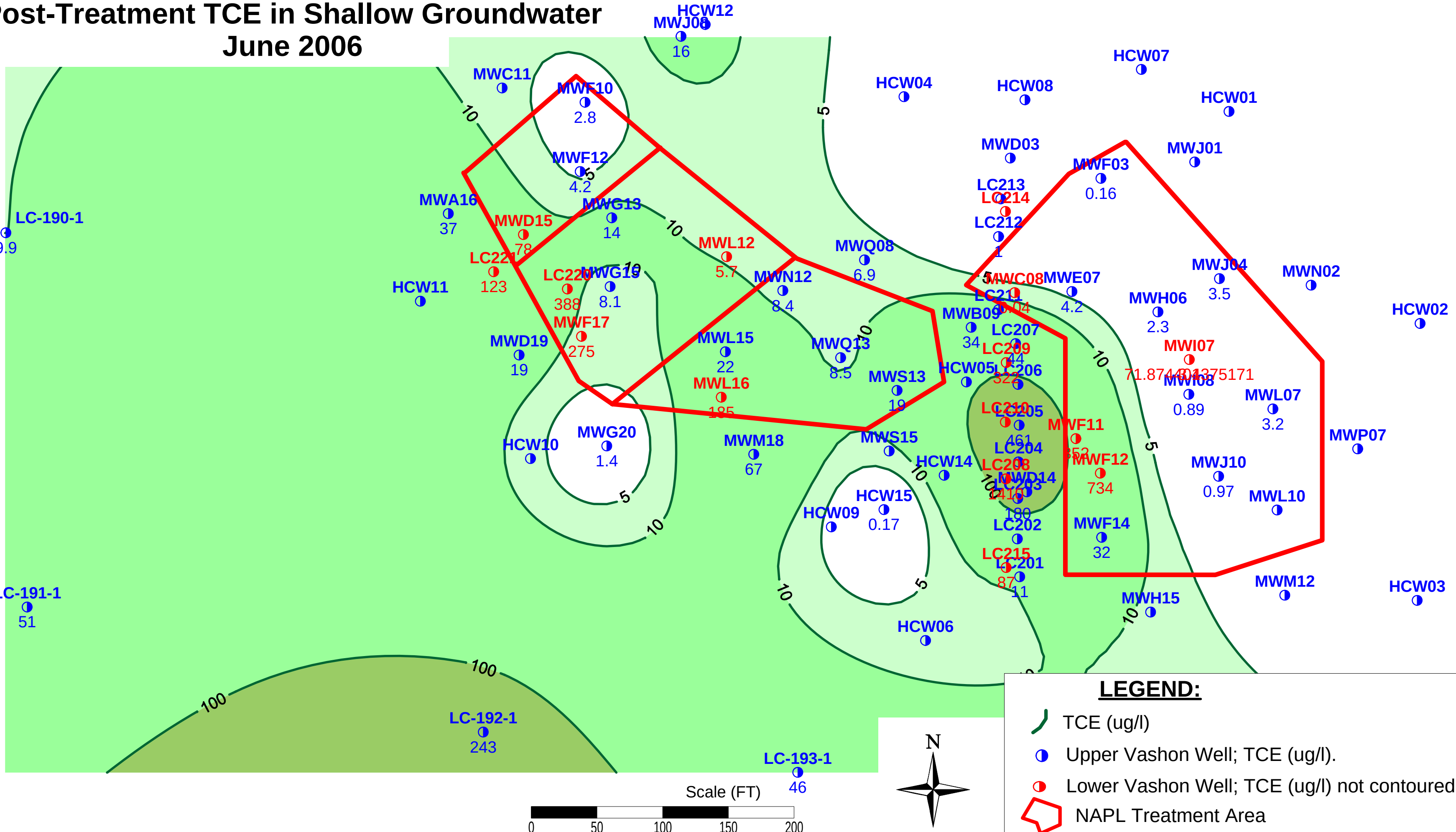
NAPL Areas 1 & 2
Post-Treatment TCE in Shallow Groundwater
September 2005



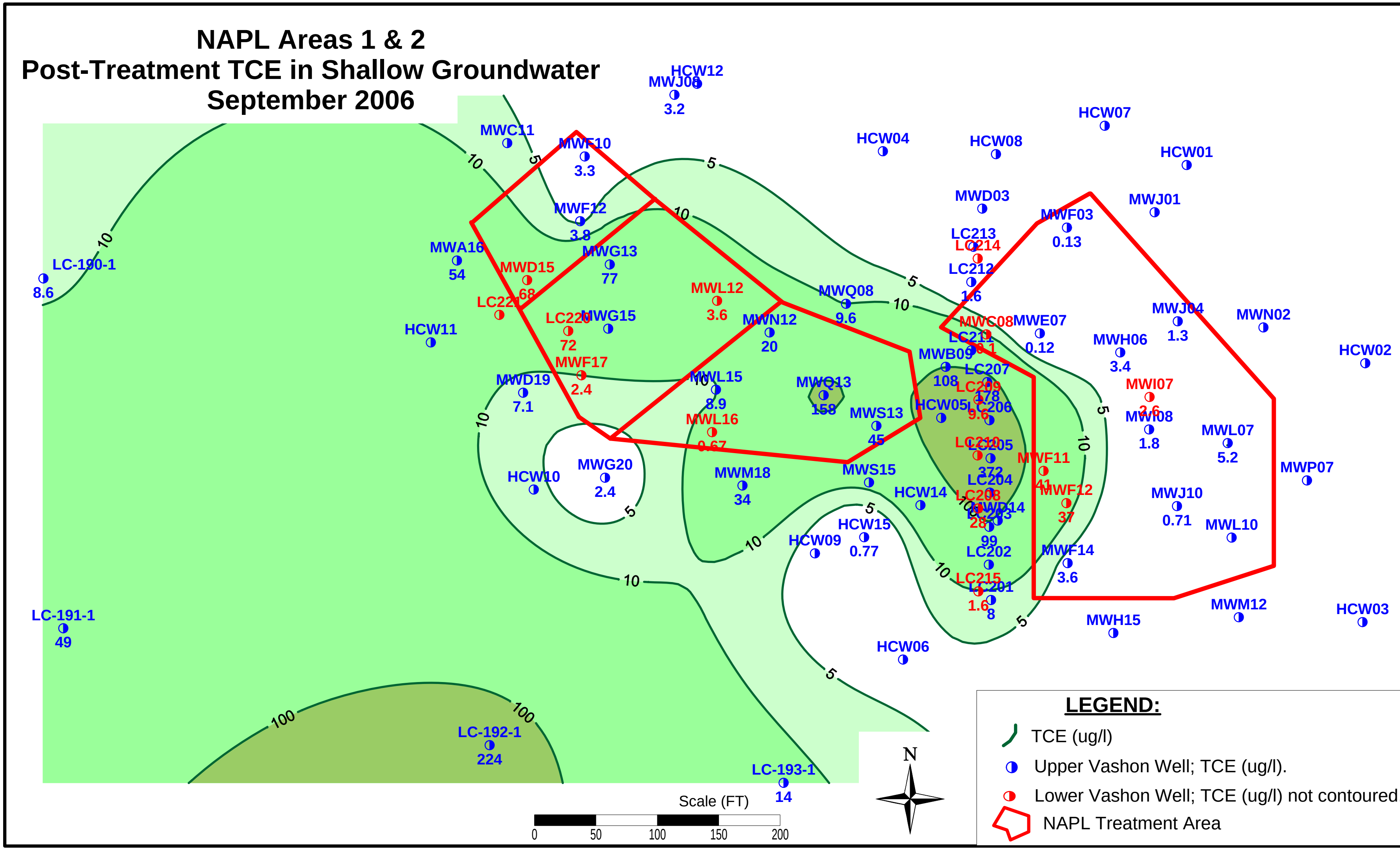


NAPL Areas 1 & 2
Post-Treatment TCE in Shallow Groundwater
March 2006
HCW12
MWJ08
14
MWC11
MWF10
5
HCW04
HCW08
HCW07
HCW01
MWF12
572
MWD03
MWJ01
MWF03
1
LC213
LC214
LC212
1
MWA16
48
MWD15
68
MWG13
6
13
LC221
109
LC220
284
MWG15
10
MWL12
8
MWQ08
8
MWN12
13
MWC08
MWE07
4
MWJ04
4
MWN02
HCW11
MWH06
3
HCW02
MWF17
415
MWD19
67
MWL15
162
MWQ13
6
MWB09
23
LC207
LC209
MWI07
2
MWI08
1
MWL16
201
MWS13
6
HCW05
LC206
MWL07
4
MWF11
MWP07
HCW10
MWG20
45
MWM18
28
MWS15
HCW14
LC204
MWJ10
2
MWF12
572
MWD14
MWL10
HCW15
HCW09
LC202
MWF14
6
LC215
LC201
118
25
LC-191-1
48
MWM12
HCW03
MWH15
HCW06
LC-192-1
298
LC-193-1
54
100
10
5
Scale (FT)
0
50
100
150
200
N
LEGEND:
TCE (ug/l)
Upper Vashon Well; TCE (ug/l).
Lower Vashon Well; TCE (ug/l) not contoured.
NAPL Treatment Area

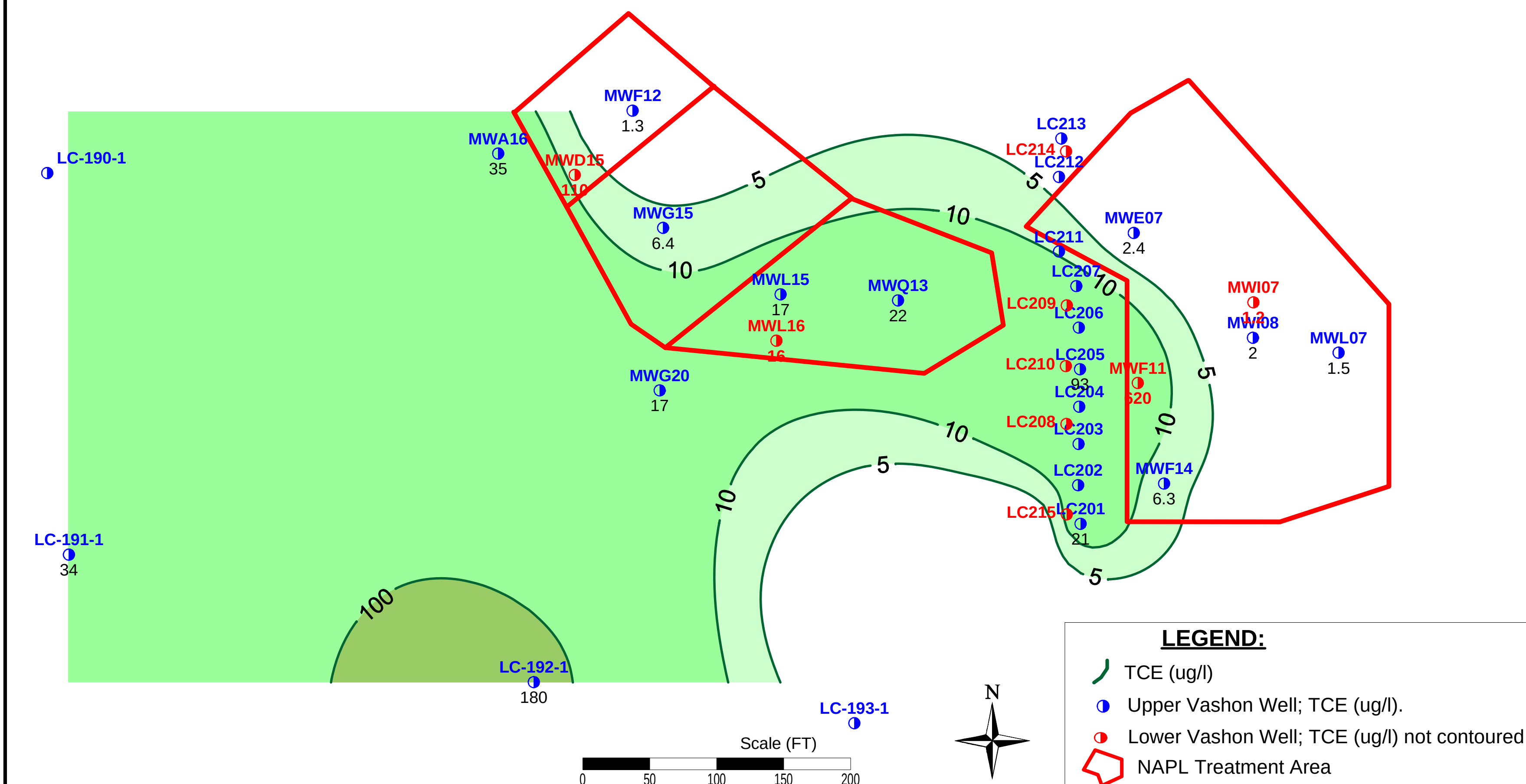
NAPL Areas 1 & 2
Post-Treatment TCE in Shallow Groundwater
June 2006



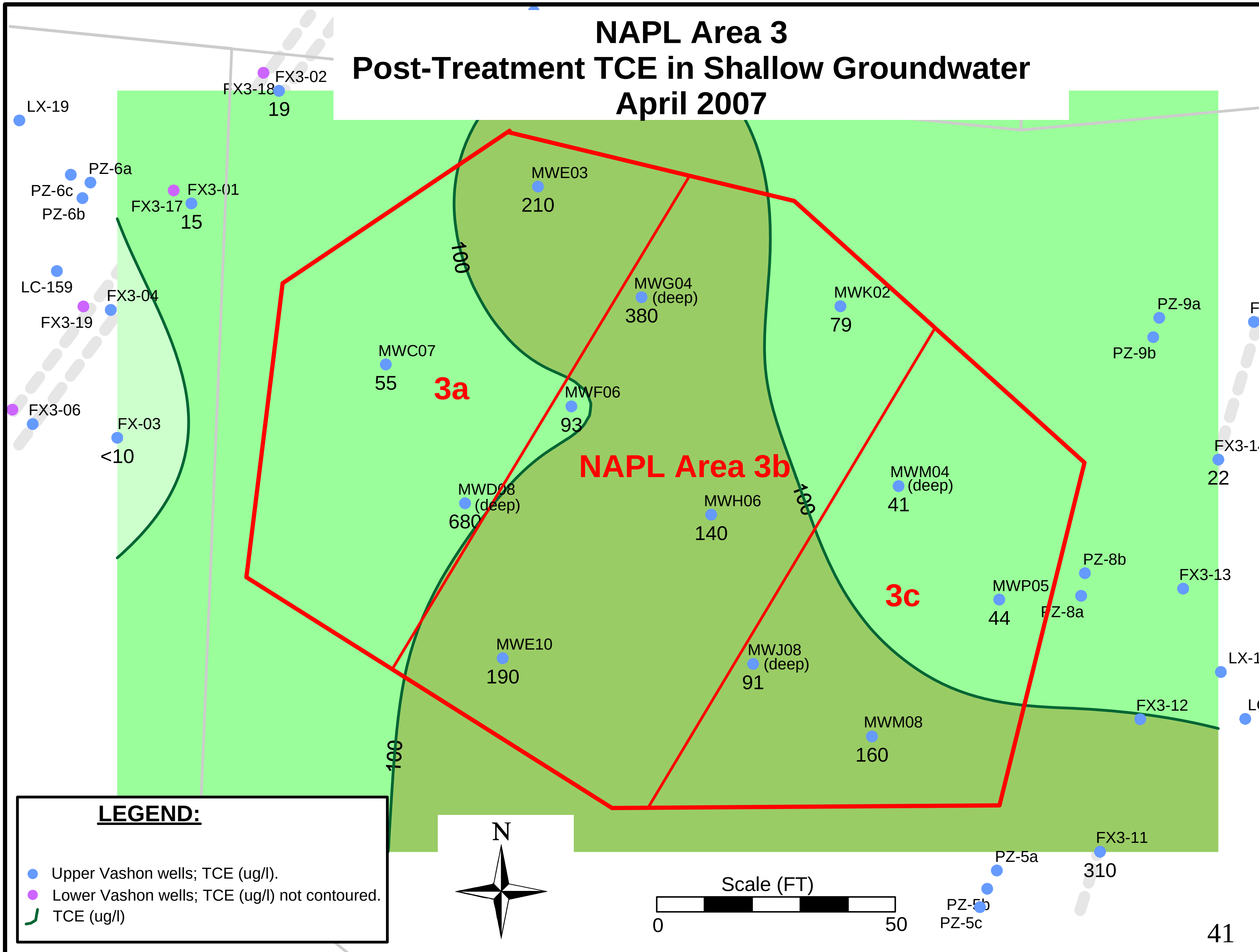
NAPL Areas 1 & 2
Post-Treatment TCE in Shallow Groundwater
September 2006



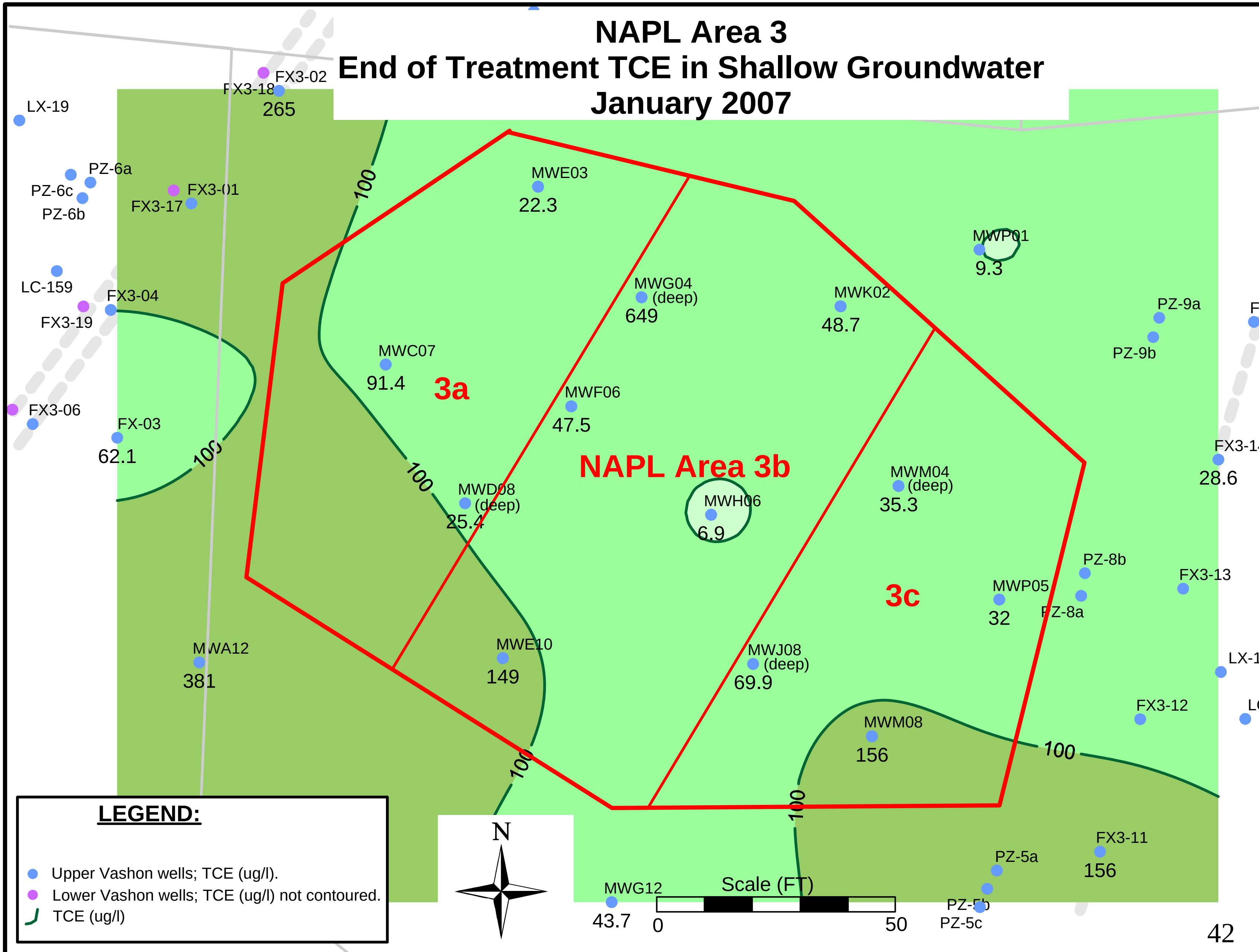
NAPL Areas 1 & 2
Post-Treatment TCE in Shallow Groundwater
April 2007



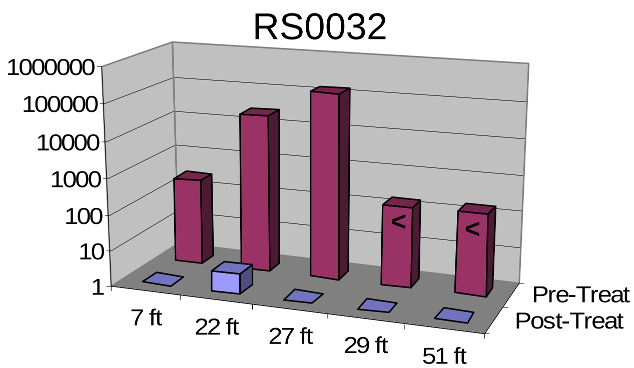
NAPL Area 3
Post-Treatment TCE in Shallow Groundwater
April 2007

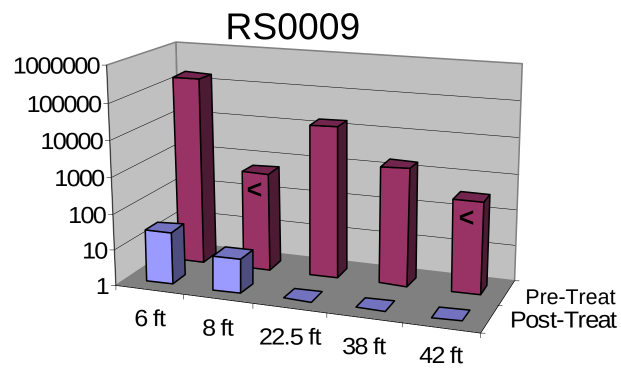


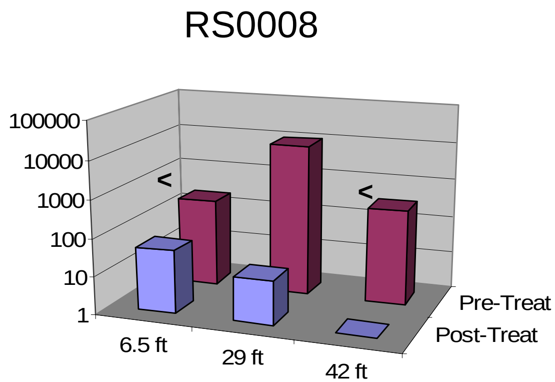
NAPL Area 3
End of Treatment TCE in Shallow Groundwater
January 2007

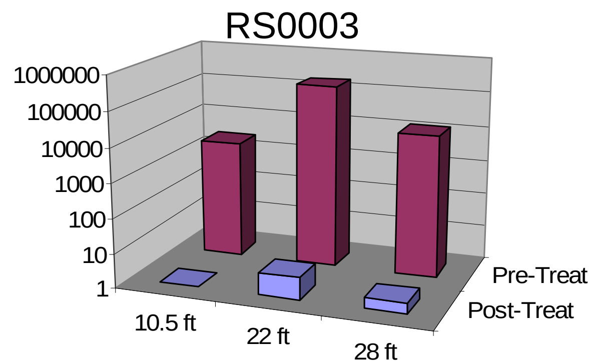


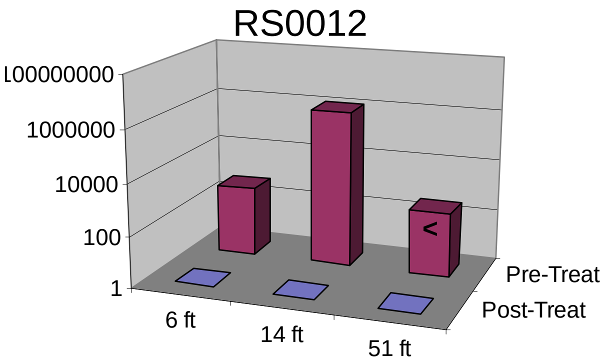
NAPL Area 1
Pre- vs. Post-Treatment TCE Soil Concentration (ug/kg)

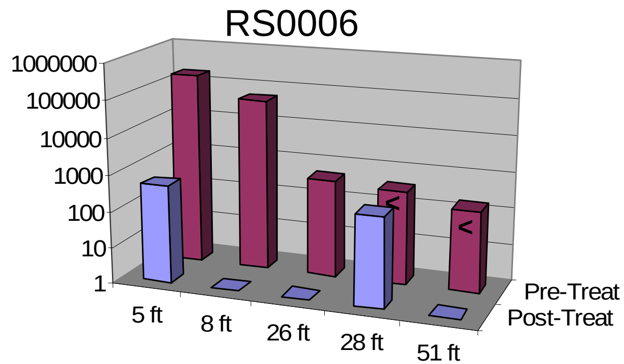












NAPL Area 2
Pre- vs. Post-Treatment TCE Soil Concentration (ug/kg)