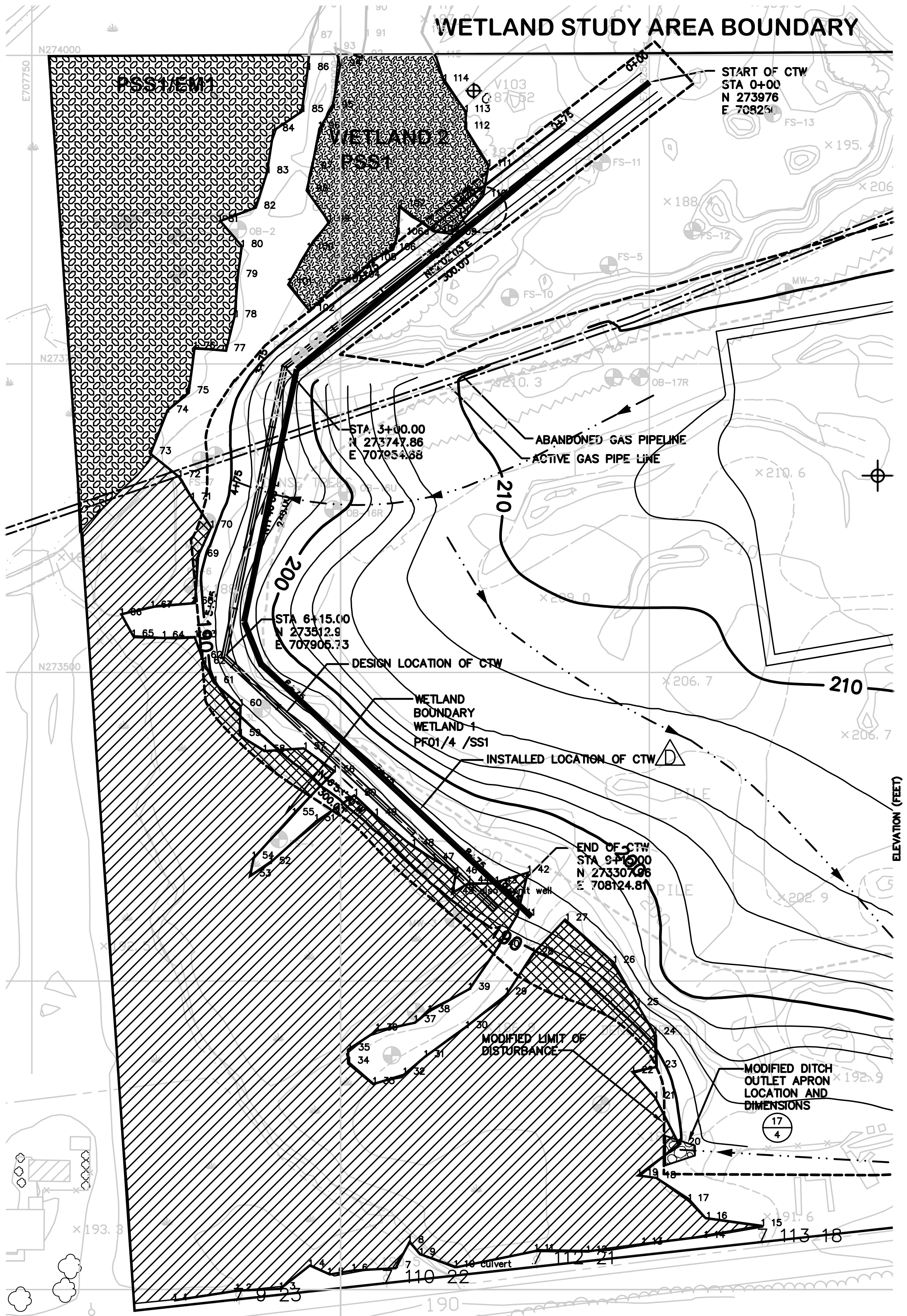


1 PLAN
3 CTW

SCALE: 1" = 50'

WETLAND BOUNDARY DELINEATED BY:

NORMANDEAU ASSOCIATES, INC.
ENVIRONMENTAL CONSULTANTS
25 Nashua Road Bedford, New Hampshire 03110-5500

NAI # 18161.000

SCHEDULE OF IRON REQUIREMENTS FOR CTW SEGMENTS							
SEGMENT NO.	BEGINNING STATION	ENDING STATION	SEGMENT LENGTH (FT)	APPROXIMATE WEIGHT OF IRON REQUIRED IN SEGMENT (TONS)	PERCENT IRON (BY WEIGHT) FOR 2-FT WIDE CTW	PERCENT IRON (BY WEIGHT) FOR 3-FT WIDE CTW	PERCENT IRON (BY WEIGHT) FOR 4-FT WIDE CTW
1	0+00	1+75	175	718	95%	71%	57%
2	1+75	2+75	100	322	80%	60%	47%
3	2+75	3+75	100	439	94%	71%	57%
4	3+75	4+95	120	819	NP	87%	71%
5	4+95	6+15	120	446	74%	55%	43%
6	6+15	7+15	100	223	50%	36%	28%
7	7+15	8+15	100	220	49%	35%	27%
8	8+15	9+15	100	365	72%	53%	42%

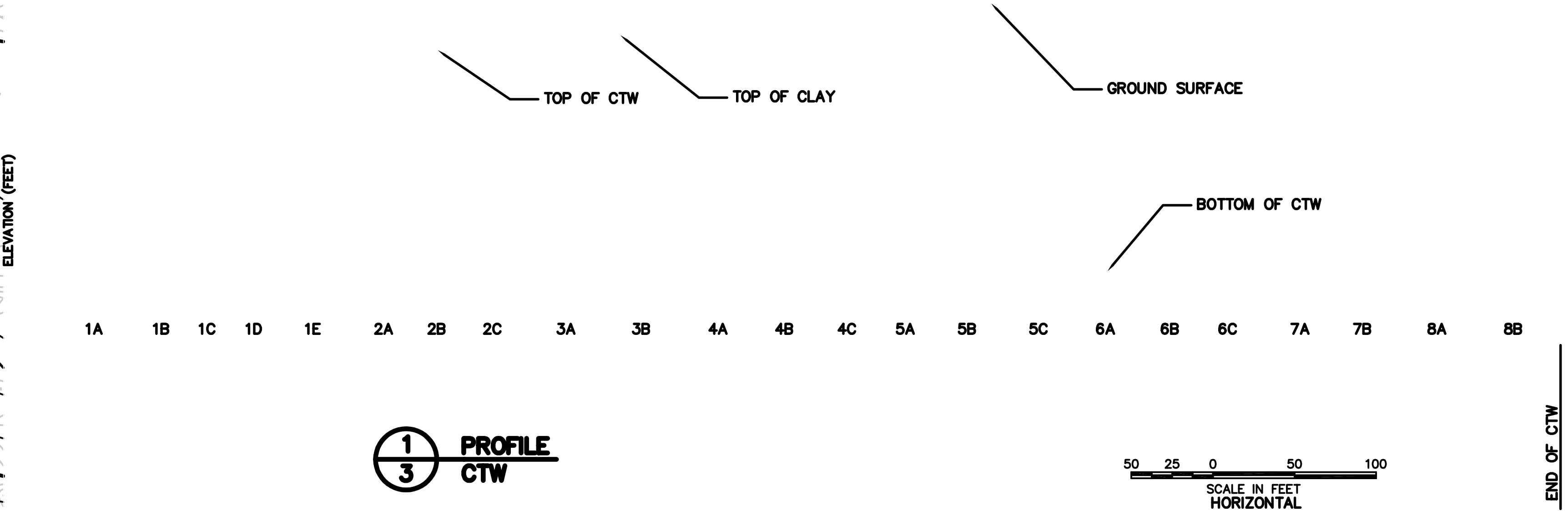
NOTE: IRON PERCENTAGES BASED ON IRON DENSITY OF 160 lb/ft~3 AND SAND DENSITY OF 100 lb/ft~3. THESE DENSITIES SHALL BE VERIFIED PRIOR TO CONSTRUCTION AND THE MIXTURE PERCENTAGES ADJUSTED ACCORDINGLY.

NP – NOT POSSIBLE

NOTES:

1. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL), NGVD 1929. GRID COORDINATES CORRESPOND TO THE MAINE STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD 1927.
2. WETLAND BOUNDARIES WITHIN THE WETLAND STUDY AREA WERE DELINEATED BY NORMANDEAU ASSOCIATES INC., BEDFORD, NH ON MAY 11 AND 12, 1999, FOLLOWING THE 1987 US ARMY CORPS OF ENGINEERS WETLAND DELINEATION MANUAL.

D



1 PROFILE
3 CTW

LEGEND

74 75 76	WETLAND BOUNDARY
▩	AREA OF IMPACTED WETLAND
▨	PF01/4 /SS1 PALUSTRINE FORESTED/SCRUB SHRUB
■	PSS1 PALUSTRINE SCRUB SHRUB
▦	PSS1/EM1 PALUSTRINE SCRUB SHRUB/EMERGENT

100% DESIGN

GeoSyntec Consultants
130 RESEARCH LANE, SUITE 2
GUELPH, ONTARIO, CANADA N1G 5G3

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
AS-BUILT CTW PLAN AND PROFILE

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	AS-BUILT	MR	TK
C	APRIL 2000	WETLAND INFORMATION ADDED	WDB	TK
B	APRIL 2000	CTW SEGMENTS RESTATIONED, IRON REQUIREMENTS CHANGED	WDB	TK
A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO.'S 6 AND 21	SMG	JFB

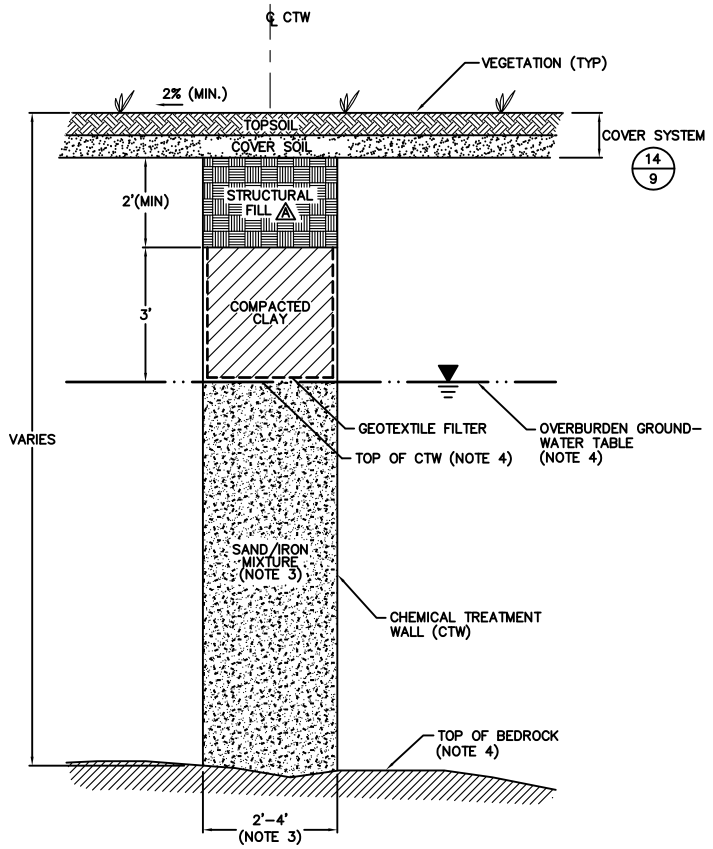
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

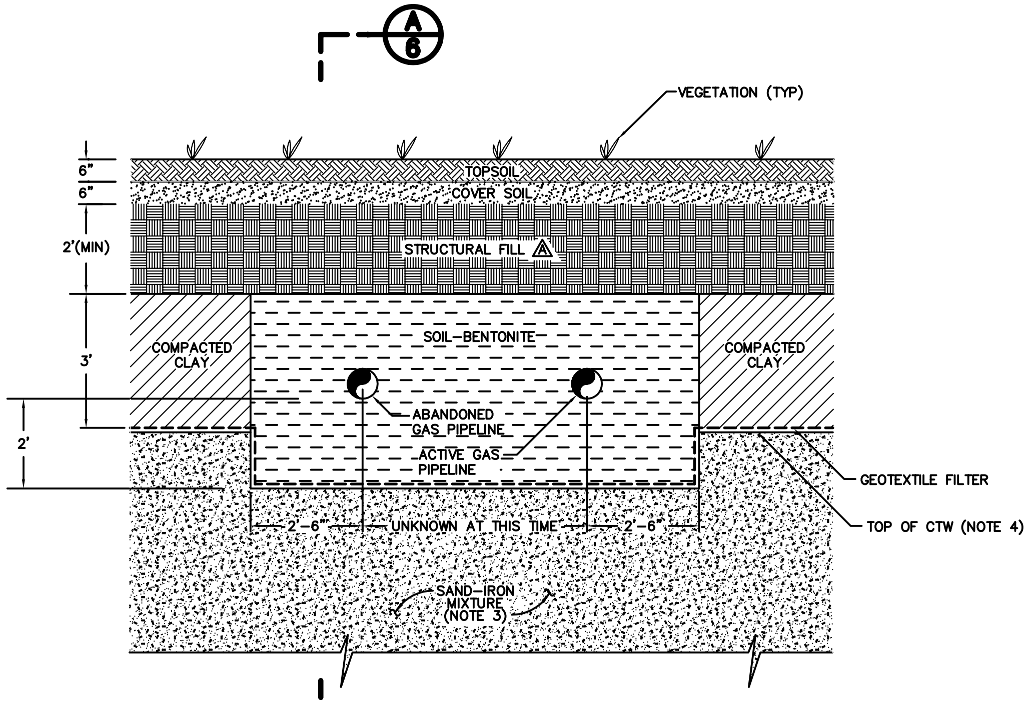
SEAL

DATE: APRIL 1999
DESIGN BY: SMG
DRAWN BY:
CHECKED BY: MJM
REVIEWED BY: TK
APPROVED BY: JFB
SCALE: AS SHOWN
JOB NO.: TR0001-01
FILE NO: 0001C005
REVISION: D
DRAWING NO: 5 OF 9



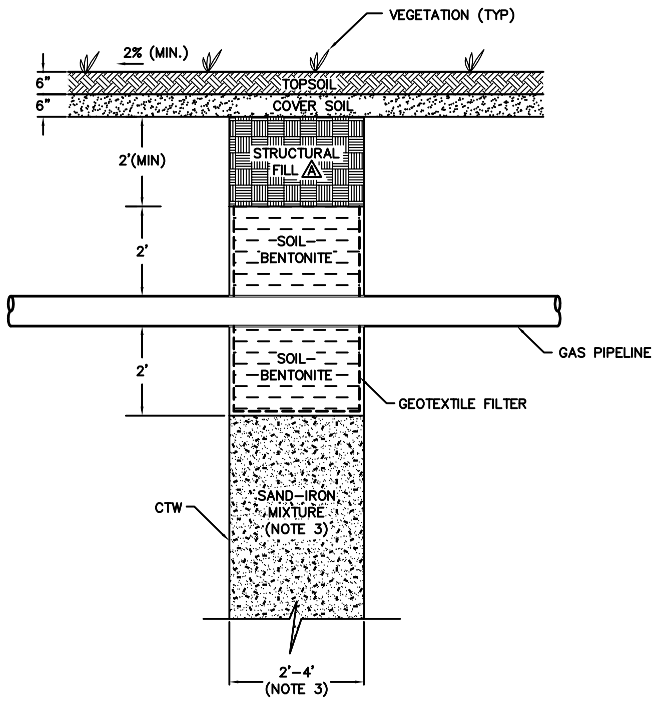
2/4 DETAIL
CHEMICAL TREATMENT WALL (CTW)

SCALE: 1" = 2'
XREF: 0001X008.DWG



3/4 DETAIL
CTW AT GAS LINE

SCALE: 1" = 2'
XREF: 0001X006.DWG



A/6 SECTION
CTW AT GAS LINE

SCALE: 1" = 2'
XREF: 0001X007.DWG

100% DESIGN

NOTES:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL TOLERANCES SHALL BE WITHIN THE LIMITS GIVEN IN THE SPECIFICATIONS.
2. CHEMICAL TREATMENT WALL (CTW) SHALL EXTEND FROM THE OVERBURDEN GROUNDWATER TABLE DOWN TO THE TOP OF BEDROCK SURFACE, AND MUST BE VERIFIED IN THE FIELD BY THE ENGINEER.
3. CTW PLAN AND PROFILE AND SAND/IRON MIXTURE RATIOS FOR EACH CTW SEGMENT AND CTW TRENCH THICKNESS ARE PROVIDED ON DRAWING 5. CONTRACTOR SHALL ADJUST SAND/IRON MIXTURE ACCORDINGLY BASED ON SELECTED CTW TRENCH WIDTH AS SHOWN ON DRAWING 5 AND DESCRIBED IN SPECIFICATIONS.
4. TOP OF CTW REFERS TO THE UPPER LIMIT OF THE SAND/IRON MIXTURE AND CORRESPONDS TO THE OVERBURDEN GROUND-WATER TABLE ELEVATION. APPROXIMATE OVERBURDEN GROUNDWATER TABLE ELEVATIONS ARE SHOWN ON DRAWING 2. APPROXIMATE TOP OF BEDROCK ELEVATIONS ALONG CTW ALIGNMENT ARE SHOWN ON DRAWING 5.
5. CONTRACTOR SHALL CONSTRUCT AROUND BOTH THE ACTIVE AND INACTIVE GAS PIPELINES AS SHOWN ON THIS DRAWING. ALTERNATIVELY, THE CONTRACTOR MAY ELECT TO DECOMMISSION (REMOVE) A SEGMENT OF THE ABANDONED GAS PIPELINE AT CONTRACTOR'S SOLE EXPENSE. DECOMMISSIONING OF THE ABANDONED GAS PIPELINE SHALL BE IN ACCORDANCE WITH NORTHERN UTILITIES RECOMMENDATIONS AND WILL REQUIRE THEIR AND THE ENGINEER'S PRE-APPROVAL OF THE CONTRACTOR'S DECOMMISSIONING PLAN. PIPELINE DECOMMISIONING SHALL COMPLY WITH ALL APPLICABLE PCB MEGA RULE REGULATIONS (40 CFR 750, 761).

GEOSYNTEC CONSULTANTS
130 RESEARCH LANE, SUITE 2
GUELPH, ONTARIO, CANADA N1G 5G3

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
CTW DETAILS

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
B	DEC 1999		SMG	JFB
A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO.'S 6 AND 21	SMG	JFB

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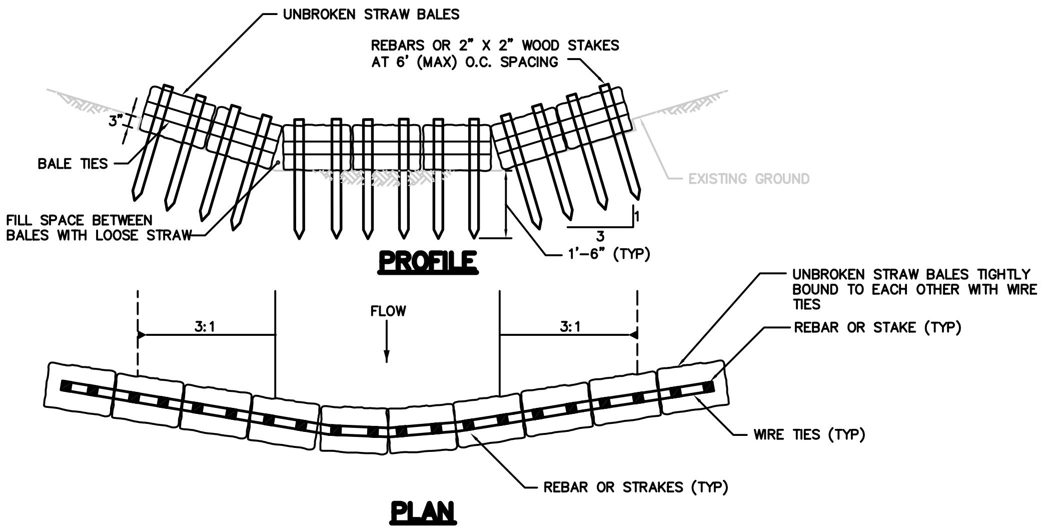
SIGNATURE

DATE

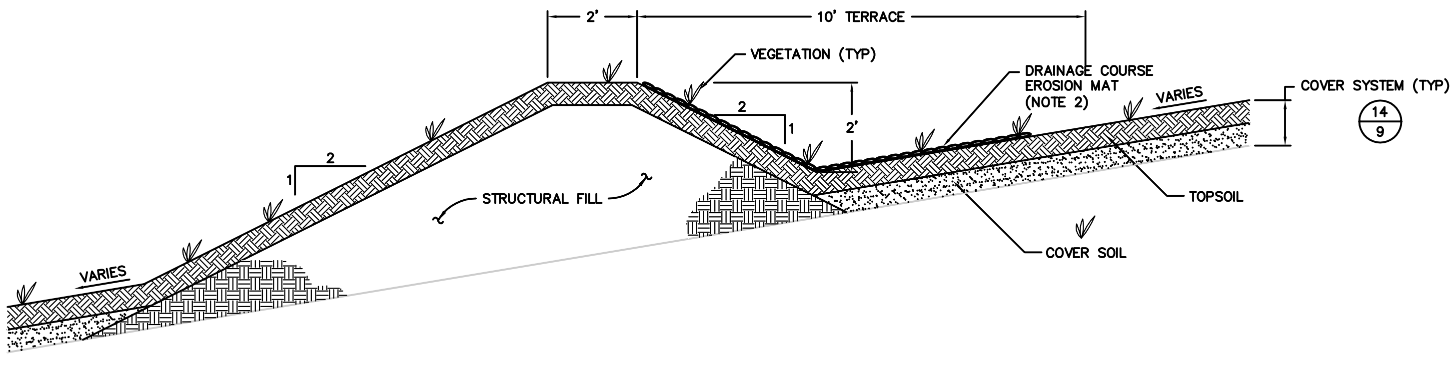
SEAL

DATE:	APRIL 1999	SCALE:	1" = 2'
DESIGN BY:	SMG	JOB NO.:	TR0001-01
DRAWN BY:	AWS/LB	FILE NO:	0001A006
CHECKED BY:	MJM	REVISION:	D
REVIEWED BY:	TK	DRAWING NO:	6 OF 9
APPROVED BY:	JFB		



4 DETAIL
TEMPORARY STRAW BALE BARRIER– CHANNEL FLOW APPLICATION

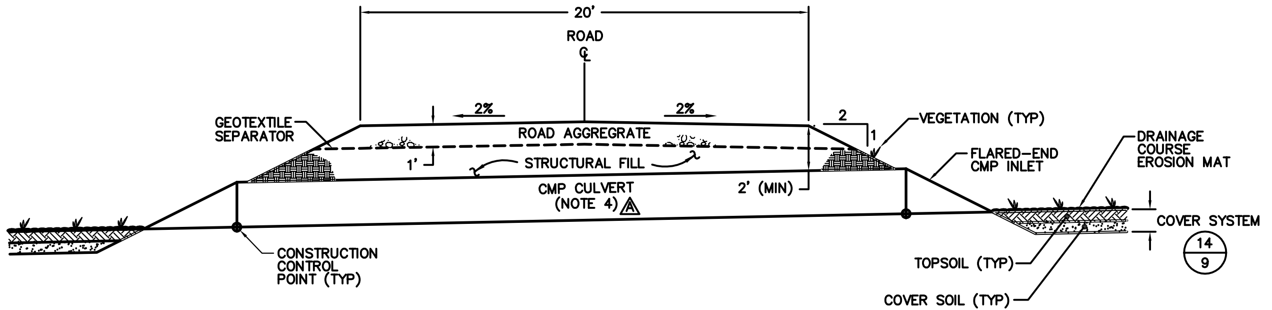
SCALE: 1" = 2'
XREF: 0001X004.DWG



7 DETAIL
4 DRAINAGE TERRACE

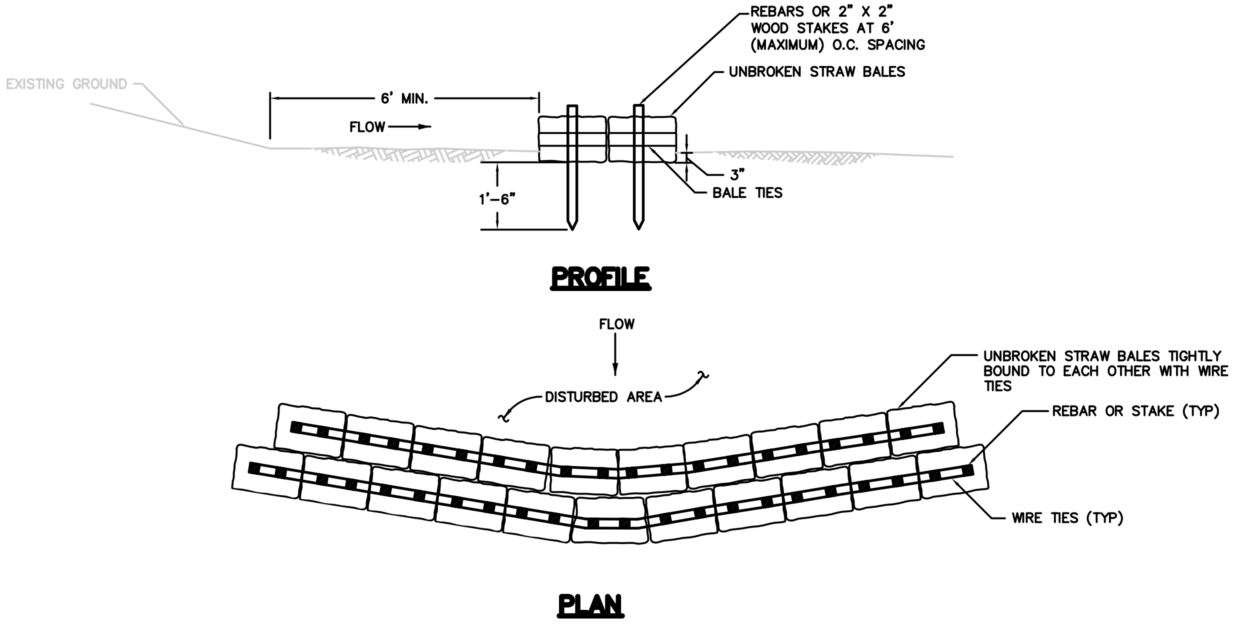
SCALE: 1" = 2'
XREF: 0001X014.DWG

DRAINAGE COURSE EROSION MAT (NOTE 2)



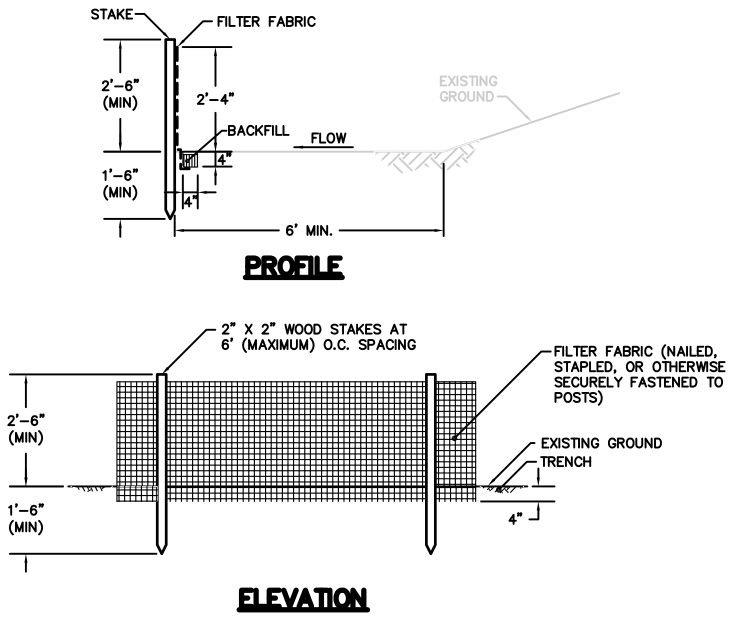
8 DETAIL
4 CULVERT

SCALE: 1" = 4'
XREF: 0001X016.DWG



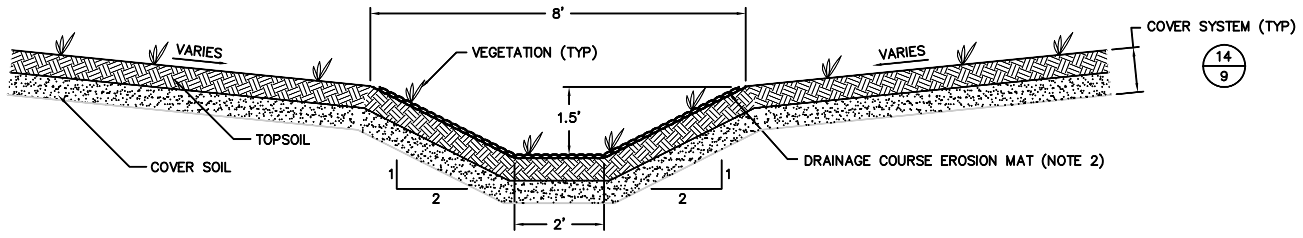
5 DETAIL
TEMPORARY STRAW BALE BARRIER– SHEET FLOW APPLICATION

SCALE: 1" = 2'
XREF: 0001X004.DWG



9 DETAIL
SILT FENCE

SCALE: 1" = 2'
XREF: 0001X004.DWG



6 DETAIL
4 DRAINAGE DITCH

SCALE: 1" = 2'
XREF: 0001X010.DWG

NOTES:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL TOLERANCES SHALL BE WITHIN THE LIMITS GIVEN IN THE SPECIFICATIONS.
2. ALL DRAINAGE COURSE EROSION MAT SHALL BE OVERLAPPED, STAKED, AND ANCHORED IN STRICT ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS FOR CHANNEL FLOW APPLICATIONS.
3. EXTENT OF STRUCTURAL FILL AROUND AND OVER CMP CULVERT SHALL BE AS-NEEDED TO ACHIEVE A MINIMUM 2-FT COVER ABOVE THE TOP OF CULVERT PIPE, AND TO MAINTAIN A SMOOTH ACCESS ROAD PROFILE.
4. △ CULVERT SIZES ARE SHOWN ON DRAWING 4.

GEOSYNTEC CONSULTANTS
130 RESEARCH LANE, SUITE 2
GUELPH, ONTARIO, CANADA N1G 5G3

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT: CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK: SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE: SURFACE WATER MANAGEMENT DETAILS

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
C	DEC 1999		SMG	JFB
B	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO. 23	SMG	JFB

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

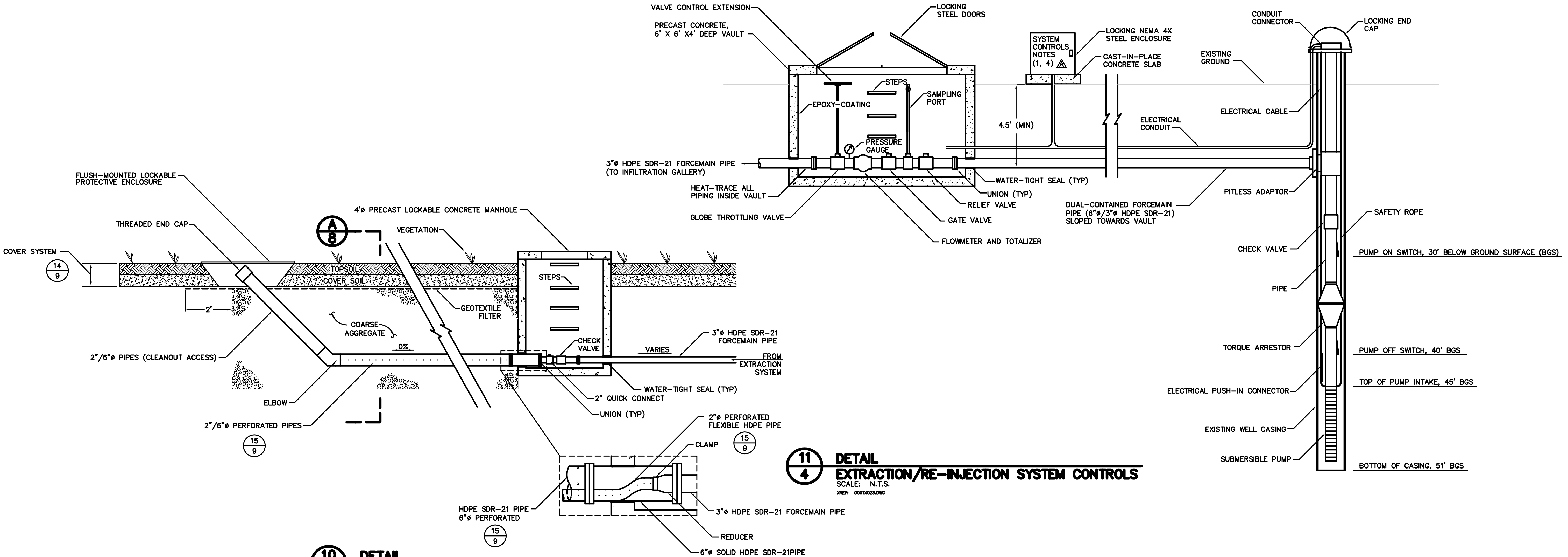
SIGNATURE

DATE

SEAL

DATE:	APRIL 1999	SCALE:	AS SHOWN
DESIGN BY:	SMG	JOB NO.:	TR0001-01
DRAWN BY:	JW/LB/AWS	FILE NO:	0001A007
CHECKED BY:	MJM	REVISION:	D
REVIEWED BY:	TK	DRAWING NO:	7 OF 9
APPROVED BY:	JFB		

100% DESIGN



11 / 4 DETAIL
EXTRACTION/RE-INJECTION SYSTEM CONTROLS

SCALE: N.T.S.

XREF: 0001X023.DWG

10 / 4 DETAIL
PROFILE OF INFILTRATION GALLERY

SCALE: 1" = 2' (NOTE 5) A

XREF: 0001X025.DWG

NOTES:

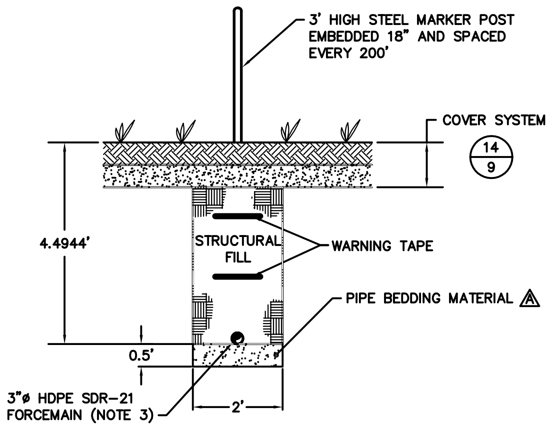
1. MECHANICAL AND ELECTRICAL COMPONENTS OF THE EXTRACTION/RE-INJECTION SYSTEM (E.G., PIPES, VALVES, FITTINGS, CONTROLS, POWER, ETC.) SHALL BE INSTALLED AS DESCRIBED FURTHER IN THE SPECIFICATIONS AND IN ACCORDANCE WITH MANUFACTURERS' RECOMMENDATIONS. ELECTRICAL INSTALLATION SHALL CONFORM TO NATIONAL ELECTRICAL CODE, AND APPLICABLE STATE/LOCAL CODES.

2. FORCEMAIN EMBEDMENT TRENCH OUTSIDE THE COVER SYSTEM LIMITS SHALL CONFORM TO THE DIMENSIONS SHOWN AND SHALL BE BACKFILLED WITH STRUCTURAL FILL, FOLLOWED BY RESTORATION OF THE EXISTING GROUND SURFACE MATERIALS AND CONDITIONS.

3. 3-INCH FORCEMAIN SHALL BE DUAL-CONTAINED BETWEEN EXTRACTION WELL AND VAULT, USING A 6-INCH DIAMETER HDPE OUTER CONTAINMENT PIPE.

A 4. CONTRACTOR SHALL SUBMIT SHOP DRAWINGS OF SYSTEM CONTROLS TO ENGINEER NO LATER THAN 30 DAYS PRIOR TO SYSTEM INSTALLATION. CONTROLS SHALL INCLUDE AN AUTOMATIC AND MANUAL OVERRIDE ON/OFF SWITCH FOR THE PUMP AND A PROGRAMMABLE LOGIC CONTROLLER WHICH RESPONDS TO THE GROUNDWATER LEVEL SWITCHES IN THE WELL, AND ADDITIONAL COMPONENTS AS NEEDED AND AS RECOMMENDED BY THE MANUFACTURER TO ENSURE THE SYSTEM FUNCTIONS AS-SPECIFIED.

A 5. INFILTRATION GALLERY SHALL HAVE A PLAN AREA OF 125' X 50' AS SHOWN ON DRAWING 4.

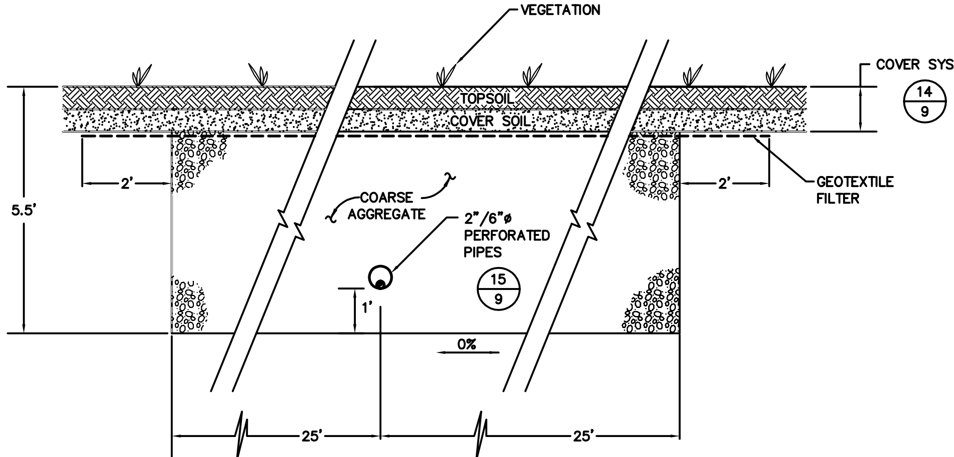


12 / – DETAIL
TYPICAL FORCEMAIN EMBEDMENT TRENCH

(NOTE 2)

SCALE: 1" = 2'

XREF: 0001X019.DWG



A / 8 SECTION
INFILTRATION GALLERY

SCALE: 1" = 2' (NOTE 5) A

XREF: 0001X020.DWG

100% DESIGN

GEOSYNTEC CONSULTANTS
130 RESEARCH LANE, SUITE 2
GUELPH, ONTARIO, CANADA N1G 5G3

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
GROUNDWATER EXTRACTION/RE-INJECTION SYSTEM DETAILS

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
B	DEC 1999		SMG	JFB
A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO'S 24, 25, AND 26	SMG	JFB

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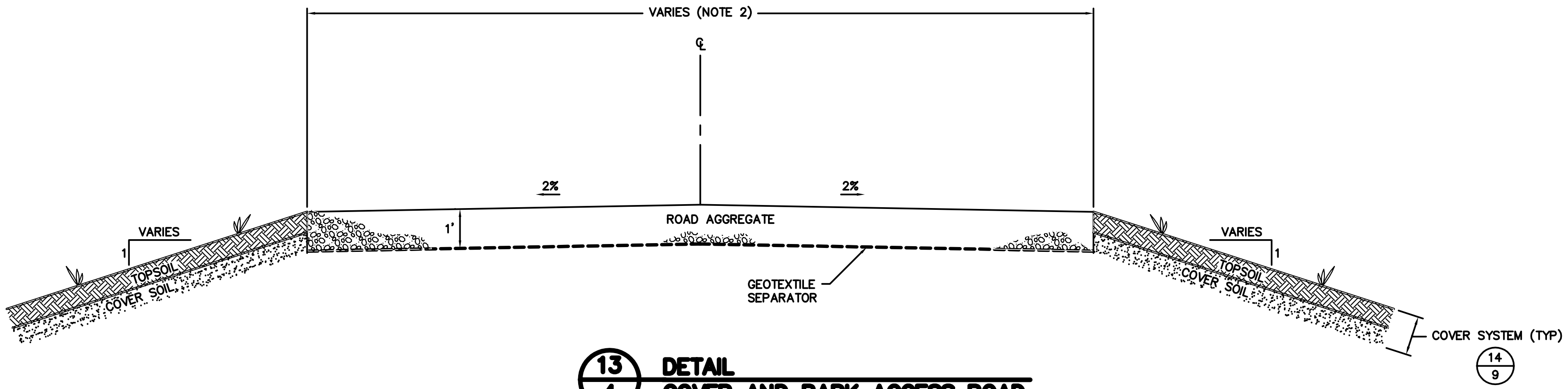
SIGNATURE

DATE

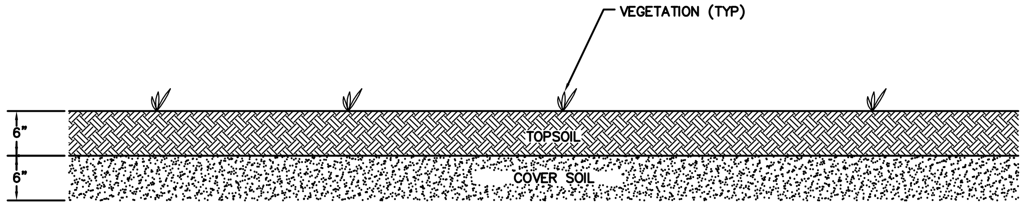
SEAL

DATE: APRIL 1999
DESIGN BY: SMG
DRAWN BY: AWS/LB
CHECKED BY: MJM
REVIEWED BY: TK
APPROVED BY: JFB
SCALE: AS SHOWN
JOB NO.: TR0001-01
FILE NO: 0001A008
REVISION: D
DRAWING NO: 8 OF 9



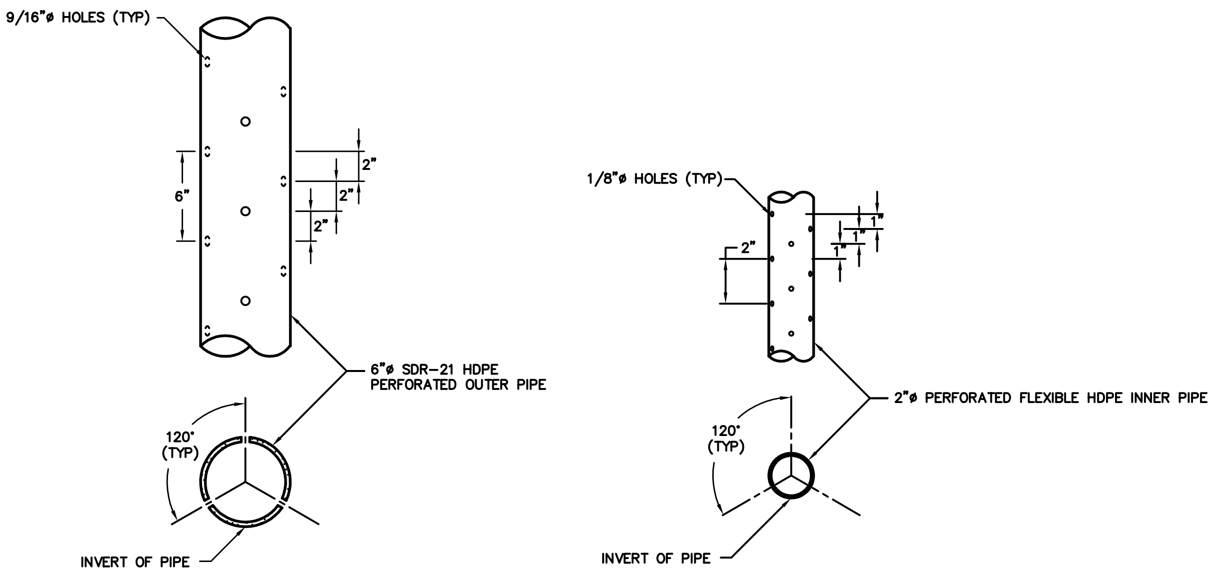
13 / 4 DETAIL COVER AND PARK ACCESS ROAD

SCALE: 1" = 2'
XREF: 0001X012.DWG



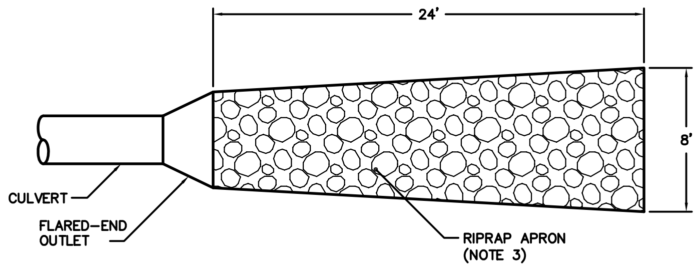
14 / 6 DETAIL COVER SYSTEM

SCALE: 1" = 1'
XREF: 0001X011.DWG



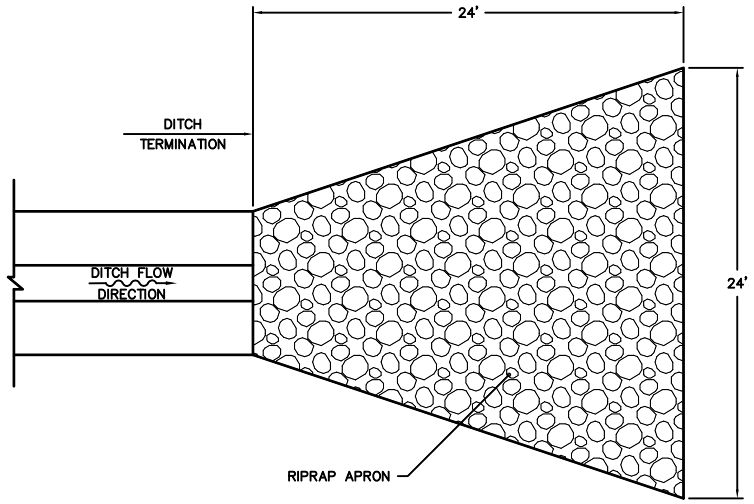
15 / 8 DETAIL PIPE PERFORATIONS

SCALE: N.T.S.
XREF: 0001X022.DWG



16 / 4 DETAIL CULVERT OUTLET APRON △A

SCALE: NOT TO SCALE
XREF: 0001X027.DWG



17 / 4 DETAIL DITCH OUTLET APRON △A

SCALE: 1" = 5'
XREF: 0001X028.DWG

NOTES:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL TOLERANCES SHALL BE WITHIN THE LIMITS GIVEN IN THE SPECIFICATIONS.
2. ACCESS ROAD LEADING FROM ENTRANCE ON BLACKWATER ROAD TO THE INFILTRATION GALLERY SHALL BE 20-FT WIDE AS SHOWN ON DRAWING 4. ACCESS ROADS AND PARKING AREAS ON-SITE THAT ARE TO HAVE THEIR PAVEMENT REMOVED SHALL BE RE-BUILT TO THEIR ORIGINAL WIDTHS.

△A 3. RIPRAP SHALL HAVE D'5'0 = 6 IN. AND D'M'A'X = 12 IN. RIPRAP APRONS SHALL BE 12 IN. THICK AND SHALL BE UNDERLAIN BY GEOTEXTILE FILTER.

GEOSYNTEC CONSULTANTS
130 RESEARCH LANE, SUITE 2
GUELPH, ONTARIO, CANADA N1G 5G3

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
GENERAL DETAILS

MARK	DATE	REVISION	BY	APPROVED
△D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
△B	DEC 1999		SMG	JFB
△A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO. 19	SMG	JFB

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

DATE: APRIL 1999
DESIGN BY: SMG
DRAWN BY: TWS
CHECKED BY: MJM
REVIEWED BY: TK
APPROVED BY: JFB

SCALE: AS SHOWN
JOB NO.: TR0001-01
FILE NO: 0001A009
REVISION: D
DRAWING NO: 9 OF 9

100% DESIGN

APPENDIX B

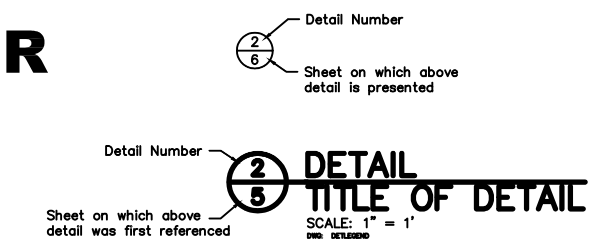
AS BUILT DRAWINGS FOR PERMEABLE LANDFILL COVER AND BEDROCK GROUNDWATER EXTRACTION SYSTEM

SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

SOMERSWORTH, NEW HAMPSHIRE
PREFERRED REMEDIAL ACTION
PERMEABLE LANDFILL COVER AND BEDROCK GROUNDWATER EXTRACTION COMPONENTS
AS-BUILT DRAWINGS

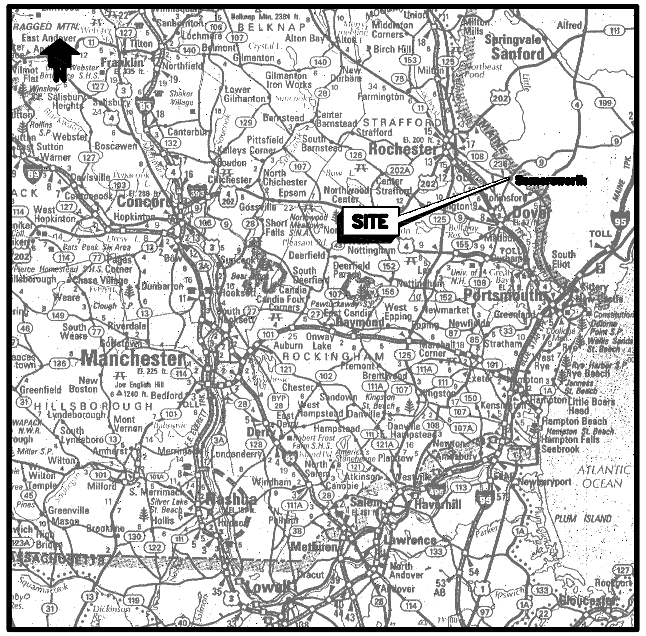
JULY 2004

DETAIL IDENTIFICATION LEGEND



Example: Detail Number 2 presented on Sheet No. 6 was referenced for the first time from Sheet No. 5.

Note: Above system also applies to section identifications.



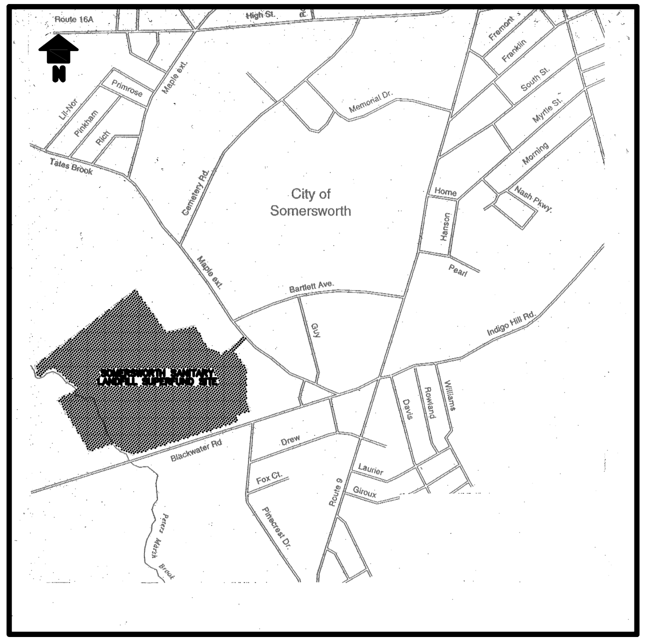
LOCATION MAP

0 10 MILES

SCALE

LIST OF DRAWINGS

DRAWING	DESCRIPTION
1	TITLE SHEET
2	PRE-CONSTRUCTION SITE CONDITIONS
3	SITE PLAN
4	PERMEABLE SOIL COVER AS-BUILT
5	SURFACE-WATER MANAGEMENT DETAILS
6	GROUNDWATER EXTRACTION/RE-INJECTION SYSTEM DETAILS
7	GENERAL DETAILS



VICINITY MAP

0 1000 FT.

SCALE

PREPARED FOR:

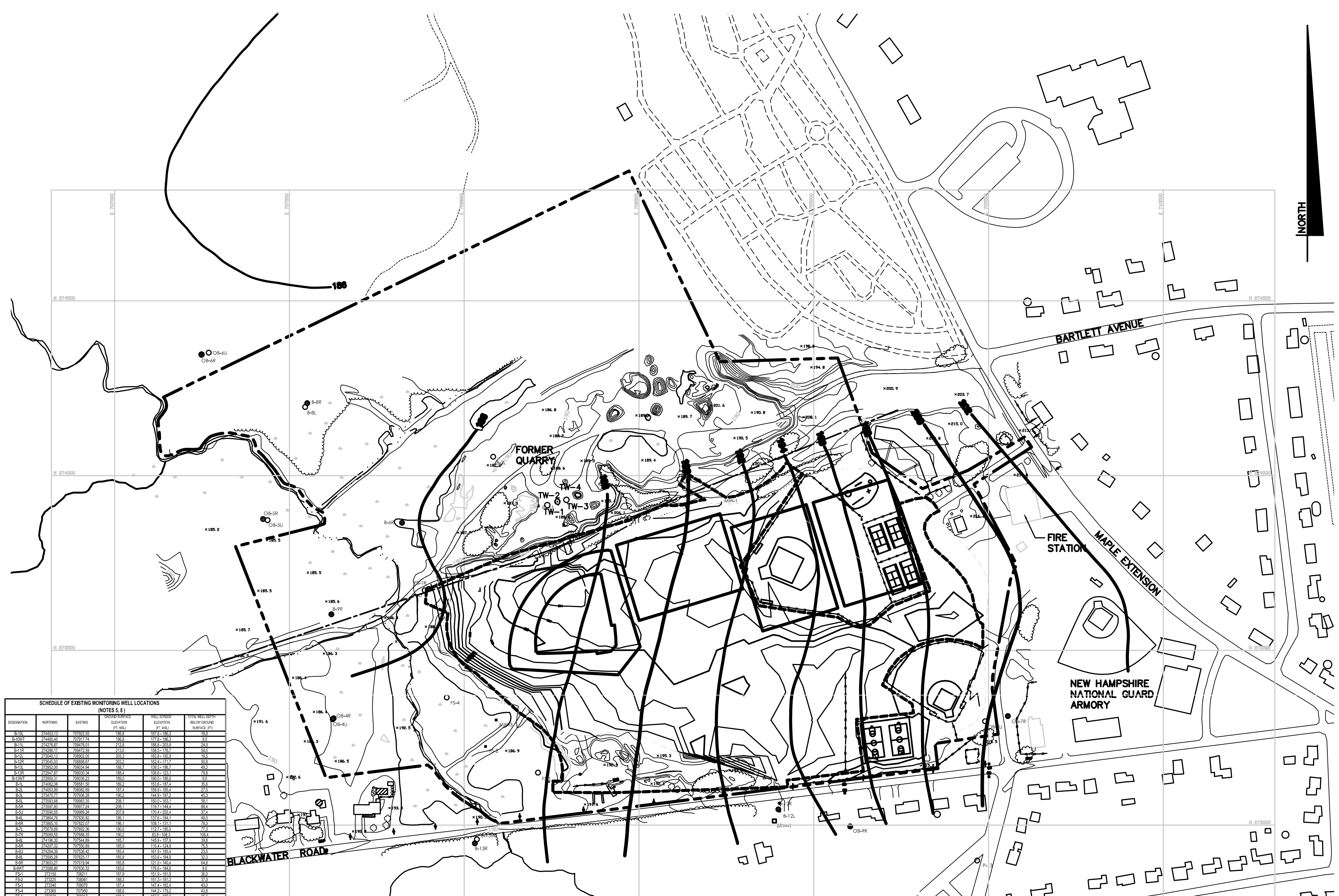
THE SOMERSWORTH LANDFILL SITE GROUP

PREPARED BY:

GEOSYNTEC CONSULTANTS

130 RESEARCH LANE, SUITE 2
GUELPH, ONTARIO, CANADA N1G 5G3
(519) 822-2230

PROJECT NUMBER TR0057-42
FILE NUMBER 0057-001
DRAWING NUMBER 1 OF 7
REVISION D



LEGEND

200	OVERBURDEN PIEZOMETRIC SURFACE (FEET)
210	EXISTING GROUND ELEVATION (FEET)
·213.1	EXISTING SPOT ELEVATION (FEET)
— — —	APPROXIMATE PROPERTY BOUNDARY (NOTE 3)
	PAVED ROAD
	UNPAVED ROAD
— · · · —	WATER LINE
	TREELINE
	APPROXIMATE EXTENT OF WASTE (NOTE 3)
— × — × — ×	FENCE
	NATURAL GAS PIPELINE (NOTES 3,4)
	UTILITY POLE
⊕ ○	MONITORING WELL (NOTE 5)
▭	WETLANDS

NOTES:

1. TOPOGRAPHIC MAP AND RELATED SITE FEATURES COMPILED BY EASTERN TOPOGRAPHICS, INC. WOLFBORO, NEW HAMPSHIRE, BASED ON AERIAL PHOTOGRAPHY TAKEN IN FALL 1996. EXISTING TOPOGRAPHY SHOWN WITHIN THE APPROXIMATE EXTENT OF WASTE LINE WAS SURVEYED BY TRITECH ENGINEERING CORPORATION IN NOVEMBER 2000.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (AMSL), NGVD 1929. GRID COORDINATES CORRESPOND TO THE MAINE STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD 1927.
3. LOCATIONS OF PROPERTY BOUNDARY, NATURAL GAS PIPELINE, AND EXTENT OF WASTE BOUNDARY ARE APPROXIMATE, AND WERE TAKEN FROM FIGURE 1.2 OF THE SEPTEMBER 1998 CONCEPTUAL DESIGN REPORT, PREPARED BY BEAK INTERNATIONAL, INC., GUELPH, ONTARIO.
4. GAS PIPELINE OWNER, NORTHERN UTILITIES, INC., HAS INDICATED THAT AN ACTIVE GAS PIPELINE AND ABANDONED GAS PIPELINE EXIST SIDE-BY-SIDE ALONG THE APPROXIMATE LOCATION SHOWN ON THIS DRAWING. CONTRACTOR IS RESPONSIBLE FOR CONTACTING NORTHERN UTILITIES AT (603)436-0310 TO LOCATE THESE GAS PIPELINES.
5. GROUNDWATER MONITORING WELL LOCATIONS, TABULATED TO THE NEAREST 0.01-FT LOCATION AND SHOWN ON THIS DRAWING, WERE TAKEN FROM JULY 1998 DESIGN INVESTIGATION REPORT FOR THE PILOT STUDY AND SITE GROUNDWATER MONITORING PROGRAM, REMEDIAL DESIGN FOR PREFERRED REMEDIAL ACTION AT THE SOMERSWORTH SANTORY LANDFILL SUPERFUND SITE, PREPARED BY BEAK INTERNATIONAL, INC.
6. OVERBURDEN PIEZOMETRIC SURFACE (I.E., WATER TABLE) IS APPROXIMATE AND SHOWS CONTOURS FROM 28 APRIL 1996. SURFACE WAS TAKEN FROM FIGURE 5.4 OF THE JUNE 1996 DESIGN INVESTIGATION REPORT FOR THE PRE-PILOT HYDROGEOLOGICAL AND GEOTECHNICAL INVESTIGATION, PREPARED BY BEAK INTERNATIONAL, INC. ADDITIONAL INFORMATION ON THE SITE HYDROGEOLOGY (E.G., WATER TABLE ELEVATIONS, TOP OF BEDROCK ELEVATIONS, ETC.) IS INCLUDED WITH THE CONTRACT DOCUMENTS. CONTRACTOR MAY PERFORM SITE INVESTIGATION AT THEIR OWN EXPENSE TO FURTHER DEFINE THE HYDROGEOLOGIC CONDITIONS THAT MAY BE ENCOUNTERED.
7. CONTRACTOR IS RESPONSIBLE FOR VERIFICATION OF EXISTING CONDITIONS SHOWN ON THIS DRAWING.
8. WELLS OB-19U AND OB-20U ARE LOCATED BEYOND THE MAPPING LIMITS SHOWN ON THIS DRAWING.

150 75 0 150 300
SCALE IN FEET

SCHEDULE OF EXISTING MONITORING WELL LOCATIONS
(NOTES 5, 8)

DESIGNATION	NORTHING	EASTING	GROUND SURFACE ELEVATION (FT, MSL)	WELL SCREEN ELEVATION (FT, MSL)	TOTAL WELL DEPTH BELOW GROUND SURFACE (FT)
B-10L	274453.13	707922.55	186.8	167.8 - 186.3	19.0
B-10WT	274460.40	707917.74	186.8	177.8 - 186.3	9.0
B-11L	274276.87	709478.01	212.8	188.8 - 203.8	24.0
B-11R	274286.17	709472.59	213.0	158.5 - 178.7	54.5
B-12L	273040.13	708902.05	203.3	183.8 - 192.9	19.5
B-12R	273045.03	708898.67	203.2	152.4 - 171.7	50.8
B-13L	272952.00	708034.94	188.7	139.5 - 186.7	49.2
B-13R	272947.87	708030.34	188.4	108.6 - 123.1	79.8
B-13WT	272959.31	708036.23	189.0	180.0 - 188.0	9.0
B-1L	274082.08	708581.50	189.2	153.6 - 187.4	35.6
B-2L	274053.99	708082.89	187.4	159.9 - 185.4	27.5
B-3L	273470.77	707936.28	190.2	144.9 - 187.2	45.3
B-5L	273593.68	709983.35	208.1	150.0 - 163.1	58.1
B-5R	273597.93	709977.24	208.1	119.7 - 144.4	88.4
B-5U	273590.55	709989.24	207.8	170.4 - 202.4	37.4
B-6L	273864.76	707830.92	186.1	137.6 - 184.1	48.5
B-6R	273865.10	707822.07	186.1	108.1 - 131.1	78.0
B-7L	275079.69	707692.36	190.0	112.7 - 185.5	77.3
B-7R	275089.55	707688.35	190.2	83.8 - 108.3	106.4
B-8L	274196.30	707544.89	185.7	145.9 - 157.9	39.8
B-8R	274207.32	707550.89	185.9	110.4 - 124.9	75.5
B-8U	274204.39	707536.42	185.4	161.9 - 185.4	23.5
B-9L	273595.28	707625.17	185.9	153.6 - 184.9	32.3
B-9R	273603.27	707619.94	185.8	121.0 - 140.4	64.8
B-9WT	273588.80	707630.32	185.6	176.6 - 184.6	9.0
FS-1	273150	708211	187.9	151.9 - 181.9	36.0
FS-2	273225	708061	188.3	151.3 - 181.3	37.0
FS-3	273340	708070	187.4	147.4 - 182.4	40.0
FS-4	273365	707950	188.0	144.2 - 179.2	43.8
FS-5	273830	708217	188.1	152.6 - 182.6	35.5
FS-6	273570	707880	189.2	158.2 - 180.7	31.0
FS-7	273672	707887	188.2	148.2 - 183.2	40.0
FS-8	273769	707982	187.7	158.9 - 181.4	28.8
FS-9	273814	708007	188.0	161.0 - 183.5	27.0
FS-10	273804	708137	187.9	161.1 - 183.6	26.8
FS-11	273913	708211	189.6	165.4 - 182.9	24.2
FS-12	273858	708285	189.3	155.8 - 185.8	33.5
FS-13	273953	708350	189.1	154.3 - 184.3	34.8
FS-14	273888	708485	189.5	155.7 - 185.7	33.8
MW-1	273947.83	708731.84	201.7	164.5 - 166.5	37.2
MW-2	273808.36	708360.16	200.9	164.0 - 166.0	36.9
MW-3	273300.66	708091.43	186.6	155.0 - 157.0	31.6
MW-4	273622.03	707891.82	186.4	145.8 - 187.8	40.6
OB-1	273822.27	707868.95	186.2	119.4 - 159.0	66.8
OB-15R	273285.88	708619.43	206.0	139.0 - 159.0	67.0
OB-15U	273273.87	708615.54	205.8	166.8- 186.8	39.0
OB-16R	273632.28	707994.02	201.5	130.5 - 150.5	71.0
OB-16U	273646.05	708005.17	201.0	156.0 - 176.0	45.0
OB-17R	273739.33	708242.31	205.9	123.9 - 143.9	82.0
OB-17U	273739.15	708220.93	206.3	156.3 - 176.3	50.0
OB-18U	274684.01	706714.31	185.0	100.5 - 110.5	84.5
OB-19U	275301.32	706264.28	184.1	154.1 - 174.1	30.0
OB-2	273859.11	707916.80	186.5	128.5 - 158.5	58.0
OB-20U	276160.11	705892.63	181.1	154.1 - 174.1	27.0
OB-3	273189.79	708041.45	187.7	141.9 - 161.7	45.8
OB-4R	273302.77	707623.79	186.0	121.5 - 156.5	64.5
OB-4U	273305.45	707626.24	186.2	161.7 - 171.7	24.5
OB-5R	273875.92	707424.67	185.0	110.0 - 145.0	75.0
OB-5U	273872.64	707437.39	185.0	155.0 - 165.0	30.0
OB-6R	274346.55	707248.57	184.9	85.9 - 120.9	99.0
OB-6U	274351.79	707269.12	185.0	130.0 - 140.0	55.0
OB-7R	273311.80	709555.20	214.4	151.4 - 161.4	63.0
OB-7U	273297.03	709490.07	214.5	182.5 - 192.5	32.0
OB-8R	273642.20	709572.30	212.8	140.8 - 155.8	72.0
OB-9R	272996.10	709104.20	211.3	174.3 - 189.3	37.0
P-10	273299.60	708617.50	207.1	177.1 - 179.1	30.0
P-11	**273606.20**	**708857.40**	**214.7**	**180.7 - 182.7**	**34.0**
P-12	273416.00	708949.50	203.1	180.1 - 182.1	23.0
P-13	272898.50	709467.40	215.1	180.1 - 182.1	35.0
P-14	273138.40	708903.80	202.6	177.6 - 179.6	25.0
PS-1R	273675.97	707898.43	187.8	133.5 - 143.5	54.3
PS-2R	273756.66	707967.17	188.0	140.4 - 150.4	47.6
PSS-4S	273650	707921	193.1	179.1 - 189.1	14.0
PSS-4I	273651	707918	193.5	168.5 - 178.5	25.0
PSS-4D	273652	707916	193.0	161.5 - 171.5	31.5
PSS-5S	273655	707897	192.0	178.0 - 188.0	14.0
PSS-5I	273658	707898	192.1	167.1 - 177.1	25.0
PSS-5D	273657	707896	191.9	159.9 - 169.9	32.0
PW-1	273853.52	707866.73	185.6	119.4 - 159.0	66.2

som.xls

FT, MSL - FEET ABOVE MEAN SEA LEVEL

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THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
PRE-CONSTRUCTION SITE CONDITIONS

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
C	DECEMBER 2000	UPDATED EXISTING TOPOGRAPHY	NLB	MJM
B	APRIL 2000	CHANGE LOCATION OF FS-11	WDB	TK
A	APRIL 1999	NO CHANGES TO THIS DRAWING	SMG	JFB

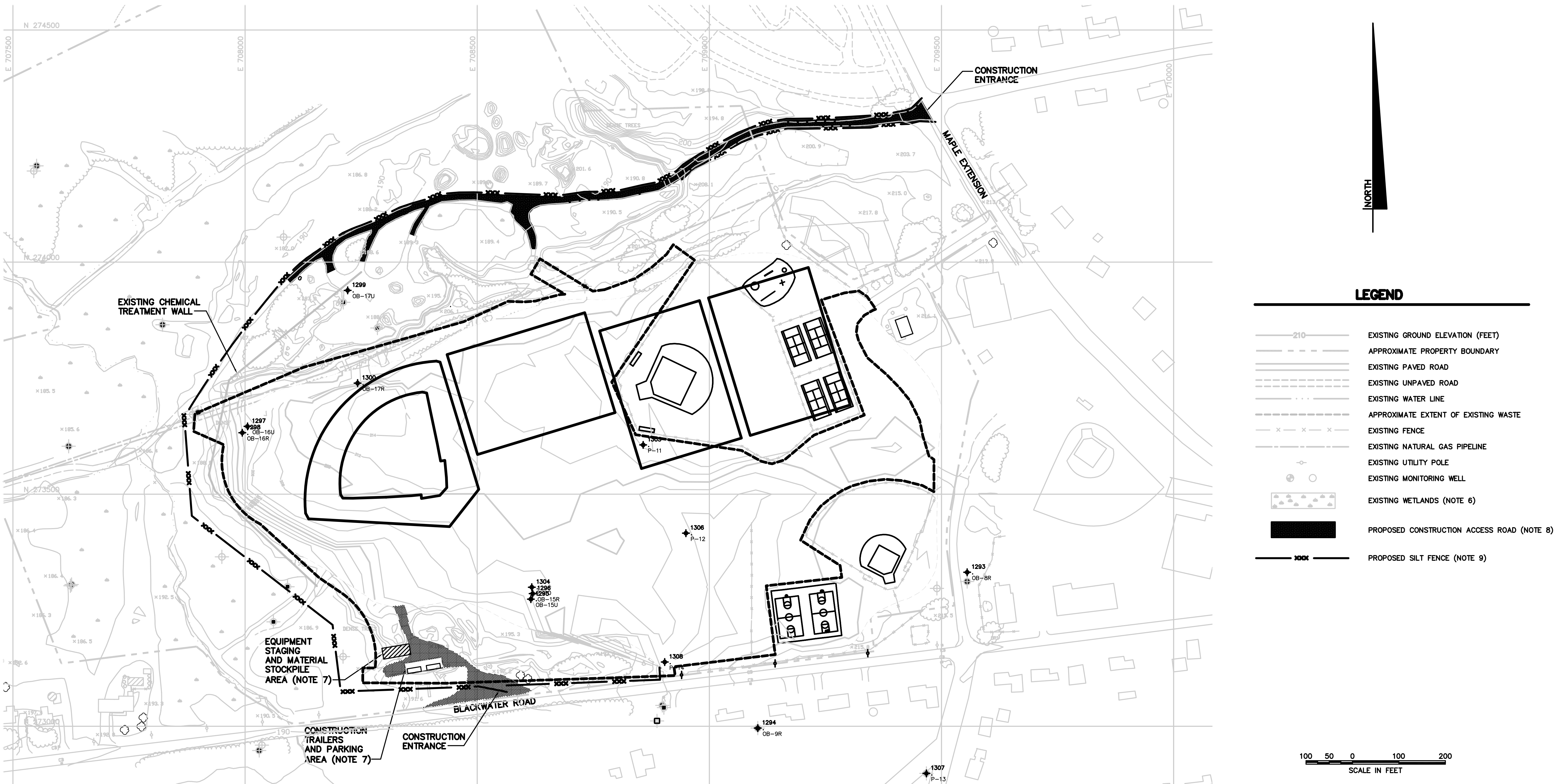
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

DATE:	DECEMBER 2000	SCALE:	1" = 150'
DESIGN BY:	SMG/NLB	JOB NO.:	TR0057-42
DRAWN BY:	JW	FILE NO:	0057-002
CHECKED BY:	MJM/CB	REVISION:	D
REVIEWED BY:	TK	DRAWING NO:	2 OF 7
APPROVED BY:	MJM		



NOTES:

1. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (AMSL), NGVD 1929. GRID COORDINATES CORRESPOND TO THE MAINE STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD 1927.
2. EXISTING CONDITIONS TAKEN FROM DRAWING 2.
3. CONTRACTOR IS RESPONSIBLE FOR ESTABLISHING SURVEY CONTROL AT THE SITE PRIOR TO CONSTRUCTION.
4. CONTRACTOR IS RESPONSIBLE FOR VERIFICATION OF EXISTING SITE CONDITIONS, AND SHALL PERFORM PRE–CONSTRUCTION SURVEY AS FURTHER DESCRIBED IN THE SPECIFICATIONS. CONTRACTOR SHALL LOCATE AND PROVIDE CLEARANCE FOR ALL ABOVE–GROUND AND UNDERGROUND UTILITIES PRIOR TO CONSTRUCTION. THE GAS PIPELINE OWNER, NORTHERN UTILITIES, INC., MAY BE REACHED AT (603) 436–0310.
5. ANY EXISTING FACILITY OR SITE FEATURE, (E.G., NATURAL GAS PIPELINE, GROUNDWATER WELLS, FENCING, ETC.) DAMAGED BY THE CONTRACTOR SHALL BE RESTORED OR REPLACED TO THE SATISFACTION OF THE SITE GROUP. THE CONTRACTOR SHALL BEAR THE ENTIRE COST OF RESTORATION AND/OR REPLACEMENT. CONSTRUCTION ACTIVITIES ADJACENT TO THESE FEATURES SHALL BE AS DESCRIBED IN THE SPECIFICATIONS.
6. THE CONTRACTOR SHALL BE AWARE OF THE MARKED WETLAND LIMITS AS DESIGNATED WITH WARNING TAPE. THE CONTRACTOR IS NOT PERMITTED TO WORK WITHIN THE WETLANDS LIMITS AT ANYTIME.
7. CONTRACTOR'S FACILITIES, MATERIAL STOCKPILES, STAGING AREAS, AND STORAGE AREAS SHALL BE LOCATED AS SHOWN ON THIS DRAWING AND DESCRIBED IN THE CONTRACT DOCUMENTS, UNLESS PRIOR APPROVAL IS OBTAINED BY THE SITE GROUP. CONTRACTOR IS RESPONSIBLE FOR MAINTAINING ALL SUCH AREAS DURING CONSTRUCTION AND FOR CLEANUP/RESTORATION OF SUCH AREAS AFTER CONSTRUCTION.
8. CONTRUCTION TRAFFIC ACCESS TO THE SITE SHALL BE RESTRICTED TO THE SITE ENTRANCE ON BLACKWATER ROAD AS SHOWN ON THIS DRAWING, UNLESS OTHERWISE APPROVED BY THE SITE GROUP. CONTRACTOR SHALL BE RESPONSIBLE FOR CONSTRUCTION/MAINTENANCE OF THE CONSTRUCTION ACCESS ROAD AND ANY OTHER TEMPORARY ACCESS ROADS NECESSARY FOR CONSTRUCTION. LOCATIONS OF TEMPORARY ACCESS ROADS SHALL BE ONLY AS APPROVED BY THE SITE GROUP.
9. STORM–WATER MANAGEMENT AND EROSION AND SEDIMENT (E&S) CONTROL FEATURES SHALL BE ESTABLISHED BY THE CONTRACTOR IN ACCORDANCE WITH APPLICABLE STATE AND LOCAL REQUIREMENTS AND THE SPECIFICATIONS. THE FEATURES SHALL BE INSTALLED BY THE CONTRACTOR AROUND AND DOWN–GRADIENT OF AREAS TO BE DISTURBED PRIOR TO CONSTRUCTION AND SHALL BE MAINTAINED BY THE CONTRACTOR AS NEEDED DURING AND AFTER CONSTRUCTION IN ACCORDANCE WITH THE SPECIFICATIONS.

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THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
SITE PLAN

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
C	DECEMBER 2000	UPDATED EXISTING TOPOGRAPHY	NLB	MJM
B	APRIL 2000	CTW EXTENDEND 75 FT. N.E.	WDB	TK
A	APRIL 1999	NO CHANGES TO THIS DRAWING	SMG	JFB

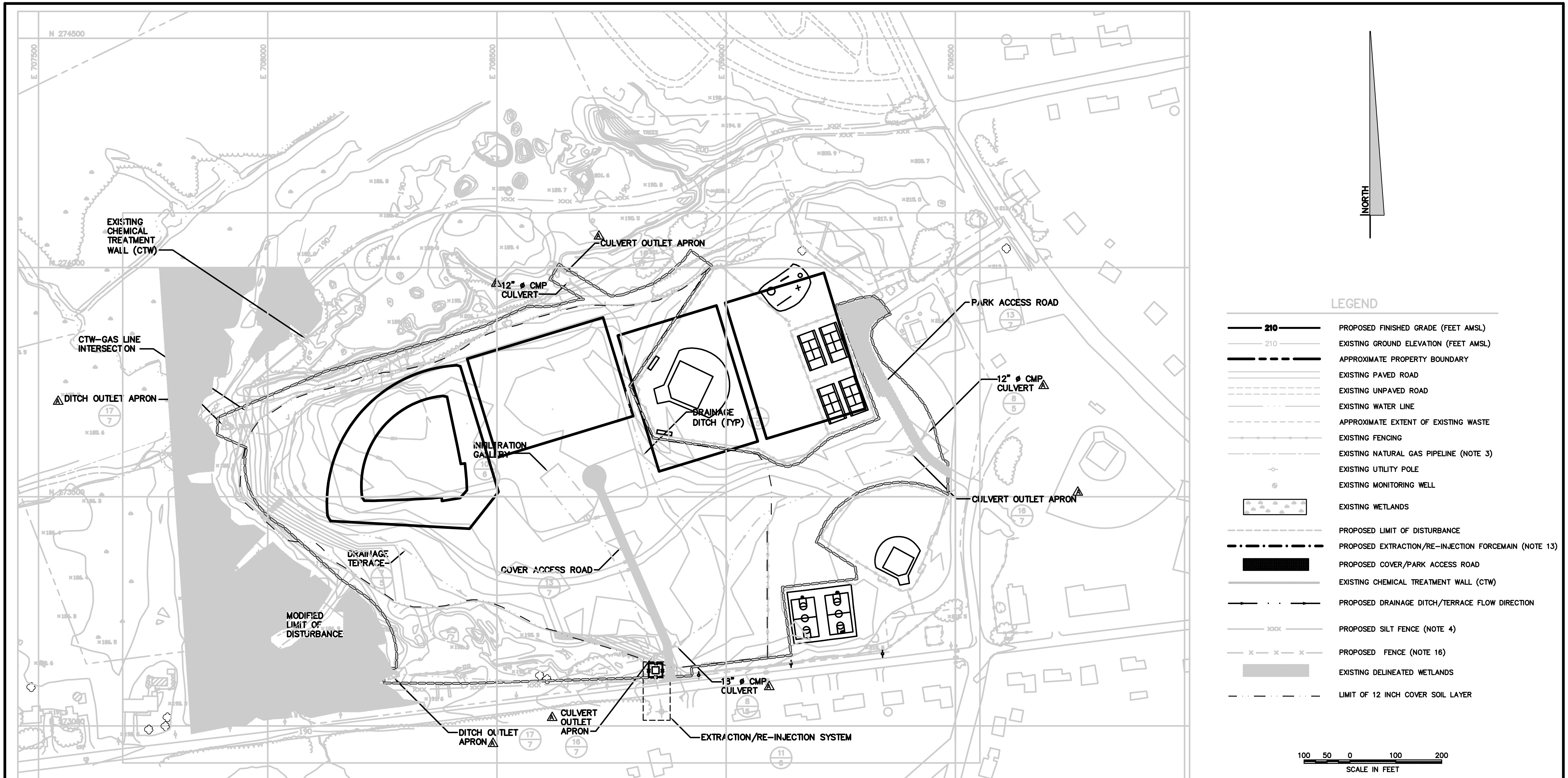
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

DATE:	DECEMBER 2000	SCALE:	1" = 100'
DESIGN BY:	SMG/NLB	JOB NO.:	TR0057–42
DRAWN BY:	JW	FILE NO:	0001–003
CHECKED BY:	MJM/CB	REVISION:	D
REVIEWED BY:	TK	DRAWING NO:	3 OF 7
APPROVED BY:	MJM		



NOTES:

1. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (AMSL), NGVD 1929. GRID COORDINATES CORRESPOND TO THE MAINE STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD 1927.
2. ANY EXISTING FACILITY OR SITE FEATURE, (E.G., NATURAL GAS PIPELINE, GROUNDWATER WELLS, FENCING, ETC.), DAMAGED BY THE CONTRACTOR SHALL BE RESTORED OR REPLACED TO THE SATISFACTION OF THE SITE GROUP. THE CONTRACTOR SHALL BEAR THE ENTIRE COST OF RESTORATION AND/OR REPLACEMENT. CONSTRUCTION ACTIVITIES ADJACENT TO THESE FEATURES SHALL BE AS DESCRIBED IN THE SPECIFICATIONS.
3. CONTRACTOR SHALL NOTIFY NORTHERN UTILITIES, INC., AT (603)436–0310 AND THE ENGINEER 3–DAYS PRIOR TO PERFORMING ANY EXCAVATION WITHIN 10–FT OF THE NATURAL GAS PIPELINE. ALL SUCH WORK SHALL BE CONDUCTED ONLY UNDER THE SUPERVISION OF A NORTHERN UTILITIES, INC. REPRESENTATIVE.
4. STORM–WATER MANAGEMENT AND EROSION AND SEDIMENT CONTROL FEATURES SHALL BE ESTABLISHED BY THE CONTRACTOR IN ACCORDANCE WITH APPLICABLE STATE AND LOCAL REQUIREMENTS AND THE SPECIFICATIONS. THE FEATURES SHALL BE INSTALLED BY THE CONTRACTOR AROUND AND DOWN–GRADIENT OF AREAS TO BE DISTURBED PRIOR TO CONSTRUCTION AND SHALL BE MAINTAINED BY THE CONTRACTOR AS NEEDED DURING AND AFTER CONSTRUCTION IN ACCORDANCE WITH THE SPECIFICATIONS.
5. THE GRADES SHOWN REPRESENT THE FINAL GRADES OF THE SUBGRADE (I.E. THE BOTTOM OF THE 12 INCH THICK COVER SOIL LAYER). THE GRADING PLAN FOR TOP OF COVER SOIL SHOULD BE CONSIDERED UNIFORMLY ONE FOOT (1.0 FT.) HIGHER IN ELEVATION THAN THE GRADING PLAN SHOWN FOR THE SUBGRADE, EXCEPT AT THE LIMITS OF THE COVER SOIL, WHICH SHALL BE BLENDED TO "TIE–IN" TO EXISTING GRADES.
6. CONSTRUCTION CONTROL POINTS ARE TO BE PROVIDED BY THE CONTRACTOR FOR USE ON THE PROJECT. IT IS THE CONTRACTOR'S RESPONSIBILITY TO ACHIEVE THE FINISHED GRADES AS REPRESENTED BY THE CONTOURS SHOWN ON THIS DRAWING.
7. LIMIT OF DISTURBANCE SHOWN ON THIS DRAWING SHOULD BE CONSIDERED APPROXIMATE AND SHALL BE FIELD–LOCATED BY THE CONTRACTOR AS APPROVED BY SITE GROUP AND ENGINEER DURING CONSTRUCTION.
8. CLEARED TREES, STUMPS, AND VEGETATION SHALL BE CHIPPED AND PLACED AS MULCH ON SITE AS DIRECTED BY THE SITE GROUP. UNDER NO CIRCUMSTANCES SHALL TREES, STUMPS, BRANCHES, OR OTHER ORGANIC MATERIAL BE PLACED WITHIN THE COVER SYSTEM LIMITS.
9. SURFACIAL CONSTRUCTION/DEMOLITION DEBRIS (E.G., CONCRETE, ASPHALT, BRICKS, ETC.) SHALL BE MOVED AND GRADED AS NECESSARY TO ACHIEVE THE REQUIRED COVER GRADES. DEBRIS MAY BE PLACED IN FILL AREAS PROVIDED THAT IT MEETS OR IS MODIFIED TO MEET THE MATERIAL REQUIREMENTS GIVEN IN THE SPECIFICATIONS. DEBRIS NOT MEETING THE FILL MATERIAL REQUIREMENTS, SUCH AS LARGE CHUNKS, SHALL BE STOCKPILED BY THE CONTRACTOR IN AN AREA APPROVED BY THE SITE GROUP.
10. CONTRACTOR SHALL REMOVE PAVED ROAD AND PARKING LOT (PARK ACCESS ROAD) WITHIN THE LIMIT OF DISTURBANCE AS SHOWN ABOVE. PAVEMENT SHALL BECOME THE CONTRACTOR'S PROPERTY FOR OFF–SITE RECYCLING IN ACCORDANCE WITH NHDES REGULATIONS. PAVEMENT SHALL NOT BE DISPOSED OF ON SITE.
11. EXISTING FENCE WITHIN THE LIMIT OF DISTURBANCE SHALL BE REMOVED AND DISPOSED OF BY THE CONTRACTOR. CONTRACTOR SHALL NOT DISTURB OR DAMAGE EXISTING FENCING OUTSIDE THE LIMIT OF DISTURBANCE.
12. AREAS REQUIRING CUT TO ACHIEVE THE REQUIRED SUBGRADE ELEVATIONS SHALL BE PROOF–ROLLED PRIOR TO CONSTRUCTION OF THE COVER SYSTEM. AREAS REQUIRING FILL TO ACHIEVE THE REQUIRED SUBGRADE ELEVATIONS SHALL BE FILLED WITH STRUCTURAL FILL IN ACCORDANCE WITH THE SPECIFICATIONS.
13. ALIGNMENT OF PROPOSED FORCEMAIN IS APPROXIMATE, AND MAY BE MODIFIED SLIGHTLY BASED ON FIELD CONDITIONS WITH PRIOR APPROVAL OF THE SITE GROUP. CONTRACTOR SHALL PRESSURE TEST FORCEMAIN IN ACCORDANCE WITH THE SPECIFICATIONS PRIOR TO BACKFILLING. TRENCHING SHALL COMPLY WITH ALL NHDOT AND OSHA REQUIREMENTS.
14. RIPRAP OUTLET APRONS SHALL BE AS SHOWN ON DRAWING 7.
15. CONTRACTOR IS RESPONSIBLE FOR LOCATING UTILITIES AND COORDINATING TRAFFIC CONTROL FOR FORCEMAIN INSTALLATION ACROSS BLACKWATER ROAD. CONTRACTOR SHALL OBTAIN ALL NECESSARY PERMITS NEEDED TO PERFORM THIS WORK.
16. CHAIN LINK FENCE AROUND THE CONCRETE EXTRACTION/RE–INJECTION VAULT AND EXTRACTION/RE–INJECTION CONTROL SYSTEM SHALL BE 7–FT HIGH FENCING WITH THREE STRAND BARBED WIRE, AND SHALL CONFORM TO NHDOT SECTION 607. FENCING SHALL INCLUDE A 12–FT WIDE GATE ALONG EAST SIDE.
17. WETLAND BOUNDARIES WITHIN THE WETLAND STUDY AREA WERE DELINEATED BY NORMANDEAU ASSOCIATES INC., BEDFORD, NH ON MAY 11 AND 12, 1999, FOLLOWING THE 1987 US ARMY CORPS OF ENGINEERS WETLAND DELINEATION MANUAL.
18. WETLAND BOUNDARY FLAGGING WAS SURVEYED WITH A GLOBAL POSITIONING SYSTEM (GPS) BY NORMANDEAU ASSOCIATES, INC. ON MAY 12, 1999.

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THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
SUBGRADE GRADING PLAN

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004		MR	TK
C	DECEMBER 2000	UPDATED EXISTING TOPOGRAPHY	NLB	MJM
B	APRIL 2000	CTW EXTENDED 75 FT. NE	WDB	TK
A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO'S 19, 20, 21, 23 AND 24.	SMG	JFB

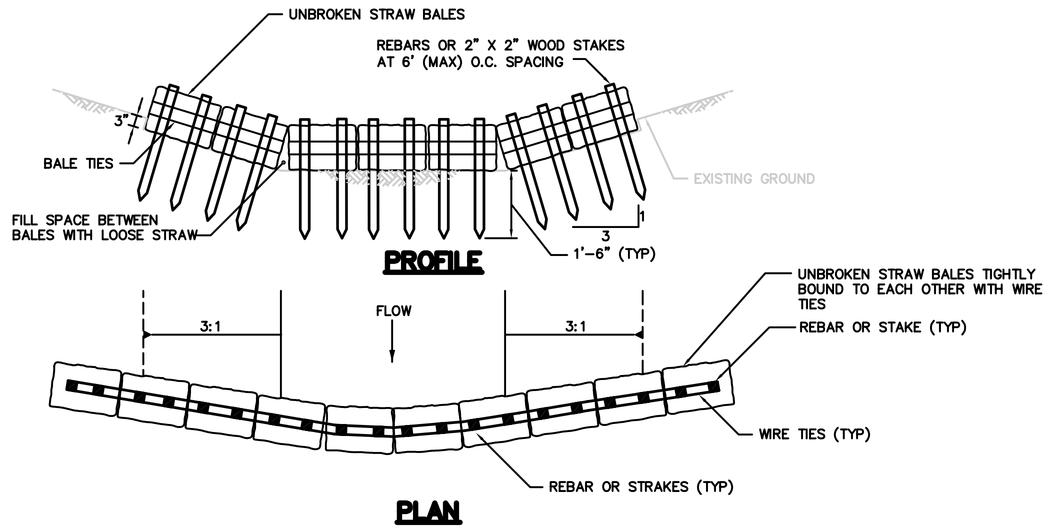
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

SEAL

DATE:	DECEMBER 2000	SCALE:	1" = 100'
DESIGN BY:	SMG/NLB	JOB NO.:	TR0057–42
DRAWN BY:	JW	FILE NO:	0057–004
CHECKED BY:	MJM/CB	REVISION:	D
REVIEWED BY:	TK	DRAWING NO:	4 OF 7
APPROVED BY:	MJM		



4
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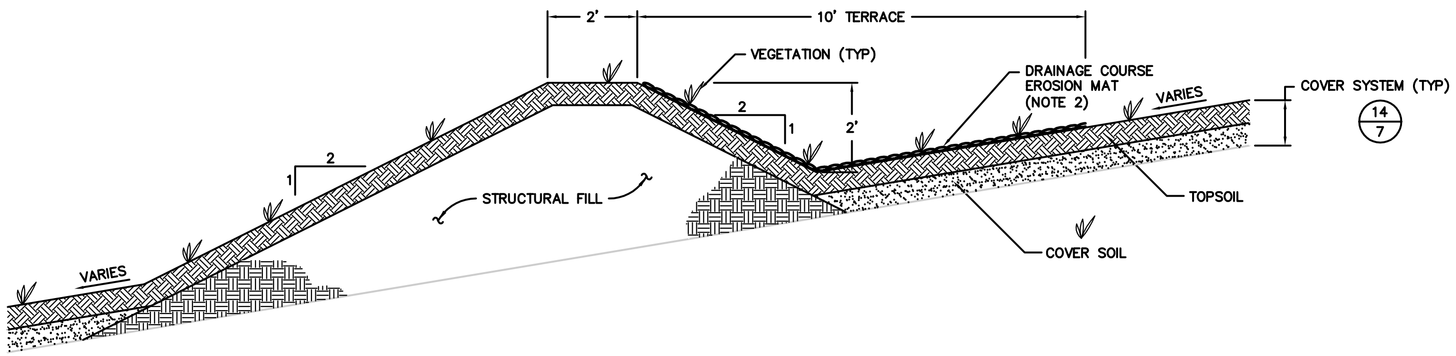
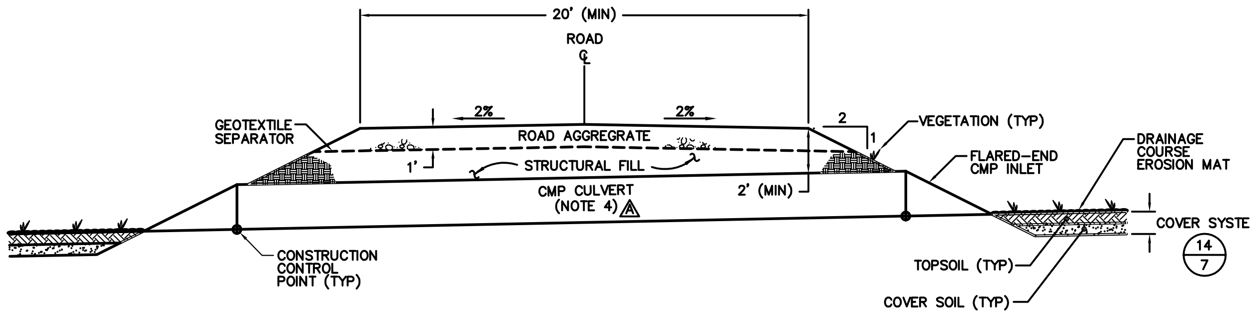
DETAIL
TEMPORARY STRAW BALE BARRIER– CHANNEL FLOW APPLICATION
SCALE: 1" = 2'
XREF: 0057X004.DWG

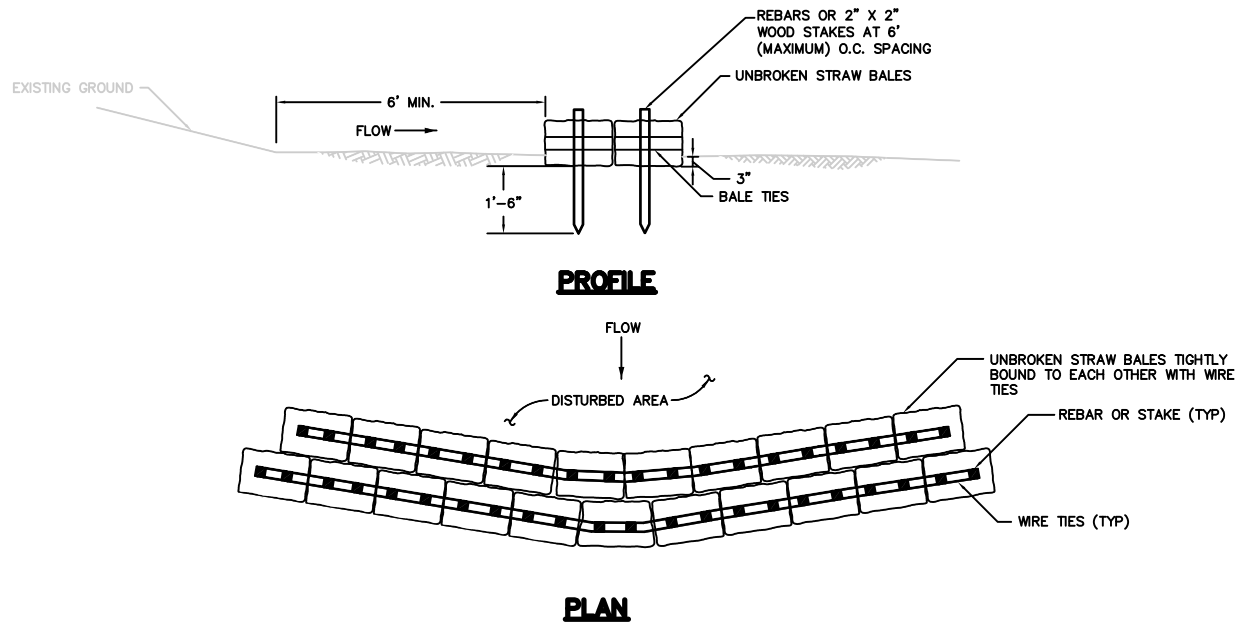


7
4
DETAIL
DRAINAGE TERRACE
SCALE: 1" = 2'
XREF: 0057x014.DWG

DRAINAGE COURSE EROSION MAT (NOTE 2)



8
4
DETAIL
CULVERT
SCALE: 1" = 4'
XREF: 0057X016.DWG



5
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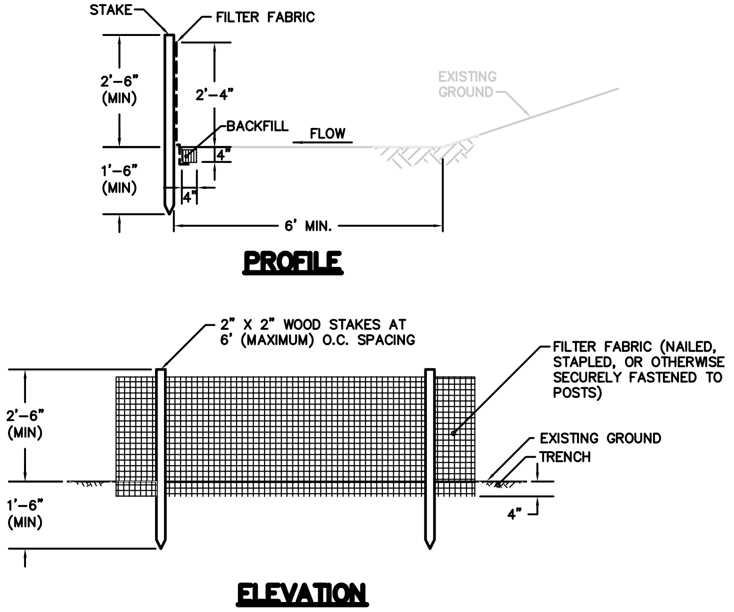
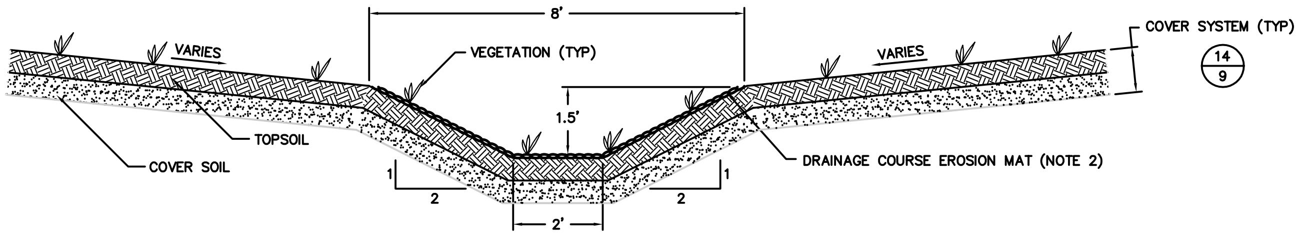
DETAIL
TEMPORARY STRAW BALE BARRIER– SHEET FLOW APPLICATION
SCALE: 1" = 2'
XREF: 0057X004.DWG



9
–
DETAIL
SILT FENCE
SCALE: 1" = 2'
XREF: 0057X004.DWG



6
4
DETAIL
DRAINAGE DITCH
SCALE: 1" = 2'
XREF: 0057x010.DWG

NOTES:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR EROSION MAT AND SILT FENCE, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL TOLERANCES SHALL BE WITHIN THE LIMITS GIVEN IN THE SPECIFICATIONS.
2. ALL DRAINAGE COURSE EROSION MAT SHALL BE OVERLAPPED, STAKED, AND ANCHORED IN STRICT ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS FOR CHANNEL FLOW APPLICATIONS.
3. EXTENT OF STRUCTURAL FILL AROUND AND OVER CMP CULVERT SHALL BE AS–NEEDED TO ACHIEVE A MINIMUM 2–FT COVER ABOVE THE TOP OF CULVERT PIPE, AND TO MAINTAIN A SMOOTH ACCESS ROAD PROFILE.

A 4. CULVERT SIZES ARE SHOWN ON DRAWING 4.

GEOSYNTEC CONSULTANTS
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GUELPH, ONTARIO, CANADA N1G 5G3

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
SURFACE WATER MANAGEMENT DETAILS

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
B	DECEMBER 2000	UPDATE FIGURE NUMBERS	NLB	MLM
A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO.23	SMG	JFB

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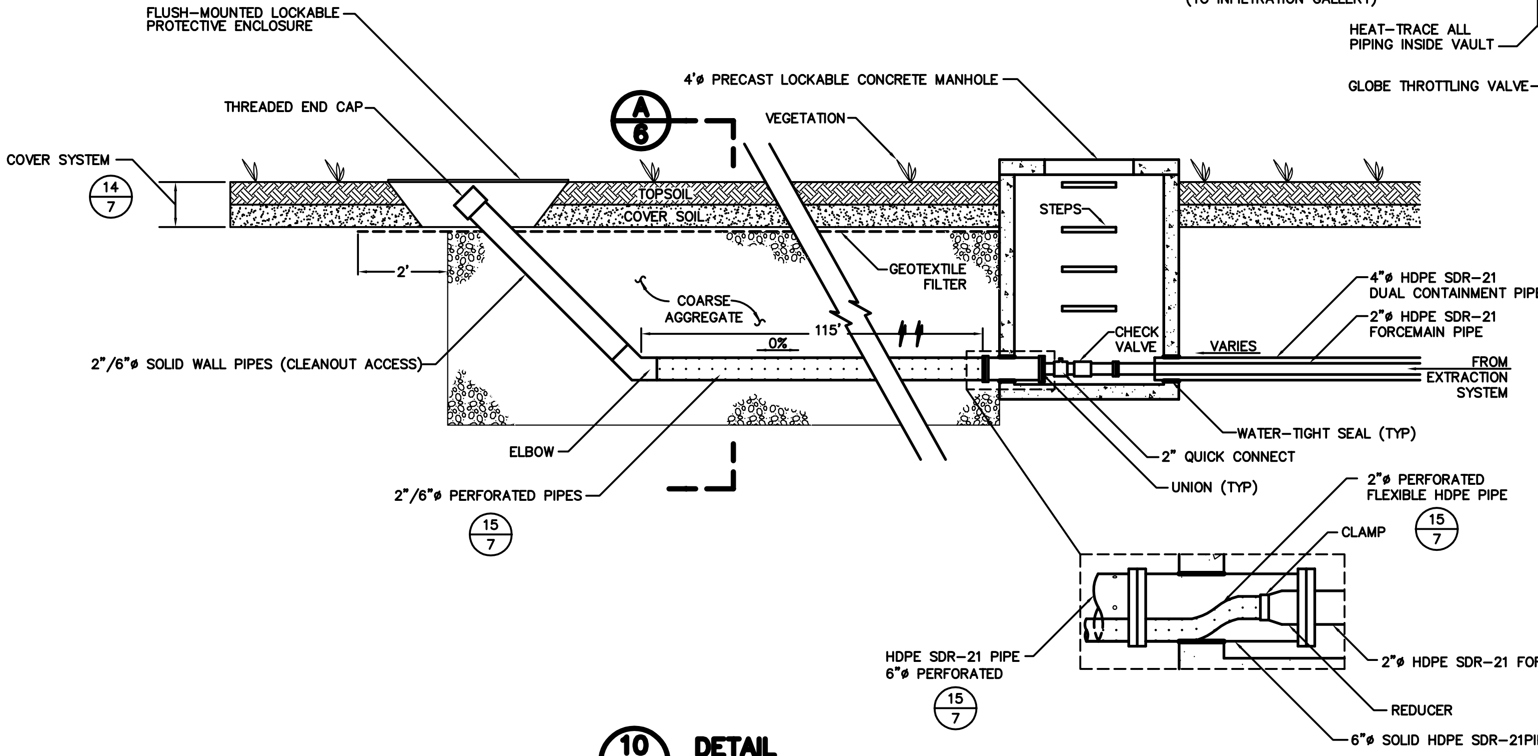
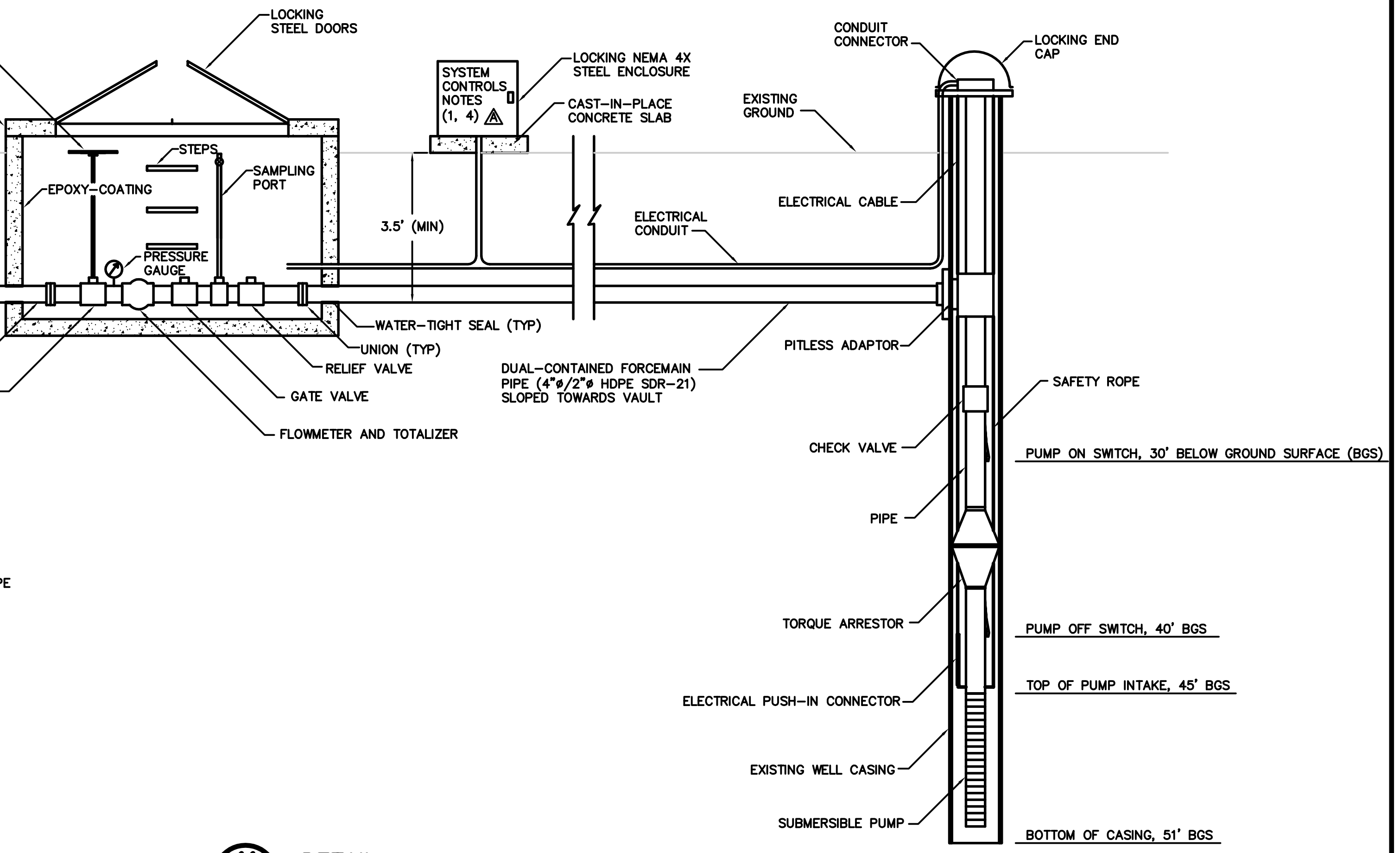
DATE:	DECEMBER 2000	SCALE:	AS SHOWN
DESIGN BY:	SMG/NLB	JOB NO.:	TR0057–42
DRAWN BY:	JW/LB/AWS	FILE NO:	0057–005
CHECKED BY:	MJM/CB	REVISION:	D
REVIEWED BY:	TK	DRAWING NO:	5 OF 7
APPROVED BY:	MJM		



10/4 DETAIL
INFILTRATION GALLERY

SCALE: 1" = 2' (NOTE 5)
XREF: 0057x025.DWG

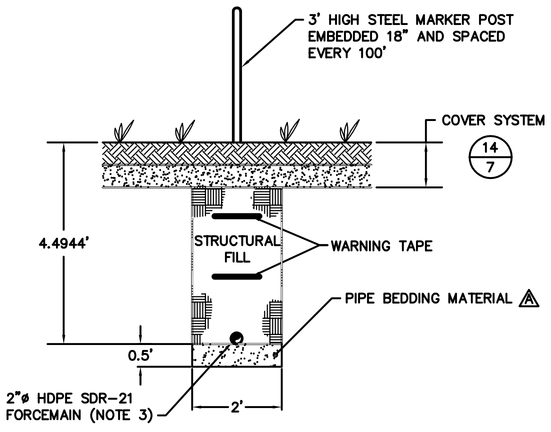


11/4 DETAIL
EXTRACTION/RE-INJECTION SYSTEM CONTROLS

SCALE: N.T.S.
XREF: 0057x023.DWG

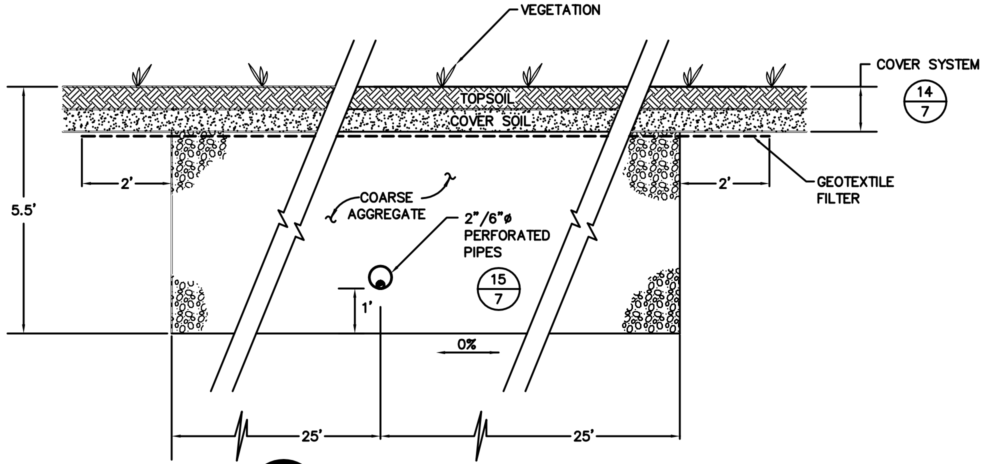
NOTES:

1. MECHANICAL AND ELECTRICAL COMPONENTS OF THE EXTRACTION/RE-INJECTION SYSTEM (E.G., PIPES, VALVES, FITTINGS, CONTROLS, POWER, ETC.) SHALL BE INSTALLED AS DESCRIBED FURTHER IN THE SPECIFICATIONS AND IN ACCORDANCE WITH MANUFACTURERS' RECOMMENDATIONS. ELECTRICAL INSTALLATION SHALL CONFORM TO NATIONAL ELECTRICAL CODE, AND APPLICABLE STATE/LOCAL CODES.
2. FORCEMAIN EMBEDMENT TRENCH OUTSIDE THE COVER SYSTEM LIMITS SHALL CONFORM TO THE DIMENSIONS SHOWN AND SHALL BE BACKFILLED WITH STRUCTURAL FILL, FOLLOWED BY RESTORATION OF THE EXISTING GROUND SURFACE MATERIALS AND CONDITIONS.
3. 2-INCH FORCEMAIN SHALL BE DUAL-CONTAINED BETWEEN EXTRACTION WELL AND VAULT, USING A 4-INCH DIAMETER SDR-21 HDPE DUAL CONTAINMENT PIPE.
4. △A CONTRACTOR SHALL SUBMIT SHOP DRAWINGS OF SYSTEM CONTROLS TO ENGINEER NO LATER THAN 30 DAYS PRIOR TO SYSTEM INSTALLATION. CONTROLS SHALL INCLUDE AN AUTOMATIC AND MANUAL OVERRIDE ON/OFF SWITCH FOR THE PUMP AND A PROGRAMMABLE LOGIC CONTROLLER WHICH RESPONDS TO THE GROUNDWATER LEVEL SWITCHES IN THE WELL, AND ADDITIONAL COMPONENTS AS NEEDED AND AS RECOMMENDED BY THE MANUFACTURER TO ENSURE THE SYSTEM FUNCTIONS AS-SPECIFIED.
5. △A INFILTRATION GALLERY SHALL HAVE A PLAN AREA OF 125' X 50' AS SHOWN ON DRAWING 4.



12/– DETAIL
TYPICAL FORCEMAIN EMBEDMENT TRENCH

(NOTE 2)
SCALE: 1" = 2'
XREF: 0057x019.DWG



A/6 SECTION
INFILTRATION GALLERY

SCALE: 1" = 2' (NOTE 5)
XREF: 0057x020.DWG

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GUELPH, ONTARIO, CANADA N1G 5G3

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
GROUNDWATER EXTRACTION/RE-INJECTION SYSTEM DETAILS

MARK	DATE	REVISION	BY	APPROVED
△D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
△B	DECEMBER 2000	UPDATE AND CLARIFIED DETIALS	NLB	MLM
△A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO.S 24,25, AND 26	SMG	JFB

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DATE:	DECEMBER 2000	SCALE:	AS SHOWN
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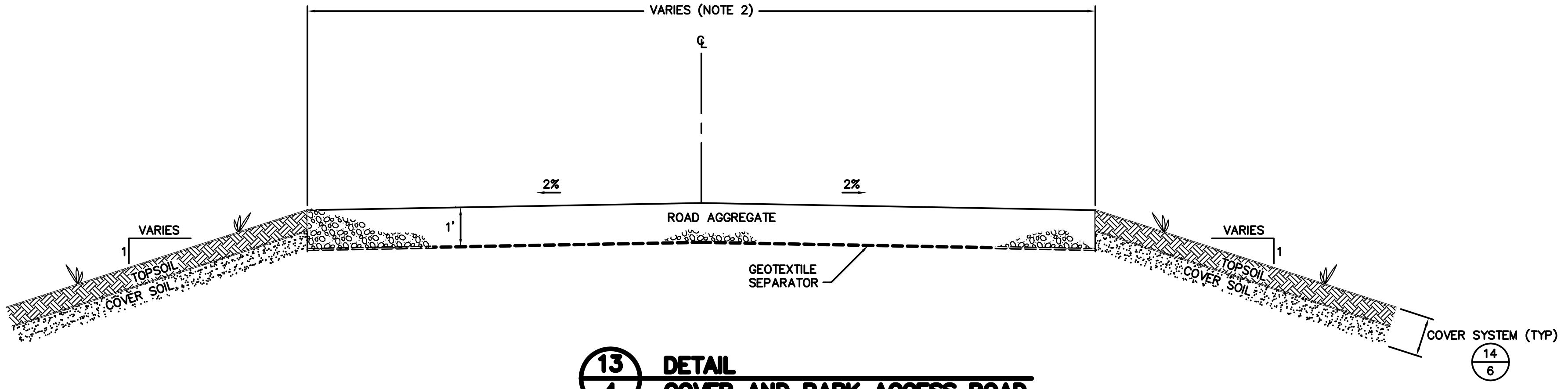
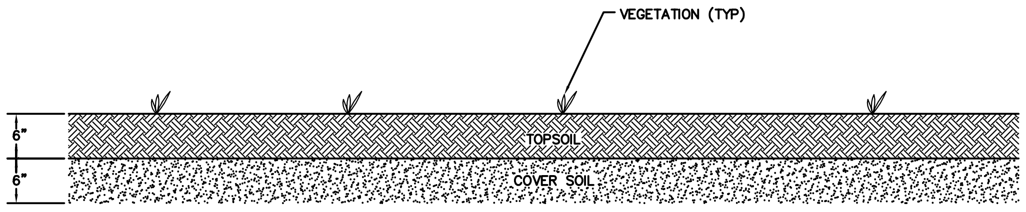
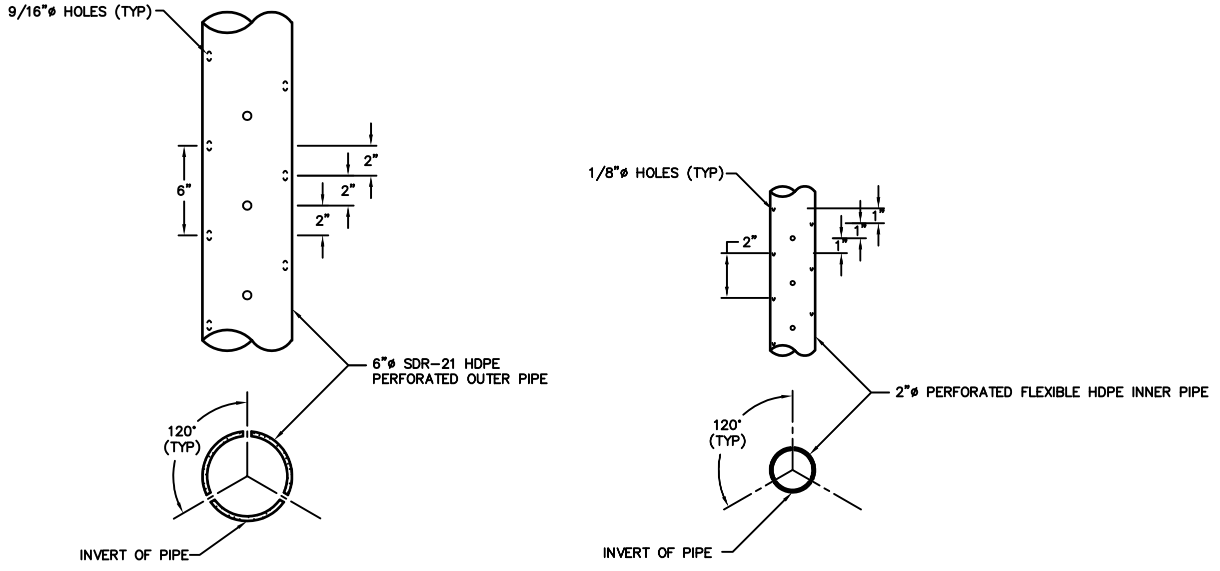
DRAWN BY:	AWS/LB	FILE NO:	0057-006
CHECKED BY:	MJM/CB	REVISION:	D
REVIEWED BY:	TK	DRAWING NO:	6 OF 7
APPROVED BY:	MJM		



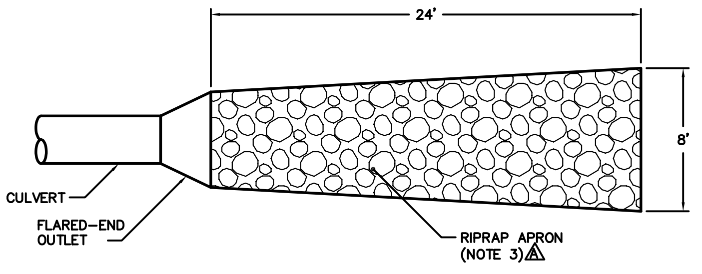
13/4 **DETAIL**
COVER AND PARK ACCESS ROAD
SCALE: 1" = 2'
XREF: 0057x012.DWG



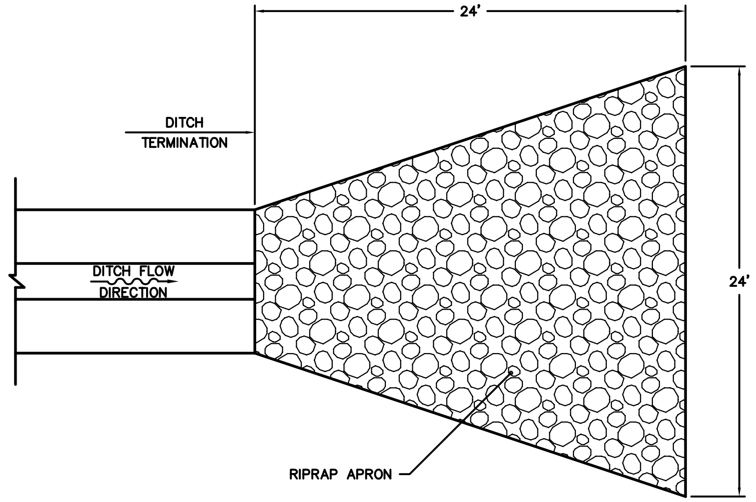
14/6 **DETAIL**
COVER SYSTEM
SCALE: 1" = 1'
XREF: 0057x011.DWG



15/6 **DETAIL**
PIPE PERFORATIONS
SCALE: N.T.S.
XREF: 0057x022.DWG



16/4 **DETAIL**
CULVERT OUTLET APRON
SCALE: NOT TO SCALE
XREF: 0057x027.DWG



17/4 **DETAIL**
DITCH OUTLET APRON A
SCALE: 1" = 5'
XREF: 0057X028.DWG

NOTES:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL TOLERANCES SHALL BE WITHIN THE LIMITS GIVEN IN THE SPECIFICATIONS.

2. ACCESS ROAD LEADING FROM ENTRANCE ON BLACKWATER ROAD TO THE INFILTRATION GALLERY SHALL BE 20-FT WIDE AS SHOWN ON DRAWING 4. ACCESS ROADS AND PARKING AREAS ON-SITE THAT ARE TO HAVE THEIR PAVEMENT REMOVED SHALL BE RE-BUILT TO THEIR ORIGINAL WIDTHS.

A 3. RIPRAP SHALL HAVE D'5'0 = 6 IN. AND D'M'A'X = 12 IN. RIPRAP APRONS SHALL BE 12 IN. THICK AND SHALL BE UNDERLAIN BY GEOTEXTILE FILTER.

GEOSYNTEC CONSULTANTS
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THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
GENERAL DETAILS

MARK	DATE	REVISION	BY	APPROVED
D	JULY 2004	TITLE BLOCK CHANGE	MR	TK
B	DECEMBER 2000	UPDATE FIGURE NUMBERS	NLB	MLM
A	APRIL 1999	RESPONSE TO MARCH 1999 USEPA COMMENT NO.19	SMG	JFB

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DESIGN BY:	SMG/NLB	JOB NO.:	TR0057-42
DRAWN BY:	AWS/LB	FILE NO:	0057-007
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REVIEWED BY:	TK	DRAWING NO:	7 OF 7
APPROVED BY:	MJM		

APPENDIX C

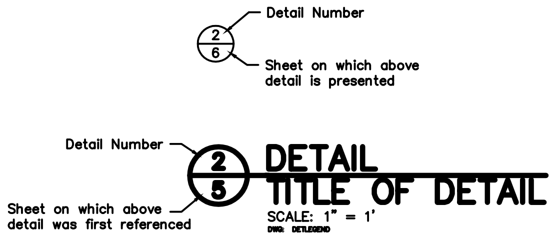
AS BUILT DRAWINGS FOR LANDFILL GAS VENTING TRENCH

SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

SOMERSWORTH, NEW HAMPSHIRE
CONSTRUCTION DRAWINGS
DESIGN FOR SOIL GAS VENTING SYSTEM

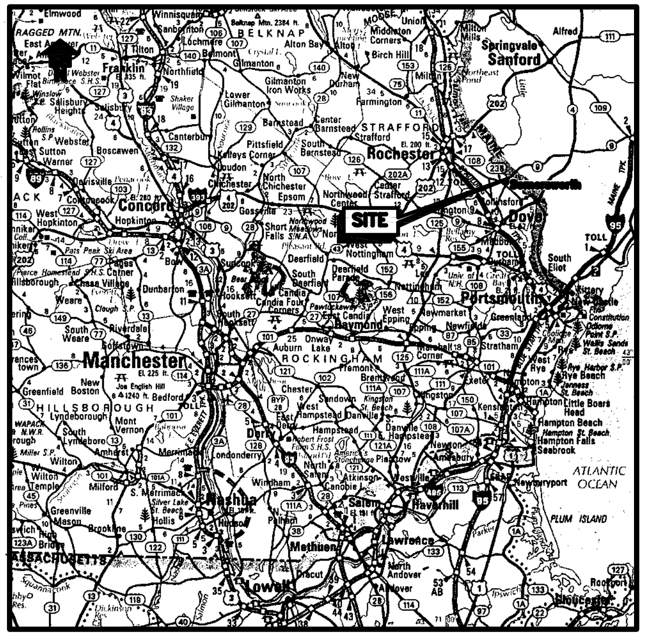
JANUARY 2003

DETAIL IDENTIFICATION LEGEND



Example: Detail Number 2 presented on Sheet No. 6 was referenced for the first time from Sheet No. 5.

Note: Above system also applies to section identifications.



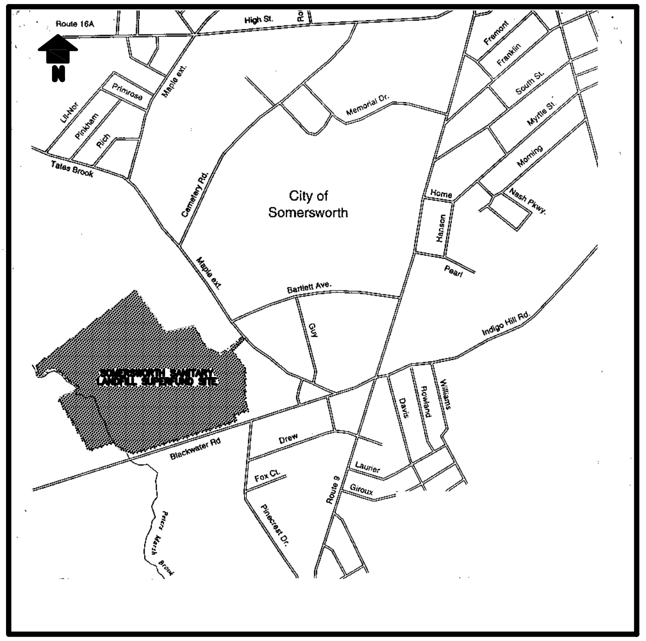
LOCATION MAP

0 10 MILES

SCALE

LIST OF DRAWINGS

DRAWING	DESCRIPTION
1	TITLE SHEET
2	GENERAL NOTES/SUMMARY OF WORK
3	SITE PLAN
4	SOIL GAS TRENCH ALIGNMENT
5	SOIL GAS TRENCH PROFILE
6	SOIL GAS TRENCH CROSS-SECTION AND DETAILS



VICINITY MAP

0 1000 FT.

SCALE

PREPARED FOR:

THE SOMERSWORTH LANDFILL SITE GROUP

PREPARED BY:

GEOSYNTEC CONSULTANTS

160 RESEARCH LANE, SUITE 206
GUELPH, ONTARIO, CANADA N1G 5B2
(519) 822-2230

PROJECT NUMBER TR0057-61
FILE NUMBER 0057-021
DRAWING NUMBER 1 OF 6

GENERAL NOTES:

1. CONTRACTOR IS RESPONSIBLE FOR COORDINATING AND MARKING EXISTING UTILITIES.
2. AIR MONITORING IS REQUIRED AT ALL TIMES DURING TRENCH EXCAVATION.
3. CONTRACTOR SHALL ESTABLISH TEMPORARY ACCESS ROAD BETWEEN THE TRENCH EXCAVATION AREA AND SOIL DISPOSAL AND STOCKPILE AREA. EQUIPMENT SHALL BE RESTRICTED TO USE OF TEMPORARY ACCESS ROAD DURING MATERIAL HANDLING ACTIVITY.
4. CONTRACTOR SHALL IMPLEMENT DUST CONTROL MEASURES FOR ALL TEMPORARY ACCESS ROADS. REFER TO SPECIFICATION SECTION 02030.
5. AS REQUIRED, REMOVE AND RE-ESTABLISH DISTURBED/EXISTING FEATURES SUCH AS GUARDRAIL AND CHAIN-LINK FENCE.
6. CONTRACTOR'S EQUIPMENT MUST BE WASHED IN EQUIPMENT DECONTAMINATION AREA PRIOR TO BEING DEMOBILIZED.

SEQUENCE OF CONSTRUCTION:

1. ESTABLISH TEMPORARY EROSION CONTROL MEASURES. REFER TO SPECIFICATION SECTION 02270.
2. ESTABLISH TEMPORARY ACCESS ROADS.
3. ESTABLISH DECONTAMINATION AREA ABOVE THE INFILTRATION GALLERY AS SHOWN ON SHEET 3.
4. ESTABLISH SOIL DISPOSAL AND STOCKPILE AREA(S) ADJACENT TO DECONTAMINATION AREA AS SHOWN ON SHEET 3. DISPOSAL AREA WILL REQUIRE EXCAVATION AND RE-INSTALLATION OF EXISTING PERMEABLE CAP. PERMEABLE CAP MATERIALS (TOPSOIL AND COVER SOIL) SHALL BE STOCKPILED TO THE EXTENT POSSIBLE FOR REUSE.
5. STRIP TOPSOIL, CLEAR BRUSH, AND GRUB STUMPS ALONG THE ALIGNMENT OF THE TRENCH SHOWN ON SHEETS 3 AND 4. STOCKPILE TOPSOIL, BRUSH, AND STUMPS IN SEPARATE AREAS OF THE SOIL DISPOSAL AND STOCKPILE AREA.
6. PERFORM EXCAVATION OF TRENCH BEGINNING FROM STATION 0+00. EXCAVATED SOIL SHALL BE TRANSPORTED TO THE SOIL DISPOSAL AND STOCKPILE AREA AS NECESSARY. INSTALL GEOMEMBRANE PANEL, BACKFILL WITH GRAVEL, CLAY PLUG INCLUDING GEOTEXTILE SEPERATOR, AND TOPSOIL (SEE SHEET 6) ONCE AN APPROPRIATE LENGTH OF TRENCH HAS BEEN EXCAVATED. AT THE LOCATIONS INDICATED IN THE DRAWINGS, INSTALL THE SOIL GAS VENT PIPES.
7. INSTALL ENCLOSURE AROUND EACH SOIL GAS VENT PIPE AS SHOWN ON SHEET 6.
8. REVEGETATE DISTURBED AREA OF TRENCH EXCAVATION.
9. REGRADE THE SOIL DISPOSAL AND STOCKPILE AREA TO BLEND IN WITH SURROUNDING CONTOURS. REPLACE APPROPRIATE THICKNESS OF PERMEABLE SOIL AND TOPSOIL AND REVEGETATE DISTURBED AREA.
10. REGRADE (IF NECESSARY) AND REVEGETATE ANY REMAINING AREAS DISTURBED DURING CONSTRUCTION (E.G. DECONTAMINATION AREA, TEMPORARY CONSTRUCTION ROADS, ETC.).

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THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
GENERAL NOTES/SUMMARY OF WORK

MARK	DATE	REVISION	BY	APPROVED

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DATE:	JANUARY 2003	SCALE:	
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DRAWN BY:	CRB	FILE NO:	0057-022
CHECKED BY:	MJM	REVISION:	0
REVIEWED BY:	TK	DRAWING NO:	2 OF 6
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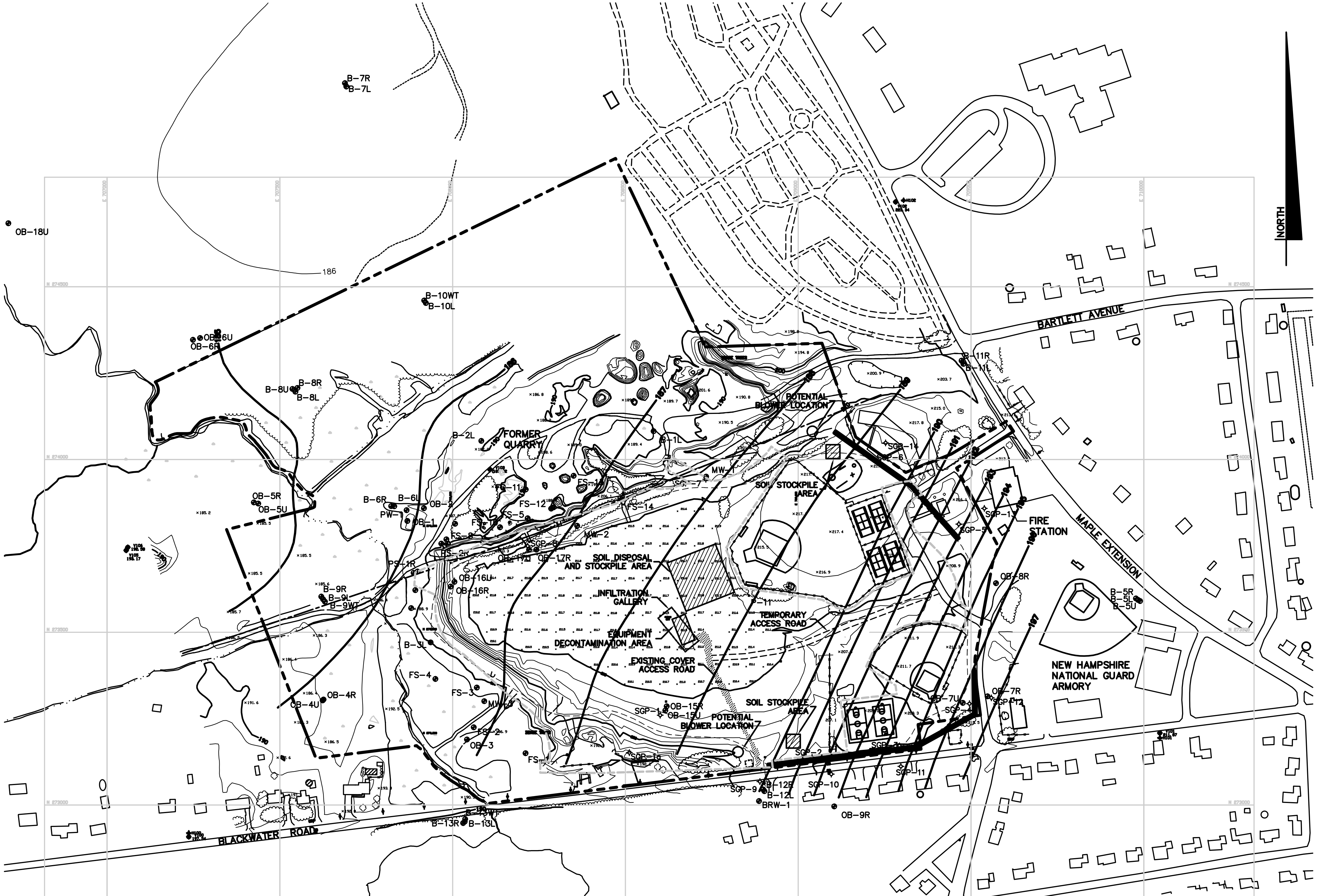

LEGEND

190 — OVERBURDEN PIEZOMETRIC SURFACE (FEET)
210 — EXISTING GROUND ELEVATION (FEET)
×213.1 EXISTING SPOT ELEVATION (FEET)
APPROXIMATE PROPERTY BOUNDARY (NOTE 3)
PAVED ROAD
UNPAVED ROAD
WATER LINE
TREELINE
APPROXIMATE EXTENT OF WASTE (NOTE 3)
APPROXIMATE EXTENT OF PERMEABLE CAP
— × — × — × FENCE
NATURAL GAS PIPELINE (NOTES 3,4)
UTILITY POLE
MONITORING WELL (NOTE 5)
SOIL GAS PROBE
WETLANDS
PROPOSED SOIL GAS VENT TRENCH

NOTES:

1. TOPOGRAPHIC MAP AND RELATED SITE FEATURES COMPILED BY EASTERN TOPOGRAPHICS, INC. WOLFBORO, NEW HAMPSHIRE, BASED ON AERIAL PHOTOGRAPHY TAKEN IN FALL 1996. EXISTING TOPOGRAPHY SHOWN WITHIN THE APPROXIMATE EXTENT OF WASTE LINE WAS SURVEYED BY TRITECH ENGINEERING CORPORATION IN OCTOBER 2001.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (AMSL), NGVD 1929. GRID COORDINATES CORRESPOND TO THE MAINE STATE PLANE COORDINATE SYSTEM, WEST ZONE, NAD 1927.
3. LOCATIONS OF PROPERTY BOUNDARY, NATURAL GAS PIPELINE, AND EXTENT OF WASTE BOUNDARY ARE APPROXIMATE, AND WERE TAKEN FROM FIGURE 1.2 OF THE SEPTEMBER 1998 CONCEPTUAL DESIGN REPORT, PREPARED BY BEAK INTERNATIONAL, INC., GUELPH, ONTARIO.
4. GROUNDWATER MONITORING WELL LOCATIONS, TABULATED TO THE NEAREST 0.01-FT LOCATION AND SHOWN ON THIS DRAWING, WERE TAKEN FROM JULY 1998 DESIGN INVESTIGATION REPORT FOR THE PILOT STUDY AND SITE GROUNDWATER MONITORING PROGRAM, REMEDIAL DESIGN FOR PREFERRED REMEDIAL ACTION AT THE SOMERSWORTH SANTORY LANDFILL SUPERFUND SITE, PREPARED BY BEAK INTERNATIONAL, INC.
5. OVERBURDEN PIEZOMETRIC SURFACE (I.E., WATER TABLE) IS APPROXIMATE AND SHOWS CONTOURS FROM SEPTEMBER 2001 (THE SEASONAL LOW GROUNDWATER LEVEL). SURFACE WAS TAKEN FROM FIGURE D-5 OF GEOSYNTEC CONSULTANTS "ANNUAL MONITORING AND DEMONSTRATION OF COMPLIANCE REPORT FOR 2001" DATED 6 FEBRUARY 2002. CONTRACTOR MAY PERFORM SITE INVESTIGATION AT THEIR OWN EXPENSE TO FURTHER DEFINE THE HYDROGEOLOGIC CONDITIONS THAT MAY BE ENCOUNTERED.
6. CONTRACTOR IS RESPONSIBLE FOR VERIFICATION OF EXISTING CONDITIONS SHOWN ON THIS DRAWING.

150 75 0 150 300
SCALE IN FEET

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GUELPH, ONTARIO, CANADA N1G 5B2

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
SITE PLAN

MARK	DATE	REVISION	BY	APPROVED
		UPDATED EXISTING TOPOGRAPHY		
		CHANGE LOCATION OF FS-11		
		NO CHANGES TO THIS DRAWING		

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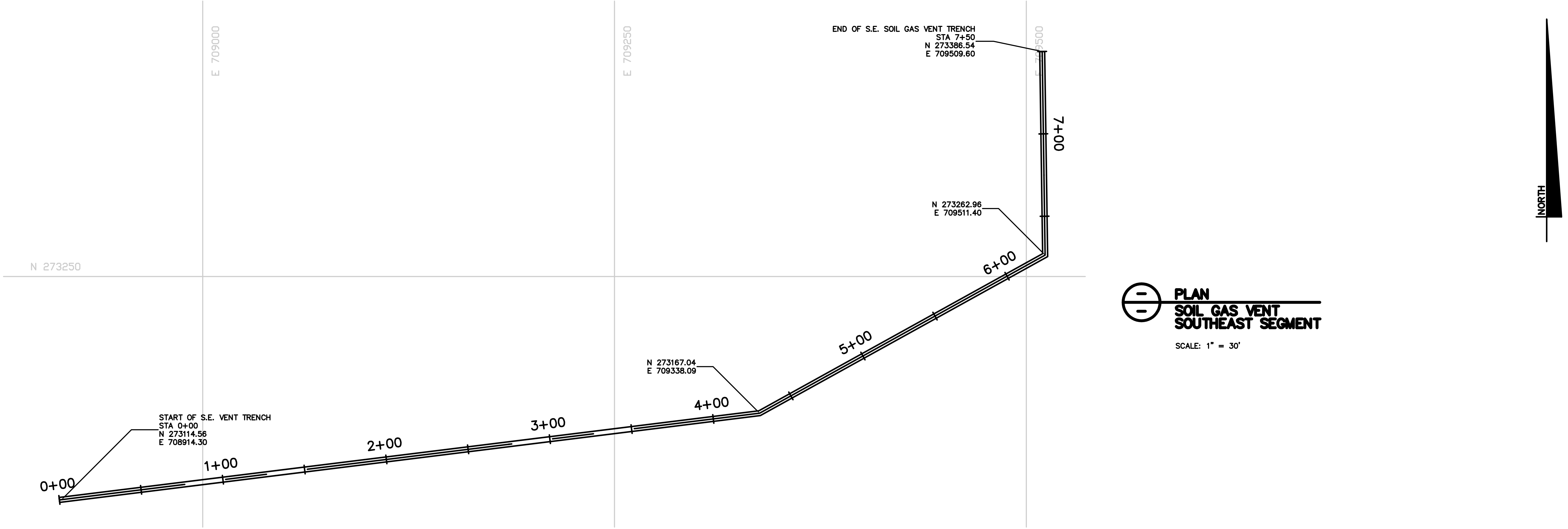
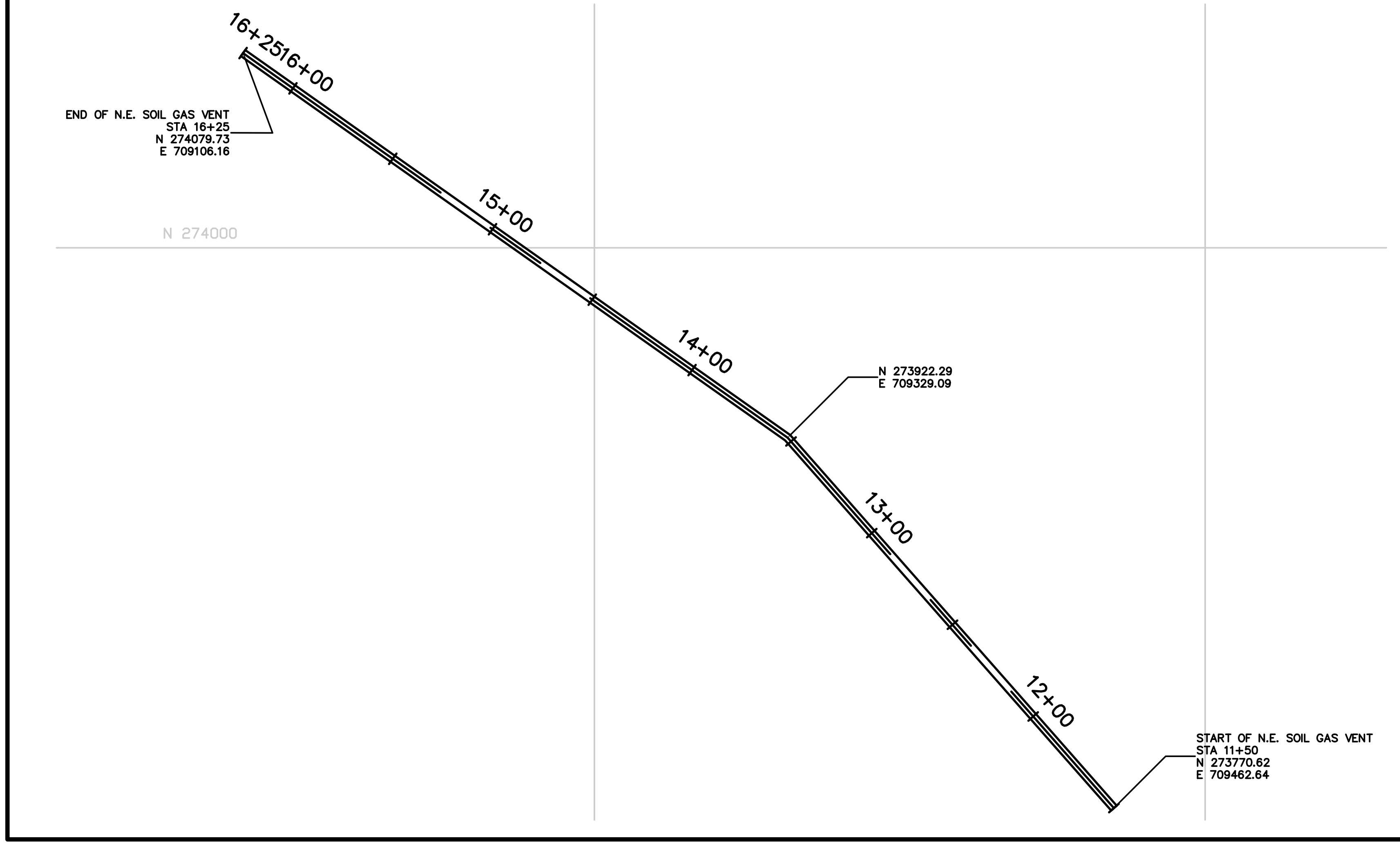
CHECKED BY:	MJM	REVISION:	0
REVIEWED BY:	TK	DRAWING NO:	3 OF 6
APPROVED BY:	MJM		



PLAN
SOIL GAS VENT SOUTHEAST SEGMENT

SCALE: 1" = 30'



PLAN
SOIL GAS VENT NORTHEAST SEGMENT

SCALE: 1" = 30'

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THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
SOIL GAS VENT ALIGNMENT

MARK	DATE	REVISION	BY	APPROVED

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REVIEWED BY:	TK	DRAWING NO:	4 OF 6
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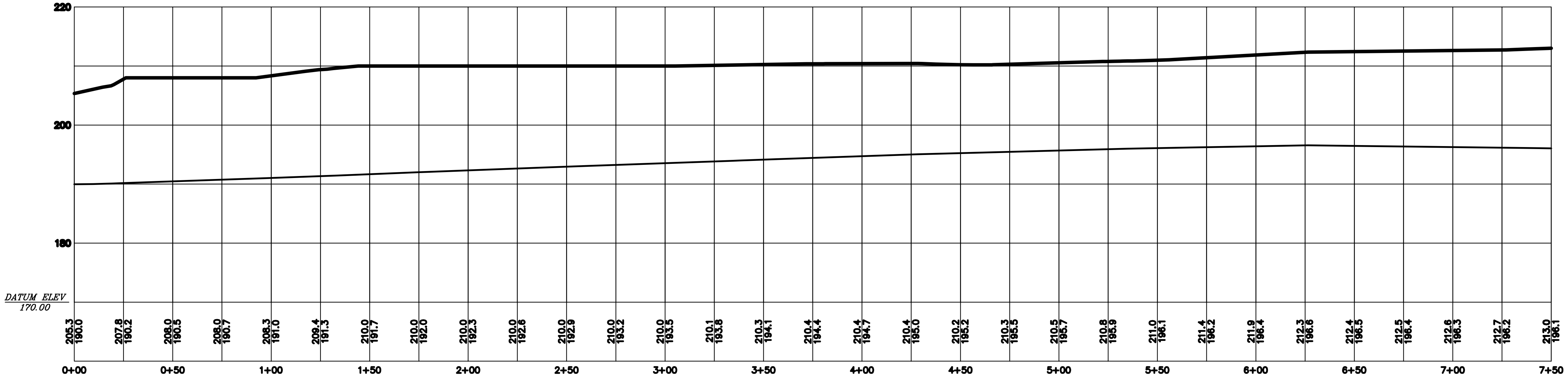
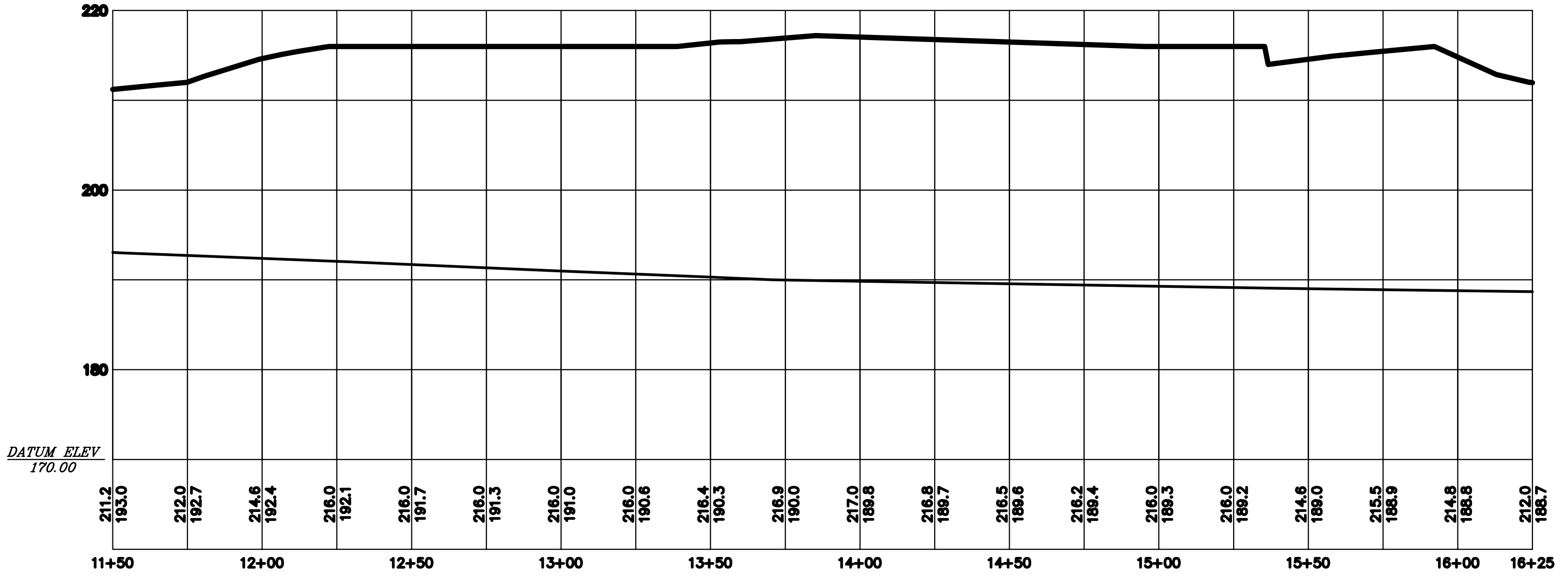


PROFILE

SOIL GAS VENT
SOUTHEAST SEGMENT

HORIZONTAL SCALE: 1"=30'
VERTICAL SCALE: 1"=10'



PROFILE

SOIL GAS VENT
NORTHEAST SEGMENT

HORIZONTAL SCALE: 1"=30'
VERTICAL SCALE: 1"=10'

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THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
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SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
SOIL GAS VENT PROFILE

MARK	DATE	REVISION	BY	APPROVED

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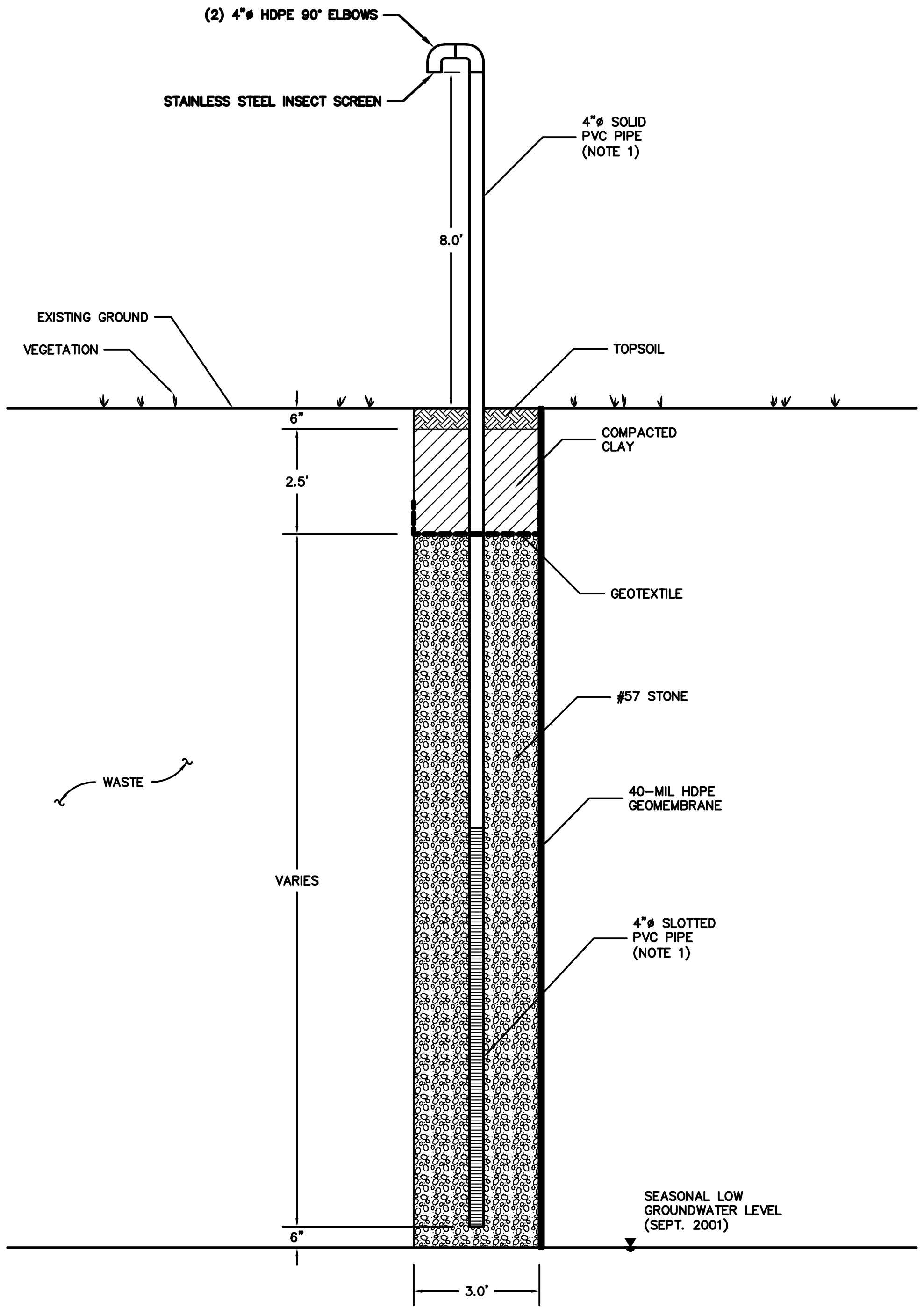
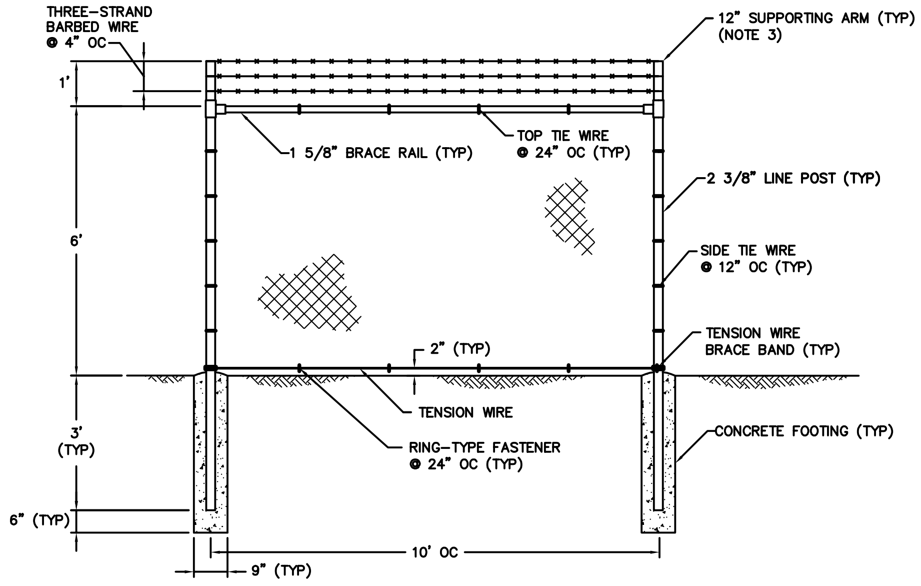
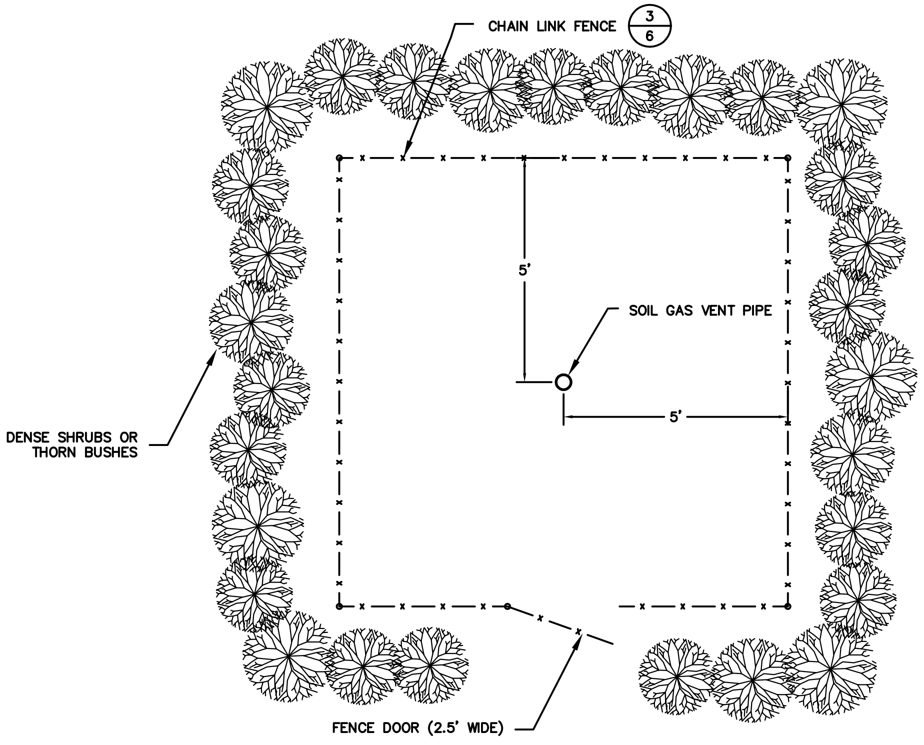
REVIEWED BY:	TK	DRAWING NO:	5 OF 6
APPROVED BY:	MJM		



1 / –
DETAIL
SOIL GAS VENT
SCALE: 1" = 2'
XREF: TRENCH X-SECTION.DWG



3 / 6
DETAIL
CHAIN LINK FENCE
SCALE: 1" = 2'
XREF: FENCE-DET2.DWG



2 / –
DETAIL
VENT PIPE PROTECTION
SCALE: 1" = 2'
XREF: TRENCH X-SECTION.DWG

NOTES:

1. SLOTTED PIPE LENGTH IS ONE-HALF THE TOTAL LENGTH OF PIPE BELOW GROUND SURFACE.
2. VENT PIPES ARE LOCATED AT THE FOLLOWING STATIONS:
   FOR SOUTHEAST TRENCH: 0+75, 2+75, 4+75, AND 6+75.
   FOR NORTHEAST TRENCH: 12+00, 14+00, AND 16+00.
3. SUPPORTING ARMS SHALL SLOPE TO OUTSIDE OF FENCED AREA AT 45 DEGREES FROM VERTICAL.

GEOSYNTEC CONSULTANTS
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GUELPH, ONTARIO, CANADA N1G 5B2

THE SOMERSWORTH LANDFILL SITE GROUP

PROJECT:
CONSTRUCTION DRAWINGS
DESIGN FOR PREFERRED REMEDIAL ACTION

WORK:
SOMERSWORTH SANITARY LANDFILL SUPERFUND SITE

TITLE:
SOIL GAS TRENCH CROSS-SECTION AND DETAILS

MARK	DATE	REVISION	BY	APPROVED

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DESIGN BY:	CRB	JOB NO.:	TR0057-61
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CHECKED BY:	MJM	REVISION:	0
REVIEWED BY:	TK	DRAWING NO:	6 OF 6
APPROVED BY:	MJM		

APPENDIX D

GROUNDWATER MANAGEMENT ORDINANCE AND FIGURE

CITY OF SOMERSWORTH, NEW HAMPSHIRE

CHAPTER 19 - ZONING ORDINANCE

SOMERSWORTH

ADOPTED BY SOMERSWORTH CITY COUNCIL - AUGUST 30,1989

AMENDED:

MARCH, 1990
AUGUST, 1990
SEPTEMBER, 1990
JANUARY, 1991
APRIL, 1991 MAY,
1991
SEPTEMBER, 1991
MAY, 1992
SEPTEMBER, 1992
JULY, 1993
SEPTEMBER, 1993
FEBRUARY, 1994
APRIL, 1994
JULY, 1994
FEBRUARY, 1995
OCTOBER, 1995
JANUARY, 1996
JULY 15, 1996
JUNE 2, 1997
APRIL 6, 1998
JUNE 1, 1998
JANUARY 18, 1999
OCTOBER 19,1999
JANUARY 10, 2000
APRIL 17, 2000
AUGUST 14, 2000
DECEMBER, 2000
MARCH, 2001
MAY 21, 2001
OCTOBER 7, 2002
OCTOBER 21, 2002
MAY 3, 2004
MARCH 21, 2005

CITY OF SOMERSWORTH

CHAPTER 19 – ZONING ORDINANCE

Amended March, 1990:
Pages 1, 2, 3,13,14, 52, 56,60 through 74. 83. 84, 85. Also, tables 4.A.1; 4.A.2; 4.A.3; 4.A.4; 4.A.5. Note #5; 5.A.1.;5.A.2.

Amended August, 1990:
Section 7, pages 16 thru 23.

Amended September, 1990:
Section 17, pages 63 thru 67. Table 5.A.1 and Table 5.A.1 Notes.

Amended January 7, 1991:
Section 20, page 89 - Zoning Board of Adjustment.

Amended April 1, 1991:
Section 18.C.4.e. - Political Signs.

Amended May 20, 1991:
Section 3.D., Page 5 - Commercial/Industrial District; Table of Uses, Tables 4.A.2; 4.A.3; 4.A.4; 4.A.5; 5.A.1.

Amended September 16, 1991:
Section 12, pages 46 thru 54 - Wetlands Conservation Overlay District.

Amended May 4, 1992:
Section 13, pages 53 thru 58 - Historic District.

Amended September 21, 1992:
Section 8, pages 24, 26 and 28 - Home Occupations.

Amended July 26, 1993:
Section 21, page 93 - Definitions; Table 4.A.4.

Amended September 7, 1993:
Section D.2., page 5 - Commercial/Industrial District.

Amended February 28, 1994:
Section 3. D.2., pages 5 & 6 - Commercial/Industrial District. Section 14, pages 60 thru 62 - Sexually Oriented Businesses (new). Section 18, page 71 on (19 pages) - Sign Regulations. Table of Uses - Table 4.A.5 (at end of chapter)

Amended April 4, 1994:
Table of Uses - Table 5.A.1 and Table 5.A.1 Notes.

Amended July 18, 1994:
Sections 11.B.4. & 11.B.5. (page 39); 11.B.8.f.& 11.B.9. (Pages 42 & 43); 11.c.(Pages 45 & 45A).

Amended February 21, 1995:
All pages renumbered to correspond with section numbers.
Table of Contents.
New Section added - "Section 15, Commercial Node District" (pages 15.1 thru 15.3).
Section 15 through Section 23 renumbered to Section 16 through Section 24.
Add Section 3.B.16. (page 3.3).
Add Section 3.D.8. (page 3.9).
Section 20.A.1. (page 20.1).
Section 20.B.3. (pages 20.1 & 20.2).
Section 20.B.3.h. (page 20.3).
Section 22 (pages 22.1 thru 22.9).
Tables 5.A.1&5.A.2

Amended October 2, 1995:
Added new Section 11 - Excavation of Earth Products (pages 11.1 to11.4)
Section 11 through Section 24 renumbered to Section 12 through Section 25.

Amended January 10, 1996:
Add Section 3.B. 15 (page 3.3).
Add new Section 16 - Recreation District (pages 16.1 thru 16.3).
Renumber all sections and pages after section 16 to reflect this change.
Section 24 (page 24.2).
Table 5.A. 1 Notes (page 8).

Amended July 15, 1996:
Delete Section 20 - Landscaping and Buffer Requirements, in its entirety.
Delete Section 22 - Circulation and Parking Regulations and replace with Section 21 – Circulation And Parking Regulations (page 21.1).
Renumber Section 23 through Section 26 to Section 22 through 25.

Amended June 2, 1997:
Section 8.D. (page 19:18)
Section 8.F.3. (page 19:18)
Section 8.F.6. (page 19:19) delete second paragraph
Table 4.A.3 & Note #6 (page 19:77)

Amended April 6, 1998:
Section 23 - Definitions (pages 68 and 70)
Table 4.A.3 and 4.A.5
Amended June 1, 1998:
Section 20 Sign Regulations - page 60.

Amended January 18, 1999:
Table 4.A.4 and 4.A.5

Amended October 19, 1999:

Added new Section 23 Naming of Public Streets and Rights of Way – pages 72-75

Renumbered Section 23 Definitions to Section 24 - pages 76-82. Renumbered Section 24 Administration & Enforcement to Section 25 - page 83. Renumbered Section 25 Interpretation, Conflicts & Separability to Section 26 - pages 84&85.

Amended January 10, 2000:
Section 8 Home Occupations - pages 18,19 & 21.
Section 10 Groundwater Protection District - pages 25 & 26.

Amended April 1, 2000:
Section 8 Home Occupations - pages 18,19 & 21.

Amended August 14, 2000:
Section 9 - Manufactured Housing District - pages 23 thru 24C. Table 4.A.5- pages 91 &92.

Amended December 11, 2000:
Section 12 - Flood Plain District - pages 32 thru 38A.

Amended March 19, 2001:
Section 3.A. - Districts - page 1.
Section 3.B.7. (deleted) - page 2.
Section 3.D.10. and 3.D.10.a. - (new) - page 7.
Section 24.NN. and 24.PP (delete) - page 79 and 80.
Tables 4.A.1. through 5.A.2 - pages 86 through 94.

Amended May 21, 2001:
Section 19.3.A. - Districts - page 1.
Section 19.3.B.14. - Purpose of Districts - page 3.
Section 19.3.D.11. - District Boundaries - page 7.
Section 19.3.D.12. - District Boundaries - pages 7 & 8.
Section 19.21. - Circulation & Parking Regulations - page 70.
Tables 4.A.1,4.A.2,4.A.3,4.A.4,4.A.5,5.A.1 - pages 85 thru 92.

Amended October 7, 2002:
Added new Section 24 Common Driveway Subdivision – pages 78 and 79.
Renumbered Section 24 thru Section 26 to Section 25 thru Section 27.

Amended October 21, 2002:
Table 4.A.3. – page 90

Amended 5/03/2004:
Section 7, Cluster Subdivision – pages 12 thru 17. Changed Cluster Subdivision to read Conservation Residential Development throughout Section.
Sections 20.D.2.a, 20.D.2.e, 20.D.2.f – page 68.
Section 20.D.4 – page 70.
Section 25, Definitions – pages 80 thru 84.
Added new Section 26, Telecommunication Facilities – pages 86 thru 93.
Amended Table of Uses (Table 4.A.3), page 98.
Amended Table of Uses (Table 4.A.5), pages 101 & 102.

Amended 3/21/2005:
Section 19.12.A. Flood Plain District, Applicability – page 34.
Section 19.14.H.2. Historic District, Appeal Process – page 52.
Section 19.20.B.13. Sign Regulations, Flashing Sign – page 61.
Section 19.20.C.2.e. Sign Regulations – page 63.
Section 19.20.C.4.a. Sign Regulations – Banner Signs – page 64.
Section 19.25.Y. Definitions, Dwelling Unit – page 82.
Section 19.25.DD. Definitions, Frontage – page 82.
Section 19.27.C. & 19.27.E. Administration & Enforcement – page 94.
Table 4.A.1. – page 96.

Section 10 Groundwater Protection District

19.10.A. AUTHORITY. In accordance with New Hampshire Revised Statutes Annotated (RSA) Chapter 4-C:22 III, as the same may be subsequently amended, the City of Somersworth hereby adopts the following Groundwater Protection District.

19.10.B. PURPOSE. The purpose of this ordinance is, in the interest of public health, safety and general welfare, to protect, preserve and maintain the existing and potential groundwater supply and groundwater recharge areas within the known aquifer from adverse development, land use practices or depletion, and to allow for the restoration of degraded ground water by the establishment of a "Ground Water Management Zone".[1]

19.10.C. LOCATION.

19.10.C.1. The boundaries of the Groundwater Protection District shall be the outermost edge of the out wash deposits of the "Lily Pond Aquifer", as designated in the "Report on Aquifer Definition Lily Pond Aquifer Somersworth, New Hampshire," prepared by BCI Geonetics, Inc., and included in the Water Master Plan Update dated June1984. The Ground Water Management Zone is designated by the Ground Water Management Zone Overlay Map included in the Preferred Remedial Action 100% Design and Demonstration of Compliance Plan prepared by Beak International, Inc. and Geo Syntec Consultants International, Inc.[1]

19.10.C.2. When the actual boundary of the Groundwater Protection District is in dispute by any owner or abutter actually affected by said boundary, the Planning Board, at the owner/abutter's expense and request, may engage a professional geologist or hydrologist to determine more accurately the precise boundary of said Groundwater Protection District.

19.10.D. APPLICABILITY.

19.10.D.1. All land use activities and development conducted within the Groundwater Protection District shall be regulated by the standards established herein.

19.10.D.2. The standards established herein shall constitute the rules of an overlay zone and shall be superimposed over other zoning districts or portions thereof. The provisions herein shall apply in addition to all other applicable ordinances and regulations. In the event of a conflict between any provision herein and any other ordinance or regulation, the more restrictive requirement shall control.

19.10.E. DEFINITIONS.

19.10.E.1. Animal Feed Lots. A plot of land on which 25 livestock or more per acre are kept for the purpose of feeding.

19.10.E.2. Groundwater. Water in the subsurface zone at or below the water table in which all pore spaces are filled with water.

19.10.E.3. Groundwater Management Zone (GMZ). The subsurface volume in which ground water contamination associated with a discharge of a regulated contaminant is contained. (State of NH Groundwater Protection Rules - Env - WS410.)[2]

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[1] Amended 1/10/2000.

[2] Passed 1/10/2000.

19.10.E.4. Hazardous and Toxic Materials. Those materials that pose a present or potential hazard to human health and the environment when improperly stored, transported or disposed of. These materials include those listed in the New Hampshire Hazardous Waste Regulations. Third Edition. Appendixes 1-4, 1985, New Hampshire Dept. of Environmental Services, Concord, as the same may be subsequently amended.

19.10.E.5 Impervious Surface. A surface covered by any material (such as pavement, cement, roofing) that prevents surface water from penetrating the soil directly.

19.10.E.6. Leachable Wastes. Waste materials including solid wastes, sewage, sludge, and agricultural wastes that are capable of releasing waterborne contaminants to the surrounding environment.

19.10.E.7. Solid Waste. Discarded solid material with insufficient liquid content to be free flowing. This includes but is not limited to rubbish, garbage, scrap materials, junk, refuse, inert fill material and landscape refuse.

19.10.F. PROHIBITED USES. The following uses are expressly prohibited from the Groundwater Protection District:

19.10.F.1. Within the Lily Pond Aquifer[1]

19.10.F.1.a. The disposal of solid waste including landfills and sewage lagoons, excepting disposal of stumps and brush;
19.10.F.1.b. Storage of road salt or other deicing chemicals except in a property constructed shelter for use on site;
19.10.F.1.c. Dumping of snow containing road salt or other deicng chemicals;
19.10.F.1.d. Motor vehicles service or repair shops;
19.10.F.1.e. Junk and salvage yards;
19.10.F.1.f. Animal feedlots;
19.10.F.1.g Commercial or industrial handling, disposal, storage or recycling of hazardous or toxic materials or wastes; and
19.10.F.1.h Underground storage or petroleum or any refined petroleum product. All existing underground tanks, including those under 1,100 gallons, must be registered with the Somersworth Fire Department within six months of the enactment of this regulation. Existing tanks over 1,100 gallons are subject to Water Supply and Pollution Control Commission regulation, pursuant to New Hampshire Code of Administration No. W5411.

19.10.F.2. Within the Groundwater Management Zone:
19.10.F.2.a. The requirements, restrictions, and prohibition of the underlying Zoning District shall continue to apply to the extent that they are not inconsistent with the provision of this section; and[2]
19.10.F.2.b. Pumping of ground water from any well, trench, sump or other structure for residential, irrigation, agricultural or industrial purpose is prohibited.[2]

19.10.G. SPECIAL CONDITIONS. The following conditions shall apply to all uses in the Groundwater Protection District:

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[1] Added 1/10/2000.
[2] Passed 1/10/2000.

19.10.G.1. A lot shall not be rendered more than ten percent (10%) impervious. A proposed development plan which will incorporate a stormwater drainage plan, approved by the City of Somersworth Planning Board and prepared by a professional engineer certified to practice in the State of New Hampshire shall be provided. The plan shall provide for the on-site retention and percolation of all development generated stormwater runoff from a ten (10) year storm. Furthermore, the stormwater drainage plan shall provide for the filtering of parking area runoff to remove oil, gasoline and other impurities prior to retention and percolation of the runoff;

19.10.G.2. Development or land use activities proposed within the Groundwater Protection District shall be connected to the municipal sewage disposal system and the municipal water system;

19.10.G.3. Any use retaining less than thirty percent (30%) of lot area, regardless of size, in its natural vegetative state with no more than minor removal of existing trees and vegetation shall require a special permit;

19.10.G.4. Mining operations, including sand and gravel removal, shall require an Earth Removal Permit, pursuant to New Hampshire Revised Statutes Annotated Chapter 155-E, which is herein incorporated by reference. Such excavation or mining shall in no case be carried out within eight (8) vertical feet of the seasonal high water table; and

19.10.G.5. The storage of petroleum or related products in a freestanding fuel oil tank within or adjacent to a residential structure which is used for the normal heating of said structure shall be permitted pursuant to the conditions outlined in subsection H below, and all applicable state regulations. All tanks shall be protected from internal and external corrosion and shall be of a design approved by the Somersworth Fire Department. All freestanding tanks shall be placed on an impermeable surface such as a concrete pad. No tank may be abandoned in place. A tank shall be disposed of after emptied of all hazardous materials if it has been out of service for a period in excess of twelve (12) months. The product and the tank shall be disposed of by the property owner as directed by the Somersworth Fire Department and all applicable state laws. All leaking tanks must be emptied by the owner or operator within twelve (12) hours after detection of the leak and removed by the owner and/or operator as per above.

19.10.H. ADMINISTRATION.

19.1 0.H.1. Development or land use activities proposed within the Groundwater Protection District that require a special permit, as provided in subsection G above, shall be reviewed' by both the Planning Board and the Somersworth Conservation Commission. The Planning Board shall either approve, conditionally approve or disapprove a special permit only after it determines that the proposed land use development and/or activities comply with the purpose of this regulation. In making such a determination, the Planning Board shall give consideration to the simplicity, reliability and feasibility of the control measures proposed and the degree of threat to groundwater quality if the control measures failed.

19.10.H.2. Development or land use activities proposed within the Groundwater Protection District that require subdivision or site plan approval from the Planning Board shall also be reviewed by the Somersworth Conservation Commission. The Planning Board and the Conservation Commission shall verify that the proposed activity will conform to the provisions of this regulation ordinance prior to action by the Planning Board to approve, conditionally approve or disapprove the application.

19.10.H.3. The Building Inspector shall not issue a building permit for development or land use activities until such time as he/she verifies that the proposed activity will conform to the provisions of this ordinance. The Building Inspector may consult with the Planning Board and/or Conservation Commission as he/she deems necessary.

19.10.H.4. Land use activities that do not require the receipt of Panning Board approval or building permits shall nonetheless be subject to the requirements and standards established herein.

19.10.H.5. A hydrogeologic study may be required by the Planning Board and/or the Conservation Commission to investigate the impacts a proposed development or land use activity will have on an existing or future groundwater supply. A qualified professional hydroiogist or geologist shall be chosen by the City of Somersworth and the applicant for approval shall pay any and all costs incurred.

19.10.H.6. For all freestanding fuel oil tanks as permitted per Section 7. F., the property owner shall file with the City of Somersworth the following information prior to the installation of a tank:

19.10.H.6.a. The size of the tank;

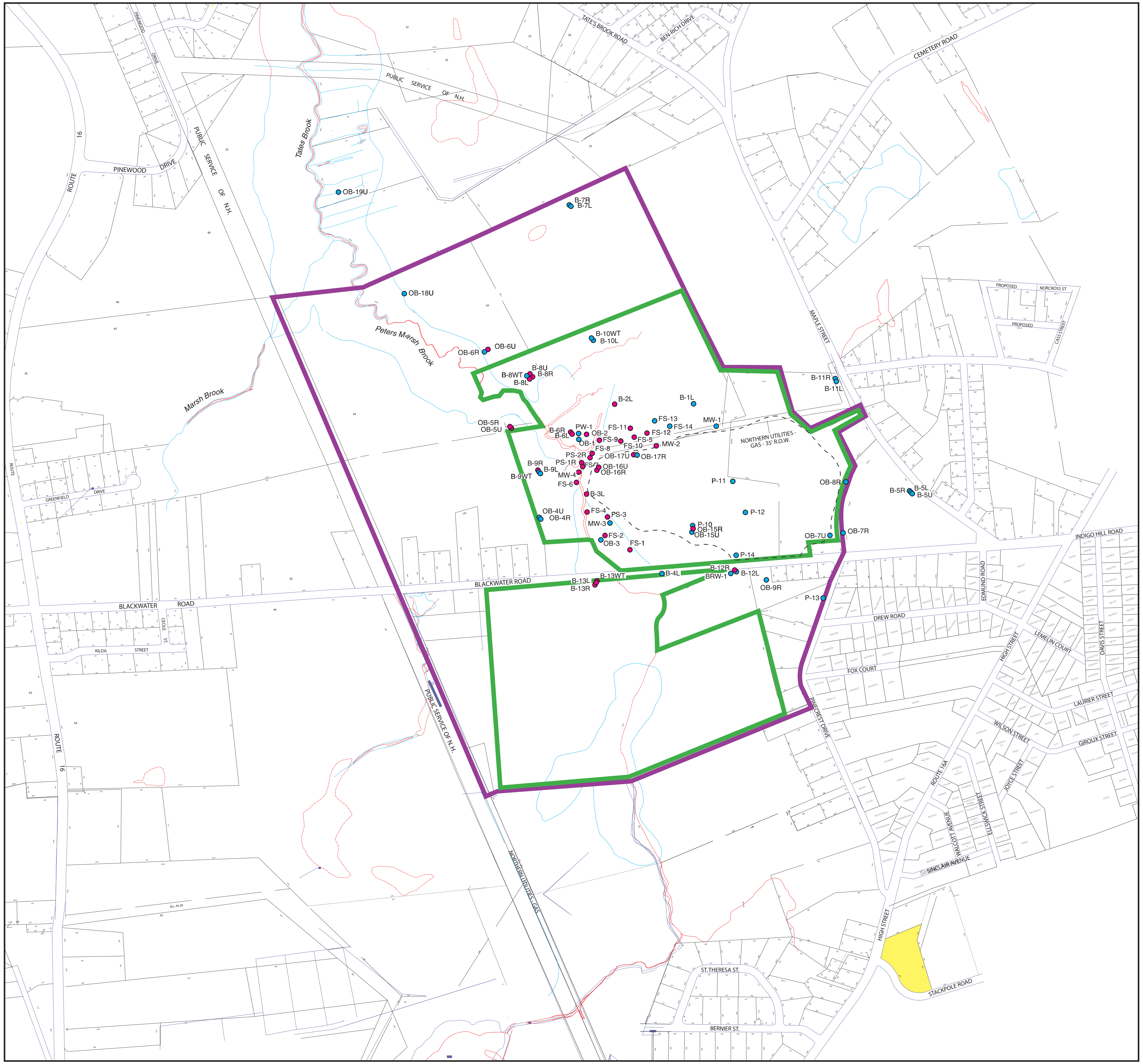
19.10.H.6.b The type of tank;

19.10.H.6.c. The type of material being stored and its quantity;

19.10.H.6.d. The location of each tank on the premises, complete with a sketch map; and

19.10.H.6.e. The age of each tank.

19.10.I. ENFORCEMENT. If the Planning Board and/or the Building Inspector finds that any of the requirements and standards established herein are in violation, the Building Inspector shall order the owner, in writing, to make such corrections as he/she deems necessary to bring the development and activities into compliance with the provisions of this ordinance. Such order shall be complied with within twenty-four (24) hours of the original notice to the owner. Where the owner fails to comply with the order of the Building Inspector, a fine of one hundred dollars ($100) per day, or the maximum amount which is authorized by statute, may be levied against said owner. The fine shall be retroactive and shall begin to accrue on the date on which the property owner receives written notice from the Building Inspector that he/she is in violation of this ordinance.



N

🟨	State Well Records Indicate a Water Supply Well on this Lot
━━	City Owned Land Within Groundwater Management Zone
- - - - -	Approximate Edge of Waste
━━	Boundary of Groundwater Management Zone
●	Between 1996 - 1998 ICLs were exceeded for at least one CE
●	Between 1996 - 1998 ICLs were not exceeded for any CE

CE - Chlorinated Ethenes (tetrachloroethene, trichloroethene, cis- and trans-1,2-dichloroethene and vinyl chloride)

0 300 600
(approximate scale)

Groundwater Management Zone

Somersworth Landfill Superfund Site, Somersworth, NH

June 2005

Figure: **7.1**

GEOSYNTEC CONSULTANTS

SOMMERS2taxmap copy.ai

Layers: 00 01 03 04 04A 05 06 08

TABLE D.1
Property Owners Within the GMZ
Somersworth Sanitary Landfill Superfund Site, Somersworth NH

Property Owner	Address	City State Zip	Location & ID
ALMEIDA STEVEN L + SUZANNE J	26 PINECREST DR	SOMERSWORTH NH 03878-1413	Loc: 26 PINECREST DR Parcel ID #: 35 11 0
ANDRIAN WILLY	26 BLACKWATER RD	SOMERSWORTH NH 03878-1504	Loc: 26 BLACKWATER RD Parcel ID #: 35 13A 0
BALL JAMES T	PO BOX 62	SOMERSWORTH NH 03878	Loc: 92 BLACKWATER RD Parcel ID #: 35 18 0
BARRY WILLIAM J + MELISSA F	93 BLACKWATER RD	SOMERSWORTH NH 03878-1519	Loc: 93 BLACKWATER RD Parcel ID #: 34 2A 0
BOWLEY PAULINE M + RALPH E / TRUSTEES REVOCABLE TRUST	81 BLACKWATER RD	SOMERSWORTH NH 03878-1519	Loc: 81 BLACKWATER RD Parcel ID #: 34 07 0
DEMOTT RITA J	22 PINECREST DR	SOMERSWORTH NH 03878-1413	Loc: 22 PINECREST DR Parcel ID #: 35 09 0
FOSTER JULIA M	94 BLACKWATER RD	SOMERSWORTH NH 03878-1504	Loc: 94 BLACKWATER RD Parcel ID #: 35 17 0
FRANCOEUR REALTY TRUST /	17 PARKVIEW TER	SOMERSWORTH NH 03878-1516	Loc: 9 PARK VIEW TER Parcel ID #: 22 50A 0
GAGNE ROGER + JANET C	81A BLACKWATER RD	SOMERSWORTH NH 03878-1519	Loc: 81 A BLACKWATER RD Parcel ID #: 34 03 0
HAMEL ROGER + SUSAN	28 BLACKWATER RD	SOMERSWORTH NH 03878-1504	Loc: 28 BLACKWATER RD Parcel ID #: 35 13B 0
HOWARD DONALD L + JOAN /	24 PINECREST DR	SOMERSWORTH NH 03878-1413	Loc: 24 PINECREST DR Parcel ID #: 35 10 0
HUYN PHI	24 BLACKWATER RD	SOMERSWORTH NH 03878-1504	Loc: 24 BLACKWATER RD Parcel ID #: 35 13 0
LACHARITE DONALD L + PATRICIA	83 BLACKWATER RD	SOMERSWORTH NH 03878-1519	Loc: 83 BLACKWATER RD Parcel ID #: 34 06 0
LETARTE GERARD E	1 BERNIER ST	SOMERSWORTH NH 03878-1001	Loc: BLACKWATER RD Parcel ID #: 34 09 0
LIBBY JEFFREY W + CAROLYN	28 1/2 BLACKWATER RD	SOMERSWORTH NH 03878-1504	Loc: 28 1\2 BLACKWATER RD Parcel ID #: 35 13C 0
MEDICAL MILE LLC / ~NH REAL ESTATE	350 ROUTE 108 SUITE 210	SOMERSWORTH NH 03878	Loc: 241 RT 108 Parcel ID #: 45 01 0
MURRAY FRANK A + DONNA M	38 PINECREST UNIT 2	SOMERSWORTH NH 03878	Loc: 5 WEXFORD LANE Parcel ID #: 35 12A 0
MURRAY FRANK A + DONNA M	38 PINECREST UNIT 2	SOMERSWORTH NH 03878	Loc: 7 WEXFORD LANE Parcel ID #: 35 12B 0
MURRAY FRANK A + DONNA M	38 PINECREST UNIT 2	SOMERSWORTH NH 03878	Loc: 38 PINECREST DR Parcel ID #: 35 12C 0
MURRAY FRANK A + DONNA M	38 PINECREST UNIT 2	SOMERSWORTH NH 03878	Loc: 32 PINECREST DR Parcel ID #: 35 12D 0
NEWMAN GEORGE C + LINDA	85 BLACKWATER RD	SOMERSWORTH NH 03878-1519	Loc: 85 BLACKWATER RD Parcel ID #: 34 05 0
PUBLIC SERVICE CO OF NH/TAX AC	1000 ELM ST - PO BOX 330	MANCHESTER NH 03105-0330	Loc: 17 BLACKWATER RD Parcel ID #: 22 09 0
REGINOD REAL ESTATE LLC / %NADCO	P O BOX 130	DOVER NH 03820-0130	Loc: 52 WILLAND, EAST DR Parcel ID #: 35 19 0
ROBIDAS DANIEL G + HEIDI A	87 BLACKWATER RD	SOMERSWORTH NH 03878	Loc: 87 BLACKWATER RD Parcel ID #: 34 5A 0
SHAW STANLEY I + HELEN T TSTEE / 50% REVOCABLE TRUST OWNERS	26 VAN BUREN AVE	PORTSMOUTH NH 03801	Loc: 97 BLACKWATER RD Parcel ID #: 34 01 0
SMITH PETER R + ELLEN	28 PINECREST DR	SOMERSWORTH NH 03878-1413	Loc: 28 PINECREST DR Parcel ID #: 35 11A 0
SULLIVAN CATHERINE / MCDONOUGH STEPHEN M	28 FRANKLIN ST APT 211	SOMERSWORTH NH 03878-3251	Loc: 89 BLACKWATER RD Parcel ID #: 34 04 0
TURCOTTE JEFFREY S + NANCY T /	14 WESTWOOD DR	SOMERSWORTH NH 03878-1538	Loc: 14 WESTWOOD DR Parcel ID #: 34 08 0
VALLEE JEANNETTE	95 BLACKWATER RD	SOMERSWORTH NH 03878-1519	Loc: 95 BLACKWATER RD Parcel ID #: 34 02 0
VINCENT KENNETH S / BUKOVSKEY LYNNE	19 VINCENT WAY	SOMERSWORTH NH 03878	Loc: 19 VINCENT WAY Parcel ID #: 34 3A 0
PENTA K REALTY TRUST	247 CONCORD RD	WAYLAND MA 01778	Loc: 100 BLACKWATER RD Parcel ID # 44 01 0
JESSE K HARDY	PO BOX 130	DOVER NH 03820	Loc: 19 SHERWOOD GLEN Parcel ID # 35 19A 0
AIKENS MARGARET L / AIKENS MARGARET J	34 BLACKWATER RD	SOMERSWORTH NH 03878	Loc: 34 BLACKWATER RD Parcel ID # 35 15 0
CITY OF SOMERSWORTH	1 GOVERNMENT WAY	SOMERSWORTH NH 03878	Loc: PINEWOOD DR Parcel ID # 46 04 0
DAIGLE WYNNE	1290 SO MILITARY TRAIL 412	DEERFIELD BEACH FL 33442	Loc: WESTWOOD DR Parcel ID # 33 02 0
CITY OF SOMERSWORTH	1 GOVERNMENT WAY	SOMERSWORTH NH 03878	Loc: TATES BROOK RD Parcel ID # 33 04 0

APPENDIX E

WELL CONSTRUCTION LOG FOR BRW-1

DRAFT

WELL CONSTRUCTION LOG

PROJECT GE Somersworth	PROJECT NUMBER 8110-003	WELL NUMBER BRW-1	
SITE Somersworth Sanitary Landfill	COORDINATES	GROUND SURFACE ELEVATION	CASING STICKUP 2.9'

Soil Boring Cross-Reference BRW-1

Town and City Somersworth

County and State Strafford County, New Hampshire

Installation Date (s) 4/4/96

Drilling Method Drive & Wash/Air Rotary

Drilling Contractor New Hampshire Boring

Drilling Fluid Water

Development Technique (s) / Dates

Overpumping and surging/ 4/5/96

Fluid Loss During Drilling (gals) 500 est.

Water Removed During Development (gals)

1510 est. -

Static Depth to Water Date 6/5/96

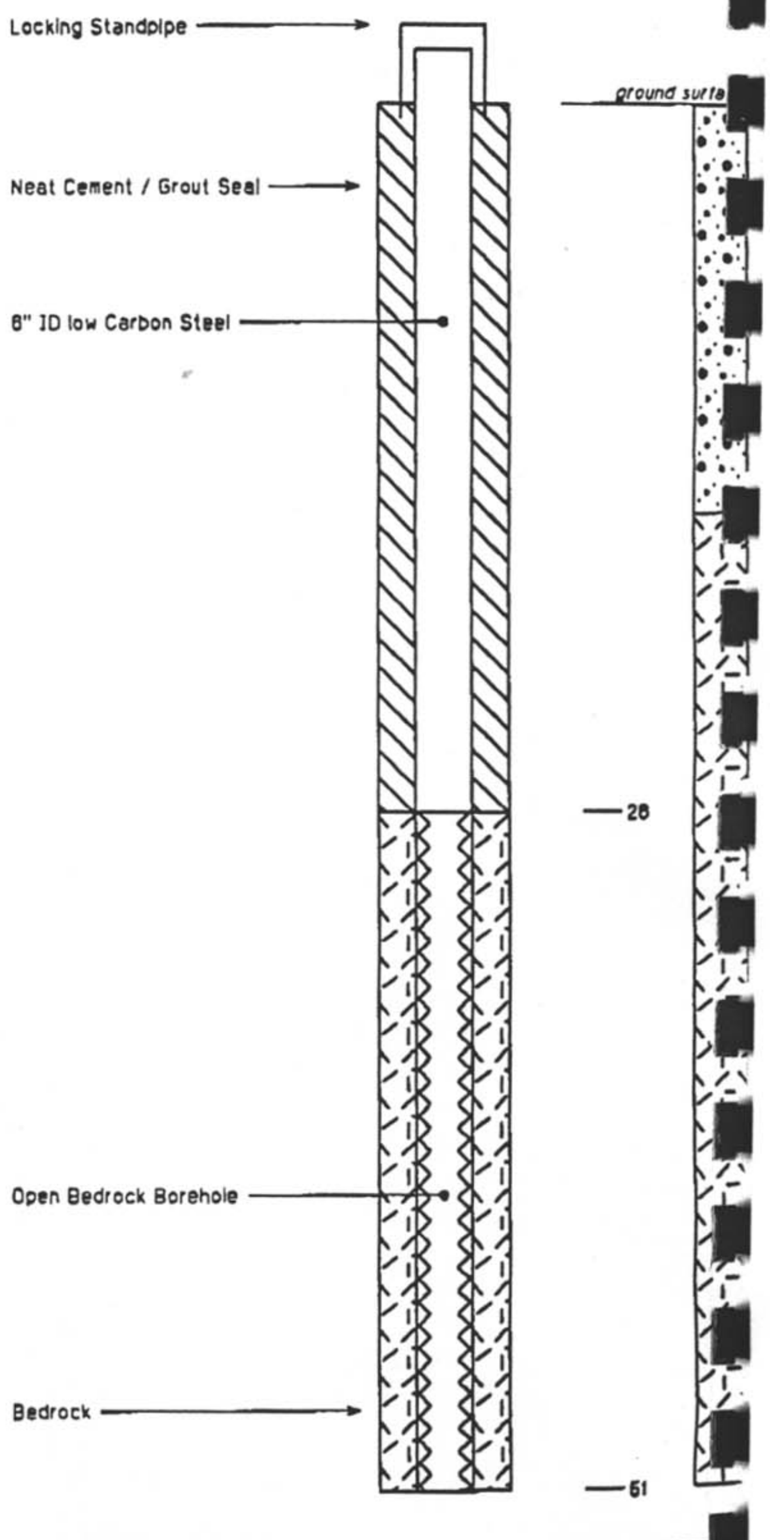
Static Depth to Water (feet) 13.17

Well Purpose Bedrock recovery well

Remarks

Prepared By J. Hershberger

Date Prepared 6/19/96



GeoTrans, Inc.

COST AND PERFORMANCE REPORT

Pump and Treat and In Situ Bioventing at the Onalaska Municipal Landfill Superfund Site
Onalaska, Wisconsin

April 2006

Prepared by:

EPA

U.S. Environmental Protection Agency
Office of Superfund Remediation
and Technology Innovation (OSRTI)

SITE INFORMATION

IDENTIFYING INFORMATION [9]

Site Name: Onalaska Municipal Landfill Superfund Site

Location: Onalaska, Wisconsin

CERCLIS #: WID980821656

ROD Date: August 14, 1990

ESD Date: September 29, 2000; November 13, 2001

TECHNOLOGY APPLICATION

Type of Action: Remedial

Period of Operation:

- Pump and Treat (P&T) (for groundwater) – June 1994 through November 2001
- In Situ Bioventing (for soil) – May 1994 to February 1997
- Monitored Natural Attenuation (MNA) (for groundwater) – November 2001 to present

Quantity of Material Treated during Application:

- 2.17 billion gallons of groundwater treated from 1994 through 2001
- Quantity of soil treated was not reported

BACKGROUND [1,3]

Waste Management Practice that Contributed to Contamination: Disposal of municipal and chemical wastes in a landfill

Facility Operations:

- The Onalaska Municipal Landfill Superfund Site (Onalaska) is located in Onalaska, Wisconsin, about 10 miles north of La Crosse, Wisconsin. The 11-acre site is located 400 feet from the Black River and within 500 feet of several residences.

- The site was used as a sand and gravel quarry from the early to mid-1960s. In the mid-1960s, the Town of Onalaska began using the site as a landfill for both municipal and chemical wastes. In 1978, the Wisconsin Department of Natural Resources (WDNR) concluded that the landfill operation did not comply with state codes and ordered the landfill closed. Landfill operations stopped in September 1980, and the landfill was capped in June 1982.

- WDNR site investigations in September 1982 identified elevated levels of organic and inorganic contaminants in the aquifer beneath the landfill, which also served as the primary source of drinking water for the residents in the area. The site was placed on the National Priorities List in September 1984.

- Results of the remedial investigation (RI) conducted in 1988 and 1989 indicated that soils above the groundwater table and adjacent to the southwestern edge of the landfill were contaminated with petroleum solvents, including naphtha, at levels as high as 550 milligrams per kilogram (mg/kg). Groundwater was contaminated with (1) volatile organic compounds (VOCs), primarily toluene; 1,1-dichloroethane (1,1-DCA); and trichloroethene (TCE); and (2) metals, including barium and arsenic. The groundwater plume extended at least 800 feet from the southwestern edge of the landfill and discharged to nearby wetlands and the adjacent river. Figure 1 shows the extent of groundwater and nonaqueous phase liquid (NAPL) contamination at the site.

- Also during the RI, the U.S. Environmental Protection Agency (EPA) determined that the landfill cap installed in 1982 did not meet state closure requirements. The cap was found to be only 1 foot thick in some areas, and the soils encountered in the landfill cap did not satisfy the requirements for particle size or saturated hydraulic conductivity. It was also found that the landfill cap had deteriorated from surface runoff and frost damage. Erosion gullies and animal burrows were also discovered in some areas. Figure 2 shows the damaged areas of the landfill cap.

- A new landfill cap was constructed in 1993 and was designed to prevent storm water infiltration into the landfill. This landfill cap was installed in accordance with applicable federal and state requirements and consists of the following layers: grading, 2-foot clay (minimum), gravel drainage, frost-protective soil, and 6-inch topsoil. The cap also has a passive methane gas venting system.

Regulatory Context:

- A record of decision (ROD) was signed in August 1990. The ROD specified a P&T system for groundwater; bioventing for soils; monitoring for groundwater, surface water and sediments; and installing a landfill cap that met federal and state requirements.

- An explanation of significant difference (ESD) was signed in September 2000, which changed the cleanup goals specified in the ROD to updated state groundwater cleanup goals.

- A second ESD was signed in November 2001, allowing for the temporary shutdown of the groundwater P&T system to study the potential for natural attenuation to address remaining contamination in groundwater and to revise the monitoring program.

- The first 5-year review of the site was conducted in 1998.

- The second 5-year review of the site was conducted in 2003.

Remedy Selection:

- Groundwater – P&T followed by MNA
- Soil – in situ bioventing

Figure 1. Extent of Groundwater and Non-Aqueous Phase Liquid Contamination [12]

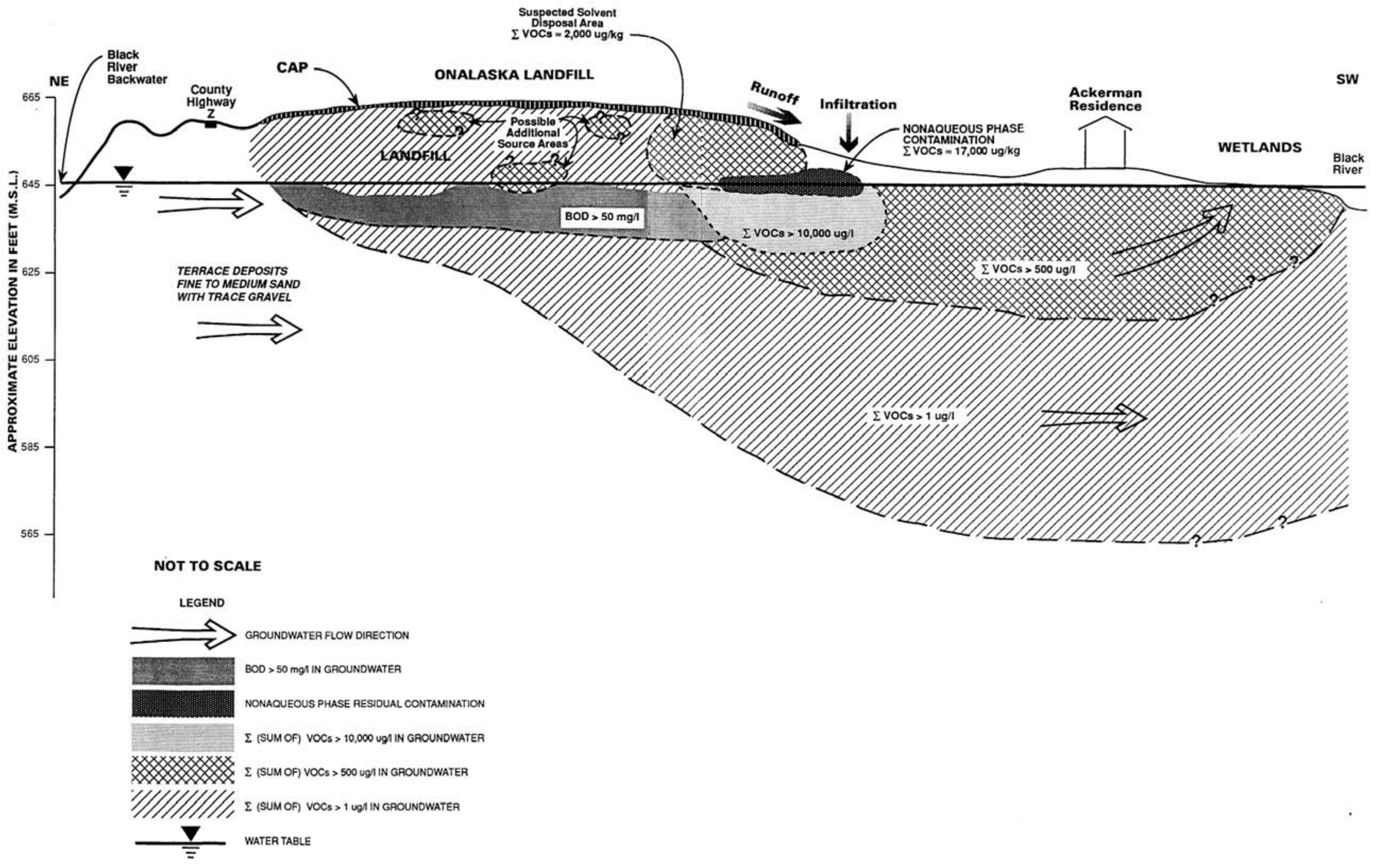
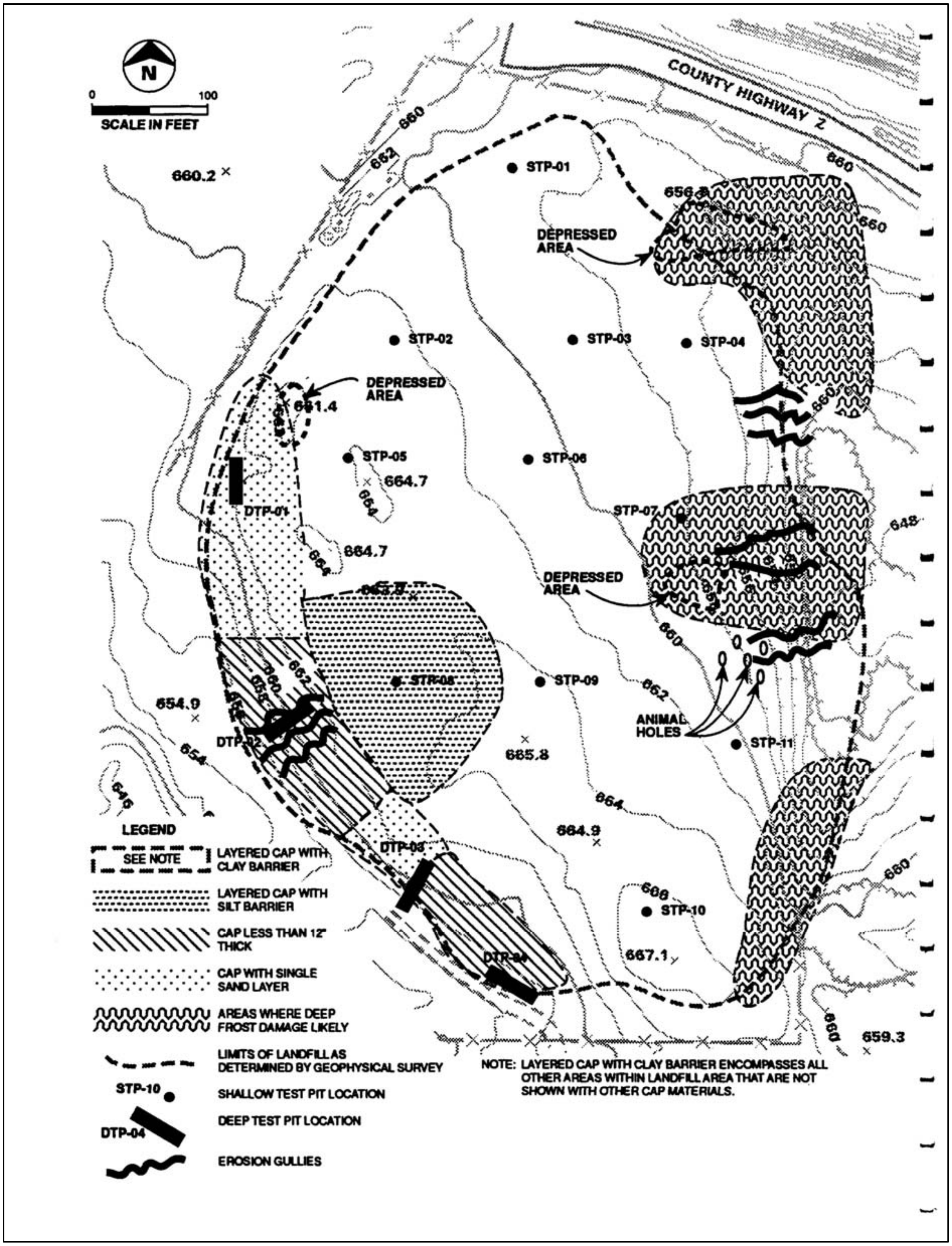


Figure 2. Damaged Areas of the Landfill Cap [12]



NOTE: LAYERED CAP WITH CLAY BARRIER ENCOMPASSES ALL OTHER AREAS WITHIN LANDFILL AREA THAT ARE NOT SHOWN WITH OTHER CAP MATERIALS.

SITE LOGISTICS/CONTACTS

Site Lead: Federal Lead/Fund Financed

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MATRIX DESCRIPTION

MATRIX IDENTIFICATION

Soil and Groundwater

CONTAMINANT CHARACTERIZATION [1,2,3,9]

Primary Contaminant Groups:

VOCs, semivolatile organic compounds (SVOCs), metals

- The groundwater beneath the landfill was contaminated with VOCs, including TCE; 1,1-DCA; 1,1,1-trichloroethane (1,1,1-TCA); 1,1-dichloroethene (1,1-DCE); 1,2-dichlorethene (1,2-DCE); and benzene, toluene, ethylbenzene, and xylene (BTEX). During the RI, concentrations of chlorinated VOCs were as high as 800 micrograms per liter (µg/L) for 1,1-DCA, 27 µg/L for 1,2-DCE, and 8 µg/L for TCA (cleanup goals are shown in Table 4).

- The soil in the vadose zone immediately above the water table and downgradient of the landfill was contaminated with petroleum hydrocarbon solvents, primarily naphtha, at levels as high as 550 mg/kg.

- Metals of concern in groundwater included barium, arsenic, iron, manganese, and lead.

MATRIX CHARACTERISTICS AFFECTING TREATMENT COSTS OR PERFORMANCE [1,2,6,9,11,12]

The table below provides matrix characteristics for each of the three remedial technologies. These values were based on baseline sampling or were observed during startup of each remedy.

Matrix Characteristics Affecting Treatment Costs or Performance

Matrix Characteristic	Value
Pump and Treat (Groundwater)	
Thickness of zone of interest	10 – 70 feet bgs
Presence of NAPLs	Yes
In Situ Bioventing (Soil)	
Depth bgs/thickness of zone of interest	11 – 15 feet
Presence of NAPLs	Yes
Oxygen	11.5%
Carbon dioxide	5.5%
Methane	1.3%
Monitored Natural Attenuation (Groundwater)	
pH	5.2 – 7.2
Thickness of zone of interest	10 – 70 feet bgs
Total organic carbon	4 mg/L
Oil & grease	0.7 mg/L
Oxidation/reduction potential	180 mV

Notes:
bgs = Below ground surface
mg/L = Milligrams per liter
mV = Millivolts

SITE HYDROGEOLOGY [1,5]

The upper groundwater aquifer consists primarily of sand and gravel and is 135 to 142 feet thick. This aquifer serves as a primary source of drinking water for local residents. The depth to the groundwater table is generally 15 feet below ground surface (bgs) but rises to 11 feet during the spring. Groundwater flow is generally to the south-southwest, toward the wetlands and the Black River, at a rate of 55 to 110 feet per year. Groundwater flow is to the south-southeast during high groundwater table conditions, which occur a few months a year.

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TECHNOLOGY

- Groundwater – P&T (treatment for metals using sodium hydroxide and polymer addition; air stripping for VOCs) followed by MNA
- Soil – in situ bioventing

SYSTEM DESCRIPTION AND OPERATION [2,4,6,7,8,9,10]

Groundwater P&T

- The groundwater P&T system consisted of five extraction wells located along the downgradient edge of the landfill, as shown in Figure 3. The design flow rate of the P&T system was 600 to 800 gallons per minute (gpm); the following describes the extraction well designs:

    - In spring 1991, a pump test was conducted to establish the number and location of wells and flowrates required to achieve the design capacity. Based on this testing, 5 extraction wells (EW-1 to -5) were identified to capture the plume and treat a total of 800 gpm. The wells were spaced 150 to 200 feet apart, with one well pumping at a rate of 100 gpm, two wells at 150 gpm, and the other two wells at 200 gpm.
    - EW-3 was designed with a 50-foot screen and a total depth of 85 feet bgs, while the other four extraction wells were each designed with a 45-foot screen and a total depth of 80 feet. All five extraction wells were 8 inches in diameter.
    - The depths specified were chosen because they contain the highest groundwater contaminant concentrations.

- The groundwater treatment system was designed to remove VOCs and iron. The system included aeration, clarification, and the addition of sodium hydroxide and polymer for iron removal. Air stripping was used to remove VOCs. The treated water was discharged to the river, and the clarifier sludge was dewatered and disposed in a landfill.

- The total volume of groundwater extracted and treated from 1994 through 2001 was more than 2 billion gallons. Table 1 provides information about the volume of groundwater treated by year, the average daily extraction rate, and the average pumping rate:

- Groundwater monitoring samples were collected from monitoring wells, extraction wells, and two residential wells. Baseline samples were collected in November 1993 (before system startup), then quarterly beginning in March 1995. In March 1997, the monitoring frequency was reduced to semi-annual.

- The system was operated from June 1994 to November 2001 and was operational about 80 percent of the time. The downtime was caused by equipment failures, maintenance, power outages, and automatic shutoffs.

- In November 2001, EPA issued an ESD allowing shutdown of the groundwater P&T system for a natural attenuation study. The system was shut down on November 26, 2001. Before the system was shut down, the groundwater monitoring program was revised to monitor plume behavior under non-pumping conditions and to allow for the natural attenuation study.

Figure 3. Extraction Well and Groundwater Monitoring Network [4]

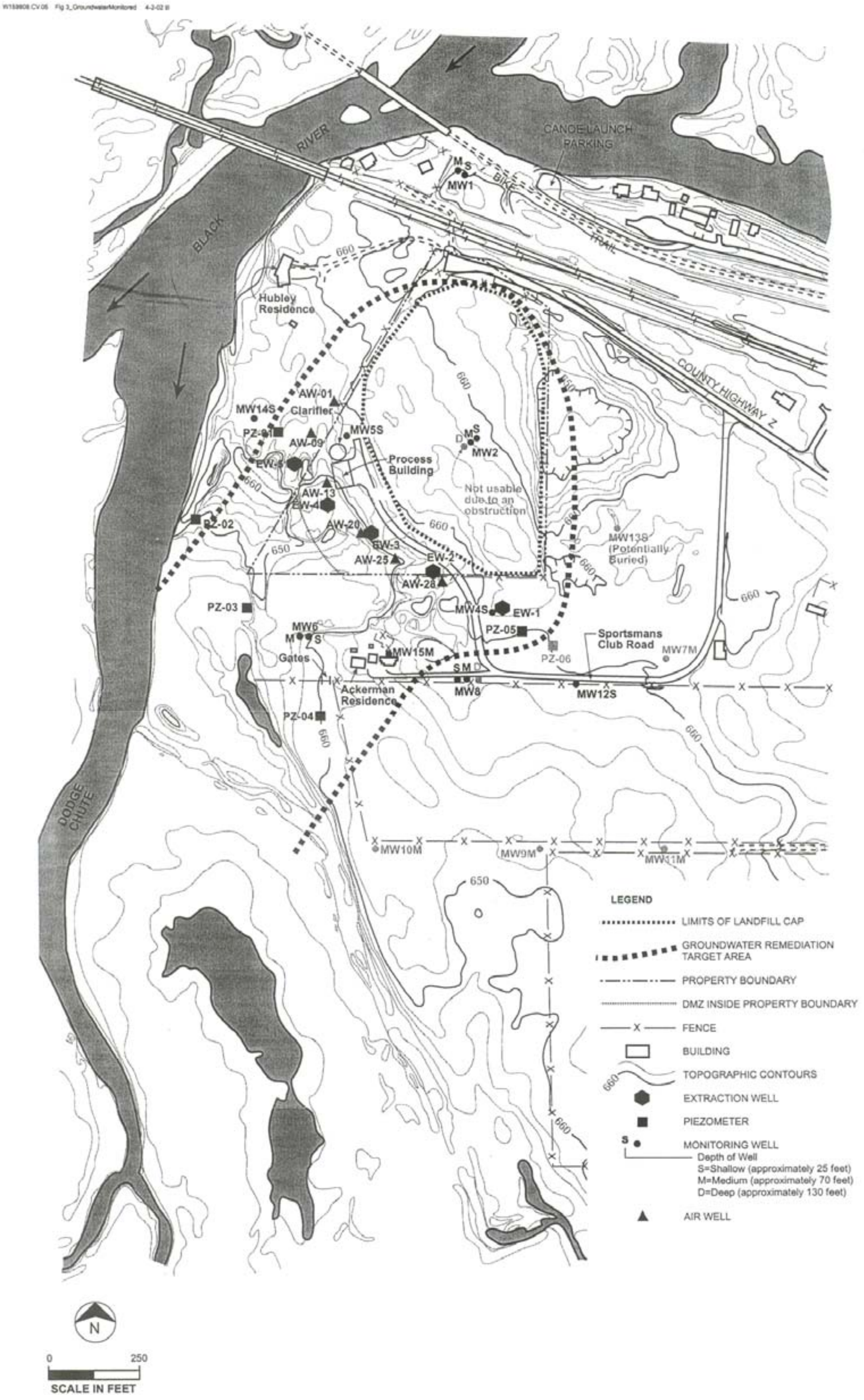


Table 1. Groundwater Pumping Rates [9]

Year	Total Volume Extracted and Treated (gal)	Average Daily Extraction Rate (gal/day)	Average Pumping Rate (gpm)
1994	176,247,120	855,568*	594*
1995	261,374,480	716,094	497
1996	247,556,080	678,236	471
1997	279,514,300	765,793	532
1998	257,877,450	706,514	491
1999	344,720,570	944,440	656
2000	365,955,490	1,002,618	696
2001	234,774,790	815,190*	566*
Total	**2,168,020,280**	**810,557**	**563**

Notes:
*Based on partial year due to startup in 1994 and shutdown in 2001.
gal = Gallons
gal/day = Gallons per day
gpm = Gallons per minute

In Situ Bioventing

- In situ bioventing of soils consisted of injecting air into the area of petroleum NAPL contamination, to stimulate naturally occurring aerobic microbes and to promote biodegradation of the organic compounds. The area of NAPL contamination targeted for bioremediation was 2.5 acres downgradient of the landfill. The 3- to 5-foot NAPL layer was estimated to be at a depth of 8 to 12 feet bgs.

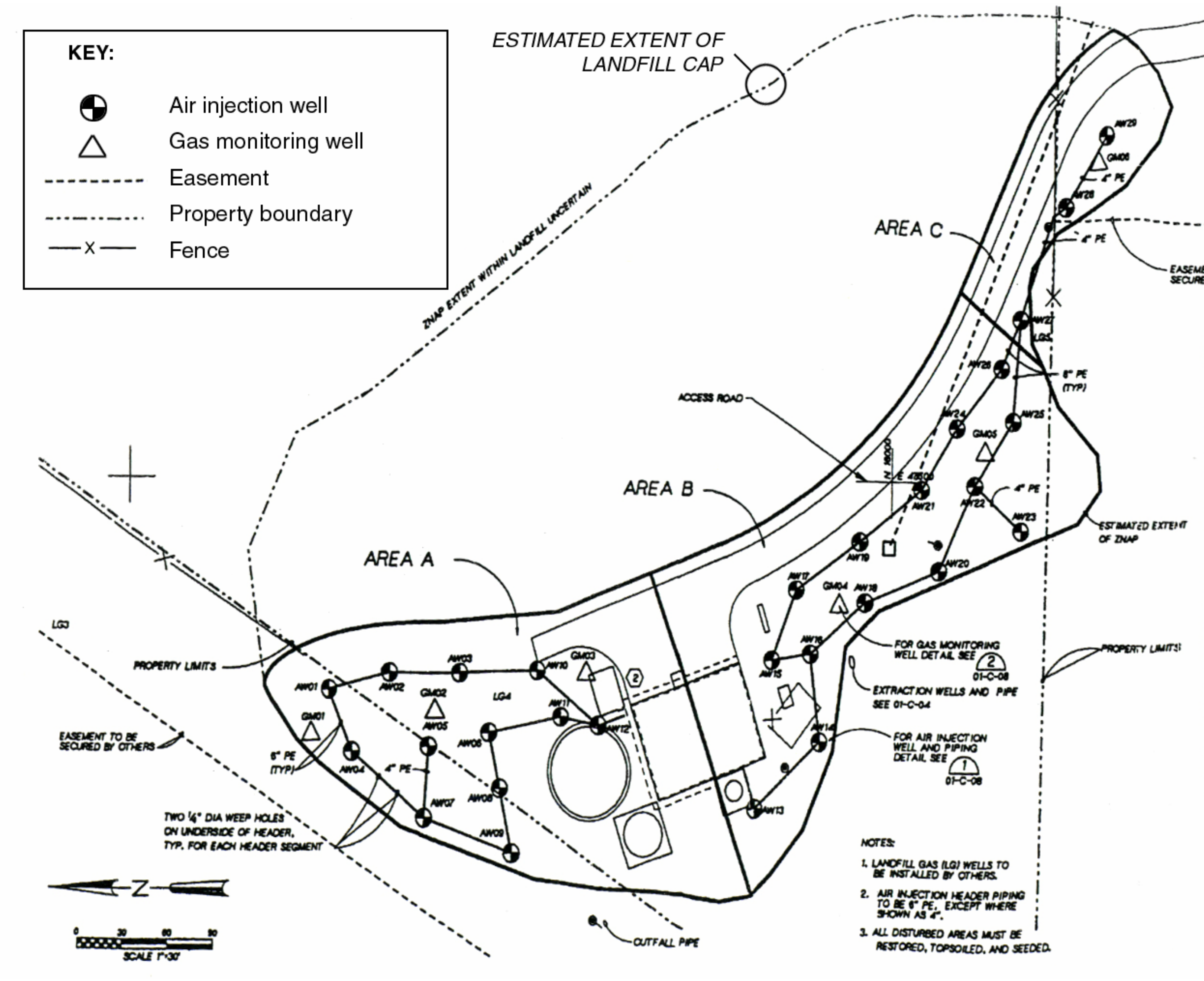
- In situ treatment to address contamination in the landfill was not considered technically feasible because of the potential for aerobic surface conditions to cause the landfill to smolder.

- The in situ remediation system, shown in Figure 4, consisted of 29 vertical air injection wells (AW-01 to AW-29), each 2 inches in diameter. The wells were installed on 40- to 50-foot centers, screened within the NAPL layer. The wells were connected by a header piping network to a single aeration well blower. The wells were equipped with valves used to modulate the air supply in response to the rate of oxygen consumption in each area. The system was designed to provide air at a rate of 100 to 420 standard cubic feet per minute (scfm). In addition, six soil gas probes were installed, with two probes per nest (one probe in the top and one in the bottom of the NAPL layer). The probes supported monitoring of subsurface conditions over time.

- Based on initial results for soil gas samples, the target NAPL area was divided into three subareas:

    - Area A – Oxygen conditions in Area A were low, but not depleted. Oxygen concentrations ranged from 9 to 19.1 percent; carbon dioxide concentrations were less than 7 percent; and methane was not detected above 1 percent. In general, soil in this area was less contaminated than in other subareas. There appeared to be ongoing microbial activity that was not limited by the availability of oxygen in soil gas.
    - Area B – Oxygen levels at Area B were significantly depleted (less than 2 percent). Carbon dioxide concentrations were as high as 17.5 percent. Methane concentrations were as high as 29 percent, although they generally measured less than 5 percent in most soils in this area. The area appeared to be the most contaminated, and microbial activity appeared to be limited by the low levels of oxygen.
    - Area C – Oxygen levels in Area C were similar to conditions in Area A. Although there was some oxygen depletion in the soil, oxygen levels were adequate to sustain microbial activity.

Figure 4. In Situ Bioventing System – Vertical Air Injection Well Locations [2]



Coordinates for Air Injection and Gas Monitoring Wells

Wells	Northing	Easting
AW01	16367	47380
AW02	16327	47390
AW03	16282	47390
AW04	16351	47346
AW05	16302	47349
AW06	16263	47357
AW07	16305	47310
AW08	16256	47326
AW09	16248	47290
AW10	16232	47391
AW11	16216	47366
AW12	16191	47361
AW13	16089	47316
AW14	16046	47353
AW15	16078	47398
AW16	16052	47402
AW17	16062	47437
AW18	16016	47431
AW19	16020	47465
AW20	15969	47449
AW21	15980	47495
AW22	15946	47498
AW23	15915	47472
AW24	15957	47530
AW25	15920	47535
AW26	15928	47565
AW27	15915	47593
AW28	15886	47657
AW29	15859	47696
GM01	16379	47357
GM02	16298	47370
GM03	16199	47392
GM04	16033	47431
GM05	15939	47518
GM06	15864	47683

- The system operated from May 1994 to February 1997. The total system air flow ranged between 270 and 320 scfm.
- In 1998, as part of the first 5-year review, EPA concluded that bioventing was no longer affecting biodegradation, and the system was shut down. Based on confirmation of oxygen levels in soil gas, EPA determined that the bioremediation cleanup phase was completed.

MNA

- The ESD issued in November 2001 allowed for the temporary shutdown of the P&T system to evaluate the effectiveness of MNA, based on the long-term groundwater monitoring that was being conducted at the site. Previous monitoring results showed consistent, low levels of groundwater contaminants, with a few exceptions. In addition, none of the wells that were used as a primary source of drinking water were within the plume area. Because of the low levels of contamination and limited exposure pathways, it was determined that P&T was likely not more effective than less expensive remedies, such as MNA, to address remaining contamination.
- A final plan was prepared in December 2001 to study natural attenuation at the site. The monitoring network comprises 26 monitoring points, including 6 air injection wells, 5 piezometers, 13 monitoring wells, and 2 residential wells. Analytes include VOCs, metals, BTEX, naphthalene, and natural attenuation parameters such as oxidation-reduction potential, dissolved oxygen, pH, temperature, and specific conductance.
- The MNA study was expected to last for at least 2 years, and the P&T system was to be restarted if concentrations increased or if the plume started to migrate.
- Baseline monitoring of natural attenuation was performed in October 2001. The second and third monitoring events occurred in December 2002 and April 2003.
- In August 2002, WDNR assumed responsibility for managing the natural attenuation study and maintaining the idle groundwater P&T and in situ bioventing systems.

OPERATING PARAMETERS THAT AFFECT TREATMENT COST OR PERFORMANCE [2,8,9]

Table 2 presents the operating parameters for each of the remedial technologies. These values were observed during operation of each remedy.

Table 2. Operating Parameters Affecting Treatment Cost or Performance

Operating Parameter	Value
Pump and Treat (Groundwater) [as of 2001]	
pH	5.2 – 7.2
Pump rate	563 gpm
In Situ Bioventing (Soil) [based on data from 1994 through 1997]	
Air flow rate	270 – 320 scfm
Operating pressure/vacuum	0.09 – 0.69 inches of water
Oxygen uptake rate	1.08% (total average change)
Carbon dioxide evolution	Decreased to less than 1%
Biodegradation rate for organics	0.55 – 1.05 mg/kg/day (3-year average)
Methane concentrations	Reduced to 0.1%

Operating Parameter	Value
Monitored Natural Attenuation (Groundwater) [based on data from 2002 and 2003]	
Temperature	7.35 – 12.4 °C
Presence of breakdown products and levels of ethane, ethene, or methane	Methane: 0.58 – 2,200 µg/L
Conductivity	0.209 – 0.709 mg/L
Alkalinity	72 – 600 mg/L
Chloride	1.8 – 16 mg/L
Redox conditions, dissolved oxygen levels, electron acceptors, electron donors	Oxidation/Reduction potential: 87 - 190mV, Dissolved oxygen: 0.23 – 7.07 mg/L, Nitrate (electron acceptor): <0.0076 – 2.2 mg/L Sulfate (electron acceptor): <0.11 – 19.7 mg/L
Total Organic Carbon	5 mg/L (approximate value)

Notes:
gpm = Gallons per minute
µg/L = Micrograms per liter
mg/kg/day = Milligrams per kilogram per day
mg/L = Milligrams per liter
mV = Millivolts
ND = Not detected
scfm = Standard cubic feet per minute

TIMELINE

Table 3 presents a timeline for remedial applications at this site.

Table 3. Timeline for this Application

Activity	Timeline
Record of decision	August 14, 1990
Groundwater pump and treat	June 8, 1994 to November 26, 2001
In situ bioventing	May 1994 to February 1997
First 5-year review	July 1998
Explanation of significant difference to update groundwater goals	September 29, 2000
Baseline monitoring for natural attenuation	October 2001
Explanation of significant difference to allow temporary shutdown of pump and treat system and begin natural attenuation study	November 3, 2001
Monitored natural attenuation monitoring and evaluation	Ongoing
Wisconsin Department of Natural Resources assumes responsibility for managing natural attenuation study and maintenance of idle pump and treat system and bioventing system	August 1, 2002
Second 5-year review	July 2003

TREATMENT SYSTEM PERFORMANCE

CLEANUP GOALS/STANDARDS [1,3,10]

The ROD did not establish chemical-specific soil cleanup goals. The estimated cleanup goal was 80 to 95 percent reduction of the organic contaminant mass in the soil. Cleanup goals for groundwater were revised to the current state goals in the ESD in 2000. Table 4 shows the original and revised site cleanup goals.

Table 4. State Groundwater Cleanup Goals for the Onalaska Municipal Landfill [1,3,10]

Compound	Original Cleanup Goal (µg/L)	Revised Cleanup Goal (µg/L)
1,1-Dichloroethane	0.04	85
1,1-Dichloroethene	0.024	0.7
1,1,1-Trichloroethane	40	40
Trichloroethene	0.18	0.5
Benzene	0.067	0.5
1,2,4- and 1,3,5- Trimethylbenzene*	NA	96*
Toluene	68.6	200
Xylene	124	1000
Ethylbenzene	272	140
Lead	5	1.5
Arsenic	5	5
Barium	200	400
Manganese*	NA	25
Iron*	NA	150

Notes:
*Not included in ROD list of contaminants
µg/L = Micrograms per liter
NA = Not applicable

The state cleanup goals for 1,1-DCA was revised to 85 µg/L based on a reclassification of 1,1-DCA from a type B-2 (probable human) carcinogen to a type C (possible human) carcinogen. State cleanup goals for benzene, TCE, and 1,1-DCE were revised because the original cleanup goals were below the standard laboratory detection limits for those compounds. In addition, state cleanup goals for ethylbenzene and lead have become more stringent. State cleanup goals for toluene, xylene, and barium were also revised.

Based on the original design of the P&T system, treated effluent was discharged to the Black River. This discharge was considered an on-site action, and therefore did not require a Wisconsin Pollutant Discharge Elimination System (WPDES) permit. However, the P&T system was required to meet the effluent standards listed in a WPDES permit, which included a daily maximum of 750 µg/L of BTEX. The state also mandated that effluent not be acutely toxic to test microorganisms.

PERFORMANCE DATA ASSESSMENT [2,4,6,7,8,9]

Groundwater P&T

- Performance data for the P&T system are available for May 2001 and for October and November 2001.

  - By May 2001, concentrations for organic contaminants (except benzene and trimethylbenzene) had decreased to below cleanup goals, based on results for samples collected from 14 wells located on- and off-site. Trimethylbenzenes (1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene), although not included in the ROD list of contaminants, were monitored starting in early 2001. Arsenic, barium, iron, and manganese continued to be detected in groundwater at concentrations above the cleanup goals.

  - As of October and November 2001, elevated concentrations of organic contaminants were present, primarily in well MW-5S. Trimethylbenzenes were present in wells MW-4S and MW-5S, with concentrations as high as 670 µg/L.

  - As of November 2001, arsenic, barium, and manganese were present in several monitoring wells at levels as high as 14.9 µg/L arsenic; 997 µg/L barium; and 3,780 µg/L manganese. Iron was detected at concentrations below the cleanup goal, with the exception of well MW-14S, which had a concentration of 9,370 µg/L. According to the contractor, it is possible that the high concentration of iron was caused by a source other than the landfill. The concentration of iron in this downgradient well is higher than at monitoring points closer to the landfill.

In Situ Bioventing

- The in situ bioventing resulted in aerobic soil conditions, as evidenced by a steady increase in oxygen concentrations at the site, to levels as high as 21 percent. Carbon dioxide concentrations decreased from an average of 10 percent to less than 1 percent, and average methane concentrations decreased from 1.4 to 0.1 percent.

- The average hydrocarbon degradation rate was estimated to be 1 milligram per kilogram per day (mg/kg/day) in Areas A and B and 0.5 mg/kg/day in Area C.

- The average oxygen uptake in each of the three areas decreased to a level where it was concluded that active aeration was no longer needed to maintain aerobic conditions in the soil.

- The total mass of hydrocarbons removed was estimated to be 7,780 kilograms (kg) from Area A; 11,000 kg from Area B and 1,247 kg from Area C.

- EPA decided not to sample the affected soil layer to evaluate whether the ROD estimate of 80 to 95 percent destruction had occurred. This decision was made because of the large variation in initial VOC concentrations in soil over a small sampling area. EPA determined that no further remediation was required to protect human health and the environment because the groundwater P&T system was expected to capture residual contamination from the soil. The bioventing system was shut down in 1998.

MNA

- Monitoring of natural attenuation at the site is ongoing. Data are available for the baseline monitoring event (October 2001) and for two additional sampling events (December 2002 and April 2003).

- As of April 2003, two organic contaminants, trimethlybenzenes and methylene chloride, remained at concentrations above their respective cleanup goals. In addition, two inorganic compounds, iron and manganese, remain at concentrations above their respective cleanup goals.

- The results of the December 2002 and April 2003 sampling events showed the potential for natural attenuation at the site. According to the August 2003 MNA report, the "data indicates that natural attenuation may be an effective modification to the ROD." The data showed that the oxidation-reduction potential (ORP) ranged from 87 to 190 millivolts (mV), indicating that reductive dechlorination may be occurring. Concentrations of dissolved oxygen ranged from 0.23 to 7.07 milligrams per liter (mg/L), indicating aerobic conditions in the groundwater.

- The MNA report recommended continuing to monitor and evaluate natural attenuation to assess whether MNA can be effective at the site and achieve cleanup goals.

TREATMENT SYSTEM COST

COST INFORMATION [7]

Operation and maintenance (O&M) costs for the P&T system were provided in the second 5-year review report. O&M costs for 1998 through 2001, before the system was shut down, were about $200,000 per year including groundwater extraction, wastewater treatment plant O&M, sampling and monitoring, monitoring well maintenance, and reporting. After system shutdown, O&M costs were about $60,000 per year for 2002 and 2003.

OBSERVATIONS AND LESSONS LEARNED

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED [2,7,9]

- The P&T system at the Onalaska Superfund Site reduced concentrations of contaminants in groundwater to below cleanup goals, with the exception of the organic contaminants trimethylbenzene, TCE, and benzene, and the metals arsenic, barium, iron, and manganese. Initial results from a MNA study suggest that natural attenuation at the site may be capable of addressing the remaining contaminants in groundwater to cleanup goals; however, further evaluation is needed and the MNA study is ongoing. In addition, the use of in situ bioventing reduced concentrations of contaminants in soil.

- During the remedial investigation of the site, trimethylbenzenes (1,2,4-trimethlbenzene and 1,3,5-trimethylbenzene) were not included in the original list of chemicals of concern and groundwater samples were not analyzed for these compounds. However, trimethylbenzenes were recently found as prominent chemicals in the groundwater at the site. Sampling for these chemical compounds began in 2001 and sampling data indicate that trimethylbenzenes exceed the state goal in 4 of the 26 wells sampled. Trimethylbenzenes were not evaluated in the original risk assessment; the toxicity data are still valid but may need to be modified to include the trimethylbenzenes.

REFERENCES

1. U.S. Environmental Protection Agency (EPA). Record of Decision. Onalaska Municipal Landfill, Onalaska, WI. August 14, 1990.

2. CH2M Hill. In Situ Bioremediation Final Report. Onalaska Municipal Landfill. July 30, 1997.

3. EPA. Explanation of Significant Differences: Onalaska Municipal Landfill, Operable Unit (OU) 1, Onalaska, WI. September 29, 2000.

4. CH2M Hill. Long-Term Remedial Action Report. Onalaska Municipal Landfill, Onalaska, WI. August 27, 2002.

5. EPA. Explanation of Significant Differences: Onalaska Municipal Landfill, OU1, Onalaska, WI. November 13, 2001.

6. EPA. Five-Year Review. Onalaska Municipal Landfill Site. 1998.

7. Wisconsin Department of Natural Resources. Second Five-Year Review Report. Onalaska Municipal Landfill Site. July 2003.

8. ENSR International. 2002/2003 Monitored Natural Attenuation Report for the Onalaska Municipal Landfill Site, Onalaska, Wisconsin. August 2003.

9. CH2MHill. Annual Groundwater Quality and Baseline Natural Attenuation Report for 2001, Onalaska Municipal Landfill Site. April 2002.

10. CH2MHill. Groundwater Extraction and Treatment Predesign Report, Onalaska Municipal Landfill. October 1991.

11. Annual Groundwater Quality Report for 2000, Onalaska Municipal Landfill Site.

12. CH2MHill. Remedial Investigation Report. Onalaska Municipal Landfill, Onalaska, Wisconsin. December 22, 1989.

ANALYSIS PREPARATION

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Office of Superfund Remediation and Technology Innovation, by Tetra Tech EM Inc., under EPA Contract No. 68-W-02-034.

Five-Year Review Report

Third Five-Year Review Report
for
Onalaska Landfill Superfund Site
Town of Onalaska
La Crosse County, Wisconsin

July 2008

PREPARED BY:

Wisconsin Department of Natural Resources
West Central Region
Eau Claire, Wisconsin

Approved by: Date:

William J. Evans 7/3/2008

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West Central Region, Wisc. Dept. of Natural Resources

9/14/08

Richard C. Karl
Division Director, Superfund
U.S. EPA, Region 5

Table of Contents

List of Acronyms

ACL	Alternative Concentration Limit
ARAR	Applicable or Relevant and Appropriate Requirement
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DMZ	Design Management Zone
ES	Wisconsin Administrative Code NR140 Enforcement Standard
ESD	Explanation of Significant Difference
IC	Institutional Control
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MNA	Monitored Natural Attenuation
NCP	National Contingency Plan
NPL	National Priorities List
O&M	Operation and Maintenance
PAL	Wisconsin Administrative Code NR140 Preventive Action Limit
PPB	Parts per billion
PPM	Parts per million
RA	Remedial Action
RAO	Remedial Action Objective
RD	Remedial Design
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager

TCE	Trichloroethene
TMB	Trimethylbenzene
U.S. EPA	United States Environmental Protection Agency
UU/UE	Unlimited Use/Unrestricted Exposure
VOC	Volatile Organic Compound
WAC	Wisconsin Administrative Code
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollutant Discharge Elimination System

Executive Summary

The United States Environmental Protection Agency (U.S. EPA), in consultation with the Wisconsin Department of Natural Resources (WDNR), began a Remedial Investigation and Feasibility Study (RI/FS) at the Onalaska, Wisconsin municipal sanitary landfill in 1988. The RI/FS was completed in 1990, upon issuance of a cleanup decision by the U.S. EPA. The U.S. EPA determined that construction of a landfill cover (cap), a groundwater extraction and treatment system, and a bioremediation system would be protective of human health and the environment.

U.S. EPA, in concert with the WDNR, began construction of the cleanup remedy in 1993. The cleanup remedy was completed in July 1994; operation of the groundwater extraction and treatment and the bioremediation systems commenced at that time. The groundwater extraction and treatment system operated until November 2001, and the bioremediation system was shut down in February 1997. The systems are currently shut down to allow the WDNR to evaluate the effectiveness of natural attenuation in reducing the levels of contamination through natural biological, physical and chemical processes.

The groundwater extraction and treatment system pumped 2.2 billion gallons of water for treatment (via air stripping), reducing the levels of contaminants in the groundwater. Current data indicates that iron, manganese and arsenic and two volatile organic chemicals (1,2,4-and 1,3,5-trimethylbenzene are the only contaminants above the WDNR Enforcement Standards. Background levels of iron and manganese in groundwater in Wisconsin are similar to the concentrations detected at the site. The bioremediation system, which supplied oxygen (air) to the subsurface soil, effectively reduced the concentrations of the hydrocarbons in the soils. The bioremediation system was discontinued in 1998 after soil gas data showed that the system no longer contributed to the cleanup.

The U.S. EPA completed an Explanation of Significant Differences (ESD) on September 29, 2000. This ESD addressed changes to the groundwater cleanup standards, bringing the standards up-to-date with then current State cleanup standards.

On November 13, 2001 U.S. EPA completed a second ESD for the site. This ESD allows for the temporary shut down of the groundwater treatment system to study natural attenuation as an alternative to cleanup the remaining groundwater contamination. The system was shut down on November 26, 2001. The WDNR took over the operation and maintenance of the site in June of 2002.

Groundwater contaminants not previously analyzed for have been observed starting in 1999. The WDNR conducted additional investigation in 2005, identifying residual soil contamination that may be acting as an on-going source of impact to the groundwater. It should be evaluated as to whether additional remediation of the soil should be implemented.

From 2001 to 2008, the Site has been evaluated for natural attenuation as a viable, cost effective remedy over the groundwater extraction remedy. Monitoring for natural attenuation began in the fall of 2001. The 2008 Monitored Natural Attenuation Study (MNA) did not recommend the adoption of MNA as an alternative remedy. However, the contaminants of concern listed in the Record of Decision (ROD), except arsenic and barium, meet the cleanup standards established in the ROD, 1991. Elevated arsenic and barium levels above the Wisconsin Administrative Code (WAC) NR140 Preventive Action Limit (PALS) are unlikely to be reduced by reactivation of the pump and treat system.

In 1999, contaminants not part of the original list in the ROD, trimethylbenzene compounds (TMBs), were detected in monitoring wells above State PALs. Because of this discovery, additional investigation of contaminated soil that may be acting as a source of TMB contamination to the groundwater is recommended.

Currently, the Onalaska Landfill Superfund Site is protective of human health and the environment in the short-term because the landfill cap is effective; groundwater monitoring assures that drinking water supplies remain safe and that the plume is contained; most contaminants of concern have been remediated to meet ROD cleanup standards, and institutional controls prevent activities that would compromise the cap or expose parties to contaminated groundwater. However, in order to remain protective in the long-term additional soil investigation, and possible remediation of TMB, will be needed, on-going monitoring and evaluation of arsenic and barium in groundwater must be done, and the required restrictive covenant for the landfill cap must be drafted and recorded as required by the 1996 Consent Decree (CD).

Long term protectiveness also requires compliance with the land and groundwater use restrictions. Compliance with effective Institutional Controls (ICs) will be ensured by implementing, monitoring and maintaining effective ICs as well as maintaining the site remedy components. Long-term stewardship must be ensured to verify compliance with ICs.

Five-Year Review Summary Form

SITE IDENTIFICATION

Site name ***(from WasteLAN)*****:** Onalaska Landfill Superfund Site

EPA ID ***(from WasteLAN)*****:** WID980821656

Region: 5 | **State:** WI | **City/County:** Town of Onalaska/La Crosse

SITE STATUS

NPL status: ☒ Final

Remediation status (choose all that apply): Operating

Multiple OUs?* No | **Construction completion date:** 06 / 01 / 1994

Has site been put into reuse? YES, the site is a natural area, and wildlife preserve

REVIEW STATUS

Lead agency: ☒ State

Author name: Eileen Kramer

Author title: Remedial Project Manager | **Author affiliation:** WDNR West Central Region

Review period:** 07 / 15 / 2003 to 07 / 16 / 2008

Date(s) of site inspection: 09 / 26-27 / 2007

Type of review: ☒ Post-SARA

Review number: ☒ 3 (Third)

Triggering action: Previous Five-Year Review Report

Triggering action date ***(from WasteLAN)*****:** 07 / 16 / 2003

Due date ***(five years after triggering action date)*****:** 07 / 16 / 2008

* ["OU" refers to operable unit.]

** [Review period should correspond to the actual start and end dates of the Five-Year Review in WasteLAN.]

Five-Year Review Summary Form, cont'd

Issues:

1. Increasing TMB concentrations in two monitoring wells located within the area where non-aqueous phase naphtha solvents had been observed during the RI.
2. Increasing TMB concentration (although not in exceedance of the PAL) in MW-8M which is located outside the design management zone (DMZ)
3. Concentrations of arsenic and barium exceed the cleanup standards, although there are no exceedances of the federal MCL or state WAC NR140 Enforcement Standards (ES) outside the DMZ.
4. Damaged fence at southern perimeter of landfill
5. A deed restriction on the landfill property that is enforceable by the WDNR and U.S. EPA has not been recorded at the La Crosse Co. Register of Deeds office. Implementing, maintaining and monitoring of the ICs will be required to assure protectiveness of the remedy.
6. The Prinsen property is located south of the site and within 1200 feet of the landfill. NR812 would prohibit construction of a water supply on the property without a variance from the WDNR, but no deed notice that runs with the land has been recorded.
7. Report of possible vehicle operation at night on the landfill.
8. MW-5S does not have an above grade protective top
9. Quality of groundwater immediately outside the landfill DMZ requires additional characterization.
10. Potable wells in proximity to the landfill.
11. The need to evaluate current ICs at the Site to determine if any additional ICs should be implemented.

Recommendations and Follow-up Actions:

1. Additional data regarding residual contamination in the soil southwest of the landfill where naphtha solvents had been observed during the RI should be acquired and evaluated to determine whether the soil is acting as an on-going source of contamination to the groundwater.
2. On-going monitoring of MW-8M to evaluate whether concentrations of TMB will begin to stabilize and decrease due to decrease in loading in the up-gradient area.
3. Proposed alternative concentration limits (ACLs) for arsenic and barium should be finalized.
4. Repair and possible improvement of the fence.
5. The Town should draft for WDNR and U.S. EPA review and approval, and record a deed instrument that restricts activities and access to the landfill to protect the integrity of the cap and to prevent exposure to contaminated media as required by the 1996 CD.
6. Regarding the Prinsen property, south of the landfill, the agencies should determine whether a deed instrument that runs with the land to restrict its use is necessary to assure protectiveness
7. Discuss with Town Administrator. Encourage routine drive-by surveillance. Evaluate whether extending fence would prevent vehicular access
8. A protective top, a metal pipe and cover that sticks up above the ground around the polyvinyl chloride well riser, that complies with NR141 WAC should be constructed for well MW-5S.

Five-Year Review Summary Form, cont'd

9. Additional monitoring wells to determine concentrations of arsenic and barium at the DMZ should be installed.
10. Monitoring of the four drinking water wells in proximity to the site should continue and the potential for impact from the landfill be evaluated again.
11. Implement an IC Plan for the Site which will evaluate the need for additional ICs.

Protectiveness Statement:

Currently, the Onalaska Landfill Superfund Site is protective of human health and the environment in the short-term because the landfill cap is effective; groundwater monitoring assures that drinking water supplies remain safe and that the plume is contained; most contaminants of concern have been remediated to meet ROD cleanup standards, and institutional controls prevent activities that would compromise the cap or expose parties to contaminated groundwater. However, in order to remain protective in the long-term additional soil investigation, and possible remediation of TMB, will be needed, on-going monitoring and evaluation of arsenic and barium in groundwater must be done, and the required restrictive covenant for the landfill cap must be drafted and recorded as required by the CD.

Long term protectiveness also requires compliance with the land and groundwater use restrictions. Compliance with effective ICs will be ensured by implementing, monitoring and maintaining effective ICs as well as maintaining the site remedy components. Long-term stewardship must be ensured to verify compliance with ICs.

Other Comments:

None

Onalaska Landfill Superfund Site
Town of Onalaska, Wisconsin
Third Five-Year Review Report

I. Introduction

The purpose of the Five-Year Review is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review reports. In addition, Five-Year Review reports identify issues found during the review, if any, and identify recommendations to address them.

The WDNR is preparing this Five-Year Review report pursuant to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) §121 and the National Contingency Plan (NCP). CERCLA §121 states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The Agency interpreted this requirement further in the NCP; 40 Code of Federal Regulations (CFR) §300.430(f)(4)(ii) states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

The WDNR, with the assistance of the U.S. EPA, conducted the Five-Year Review of the remedy implemented at the Onalaska Landfill Superfund Site in the Town of Onalaska, Wisconsin. This review was conducted by the Remedial Project Manager (RPM) for the entire site from September 2007 through July 2008. This report documents the results of the review.

This is the third Five-Year Review for the Onalaska Landfill Superfund Site. The triggering action for this statutory review is the completion of the second Five-Year Review on July 16, 2003. The Five-Year Review is required due to the fact that hazardous substances, pollutants, or contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure.

II. Site Chronology

Table 1 - Chronology of Site Events

Event	Date
The site was mined as a sand and gravel quarry in the early 1960s. Quarry operations ceased in the mid-1960s and the Town began to use the site as a municipal landfill.	1960s
In 1978, the WDNR determined that the landfill operation did not meet state solid waste codes and ordered the Town to close the landfill by September 1980. After disposal operations ceased, the Town capped the landfill in June 1982.	1978 to 1982
In September 1982, the WDNR sampled four landfill monitor wells and several nearby residential wells for compliance with drinking-water standards, and determined that one residential well, located southwest of the landfill, was found to exceed the Federal drinking-water standard for barium (1.0 mg/L). The well sample also contained five organic compounds at concentrations above background levels. The Town replaced the contaminated residential well with a deep, uncontaminated well in January 1983.	1982 to 1983
Pursuant to CERCLA, U.S. EPA inspected the Onalaska site in 1983. Subsequent to the submittal of the Site Inspection report in May 1983, the U.S. EPA placed the site on the NPL in September 1984.	1983 to 1984
U.S. EPA, in consultation with the WDNR, completed a RI at the Onalaska Landfill on December 22, 1989. The RI concluded that the landfill is the source of groundwater contamination, and that the original landfill cap had deteriorated and did not meet the landfill closure regulations in effect at the time the landfill closed	12/22/1989
Based on the findings of the RI, U.S. EPA completed an FS that evaluated remedial alternatives to address migration of the groundwater contaminant plume. U.S. EPA completed the FS in December 1989.	12/1989
U.S. EPA then issued a ROD in August 1990 that called for the: installation of a landfill cap in accordance with federal and state requirements; installation of a groundwater extraction and treatment system to capture and treat contaminants in the groundwater immediately downgradient of the landfill; installation of an air injection system within the area of soils contamination to enhance the bioremediation of organic contaminants; and implementation of a groundwater, surface water, and sediment monitoring program to ensure the adequacy of the cleanup	8/1990
U.S. EPA entered into a Superfund State Contract with WDNR in 1991 which provided that the state would fund 50% of the remedial action	1991
U.S. EPA completed the landfill cap remedial design (RD) in July 1992 and the groundwater extraction and treatment and the bioremediation systems RD in September 1992	1992
The landfill cap construction subcontract was awarded on March 25, 1993, and construction commenced on May 1, 1993. A multi-layer clay cap was installed over the landfill. The cap was completed in November 1993. The groundwater and soils construction subcontract was awarded on June 11, 1993, and construction began on July 12, 1993. The groundwater extraction and treatment system was completed in June 1994.	1993 to 1994

A pre-final inspection was conducted by the project managers for U.S. EPA and WDNR on June 1, 1994. At that time, it was determined that the landfill cap, groundwater, and bioremediation systems were constructed as designed and that they were operational.	6/1/1994
U.S. EPA entered into a CD with the town of Onalaska that would address additional ICs needed at the Site and to outline who would perform the Operation and Maintenance at the Site.	10/29/1996
The Five-Year Review Report at the Onalaska site was completed on July 13, 1998	7/13/1998
U.S. EPA issued an ESD for the Onalaska Municipal Landfill on September 29, 2000. The ESD addressed changes to the performance standards addressed in the ROD based on changes to State of Wisconsin drinking Public Health and Public Welfare Groundwater Quality Standards	9/29/2000
U.S. EPA issued an ESD for the Onalaska Municipal Landfill on November 13, 2001. The ESD allows for the temporary shutdown of the groundwater extraction and treatment system to evaluate the need for continuous operation of the system and to determine whether natural attenuation processes exist at the site which might address the remaining groundwater contamination	11/13/2001
In June 2002, WDNR assumed the lead in the operation and maintenance of the Site.	June 2002
The second Five-Year Review Report was completed.	July 20, 2003
WDNR conducted additional investigation, installing four new monitoring wells.	March 2006
WDNR developed proposed ACLs in accordance with the ROD and WAC NR140.	June 2006
The third Five-Year Review started.	Sept. 2007
A report, Evaluation of Monitored Attenuation as a Containment Remedy for the Onalaska Municipal Landfill Site was completed.	June 2008

III. Background

Physical Characteristics

The Onalaska site is located in the Township of Onalaska, about 10 miles north of La Crosse, Wisconsin. Figure 1, presented in Attachment 1, is a map illustrating the Site location. The 11-acre site includes the 7-acre former Township landfill and is situated 400 feet east of the Black River, near the confluence of the Mississippi and Black Rivers. The Black River is located within the Upper Mississippi River Wildlife and Fish Refuge, a wetlands area that supports numerous migrating species of birds and is also used for hiking, fishing, hunting, and other recreational purposes by area residents and visitors.

The area surrounding the site is generally rural, although several residences are located within 500 feet to the north and to the south of the landfill. A subdivision of about 50 homes is located about 1.25 miles southeast of the site. Agricultural lands are located south of the landfill, and intermittent woods and grasslands border the site to the east. A railroad line runs west-northwest approximately 200 feet north of the northern extent of the waste. North of the rail line there is a state recreational bike trail developed on old railroad bed. There is a public canoe landing on the Black River about 500 feet north of the landfill.

The December 1989 remedial investigation report indicates that the site sits on glacio-fluvial and alluvial sand and gravels that was deposited as glacial outwash in an eroded bedrock valley. The underlying sandstone bedrock was encountered in four borings at depths from 118 to 140 feet below ground surface. Groundwater flow direction was found to be predominantly to south-southwest, with springtime periods of high river stage causing flow to the south-southeast. In-situ testing in several site monitoring wells determined that hydraulic conductivity at the site averages 0.039 centimeters/second (cm/sec). The hydraulic gradient, is approximately 0.006 (no units).

Land and Resource Use

The Onalaska site was mined as a sand and gravel quarry in the early 1960s. Quarry operations ceased in the mid-1960s and the Town began to use the site as a municipal landfill, although for a time both municipal and chemical wastes were disposed of in the landfill. In 1978, the WDNR determined that the landfill operation did not meet state solid waste codes and ordered the Town to close the landfill by September 1980. After disposal operations ceased, the Town capped the landfill in June 1982.

The site is adjacent to the Upper Mississippi River Wildlife and Fish Refuge, which contains a wide variety of wildlife. The area is used for fishing, hiking, and other recreational purposes. The site is a known nesting area for turtles including several threatened species.

History of Contamination

In September 1982, the WDNR sampled four landfill monitor wells and several nearby residential wells for compliance with drinking-water standards. The investigation documented that the sand and gravel aquifer beneath the landfill serves as the primary source of drinking water for area residents and that groundwater contamination had occurred within and around the site. One residential well, located southwest of the landfill, was found to exceed the Federal drinking-water standard for barium (1.0 mg/L). The residential well sample also contained five organic compounds at concentrations above background levels. A landfill monitor-well sample was found to be contaminated with toluene at a concentration of 14.7 mg/L, which is above the State groundwater-quality ES (1 mg/L) and the federal drinking water (1.0 mg/L) standard. The Town replaced the contaminated residential well with a deep, uncontaminated well in January 1983.

Initial Response

Pursuant to CERCLA, U.S. EPA inspected the Onalaska site in 1983. Subsequent to the submittal of the Site Inspection report in May 1983, the U.S. EPA placed the site on the NPL in September 1984.

Basis for Taking Action

U.S. EPA, in consultation with the WDNR, conducted a RI/FS at Onalaska from April 1988 through December 1989. The major findings of the RI included:

- The landfill is the source of groundwater contamination. Soils located above the water table and adjacent to the southwestern edge of the landfill were contaminated with naphtha solvents that migrated from the landfill. The contaminated soil zone occurred from 11 feet to 15 feet below ground surface and up to 150 feet from the landfill. Soil samples indicated that contaminant levels of up to 550 mg/kg were present and were a continual source of groundwater contamination.
- The aqueous phase plume consisting of organic and inorganic compounds had migrated at least 800 feet from the southwestern edge of the landfill. The leading edge of the contaminant plume appeared to be discharging into nearby wetlands and the adjacent Black River.
- The upper aquifer consists primarily of sand and is approximately 135 feet thick. Local residences utilized this aquifer as a primary source of drinking water.
- The predominant organic compounds of concern included toluene, xylene, 1, 1 - dichloroethane, and trichloroethene (TCE), based upon concentrations and potential impacts to human health and the environment.
- Site original landfill cap had deteriorated and did not meet the landfill closure regulations in effect at the time the landfill closed. The cap was originally to be composed of 2 feet of compacted clay, but the RI showed that the cap was composed of sandy soils in certain portions and that it was only one foot thick in other portions.
- Magnetometer anomalies, as well as site records, suggested that up to 1000 55-gallon drums were likely to have been disposed of in the landfill. Although several crushed and empty drums were found in the landfill during excavation of test pits, the RI could not ascertain whether the drums are concentrated in any one area, although it may be likely that many of the drums would be in the same condition as the drums that were found in the test pits.
- The average depth to the water table and the depth of waste disposal was 15 feet. Thus, the refuse was periodically in direct contact with groundwater. Soil below the water table did not appear to be greatly affected by landfill contaminants.

The ROD identified Chemicals of Concern as follows:

Toluene
Xylene
Barium
Ethylbenzene
Lead
1,1,1-Trichloroethane
Benzene
Arsenic
Trichloroethene
1,1-Dichloroethane
1,1-Dichloroethene

Potential long-term exposure to low levels of volatile organic compounds (VOCs) through the use of private wells in contaminated groundwater and plausible adverse discharges of contaminants to the wetlands and Black River downgradient of the landfill were identified as the principal threats to human health and the environment.

In 1996, the town of Onalaska entered into a CD with U.S. EPA providing access to all site personnel who would be conducting sampling and other work activities at the Site. The CD also outlined numerous ICs that were to be implemented at the Site, including installation of a perimeter fence, recording restrictive covenants on the landfill property that prohibit construction, well installation and recreational activities on the Site and recording restrictive covenants on adjoining properties which the town purchased in the form of conservation easements, compatible with the use of the adjoining National Wildlife Refuge. The CD also provided specific instruction on the Operation and Maintenance (O&M) activities that were to be conducted relating to the landfill.

IV. Remedial Actions

Remedy Selection

Based on the findings of the RI, U.S. EPA completed a FS that evaluated remedial alternatives to address migration of the groundwater contaminant plume. U.S. EPA completed the FS in December 1989. U.S. EPA then issued a ROD in August 1990 that stated, "The principal threats at the site are considered to be the groundwater contaminant plume and a contaminated soil zone adjacent to the southwestern portion of the landfill, which is a major source of groundwater contamination. The landfill itself is considered to be a low-level, long-term threat to human health and the environment, primarily as a further source of groundwater contamination. The ROD called for the following actions to mitigate the areas of concern:

- Installation of a landfill cap in accordance with federal and state requirements;
- Installation of a groundwater extraction and treatment system to capture and treat contaminants in the groundwater immediately downgradient of the landfill;
- Installation of an air injection system within the area of soils contamination to enhance the bioremediation of organic contaminants; and
- Implementation of a groundwater, surface water, and sediment monitoring program to ensure the adequacy of the cleanup.
- Institutional controls including deed restrictions limiting surface and ground-water use at the site; and State regulations governing groundwater use within 1200 feet of landfills and the development of landfills.

The selected remedy established a containment and treatment system to eliminate the principal threat posed to human health and the environment by capping the landfill to isolate the source of groundwater contaminants in the landfill; eliminating contaminants in the adjacent soils by enhanced bio-remediation; preventing the further migration of VOCs in groundwater by extracting contaminated groundwater; and treating extracted groundwater to acceptable discharge limits.

The ROD established cleanup standards for groundwater based on Safe Drinking Water Act Maximum Contaminant Levels (MCLs) and WAC NR 140 ES and PALs for groundwater protection. The selected remedy established an estimated cleanup goal of 80 to 95 percent biodegradation of the organic compounds in the soils adjacent to the landfill.

U.S. EPA entered into a Superfund State Contract with WDNR in 1991, which provided that the state would fund 50% of the remedial action. U.S. EPA then began to implement the RD and Remedial Action (RA).

Remedy Implementation

- U.S. EPA completed the landfill cap RD in July 1992 and the groundwater extraction and treatment and the bioremediation systems RD in September 1992.
- A Wisconsin Pollution Discharge Elimination System (WPDES) "permit" was issued by the WDNR for the discharge of treated groundwater to the Black River. WDNR determined that air stripping and iron precipitation were acceptable Best Available Technology for treatment.
- A 3-month soil treatability study was conducted in the laboratory to determine the ability of the organic contaminants to degrade and to attempt to determine plausible cleanup goals, optimal air injection conditions, and losses of VOCs due to air stripping or volatilization. Testing showed that approximately 15% of the hydrocarbons were biodegraded during the 3-month test and that approximately 5-6 years of air injection would be needed to reach the target cleanup goal. As a result, U.S. EPA recommended that a full-scale biotreatment system be installed, for the cost of performing a pilot study in the field would approach that of a full-scale treatment system.
- The landfill cap construction subcontract was awarded on March 25, 1993, and construction commenced on May 1, 1993. A multi-layer clay cap was installed over the landfill. The cap was completed in November 1993.
- The groundwater and soils construction subcontract was awarded on June 11, 1993, and construction began on July 12, 1993. Five groundwater extraction wells were installed downgradient of the landfill and are designed to pump a total of 800 to 1000 gallons per minute. A treatment plant was constructed nearby, where the extracted groundwater is subjected to aeration and pH adjustment (iron precipitation), clarification (iron removal), air stripping (VOC removal), and pH readjustment prior to discharge to the Black River. Temporary activated carbon units were placed in the treatment train prior to discharge as a back-up measure while the treatment plant components underwent a 3-month "shakedown" period. The groundwater extraction and treatment system was completed in June 1994.
- Approximately 29 shallow air-injection wells were installed to enhance bioremediation of the organic compounds in the contaminated soils adjacent to the landfill. During start-up, the contractor turned the air injection system on to achieve steady-state conditions, and then off to measure oxygen uptake (respiration) rates in the wells. Results showed that biodegradation was occurring as oxygen levels began to fall rapidly. The air permeability of the soil was measured and found to be as predicted, based on the laboratory study. Lastly, the system was balanced so that each well was injecting the proper amount of air into the soil. Installation of the biotreatment system was completed in June 1994.
- The project managers conducted a pre-final inspection for U.S. EPA and WDNR on June 1, 1994. It was determined that the landfill cap, groundwater extraction and treatment, and soil bioremediation systems were constructed as designed and that they were operational. A punch list of minor tasks to be completed was developed and a schedule for completion of those items was given to the landfill cap and the groundwater subcontractors by U.S. EPA's contractor.
- Region 5 signed the Onalaska preliminary close-out report on July 29, 1994, and within that document scheduled the completion of the first Five-Year Review by May 1998.
- In 1999, a full priority pollutant scan was performed on site groundwater samples to determine whether any new contaminants were present. Previous groundwater analyses were limited to the

chemical of concern identified in the ROD. The priority pollutant scan detected TMB compounds at levels greater than the NR140 ES

- On September 29, 2000, U.S. EPA completed an ESD revising the Site cleanup standards to reflect the then current State of Wisconsin groundwater cleanup standards.
- U.S. EPA issued an ESD for the Onalaska Municipal Landfill on November 13, 2001. The ESD allows for the temporary shutdown of the groundwater extraction and treatment system to evaluate the need for continuous operation of the system and to determine whether natural attenuation processes exist at the site, which might address the remaining groundwater contamination.
- On November 26, 2001, the groundwater extraction and treatment system was shut down.
- In June 2002, WDNR assumed responsibility for the operation and maintenance of the Site.
- From 2002 until today, a groundwater sampling program has been implemented to determine whether MNA will be an effective remedy at the site and to verify that the groundwater contamination plume does not expand.
- In 2006, in order to improve the quality of groundwater data, the WDNR installed four additional NR 140 compliant monitoring wells.
- In June 2008 the Monitored Attenuation Report was completed

Institutional Controls

A review of institutional controls was conducted for this Five-Year Review. ICs are required to ensure the protectiveness of the remedy. ICs are non-engineered instruments, such as administrative and/or legal controls, that help minimize the potential for exposure to contamination and protect the integrity of the remedy. Compliance with ICs is required to assure long-term protectiveness for any areas which do not allow for unlimited use or unrestricted exposure (UU/UE).

The following table lists institutional controls that are known at this time to be required, implemented or recommended.

Table 2: Institutional Controls Summary Table

Media, Engineered Controls & Areas that Do Not Support UU/UE based on Current Conditions	Institutional Control Objective	Title of IC Instrument Implemented, Planned or Recommended
Landfill cap and other remedy components	To prevent activity that would compromise integrity of the cap or the passive gas vent system. To prevent exposure to waste or contaminated soil or groundwater.	WAC NR506.085 currently prohibits use of the waste area for agriculture, construction of any building, and excavation of the cover or any waste material. It is recommended that a deed restriction that runs with the land be recorded.
Contaminated Groundwater	To prevent consumption of or other exposure to contaminated groundwater.	A Declaration of Restriction on Use of Real Property has been recorded at the La Crosse Co.

Media, Engineered Controls & Areas that Do Not Support UU/UE based on Current Conditions	Institutional Control Objective	Title of IC Instrument Implemented, Planned or Recommended
		Register of Deeds Office. The instrument applies to three parcels west, south and east of the landfill property, but not the landfill property itself. The Restriction prohibits use of groundwater underlying the three parcels, any activity that may interfere with the remedy, any construction not approved by the U.S. EPA, and any residential use of the properties. A similar document must be recorded for the real estate parcel on which the landfill itself is located. WAC NR812.08(4)(g) prohibits construction of a water supply well within 1200' of the nearest area of waste disposal. Variances to this prohibition can be issued by WDNR.

Maps which depict the current conditions of the site and areas which do not allow for UU/UE will be developed as part of an IC Plan discussed below.

At this time, initial IC evaluation activities have determined that required ICs have been implemented on three parcels adjacent to the Site but not on the Landfill property. Initial IC evaluation activities have also revealed that additional steps must be taken to evaluate the protectiveness of existing ICs. It is anticipated that the IC Plan, which includes evaluation activities and planning for implementation of ICs at the landfill, will be completed by U.S. EPA and WDNR within 6 months of the Five-Year Review.

ROD Requirement:

The 1990 ROD addressed the need for ICs at the Site. It stated that institutional controls including deed restrictions limiting surface and ground-water use at the site; and State regulations governing groundwater use within 1200 feet of landfills and the development of landfills would be relied on. The ROD did not specifically address or include objectives to prevent interference with the landfill cap (except routine maintenance) nor prohibit any uses of the area such as for residential, commercial or industrial purposes. EPA and DNR will create and IC Plan for the Site which will evaluate the need for any additional ICs that need to be implemented at the Site.

Existing ICs:

Based on the initial evaluation of the institutional controls in place, the following additional actions should be taken: 1) There is no current evaluation of the title for the three properties. An evaluation of the site title should be performed for each property to ensure that there are no prior in time encumbrances or interests such as a mortgage or utility easement which would defeat the efficacy of the restrictive covenants. 2) Maps should be developed to show the restrictions in place for both the on-site and off-site areas. 3) The covenants should be reviewed to ensure that they cover the areas of concern, that the restrictions properly address the IC objectives required by U.S. EPA and WDNR, and that the instruments run with the land and are enforceable. 4) A mechanism and responsible party for long-term stewardship through inspection and monitoring of the institutional controls should also be developed. The IC Plan will address the IC evaluation activities which need to be completed, and additional IC activities as needed to plan for long-term site stewardship. The IC Plan will be developed by U.S. EPA and WDNR within six months of this review.

Current Compliance:

Based on inspections and interviews, neither the U.S. EPA nor WDNR is aware of any uses of the Site including groundwater which are inconsistent with the objectives which will be served by the planned ICs. There is no evidence of Site or groundwater uses which are inconsistent with the objectives of the required use restrictions. There appears to be compliance with the stated objectives of areas requiring use restrictions. No one is being exposed to site-related contaminants. There are no drinking water supply wells installed within the impacted groundwater area. Access to the site is limited. Restrictions on site access and groundwater restrictions appear to be functioning as intended. Long-term compliance with ICs will be accomplished by implementing an IC Plan, which will include various activities such as mapping and a title search, and by providing for long-term stewardship of the Site, which includes maintaining and monitoring effective ICs for the long term.

Long-Term Stewardship:

Since compliance with ICs is necessary to assure the protectiveness of the remedy, planning for long-term stewardship is required. Long-term stewardship involves assuring effective procedures are in place to properly maintain and monitor the site. Long-term stewardship will ensure effective ICs are maintained and monitored and the remedy continues to function as intended with regard to ICs. An IC Plan will be developed to include procedures to ensure long-term IC stewardship such as regular inspection of ICs at the site and annual certification to U.S. EPA and WDNR that ICs are in place and effective.

System Operation/Operation and Maintenance

In accordance with the November 2001 ESD allowing for the temporary shutdown of the groundwater pump and treat system, operation and maintenance for the period of this Five-Year Review include facility maintenance activities conducted in accordance with the Groundwater Treatment Facility Shutdown/Restart Plan (December 5, 2001), groundwater and drinking water sampling and analyses, monitoring well maintenance, and reporting.

Prior to the shut down of the groundwater pump and treat system, annual O &M costs for the years of 1998 through 2001 were approximately $200,000 per year. O&M costs for the groundwater remedy had been estimated in the 1990 ROD to be $150,000 per year. Since shut down of the system, O&M costs from

2002 to 2005 were approximately $60,000 per year. For the years 2006 and 2007, annual O&M costs were about $59,000 per year.

Maintenance of the landfill cap and passive gas vent system, and landfill gas monitoring are carried out by the Town of Onalaska. The prairie grass cap is mowed annually by the Town of Onalaska. Perimeter gas probes are sampled and a report submitted to the WDNR every 3 months.

V. Progress Since the Last Five-Year Review

Table 3: Actions Taken Since the Last Five-Year Review

Issues from Previous Review	Recommendations of Previous Review	Party Respon-sible	Mile-stone Date	Action Taken/Outcome	Date
Review of data indicates that MNA may be effective.	Continue MNA monitoring. Consider whether ROD can be modified to MNA	WDNR	2005	WDNR installed four additional monitoring wells to evaluate concentrations of TMBs near the landfill and within the naphtha contaminated area southwest of the landfill. Data supporting MNA is not strong enough to support amendment to ROD at this time. U.S EPA contracted for evaluation of groundwater data.	2005 2008
1,2,4- and 1,3,5-TMBs were not identified in the ROD as chemicals of concern and were not evaluated for health impacts	Determine if the TMBs require an additional health assessment.	WDNR	2005	Four potable wells were sampled semi-annually. TMBs exceed ES in 4 monitoring wells within the DMZ and close to the waste boundary. There are no exceedances of PAL for TMBs outside DMZ.	2005
Methylene chloride and acetone appear to be lab artifacts in analytical data.	Require laboratory to implement better practices.	WDNR		Lab contaminants were detected occasionally, but not consistently in site samples during the past five year period.	2008
Iron and manganese in groundwater exceed ES in background as well as downgradient wells.	Develop ACLs in accordance with WAC NR140.	WDNR	2005	ACLs are not required, as these are not contaminants of concern in the ROD, background levels are high, and they pose no human health or ecological risk..	2006

Issues from Previous Review	Recommendations of Previous Review	Party Respon-sible	Mile-stone Date	Action Taken/Outcome	Date
The Ackerman private well is directly down-gradient of the landfill.	Increase sampling frequency to semi-annual to assure protectiveness	WDNR	2003	Ackerman well was sampled semi-annually during this five year period and no VOC impacts have been observed. Iron exceeds the PAL, but it should be noted the Ackerman well is deeper than any background wells, draws water from the sandstone, and may have high naturally occurring iron.	2003-2007

VI. Five-Year Review Process

Administrative Components

From September 2007 to July 2008, the review team established the review schedule which included the following components:

- Community Involvement,
- Document Review,
- Data Review,
- Site Inspection,
- Local Interviews, and
- Five-Year Review Report Development and Review.

Members of the review team include Eileen Kramer, Hydrogeologist and Project Manager for the WDNR, Kyle Rogers, Environmental Scientist and Remedial Project Manager for the U.S. EPA.

Community Involvement

Activities to involve the community in the Five-Year Review were initiated in September 2007, with a notification to the Town of Onalaska Chairman of the conduct and goals of the Five-Year Review. In October 2007 display ads were placed in the La Crosse Tribune, Holmen Courier and Onalaska Community Life advising the public that a Five-Year Review would be conducted and providing contact information for individuals wishing to comment or provide information.

Interviews were conducted with members of the community, including Mr. Tim Dienger, the Town Administrator, Mr. Frank Fogel a member of the Town Board, and other local residents.

Document Review

This Five-Year Review consisted of a review of relevant documents including semi-annual and annual groundwater monitoring and O&M reports, the ROD, the two ESDs, the CD between the U.S. EPA and the Town of Onalaska, and ICs related to this site.

Data Review

Groundwater Monitoring

A monitoring program was established for the Long Term Response Action, O&M and Natural Attenuation phases of the cleanup. Initially, quarterly groundwater monitoring was performed to ensure that hydraulic capture of the plume was occurring and that chemical levels in the groundwater were decreasing. Analytes included the chemicals of concern listed in the ROD and those parameters required under the WPDES discharge "permit" issued by WDNR.

When the active groundwater pump and treat system was shut down in accordance with the 2001 ESD, a monitored natural attenuation sampling and analysis program was established. That program has been modified several times based on the interpretation of analytical results and the construction of four new NR141 compliant groundwater monitoring wells. Currently groundwater sampling is performed on a semi-annual basis.

Groundwater flow direction is usually to the west southwest, toward the Black River. Springtime, during high river stage, flow direction swings toward the south. The water table is observed at approximately 10 to 15 feet below ground surface. Monitoring wells with an "S" suffix are water table wells. Monitoring wells with an "M" suffix are approximately 75 feet deep and have 10 foot screens. The wells labeled with "PZ" are screened at about 20 to 30 feet bgs. "EW" wells are extraction wells and are screened from 32 to 82 feet bgs.

- Of the eight VOCs identified in the ROD as chemicals of concern, only benzene has been detected at levels greater than the NR140 PAL during this review period. These exceedances were observed in water from two wells, both within the 250 foot DMZ (See Attachment 9 – Papadopoulos & Associates Report – Figure 4). The last exceedances occurred in 2007. This contrasts with the previous five-year period of January 1998 to December 2002 during which time there were exceedances of five VOC chemicals of concern; benzene, 1,1-dichloroethene, TCE, xylene, and toluene.

- In 1999, a full priority pollutant scan was performed on groundwater samples to determine whether any new contaminants were present. Previous groundwater analyses had been limited to the chemicals of concern identified in the ROD. The priority pollutant scan detected TMB compounds at levels greater than the NR140 ES. Groundwater VOC analyses since 2001 have included full VOCs, including naphthalene and TMBs.

- During this five-year period, naphthalene has exceeded the PAL at least once at five monitoring points. All but one (MW-14S) of these wells are within the landfill DMZ. MW-14S is in close proximity to the Johnson (former Hubley) well. No landfill related VOCs have been detected in water samples collected from the Johnson well during this review period. There have been no exceedances of the NR140 ES for naphthalene in any of the groundwater samples collected during this Five-Year Review period.

- TMBs have exceeded the ES at least once at seven monitoring wells; all of these wells are well within the 250 foot landfill DMZ. An additional three monitoring wells have had at least one exceedance of the PAL for TMBs. Utilizing Mann-Kendall statistical analysis, two monitoring wells, MW-5S and MW-16S, show increasing trends; one well, MW-4S, is stable; and one well, MW-17S, is determined to be non-stable with no trend.

- Wells MW-5S and MW-16S have apparent increasing trends for TMBs. Results from other wells down-gradient of these two should be evaluated. MW-5S and MW-16S are both located within the DMZ and the area observed during the RI to be impacted by non-aqueous phase naphtha solvents.

  Wells down-gradient of MW-5S are PZ-1, EW-5, MW-17S and MW-17M. Groundwater samples from PZ-1 have been collected five times during this review period with no detects of TMBs. EW-5 has been sampled three times with one detect of 0.98 parts per billion (ppb) of 1,2,4-TMB. MW-17S has ES exceedances of TMBs that do not indicate an upward or downward trend. PZ-2, which is down-gradient of MW-17S and outside the DMZ, has had no detects of TMBs. MW-17M, which is within the DMZ, has had low level detects, although no PAL exceedances of TMBs. To date, exceedances of TMBs in the area of MW-5S and down-gradient are confined to within the landfill DMZ. The VOC plume does not appear to be expanding in the area of and down-gradient of MW-5S.

  Wells down-gradient of MW-16S include EW-4, PZ-2, PZ-3, MW-6S, and MW-6M. These wells are outside of the landfill DMZ except for EW-4. EW-4 was sampled three times during the review period and samples exceeded the PAL for TMBs for two of those sample events. PZ-2 and PZ-3, sampled annually, had no exceedances for TMBs and for the most part detects were single digit ppb. MW-6S and MW-6M were sampled annually and had no exceedances and only very low level (<1ppb) detects of TMBs. Based on this data, it appears that TMBs in the area of and down-gradient of MW-16S exceed PAL only within the landfill DMZ; TMBs observed outside the DMZ are well below the PAL. Evaluation of VOC analyses provides no evidence of VOC plume expansion in the area and down-gradient of MW-16S.

- Samples collected from MW-8M, which is located outside of the DMZ, approximately 300 feet south of the waste, have shown increasing concentrations of TMBs, although there have been no exceedances. Wells which are up-gradient of MW-8M and down-gradient of the waste are PZ-5 and MW-4S. While MW-4S, located 40 feet south of the waste, has ES exceedances for TMBs, the trend according to the Mann-Kendall analysis is stable. PZ-5 has had detects of TMBs in two of eight sampling events, although concentrations have been less than 10 ppb, well below the PAL. If groundwater quality up-gradient of MW-8M does not continue to degrade, water quality at MW-8M should eventually improve. MW-10M is down-gradient of MW-8M and has no detects of TMBs during this review period. MW-8M should continue to be monitored with frequent evaluation of results.

- Manganese and iron are the only metals that exceeded the ES outside of the DMZ during this review period. The concentrations of manganese and iron detected at the site are within a general range of background levels of manganese and iron in groundwater in Wisconsin. In the sand and gravel aquifer in the Trempealeau—Black River hydrologic basin, iron in groundwater generally can range from zero to almost 8000 parts per billion, with a great deal of variability within short distances. (Young and Borman, USGS). Observed levels of iron and manganese in drinking water wells up-gradient of the site indicate that much of the dissolved iron and manganese down-gradient of the landfill can be attributed to natural background. These are not contaminants of concern for the site as they pose no human health or ecological risk.

- The MCL for arsenic has been revised. It is now 10 ppb. Wells MW-2M, MW-16M, EW-2, EW-3, EW-4 and EW-5 exceed the MCL for arsenic. These wells are all located within the landfill DMZ. The ES for barium is not exceeded in any monitoring point. The PAL for barium is exceeded at four wells outside the DMZ (MW-6M, MW-8M, MW-15M, and the Miller well) and at seven wells within the DMZ (MW-2M, MW-16S, MW-16M, MW-17M, EW-2, EW-3 and EW-4).

- The Ackerman residential well is located downgradient of the landfill and has been sampled semi-annually. The well is open in sandstone from 181 to 207 feet bgs. No VOCs have been detected. Iron and manganese are observed consistently in exceedance of the ES. Based on the depth of the well and distance from the waste, it is most likely that the observed dissolved metals are naturally occurring.

- The Johnson private well is side-gradient of the landfill and has also been sampled semi-annually. No VOCs have been detected during this review period, except one detect of 1,2,4-TMB at 0.18 ppb in October 2003. Iron and manganese have been detected in exceedance of PAL and ES, although concentrations are within the range of naturally occurring concentrations.

- The Miller and Pretasky private wells are up-gradient of the landfill, have been sampled semi-annually during this review period, and have had exceedances of iron, manganese and arsenic. Neither has had detects of landfill related VOCs. The Miller well is 300 feet north of the landfill and approximately 50 feet from the Black River. The Pretasky well is about 230 feet north of the landfill and 175 feet from the Black River. The concentrations of iron and manganese in the Miller well are about five times the concentrations in the Pretasky well. A review of groundwater elevations and potentiometric surfaces including data from up-gradient and source area monitoring wells, does not indicate groundwater mounding and radial flow from the landfill nor any other instances of groundwater flow toward the north. Given the relative locations of these two private wells along with lack of evidence for groundwater mounding under the landfill nor any component of groundwater movement from the landfill to the north, it does not appear likely that the metals in these two private wells are migrating from the landfill. Iron and manganese concentrations exceed the ES. Arsenic concentrations in these two drinking water wells have exceeded the PAL, but not the ES or MCL.

U.S. EPA contracted with S.S. Papadopoulos & Associates for an evaluation report on the MNA monitoring at the site. The text portion of the report is included as Attachment 9. Groundwater data tables, as well as the groundwater sampling schedule, are included in Attachment 3.

Soil

In March 2006, four new monitoring wells were installed by WDNR to obtain more representative groundwater data than data acquired from the "AW" wells which are screened only one foot into the water table. Two water table wells and two medium depth piezometers nested with the water table wells were constructed; the MW-16 nest about 45 feet west of the waste and the MW-17 nest about 150 feet west of the waste. Both are within the area documented during the RI to be impacted by non aqueous phase naphtha solvents. Soil samples were collected in each of the borings for the shallow wells at the water table. The highest concentrations in soil were of the TMB compounds. Combined TMBs in soil at MW-16S were 96 parts per million (ppm); at MW-17S they were 6.53 ppm. WAC NR720 does not specify allowable residual contaminant levels for the TMBs. It is not known whether the contaminated soil may be a source of the increasing levels of TMBs in the groundwater. Additional data regarding residual contamination in the soil southwest of the landfill where naphtha solvents had been observed during the RI should be acquired and evaluated to determine whether the soil is acting as an on-going source of contamination to the groundwater.

Soil Vapors

In March 2006, soil gas samples were collected and evaluated. Field screening with a landfill gas meter and a photoionization detector indicated that an area around AW-15 and GM-4 had soil vapors with depleted oxygen and elevated methane and carbon dioxide. Five vapor samples were collected with Summa canisters and laboratory analyzed. The highest concentrations of benzene and TMBs were observed in the sample from AW-15. The figure indicating the locations where vapor samples were collected and tabulated results are included in Attachment 4.

Site Inspection

Inspection of the site was conducted on September 26 and 27, 2007, by the WDNR project manager and hydrogeologist and the U.S. EPA RPM. The purpose of the inspection was to assess the protectiveness of the remedy, including the presence of fencing to restrict access, the integrity of the cap and the condition of the remediation system.

No significant issues were identified at any time regarding the cap. The prairie grass cover was observed to cover the cap evenly, although it had just been mowed to facilitate the inspection. The ROD requires a line of fencing to limit vehicular access at the southern edge of the landfill. The split rail fence was observed to be damaged and should be repaired and possibly improved. It should be noted that fencing at the site is intended to allow the movement of wildlife. The site is adjacent to a U.S. Fish and Wildlife Service Preserve and is a known turtle nesting area. No evidence of trespassing or vandalism was noted.

The groundwater pump & treat system and its associated building and equipment were observed to be in good condition and regularly maintained. Four of the five extraction wells are pumped for five minutes each once per month to minimize fouling and assure operation of the pumps. One well, EW-1, is not operable and would require troubleshooting and repair if the active groundwater remediation were required to be re-started. (The site maintenance person believes it may be a faulty electric transformer.) The components of the soil bio-remediation air injection system are still present and in good condition, although injection wells may require cleaning out if the air injection system were re-started. The condensate trap on the large Ingersoll Rand air compressor would need to be repaired if the active groundwater remediation were to be re-started. Also, the bearings in the floor sump pump are noisy when the pump is operated, and would require repair if the facility were to return to full-time use. Rubber gaskets in the sludge pumps would need to be replaced if the sludge press and pumps were re-activated. The overall condition of the facility is very good.

The monitoring wells were located and inspected. All wells were in good condition, properly labeled, and accessible. All wells, except MW-5S, had appropriate protective tops or flush mounts and surface seals in good condition. MW-5S was recently converted to a stick up type well to alleviate the potential for ponding around the well where the ground surface grade had been raised. An above-grade protective top is yet to be installed.

Interviews

Interviews were conducted with various parties connected to the site. Peter Moore of ENSR, the State's contractor for the site, has provided maintenance and monitoring oversight at the site for at least eight years. Work at the site has gone well. The neighbors have been cooperative in allowing potable well sampling. Bill Wood, an employee of ENSR, has provided most of the on-site maintenance. He has been associated with the site also for at least eight years. He is concerned that the equipment remain in good condition and operable. Mr. Frank Fogel, a member of the Town of Onalaska Board, was interviewed on the phone. Mr. Fogel expressed concern with the increasing cost of the quarterly landfill gas monitoring.

On September 27, 2007, the U.S.EPA and WDNR representatives visited Mr. Tim Dienger, Administrator for the Town of Onalaska. Mr. Dienger stated that he is pleased with the progress that has been made at the site. The agencies and Mr. Dienger discussed a recent request from the Prinsens who own a land parcel south of the site, for an easement across the adjacent Town owned parcel for road access. The Prinsens have advertised for the sale of their parcel. The agencies have encouraged the Town to purchase the Prinsen parcel to assure its future use being consistent with the neighboring wildlife preserve. Based on proximity to the landfill, WAC NR812.11 would not allow construction of a water supply well on the Prinsen parcel making its use for commercial or residential development questionable.

During the site inspection the agencies also visited with Mr. Roy Ackerman who lives south of the site and whose water supply well is sampled regularly by the WDNR. Mr. Ackerman stated that he observes "headlights" of vehicles on the cap sometimes at night. This information was passed on to the Town administrator along with direction that the fence at the south end of the landfill should be repaired. A follow-up inspection should be conducted.

Photos from the site inspection and the Site Inspection Checklist are included in Attachments 10 and 7 respectively.

VII. Technical Assessment

Question A: Is the remedy functioning as intended by the decision documents?

Yes. From 2001 to 2008, the Site has been evaluated for natural attenuation as a viable cost effective remedy over the groundwater extraction remedy. Monitoring for natural attenuation began in the fall of 2001. Results do not demonstrate that natural attenuation is more effective than the current remedy, and the contaminants of concern, except for arsenic and barium, within the design management zone meet the cleanup standards established in the 1991 ROD and subsequent ESD. The elevated arsenic and barium levels are unlikely to be reduced below cleanup standards through the pump and treat system.

In 1999, new contaminants of concern were identified. Trimethylbenzene compounds were detected in monitoring wells above State PALs, A risk analysis for these contaminants and additional investigation of contaminated soil that may be acting as a source of contamination to the groundwater is recommended.

Currently, the Onalaska Landfill Superfund Site is protective of human health and the environment because the landfill cap is effective; groundwater monitoring assures that drinking water supplies remain safe; and that the plume is contained, most of the contaminants have been remediated; and institutional controls prevent activities that would compromise the cap or expose parties to contaminated groundwater.

Institutional controls including deed restrictions and the WAC Ch. NR812 *prohibition on* construction of water supply wells within 1200 feet of any landfill prevent potential exposure to contaminated groundwater. The water supply wells have been sampled regularly and should continue to be sampled regularly to prevent any potential exposure.

The institutional controls that are in place include prohibitions on the use or disturbance of groundwater until cleanup levels are achieved, and prohibitions on excavation activities, disturbance of the cap, and any other activities or actions that might interfere with the implemented remedy. No activities were observed that would have violated the institutional controls. The cap and the surrounding area were undisturbed, and no new uses of groundwater were observed. The fence around the site is intact, but in need of some repair.

While deed restrictions have been recorded on Town owned parcels adjacent to the landfill property, and WAC NR506 prohibits activities on the landfill property that would compromise the cap and the protectiveness of the remedy, a deed restriction has not been recorded for the property on which the landfill is located. An appropriate document should be drafted by the Town, reviewed by the US. EPA and WDNR , and recorded at the La Crosse County Register of Deeds Office.

Additionally, to assure that the remedy continues to function as intended, the ICs must be fully evaluated to assure that effective ICs are implemented, monitored and maintained. To that end, an IC Plan will be prepared.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of the remedy selection still valid?

No, WAC NR140 standards for arsenic have changed. In January 2001, the U.S. EPA established a new federal drinking water MCL of 10 ppb. Subsequently the State has adopted the federal MCL of 10 ppb as the NR 140 enforcement standard for arsenic. Because arsenic is a known carcinogen, an NR 140 preventive action limit of 1 ppb, 10% of the recommended 10 ppb enforcement standard, has been promulgated. On March 1, 2004, the NR140 standards for arsenic changed from an ES of 50 ppb to 10 ppb, and the PAL from 5 ppb to 1 ppb. Other exposure assumptions, toxicity data, cleanup levels and RAOs are still valid. There have been no changes in the physical conditions of the site that would affect the protectiveness of the remedy.

The change in NR140 standards for arsenic results in ES exceedances for arsenic within the landfill DMZ. NR140 specifies a range of responses for ES exceedances within a DMZ; one of which is "no action".

Applicable or Relevant and Appropriate Requirements (ARARs) that still must be met at this time and that have been evaluated include: the Safe Drinking Water Act (40 CFR 141.11-141.16) and WAC NR140 from which many of the groundwater cleanup levels were derived - [NR140 PAL and ES, MCLs, and MCL Goals (MCLGs)]; and ARARs related to post-closure monitoring.

The exposure assumptions used to develop the Human Health Risk Assessment included the ingestion of contaminated groundwater, ingestion of and/or dermal contact with on-site soils, and direct contact with contaminated surface waters or sediments due to recreational use of the Black River and wetlands area. Based on data collected to date, there has been no impact to surface waters or sediments surrounding the Site, and thus there is no exposure risk associated with the recreational use of the Black River or wetlands area. The remaining exposure pathways consist of ingestion of and/or dermal contact with contaminated groundwater and with on-site soils. There are currently institutional controls that prohibit construction in or disturbance of site soils and construction of wells near the site. Overall the concentrations of total VOCs at the site have been reduced since the 1992 risk assessment through operation of the treatment systems, and thus the resulting toxicity of the chemicals is now lower. Therefore the risk associated with VOCs in site soils and groundwater has been minimized. The trimethylbenzenes were not included as chemicals of concern in the risk assessment and were found in the groundwater at the site during a priority pollutant scan in 1999. It should be noted that there has only been one PAL exceedance for TMBs outside the 250 foot landfill DMZ during this review period. Arsenic was observed to exceed the NR140 PAL at one monitoring well, MW-8. Groundwater and drinking water monitoring have demonstrated that impacts to the groundwater are not affecting potable wells.

The original exposure assumptions used in the risk assessment are considered to be conservative and reasonable in evaluating risk and developing risk-based cleanup levels. No changes to these assumptions is warranted. There have been no changes to the standardized risk assessment methodology that could affect the protectiveness of the remedy.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

No, no other information has come to light that calls into question the protectiveness of the remedy.

Technical Assessment Summary

There have been no changes in the physical conditions of the site that would affect the short-term protectiveness of the remedy. There have been no changes in the toxicity factors for the contaminants of concern that were used in the baseline risk assessment other than those noted above, and there has been no change to the standardized risk assessment methodology that could affect the protectiveness of the remedy. There is no other information that calls into question the short-term protectiveness of the remedy.

VIII. Issues

Table 4 - Issues

Issue	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
1. Increasing TMB concentrations in two monitoring wells located within the area where non-aqueous phase naphtha solvents had been observed during the RI.	N	Y
2. Increasing TMB concentration (although not in exceedance of the PAL) in MW-8M which is located outside the DMZ	N	Y
3. Concentrations of arsenic and barium exceed the cleanup standards, although there are no exceedances of the federal MCL or State ES outside the DMZ.	N	Y
4. Damaged fence at southern perimeter of landfill	N	Y
5. The required deed restriction on the landfill property that is enforceable by the WDNR and U.S. EPA has not been recorded at the La Crosse Co. Register of Deeds office. Implementing, maintaining and monitoring of the ICs will be required to assure protectiveness of the remedy.	N	Y
6. Prinsen property is located south of the site and within 1200 feet of the landfill. NR812 prohibits construction of a water supply on the property without a variance from the WDNR, but no deed notice that runs with the land has been recorded.	N	Y
7. Report of possible vehicle operation at night on the landfill.	N	Y
8. MW-5S does not have an above-grade protective top.	N	N
9. Quality of groundwater immediately outside the landfill DMZ requires additional characterization.	N	Y
10. Potable wells in proximity to landfill.	N	Y
11. The need to evaluate current ICs at the Site to determine if any additional ICs should be implemented.	N	Y

IX. Recommendations and Follow-Up Actions

Table 5 - Recommendations and Follow-Up Actions

Issue	Recommendations/ Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
1. Increasing concentrations of TMBs in some monitoring wells	Additional data regarding residual contamination in the soil southwest of the landfill where naphtha solvents had been observed during the RI should be acquired and evaluated to *determine whether the* soil is acting as an on-going source of contamination to the groundwater.	U.S. EPA WDNR	U.S. EPA WDNR	Finalize scope of work by January 2009. Initiate field work by May 2009.	N	Y
2. Increasing TMB concentration (although not in exceedance of the PAL) in MW-8M which is located outside the DMZ.	On-going monitoring of MW-8M to evaluate whether concentrations will begin to stabilize and decrease due to decrease in loading in the up-gradient area.	U.S. EPA WDNR	U.S. EPA WDNR	Annual	N	Y
3. Arsenic and barium exceed the cleanup standards	Proposed ACLs for arsenic, barium which occur naturally should be finalized.	WDNR	WDNR U.S. EPA	April 2009	N	Y
4. Damaged fence at southern *perimeter of* landfill	The fence should be restored and perhaps extended.	Town of Onalaska	WDNR	December 2008	N	Y

Issue	Recommendations/ Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
5. A deed restriction on the landfill property that is enforceable by the WDNR and U.S. EPA has not been recorded at the La Crosse Co. Register of Deeds office.	*The Town should* draft for WDNR and U.S. EPA review and approval a deed instrument that restricts activities and access to the landfill to protect the integrity of the cap and to prevent exposure to contaminated media.	Town of Onalaska	WDNR U.S. EPA	June 2009	N	Y
6. Prinsen property is located south of the site. NR812 would prohibit construction of a water supply on the property without a variance from the WDNR, but no deed notice that runs with the land has been recorded.	The agencies should determine whether a deed instrument that runs with the land to restrict its use is necessary to assure protectiveness	WDNR U.S. EPA	WDNR U.S. EPA	June 2010	N	Y
7. Report of possible vehicle operation at night on the landfill.	Discuss with Town Administrator. Encourage routine drive-by surveillance. Evaluate whether extending fence would prevent vehicular access	Town of Onalaska	WDNR	December 2008	N	Y

Issue	Recommendations/ Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
8. MW-5S	A protective top that complies with NR141 WAC should be constructed.	WDNR	WDNR	June 2009	N	N
9. Quality of groundwater immediately outside the DMZ	Additional monitoring wells to determine concentrations of arsenic and barium at the DMZ should be installed.	WDNR U.S. EPA	WDNR U.S. EPA	August 2009	N	Y
10. Potable wells in proximity to landfill	Monitoring of the four drinking water wells in proximity to the site should continue and the potential for impact from the landfill be evaluated again.	WDNR U.S. EPA	WDNR U.S. EPA	Annually	N	Y
11. No IC Plan in place for the Site	Implement an IC Plan for the Site to evaluate if any additional ICs need to be added.	WDNR U.S. EPA	WDNR U.S. EPA	June 2009	N	Y

X. Protectiveness Statement

Currently, the Onalaska Landfill Superfund Site is protective of human health and the environment in the short-term because the landfill cap is effective; groundwater monitoring assures that drinking water supplies remain safe and that the plume is contained; most contaminants of concern have been remediated to meet ROD cleanup standards; and institutional controls prevent activities that would compromise the cap or expose parties to contaminated groundwater. However, in order to remain protective in the long-term additional soil investigation, and possible remediation of TMB, will be needed, on-going monitoring and evaluation of arsenic and barium in groundwater must be done, and the required restrictive covenant for the landfill cap must be drafted and recorded as required by the Consent Decree.

Long term protectiveness also requires compliance with the land and groundwater use restrictions. Compliance with effective ICs will be ensured by implementing, monitoring and maintaining effective ICs as well as maintaining the site remedy components. Long-term stewardship must be ensured to verify compliance with ICs.

XI. Next Review

The next Five-Year Review for the Onalaska Landfill Superfund Site is required by July 2013, five years from the date of this review.

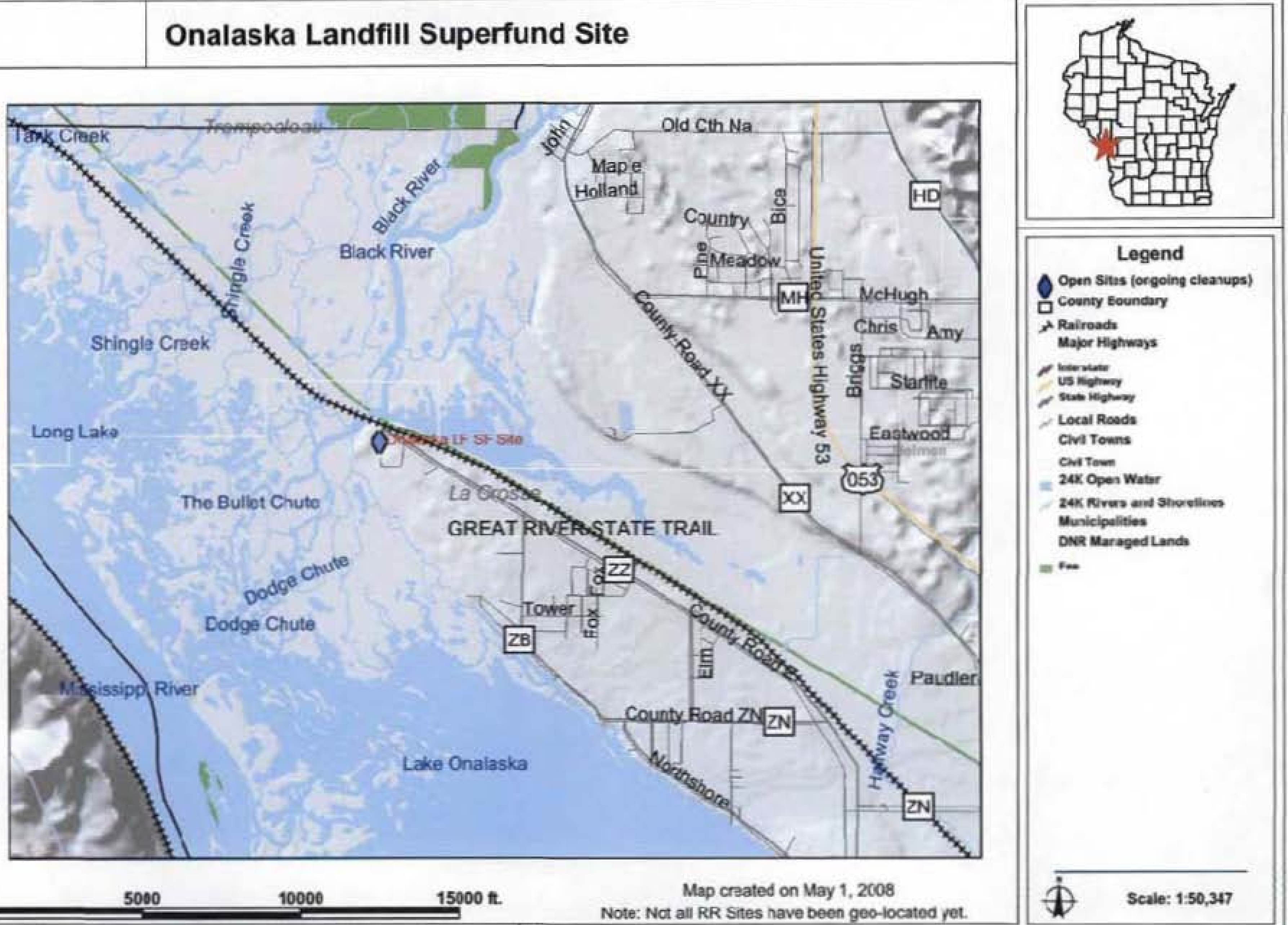
ATTACHMENTS

ATTACHMENT 1
MAPS

Site Location

Site Features

Onalaska Landfill Superfund Site



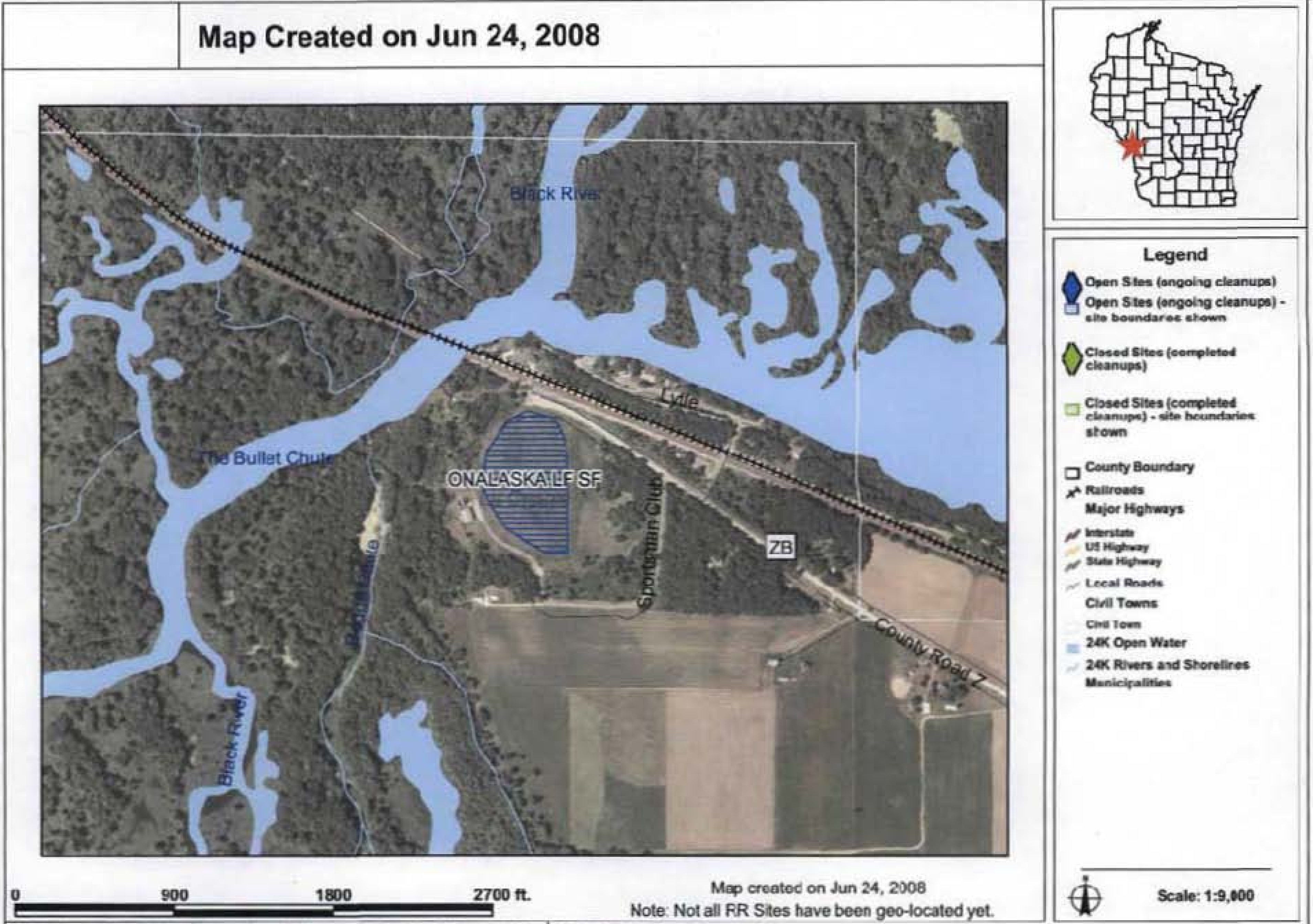
Map created on May 1, 2008

Note: Not all RR Sites have been geo-located yet.

Notes: Location in La Crosse County

Figure 1

Map Created on Jun 24, 2008

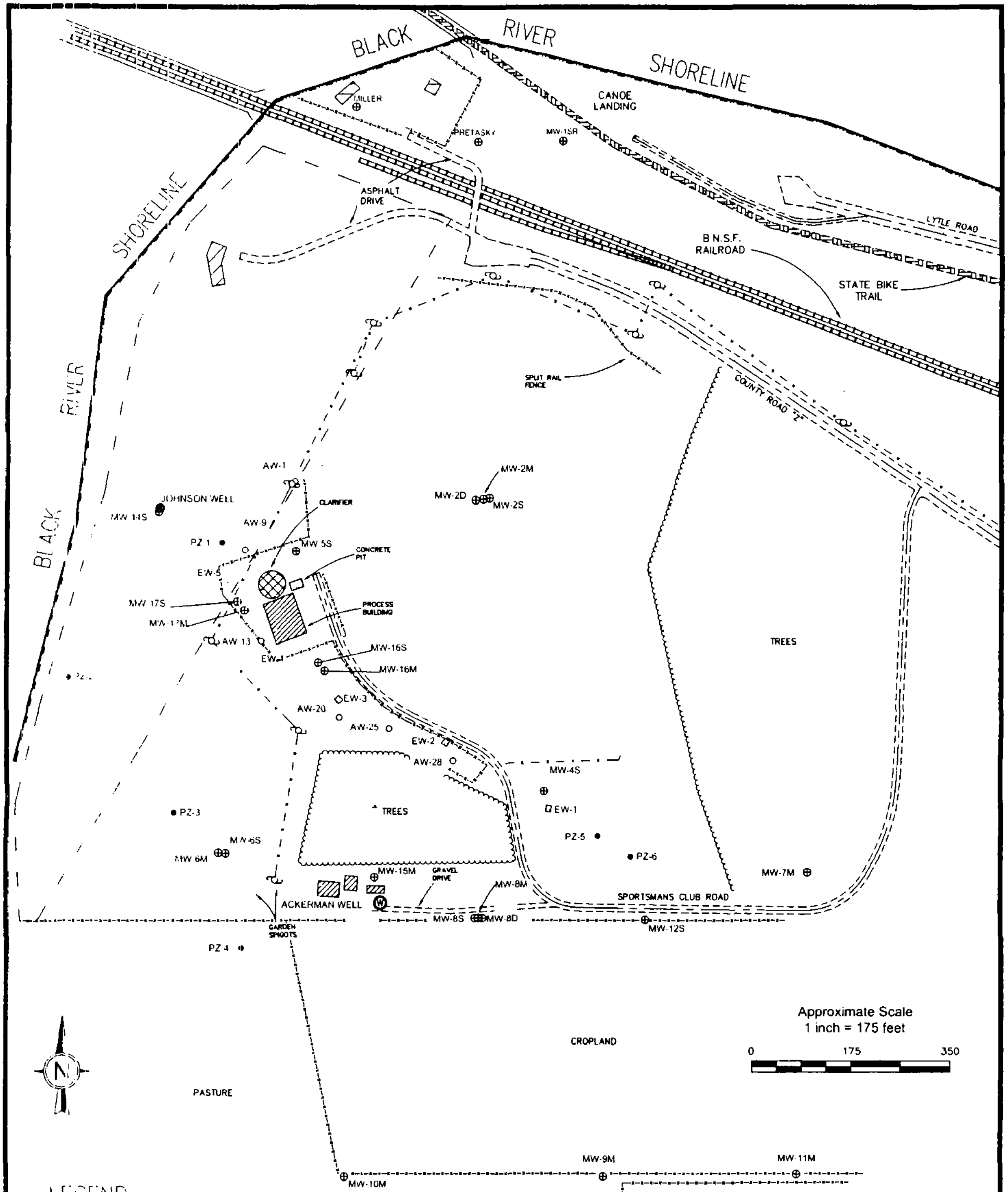


Map created on Jun 24, 2008
Note: Not all RR Sites have been geo-located yet.

This map is a user generated static output from an Internet mapping site and is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. THIS MAP IS NOT TO BE USED FOR NAVIGATION.

Notes: Onalaska Landfill Superfund Site
Town of Onalaska
La Crosse County
Wisconsin

FIGURE 1 A



LEGEND

⊕ = Monitoring Well
● = Piezometer
· = Extraction Well
○ = Air Well
— — — = Approximate Property Line
—— - —— = Centerline
—·—·— = Fence line
→ → · = Utility lines
⊸ = Utility pole
⚲ = Hydrant

NOTES

Source:
Onalaska Landfill Site Plan Survey, prepared by Coulee Region Land Surveyors, Inc., project no. S-4754, dated 5/14/03.

FIGURE NUMBER	SITE PLAN ONALASKA LANDFILL ONALASKA, WISCONSIN			ENSR | AECOM ENSR CORPORATION ST LOUIS PARK, MINNESOTA 55416 PHONE: (952) 924-0117 FAX: (952) 942-0317 WEB: HTTP://WWW.ENSR.AECOM.COM	DESIGNED BY: AC DRAWN BY: BLK CHECKED BY: DCP APPROVED BY: PJM
SHEET NUMBER	SCALE: 1" =	DATE: 11/16/07	PROJECT NUMBER 7349-002		

REVISIONS			
NO.:	DESCRIPTION	DATE.	BY

ATTACHMENT 2

List of Documents Reviewed

DOCUMENTS REVIEWED

CH2M HILL, Remedial Investigation Report, Onalaska Municipal Landfill, December 22, 1989.

CH2M HILL, Groundwater Treatment Facility Shutdown/Restart Plan, Onalaska Municipal Landfill, December 2001.

CH2M HILL, Monitored Natural Attenuation Plan, Onalaska Municipal Landfill Site, 2001.

ENSR International, 2004/2005 Annual Monitored Natural Attenuation Report for the Onalaska Municipal Landfill Site, September 2005.

ENSR/AECOM, *2006 Annual Monitored Natural Attenuation Report for the Onalaska Municipal Landfill* Site, November 2006.

ENSR/AECOM, 2007, Annual Monitored Natural Attenuation Report for the Onalaska Municipal Landfill Site, November 2007.

Papadopulos, S.S., Evaluation of Monitored Natural Attenuation as A Containment Remedy for the Onalaska Municipal Landfill Site, Onalaska, Wisconsin, June 2008.

U.S. EPA, Record of Decision, Selected Remedial Alternative for the Onalaska Municipal Landfill Site, August 14, 1990.

U.S. EPA, Explanation of Significant Difference, Onalaska Municipal Landfill Superfund Site, September 29, 2000.

U.S. EPA, Explanation of Significant Difference, Onalaska Municipal Landfill Superfund Site, November 13, 2001.

WDNR, *Second Five-Year Review Report of the Onalaska Municipal Landfill Site, July 2003.*

ATTACHMENT 3

Groundwater Data

MW-4S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**12/12/2002**	**04/22/2003**	**10/08/2003**	**04/13/2004**	**09/24/2004**	**12/02/2004**	**03/10/2005**	**06/09/2005**	**03/23/2006**	**09/07/2006**
1,2,4-Trimethylbenzene	**540**	**780**	**1100**	**1100**	**1900**	**1600**	**1100**	**1500**	**580**	**1200**
1,3,5-Trimethylbenzene	**120**	**170**	**230**	**310**	**390**	**410**	**260**	**380**	**150**	**260**
Acetone	< 28	< 31	< 55	< 26	<53	<37	<25	<37	48	<25
Benzene	< 9.2	< 11	< 17	**13**	<16	<11	<7.3	<11	<3.7	<7.3
Ethylbenzene	10	16	38	9.4	50	26	21	32	4.1	9.6
Methylene chloride	< 7.2	< 8.3	< 23	< 11	<14	**49**	<6.3	<9.5	<3.2	<6.3
Naphthalene	< 10	14	20	< 6.4	<11	<7.5	14	32	7	18
Xylenes (total)	29	54	160	52	210	93	77	140	23	52

Metals, mg/L

Arsenic	0.0089	0.0065	0.0091	0.0086	0.0066	0.0095	0.0083	0.0091	0.0052	<0.0043
Barium	0.3	0.26	0.29	0.33	0.29	0.32	0.315	0.361	0.248	0.267
Cadmium	< 0.00028	< 0.00028	< 0.00036	< 0.00028	<0.00028	<0.00028	<0.00028	<0.00028	<0.00042	<0.00042
Cobalt	< 0.00074	< 0.00074	< 0.0011	< 0.00096	<0.00096	<0.00096	<0.00096	<0.00096	<0.0012	<0.0012
Iron	**16.9**	**15.4**	**18.9**	**24.7**	**18**	**22.9**	**23.8**	**27.5**	**17**	**16.1**
Lead	< 0.0016	< 0.0016	< 0.0023	< 0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017
Manganese	**2.1**	**1.8**	**2.1**	**2.1**	**2.1**	**2.5**	**2.14**	**2.29**	**1.41**	**1.78**
Mercury	< 0.000087	< 0.000087	< 0.000067	< 0.000029	0.000045	<0.000029	<0.000029	0.000087	<0.00009	<0.00009
Vanadium	< 0.00067	< 0.00067	< 0.00096	< 0.00071	<0.00071	<0.00071	0.0011	<0.00071	<0.0019	<0.0019

Natural Attenuation Parameters, mg/L

Chloride	13.5	10.2	7.7	11.4	---	5.9	----	15.9	13.8	9.6
Nitrate as N	< 0.0076	< 0.0076	< 0.019	< 0.016	---	<0.016	----	<0.016	<0.015	<0.031
Sulfate	0.98	0.22	0.15	1	---	0.14	----	0.16	2.9	0.68
Total Alkalinity	280	260	290	310	---	---	----	----	220	260
Total Organic Carbon	5	5	4	12	---	---	----	----	9	12

pH	6.66	---	6.825	---	6.34	6.61	7.22	6.44	6.96	-94.2
Conductivity (mS/cm)	0.612	---	0.611	---	0.635	0.645	0.596	391	330	343
Temperature (C)	12.02	---	11.72	---	11.88	12.44	11.19	10.49	11.21	12.13
ORP (mV)	117	---	133	---	181	173	179	-78.3	-73	-94.2
Dissolved Oxygen (mg/L)	4.49	---	7.49	---	3.02	1.13	2.08	1.43	3.6	0.18

MW-4S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	03/22/2007	09/11/2007	PAL	ES
1,2,4-Trimethylbenzene	**660**	**1200**	96	480
1,3,5-Trimethylbenzene	**110**	**280**	96	480
Acetone	<12	<55	200	1000
Benzene	<3.7	<6.5	0.5	5
Ethylbenzene	3.7	19	140	700
Methylene chloride	<3.2	<16	0.5	5
Naphthalene	8.3	30	10	100
Xylenes (total)	25	120	1,000	10,000

Metals, mg/L				
Arsenic	<0.0043	0.0058	0.001	0.01
Barium	0.244	0.328	0.4	2
Cadmium	<0.00042	<0.00042	0.0005	0.005
Cobalt	<0.0012	<0.0012	0.008	0.04
Iron	**13.3**	**14.9**	0.15	0.3
Lead	<0.0017	<0.0017	0.0015	0.015
Manganese	**1.28**	**1.84**	0.025	0.05
Mercury	<0.00009	<0.00009	0.0002	0.002
Vanadium	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L				
Chloride	8.9	4.4	125	250
Nitrate as N	0.36	<0.023	2	10
Sulfate	0.83	<0.12	125	250
Total Alkalinity	240	340	----	----
Total Organic Carbon	10	14	----	----

pH	6.89	6.75	----	----
Conductivity (mS/cm)	350	0.404	----	----
Temperature (C)	10.58	11.73	----	----
ORP (mV)	-56.7	118.6	----	----
Dissolved Oxygen (mg/L)	0.75	1.09	----	----

MW-5S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**03/10/2005**	**06/10/2005**	**Duplicate 6/10/2005**	**03/23/2006**	**09/07/2006**	**03/22/2007**	**09/11/2007**	**PAL**	**ES**
1,2,4-Trimethylbenzene	**490**	**1300**	**1200**	**670**	**710**	**1200**	**1100**	96	480
1,3,5-Trimethylbenzene	**48**	**390**	**370**	**73**	**110**	**120**	**160**	96	480
2-Butanone	<4.9	<16	<16	10	<7.1	<7.8	<28	90	460
Acetone	<9.2	<31	<31	38	<13	<15	<55	200	1000
Benzene	<2.8	<9.2	<9.2	<4.4	<4	<4.4	<6.5	0.5	5
Ethylbenzene	17	57	51	41	19	23	10	140	700
Methylene chloride	<2.4	<7.9	<7.9	<3.8	<3.5	<3.8	<16	0.5	5
Naphthalene	19	41	40	48	42	44	32	10	100
Xylenes (total)	61	250	240	53	83	30	40	1,000	10,000

Metals, mg/L

Arsenic	**0.0151**	**0.0231**	**0.0227**	**0.0137**	**0.0138**	**0.0121**	0.0062	0.001	0.01
Barium	0.391	0.5	0.519	0.392	0.382	0.383	0.281	0.4	2
Cadmium	<0.00028	<0.00028	<0.00028	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	0.0086	0.0126	0.0127	0.0099	0.0105	0.0109	0.0056	0.008	0.04
Iron	**39.7**	**60.7**	**59.1**	**39.2**	**40.7**	**39.1**	**14.6**	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.83**	**3.86**	**3.83**	**3.98**	**4.87**	**3.79**	**1.85**	0.025	0.05
Mercury	<0.000029	0.00009	0.000058	<0.00009	<0.00009	<0.00009	<0.00009	0.0002	0.002
Vanadium	<0.00071	0.0013	<0.00071	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	----	4.8	4.6	6	2.5	5.9	4.2	125	250
Nitrate as N	----	<0.016	<0.016	0.18	<0.031	0.63	0.2	2	10
Sulfate	----	0.2	0.18	0.52	2.5	1	3.6	125	250
Total Alkalinity	----	----	----	200	250	220	280	----	----
Total Organic Carbon	----	----	----	9	13	9	7	----	----

pH	7.12	6.08	----	6.76	6.59	6.71	6.49	----	----
Conductivity (mS/cm)	0.489	340	----	320	365	339	0.367	----	----
Temperature (C)	10.51	10.5	----	10.69	12.64	9.83	13.27	----	----
ORP (mV)	183	-75.2	----	-59.2	-88.8	-53.5	168.1	----	----
Dissolved Oxygen (mg/L)	2.51	0.76	----	0.97	0.62	0.65	0.53	----	----

MW-5S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**12/12/2002**	**04/22/2003**	**10/07/2003**	**04/14/2004**	**Duplicate 4/14/2004**	**09/23/2004**	**Duplicate 9/23/2004**	**12/02/2004**	**Duplicate 12/2/2004**
1,2,4-Trimethylbenzene	210	180	**750**	67	51	210	150	**1300**	**1200**
1,3,5-Trimethylbenzene	47	38	**200**	2.7	2.4	19	15	**350**	**330**
2-Butanone	< 4.5	< 3.4	< 24	< 1.2	< 0.72	<2.2	<3	<20	<20
Acetone	< 8.5	< 6.3	< 44	< 2.2	< 1.3	<4.2	<5.7	<37	<37
Benzene	< 2.8	< 2.1	< 13	1.5	0.56	<1.3	<1.7	<11	<11
Ethylbenzene	6.2	5.1	29	1.5	1.2	5.9	5.7	60	54
Methylene chloride	3.9	< 1.7	< 19	< 0.93	< 0.56	<1.1	<1.5	**41**	**41**
Naphthalene	6.2	5.4	28	2.2	1.6	7.7	14	<7.5	<7.5
Xylenes (total)	12	13	150	2	1.8	120	94	160	160
Metals, mg/L									
Arsenic	0.0098	**0.011**	**0.022**	**0.01**	**0.012**	0.0053	0.0047	**0.012**	**0.012**
Barium	0.18	0.28	0.27	0.27	0.28	0.29	0.29	0.31	0.29
Cadmium	< 0.00028	< 0.00028	< 0.00036	< 0.00028	< 0.00028	<0.00028	<0.00028	0.00032	0.00033
Cobalt	0.0025	0.0041	0.0058	0.0045	0.0041	0.0056	0.0054	0.0094	0.0091
Iron	**10.2**	**19.4**	**30.5**	**11.2**	**11.7**	**15.9**	**16.3**	**34.7**	**31.9**
Lead	< 0.0016	< 0.0016	< 0.0023	< 0.0017	< 0.0017	<0.0017	0.003	<0.0017	<0.0017
Manganese	**1.6**	**2**	**2.3**	**1.3**	**1.3**	**2.5**	**2.6**	**3.3**	**3.1**
Mercury	0.000088	< 0.000087	0.000075	< 0.000029	< 0.000029	<0.000029	<0.000029	<0.000029	<0.000029
Vanadium	< 0.00067	< 0.00067	< 0.00096	< 0.00071	< 0.00071	<0.00071	<0.00071	<0.00071	<0.00071
Natural Attenuation Parameters, mg/L									
Chloride	5.8	5.7	4.3	4.6	4.5	---	---	5	5
Nitrate as N	0.1	0.62	0.02	0.94	1.3	---	---	0.47	0.45
Sulfate	0.34	3.3	0.16	1.8	2.3		---	0.77	0.81
Total Alkalinity	140	160	180	160	160	---	---	---	---
Total Organic Carbon	5	4	9	6	6	---	---	---	---
pH	6.99	7.12	6.65	---	---	6.1	---	6.42	---
Conductivity (mS/cm)	0.333	0.379	0.425	---	---	0.645	---	0.549	---
Temperature (C)	12.4	9.66	12.77	---	---	13.51	---	12.73	---
ORP (mV)	106	117	151	---	---	192	---	178	---
Dissolved Oxygen (mg/L)	1.75	0.74	5.12	---	---	2.27	---	1.17	---

MW-6S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	12/12/2002	10/07/2003	12/02/2004	06/08/2005	03/21/2007	PAL	ES
1,1-Dichloroethane	0.55	0.71	0.29	0.31	<0.21	85	850
1,2,4-Trimethylbenzene	< 0.37	< 0.14	<0.12	<0.12	0.27	96	480
Acetone	2.6	< 0.66	<0.74	<0.74	<0.74	200	1000
cis-1,2-Dichloroethene	< 0.35	0.59	0.36	0.49	0.33	7	70
Methylene chloride	2.2	< 0.28	0.54	<0.19	<0.19	0.5	5
Trichloroethene	< 0.42	0.37	<0.28	<0.28	<0.28	0.5	5

Metals, mg/L

Arsenic	< 0.0021	< 0.0029	<0.0026	<0.0026	<0.0043	0.001	0.01
Barium	0.17	0.13	0.22	0.265	0.191	0.4	2
Cadmium	< 0.00028	< 0.00036	<0.00028	<0.00028	<0.00042	0.0005	0.005
Cobalt	0.0022	< 0.0011	0.0025	0.0019	0.0016	0.008	0.04
Iron	0.065	< 0.044	0.25	0.16	<0.032	0.15	0.3
Lead	< 0.0016	< 0.0023	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.7**	**2.7**	**3.6**	**4.68**	**2.72**	0.025	0.05
Mercury	< 0.000087	< 0.000067	<0.000029	<0.000029	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	0.00071	<0.00071	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	6.7	5.6	11	12.7	8.8	125	250
Nitrate as N	< 0.0076	< 0.019	<0.016	<0.016	<0.031	2	10
Sulfate	4	3.6	9.7	0.99	0.86	125	250
Total Alkalinity	160	150	---	----	210	----	----
Total Organic Carbon	6	5	---	----	4	----	----

pH	7.45	7.37	7.25	6.97	7.3	----	----
Conductivity (mS/cm)	0.342	0.307	0.506	316	274	----	----
Temperature (C)	11.1	10.28	11.4	9.17	9.53	----	----
ORP (mV)	113	127	191	31	69.5	----	----
Dissolved Oxygen (mg/L)	2.86	3.08	0.84	7.47	0.66	----	----

MW-6M
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**12/12/2002**	**10/07/2003**	**12/02/2004**	**06/08/2005**	**03/21/2007**	**PAL**	**ES**
1,1-Dichloroethane	< 0.3	0.61	0.27	0.21	<0.21	85	850
1,2,4-Trimethylbenzene	< 0.37	< 0.14	0.23	26	<0.12	96	480
1,3,5-Trimethylbenzene	< 0.4	< 0.18	<0.16	<0.16	<0.16	96	480
Acetone	2.1	< 0.66	<0.74	<0.74	<0.74	200	1000
cis-1,2-Dichloroethene	< 0.35	0.42	0.35	0.42	<0.21	7	70
Ethylbenzene	< 0.41	< 0.19	<0.19	0.22	<0.19	140	700
Methylene chloride	2.1	< 0.28	0.44	<0.19	<0.19	0.5	5

Metals, mg/L

Arsenic	0.0024	< 0.0029	<0.0026	<0.0026	<0.0043	0.001	0.01
Barium	0.75	0.89	0.77	1.07	0.744	0.4	2
Cadmium	< 0.00028	< 0.00036	<0.00028	<0.00028	<0.00042	0.0005	0.005
Cobalt	< 0.00074	< 0.0011	<0.00096	<0.00096	<0.0012	0.008	0.04
Iron	< 0.042	0.12	<0.049	<0.049	<0.032	0.15	0.3
Lead	< 0.0016	0.0024	0.0023	<0.0017	<0.0017	0.0015	0.015
Manganese	**1.7**	**2.8**	**2**	**2.48**	**1.9**	0.025	0.05
Mercury	0.000097	< 0.000067	<0.000029	0.000055	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	<0.00071	<0.00071	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	6	4.7	5	7.4	5.5	125	250
Nitrate as N	< 0.0076	0.02	<0.016	<0.016	<0.031	2	10
Sulfate	0.42	1.8	0.2	0.21	<0.12	125	250
Total Alkalinity	100	140	---	----	130	----	----
Total Organic Carbon	4	3	---	----	4	----	----

pH	7.49	7.44	7.64	7.53	7.75	----	----
Conductivity (mS/cm)	0.227	0.289	0.3	199	178	----	----
Temperature (C)	10.5	10.71	10.25	10.51	10.13	----	----
ORP (mV)	96	140	195	25.4	77.9	----	----
Dissolved Oxygen (mg/L)	0.42	4.41	3.22	1.42	1.67	----	----

MW-8S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	12/11/2002	10/07/2003	12/02/2004	06/08/2005	03/21/2007	PAL	ES
Acetone	2.2	< 0.66	<0.74	<0.74	1	200	1000
Methylene chloride	2.6	< 0.28	0.5	<0.19	0.2	0.5	5

Metals, mg/L

Arsenic	< 0.0021	< 0.0029	<0.0026	<0.0026	<0.0043	0.001	0.01
Barium	0.088	0.093	0.073	0.0637	0.0525	0.4	2
Cadmium	< 0.00028	< 0.00036	0.00029	<0.00028	<0.00042	0.0005	0.005
Cobalt	< 0.00074	< 0.0011	<0.00096	<0.00096	<0.0012	0.008	0.04
Iron	0.052	< 0.044	**0.45**	<0.049	<0.032	0.15	0.3
Lead	< 0.0016	< 0.0023	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**0.59**	**0.32**	**0.79**	**0.33**	**0.135**	0.025	0.05
Mercury	< 0.000087	< 0.000067	<0.000029	<0.000029	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	0.001	<0.00071	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	9.5	17.2	7.1	6.8	17.4	125	250
Nitrate as N	1.5	0.15	0.21	0.087	0.051	2	10
Sulfate	12.3	5.6	12.2	9.4	2.4	125	250
Total Alkalinity	190	230	---	---	230	----	----
Total Organic Carbon	0.9	2	---	---	3	----	----

pH	7.32	7.15	7.41	7.15	7.32	----	----
Conductivity (mS/cm)	0.44	0.497	0.373	237	316	----	----
Temperature (C)	11.73	11.96	12.14	9.5	9.52	----	----
ORP (mV)	124	177	208	163	271.5	----	----
Dissolved Oxygen (mg/L)	7.07	4.3	3.34	6.64	5.32	----	----

MW-8M
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	12/11/2002	10/07/2003	12/02/2004	06/08/2005	03/21/2007	PAL	ES
1,2,4-Trimethylbenzene	< 0.37	0.36	1.7	4.1	28	96	480
1,3,5-Trimethylbenzene	< 0.4	0.22	<0.16	1.6	<0.27	96	480
Acetone	2.9	< 0.66	<0.74	<0.74	1.9	200	1000
Benzene	< 0.37	< 0.2	0.3	0.53	<0.37	0.5	5
Chloroethane	< 0.29	< 0.22	0.43	<0.24	<0.4	80	400
cis-1,2-Dichloroethene	< 0.35	< 0.25	0.41	0.39	<0.35	7	70
Ethylbenzene	< 0.41	< 0.19	2.4	2.6	0.74	140	700
Methylene chloride	3.2	< 0.28	0.55	<0.19	0.32	0.5	5
Naphthalene	< 0.42	< 0.16	<0.15	0.43	<0.25	10	100
Trichloroethene	< 0.42	0.23	0.3	<0.28	<0.47	0.5	5

Metals, mg/L

Arsenic	< 0.0021	< 0.0029	0.0027	0.0047	0.0058	0.001	0.01
Barium	0.68	0.73	0.7	0.997	0.874	0.4	2
Cadmium	< 0.00028	< 0.00036	0.0003	<0.00028	<0.00042	0.0005	0.005
Cobalt	< 0.00074	< 0.0011	<0.00096	<0.00096	<0.0012	0.008	0.04
Iron	< 0.042	0.045	0.12	**0.4**	0.27	0.15	0.3
Lead	< 0.0016	< 0.0023	0.002	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.7**	**2.8**	**3.3**	**4.34**	**3.97**	0.025	0.05
Mercury	0.00009	< 0.000067	<0.000029	0.000063	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	<0.00071	<0.00071	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	2.6	12.8	14	21.9	12.4	125	250
Nitrate as N	< 0.0076	< 0.019	<0.016	<0.016	<0.031	2	10
Sulfate	5.7	1.1	0.84	0.48	0.45	125	250
Total Alkalinity	220	240	---	----	330	----	----
Total Organic Carbon	2	3	---	----	4	----	----

pH	7.41	7.31	7.37	7.3	7.48	----	----
Conductivity (mS/cm)	0.422	0.479	0.558	393	426	----	----
Temperature (C)	9.95	10.44	10.21	10.88	10.64	----	----
ORP (mV)	105	150	194	-49.1	-39.1	----	----
Dissolved Oxygen (mg/L)	1.74	0.92	1.02	0.79	1	----	----

MW-10M
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	06/08/2005	03/22/2006	03/21/2007	PAL	ES
Acetone	1	0.79	<0.74	200	1000
Carbon disulfide	0.71	<0.28	<0.28	200	1000
cis-1,2-Dichloroethene	0.34	0.21	0.25	7	70
Methylene chloride	<0.19	0.38	<0.19	0.5	5
Trichloroethene	0.37	<0.28	<0.28	0.5	5

Metals, mg/L					
Arsenic	<0.0026	<0.0043	<0.0043	0.001	0.01
Barium	0.104	0.0653	0.0604	0.4	2
Cadmium	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	0.0012	<0.0012	<0.0012	0.008	0.04
Iron	0.068	<0.032	0.035	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.33**	**1.86**	**1.52**	0.025	0.05
Mercury	0.000048	<0.00009	<0.00009	0.0002	0.002
Vanadium	0.00095	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L					
Chloride	1.6	3	3.6	125	250
Nitrate as N	<0.016	<0.015	<0.031	2	10
Sulfate	6.2	8.7	5.2	125	250
Total Alkalinity	----	220	170	----	----
Total Organic Carbon	----	1	2	----	----

pH	7.22	7.55	7.51	----	----
Conductivity (mS/cm)	232	2.65	236	----	----
Temperature (C)	11.06	10.73	10.69	----	----
ORP (mV)	126	112	123	----	----
Dissolved Oxygen (mg/L)	1.45	1.1	0.53	----	----

MW-12S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	12/11/2002	10/07/2003	06/09/2005	PAL	ES
Acetone	3	< 0.66	<0.74	200	1000
Methylene chloride	2.7	< 0.28	<0.19	0.5	5
Naphthalene	< 0.42	< 0.16	0.17	10	100

Metals, mg/L

Arsenic	< 0.0021	< 0.0029	<0.0026	0.001	0.01
Barium	0.021	0.021	0.0158	0.4	2
Cadmium	< 0.00028	< 0.00036	<0.00028	0.0005	0.005
Cobalt	< 0.00074	< 0.0011	<0.00096	0.008	0.04
Iron	< 0.042	< 0.044	<0.049	0.15	0.3
Lead	0.0034	< 0.0023	<0.0017	0.0015	0.015
Manganese	0.0023	0.0017	0.0025	0.025	0.05
Mercury	< 0.000087	< 0.000067	<0.000029	0.0002	0.002
Vanadium	< 0.00067	0.0013	<0.00071	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	24.3	9.1	3.5	125	250
Nitrate as N	1.6	1.4	1	2	10
Sulfate	7.2	5	4.4	125	250
Total Alkalinity	170	210	---	---	---
Total Organic Carbon	1	0.8	---	---	---

pH	7.29	7.44	6.81	---	---
Conductivity (mS/cm)	0.444	0.438	197	---	---
Temperature (C)	12.04	11.97	9.34	---	---
ORP (mV)	132	190	185.5	---	---
Dissolved Oxygen (mg/L)	5.86	9.0	11.92	---	---

MW-14S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**12/12/2002**	**04/23/2003**	**10/08/2003**	**04/13/2004**	**12/02/2004**	**06/09/2005**	**03/22/2006**	**09/08/2006**	**03/22/2007**	**09/10/2007**	**PAL**	**ES**
1,2,4-Trimethylbenzene	1.7	0.97	5.5	2.1	3.1	2.5	1.9	3.7	1.1	4.4	96	480
1,3,5-Trimethylbenzene	0.64	< 0.4	1.8	0.8	1.3	0.96	0.66	1.1	0.34	1.8	96	480
2-Butanone	< 0.59	< 0.59	< 1.8	< 0.36	<0.65	<0.39	1.2	<0.65	<0.39	<0.57	90	460
Acetone	4.3	< 1.1	< 3.3	< 0.66	2	<0.74	2.3	<1.2	2.1	<1.1	200	1000
Benzene	< 0.37	< 0.37	< 1	0.43	<0.37	<0.22	<0.22	<0.37	<0.22	<0.13	0.5	5
Ethylbenzene	< 0.41	< 0.41	1.2	0.4	0.78	0.76	0.49	0.98	0.35	1	140	700
Methylene chloride	2.1	< 0.29	< 1.4	< 0.28	1.2	<0.19	<0.19	<0.32	0.3	<0.33	0.5	5
Naphthalene	5	2.2	18	6	11	13	8.8	18	7.5	16	10	100
Xylenes (total)	1.4	0.47	2.3	1.1	2.1	2.3	1.4	2.6	0.86	2.9	1,000	10,000

Metals, mg/L												
Arsenic	< 0.0021	< 0.0021	< 0.0029	< 0.0026	0.0029	<0.0026	<0.0043	<0.0043	<0.0043	<0.0043	0.001	0.01
Barium	0.18	0.084	0.19	0.11	0.16	0.168	0.117	0.154	0.0893	0.13	0.4	2
Cadmium	*0.00045*	*< 0.00028*	*< 0.00036*	*< 0.00028*	*<0.00028*	*<0.00028*	*<0.00042*	*<0.00042*	*<0.00042*	*<0.00042*	*0.0005*	*0.005*
Cobalt	0.0052	0.0015	< 0.0011	0.0017	0.0013	0.0018	<0.0012	<0.0012	<0.0012	0.0013	0.008	0.04
Iron	**11.6**	**2.5**	**17.8**	**5.4**	**12.1**	**12.9**	**7.4**	**13.6**	**3.5**	**8.4**	0.15	0.3
Lead	< 0.0016	< 0.0016	< 0.0023	< 0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**3.7**	**0.83**	**7**	**1.9**	**3.1**	**2.88**	**1.9**	**3.36**	**1.05**	**2.2**	0.025	0.05
Mercury	0.000088	< 0.000087	< 0.000067	< 0.000029	<0.000029	0.000069	<0.00009	<0.00009	<0.00009	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00067	< 0.00096	< 0.00071	0.0011	<0.00071	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Natural Attenuation *Parameters, mg/L*												
Chloride	5	5.4	7.3	5.7	3.4	4.4	6	5.6	5.8	2.6	125	250
Nitrate as N	0.01	0.34	< 0.019	0.21	0.082	0.13	0.16	<0.031	0.16	0.1	2	10
Sulfate	3	5.4	0.18	8.4	4.3	3.9	7.9	2.6	4.4	6.3	125	250
Total Alkalinity	210	150	170	160	---		170	180	140	190	----	----
Total Organic Carbon	14	5	12	10	---		7	9	6	13	----	----

pH	6.88	6.96	6.89	---	6.41	6.45	6.91	6.75	6.77	6.59	----	----
Conductivity (mS/cm)	0.441	0.328	0.404	---	0.385	229	223	247	201	0.248	----	----
Temperature (C)	11.13	7.7	12.24	---	11.6	9.3	8.52	12.05	7.97	12.38	----	----
ORP (mV)	114	166	162	---	188	-45.5	-23.3	-88.1	13.4	181.3	----	----
Dissolved Oxygen (mg/L)	3.22	5.02	6.03	---	2.11	4.08	7.56	0.84	4.35	6.13	----	----

MW-15M
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**12/12/2002**	**10/07/2003**	**Duplicate 10/7/2003**	**12/02/2004**	**06/08/2005**	**03/22/2006**	**09/07/2006**	**03/22/2007**	**09/11/2007**	**PAL**	**ES**
1,1-Dichloroethane	1	< 0.26	< 0.26	<0.21	<0.21	<2.1	<0.21	<0.21	<0.15	85	850
1,2,4-Trimethylbenzene	< 0.37	0.29	0.28	<0.12	<0.12	290	12	4.1	<0.12	96	480
1,3,5-Trimethylbenzene	< 0.4	< 0.18	< 0.18	<0.16	<0.16	<1.6	<0.16	<0.16	<0.096	96	480
2-Butanone	< 0.59	< 0.36	< 0.36	<0.39	<0.39	5.7	<0.39	<0.39	<0.57	90	460
Acetone	< 1.1	< 0.66	< 0.66	<0.74	<0.74	12	<0.74	<0.74	1.2	200	1000
Chlorobenzene	< 0.38	< 0.16	< 0.16	<0.2	0.26	<2	<0.2	<0.2	0.39	-----	-----
cis-1,2-Dichloroethene	0.56	0.29	0.26	<0.21	<0.21	<2.1	<0.21	<0.21	0.24	7	70
Methylene chloride	3	< 0.28	< 0.28	0.44	<0.19	<1.9	<0.19	<0.19	<0.33	0.5	5
Naphthalene	< 0.42	< 0.16	< 0.16	<0.15	<0.15	2.5	<0.15	<0.15	<0.24	8	40
Metals, mg/L											
Arsenic	0.0054	< 0.0029	< 0.0029	<0.0026	0.0026	<0.0043	<0.0043	<0.0043	<0.0043	0.001	0.01
Barium	0.86	0.74	0.75	0.44	0.958	1.06	0.874	0.679	0.834	0.4	2
Cadmium	0.00031	0.00092	< 0.00036	<0.00028	<0.00028	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	0.0012	< 0.0011	< 0.0011	<0.00096	<0.00096	<0.0012	<0.0012	<0.0012	<0.0012	0.008	0.04
Iron	**1.1**	**4.1**	**1.6**	**0.51**	**0.64**	**0.67**	0.13	0.069	**0.3**	0.15	0.3
Lead	0.0049	**0.13**	**0.043**	<0.0017	0.002	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**3.6**	**3.4**	**3.5**	**2.2**	**4.65**	**5.53**	**5.01**	**3.43**	**4.72**	0.025	0.05
Mercury	0.000092	< 0.000067	< 0.000067	<0.000029	0.0001	<0.00009	<0.00009	<0.00009	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	< 0.00096	<0.00071	<0.00071	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03
Natural Attenuation Parameters, mg/L											
Chloride	5.2	5.1	5.2	3.8	12.3	7.3	9.1	8.5	12.8	125	250
Nitrate as N	0.03	< 0.019	< 0.019	<0.016	<0.016	<0.015	<0.031	<0.031	<0.023	2	10
Sulfate	2.4	5.8	5.6	5.5	3.6	0.84	0.67	1.8	0.2		250
Total Alkalinity	240	230	230	---	---	330	300	220	320	----	----
Total Organic Carbon	3	2	2	---	---	7	5	6	5	----	----
pH	7.25	7.2	---	7.44	7.2	7.43	7.41	7.44	7.3	----	----
Conductivity (mS/cm)	0.466	0.469	---	0.299	320	397	344	297	0.377	----	----
Temperature (C)	10.65	10.76	---	10.31	10.64	10.18	10.84	10.18	10.67	----	----
ORP (mV)	93	100	---	172	-59.2	-50	-74.6	-32.5	202.3	----	----
Dissolved Oxygen (mg/L)	0.51	2.3	---	0.68	0.66	1.42	0.64	0.71	0.56	----	----

MW-16S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	03/23/2006	06/09/2006	09/07/2006	12/11/2006	03/23/2007	06/21/2007	09/11/2007	PAL	ES
1,2,4-Trimethylbenzene	**1500**	390	**1800**	400	370	**610**	400	96	480
1,3,5-Trimethylbenzene	**150**	16	**200**	9.8	9.3	**11**	<2.7	96	480
Acetone	120	27	<46	<4.9	<4.9	<37	<31	200	1000
Chlorobenzene	<13	<3.3	<12	<1.3	1.7	<5	<4.3	-----	-----
Ethylbenzene	22	4.6	20	8.1	8.1	<5.7	<4.9	140	700
Methylene chloride	<13	<3.2	<12	4.7	<1.3	**58**	<9.4	0.5	5
Naphthalene	**37**	4.9	**37**	**27**	**49**	8	7.1	10	10
Xylenes (total)	91	22	61	15	12	16	16	1,000	10,000

Metals, mg/L

Arsenic	0.0099	0.0076	**0.0111**	0.0057	**0.0124**	**0.012**	**0.0104**	0.001	0.01
Barium	0.45	0.408	0.366	0.212	0.274	0.513	0.461	0.4	2
Cadmium	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	0.0052	0.0072	0.0039	0.0021	0.0025	0.0054	0.0036	0.008	0.04
Iron	**42.6**	**46.4**	**37.3**	**22.3**	**32.6**	**43.1**	**29.6**	0.15	0.3
Lead	0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**9.53**	**12.2**	**8.42**	**4.52**	**5.38**	**11.8**	**12.2**	0.025	0.05
Mercury	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	0.000095	<0.00009	0.0002	0.002
Vanadium	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	4.7	17.8	12.3	36.2	21.8	14.2	39.7	125	250
Nitrate as N	<0.015	<0.015	<0.031	<0.031	<0.031	<0.031	<0.023	2	10
Sulfate	2.4	4.4	<0.12	<0.12	1.9	6.1	1.8		250
Total Alkalinity	470	570	460	180	260	610	590	----	----
Total Organic Carbon	12	9	11	7	10	11	10	----	----

pH	6.75	6.62	6.58	6.68	6.63	6.69	6.58	----	----
Conductivity (mS/cm)	624	766	625	393	419	819	0.843	----	----
Temperature (C)	9.27	10.44	14.16	11.59	9.3	10.79	15.49	----	----
ORP (mV)	-55.8	-89.1	-110.6	-92	-42.5	-82.3	-64.3	----	----
Dissolved Oxygen (mg/L)	2.22	2.2	0.83	1.59	0.54	1.42	1.17	----	----

MW-16M
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	03/23/2006	Duplicate 3/23/2006	06/09/2006	09/07/2006	12/11/2006	03/23/2007	Duplicate 3/23/2007	06/21/2007	09/11/2007	PAL	ES
1,2,4-Trimethylbenzene	34	37	15	190	68	240	240	47	2.7	96	480
1,3,5-Trimethylbenzene	<0.32	<0.32	<0.16	<1.1	<0.16	7.1	8.6	<0.24	<0.096	96	480
2-Butanone	<0.78	1.4	<0.39	<2.6	<0.39	<1.3	<1.3	<1.4	<0.57	90	460
Acetone	4.3	4.2	<0.74	<4.9	<0.74	<2.5	<2.5	<2.8	<1.1	200	1000
Benzene	0.97	0.86	0.76	<1.5	0.59	1.6	1.7	<0.32	0.88	0.5	5
Chlorobenzene	2.2	2.2	1.7	<1.3	1.7	2.9	2.8	1.8	1	-----	-----
Chloroethane	1.3	1.4	1.3	<1.6	<0.24	<0.8	0.87	<0.72	0.44	80	400
Methylene chloride	<0.38	<0.38	<0.19	<1.3	<0.19	<0.63	<0.63	2.7	<0.33	0.5	5
Naphthalene	3.1	3	1.8	23	5.8	13	12	2.1	0.3	1-	100
Xylenes (total)	4.2	4	1.4	3.6	2.7	5	7	<0.7	0.7	1,000	10,000

Metals, mg/L											
Arsenic	**0.0225**	**0.0213**	**0.0204**	**0.0103**	<0.0043	**0.0277**	**0.0245**	**0.0234**	**0.0141**	0.001	0.01
Barium	1.04	0.981	1.13	1.31	1.14	1.84	1.81	1.01	1.13	0.4	2
Cadmium	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	<0.0012	<0.0012	<0.0012	0.0022	<0.0012	0.0013	<0.0012	<0.0012	<0.0012	0.008	0.04
Iron	**22.1**	**20.7**	**22.6**	**20.9**	**7.5**	**32.9**	**31.8**	**18.1**	**18**	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**1.43**	**1.36**	**1.28**	**1.88**	**1.14**	**1.82**	**1.78**	**1.06**	**1.32**	0.025	0.05
Mercury	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	0.0002	0.002
Vanadium	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L											
Chloride	31.9	32	41.1	43.5	42.4	35.2	35.3	23.8	30.1	125	250
Nitrate as N	<0.015	<0.015	<0.015	<0.031	<0.031	<0.031	<0.031	<0.031	<0.023	2	10
Sulfate	<0.12	<0.12	0.34	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12		250
Total Alkalinity	180	180	170	250	170	260	270	170	180	----	----
Total Organic Carbon	5	120	5	7	5	7	7	5	5	----	----

pH	7.15	---	7.05	6.99	7.31	7.2	----	7.27	7.17	----	----
Conductivity (mS/cm)	329	---	355	410	352	481	----	327	0.301	----	----
Temperature (C)	10.83	---	11.27	11.48	9.85	11.17	----	11.38	10.87	----	----
ORP (mV)	-114	---	-140.6	-149.7	-153	-131.5	----	-155.3	-40.5	----	----
Dissolved Oxygen (mg/L)	0.88	---	0.85	0.17	0.48	0.52	----	0.4	0.62	----	----

MW-17S
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	03/23/2006	06/09/2006	09/07/2006	12/11/2006	03/23/2007	06/21/2007	09/11/2007	PAL	ES
1,2,4-Trimethylbenzene	400	420	1100	550	240	1200	1200	96	480
1,3,5-Trimethylbenzene	47	74	67	38	21	45	15	96	480
Acetone	82	14	<25	<7.4	<2.5	<69	<69	200	1000
Ethylbenzene	7.8	4.9	<6.3	2.7	1.6	<11	<11	140	700
Methylene chloride	<7.6	<2.7	<6.3	6.3	<0.63	130	<21	0.5	5
Naphthalene	<6	<2.1	7.7	10	1.4	<15	<15	10	100
Xylenes (total)	22	17	<15	8.7	1.8	<18	<18	1,000	10,000

Metals, mg/L

Arsenic	0.0086	0.0095	0.009	0.0063	<0.0043	0.0117	0.0116	0.001	0.01
Barium	0.23	0.183	0.229	0.216	0.146	0.265	0.272	0.4	2
Cadmium	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	<0.0012	0.0016	<0.0012	<0.0012	0.0017	<0.0012	0.0025	0.008	0.04
Iron	21	22.2	25.4	22.3	7.6	31.7	30.4	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	3.65	3.22	3.79	3.33	1.39	3.51	4.38	0.025	0.05
Mercury	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	0.00011	<0.00009	0.0002	0.002
Vanadium	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	4.2	5.8	4.9	6.4	4.6	4.5	3.1	125	250
Nitrate as N	0.97	0.29	<0.031	0.2	2.1	0.3	0.4	2	10
Sulfate	1.6	3.3	0.34	0.63	16	1.5	2.7		250
Total Alkalinity	230	190	200	190	220	250	300	----	----
Total Organic Carbon	4	4	4	3	3	3	5	----	----

pH	7.06	1.51	6.78	6.92	6.97	6.88	6.67	----	----
Conductivity (mS/cm)	322	295	313	324	312	375	0.418	----	----
Temperature (C)	9.29	10.33	13.35	11.24	7.79	9.99	13.8	----	----
ORP (mV)	-88.7	-92.7	-123	-103.8	-12.4	-86.7	49.5	----	----
Dissolved Oxygen (mg/L)	1.1	1.51	0.26	1.43	3.09	1.25	0.45	----	----

MW-17M
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	03/23/2006	06/09/2006	09/07/2006	12/11/2006	03/23/2007	06/21/2007	09/11/2007	PAL	ES
1,2,4-Trimethylbenzene	<0.12	1.3	<0.12	5.2	<0.12	34	9.7	96	480
1,3,5-Trimethylbenzene	<0.16	<0.16	<0.16	<0.16	<0.16	<0.096	<0.096	96	480
Acetone	1.6	1.3	<0.74	<0.74	<0.74	<1.1	<1.1	200	1000
Methylene chloride	<0.19	1.7	<0.19	<0.19	<0.19	<0.33	<0.33	0.5	5
Toluene	<0.17	0.56	<0.17	<0.17	<0.17	<0.13	<0.13	200	1,000

Metals, mg/L

Arsenic	0.0059	0.0078	0.006	<0.0043	0.0069	0.0086	0.0074	0.001	0.01
Barium	0.433	0.586	0.713	0.756	0.683	0.77	1.05	0.4	2
Cadmium	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	0.008	0.04
Iron	**2.8**	**4.1**	**0.53**	0.11	**4.7**	**4.7**	**2.5**	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**1.71**	**2.03**	**2.43**	**2.27**	**2.09**	**2.2**	**3.52**	0.025	0.05
Mercury	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	0.000093	<0.00009	0.0002	0.002
Vanadium	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	4.8	6.1	5.4	5	4.9	3.2	5.1	125	250
Nitrate as N	<0.015	<0.015	<0.031	<0.031	<0.031	<0.031	<0.023	2	10
Sulfate	0.89	0.83	0.35	<0.12	2.2	1.9	0.6		250
Total Alkalinity	150	190	200	240	210	260	320	----	----
Total Organic Carbon	5	6	8	7	4	4	5	----	----

pH	7.39	7.23	7.4	7.61	7.56	7.56	7.54	----	----
Conductivity (mS/cm)	204	257	249	305	288	332	0.361	----	----
Temperature (C)	10.53	10.97	11.12	9.65	10.48	10.84	10.76	----	----
ORP (mV)	-113	-136.8	-159	-162.7	-146	-159.3	-155.6	----	----
Dissolved Oxygen (mg/L)	2.45	1.23	0.18	0.31	0.35	0.45	0.61	----	----

PZ-1
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	12/12/2002	04/23/2003	10/08/2003	04/13/2004	03/22/2006	03/22/2007	PAL	ES
Acetone	< 1.1	< 1.1	< 0.66	< 0.66	1.3	<0.74	200	1000
Benzene	< 0.37	< 0.37	< 0.2	0.5	<0.22	<0.22	0.5	5
Methylene chloride	3.4	< 0.29	< 0.28	< 0.28	0.39	<0.19	0.5	5

Metals, mg/L

Arsenic	0.0029	< 0.0021	< 0.0029	0.0035	<0.0043	<0.0043	0.001	0.01
Barium	0.024	0.031	0.033	0.039	0.0245	0.0349	0.4	2
Cadmium	< 0.00028	< 0.00028	< 0.00036	< 0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	< 0.00074	< 0.00074	< 0.0011	< 0.00096	<0.0012	<0.0012	0.008	0.04
Iron	< 0.042	< 0.042	< 0.044	0.058	<0.032	<0.032	0.15	0.3
Lead	< 0.0016	< 0.0016	< 0.0023	< 0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**0.19**	**0.3**	**0.37**	**0.49**	**0.258**	**0.371**	0.025	0.05
Mercury	0.000091	< 0.000087	< 0.000067	< 0.000029	<0.00009	<0.00009	0.0002	0.002
Vanadium	0.0013	0.0011	0.0012	0.0015	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	9.4	12.8	5.8	7.2	8.5	7.3	125	250
Nitrate as N	0.23	0.23	< 0.019	< 0.016	<0.015	<0.031	2	10
Sulfate	1.6	5.5	6.1	9.1	9.5	9	125	250
Total Alkalinity	120	130	190	150	120	130	---	---
Total Organic Carbon	3	< 0.7	2	3	2	2	---	---

pH	7.54	7.43	7.31	---	8.08	7.97	---	---
Conductivity (mS/cm)	0.271	0.314	0.404	---	170	194	---	---
Temperature (C)	11.33	9.93	11.09	---	9.96	9.74	---	---
ORP (mV)	105	169	186	---	223.6	70.2	---	---
Dissolved Oxygen (mg/L)	2.78	4.8	3.99	---	3.3	0.64	---	---

PZ-2
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	12/11/2002	10/07/2003	12/02/2004	06/09/2005	03/22/2006	03/22/2007	PAL	ES
Acetone	2.6	< 0.66	2.9	<0.74	0.76	<0.74	200	1000
Carbon disulfide	< 0.24	< 0.21	<0.28	0.56	<0.28	<0.28	200	1000
Methylene chloride	2.4	< 0.28	0.64	<0.19	0.42	<0.19	0.5	5

Metals, mg/L

Arsenic	**0.056**	< 0.0029	**0.011**	0.007	<0.0043	<0.0043	0.001	0.01
Barium	0.66	0.071	0.14	0.117	0.0601	0.0522	0.4	2
Cadmium	< 0.00028	< 0.00036	0.00033	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	0.011	< 0.0011	0.0024	0.0046	<0.0012	<0.0012	0.008	0.04
Iron	**98.8**	**20.8**	**39.6**	**17.3**	**35.6**	**13.5**	0.15	0.3
Lead	0.0062	< 0.0023	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**5.2**	**1.5**	**3.4**	**3.59**	**4.04**	**1.51**	0.025	0.05
Mercury	0.00013	< 0.000067	<0.000029	0.00005	0.00014	<0.00009	0.0002	0.002
Vanadium	0.026	0.0016	0.0017	0.0014	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	8.6	6.6	9.1	6.7	8.2	11.9	125	250
Nitrate as N	< 0.0076	< 0.019	<0.016	<0.016	<0.015	<0.031	2	10
Sulfate	2.4	< 0.14	3.2	2	0.81	9	125	250
Total Alkalinity	160	77	---	---	160	110	----	----
Total Organic Carbon	15	7	---	---	9	6	----	----

pH	6.68	6.67	6.41	5.72	6.83	6.79	----	----
Conductivity (mS/cm)	0.432	0.239	0.412	235	275	207	----	----
Temperature (C)	11.03	11.08	10.89	8.85	8.4	8.02	----	----
ORP (mV)	116	149	173	-68.1	-78.7	-33.1	----	----
Dissolved Oxygen (mg/L)	5.14	4.43	1.6	0.92	8.45	1.38	----	----

PZ-3
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic **Compounds (VOC), ug/L**	12/11/2002	10/07/2003	12/02/2004	06/08/2005	03/22/2006	03/21/2007	PAL	ES
1,2,4-Trimethylbenzene	< 0.37	< 0.14	<0.12	4.3	<0.12	2.1	96	480
Acetone	3.1	< 0.66	1.3	<0.74	0.8	1.1	200	1000
cis-1,2-Dichloroethene	< 0.35	< 0.25	<0.21	0.26	0.23	0.26	7	70
Methylene chloride	2.5	< 0.28	1.1	<0.19	0.38	0.21	0.5	5
Metals, mg/L								
Arsenic	0.0038	< 0.0029	<0.0026	<0.0026	<0.0043	<0.0043	0.001	0.01
Barium	0.097	0.081	0.16	0.166	0.148	0.152	0.4	2
Cadmium	0.00099	< 0.00036	<0.00028	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	0.0018	< 0.0011	0.0014	0.0016	<0.0012	0.0021	0.008	0.04
Iron	**1.2**	**0.58**	**1.5**	**2.4**	**0.7**	0.28	0.15	0.3
Lead	< 0.0016	< 0.0023	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.7**	**2.2**	**3.9**	**4.14**	**3.87**	**4.2**	0.025	0.05
Mercury	0.00012	0.00007	<0.000029	0.000055	<0.00009	<0.00009	0.0002	0.002
Vanadium	0.0028	< 0.00096	0.00092	0.0012	<0.0019	<0.0019	0.006	0.03
Natural Attenuation Parameters, mg/L								
Chloride	6.3	5.5	7.8	6.9	7.1	5.1	125	250
Nitrate as N	< 0.0076	< 0.019	<0.016	<0.016	<0.015	<0.031	2	10
Sulfate	1.2	3.5	0.74	1.5	1.7	0.42	125	250
Total Alkalinity	160	180	---	---	260	300	----	----
Total Organic Carbon	---	6	---	---	6	6	----	----
pH	7.06	6.96	6.97	6.89	7.25	7.14	----	----
Conductivity (mS/cm)	0.33	0.363	0.558	304	313	370	----	----
Temperature (C)	10.98	10.18	11.09	9.46	9.97	9.81	----	----
ORP (mV)	133	191	179	-18.9	-14.9	13.7	----	----
Dissolved Oxygen (mg/L)	4.48	3.83	0.78	1.39	4.27	0.43	----	----

PZ-4
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**12/12/2002**	**10/07/2003**	**06/08/2005**	**PAL**	**ES**
1,1-Dichloroethane	< 0.3	0.33	0.25	85	850
Acetone	3.5	< 0.66	<0.74	200	1000
cis-1,2-Dichloroethene	< 0.35	0.46	0.55	7	70
Methylene chloride	2.6	< 0.28	<0.19	0.5	5
Trichloroethene	< 0.42	0.34	<0.28	0.5	5

Metals, mg/L

Arsenic	< 0.0021	< 0.0029	<0.0026	0.001	0.01
Barium	0.12	0.077	0.145	0.4	2
Cadmium	< 0.00028	< 0.00036	<0.00028	0.0005	0.005
Cobalt	0.001	< 0.0011	0.0029	0.008	0.04
Iron	< 0.042	< 0.044	<0.049	0.15	0.3
Lead	< 0.0016	< 0.0023	<0.0017	0.0015	0.015
Manganese	**2.6**	**2**	**3.84**	0.025	0.05
Mercury	0.000088	< 0.000067	<0.000029	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	<0.00071	0.006	0.03

Natural Attenuation Parameters, mg/L

Chloride	5.5	4.5	13.1	125	250
Nitrate as N	< 0.0076	< 0.019	<0.016	2	10
Sulfate	4.2	5.1	1.7	125	250
Total Alkalinity	130	130	---	---	---
Total Organic Carbon	5	4	---	---	---

pH	7.53	7.17	7.11	---	---
Conductivity (mS/cm)	0.278	0.283	239	---	---
Temperature (C)	11.80	11.52	9.68	---	---
ORP (mV)	105	133	67	---	---
Dissolved Oxygen (mg/L)	12	3.89	0.84	---	---

PZ-5
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	12/12/2002	04/23/2003	10/08/2003	04/13/2004	12/02/2004	06/09/2005	03/23/2006	03/22/2007	PAL	ES
1,2,4-Trimethylbenzene	< 0.37	< 0.37	< 0.14	< 0.14	<0.12	<0.12	5.9	5.7	96	480
1,3,5-Trimethylbenzene	< 0.4	< 0.4	< 0.18	< 0.18	<0.16	<0.16	2.6	2.4	96	480
Acetone	3	< 1.1	< 0.66	< 0.66	<0.74	<0.74	0.91	<0.74	200	1000
Benzene	< 0.37	< 0.37	< 0.2	0.49	<0.22	<0.22	<0.22	<0.22	0.5	5
Methylene chloride	2.5	0.34	< 0.28	< 0.28	0.48	<0.19	0.45	0.21	0.5	5
Xylenes (total)	< 0.44	< 0.44	< 0.45	< 0.45	<0.44	<0.44	0.52	<0.44	1,000	10,000

Metals, mg/L										
Arsenic	< 0.0021	< 0.0021	< 0.0029	< 0.0026	<0.0026	<0.0026	<0.0043	<0.0043	0.001	0.01
Barium	0.091	0.075	0.082	0.061	0.061	0.0767	0.097	0.0957	0.4	2
Cadmium	< 0.00028	< 0.00028	< 0.00036	< 0.00028	0.00048	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	< 0.00074	< 0.00074	< 0.0011	0.001	<0.00096	0.0019	0.0018	<0.0012	0.008	0.04
Iron	0.13	0.12	< 0.044	**0.59**	0.091	0.074	0.069	**0.38**	0.15	0.3
Lead	< 0.0016	< 0.0016	< 0.0023	< 0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**0.18**	**0.17**	**0.43**	**0.67**	**0.73**	**1.67**	**3.69**	**4.46**	0.025	0.05
Mercury	0.000098	< 0.000087	< 0.000067	< 0.000029	<0.000029	0.000048	<0.00009	<0.00009	0.0002	0.002
Vanadium	0.0011	0.00075	< 0.00096	0.0012	0.0011	<0.00071	<0.0019	<0.0019	0.006	0.03

Natural Attenuation Parameters, mg/L										
Chloride	9.7	8.6	5.6	2.6	1.4	2.8	4.9	2	125	250
Nitrate as N	0.48	0.37	0.28	0.47	0.088	1.3	0.16	0.094	2	10
Sulfate	5.7	10.1	5.5	4.6	3.6	6.5	3.4	4.5	125	250
Total Alkalinity	260	220	260	190	---	----	270	240	----	----
Total Organic Carbon	2	1	2	2	---	----	0.7	2	----	----

pH	7.15	7.18	7.16	---	7.31	6.87	7.38	7.24	----	----
Conductivity (mS/cm)	0.529	0.469	0.492	---	0.361	249	302	301	----	----
Temperature (C)	10.98	8.72	10.56	---	10.95	9.11	9.75	9.41	----	----
ORP (mV)	112	159	157	---	208	164.4	35.8	33.5	----	----
Dissolved Oxygen (mg/L)	1.21	2.42	3.63	---	4.17	4.32	2.98	3.2	----	----

Ackerman
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**04/22/2003**	**10/07/2003**	**09/23/2004**	**06/08/2005**	**06/09/2006**	**09/07/2006**	**06/21/2007**	**09/10/2007**	**PAL**	**ES**
1,2,4-Trimethylbenzene	< 0.37	< 0.14	<0.12	<0.12	0.16	<0.12	<0.12	<0.12	96	480
1,3,5-Trimethylbenzene	< 0.4	< 0.18	<0.16	<0.16	<0.16	<0.16	<0.096	<0.096	96	480
Acetone	< 1.1	< 0.66	<0.74	<0.74	1.3	<0.74	<1.1	<1.1	200	1000
Chloromethane	< 0.49	< 0.26	<0.14	<0.14	0.17	<0.14	<0.3	<0.3	0.3	3
	(No VOCs Detected)									
Metals, mg/L										
Arsenic	< 0.0021	< 0.0029	<0.0026	<0.0026	<0.0043	<0.0043	<0.0043	<0.0043	0.001	0.01
Barium	0.024	0.023	0.022	0.0217	0.0202	0.0181	0.0217	0.0197	0.4	2
Cadmium	< 0.00028	< 0.00036	<0.00028	<0.00028	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	< 0.00074	< 0.0011	<0.00096	<0.00096	<0.0012	<0.0012	<0.0012	<0.0012	0.008	0.04
Iron	**5.9**	**1.7**	**5.4**	**3.8**	**4.1**	**0.57**	**4.4**	**0.88**	0.15	0.3
Lead	0.0034	< 0.0023	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**0.12**	**0.085**	**0.13**	**0.105**	**0.116**	**0.138**	**0.132**	**0.148**	0.025	0.05
Mercury	< 0.000087	< 0.000067	0.000061	0.000044	<0.00009	<0.00009	<0.00009	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	<0.00071	<0.00071	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Johnson
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	04/22/2003	10/08/2003	09/23/2004	12/02/2004	03/10/2005	06/09/2005	03/23/2006	09/07/2006	03/22/2007	09/10/2007	PAL	ES
1,2,4-Trimethylbenzene	< 0.37	0.18	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	96	480
1,3,5-Trimethylbenzene	< 0.4	< 0.18	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.096	96	480
Acetone	< 1.1	< 0.66	<0.74	<0.74	<0.74	<0.74	0.77	0.82	<0.74	<1.1	200	1000
Chloromethane	< 0.49	< 0.26	0.18	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.3	0.3	3
Methylene chloride	< 0.29	< 0.28	<0.19	0.4	<0.19	<0.19	<0.19	0.2	0.24	<0.33	0.5	5

Metals, mg/L

Metals, mg/L												
Arsenic	< 0.0021	< 0.0029	<0.0026	<0.0026	<0.0026	<0.0026	<0.0043	<0.0043	<0.0043	<0.0043	0.001	0.01
Barium	0.084	0.087	0.083	0.089	0.0751	0.116	0.0827	0.0815	0.0829	0.0726	0.4	2
Cadmium	< 0.00028	< 0.00036	<0.00028	<0.00028	<0.00028	<0.00028	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	< 0.00074	< 0.0011	<0.00096	<0.00096	<0.00096	<0.00096	<0.0012	<0.0012	<0.0012	<0.0012	0.008	0.04
Iron	0.16	0.16	0.079	0.17	0.0576	**0.72**	0.038	<0.032	0.06	0.033	0.15	0.3
Lead	< 0.0016	< 0.0023	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**0.2**	**0.32**	**0.35**	**0.2**	0.0424	**0.948**	0.0477	**0.295**	0.0378	**0.277**	0.025	0.05
Mercury	< 0.000087	< 0.000067	<0.000029	<0.000029	<0.000029	0.000086	<0.00009	<0.00009	<0.00009	<0.00009	0.0002	0.002
Vanadium	< 0.00067	< 0.00096	<0.00071	<0.00071	<0.00071	<0.00071	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

Pretasky
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	04/14/2004	09/23/2004	12/02/2004	03/10/2005	06/09/2005	03/23/2006	09/07/2006	03/22/2007	09/10/2007	PAL	ES
Acetone	< 0.66	<0.74	<0.74	<0.74	<0.74	0.87	1.7	<0.74	<1.1	200	1000
Benzene	0.34	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.13	0.5	5
Chloromethane	< 0.26	0.16	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.3	0.3	3
Methylene chloride	< 0.28	<0.19	0.58	<0.19	<0.19	<0.19	0.22	0.23	<0.33	0.5	5
Metals, mg/L											
Arsenic	0.0082	0.0035	0.0074	0.0068	0.0081	0.0066	0.0057	0.0077	0.0055	0.001	0.01
Barium	0.083	0.1	0.093	0.0962	0.116	0.119	0.105	0.122	0.107	0.4	2
Cadmium	< 0.00028	<0.00028	<0.00028	<0.00028	<0.00028	<0.00042	<0.00042	<0.00042	<0.00042	0.0005	0.005
Cobalt	< 0.00096	<0.00096	<0.00096	<0.00096	<0.00096	<0.0012	<0.0012	<0.0012	<0.0012	0.008	0.04
Iron	0.22	**0.51**	0.15	0.17	0.19	0.091	<0.032	0.24	0.1	0.15	0.3
Lead	< 0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**1.1**	**1.3**	**1.2**	**1.17**	**1.41**	**1.52**	**1.44**	**1.52**	**1.46**	0.025	0.05
Mercury	< 0.000029	0.000061	<0.000029	<0.000029	0.000053	<0.00009	<0.00009	<0.00009	<0.00009	0.0002	0.002
Vanadium	0.0019	<0.00071	0.0015	0.001	0.0012	<0.0019	<0.0019	<0.0019	<0.0019	0.006	0.03

EW-2
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	06/09/2005	03/23/2006	03/22/2007	PAL	ES
1,2,4-Trimethylbenzene	68	3.4	1.1	96	480
1,3,5-Trimethylbenzene	<0.32	1.2	<0.16	96	480
Acetone	1.7	1.3	0.82	200	1000
Carbon disulfide	1.5	<0.28	<0.28	200	1000
Chlorobenzene	<0.4	0.21	<0.2	-----	-----
Methylene chloride	<0.38	0.35	0.23	0.5	5
Naphthalene	1.4	2.1	<0.15	10	100
Xylenes (total)	1.6	<0.44	<0.44	1,000	10,000
Metals, mg/L					
Arsenic	**0.0353**	**0.0212**	**0.0242**	0.001	0.01
Barium	0.918	0.637	0.638	0.4	2
Cadmium	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	<0.00096	<0.0012	<0.0012	0.008	0.04
Iron	**13.2**	**5.4**	**4**	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.16**	**1.37**	**1.27**	0.025	0.05
Mercury	0.000076	<0.00009	<0.00009	0.0002	0.002
Vanadium	<0.00071	<0.0019	<0.0019	0.006	0.03

EW-3
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	06/09/2005	Duplicate 6/9/2005	03/23/2006	03/22/2007	PAL	ES
1,2,4-Trimethylbenzene	9.3	9.2	1.2	7.1	96	480
1,3,5-Trimethylbenzene	1.6	1.7	<0.16	<0.16	96	480
Acetone	0.91	0.91	1	0.84	200	1000
Benzene	0.44	0.43	0.23	0.45	0.5	5
Carbon disulfide	0.72	0.77	<0.28	<0.28	200	1000
Chlorobenzene	0.66	0.65	<0.2	0.35	-----	-----
Chloroethane	1	<0.24	<0.24	<0.24	80	400
Methylene chloride	<0.19	<0.19	0.64	<0.19	0.5	5
Naphthalene	0.37	0.38	2	0.27	10	100
Xylenes (total)	0.92	0.88	<0.44	0.64	1,000	10,000

Metals, mg/L

Arsenic	**0.0335**	**0.0314**	**0.016**	**0.0214**	0.001	0.01
Barium	1.1	1.1	1.02	0.964	0.4	2
Cadmium	<0.00028	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	0.00098	0.0013	<0.0012	<0.0012	0.008	0.04
Iron	**11.6**	**11.5**	**4.7**	**5.9**	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.98**	**2.98**	**3.12**	**2.67**	0.025	0.05
Mercury	0.00012	0.000051	0.00009	<0.00009	0.0002	0.002
Vanadium	<0.00071	<0.00071	<0.0019	<0.0019	0.006	0.03

EW-4
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	06/09/2005	03/23/2006	03/22/2007	PAL	ES
1,2,4-Trimethylbenzene	86	150	160	96	480
1,3,5-Trimethylbenzene	3	2.5	<1	96	480
Acetone	2.6	1.7	<4.6	200	1000
Carbon disulfide	2	<0.47	<1.8	200	1000
Ethylbenzene	<0.48	1.9	<1.2	140	700
Methylene chloride	<0.48	0.68	3	0.5	5
Naphthalene	1.1	3.9	4.6	10	100
Xylenes (total)	2.5	3.2	<2.8	1,000	10,000

Metals, mg/L

Arsenic	**0.0282**	**0.0199**	**0.0272**	0.001	0.01
Barium	0.896	0.717	1.17	0.4	2
Cadmium	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	<0.00096	<0.0012	<0.0012	0.008	0.04
Iron	**11.9**	**4.8**	**7.5**	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**2.11**	**2.05**	**3.31**	0.025	0.05
Mercury	0.00011	<0.00009	<0.00009	0.0002	0.002
Vanadium	0.00083	<0.0019	<0.0019	0.006	0.03

EW-5
Summary of Detected Compounds
Former Onalaska Landfill

Volatile Organic Compounds (VOC), ug/L	**06/09/2005**	**03/23/2006**	**03/22/2007**	**PAL**	**ES**
1,2,4-Trimethylbenzene	<0.12	0.98	<0.12	96	480
Acetone	<0.74	<0.74	1	200	1000
Methylene chloride	<0.19	0.44	0.29	0.5	5

Metals, mg/L					
Arsenic	**0.0152**	**0.0148**	**0.0168**	0.001	0.01
Barium	0.384	0.313	0.373	0.4	2
Cadmium	<0.00028	<0.00042	<0.00042	0.0005	0.005
Cobalt	<0.00096	<0.0012	<0.0012	0.008	0.04
Iron	**1.7**	0.28	**0.97**	0.15	0.3
Lead	<0.0017	<0.0017	<0.0017	0.0015	0.015
Manganese	**1.07**	**0.984**	**1.03**	0.025	0.05
Mercury	0.000053	<0.00009	<0.00009	0.0002	0.002
Vanadium	<0.00071	<0.0019	<0.0019	0.006	0.03

2006-2007 Groundwater Monitoring Program

Quarterly: MW-16S, MW-16M, MW-17S and MW-17M. (December 2006, March 2007, June 2007 and September 2007)

Semiannual: MW-4S, MW-5S, MW-15M, AW-13, AW-20, AW-25, AW-28, and MW-14S (March 2007 and September 2007)

Annual: AW-1, MW-1SR, MW-2S, MW-2M, MW-10, EW-2, EW-3, EW-4, EW-5, PZ-1, PZ-2, PZ-3, PZ-5 (March 2007)

Four nearby private water supply wells (Ackerman, Miller, Pretasky, and Johnson) were sampled semiannually (March and September) for organics and metals only. ENSR facilitated access arrangements for the residential wells.

At the request of the WDNR, there was a modification to the March 2007 sampling event. The purpose of the modification was to further evaluate groundwater conditions at the downgradient extent of the plume. Thus, in lieu of sampling AW-13, AW-20, and AW-28; wells MW-6S, MW-6M, MW-8S, and MW-8M were sampled.

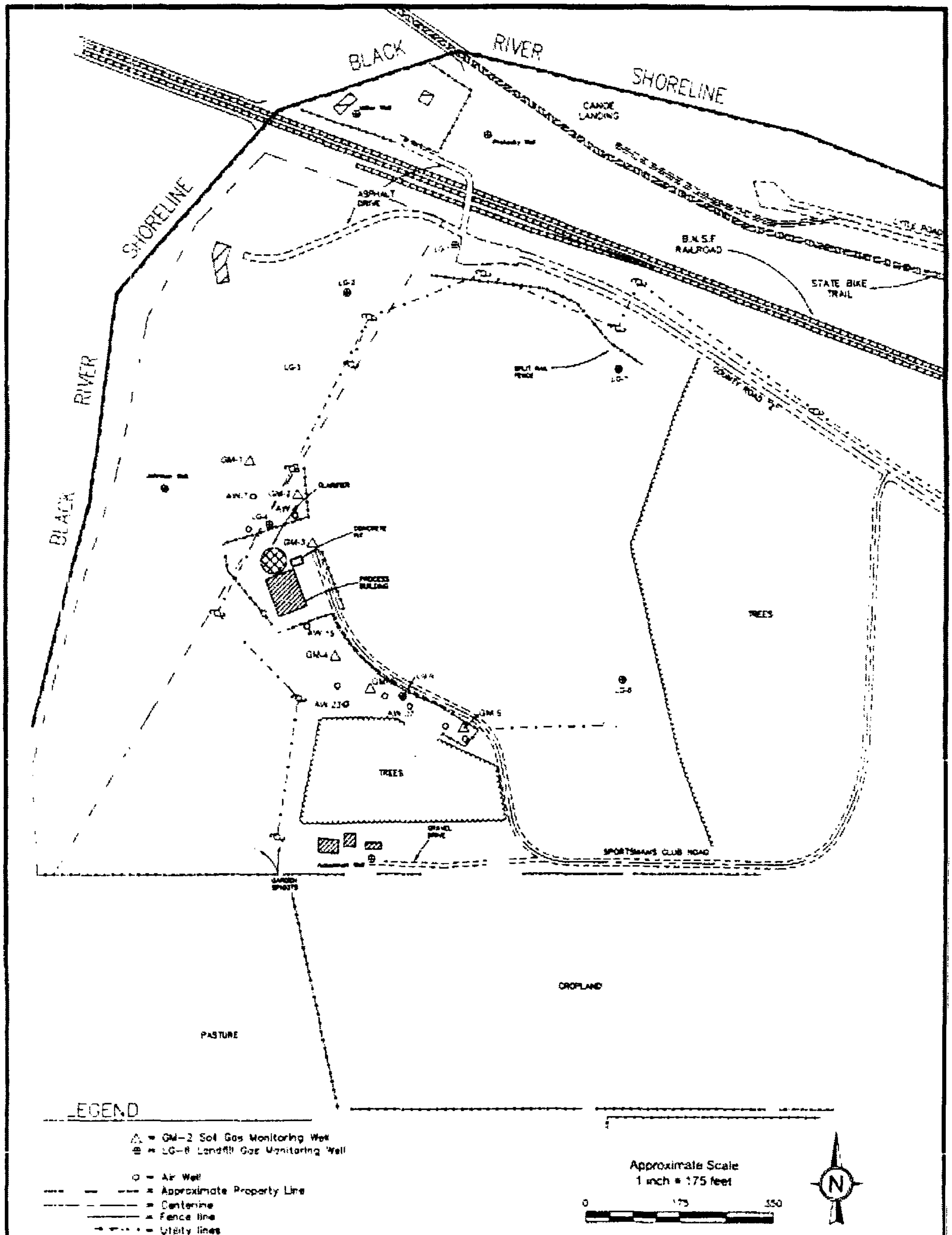
Notes:

1. Residential wells were sampled for VOCs and metals.
2. All other wells were sampled for VOCs, metals, chloride, nitrate, sulfate, total alkalinity, and total organic carbon.

Source Sampling schedule and testing requirements established by the WDNR.

ATTACHMENT 4

Soil and Soil Vapor Data



Source:
Onalaska Landfill Site Plan Survey, prepared by Coulee Region Land Surveyors, Inc., project no. S-4754 dated 5/14/03.
Location of landfill gas monitoring wells (LG) based upon a CH2MHILL figure - Landfill Gas Piping, June 1992.

Note:

Soil Gas Samples Collected on March 7, 2006

FIGURE NUMBER
5

SHEET NUMBER

Vapor Testing Points
MARCH 2006

ONALASKA LANDFILL
ONALASKA, WISCONSIN

SCALE:	DATE:	PROJECT NUMBER
1"=175'	6-12-06	7349-002

ENSR

ENSR CORPORATION
ST. LOUIS PARK, MINNESOTA 55416
PHONE: (952) 924-0117
FAX: (952) 942-0317
WEB: HTTP://WWW.ENSR.AECOM.COM

DESIGNED BY: AC
DRAWN BY: BLK
CHECKED BY: CCP
APPROVED BY: PJM

REVISIONS			
NO.	DESCRIPTION	DATE	BY

Soil Gas Results Table
Summary of Detected Compounds
Former Onalaska Landfill

Compound Name	AW-15 3/7/2006 ppm (v/v)	GM-3 3/7/2006 ppm (v/v)	GM-4 3/7/2006 ppm (v/v)	GM-5 3/7/2006 ppm (v/v)	GM-6 3/7/2006 ppm (v/v)
1,1,1-Trichloroethane	<0.00036	0.0026	0.00064	0.0017	0.00069
1,1,2-Trichloro-1,2,2-trifluoroethane	<0.00036	0.00009	0.000055	0.000079	0.000077
1,1-Dichloroethane	0.0029	0.00017	<0.000029	<0.000029	0.000092
1,2,4-Trimethylbenzene	0.0098	0.00026	0.0003	0.00022	0.00025
1,2-Dichloro-1,1,2,2-tetrafluoroethane	0.011	0.00017	<0.000057	0.00041	<0.000057
1,3,5-Trimethylbenzene	0.0031	0.000071	0.00007	0.00006	0.000085
Benzene	0.0024	0.00015	0.00012	0.00011	0.00012
Carbon tetrachloride	<0.00044	<0.000024	<0.000024	<0.000024	0.000034
Chloroethane	0.0033	<0.000051	<0.000051	<0.000051	<0.000051
Chloroform	<0.00055	<0.00003	0.00038	0.000048	0.000042
Chloromethane	<0.0018	0.00037	<0.000099	<0.000099	<0.000099
cis-1,2-Dichloroethene	0.0022	<0.000027	<0.000027	<0.000027	<0.000027
Dichlorodifluoromethane	<0.00075	0.0019	0.0018	0.0091	0.00082
Ethylbenzene	0.0016	0.00088	0.00095	0.00069	0.00087
Methylene chloride	0.0012	0.000099	0.00016	0.00011	0.00019
m-Xylene & p-Xylene	0.0061	0.0036	0.0041	0.0027	0.003
o-Xylene	<0.0012	0.00083	0.0011	0.00064	0.00068
Styrene	<0.0012	<0.000068	<0.000068	<0.000068	0.00039
Tetrachloroethene	<0.00058	<0.000032	0.0009	0.00082	0.00023
Toluene	0.0036	0.0007	0.00078	0.0006	0.0016
Trichloroethene	<0.00065	<0.000036	<0.000036	<0.000036	0.000051
Trichlorofluoromethane	<0.0013	0.00065	0.00023	0.00048	0.00025

Note: < indicates compound was not detected at or above the specified detection limit.

Field Screening Results
March 3, 2006
Former Onalaska Landfill

Sample ID	Date	PID [1]	CO_2	O_2	Methane
		ppmeq	%	%	%
LG-1	3/6/2006	0.0	1.7	19.3	0.0
LG-2	3/6/2006	0.0	0.6	20.2	0.0
LG-3	3/6/2006	0.0	0.0	20.5	0.0
LG-4	3/6/2006	0.0	0.0	20.2	0.0
LG-5	3/6/2006	0.0	0.3	20.2	0.0
LG-6	3/6/2006	0.0	0.3	20.3	0.0
LG-7	3/6/2006	0.0	1.4	19.5	0.0
GM-01	3/6/2006	0.0	2.4	18.5	0.0
GM-02	3/6/2006	0.0	2.0	18.5	0.0
GM-03 Shallow	3/6/2006	0.0	0.8	19.6	0.0
GM-03 Deep	3/6/2006	0.0	8.6	9.5	0.0
GM-04 Shallow	3/6/2006	2.8*	6.8	11.1	0.0
GM-04 Deep	3/6/2006	12.2*	11.8	0.0	3.0
GM-05	3/6/2006	3.4*	4.4	16.5	0.0
GM-06	3/6/2006	2.2*	0.7	20.0	0.0
AW-06	3/6/2006	0.0	3.6	15.9	0.0
AW-07	3/6/2006	0.0	0.6	20.3	0.0
AW-15	3/6/2006	0.2	5.8	0.0	15.1
AW-23	3/6/2006	5.7*	1.6	19.2	0.0
AW-27	3/6/2006	2.3*	2.5	16.8	1.2

Notes:

1. PID = Photoionization Detector. Readings measured in parts per million (ppm) equivalent units (calibrated to 100 ppm isobutylene).

* Indicated the PID may not have been functioning properly.

CO_2, O_2, and methane were measured using a Land Tech GA 90 Analyzer.

"Kramer, Eileen - DNR"
<Eileen.Kramer@wisconsin.gov>
07/03/2008 02:16 PM

To

Subject Onalaska

<<OnalaskaSigPage.pdf>> <<onalaskaVaporStudy.pdf>>
Kyle, here are three pages with figure and data tables from the semi-annual report that included the vapor work. Also, I have included the signature page with my boss' approval. I will send you the Docs Reviewed sheet as soon as I get back to my own computer. I have hijacked someone else's computer that has a scanner. OnalaskaSigPage.pdf onalaskaVaporStudy.pdf

INSTITUTIONAL CONTROLS

Institutional Controls

Map of Real Estate Parcels with Parcel ID Numbers &
Indicating Which Parcels Have Been Restricted

Declaration of Restrictions
Recorded April 14, 1997 by Town of Onalaska

Most Recent Recorded Deed for Landfill
Parcel ID 1418-0

Most Recent Recorded Deed for Parcel East of Landfill
Parcel ID 1422-0

Most Recent Recorded Deed for Parcel West of Landfill
Parcel ID1417-4

Most Recent Recorded Deed for Parcel South of Landfill
Parcel ID1423-0

Easement Granted by Township to Owners of
Parcel ID 1419-0 for Ingress/Egress Across Parcel ID 14230-0

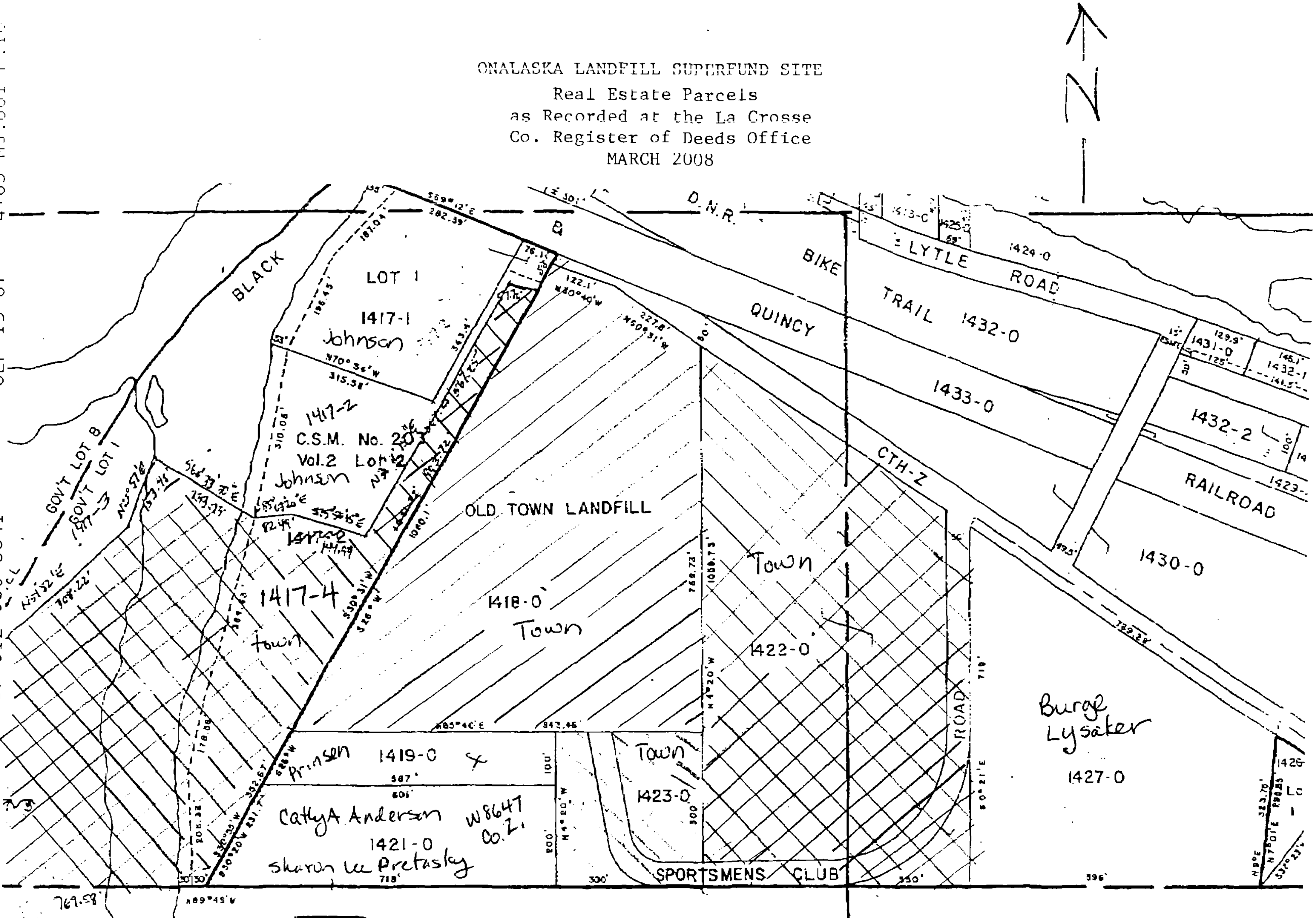
Wisconsin Administrative Code Ch. NR 500.06(4)
Affidavit of Facility Registry

Wisconsin Administrative Code Ch. NR 506.085
Final Use of Landfill

Wisconsin Administrative Code Ch. NR 812.08(4)(g)
Supply Well Location in Relation to Contamination Sources

ONALASKA LANDFILL SUPERFUND SITE

Real Estate Parcels
as Recorded at the La Crosse
Co. Register of Deeds Office
MARCH 2008



▨ PARCEL OWNED BY TOWN OF ONALASKA

▦ PARCEL OWNED BY TOWN OF ONALASKA & RESTRICTED BY DOCUMENT RECORDED AT LA CROSSE COUNTY

1171023

Document Number

DECLARATION OF RESTRICTION
ON USE OF REAL PROPERTY

Document Title

RECORD

AT 3:45 P. M

APR 14 1997

DEBORAH J. FLOCK
REGISTER OF DEEDS
LA CROSSE COUNTY

Recording Area #45 26.00

Name and Return Address

Daniel E. Dunn
401 Main Street
Ste. 400
PO BOX 1627
LaCrosse, WI 54602-1627

Parcel Identification Number (PIN)

This information must be completed by submitter: document title, name & return address, and PIN (if required). *Other information such as the granting clauses, legal description, etc. may be placed on this first page of the document or may be placed on additional pages of the document. Note: Use of this cover page adds one page to your document and $2.00 to the recording fee. Wisconsin Statutes, 59.517.* WRDA 2/96

26.00

DECLARATION OF RESTRICTION ON USE OF REAL PROPERTY

The record owner(s) hereby declare and impose the following restrictions on the real property (also known as the Onalaska Municipal Landfill) located in the County of LaCrosse, Onalaska Township, more particularly described as follows:

See Exhibits "A", "B" and "C".

RECITALS

WHEREAS, the United States Environmental Protection Agency (U.S. EPA) has issued a Record of Decision (ROD) adopting a remedial action plan which requires remedial action to be undertaken on the property and further institutional controls to assure that the remedy is protective of human health and the environment;

WHEREAS, the United States District Court for the Western District of Wisconsin has approved a Consent Decree entered into between the United States of America and Settling Defendant and (in a case styled United States of America v. Township of Onalaska) which Consent Decree concerns the remedial actions to be undertaken at the Onalaska Municipal Landfill. Section IX, of the Consent Decree identifies institutional controls which are necessary to effectuate and protect the remedial action chosen in the ROD at the Onalaska Municipal Landfill and to protect the public health or welfare or the environment at the Onalaska Municipal Landfill site;

NOW, THEREFORE, by this instrument there are created, declared and established at the property the following restrictive covenants and requirements, which shall, unless amended, run with land and remain in full force and effect in perpetuity from the date hereof, irrespective of any sale, conveyance, alienation, or other transfer of any interest or estate in such property.

RESTRICTIONS APPLICABLE TO THE PROPERTY

The following restrictions shall apply to the property described above:

1. There shall be no consumptive or other use of the groundwater underlying the property.
2. There shall be no use of, or activity at, the property that may interfere with the work performed or to be performed under the Consent Decree or pursuant to the ROD at the property, or any activity which may damage any remedial action component constructed for or installed pursuant to the Consent Decree or the ROD or otherwise impair the effectiveness of any Work to be performed pursuant to the Consent Decree or the ROD.
3. There shall be no installation, construction, removal or use of any buildings, wells, pipes, roads, ditches or any other structures at the property except as approved by the U.S. EPA as consistent with the Consent Decree and the ROD.
4. There shall be no residential use of the property.

The restrictions specified above shall continue in full force and effect until the Onalaska Municipal Landfill site is deleted from the National Priorities List, all remedial action clean-up and performance standards have been met, or until such time as the U.S. EPA issues a determination in writing or the court rules to either modify or terminate the restrictions in response to a petition from the owner(s) of the property, as provided below.

If the Owner, its successors and assigns, at any time violates, threatens or attempts to violate, or fails to faithfully observe or perform each of the foregoing restrictions and covenants upon the Real Estate, it shall be lawful for U.S. EPA, the State of Wisconsin or the Settling Defendants, in addition to other remedies available under law or equity, to institute and prosecute appropriate proceedings, judicial or other, at law or in equity for the wrong done, threatened or attempted.

COPY OF RESTRICTIONS

A copy of these restrictions shall be provided by the owner(s) of the property to all respective successors, assigns and transferee of the property.

PETITION TO MODIFY OR TERMINATE DEED RESTRICTIONS

After all work, as defined in the Consent Decree and as required to be performed under the ROD, has been completed and upon achievement of Cleanup Standards, consistent with the ROD, the owner(s) of the property may petition the Regional Administrator of the U.S. EPA, Region V, or his delegate, to modify or terminate the deed restrictions. Any petition for modification or termination shall state the specific provision sought to be modified or terminated and any proposed additional uses of the property. Any proposed modification or terminations must not be inconsistent with the requirements set forth in the Consent Decree.

The property owner(s) shall provide to the Settling Defendant a copy of any petition for modification or termination of deed restriction submitted to the U.S. EPA. Any party may object to the proposed use of the property on the grounds that such use is not consistent with the Consent Decree, or may result in exceedances of the Clean-up Standards required by the ROD. Any party so objecting shall notify the owner(s) of the property, the U.S. EPA, and the State of Wisconsin in writing, within thirty (30) days of receipt of the petition. The Regional Administrator may allow or deny the owner's petition for modification or termination in whole or in part. Any dispute as to the Regional Administrator's determination is subject to Section XI (Dispute Resolution) of the Consent Decree.

SEVERABILITY

If any provision of this Declaration of Restriction On User of Real Property is held to be invalid by any court of competent jurisdiction, the invalidity of such provision shall not affect the validity of any other provisions hereof. All such other provisions shall continue unimpaired in full force and effect.

CONFLICT OF LAWS

If any provision of this Declaration of Restrictions On Use of Real Property is also the subject of any law or regulation established by any federal, state or local government, the stricter of the two standards shall prevail.

HARMONIOUS CONSTRUCTION

No provision of this Declaration of Restriction On Use of Real Property shall be construed so as to violate any applicable zoning laws, regulations or ordinances. If any such conflict does arise, the applicable zoning laws, regulations or ordinances shall prevail, unless they are inconsistent with CERCLA.

The undersigned persons executing this Declaration of Restrictions On Use of Real Property on behalf of the owner(s) of the property represent and certify that they are duly authorized and have been fully empowered to execute this Declaration.

IN WITNESS WHEREOF, the owner(s) of the property have caused this Declaration of Restrictions On Use of Real Property to be executed on this 2 day of April, 1997.

OWNER SETTLING DEFENDANT
TOWN OF ONALASKA

By: Carl Pedretti
Carl Pedretti, Chairman

By: Linda M. Carlson
Linda Carlson, Clerk

Subscribed and sworn to before me
this 2nd day of April, 1997.

Notary Public, State of Wisconsin
My commission ~~expires~~: is permanent

DRAFTED BY:
Attorney Daniel E. Dunn
Fitzpatrick, Smyth, Dunn &
Fitzpatrick
401 Main Street, Suite 400
La Crosse, WI 54601

Part of Lot Two (2) of Certified Survey Map #203, Doc. #954321, filed in Volume 2 of La Crosse County Certified Survey Maps, Page 203 and part of Government Lot One (1) (being that part of the Southwest quarter of the Southeast quarter (SW 1/4-SE 1/4) and that part of the Southeast quarter of the Southwest quarter (SE 1/4-SW 1/4), lying Easterly of the Black River) of Section 9, Township 17 North, Range 8 West, described as follows: Commencing at the Southeast corner of said Section 9; thence North 89' 49' 48" West, along the South line of said Section 9, a distance of 2640.26 feet to the Southeasterly corner of said Lot 2 of Certified Survey Map #203 and the point of beginning of this description; thence South 89' 56' 30" West, along the South line of said Section 9, a distance of 769.58 feet to a point on the Easterly boundary of the United States Department of Agriculture, Upper Mississippi River Wildlife and Fish Refuge; thence North 34' 36' 00" East, along said Refuge boundary, 300.30 feet; thence continue along said Refuge boundary North 40' 42' 00" East 326.04 feet; thence continue along said Refuge boundary North 51' 52' 00" East 308.22 feet; thence continue along said refuge boundary North 23' 57' 00" East 153.48 feet; thence South 60' 33' 30" East 233.73 feet; thence North 85' 03' 20" East 82.49 feet; thence South 75' 50' 35" East 144.94 feet; thence North 30' 11' 15" East 567.25 feet; thence South 77' 11' 00" East 57.72 feet to a point of the Easterly line of said Lot 2 of Certified Survey Map #203; thence South 30' 31' 50" West, along the Easterly line of said Lot 2, a distance of 993.72 feet; thence continue along said Easterly line South 30' 55' 46" West 352.67 feet to the point of beginning.

This is description
of PID# 10-1417-4

EXHIBIT "A"

Part of the Southeast quarter of the Southeast quarter (SE 1/4 - SE 1/4) and part of Government Lot One (1), of Section 9, Township 17 North, Range 8 West, described as follows: Commencing at the Southeast corner of said Section 9; thence South 85 40' West 1618.60 feet to the point of beginning of this description; thence North 04 20' West 1059.73 feet; thence South 60 31' East 661.15 feet; thence South 04 20' East 719.00 feet; thence South 85 40' West 550.00 feet to the point of beginning.

This is description
of PID# 10-1422-0

EXHIBIT "B"

Part of Government Lot One (1), (being that part of the Southwest quarter of the Southeast quarter (SW 1/4-SE 1/4), lying Easterly of the Black River), of Section 9, Township 17 North, Range 8 West, described as follows: Commencing at the Southeast corner of the SE 1/4 of the SE 1/4 of said Section; thence South 85° 40' West, along the South line of said Section, a distance of 1618.6 feet to the point of beginning of this description; thence North 04° 20' West 300.0 feet; thence South 85° 40' West 300.0 feet; thence South 04° 20' East 300.0 feet; thence North 85° 40' East 300.0 feet to the point of beginning.

This is description
of PID # 10-1423-0

EXHIBIT "C"

PID #: 1418-0

DOCUMENT NO. 281241

VOL 432 PAGE 446

WARRANTY DEED—~~By~~ To Corporation
STATE OF WISCONSIN—FORM 4
THIS SPACE RESERVED FOR RECORDING DATA

RECORDED
SEP 18 1967
AT 11:20 A. M.
EVERETTE B. RUNGE
REGISTER OF DEEDS

RETURN TO

THIS INDENTURE, Made this 22nd day of August A. D., 19 67, between Fred J. Domke, a widower, part y of the first part and Town of Onalaska, a Municipal Corporation duly organized and existing under and by virtue of the laws of the State of Wisconsin, located at Onalaska Wisconsin, party of the second part.

Witnesseth, That the said part y of the first part, for and in consideration of the sum of One Dollar and other good and valuable consideration to him in hand paid by the said party of the second part, the receipt whereof is hereby confessed and acknowledged, has given, granted, bargained, sold, remised, released, aliened, conveyed and confirmed, and by these presents does give, grant, bargain, sell, remise, release, alien, convey and confirm unto the said party of the second part, its successors and assigns forever, the following described real estate situated in the County of LaCrosse and State of Wisconsin, to-wit:

Part of the SW¼ of the SE¼ of Section 9, Township 17 North, Range 8 West, lying in Government Fractional Lot 1, and described as follows:

Commencing at the SE corner of said Section 9; thence South 85° 40' West along the South line thereof 1618.6 feet; thence North 4° 20' West 300 feet to the point of beginning; thence continuing North 4° 20' West 759.73 feet; thence North 60° 31' West 227.8 feet; thence North 80° 40' West 122.1 feet; thence South 26° 00' West 1060.1 feet; thence North 85° 40' East 843.46 feet to the point of beginning, containing 11.66 acres.

This deed corrects an erroneous description in deed recorded in Volume 347 of Records, Page 563 and therefore, (OVER)

Together with all and singular the hereditaments and appurtenances thereunto belonging or in any wise appertaining; and all the estate right, title, interest, claim or demand whatsoever, of the said part y of the first part, either in law or equity, either in possession or expectancy of, in and to the above bargained premises, and their hereditaments and appurtenances.

To Have and To Hold the said premises as above described with the hereditaments and appurtenances unto the said party of the second part, and to its successors and assigns FOREVER.

And the said Fred J. Domke, a widower, for himself and his heirs, executors and administrators, does covenant, grant, bargain and agree to and with the said party of the second part, its successors and assigns, that at the time of the ensealing and delivery of these presents he is well seized of the premises above described, as of a good, sure, perfect, absolute and indefeasible estate of inheritance in the law, in fee simple, and that the same are free and clear from all incumbrances whatever,

and that the above bargained premises in the quiet and peaceable possession of the said party of the second part, its successors and assigns, against all and every person or persons lawfully claiming the whole or any part thereof, it will forever WARRANT AND DEFEND.

In Witness Whereof, the said part y of the first part has hereunto set his hand and seal this 22nd day of August, A. D., 19 67.

SIGNED AND SEALED IN PRESENCE OF

Robert C. Skemp

Doris Horton

Fred J. Domke (SEAL)
Fred J. Domke

(SEAL)

(SEAL)

(SEAL)

STATE OF WISCONSIN,
La Crosse County. } ss.

Personally came before me, this 22nd day of August, A. D., 19 67 the above named Fred J. Domke, a widower, to me known to be the person who executed the foregoing instrument and acknowledged the same.

NOTARY SEAL

Robert C. Skemp
Notary Public LaCrosse County, Wis.
My Commission (Expires) (Is) permanent.

This instrument drafted by
Peter G. Pappas

(Section 59.51 (1) of the Wisconsin Statutes provides that all instruments to be recorded shall have plainly printed or typewritten thereon the names of the grantors, grantees, witnesses and notary).

PID# 10-1422-0

DOCUMENT NO.

1132938

WARRANTY DEED
STATE OF WISCONSIN—FORM 10

THIS SPACE RESERVED FOR RECORDING DATA

VOL 1084 PAGE 86
RECORDED
AT 3:45 PM
MAY 11 1995
DEBORAH J. FLOCK
REGISTER OF DEEDS
La Crosse County, WI

RETURN TO

#45 $10.00

THIS INDENTURE, Made by Fifteen "15" Sportsmen's Club, Inc.
a Corporation duly organized and existing under and by virtue of the laws of the State of Wisconsin, grantor, of La Crosse County, Wisconsin, hereby conveys and warrants to Town of Onalaska
grantee, of La Crosse County, Wisconsin, for the sum of
the following tract of land in La Crosse County, State of Wisconsin:

Part of the Southeast quarter of the Southeast quarter (SE 1/4 - SE 1/4) and part of Government Lot One (1), of Section 9, Township 17 North, Range 8 West, described as follows: Commencing at the Southeast corner of said Section 9; thence South 85 40' West 1618.60 feet to the point of beginning of this description; thence North 04 20' West 1059.73 feet; thence South 60 31' East 661.15 feet; thence South 04 20' East 719.00 feet; thence South 85 40' West 550.00 feet to the point of beginning.

FEE
77.25 (12)
EXEMPT

(IF NECESSARY, CONTINUE DESCRIPTION ON REVERSE SIDE)

In Witness Whereof, the said grantor has caused these presents to be signed by CLAIR RUSSELL, its President, and countersigned by GARY SKOGEN its Secretary, at LA CROSSE, Wisconsin, and its corporate seal to be hereunto affixed this 18th day of April, A. D., 1995.

SIGNED AND SEALED IN PRESENCE OF

Fifteen "15" Sportsmen's Club, Inc.
Corporate Name
x Clair Russell
Clair Russell
President
COUNTERSIGNED:
x Gary Skogen
Gary Skogen
Secretary

STATE OF WISCONSIN
LA CROSSE County. } ss.

Personally came before me, this 18th day of April, A. D., 1995 CLAIR RUSSELL, President, and GARY SKOGEN, Secretary of the above named Corporation, to me known to be the persons who executed the foregoing instrument, and to me known to be such President and Secretary of said Corporation, and acknowledged that they executed the foregoing instrument as such officers as the deed of said Corporation, by its authority.

JAMES J BANNEN
NOTARY SEAL
Notary Public, LA CROSSE County, Wis.
My commission ~~(expires)~~ (is) Perm

THIS INSTRUMENT WAS DRAFTED BY

Bannen & Bannen
305 State Bank Bldg., La Crosse, WI 54601

(Section 59.51 (1) of the Wisconsin Statutes provides that all instruments to be recorded shall have plainly printed or typewritten thereon the names of the grantors, grantees, witnesses and notary. Section 59.513 similarly requires that the name of the person who, or governmental agency which, drafted such instrument, shall be printed, typewritten, stamped or written thereon in a legible manner.)

WARRANTY DEED — By Corporation
STATE OF WISCONSIN
FORM No 10

Wisconsin Legal Blank Co. Inc.
Milwaukee, Wis.

Parcel ID# 10-1417-4

DOCUMENT NO.

1132936

WARRANTY DEED

STATE BAR OF WISCONSIN FORM 2 — 1982

THIS SPACE RESERVED FOR RECORDING DATA

VOL 1084 PAGE 83

RECORDED
AT 3:45 PM
MAY 11 1995
DEBORAH J. FLOCK
REGISTER OF DEEDS
La Crosse County, WI

RETURN TO

\$45 \$10.00

Tax Parcel No:

Raymond C. Hubley, Jr. and Mary J. Hubley, husband and wife

conveys and warrants to The Town of Onalaska

the following described real estate in La Crosse County, State of Wisconsin:

Part of Lot Two (2) of Certified Survey Map #203, Doc. #954321, filed in Volume 2 of La Crosse County Certified Survey Maps, Page 203 and part of Government Lot One (1) (being that part of the Southwest quarter of the Southeast quarter (SW 1/4-SE 1/4) and that part of the Southeast quarter of the Southwest quarter (SE 1/4-SW 1/4), lying Easterly of the Black River) of Section 9, Township 17 North, Range 8 West, described as follows: Commencing at the Southeast corner of said Section 9; thence North 89° 49' 48" West, along the South line of said Section 9, a distance of 2640.26 feet to the Southeasterly corner of said Lot 2 of Certified Survey Map #203 and the point of beginning of this description; thence South 89° 56' 30" West, along the South line of said Section 9, a distance of 769.58 feet to a point on the Easterly boundary of the United States Department of Agriculture, Upper Mississippi River Wildlife and Fish Refuge; thence North 34° 36' 00" East, along said Refuge boundary, 300.30 feet; thence continue along said Refuge boundary North 40° 42' 00" East 326.04 feet; thence continue along said Refuge boundary North 51° 52' 00" East 308.22 feet; thence continue along said refuge boundary North 23° 57' 00" East 153.48 feet; thence South 60° 33' 30" East 233.73 feet; thence North 85° 03' 20" East 82.49 feet; thence South 75° 50' 35" East 144.94 feet; thence North 30° 11' 15" East 567.25 feet; thence South 77° 11' 00" East 57.72 feet to a point of the Easterly line of said Lot 2 of Certified Survey Map #203; thence South 30° 31' 50" West, along the Easterly line of said Lot 2, a distance of 993.72 feet; thence continue along said Easterly line South 30° 55' 46" West 352.67 feet to the point of beginning.

CONTAINING 12.305 ACRES, RCH MJH

This is homestead property.
(is) (is not)

FEE
77.25 (12)
EXEMPT

Exception to warranties: easements, restrictions and zoning ordinances of record.

Dated this 3rd day of May, 19 95.

Raymond C. Hubley Jr. (SEAL)
* Raymond C. Hubley, Jr.

Mary J. Hubley (SEAL)
* Mary J. Hubley

(SEAL)
*

(SEAL)
*

AUTHENTICATION

Signature(s) Raymond C. Hubley, Jr. and Mary J. Hubley

authenticated this 3rd day of May, 19 95

* Daniel E. Dunn

TITLE: MEMBER STATE BAR OF WISCONSIN

(If not, authorized by § 706.06, Wis. Stats.)

THIS INSTRUMENT WAS DRAFTED BY

Attorney Daniel E. Dunn
401 Main Street, Suite 400
La Crosse, WI 54601

(Signatures may be authenticated or acknowledged. Both are not necessary.)

ACKNOWLEDGMENT

STATE OF WISCONSIN }
County. } ss.

Personally came before me this .... day of ...., 19...... the above named

to me known to be the person .... who executed the foregoing instrument and acknowledge the same.

*

Notary Public .... County, Wis.
My Commission is permanent. (If not, state expiration date: ...., 19 .... .)

---

*Names of persons signing in any capacity should be typed or printed below their signatures.

Wisconsin Legal Blank Co., Inc.
Milwaukee, Wisconsin

PID#10-423-0

DOCUMENT NO.

1131612

WARRANTY DEED

STATE BAR OF WISCONSIN FORM 2 — 1982

THIS SPACE RESERVED FOR RECORDING DATA

VOL 1081 PAGE 201

RECORDED
AT 3:00 P M
APR 13 1995
DEBORAH J. FLOCK
REGISTER OF DEEDS
La Crosse County, WI

RETURN TO

#45 $10.00

Leroy E. Holley

conveys and warrants to The Town of Onalaska

the following described real estate in La Crosse County, State of Wisconsin:

Tax Parcel No: ....

Part of Government Lot One (1), (being that part of the Southwest quarter of the Southeast quarter (SW 1/4-SE 1/4), lying Easterly of the Black River), of Section 9, Township 17 North, Range 8 West, described as follows: Commencing at the Southeast corner of the SE 1/4 of the SE 1/4 of said Section; thence South 85° 40' West, along the South line of said Section, a distance of 1618.6 feet to the point of beginning of this description; thence North 04° 20' West 300.0 feet; thence South 85° 40' West 300.0 feet; thence South 04° 20' East 300.0 feet; thence North 85° 40' East 300.0 feet to the point of beginning.

FEE
77.25 (12)
EXEMPT

This is not homestead property.
(is) (is not)

Exception to warranties: easements, restrictions and zoning ordinances of record.

Dated this 5th day of April, 1995.

.... (SEAL) .... (SEAL)
* Leroy E. Holley * ....

.... (SEAL) .... (SEAL)
* .... * ....

AUTHENTICATION

Signature(s) Leroy E. Holley

authenticated this 5th day of April, 1995

* Daniel E. Dunn
TITLE: MEMBER STATE BAR OF WISCONSIN
(If not, ...
authorized by § 706.06, Wis. Stats.)

THIS INSTRUMENT WAS DRAFTED BY

Attorney Daniel E. Dunn
401 Main Street, Suite 400
La Crosse, WI 54601

(Signatures may be authenticated or acknowledged. Both are not necessary.)

ACKNOWLEDGMENT

STATE OF WISCONSIN } ss.
.... County. }

Personally came before me this .... day of ...., 19...... the above named ....

to me known to be the person .... who executed the foregoing instrument and acknowledge the same.

* ....
Notary Public .... County, Wis.
My Commission is permanent. (If not, state expiration date: ...., 19........)

*Names of persons signing in any capacity should be typed or printed below their signatures.

Wisconsin Legal Blank Co., Inc
Milwaukee, Wisconsin

Document Number	Document Title
	EASEMENT

1479124
LACROSSE COUNTY
REGISTER OF DEEDS
CHERYL A. MCBRIDE

RECORDED ON
06/28/2007 02:09PM

REC FEE: 15.00
TRANSFER FEE:
EXEMPT #:

PAGES: 3

Recording Area

Name and Return Address

Richard & Sue Prinsen
W4867 Gills Coulee Rd
West Salem WI 54669

10-1419-0

Parcel Identification Number (PIN)

See legal description for easement located on page 2 of 2 of attached Plat of Survey

This instrument was drafted by David Karl

This information must be completed by submitter: <u>document title, name & return address</u>, and <u>PIN</u> (if required). Other information such as the granting clauses, legal description, etc. may be placed on this first page of the document or may be placed on additional pages of the document. <u>Note:</u> Use of this cover page adds one page to your document and <u>$2.00 to the recording fee</u>. Wisconsin Statutes, 59.43(2m) WRDA 2/99

215 32 (2/99)

LAND SURVEYOR
DAVID J. KARL
2222 MISSISSIPPI ST.
LA CROSSE, WI 54601

I, DAVID J. KARL, A WISCONSIN REGISTERED LAND SURVEYOR, HEREBY CERTIFY THAT THIS SURVEY HAS BEEN PREPARED UNDER MY DIRECTION AND CONTROL. I FURTHER CERTIFY THAT THIS INFORMATION IS CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

DAVID J. KARL
S-2136
LA CROSSE
WI

6/20/2007

PLAT OF SURVEY

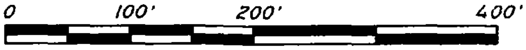
LOCATED IN GOVERNMENT LOT 1, SECTION 9, T 17 N, R 8 W, TOWN OF ONALASKA, LA CROSSE COUNTY, WISCONSIN.

PARCEL IS DESCRIBED AS COMMENCING AT THE SOUTHEAST CORNER OF SECTION 9, T17N, R8W; THENCE WESTERLY ALONG THE SOUTH LINE OF GOVERNMENT LOT 1 TO THE SOUTHEAST CORNER OF A CSM RECORDED ON PAGE 203 OF VOLUME 2 OF LA CROSSE COUNTY; THENCE NORTHEASTERLY ALONG THE EAST LINE OF SAID CSM TO A PIPE AT THE SOUTHWEST CORNER OF THE LOT SURVEYED AND DESCRIBED HEREIN, SAID CORNER ALSO BEING THE P.O.B. THENCE S 89°49'48" E, A DISTANCE OF 586.35' TO A PIPE AT THE SOUTHEAST CORNER OF THIS PARCEL; THENCE N 0°10'12" E, A DISTANCE OF 100.00'; THENCE N 89°49'48" W, A DISTANCE OF 526.69' TO A PIPE ON THE EAST LINE OF THE AFOREMENTIONED CSM, SAID PIPE BEING THE NORTHWEST CORNER OF THIS PARCEL, THENCE S 30°58'35" W ALONG SAID EAST LINE, A DISTANCE OF 116.46' TO THE P.O.B.

LAND OWNERS

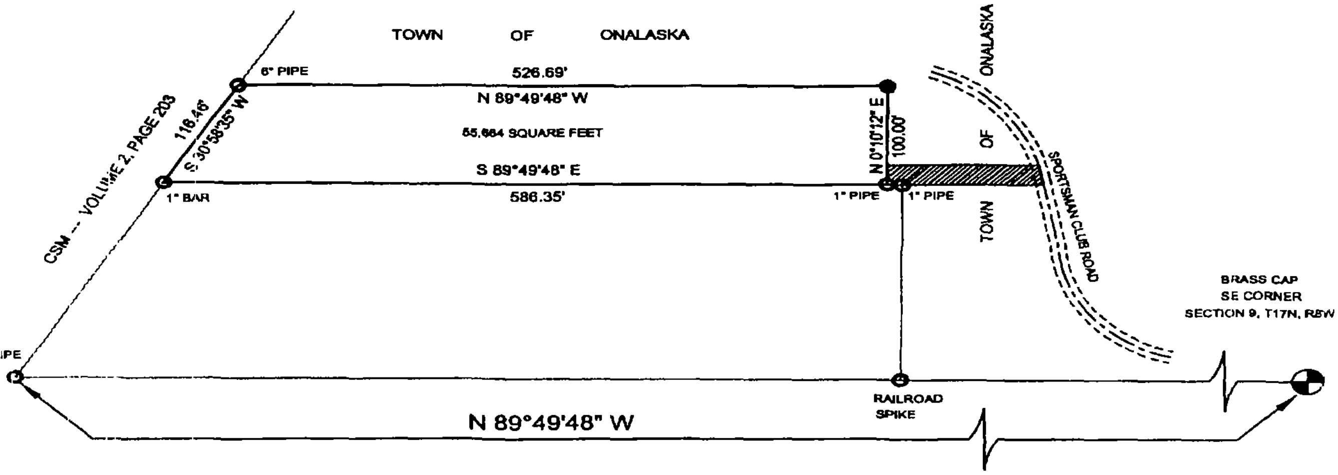
RICHARD & SUE PRINSEN
W4567 GILLS COULEE ROAD
WEST SALEM, WI 54669

SCALE: 1" = 150'



BASIS OF BEARING IS REFERENCED TO THE SOUTH LINE OF SECTION 9 AS N 89°49'48" W.

LEGEND		
○	=	FOUND MONUMENT
●	=	SET 24" x 3/4" IRON BAR @ 1.5# / FT.
▨	=	PROPOSED EASEMENT



LAND SURVEYOR

DAVID J. KARL
2222 MISSISSIPPI ST.
LA CROSSE, WI 54601

I, DAVID J. KARL, A WISCONSIN REGISTERED LAND SURVEYOR, HEREBY CERTIFY THAT THIS SURVEY HAS BEEN PREPARED UNDER MY DIRECTION AND CONTROL. I FURTHER CERTIFY THAT THIS INFORMATION IS CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

DAVID J. KARL
S-2136
LA CROSSE
WI

6/20/2007

GRANT OF EASEMENT

LOCATED IN GOVERNMENT LOT I, SECTION 9, T 17 N, R 8 W, TOWN OF ONALASKA, LA CROSSE COUNTY, WISCONSIN.

EASEMENT PARCEL IS DESCRIBED AS COMMENCING AT THE SOUTHEAST CORNER OF SECTION 9, T17N, R8W; THENCE WESTERLY ALONG THE SOUTH LINE OF GOVERNMENT LOT 1 TO THE SOUTHEAST CORNER OF A CSM RECORDED ON PAGE 203 OF VOLUME 2 OF LA CROSSE COUNTY; THENCE NORTHEASTERLY ALONG THE EAST LINE OF SAID CSM TO A PIPE AT THE SOUTHWEST CORNER OF THE LOT SURVEYED AND DESCRIBED HEREIN, THENCE S 89°49'48" E, A DISTANCE OF 586.35' TO A PIPE AT THE SOUTHEAST CORNER OF THIS PARCEL AND THE P.O.B. OF THIS EASEMENT. THENCE CONTINUING S 89°49'48" E, A DISTANCE OF 126.30' TO THE CENTERLINE OF SPORTSMAN CLUB ROAD; THENCE N 11°04'09" W ALONG SAID CENTERLINE, A DISTANCE OF 20.39'; THENCE N 89°49'48" W, A DISTANCE OF 122.33' TO THE EAST LINE OF THE LOT SURVEYED AND DESCRIBED HEREIN, THENCE S 0°10'12" W ALONG SAID EAST LINE, A DISTANCE OF 20.00' TO THE P.O.B. OF THIS EASEMENT DESCRIPTION.

TOWN OF ONALASKA RESOLUTION

THE TOWN OF ONALASKA GRANTS AN INGRESS/EGRESS EASEMENT TO RICHARD AND SUE PRINSEN, OR THEIR ASSIGNS, ALLOWING ACCESS TO THE PARCEL DESCRIBED ON PAGE 1 OF THIS DOCUMENT. THIS PERMANENT EASEMENT WILL BE 20 FEET IN WIDTH AND IS DESCRIBED ABOVE.

RESOLVED THIS 25th DAY OF JUNE, 2007.

Stanley S Hauser

CHAIR, TOWN OF ONALASKA, WISCONSIN

THE ABOVE RESOLUTION WAS PASSED BY THE TOWN BOARD OF ONALASKA, WISCONSIN.
DATED THIS 25th DAY OF JUNE, 2007.

Sue Schultz

CLERK, TOWN OF ONALASKA, WISCONSIN

STATE OF WISCONSIN)
)ss.
COUNTY OF LA CROSSE)

Personally came before me this 25th day of June, 2007, the above named Stanley S. Hauser and Sue Schultz to me known as the persons who executed the foregoing instrument and acknowledged the same.

SUE A. PRINSEN

Sue A Prinsen

Notary Public, La Crosse County, WI
My commission expires: 7-18-2010

GRANTOR
TOWN OF ONALASKA, WISCONSIN

GRANTEE SP
RICHARD AND SUE PRINSEN

NR 500.05 General submittal requirements. Unless otherwise specified, all submittals for review and approval of any initial site report, feasibility report, plan of operation, site investigation report, remedial action options report, construction documentation report or closure plan shall include the following:

(1) Review fee. The appropriate review fee specified in s. NR 520.04 shall be identified. The department will send an invoice for the plan review fee to the contact for the facility upon receipt of the submittal. Payment in check or money order shall be sent to the department's bureau of finance within 30 days after receipt of the invoice.

(2) Cover letter. A letter detailing the desired department action or response.

(3) Paper and electronic copies. Unless otherwise specified, 4 paper copies and one electronic copy of the plan or report prepared pursuant to the appropriate section of chs. NR 500 to 538, and an additional electronic copy of any plan sheets or drawings submitted as a part of the plan or report. Three paper copies shall be submitted to the department's field office responsible for the area in which the facility is located and one paper copy, one electronic copy, and the additional electronic copy of associated plans or drawings shall be submitted to the bureau of waste management in Madison unless otherwise specified by the department. The complete electronic copy of the report and the separate electronic copy of any plan sheets or drawings shall be provided in formats and on media acceptable to the department.

(4) Certification. (a) The reports and plan sheets shall be under the seal of a licensed professional engineer. In addition, the following certification shall be included:

"I, ________________________, hereby certify that I am a licensed professional engineer in the State of Wisconsin in accordance with the requirements of ch. A–E 4, Wis. Adm. Code; that this document has been prepared in accordance with the Rules of Professional Conduct in ch. A–E 8, Wis. Adm. Code; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 500 to 538, Wis. Adm. Code."

(b) Initial site reports, feasibility reports, plans of operation, site investigation, remedial action options reports and any other reports where interpretation of geology or hydrogeology is necessary shall be under the seal of a licensed professional geologist. In addition, the following certification shall be included:

"I, __________________, hereby certify that I am a licensed professional geologist in the State of Wisconsin in accordance with the requirements of ch. GHSS 2, Wis. Adm. Code; that the preparation of this document has not involved any unprofessional conduct as detailed in ch. GHSS 5, Wis. Adm. Code; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 500 to 538, Wis. Adm. Code."

(5) Technical procedures. All technical procedures used to investigate a solid waste facility shall be the current standard procedures as specified by ASTM International, United States geological survey, USEPA's standard methods for the examination of water and wastewater, or other equivalent or appropriate methods approved by the department. Test procedures used shall be specified. Any deviation from a standard method shall be explained in detail with reasons provided.

(6) Visuals. Maps, figures, photographs and tables to clarify information or conclusions. The visuals shall be legible. All paper copies of maps, plan sheets, drawings, isometrics, cross–sections and aerial photographs shall meet the following requirements:

(a) No larger than 32 inches by 44 inches and no smaller than 8 ½ inches by 11 inches.

(b) Be of appropriate scale to show all required details in sufficient clarity.

(c) Be numbered, referenced in the narrative, titled, have a legend of all symbols used, contain horizontal and vertical scales, where applicable, and specify drafting or origination dates.

(d) Use uniform scales.

(e) Contain a north arrow.

(f) Use mean sea level as the basis for all elevations.

(g) Contain a survey grid based on monuments established in the field which utilizes a coordinate system and datum acceptable to the department. Examples of acceptable coordinate systems include state plane, Universal Transverse Mercator, and Wisconsin Transverse Mercator.

(h) Show original topography and the grid system on plan sheets showing construction, operation or closure topography. For complex plans, existing conditions within the landfill area may be shown by lighter lines or may be eliminated.

(i) Show survey grid location and reference major plan sheets on all cross–sections. A reduced diagram of a cross–section location plan view map shall be included on the sheets with the cross–sections.

(7) Table of contents. A table of contents listing all sections of the submittal.

(8) Appendix. An appendix listing names of all references, all raw data, testing and sampling procedures and calculations.

History: Cr. Register, January, 1988, No. 385, eff. 2–6–88; am. (intro.), (1), (3), (4) and (6) (h), Register, June, 1996, No. 486, eff. 7–1–96; am. (3) and (4), Register, December, 1997, No. 504, eff. 1–1–98; **CR 05–020: am. (3), (4), (5), (6) (intro.), (a), (f) and (g) Register January 2006 No. 601, eff. 2–1–06.**

NR 500.06 License applications. Unless otherwise specified, no person may operate or maintain a solid waste facility without a license from the department. A submittal for initial licensing or relicensing of any solid waste facility shall include:

(1) License fee. The appropriate fee as specified in s. NR 520.04 in check or money order payable to the department. Except as provided in s. NR 500.065, license fees are not transferable, proratable or refundable.

(2) Application form. A completed copy of the appropriate application form.

(3) Financial responsibility. For all land disposal facilities with plans of operation approved under s. 289.30, Stats., proof of financial responsibility as specified in s. NR 520.05.

(4) Affidavit of facility registry. Submittal on form 4400–067 that proof that a notation of the existence of the facility has been recorded in the office of the register of deeds in each county in which a portion of the facility is located. Owners of landfills applying for relicensure need only submit this form if the legal description of the landfill has changed from that identified on a previously submitted form 4400–067.

Note: This form may be obtained from the Department of Natural Resources, Bureau of Waste Management, 101 S. Webster Street, P.O. Box 7921, Madison, WI 53707–7921, (608) 266–2111, waste.management@dnr.state.wi.us.

(5) Noncompliance with plans or orders. A submittal for initial licensing of a new or expanded solid waste disposal facility shall contain the following information:

(a) Identification of all persons owning a 10% or greater legal or equitable interest in the applicant or in the assets of the applicant, including shareholders of a corporation which is an applicant and partners of a partnership which is an applicant.

(b) Identification of all other Wisconsin solid or hazardous waste facilities for which the applicant or any person identified in par. (a), is named in, or subject to an order or plan approval issued by the department.

(c) Identification of all other Wisconsin solid or hazardous waste facilities which are owned by persons, including corporations and partnerships, in which the applicant or person identified in par. (a) owns or previously owned a 10% or greater legal or equitable interest or a 10% or greater interest in the assets.

all users of the landfill of the intent to close the landfill so that alternative disposal options can be arranged.

(b) Signs shall be posted at all points of access to the landfill at least 30 days prior to closure indicating the date of closure and alternative disposal facilities. Facilities which are operated by and serve only a single waste generator and are not open to the public are exempt from this provision.

(c) Notice of the upcoming closure shall be published in a local newspaper at least 30 days prior to closure and a copy of the notice shall be provided to the department within 10 days of the date of publication. Facilities which are operated by and serve only a single waste generator and are not open to the public are exempt from this provision.

(2) GENERAL REQUIREMENTS. Within 10 days after ceasing to accept solid waste, the owner or operator shall restrict access by the use of gates, fencing or other appropriate means to insure against further use of the landfill. If the final use allows access, such access shall be restricted until closure has been completed and approved by the department.

(3) CLOSURE. Closure activities shall begin within 30 days after ceasing to accept solid waste. Closure shall be accomplished in the following manner for facilities without a closure plan or plan of operation approved in writing by the department. Placement of final cover in accordance with s. NR 504.07 may be required if the department determines that this type of final cover system is necessary to prevent or abate attainment or exceedance of the groundwater standards contained in ch. NR 140. Municipal solid waste landfills that accepted greater than 100 tons of solid waste per day on an annual basis and ceased accepting municipal solid waste on or before October 8, 1993 shall have final cover placement completed by July 1, 1996. Municipal solid waste landfills that accepted 100 tons or less of solid waste per day on an annual basis and ceased accepting municipal solid waste on or before April 8, 1994 shall have final cover placement completed by July 1, 1996.

(a) The entire area previously used for disposal purposes shall be covered with at least 2 feet of compacted earth having a hydraulic conductivity of no more than $1x10^{-5}$ cm/sec or if the hydraulic conductivity of the underlying soils or any base liner system is less than $1x10^{-5}$ cm/sec, then the 2 feet of compacted earth shall have a hydraulic conductivity that is equal to or less than the underlying soils or any base liner system. The final grades shall be sloped adequately to allow storm water runoff. A specific soil type may be required by the department for this 2–foot layer. The department may require the cover layer to be more than 2 feet thick.

(b) Storm water run–on shall be diverted around all areas used for solid waste disposal to limit the potential for erosion of the cover soils and increased infiltration. Drainage swales conveying storm water runoff over previous solid waste disposal areas shall be lined with a minimum thickness of 2 feet of clay.

(c) The final slopes of the landfill shall be greater than 5%, but may not exceed 4 horizontal to one vertical unless otherwise approved by the department.

(d) The finished surface of the disposal area shall be covered with a minimum of 6 inches of topsoil.

(4) ESTABLISHMENT OF VEGETATION. Within 180 days after ceasing to accept solid waste, or if solid waste termination is after September 15, by June 15 of the following year, the owner or operator shall complete seeding, fertilizing and mulching of the finished surface. The seed type and amount of fertilizer applied shall be selected depending on the type and quality of topsoil and compatibility with both native vegetation and the final use. Unless otherwise approved by the department in writing, seed mixtures and sowing rates shall be those specified for right–of–ways in accordance with section 630, Wisconsin department of transportation standard specifications for highway and structure construction.

Note: The Wisconsin department of transportation standard specifications for highway and structure construction is available at www.dot.wisconsin.gov/business/engrserv/construction–library.htm or can be obtained from the department of natural resources, bureau of waste management, 101 S. Webster Street, P.O. Box 7921, Madison, WI 53707–7921, (608) 266–2111, waste.management@dnr.state.wi.us. Copies are also available for inspection at the offices of the legislative reference bureau and the secretary of state.

(5) DEED NOTATION. Following closure of a landfill phase which accepted municipal solid waste after July 1, 1996, the owner or operator shall, within 90 days after closure, record a notation on the deed to the landfill property. The notation in the deed shall in perpetuity notify any potential purchaser of the property that the land has been used as a landfill and its use is restricted to prevent disturbing the integrity of the final cover, liner or any other components of the containment system or the function of the monitoring systems.

(6) HAZARDOUS AIR CONTAMINANT CONTROL. All landfills which have a design capacity of greater than 500,000 cubic yards and have accepted municipal solid waste shall install a department approved system to efficiently collect and combust hazardous air contaminants emitted by the landfill within 18 months of February 1, 1988 unless the owner can demonstrate that the performance criteria of s. NR 504.04 (4) (f) can be achieved without implementing such a system. Control techniques other than combustion may be approved by the department.

History: Cr. Register, January, 1988, No. 385, eff. 2–6–88; am. (intro.), (1) (a), (b), (2), (3) (intro.), (a) to (c), (4), (6), r. and recr. (5), Register, June, 1996, No. 486, eff. 7–1–96; CR 05–020: am. (4) Register January 2006 No. 601, eff. 2–1–06.

NR 506.085 Final use. The following activities are prohibited at solid waste disposal facilities which are no longer in operation unless specifically approved by the department in writing:

(1) Use of the waste disposal area for agricultural purposes.

(2) Establishment or construction of any buildings over the waste disposal area.

(3) Excavation of the final cover or any waste materials.

Note: Activities at closed solid waste disposal facilities shall be restricted in accordance with the applicable transference of responsibility provisions of s. 289.46 (2), Stats.

History: Cr. Register, June, 1996, No. 486, eff. 7–1–96.

NR 506.09 Waste characterization. (1) GENERAL. No person may dispose in a landfill prohibited items under s. NR 506.095. Wastes which are limited under ss. NR 506.10 to 506.155 may only be disposed in accordance with those sections. Solid wastes which are not prohibited or limited under ss. NR 506.095 to 506.155 and which do not constitute more than 5% of the total proposed design capacity may be disposed without additional department approval providing they do not pose a significant threat to landfill operations, leachate or landfill gas quality, or groundwater quality, and they are handled in accordance with an approved special waste management plan. The physical and chemical characteristics of any high volume industrial waste stream such as foundry process waste, papermill sludge, utility coal–ash wastes, and other non–municipal waste streams that are anticipated to individually constitute more than 5% of the total proposed design capacity shall be analyzed and described in accordance with this section.

(2) SUBMITTAL REQUIREMENTS. Requests for authorization to accept additional waste types shall include the following information at a minimum:

(a) Detailed physical and chemical characteristics including percent solids, material safety data sheets where appropriate and the results of the paint filter test.

(b) The volume of waste to be disposed of on a daily and yearly basis.

(c) The source of the wastes and a description of the processes which generated the waste.

(d) The duration of disposal.

(121) "Well casing pipe" means pipe meeting standards specified in s. NR 812.17 which is driven or set to seal off the vertical zone of contamination.

(122) "Well constructor" means any person, firm or corporation that constructs a well which is not required to be constructed by a licensed well driller.

(123) "Well driller" has the meaning as designated in ch. 280, Stats.

(124) "Well drilling" has the meaning designated in ch. 280, Stats., and includes any activity which requires the use of a well drilling rig or similar equipment, any activity which changes the character of a drilled well or which is conducted using a well drilling rig or similar equipment with the exception of the driving of points. Well drilling includes constructing, reconstructing or deepening a well, installation of a liner, installing or replacing a screen, well rehabilitation, hydrofracturing, blasting and chemical conditioning.

(125) "Well-point driving" means constructing a well by joining a drive point screen with lengths of pipe and driving the assembly into the ground with percussion equipment or by hand, but without removing material from a drillhole more than 10 feet below the ground surface.

(126) "Well vent" means a screened opening in a well seal to allow atmospheric pressure to be maintained in the well.

(127) "Well yield" means the quantity of water which may flow or be pumped from the well per unit of time.

(128) "Zone of saturation" means that part of the earth's crust beneath the shallowest water table in which all voids are filled with water under pressure greater than atmospheric.

History: Cr. Register, January, 1991, No. 421, eff. 2–1–91; am. (3), (4), (48), (61m), (74) (b), (79), (81), (82), (107) and (119) cr. (27m) (30l), (30m), (30t), (30x), (72m), (79m), (97m) and (110m), renum. (36) and (39) to be (61q) and (61u) and am. Register, September, 1994, No. 465, eff. 10–1–94; corrections made under s. 13.93 (2m) (b) 7., Stats., Register, September, 1994, No. 465; correction in (29), (30) and (79m) made under s. 13.93 (2m) (b) 6. and 7., Stats., Register, September, 1996, No. 489; corrections in (50), (81), (97), (123) and (124) made under s. 13.93 (2m) (b) 7., Stats., Register, December, 1998, No. 516, correction in (71) made under s. 13.93 (2m) (b) 7., Stats., Register July 2002 No. 559. **CR 05–020: cr. (24m) and (57w) Register January 2006 No. 601, eff. 2–1–06; correction in (56) made under s. 13.93 (2m) (b) 7., Stats.**

NR 812.08 Well, reservoir and spring location.

(1) GENERAL. Any potable or nonpotable well or reservoir shall be located:

(a) So the well and its surroundings can be kept in a sanitary condition.

(b) At the highest point on the property consistent with the general layout and surroundings if reasonably possible, but in any case protected against surface water flow and flooding and not downslope from a contamination source on the property or on an adjacent property regardless of what was installed first, the well or the contamination source. When a contamination source is installed upslope from a well in violation of this section after the well construction has been completed, the violation is not the responsibility of the well driller, except if the well driller knew or should have known of the proposed upslope installation of the contamination source. When there is no location on the property where this requirement can be met a well may be constructed without a variance if it is constructed with a minimum of 20 or more feet of well casing pipe than is required by ss. NR 812.12 and 812.13 and Tables I and II or with a minimum of 60 feet of well casing pipe provided that the minimum well casing pipe depth requirements of s. NR 812.12 or 812.13 and Table I or II are met. This exception does not apply to high capacity, school or wastewater treatment plant wells. A well or reservoir is located downslope from a contamination source, regardless of the presence or absence of a structure between the well and the contamination source, if:

1. The ground surface elevation at the well or reservoir is lower than the elevation at the contamination source, and

2. Surface water that washes over the contamination source would travel within eight feet of the well or reservoir, or over the well or reservoir.

(c) As far away from any known or possible source of contamination as the general layout of the premises and the surroundings allow.

Note: Section PSC 114.234 C8 requires that a horizontal clearance of at least 3/4 of the vertical clearance of the conductors, including overhead power lines to the ground required by Rule 232 shall be maintained between open conductors and wells. Persons installing wells must comply with this requirement.

(d) Such that any potential contaminant source, not identified in this section or in Table A, is a minimum of 8 feet from the well or reservoir.

(e) Every well shall be located so that it is reasonably accessible with proper equipment for cleaning, treatment, repair, testing, inspection and any other maintenance that may be necessary.

(2) RELATION TO BUILDINGS. In relation to buildings, the location of any potable or nonpotable well shall be as follows:

(a) When a well is located outside and adjacent to a building, it shall be located so that the center line of the well extended vertically will clear any projection from the building by not less than 2 feet and so that the top of the well casing pipe extends at least 12 inches above the final established ground grade.

(b) When a structure is built over a drilled well, it shall have an access hatch or removable hatch, or provide other access to allow for pulling of the pump. The well casing pipe shall extend at least 12 inches above the floor and be sealed watertight at the point where it extends through the floor.

(c) No well may be located, nor a building constructed, such that the well casing pipe will terminate in or extend through the basement of any building or terminate under the floor of a building having no basement. The top of a well casing pipe may terminate in a walkout basement meeting the criteria of s. NR 812.42 (9) (b) 1. to 4. A well may not terminate in or extend through a crawl space having a below ground grade depression or excavation.

(3) RELATION TO FLOODPLAINS. (a) A potable or nonpotable well may be constructed, reconstructed or replaced in a floodfringe provided that the top of the well is terminated at least 2 feet above the regional flood elevation for the well site.

(b) A well may be reconstructed or replaced in a floodway provided that the top of the well is terminated at least 2 feet above the regional flood elevation for the well site.

(c) A well may not be constructed on a floodway property that is either undeveloped or has building structures but no existing well.

(d) The regional flood elevation may be obtained from the department.

(4) RELATION TO CONTAMINATION SOURCES. Minimum separating distances between any new potable or nonpotable well, reservoir or spring and existing sources of contamination; or between new sources of contamination and existing potable or nonpotable wells, reservoirs or springs shall be maintained as described in this subsection. The minimum separating distances of this subsection do not apply to dewatering wells approved under s. NR 812.09 (4) (a). Greater separation distances may be required for wells requiring plan approval under s. NR 812.09. Separation distance requirements to possible sources of contamination will not be waived because of property lines. Minimum separating distances are listed in Table A and are as follows:

(a) Eight feet between a well or reservoir and a:

1. Buried gravity flow sanitary or storm building drain having pipe conforming to ch. Comm 84;

2. Buried gravity flow sanitary or storm building sewer having pipe conforming to ch. Comm 84;

3. Watertight clear water waste sump;

4. Buried clear water waste drain having pipe conforming to ch. Comm 84;

5. Buried gravity flow foundation drain;

6. Rainwater downspout outlet;

7. Cistern;

8. Buried building foundation drain connected to a clear water waste drain or other subsoil drain;

9. Noncomplying pit, subsurface pumproom, alcove, or reservoir;

10. Nonpotable well;

11. Fertilizer or pesticide storage tank with a capacity of less than 1,500 gallons, but only when the well is nonpotable;

Note: For potable wells see par. (d) 1.

12. Plastic silage storage and transfer tube;

13. Yard hydrant;

14. Swimming pool, measured to the nearest edge of the water; or

15. Dog or other small pet house, animal shelter or kennel housing not more than 3 adult pets on a residential lot.

(b) Twenty–five feet between a well or reservoir and a:

1. Buried grease interceptor or trap;

2. Septic tank;

3. Holding tank;

4. Buried building drain or building sewer having pipe not conforming to ch. Comm 84, wastewater sump, or non–watertight clear water waste sumps.

5. Buried pressurized sanitary building sewer having pipe conforming to ch. Comm 84;

6. Buried gravity manure sewer;

7. Lake, river, stream, ditch or stormwater detention pond or basin measured to the regional high water elevation in the case of a lake or stormwater detention pond, to the edge of the floodway in the case of a river or stream or to the edge in the case of a ditch or stormwater detention basin;

9. Liquid–tight barn gutter;

10. Animal barn pen with concrete floor;

11. Buried pressurized sewer pipe conveying manure provided that the pipe meets ASTM specification D 2241, with standard dimension ratio of 21 or less or pressure pipe meeting the requirements of s. NR 110.13 (6) (f) or 811.62.

Note: There is no NR 110.13 (6) (f).

12. Buried fuel oil tanks serving single family residences, including any associated buried piping;

13. Discharge to ground from a water treatment device;

14. Vertical shaft installed below grade used for intake of air for a heating or air conditioning system; or

15. Buried sanitary or storm collector sewer serving 4 or fewer living units or having a diameter of 6 inches or less.

(c) Fifty feet between a well or reservoir and a:

1. Soil absorption unit receiving less than 8,000 gallons/day, existing, abandoned or alternate, but not including a school soil absorption unit;

Note: For school soil absorption units see par. (e); for soil absorption units receiving more than 8,000 gallons/day see par. (f) 3

2. Privy;

3. Pet waste pit disposal unit;

4. Animal shelter;

5. Animal yard;

6. Silo;

7. Buried sewer used to convey manure having pipe conforming to ch. Comm 84 that does not meet the specifications in par. (b);

8. Liquid tight manure hopper or reception tank;

9. Filter strip;

10. Buried sanitary or storm collector sewer serving more than 4 living units or larger than 6 inches in diameter except that wells may be located or sewers installed such that a well is less than 50 feet, but at least 25 feet, from gravity collector sewers smaller than 16 inches in diameter or from force main collector sewers 4 inches or smaller in diameter provided that within a 50–foot radius of the well the installed sewer pipe meets the allowable leakage requirements of AWWA C600 and the requirements for water main equivalent type pipe as follows:

a. For sewers > 4″ diameter, but < 16″ diameter: PVC pipe > 4″ diameter, but < 12″ diameter shall meet AWWA C900 with elastomeric joints having a standard dimension ratio of 18 or less; PVC pipe > 12″ diameter, but < 16″ diameter shall meet AWWA C905 with elastomeric joints having a standard dimension ratio of 18 or less; Ductile iron pipe shall meet AWWA C115 or AWWA C151 having a thickness class 50 or more.

b. For sewers < 3″ diameter, the pipe shall be any rigid pipe in the ch. Comm 84 "Table for Pipe and Tubing for Water Services and Private Water Mains," including approved ABS, brass, cast iron, CPVC, copper (not including type M copper) ductile iron, galvanized steel, polybutylene (PB), polyethylene (PE), PVC, or stainless steel pipe.

11. An influent sewer to a wastewater treatment plant;

12. The nearest existing or future grave site in cemeteries;

13. Wastewater treatment plant effluent pipe;

14. Buried pressurized sewer having pipe not conforming to ch. Comm 84; or

15. Manure loading area.

Note: The minimum separating distance between a well or reservoir and a lift station is based on the presence of a sewer force main at the lift station.

(d) One hundred feet between a well or reservoir and a:

1. Bulk surface storage tank with a capacity greater than 1,500 gallons or any bulk buried storage tank regardless of capacity, including, for both surface or buried tanks, associated buried piping for any solid, semi–solid or liquid product but not including those regulated under par. (b) 12. This subdivision includes, but is not limited to petroleum product tanks, waste oil tanks and pesticide or fertilizer storage tanks not regulated under par. (a) 11. This subdivision does not include septic, holding and manure reception tanks, or liquified petroleum gas tanks as specified in ch. Comm 11.

2. Liquid–tight, fabricated manure or silage storage structure, in ground or at ground surface;

3. Wastewater treatment plant structure, conveyance or treatment unit; or

4. Dry fertilizer or pesticide storage building or area when more than 100 pounds of either or both materials are stored;

5. Well, drillhole or water system used for the underground placement of any waste, surface or subsurface water or any substance as defined in s. 160.01 (8), Stats.;

6. Stormwater infiltration basin;

7. Uncovered storage of silage on the ground surface;

8. Water–tight silage storage trench or pit; or

9. Lift station.

(e) Two hundred feet between a school well and a soil absorption unit receiving less than 8,000 gallons per day, existing or abandoned.

(ee) One hundred fifty feet between a well or reservoir and a temporary manure stack.

(f) Two hundred fifty feet between a well or reservoir and a:

1. Manure stack.

2. Earthen or excavated manure storage structure.

Note: Variances from the separating distances may be granted as specified in s. NR 812.43 for earthen storage and manure stacks constructed and maintained to the specifications of Soil Conservation Standards No. 425 or 312, respectively.

3. Soil absorption unit receiving 8,000 or more gallons per day, existing, abandoned, or alternate.

4. Sludge landspreading or drying area.

5. An earthen silage storage trench or pit.

6. *Liquid waste disposal system including, but not limited to* a treatment pond or lagoon, ridge and furrow system and spray irrigation system.

Note: Variance from this separating distance may be granted for treatment ponds or lagoons constructed and maintained to an approval granted under ch. NR 213

7. Salvage yard.

8. A salt or deicing material storage area including the building structure and the surrounding area where the material is transferred to vehicles. This subdivision does not include bagged deicing material.

9. Solid waste processing facility.

10. Solid waste transfer facility.

11. The boundaries of a landspreading facility for spreading of petroleum–contaminated soil regulated under ch. NR 718 while that facility is in operation.

(g) Twelve hundred feet between a well or reservoir and:

1. The nearest edge of the limits of filling of an existing, proposed or abandoned landfill, measured to the nearest fill area of abandoned landfills, if known. Otherwise measured to the nearest property line where the landfill is located. The department may require, as part of a variance request, a land survey map, a scaled diagram of the landfill and the well location, or another accurate measurement method to determine and demonstrate the distance between the landfill and the well;

2. The nearest edge of a coal storage area in excess of 500 tons; or

3. A hazardous waste treatment facility regulated by the department.

ATTACHMENT 6

Community Notice

SUDOKU

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10/18

Wisconsin Department of Natural Resources to Review Onalaska Landfill Cleanup
Brice Prairie, La Crosse County, Wisconsin

In accordance with Superfund law the Wisconsin Department of Natural Resources is conducting a Five Year Review of the Onalaska Landfill cleanup. These reviews are done where construction of the cleanup is complete but hazardous waste remains on the site. Soil and groundwater have been contaminated with volatile organic compounds related to past disposal practices. The remedy at the site includes a multi-layer cap on the landfill, passive gas venting and groundwater extraction and treatment. In 2002 the groundwater extraction system was shut down for the purpose of studying the effectiveness of groundwater monitored natural attenuation. The purpose of this review is to verify that the remedy continues to protect human health and the environment.

The public is invited to comment and provide input. To comment or to obtain additional information contact:

Eileen Kramer
Hydrogeologist
Wisconsin Department of Natural Resources
1300 W. Clairemont Ave.
P. O. Box 4001
Eau Claire, WI 54702

715-839-3824 E-mail: eileen.kramer@wisconsin.gov

The five-year review report will be completed July 14, 2008.

20067500

CORRECTION

The inauguration of Chancellor Joe Gow will be Friday at the Recreational Eagle Center on the University of Wisconsin-La Crosse Crosse campus. The location was incorrect in Wednesday's Tribune.

The La Crosse Tribune believes accuracy is important and publishes corrections when necessary. If you have a question or information regarding any news story, call (608) 782-9710 and ask for the local news desk.

LOTTERIES

Wednesday's numbers:
Powerball:
14-15-19-42-46
Powerball: 37
Power Play: 4
Jackpot: $20 million
Wisconsin SuperCash:
10-15-21-22-27-34
Wisconsin Megabucks:
6-29-36-38-41-42
Jackpot: $3.7 million
Wisconsin Pick 3:
7-3-9
Wisconsin Pick 4:
9-7-6-6
Wisconsin Badger 5:
4-10-16-25-28
Minnesota Daily 3:
4-7-5
Minnesota Northstar Cash:
3-6-9-16-22
Iowa Pick 3:
6-3-1
Iowa Pick 4:
7-5-3-4

8297.

Album Encounters: Jimi Hendri "Electric Ladyland," 7 p.m., Planetarium, Cowley Hall, Basement Room 20, UW-L, $3, (608) 785-8669.

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including $212,000 for fill and site preparation, but the building will last "longer than our children will be around," said Hagman.

The center will continue to be on hold for at least another month, as state Sen. Jeffrey Plale, D-South Milwaukee, took Division of Facilities Development's recommendation to defer it and visitors centers at Council Grounds and Blue Mound State Park, along with replacing a ranger station at Tomah, to the November meeting. And that will be contingent on having a state budget by then.

Plans for 20 new walk-in campsites near Wildcat Mountain's family campground won't be held up by a lack of a state budget, said Schroeder.

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centage point lower than the 3.3 percent adjustment for 2007. In 2006, the COLA increase was 4.1 percent, the largest in 15 years.

Advocates for the elderly said the small increase high-

he Year of Fog' well worth a read

le, a novel about a
hild won't get my
I know it will be sad,

LIBRARY NOTES

Libraries launch 'I Want My Mummy'

door or by calling 785-8415. Suggested
nations are $3 for students and $5 for adults.

8-9 and 15-16 at 1 p.m. "I Want My Mummy" is An adult must accompany

www.bjorkostrom.com.

Wisconsin Department of Natural Resources to Review Onalaska Landfill Cleanup

Brice Prairie, La Crosse County, Wisconsin

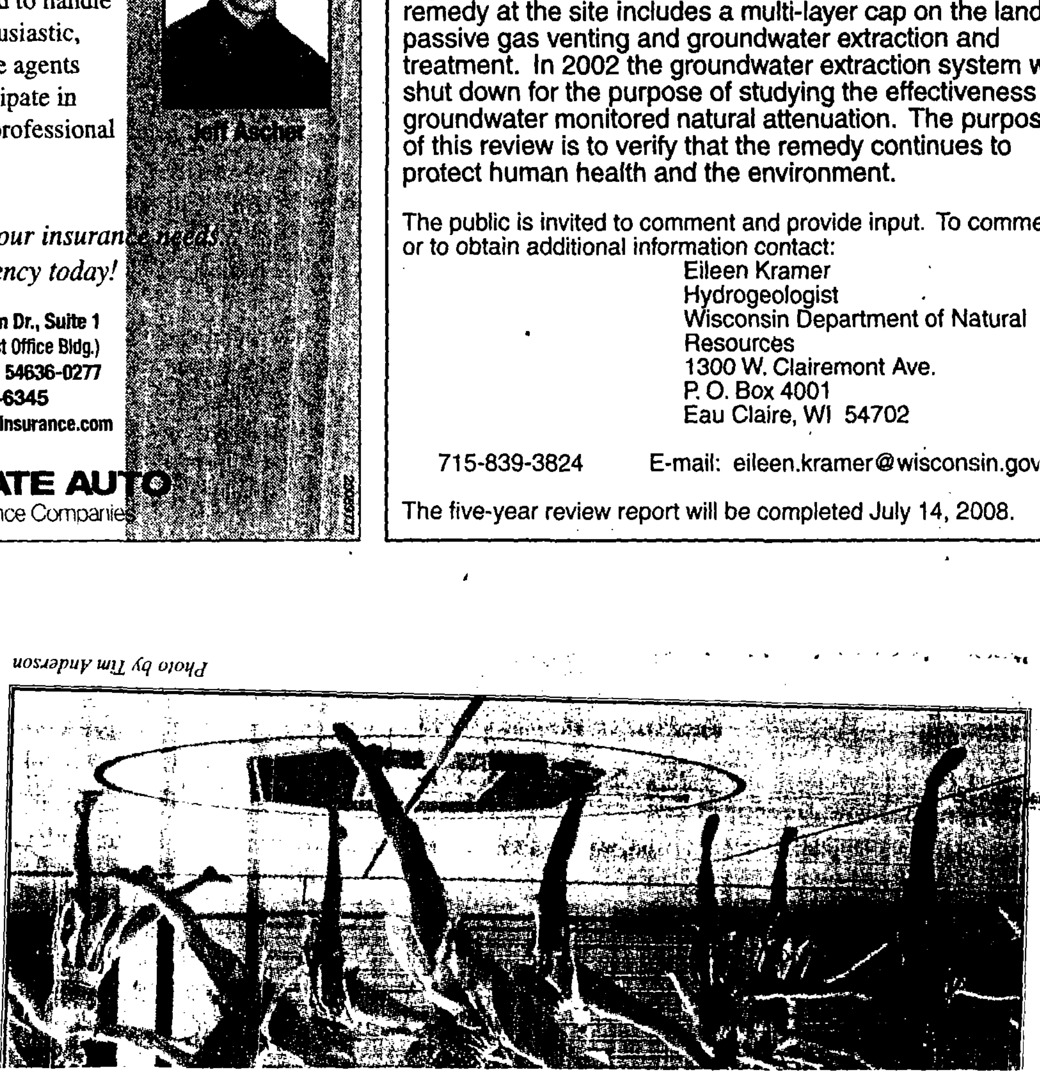
In accordance with Superfund law the Wisconsin Department of Natural Resources is conducting a Five Year Review of the Onalaska Landfill cleanup. These reviews are done where construction of the cleanup is complete but hazardous waste remains on the site. Soil and groundwater have been contaminated with volatile organic compounds related to past disposal practices. The remedy at the site includes a multi-layer cap on the landfill, passive gas venting and groundwater extraction and treatment. In 2002 the groundwater extraction system was shut down for the purpose of studying the effectiveness of groundwater monitored natural attenuation. The purpose of this review is to verify that the remedy continues to protect human health and the environment.

The public is invited to comment and provide input. To comment or to obtain additional information contact:

Eileen Kramer
Hydrogeologist
Wisconsin Department of Natural Resources
1300 W. Clairemont Ave.
P. O. Box 4001
Eau Claire, WI 54702

715-839-3824 E-mail: eileen.kramer@wisconsin.gov

The five-year review report will be completed July 14, 2008.



he Year of Fog' well worth a read

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about him at www.bjorkostrom.com.

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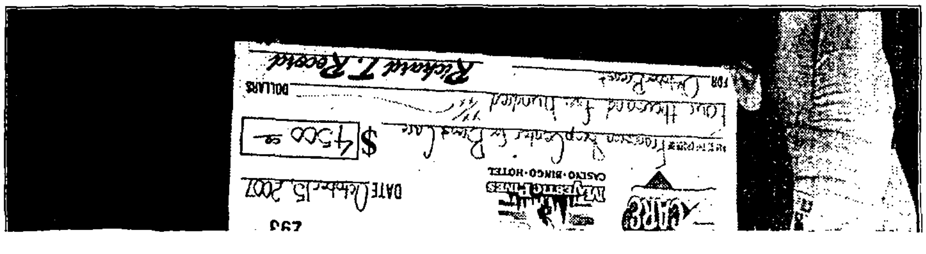
20067500



Contributed photo

Pictured above for a ceremonial check signifying a $4,500 donation to the Franciscan Skemp Healthcare Center for Breast Care, are, from left, Lisa Belling, Franciscan Skemp breast health educator, Dr. Kathleen Christian, Franciscan Skemp surgeon/breast clinician, Jen O'Brien, Z93 program director and Michelle Amberg, Majestic Pines Casino public relations manager.

The clinic, which averages 100 visits a week, serves those who ar gible for private, state or federal h and reside in Houston, La Crosse, Trempealeau or Vernon counties.

It is estimated that 45 million A are without health insurance and n mission's patients are the working

"Over 250 volunteers give their talent to the mission, treating pati conditions from the common cold heart disease and cancer," said Sa Brekke, director of St. Clare Healt Mission.

ATTACHMENT 7

Site Inspection Check List

Five-Year Review Site Inspection Checklist (Template)

(Working document for site inspection. Information may be completed by hand and attached to the Five-Year Review report as supporting documentation of site status. "N/A" refers to "not applicable.")

I. SITE INFORMATION

Site name: Onalaska Landfill	**Date of inspection:** Sept. 26 + 27, 2007
Location and Region: Brice Prairie / Reg. 5	**EPA ID:** WID 980821656
Agency, office, or company leading the five-year review: WDNR	**Weather/temperature:** Sunny, lt. cloudy ~60°F

Remedy Includes: (Check all that apply)

✓ Landfill cover/containment
✓ Access controls
✓ Institutional controls
✓ Groundwater pump and treatment
Surface water collection and treatment
Other____

✓ Monitored natural attenuation
Groundwater containment
Vertical barrier walls

Attachments: yes [✓ ~~Inspection team roster attached~~] [✓ Site map attached]

II. INTERVIEWS (Check all that apply)

1. **O&M site manager** Peter Moore — Hydrogeologist — 9/26/2007
Name — Title — Date
Interviewed [✓ at site] ~~at office~~ ~~by phone~~ Phone no. 952-924-0117
Problems, suggestions; Report attached ______________________________

2. **O&M staff** Bill Wood — Operator — 9/26/2007
Name — Title — Date
Interviewed ✓ at site at office by phone Phone no. 608-792-9510
Problems, suggestions; Report attached ______________________________

3. **Local regulatory authorities and response agencies** (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Agency Town of Onalaska
Contact Tim Dienger Administrator 9/27/2007 608-783-4958
Name Title Date Phone no.
Problems; suggestions; Report attached

Agency
Contact
Name Title Date Phone no.
Problems; suggestions; Report attached

Agency
Contact
Name Title Date Phone no.
Problems; suggestions; Report attached

Agency
Contact
Name Title Date Phone no.
Problems; suggestions; Report attached

4. **Other interviews** (optional) Report attached.

Mr. Roy Ackerman, neighbor

III. ON-SITE DOCUMENTS & RECORDS VERIFIED (Check all that apply)

1. **O&M Documents**
   - [✓ O&M manual] [✓ Readily available] [✓ Up to date] N/A
   - [✓ As-built drawings] [✓ Readily available] [✓ Up to date] N/A
   - [✓ Maintenance logs] [✓ Readily available] [✓ Up to date] N/A
   - Remarks____________________

2. **Site-Specific Health and Safety Plan** [✓ Readily available] [✓ Up to date] N/A
   - Contingency plan/emergency response plan [✓ Readily available] [✓ Up to date] N/A
   - Remarks____________________

3. **O&M and OSHA Training Records** [✓ Readily available] [✓ Up to date] N/A
   - Remarks____________________

4. **Permits and Service Agreements**
   - Air discharge permit Readily available Up to date [✓ N/A]
   - Effluent discharge [✓ Readily available] [✓ Up to date] N/A
   - Waste disposal, POTW [✓ Readily available] [✓ Up to date] N/A
   - Other permits____________________ Readily available Up to date N/A
   - Remarks____________________

5. **Gas Generation Records** Readily available Up to date [✓ N/A]
   - Remarks____________________

6. **Settlement Monument Records** Readily available Up to date [✓ N/A]
   - Remarks____________________

7. **Groundwater Monitoring Records** [✓ Readily available] [✓ Up to date] N/A
   - Remarks____________________

8. **Leachate Extraction Records** Readily available Up to date [✓ N/A]
   - Remarks____________________

9. **Discharge Compliance Records**
   - Air Readily available Up to date [✓ N/A]
   - Water (effluent) [✓ Readily available] [✓ Up to date] N/A
   - Remarks Wastewater discharge during this period was to La Crosse POTW.

10. **Daily Access/Security Logs** Readily available Up to date [✓ N/A]
    - Remarks____________________

IV. O&M COSTS

1. **O&M Organization**

State in-house ✓Contractor for State
PRP in-house Contractor for PRP
Federal Facility in-house Contractor for Federal Facility
Other ENSR Corp. has been contractor for maintenance + monitoring since 2002

2. **O&M Cost Records**

✓Readily available ✓Up to date
Funding mechanism/agreement in place
Original O&M cost estimate $150K/an. Breakdown attached
Original O+M estimate referred to operation of P+T
Total annual cost by year for review period if available

From______ To______ ______ Breakdown attached
Date Date Total cost

From______ To______ ______ Breakdown attached
Date Date Total cost

From______ To______ ______ Breakdown attached
Date Date Total cost

From______ To______ ______ Breakdown attached
Date Date Total cost

From______ To______ ______ Breakdown attached
Date Date Total cost

Facility maintenance + groundwater monitoring - approx $60K/an.

3. **Unanticipated or Unusually High O&M Costs During Review Period**

Describe costs and reasons: None

V. ACCESS AND INSTITUTIONAL CONTROLS [✓ Applicable] N/A

A. Fencing

1. **Fencing [✓ damaged]** ✓Location shown on site map ✓Gates secured N/A
Remarks Damage to split rail fence at landfill perimeter. Chain link fence around remediation facility is in v. good condition

B. Other Access Restrictions

1. **Signs and other security measures** ✓Location shown on site map N/A
Remarks______

C. Institutional Controls (ICs)

1. **Implementation and enforcement**

Site conditions imply ICs not properly implemented Yes [✓ No] N/A
Site conditions imply ICs not being fully enforced Yes [✓ No] N/A

Type of monitoring (*e.g.*, self-reporting, drive by) Site visits by WDNR
Frequency 3/year
Responsible party/agency Wisc. Dept. of Natural Resources
Contact Eileen Kramer Hydrogeologist 715-839-3824
Name Title ~~Date~~ Phone no.

Reporting is up-to-date Yes No [✓ N/A]
Reports are verified by the lead agency Yes No [✓ N/A]

Specific requirements in deed or decision documents have been met Yes [✓ No] N/A
Violations have been reported Yes [✓ No] N/A
Other problems or suggestions: Report attached

Deed restriction has not been recorded for real estate parcel on which landfill is located

2. **Adequacy** ICs are adequate [✓ ICs are inadequate] N/A
Remarks Restriction or covenant to run with land must be recorded for real estate parcel where land fill is located

D. General

1. **Vandalism/trespassing** Location shown on site map [✓ No vandalism evident]
Remarks

2. **Land use changes on site** N/A
Remarks None

3. **Land use changes off site** N/A
Remarks None at present. Owner of parcel south of site may sell property to commercial developer.

VI. GENERAL SITE CONDITIONS

A. Roads [✓ Applicable] N/A

1. **Roads damaged** Location shown on site map [✓ Roads adequate] N/A
Remarks

B. Other Site Conditions

Remarks______________________________

VII. LANDFILL COVERS [✓ Applicable] N/A

A. Landfill Surface

1. **Settlement** (Low spots) Location shown on site map [✓ Settlement not evident]
Areal extent__________ Depth__________
Remarks Slightly depressed area observed - no evidence of standing water

2. **Cracks** Location shown on site map [✓ Cracking not evident]
Lengths__________ Widths__________ Depths__________
Remarks______________________________

3. **Erosion** Location shown on site map [✓ Erosion not evident]
Areal extent__________ Depth__________
Remarks______________________________

4. **Holes** Location shown on site map [✓ Holes not evident]
Areal extent__________ Depth__________
Remarks______________________________

5. **Vegetative Cover** Grass [✓ Cover properly established] No signs of stress
Trees/Shrubs (indicate size and locations on a diagram)
Remarks Some invasive grass noted, does not compromise cap

6. **Alternative Cover (armored rock, concrete, etc.)** [✓ N/A]
Remarks______________________________

7. **Bulges** Location shown on site map [✓ Bulges not evident]
Areal extent__________ Height__________
Remarks______________________________

8. **Wet Areas/Water Damage** ✓ Wet areas/water damage not evident
Wet areas Location shown on site map Areal extent______________
Ponding Location shown on site map Areal extent______________
Seeps Location shown on site map Areal extent______________
Soft subgrade Location shown on site map Areal extent______________
Remarks____

9. **Slope Instability** Slides Location shown on site map ✓ No evidence of slope instability
Areal extent______________
Remarks____

B. Benches Applicable [✓ N/A]
(Horizontally constructed mounds of earth placed across a steep landfill side slope to interrupt the slope in order to slow down the velocity of surface runoff and intercept and convey the runoff to a lined channel.)

1. **Flows Bypass Bench** Location shown on site map N/A or okay
Remarks____

2. **Bench Breached** Location shown on site map N/A or okay
Remarks____

3. **Bench Overtopped** Location shown on site map N/A or okay
Remarks____

C. Letdown Channels Applicable [✓ N/A]
(Channel lined with erosion control mats, riprap, grout bags, or gabions that descend down the steep side slope of the cover and will allow the runoff water collected by the benches to move off of the landfill cover without creating erosion gullies.)

1. **Settlement** Location shown on site map No evidence of settlement
Areal extent______________ Depth____________
Remarks____

2. **Material Degradation** Location shown on site map No evidence of degradation
Material type______________ Areal extent______________
Remarks____

3. **Erosion** Location shown on site map No evidence of erosion
Areal extent______________ Depth____________
Remarks____

4. **Undercutting** Location shown on site map No evidence of undercutting
Areal extent________ Depth________
Remarks________

5. **Obstructions** Type________ No obstructions
Location shown on site map Areal extent________
Size________
Remarks________

6. **Excessive Vegetative Growth** Type________
No evidence of excessive growth
Vegetation in channels does not obstruct flow
Location shown on site map Areal extent________
Remarks________

D. Cover Penetrations [✓ Applicable] N/A

1. **Gas Vents** Active [✓ Passive]
Properly secured/locked Functioning Routinely sampled [✓ Good condition]
Evidence of leakage at penetration -NO NO Needs Maintenance
N/A
Remarks________

2. **Gas Monitoring Probes**
[✓ Properly secured/locked] [✓ Functioning] [✓ Routinely sampled] [✓ Good condition]
Evidence of leakage at penetration Needs Maintenance N/A
Remarks________

3. **Monitoring Wells** (within surface area of landfill)
[✓ Properly secured/locked] [✓ Functioning] [✓ Routinely sampled] [✓ Good condition]
Evidence of leakage at penetration Needs Maintenance N/A
Remarks Three nested groundwater wells present. The deepest well has some blockage + cannot be sampled

4. **Leachate Extraction Wells**
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance [✓ N/A]
Remarks________

5. **Settlement Monuments** Located Routinely surveyed [✓ N/A]
Remarks________

E. Gas Collection and Treatment Applicable [✓ N/A]

1. **Gas Treatment Facilities**
Flaring Thermal destruction Collection for reuse
Good condition Needs Maintenance
Remarks______________________________

2. **Gas Collection Wells, Manifolds and Piping**
Good condition Needs Maintenance
Remarks______________________________

3. **Gas Monitoring Facilities** (*e.g.*, gas monitoring of adjacent homes or buildings)
Good condition Needs Maintenance N/A
Remarks______________________________

F. Cover Drainage Layer Applicable [✓ N/A]

1. **Outlet Pipes Inspected** Functioning N/A
Remarks______________________________

2. **Outlet Rock Inspected** Functioning N/A
Remarks______________________________

G. Detention/Sedimentation Ponds Applicable [✓ N/A]

1. **Siltation** Areal extent__________ Depth__________ N/A
Siltation not evident
Remarks______________________________

2. **Erosion** Areal extent__________ Depth__________
Erosion not evident
Remarks______________________________

3. **Outlet Works** Functioning N/A
Remarks______________________________

4. **Dam** Functioning N/A
Remarks______________________________

H. Retaining Walls Applicable [✓ N/A]

1. **Deformations** Location shown on site map Deformation not evident
Horizontal displacement__________ Vertical displacement__________
Rotational displacement__________
Remarks____

2. **Degradation** Location shown on site map Degradation not evident
Remarks____

I. Perimeter Ditches/Off-Site Discharge Applicable [✓ N/A]

1. **Siltation** Location shown on site map Siltation not evident
Areal extent__________ Depth__________
Remarks____

2. **Vegetative Growth** Location shown on site map N/A
Vegetation does not impede flow
Areal extent__________ Type__________
Remarks____

3. **Erosion** Location shown on site map Erosion not evident
Areal extent__________ Depth__________
Remarks____

4. **Discharge Structure** Functioning N/A
Remarks____

VIII. VERTICAL BARRIER WALLS Applicable [✓ N/A]

1. **Settlement** Location shown on site map Settlement not evident
Areal extent__________ Depth__________
Remarks____

2. **Performance Monitoring** Type of monitoring__________________
Performance not monitored
Frequency____________________ Evidence of breaching
Head differential____________________
Remarks____

IX. GROUNDWATER/SURFACE WATER REMEDIES [✓ Applicable] N/A

A. Groundwater Extraction Wells, Pumps, and Pipelines [✓ Applicable] N/A

1. **Pumps, Wellhead Plumbing, and Electrical**
✓ Good condition ✓ All required wells properly operating Needs Maintenance N/A
Remarks Except EW-1, which would require repair to actively operate groundwater pump + treat system

2. **Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
✓ Good condition Needs Maintenance
Remarks

3. **Spare Parts and Equipment**
✓ Readily available ✓ Good condition Requires upgrade Needs to be provided
Remarks

B. Surface Water Collection Structures, Pumps, and Pipelines Applicable [✓ N/A]

1. **Collection Structures, Pumps, and Electrical**
Good condition Needs Maintenance
Remarks

2. **Surface Water Collection System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
Good condition Needs Maintenance
Remarks

3. **Spare Parts and Equipment**
Readily available Good condition Requires upgrade Needs to be provided
Remarks

C. Treatment System [✓ Applicable] N/A Currently shut down in accordance w/ 2001 ESD.

1. **Treatment Train** (Check components that apply)
[✓ Metals removal] Oil/water separation [✓ Bioremediation]
[✓ Air stripping] Carbon adsorbers
Filters
[✓ Additive (*e.g.*, chelation agent, flocculent)]
Others
[✓ Good condition] Needs Maintenance
[✓ Sampling ports properly marked and functional]
[✓ Sampling/maintenance log displayed and up to date]
[✓ Equipment properly identified]
Quantity of groundwater treated annually 0
Quantity of surface water treated annually 0
Remarks System being maintained in good stand-by status

2. **Electrical Enclosures and Panels** (properly rated and functional)
N/A [✓ Good condition] Needs Maintenance
Remarks

3. **Tanks, Vaults, Storage Vessels**
N/A [✓ Good condition] [✓ Proper secondary containment] Needs Maintenance
Remarks

4. **Discharge Structure and Appurtenances**
N/A [✓ Good condition] Needs Maintenance
Remarks

5. **Treatment Building(s)**
N/A [✓ Good condition (esp. roof and doorways)] Needs repair
[✓ Chemicals and equipment properly stored]
Remarks no treatment chemicals currently on site

6. **Monitoring Wells** (pump and treatment remedy)
[✓ Properly secured/locked] [✓ Functioning] [✓ Routinely sampled] [✓ Good condition]
[✓ All required wells located] Needs Maintenance - MW-5S N/A
Remarks All wells in good condition except MW-5S which requires a protective cover

D. Monitoring Data

1. Monitoring Data
[✓ Is routinely submitted on time] [✓ Is of acceptable quality]

2. Monitoring data suggests:
[✓ Groundwater plume is effectively contained] Contaminant concentrations are declining

D. Monitored Natural Attenuation

1. **Monitoring Wells** (natural attenuation remedy)
[✓ Properly secured/locked] [✓ Functioning] [✓ Routinely sampled] [✓ Good condition]
[✓ All required wells located] Needs Maintenance - MW-55 N/A
Remarks______________________________________

X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy. An example would be soil vapor extraction.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

The groundwater plume appears to be contained adequately. Continued ground water monitoring is necessary to ~~evaluate for natural attenuation~~ + assure protectiveness.

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

O&M is adequate. If it were necessary to restart the groundwater pump & treat system or the ~~[illegible]~~ soil air injection system, it could be accomplished within two weeks with an estimated expenditure of $15K.

C. **Early Indicators of Potential Remedy Problems**

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future.

None

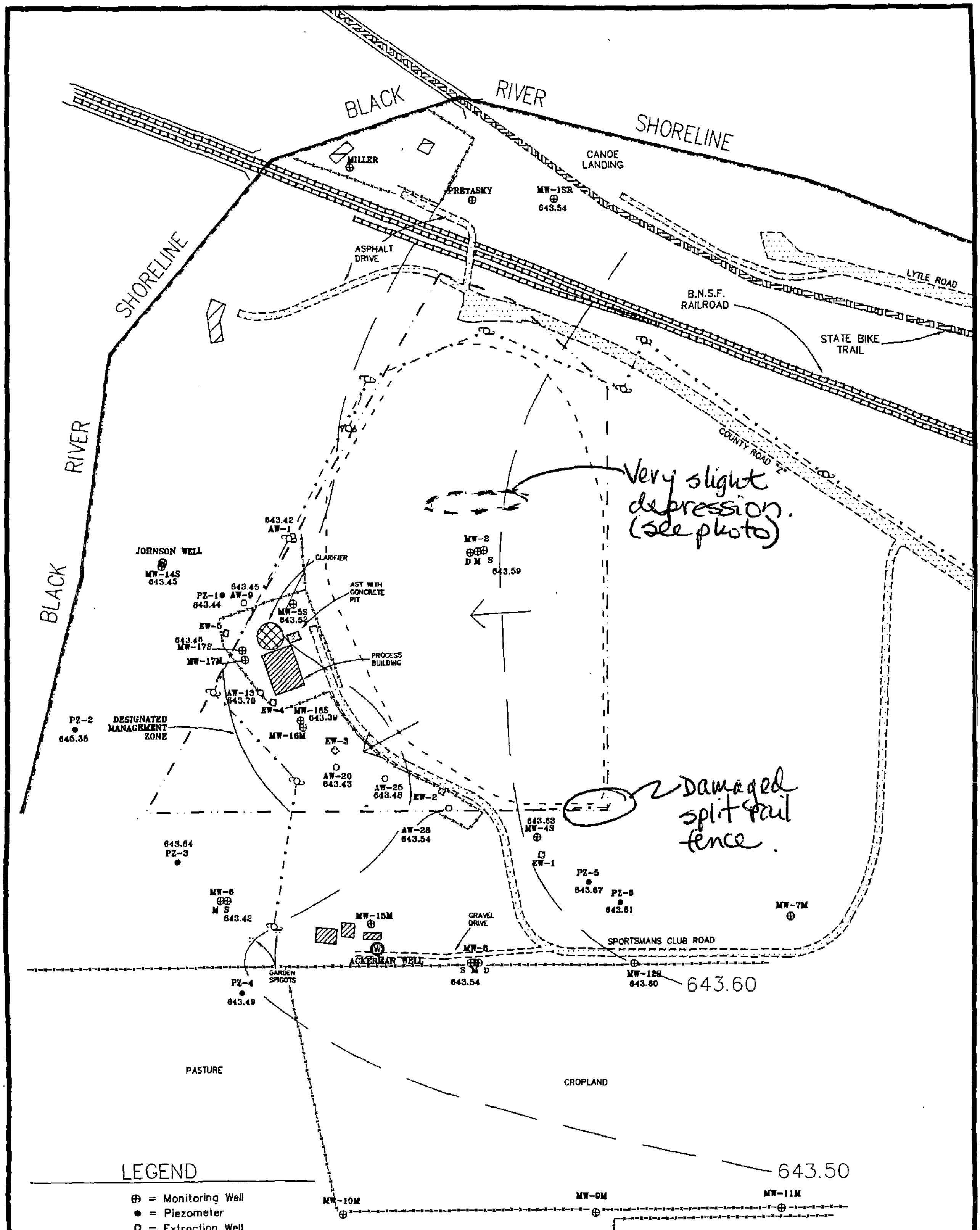
D. **Opportunities for Optimization**

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

Long term groundwater monitoring should continue.

Onalaska Municipal
Landfill Site
Five-Year Review Site Inspection
Sept. 26, 2007
Roster

Name	Organization
Eileen Kramer	Wisc DNR
Peter Moore	ENSR
Kyle Rogers	US EPA
William Wood	ENSR



LEGEND

⊕ = Monitoring Well
● = Piezometer
◻ = Extraction Well
○ = Air Well
— · · — = Approximate Property Boundary
- - - - - - - = Approximate extent of landfill cap
—x—x— = Fence line
— u — u — = Utility lines
= Utility pole
= Hydrant
← = Inferred Direction of Groundwater Flow

Approximate Scale
1 inch = 175 feet
0 175 350

N

Source:

Onalaska Landfill Site Plan Survey, prepared by Coulee Region Land Surveyors, Inc., project no. S-4754, dated 5/14/03.

Note:

Groundwater Elevations were Gauged on September 10 and September 11, 2007

FIGURE NUMBER:			
3-3	Groundwater Elevation Map Shallow Zone Wells SEPTEMBER 2007 ONALASKA LANDFILL ONALASKA, WISCONSIN		
SHEET NUMBER:	SCALE:	DATE:	PROJECT NUMBER:
1	1"=175'	10-16-07	7349-002

ENSR AECOM

ENSR CORPORATION
ST. LOUIS PARK, MINNESOTA 55416
PHONE: (952) 924-0117
FAX: (952) 942-0317
WEB: HTTP://WWW.ENSR.AECOM.COM

DESIGNED BY:	REVISIONS			
AC	NO.:	DESCRIPTION:	DATE:	BY:
DRAWN BY:				
AC				
CHECKED BY:				
PJM				
APPROVED BY:				
PJM				

ATTACHMENT 8

Interviews

INTERVIEW DOCUMENTATION FORM

The following is a list of individual interviewed for this five-year review. See the attached contact record(s) for a detailed summary of the interviews.

Peter Moore	Project Manager	ENSR	9/26/07
Name	Title/Position	Organization	Date
William Wood	Operator Maint. Staff	ENSR	9/26/07
Name	Title/Position	Organization	Date
Tim Dienger	Town Administrator	Town of Onalaska	9/27/07
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date

INTERVIEW RECORD

Site Name: Onalaska Municipal Landfill Site
EPA ID No.: WID980821656
Subject: Five Year Review
Time: 9AM **Date:** 9/27/07
Type: Telephone [✓ Visit] Other
Location of Visit: Town of Onalaska Hall
Incoming Outgoing

Contact Made By:

Name: Eileen Kramer
Title: Hydrogeologist
Organization: WDNR

Individual Contacted:

Name: Tim Dienger
Title: Town Administrator
Organization: Town
Telephone No: 608-783-4958
Fax No: 608-779-9605
E-Mail Address: tadon-townona@charter.net
Street Address: W7052 Second St
City, State, Zip: Onalaska, WI 54650

Summary Of Conversation

Mr. Dienger has been impressed by progress at the site. He has heard of potential future use of Prinsen property for boat storage. He will discuss possible town acquisition of property with the Town board; Town board mtgs are 4th Monday. Town has a potential brownfield - a former petroleum above ground tank facility.
(DNR sent follow up info about Brownfields assistance)

Page 1 of 1

INTERVIEW RECORD

Site Name: Onalaska Municipal Landfill Site

EPA ID No.: WID980821656

Subject: Five Year Review

Time: 1 PM

Date: 9/26/07

Type: Telephone [✓ Visit] Other

Location of Visit: Site

Incoming Outgoing

Contact Made By:

Name: Eileen Kramer

Title: Hydrogeologist

Organization: WDNR

Individual Contacted:

Name: William Wood

Title: Maintenance Staff

Organization: ENSR

Telephone No: 608-792-9510

Fax No:

E-Mail Address:

Street Address: W2788 Birch Lane

City, State, Zip: La Crosse, WI 54601

Summary Of Conversation

Maintenance of the system has been going well with no major problems. Plant does need a portable sump pump w/ ~30' head to help handle the water storage during the winter. The electrician has ordered a new part for the control panel & Bill will make arrangements to get the work finished.

Bill has not noticed any unusual activities or circumstances at plant or on landfill. He provided orientation & description of operations for water treatment plant.

Page 1 of 1

INTERVIEW RECORD

Site Name: Onalaska Municipal Landfill Site
EPA ID No.: WID980821656
Subject: Five Year Review
Time: 1 PM **Date:** 9/26/2007
Type: Telephone [✓ Visit] Other
Location of Visit: Site
Incoming Outgoing

Contact Made By:

Name: Eileen Kramer **Title:** Hydrogeologist **Organization:** WDNR

Individual Contacted:

Name: Peter Moore **Title:** Project Manager **Organization:** ENSR

Telephone No: 952-924-0117
Fax No:
E-Mail Address:
Street Address: 4500 Park Glen Rd.
City, State, Zip: St. Louis Park, MN 55416

Summary Of Conversation

Work at the site has been going well. There have been no surprises. Peter provided an orientation to the site. Helped locate the monitoring wells for inspection. Discussed the history of the site.

Page 1 of 1

ATTACHMENT 9

Text Portion of Evaluation of Monitored Natural Attenuation as a Containment Remedy For the Onalaska Municipal Landfill Site

Evaluation of Monitored Natural Attenuation as a Containment Remedy for the Onalaska Municipal Landfill Site, Onalaska, Wisconsin

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

GEOS

June 2008

7944 Wisconsin Avenue, Bethesda, Maryland 20814-3620 • (301) 718-8900

Evaluation of Monitored Natural Attenuation as a Containment Remedy for the Onalaska Municipal Landfill Site, Onalaska, Wisconsin

Prepared for:

U.S. EPA Region 5

Prepared by:

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

GEOS

June 2008

7944 Wisconsin Avenue, Bethesda, Maryland 20814-3620 • (301) 718-8900

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REPORT

Section 1
Introduction

The Onalaska Municipal Landfill site is located in the Township of Onalaska, about 10 miles north of La Crosse, Wisconsin (Figure 1). The site is situated 400 feet east of the Black River, near the confluence of the Mississippi and Black Rivers. The 11- acre site includes the 7-acre former township landfill which was in use between 1969 and 1980, and prior to 1969 the site was mined as a sand and gravel quarry.

The Black River is located within the Upper Mississippi River Wildlife and Fish Refuge, a wetlands area that supports numerous migrating species of birds and is also used for hiking, fishing, hunting, and other recreational purposes by area residents and visitors. The area surrounding the site is generally rural, although several residences are located within 500 feet of the landfill. A subdivision of about 50 homes is located about 1.25 miles southeast of the site. Agricultural lands are located south of the landfill, and intermittent woods and grasslands border the site to the east.

The site consists of 135 to 142 feet thick unconsolidated deposits primarily composed of sand and gravel (Figure 2). Beneath the unconsolidated deposits lies sandstone bedrock. The natural groundwater flow direction in the unconsolidated material is predominantly south-southwesterly toward the wetlands that border the Black River. During high river stages (i.e. spring), the groundwater flow direction is toward the south-southeast (Figure 3). Average groundwater flow velocity beneath the site was estimated during the Remedial Investigation (CH2M Hill, 1989) to range between 55 and 110 feet per year, with an estimated average of 70 feet per year.

Investigation and Remediation History

In September 1982, Wisconsin Department of Natural Resources (WDNR) sampled and analyzed water from site monitoring wells and nearby private wells for compliance with drinking water standards for organic and inorganic constituents. The investigations indicated that groundwater contamination had occurred. The barium concentrations in the water from a residential well south of the site exceeded the drinking water standard, and five organic compounds were detected above background levels.

On May 2, 1983, an EPA Potential Hazardous Waste site inspection report was submitted. In September 1984, the Onalaska Landfill was placed on the National Priorities List. U.S. EPA, in consultation with the WDNR, conducted a Remedial Investigation and Feasibility Study (RI/FS) at Onalaska from April 1988 through December 1989. The RI determined the landfill as the source of groundwater contamination at the site. According to the study, a groundwater contaminant plume consisting of organic and inorganic compounds had migrated at least 800 feet from the southwestern edge of the landfill. The report identified potential long-term exposure to low levels of volatile organic compounds (VOCs) from private wells and plausible discharges of contaminants to the wetlands and Black River as the principal threats to human health and the environment.

Preliminary investigations determined that contaminant concentrations in the groundwater at individual monitoring wells exceeded one or more Federal or State standards or criteria. The Safe Drinking Water Act maximum contaminant levels (MCLs) for the following contaminants were exceeded at one or more monitoring well locations.

- arsenic,
- barium,
- benzene,
- 1,1- dichloroethene(1,1-DCE),
- toluene,
- 1,1,1-trichloroethane(1,1,1-TCA),
- trichloroethene, and
- xylenes

The majority of volatile organic compounds (VOCs) detected were in shallow monitoring wells (MW-5S and MW-3S and B4S) and consisted of benzene, toluene, ethylbenzene and xylenes (BTEX). The vertical extent of BTEX and chlorinated compounds contamination was found to be confined to the upper 10 to 20 feet of the aquifer. Ethylbenzene, 1 ,1- DCA and chloroethane, however, were detected at depths up to 50 to 60 feet below the water table. The vertical extent of semi-volatile organic compounds (SVOCs) contamination was also mostly confined to the upper 10 to 20 feet of the aquifer. There were no SVOCs detected in any of the deep monitoring wells. Based on these findings, U.S. EPA issued a Record of Decision (ROD) in August 1990 that called for the following actions to mitigate the areas of concern:

- Installation of a landfill cap in accordance with federal and state requirements (completed in November 1993);
- Installation of a groundwater extraction and treatment system to capture and treat contaminants in the groundwater immediately downgradiant of the landfill (5 extraction wells were installed in June 1994);
- Installation of an air injection system within the area of soils contamination to enhance the bioremediation of organic contaminants (29 shallow injection wells were completed in June 1994);
- Implementation of a groundwater, surface water, and sediment monitoring program to ensure the adequacy of the cleanup.

The selected remedy established a containment and treatment system to eliminate the principal threat posed to human health and the environment by isolating the source of groundwater contaminants in the landfill and eliminating those in the adjacent soils, preventing the further migration of VOCs in groundwater, and by treating extracted groundwater to acceptable discharge limits.

The original groundwater monitoring program at the site was implemented in 1995 and included collection of groundwater samples from monitoring wells, extraction wells, and nearby residential wells. In addition to sampling, groundwater elevations were measured in monitoring wells, air injection wells (i.e. bioventing wells), and piezometers (Figure 4). From March 1995, through December 1996, sampling was conducted quarterly. From 1997 to 2004, sampling was completed semiannually, and from 2005 to the present, sampling has been completed quarterly, semi-annually, or annually for different wells. The wells included in the groundwater-monitoring program, as well as the parameters analyzed, have changed on several occasions since the groundwater monitoring program was implemented in 1995. The rationales for these changes are documented in the Annual Monitored Natural Attenuation Reports for the Onaslaska Municipal Landfill Site. Each change was approved by the USEPA prior to implementation.

On November 13, 2001, U.S. EPA issued an Explanation of Significant Difference (ESD) for the Onalaska Municipal Landfill, based on the results from the long-term groundwater study, which showed significantly reduced levels of contaminants and limited exposure pathways. The document concluded that continued operation of the groundwater extraction/treatment system may be no more effective than other, more cost-effective methods in addressing the remaining contamination. The ESD allowed for the temporary shutdown of the groundwater extraction and treatment to evaluate the need for continuous operation of the system and to determine whether natural attenuation processes exist at the site.

The groundwater extraction system has been on stand-by since November 26, 2001 and natural attenuation is being evaluated as a potential modification to the ROD. The most recent report on Monitored Natural Attenuation is the 2007 report (ENSR, 2007).

Section 2
Contaminant Concentrations

Under the remedy selected in the ROD, the following cleanup standards were adopted (ENSR Corporation, 2007):

- The contaminant plume located at any point beyond the property boundary or design management zone (DMZ) must meet the following criteria:
  - Preventive Action Limits (PALs) from Wisconsin Administrative Code Chapter NR 140
- The groundwater contaminant plume located at the landfill waste boundary must meet the following criteria:
  - Maximum Contaminant Levels (MCLs) from the Safe Drinking Water Act, 40 CFR 141 .61 and 40CFR143
  - Non-zero Maximum Contaminant Level Goals (MCLGs) from the Safe Drinking Water Act, 40 CFR 141. 50

The DMZ defined for the Onalaska site extends 250 feet horizontally from the waste boundary. Wisconsin standards (PALs) must be met at any point beyond the property boundary or the DMZ. The DMZ, as defined in NR 140, is a 3-dimensional boundary surrounding a regulated facility and extends from the ground surface through all saturated geological strata. Specific cleanup standards (i.e., chemical-specific concentrations) were established in the ROD for 11 indicator chemicals (e.g. Chemicals of Concern).

The USEPA amended the ROD on October 10, 2000, by an Explanation of Significant Differences (ESD) to revise the cleanup standards for these chemicals to the latest NR 140 PALs and Enforcement Standards (ESs). Thus, the ES is the cleanup goal for the DMZ and the PAL is the cleanup goal for areas outside the DMZ. The list of contaminants (e.g. contaminants of concern (COC)) included in the MNA Plan consists of the original 11 indicator chemicals, other contaminants detected at concentrations above PALs during the Remedial Investigation, and contaminants identified above Wisconsin PALs since the groundwater monitoring program was implemented in 1995. This list and the applicable cleanup standards are presented in Table 1. If it becomes apparent that it is technically impracticable to achieve the groundwater cleanup standards, including potential Alternate Concentration Limits (ACLs), then USEPA in consultation with the WDNR may consider the use of alternate methods to control the groundwater contaminant plume or source to achieve the standards. If those alternate methods cannot attain groundwater cleanup standards, including potential ACLs, then a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) waiver may be considered.

Current Conditions (2002 to 2007)

Figure 5 illustrates the VOC contaminants predominantly detected above regulatory limits in the past five years. The BTEX compounds are excluded from Figure 5. These compounds – benzene, ethylbenzene, toluene, and xylenes are also detected in groundwater at the site. Xylenes are present at concentrations in the hundreds of ug/l, but because the PAL standard for xylenes is 1,000 ug/l, these concentrations do not exceed standards. There have also been limited detections of benzene above the PAL standard (0.5 ug/L) outside the DMZ in 2002 and 2005. These included detections in the upgradient wells MW-1S and MW-1M. Because of the sporadic nature of these occurrences, however, they are not highlighted in this report. The key contaminants under current conditions are:

- 1,2,4-trimethylbenzene (124-TMB)
- 1,3,5-trimethylbenzene (135-TMB)
- naphthalene

In 2002, 1,1-dichloroethylene, tetrachloroethene, trichloroethene, and vinyl chloride were also detected above PAL levels in wells MW-2S, MW-2M, MW-5S, and MW-14S. These compounds have not been detected above regulatory limits in subsequent years, however. 1,2-Dichloromethane (methylene chloride) has also been detected in a number of wells. These occurrences are likely an artifact of laboratory contamination, and this compound is not considered a contaminant of concern at the site.

Total VOCs (excluding BTEX) observed over the 2002 to 2007 time period are represented in Figures 6 and 7. These data represent the sum of all VOCs detected in any monitoring wells, as averaged over the entire year.

A number of metals are also detected in groundwater at the site above regulatory levels. These include arsenic, barium, cadmium, iron, manganese, and lead. These are also contaminants of concern at the Onalaska site (Table 1). Because of the close relationship between redox conditions and metals concentration in groundwater, and the fact that these metals are naturally occurring, these will be addressed separately in later sections of this report.

Statistical Trends

SSP&A collaborated with USEPA Region V to complete statistical analyses of groundwater concentration data for the principal COCs at all monitoring locations throughout the site. This report only presents the results of the analyses completed for TMBs and naphthalene. USEPA staff used an in-house statistical analysis program, the PAM statistical software package, developed by Subterranean Research Inc., to complete the following three analyses for each sampled location:

- Standard Test: compares the 95% upper confidence limit (UCL) calculated using the 4 most recent data points, or using data collected after a specified date, to COC-specific standards. The Standard Test reports the result (Compliance, Exceedance), the 95% UCL, and the COC specific standard in consistent units.

- Trend Test: identifies upward or downward trends through time. The trend method used is the Sen's Test, a non-parametric trend analysis similar to the Mann-Kendall test. The trend statistics reported are the slope result (Upward, Downward, No Trend) and the slope estimate (in concentration units per year). Upward and Downward tests are each calculated at the 95% confidence level. Because the trend is calculated on the natural logarithm of the concentration, the slope estimate is reported in terms of the log of the concentration units per year.
- Baseline Test: compares the most recent datum to the upper prediction limit (UPL) calculated from a baseline subset of the data, the first 8 available samples collected at each point. The Baseline Test reports the result (Better, Worse, No Change); and the 95% prediction limit UPL.

Results of the PAM analyses are provided in the Appendix. The calculated UCLs are used in this report to prepare maps illustrating the approximate extent of the contaminants of concern.

Contaminant Concentration Trends - VOCs

Figure 8 through 11 show the concentration trends calculated with the PAM analysis for the three primary contaminants of concern. For both the trimethylbenzenes, as well as naphthalene, increasing concentration trends are observed in at least one of the following wells: MW-4S, MW-5S, MW-8M, MW-14S, and MW-17S (Table 2). Of these wells, only a single one is screened in the medium depth wells, MW-8M. Concentrations of 1,2,4-trimethylbenzene have been increasing in this well since 2003. A single well, AW-25 exhibits decreasing 1,2,4-TMB concentrations. Four shallow wells (AW-13, AW-20, MW-16S, and AW-28) indicate decreasing concentrations of 1,3,5-TMB over the same period. The AW wells are typically screened across only the upper foot (or less) of the saturated zone. Consequently, their results may not be representative of deeper portions of the saturated zone.

Three of the shallow wells with increasing 1,2,4-TMB concentrations- MW-4S, MW-5S, and MW-14S- also show increasing naphthalene concentrations. No increasing concentrations of naphthalene were observed in the wells screened at medium depths.

Contaminant Concentration Trends - Metals

Figure 12 and 13 show the concentration trends calculated with the PAM analysis for arsenic and barium. These metals are highlighted because they are COCs, occur in excess of the Wisconsin PAL standards, and are not commonly-used indicators of redox conditions (e.g. Mn and Fe). Other metals, including cobalt exhibit more limited exceedances and/or upward concentration trends. These are highlighted in the summary of statistical analyses in the Appendix.

Section 3
Target Zones

Values for Upper Confidence Limits (UCLs) were calculated from the time series data (concentration data) as part of the PAM analysis. These were calculated for naphthalene concentrations and for total TMBs.

Figures 14 through 16 depict the extent of target zones for these contaminants. The target zones are defined as that area in the aquifer that is likely to exceed cleanup criteria. They are constructed using the UCL values calculated for each COC at each well, and by applying a contouring (kriging) technique to interpolate between those values. The boundaries of the target zones are defined by a lower cutoff value, typically equal to the cleanup criteria for the relevant compound(s). In this report, the target zones are represented with lower cutoff values equal to the PAL regulatory levels. To calculate the total TMBs, non-detect values were treated as equal to one-half the detection limit. This introduces some uncertainty into the UCL calculations. For total TMBs, however, the PAL regulatory level is 96 ug/l, whereas detection limits were generally below 1 ug/l. Thus, the actual uncertainty introduced is minimal with respect to the regulatory levels.

For both the shallow and medium-depth wells, portions of the UCL target zones extend beyond the DMZ at 250 feet from the edge of the landfill cap. On the northwest and southern edges of the DMZ, these excursions outside of the DMZ are associated with wells with increasing TMB and naphthalene trends – e.g. Wells MW-14S and MW-8M.

The target zones for arsenic and barium are depicted in Figures 17 and 18. All of the UCL values for As exceed the PAL standard of 1 ug/l. In addition, increasing arsenic trends are calculated for MW-8M and at PZ-02. Reported detection limits for arsenic, however, are generally greater than the PAL standard of 1 ug/l. The reported detection limits range from 1.1 ug/l to 10 ug/l, but are generally 5 ug/l or less. Because the ND surrogate used in the statistical calculations is 0.5 x the median of reported detection limits, these UCLs and resultant target zones are strongly impacted by these detection limits. At PZ-02, for example, the upward trend calculated by PAM is influenced by varying detection limits and may not be meaningful (Appendix). Consequently, the actual extent of the As target zone depicted here will be impacted by these relatively elevated detection limits, and should be considered with caution below values of 5 ug/l.

The extent of the target zones for Ba above the PAL standard outside of the DMZ is greater for the medium-depth than shallow-depth wells. In addition, increasing barium trends are observed in MW-8M outside of the DMZ.

The PAM analysis of dissolved lead indicates no upward trends in shallow and medium-depth wells, but many wells are determined to be in exceedance of the the PAL standards outside of the DMZ. These lead exceedances, however, are calculated largely on the basis of detection limits close to or in excess of the PAL standard of 0.5 ug/l. Consequently, it is not clear if lead concentrations do exceed the standard or if it is merely an artifact of an elevated detection limit with respect to the standard.

Section 4
Natural Attenuation as a Remedy

The primary goal of this evaluation is to determine whether monitored natural attenuation (MNA) is a suitable final remedy for the Onalaska Landfill site. Groundwater parameters descriptive of redox conditions in the groundwater have been collected at the site. From 2002 to 2007, in particular, the following data were collected for evaluation of MNA:

- Oxidation-Reduction Potential (ORP; field parameter)
- Dissolved Oxygen (field parameter)
- Dissolved Iron
- Dissolve Manganese
- Total Sulfate
- Total Nitrate
- Methane
- Chloride

Figure 19 illustrates trends in ORP from 2002 to 2007. For many wells in both the shallow and medium depth zones, there is an apparent trend from more oxidizing conditions in 2002-2003 followed by a swing to more reducing conditions in 2005. In some wells, this trend appears to have reversed starting in 2006. Dissolved oxygen data collected simultaneously with the ORP data are more variable, and not well correlated with the ORP results.

The air-injection system at the Onalaska Landfill was shut down in 1997. It is therefore conceivable that the observed redox trends could be related to this change in the subsurface environment. Examination of the ORP trends for the air-injection (AW) wells suggests that generally oxidizing conditions persisted in these wells through 2004 or 2005, but that the swing to more reducing ORP values (Figure 19) occurred nearly simultaneously across the site, including in the AW bioremediation wells. It is difficult to conceptualize a physical mechanism whereby all monitoring wells at the site would respond simultaneously to the AW well shutdown, regardless of proximity of the AW wells, their shallow screens, or groundwater flow direction and rates. Similarly, the groundwater extraction system was shut down in 2001. While this may have impacted redox conditions in the subsurface, it is unlikely that the rapid change in redox conditions, several years later, across the entire site is a response to the extraction well shutdown.

It is noted in the annual MNA reports produced by ENSR Corporation (2003 to 2007) that field parameters were measured during

> "the purging process using a water quality meter equipped with a flow-through cell (when possible). If using a flow cell was not possible, then field parameters were measured from purge water collected in a container."

Considering the apparent variations in field methods for collecting these parameters, and the difficulty of achieving good ORP and DO measurements without interference or calibration drift, it is most likely that the observed trends in ORP and dissolved oxygen values are influenced more by the collection methodology than actual redox condtions in the aquifer.

Other redox parameters collected for Onalaska site include major ions and methane in groundwater. Across the site as a whole, these redox parameters have varied both geographically and temporally (Figures 20 – 27). To interpret these data, it is essential that redox conditions downgradient of the landfill be considered with respect to upgradient or background conditions. There are few data collection locations situated upgradient of the landfill and of known screen depth. These locations are MW-1S, its replacement MW-1SR (both which are screened in the shallow interval) and MW-1M, screened in the medium-depth interval. Other upgradient private wells are either screened in the deep aquifer or at an unknown interval.

To facilitate an interpretation, all MNA parameter analytical results for the background wells were plotted against downgradient wells in cumulative frequency distribution curves (Figure 28). In each of these curves, all of the data were ranked in ascending order and then assigned a percentile ranking from 0 to 1.0. When viewed in this format, a number of key observations are clear:

- For a given percentile value, concentrations of nitrate are generally higher in the upgradient than in the downgradient wells
- Similarly, concentrations of sulfate are higher in the background well(s) than in the downgradient wells
- For a given percentile value, concentrations of Fe and Mn are generally higher in the downgradient than the upgradient wells

To put the redox conditions at the Onalaska site into broader perspective, site data was compared to major ion concentrations elsewhere in the sand and gravel aquifer of the Black River watershed. The background data used for comparison were obtained from the USGS NWIS database. Locations were selected that were located within the Black River watershed (hydrological unit HUC 07040007) and the sand and gravel aquifer. The selected 12 background wells ranged from 12-108 feet in depth. All the background wells were located upstream of the Onalaska site, with the closest site being 32 miles from the Onalaska landfill perimeter, and the farthest background site 90 miles away. The samples at the background sites were collected between 1946 and 1986.

As shown on Figure 29, the nitrate concentrations are generally higher in the background wells than in the site wells, with the 75th percentile value equal to 2.7 mg/l, as compared to 0.52 and 0.02 mg/l on-site (excluding MW-1S and MW-1SR). Background nitrate concentrations in the aquifer have a median value of about 0.7 mg/l, whereas wells in the shallow and medium depth site wells have median values between 0.01and 0.1 mg/l. Similarly, the 75th percentile sulfate value for background wells is 21 mg/l, as compared to 5.7 to 2.4 mg/l on-site. The median background sulfate concentrations are 10 mg/l, as compared to 2.9 mg/l and 0.67 mg/l on-site. Dissolved iron and manganese in the background aquifer are both higher on-site than in the background, although dissolved iron concentrations in the shallow wells are higher than in the medium-depth wells. In addition, the range of chloride concentrations in the downgradient wells exceeds the background well by more than an order of magnitude

Collectively, these data are consistent with a scenario in which all of the monitoring wells at the Onalaska site, with the exception of MW-1S, MW-1SR, and MW-1M are influenced by the reducing redox conditions typically observed downgradient of landfills. Wastes and disposal methods at the site are typical of municipal landfills, where conditions are generally more reducing than surrounding areas (Kjeldsen et al 2002). The Onalaska landfill was used for municipal, commercial, and industrial waste disposal from 1969 to 1980. Wastes deposited at the Site include municipal refuse, animal carcasses, septic sludge, construction debris, tires, industrial solvents, and other chemicals (Table 3). Municipal, commercial, and industrial wastes were usually not segregated, and are mixed throughout the landfill (CH2MHill 1989). Chloride is often a significant component of municipal landfill leachate; the data described here suggest that the highest chloride concentrations do also occur downgradient of the landfill.

Correlation of MNA Parameters with Observed Contaminant Trends

Trimethylbenzenes and naphthalene will degrade through biologically-mediated reactions under aerobic redox conditions in groundwater. Both are more recalcitrant under reducing conditions, although their degradation under nitrate-reducing and sulfate-reducing conditions has been demonstrated (Thierrin et al. 1993; Haner et al., 1997; Zheng et al., 2001). In fact, stability of the TMBs under reducing conditions is sufficient that they have been used as conservative tracers for other more degradable petroleum components (Weidemeier et al., 1996).

The MNA data outlined above suggest a correlation between reducing redox conditions, and increasing trends in TMBs and naphthalene. Prior to 2002, the groundwater environment downgradient of the landfill was potentially altered substantially by the pumping of extraction wells, and the presence of air injection wells. Absent these disturbances, the predominant groundwater conditions downgradient of the landfill are under conditions at least as reducing as sulfate-reducing. (Some methane has also been detected, suggesting methanogenic conditions locally.) Consequently, it is consistent with these conditions for TMBs and naphthalene to persist in groundwater downgradient of the landfill.

The trends in 1,2,4-TMB and naphthalene are consistent across several wells. It is therefore likely that these contaminant concentration trends reflect redox conditions, and that increases in TMBs and naphthalene since 2002 are a product of groundwater conditions under non-pumping, non-air-injecting conditions. This relationship is not absolute – note, for example the decreasing trends in 1,3,5-TMB during the same time period. There is some research to suggest that 1,3,5-TMB may degrade under sulfate-reducing conditions (Thierrin et al. 1993), which could be an explanation for the varying response to 1,2,4-TMB and 1,3,5-TMB in different wells. Of course, subsurface heterogeneity, and the presence of redox microenvironments cannot be discounted.

It is possible that further downgradient of the DMZ, redox conditions dominated by the natural, more oxidizing background geochemistry are present, thereby enabling degradation of the TMBs and naphthalene (i.e., a mixed Type I to Type III system, Weidemeir et al., 1999). But there are no monitoring data available with which to test this theory.

As noted above, arsenic and barium are observed at concentrations that have remained above relevant standards (Table 4). Both of these are naturally-occurring elements whose concentrations in groundwater are highly dependent upon redox conditions. Arsenic in groundwater can be present in various forms such as H_3AsO_3, H_2AsO_3, $HAsO_3$, H_3AsO_4, H_2AsO_4 and $HAsO_4$. The dominant As oxidation states in water are arsenate As^{5+} and arsenite As^{3+} (Hem, 1985). Studies have shown that concentrations of dissolved arsenic increases with decreasing pH and Eh (Saxena et al, 2004). At the same time, removal mechanisms include adsorption of As by hydrous iron oxides or coprecipitation with sulfides, depending upon redox conditions and availability of other ions. The speciation of As at the Onalaska site is not known, but its solubility is strongly influenced by redox conditions, and under existing conditions, As concentrations exceed the PAL standards.

Concentrations of barium in water are controlled mainly by sulfate concentrations. Formation of barium sulfate or barite is highly favorable thermodynamically and barite is highly insoluble (Hem, 1985). Reducing conditions at the Onalaska site and limited sulfate concentrations may hinder the formation barium sulfate, thereby enhancing the concentrations of dissolved barium. Barium concentrations in water are also limited by adsorption to metal oxides or hydroxides (Hem, 1985). Under the redox conditions observed at this site, such adsorption would be limited.

Section 5
Discussion, Conclusions and Recommendations

Groundwater conditions at the Onalaska Municipal Landfill site are characterized by a relatively homogenous aquifer. Wells are screened at multiple depths, but do not indicate significant upward or downward gradients. This is consistent with the persistence of groundwater contamination primarily with the shallow zone, with limited apparent migration to the deeper zones.

Evaluation of MNA parameter data collected since 2002 suggests that redox conditions in groundwater downgradient of the landfill are more highly reducing than under background conditions in the aquifer. Under these conditions, TMBs and naphthalene, compounds that are persistent under anaerobic conditions, are seen to be increasing in concentration both inside and outside of the DMZ. It is possible that further downgradient, redox conditions dominated by the natural, more oxidizing background geochemistry are present, thereby enabling degradation of the TMBs and naphthalene. There are, however, no monitoring data available with which to test this theory.

While MNA parameters have been collected over an appropriate period of time, and at suitable intervals, the collection and analysis of these data could be improved to enhance monitoring of MNA and compliance with ROD requirements. While the MNA evaluation reports (e.g. ENSR, 2007) address degradation of chlorinated solvents, they do not explicitly include the possibility of compounds that are persistent under the reducing conditions that facilitate dechlorination. Nor do they include a full evaluation of COC metals such as arsenic and barium whose concentrations are strongly impacted by redox condition. Previous MNA analyses have failed to take into account variations in background versus downgradient conditions. Ultimately, all of these shortcomings reflect the lack of a relevant site conceptual model that is appropriate for this landfill (e.g. USEPA, 2008). A complete site conceptual model for the MNA remedy must consider

- Groundwater flow directions and monitoring of locations upgradient, downgradient, and side-gradient (USEPA, 2008)
- The amenability of each COC to degrade under varying redox conditions
- An understanding of the geographic and hydrostratigraphic limits of each redox zone, so that these may be compared to the extent of COC contamination
- The impact of site activities (e.g. pumping, landfill capping, air injection) on subsurface redox conditions.

Conclusions

At the current time, the target zones for contaminant containment, based upon UCL concentrations, extend beyond the Design Management Zone. In addition, at locations outside the DMZ, concentrations of TMBs and naphthalene are increasing. The naturally-occurring metals iron, manganese, arsenic, and barium are currently present at concentrations that exceed PAL standards outside the DMZ, and at the most distal monitoring well locations. While MNA may be an appropriate final remedy for the Onalaska Municipal Landfill, the redox parameters collected to date are, with the exception of a single upgradient well in each of the shallow and medium-depth zones, influenced by the highly reducing conditions associated with the landfill. Consequently, the data are insufficient to determine if TMBs and naphthalene will degrade to acceptable levels in groundwater beyond the existing groundwater monitoring system.

Recommendations

The following recommendations address shortcomings that may be considered to improve the MNA program.

- The site conceptual model should be updated to incorporate the degradation potential of all COCs (including metals other than Fe and Mn), and the redox conditions under which they may be degraded or immobilized, groundwater flow directions, and the extent of different redox zones
- Because of the apparent persistence of compounds downgradient of the DMZ, it is recommended that additional monitoring of MNA parameters be conducted in the shallow and medium zones beyond the current extent of monitoring wells. This monitoring will help determine if redox conditions downgradient of the landfill are suitable for further immobilization of dissolved contaminants. In addition, "side-gradient" monitoring wells should be considered (EPA, 2008) to help define the lateral extents of the downgradient redox zones
- Continue monitoring groundwater levels, contaminants of concern and MNA parameters on the current schedule, but include water level measurements during all sampling events;
- To improve understanding of groundwater flow directions and mapping, water level measurements should include stage measurements on the Black river, north and west of the landfill; these measurements should be tied into the same vertical and horizontal datums as the existing monitoring well network, and should be collected at the same time as water levels from the monitoring wells.
- Additional MNA parameters should be incorporated into the analytical set to facilitate evaluation of redox zonation. In order to better delineate redox zones the following parameters should be included:
    - Nitrite, and
    - Sulfide
- Annual MNA reports should include interpretations of the shallow and medium depth zones independently. These interpretations should include

  - Maps of complementary oxidized/reduced pairs such as nitrate/nitrite and sulfate/sulfite to establish relative zone of redox conditions
  - Comparison of these data to background levels in the aquifer
  - Evaluation of parameters such as chloride should consider known background concentrations in the aquifer and the likelihood that chloride is also a common contaminant from landfills unrelated to dechlorination reactions.
- Each year, MNA conditions and contaminant concentration trends should be re-evaluated to determine whether site conditions are sufficiently stable to rely upon MNA as a final remedy for the site.

Notwithstanding these recommendations for improving the MNA program, the Onalaska site is not currently in compliance outside of the DMZ for naphthalene (at MW-14S) several metals (Table 4). If current trends continue, it may soon be out of compliance for the sum of trimethylbenzenes at MW-8M. The analysis completed here suggests that many or all of these contaminant concentrations are reflecting the predominantly reducing redox conditions present at both the shallow and medium depth intervals in the aquifer. Consequently, remedial options to address these issues may include:

- Resumption of the air-injection system downgradient of the landfill. The injection of air may serve to induce oxidizing conditions suitable for degradation of BTEX, TMBs, and naphthalene, and help maintain low levels of chlorinated solvents through direct physical transfer of VOCs to the vapor phase. The most positive impact of this approach will be on the shallowest portion of the aquifer (where the AW wells are screened) and possible in overlying source area materials. It is not clear whether resumption of air injection will have a positive impact on contaminant concentrations in the entire shallow depth zone or medium-depth zone, but this should be evaluated prior to resumption of the remedy.
- Alternately, resumption of active pumping in extraction wells EW-1 though EW-5 may be a reasonable approach, as this will serve to contain contaminant within the DMZ (assuming the design- and actual pumping rates are appropriate). It may also serve to bring addition oxygenated shallow water into the medium-depth portions of the aquifer thereby enhancing containment of metals including arsenic and barium.

In addition, reported detection limits for some COCs, particularly the metals arsenic and lead, are frequently higher than the relevant groundwater standards. This makes evaluation of compliance difficult, at best. Work plans for future monitoring must consider the detection limits for these compound with regard to the relevant standards to ensure that useable data are obtained.

Section 6
References

CH2M Hill, (1989). Remedial Investigation (RI) Report. Vol 1.

ENSR Corporation (2007). Annual Monitored Natural Attenuation Report for the Onalaska Municipal Landfill Site, Onalaska, Wisconsin, Wisconsin Department of Natural Resources.

Haner, A., Hohener, P., and Zayer, J., 1997, Degradation of Trimethylbenzene Isomers by an Enrichment Culture under N2O-Reducing Conditions, Applied and Environemental Microbiology, 63, 3, 1171-1174.

Hem, J.D. (985). Study and Interpretation of the Chemical Characteristics of Natural Water. U.S. Geological Survey. Water-Supply Paper 2254. Washington D.C.

Kjelsdsen, P., Barlaz, M., Rooker, A., Baun, A., Ledlin, A., Christensen, T., 2002, Present and Long-Term Composition of MSW Landfill Leachate: A Review, Critical Reviews in Environmental Science and Technology, 32, 4, 297-336.

Saxena, V.K., Kumar, S., and Singh, V.S., 2004, Occurrence, behavior and speciation of arsenic in groundwater, Current Science, 86: 2, 281-284.

Thierrin, J, Davis, G, Barber, BP. et. al.(1993) Natural degradation rates of BTEX compounds and naphthalene in a sulfate reducing groundwater environment. Hydrological Sciences. 38(4), 309-322.

U.S. Environmental Protection Agency (USEPA) (2001). Explanation of Significant Differences (ESD) Onalaska Municipal Landfill.

Zheng, Z., Breedveld G., and Aagaard, A., 2001. Biodegradation of soluble aromatic compounds of jet fuel under anaerobic conditions: laboratory batch experiments, Applied Microbiology and Biotechnology, 57, 572-578.

Wiedemeier TH, Swanson MA, Wilson JT, Kampbell DH, Miller RN, Hansen JE (1996) approximation of biodegradation rate constants for monoaromatic hydrocarbons (BTEX) in ground water. Ground Water Monit Rem 16:186–194

Wiedemeier TH, Rifai, HS., Newell, CJ, and Wilson, JT. 1999, Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface, New York, John Wiley & Sons, 617 pp.

FIGURES

Figure 1 Location of the Onalaska Municipal Landfill Site

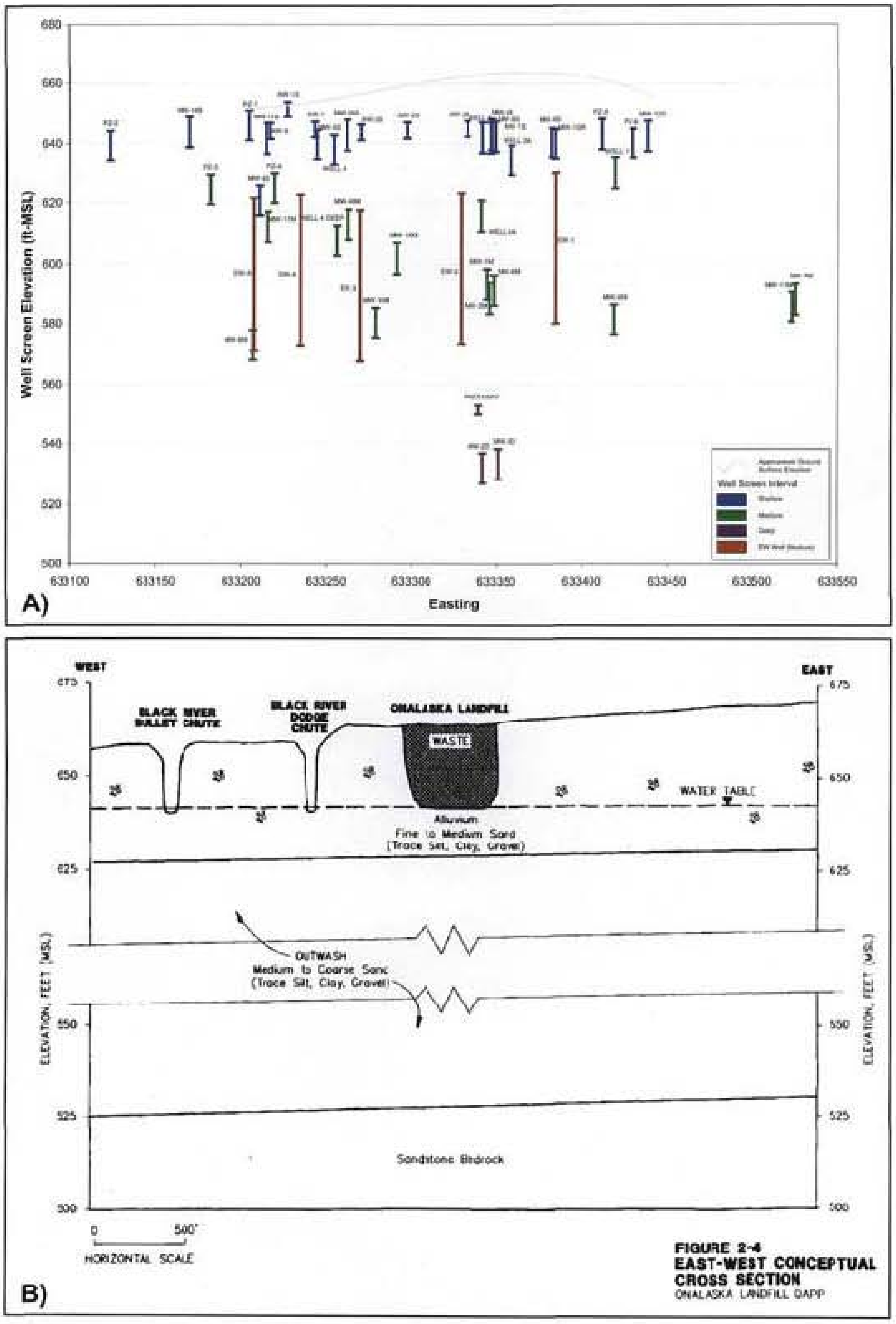


Figure 2 East West Cross Sections showing A) Well Screen Elevations, and B) Conceptual Cross Section (from CH2M Hill, Inc. 1989)

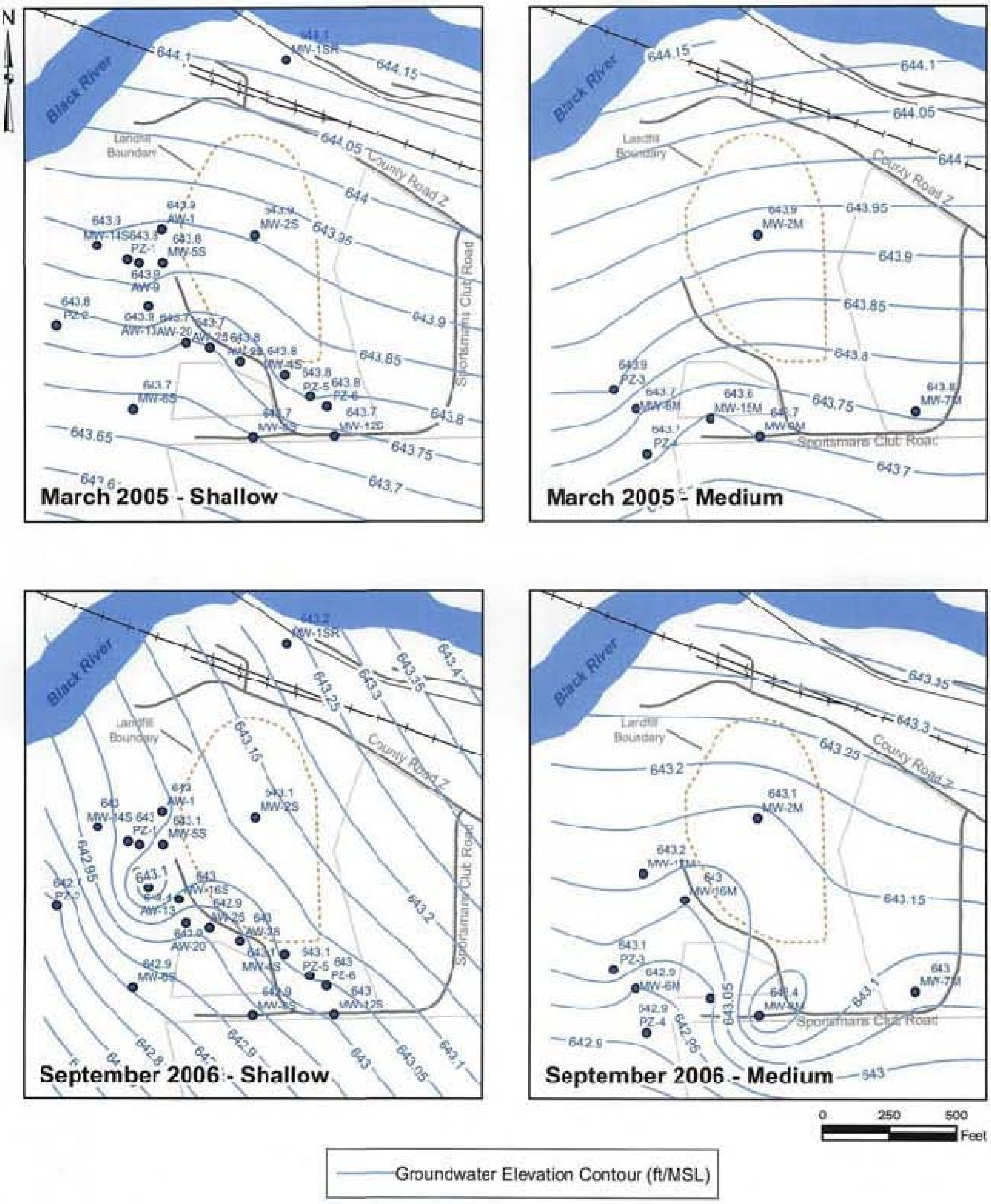


Figure 3 Groundwater Contours in March 2005 and September 2006, in Shallow and Medium-Depth Intervals

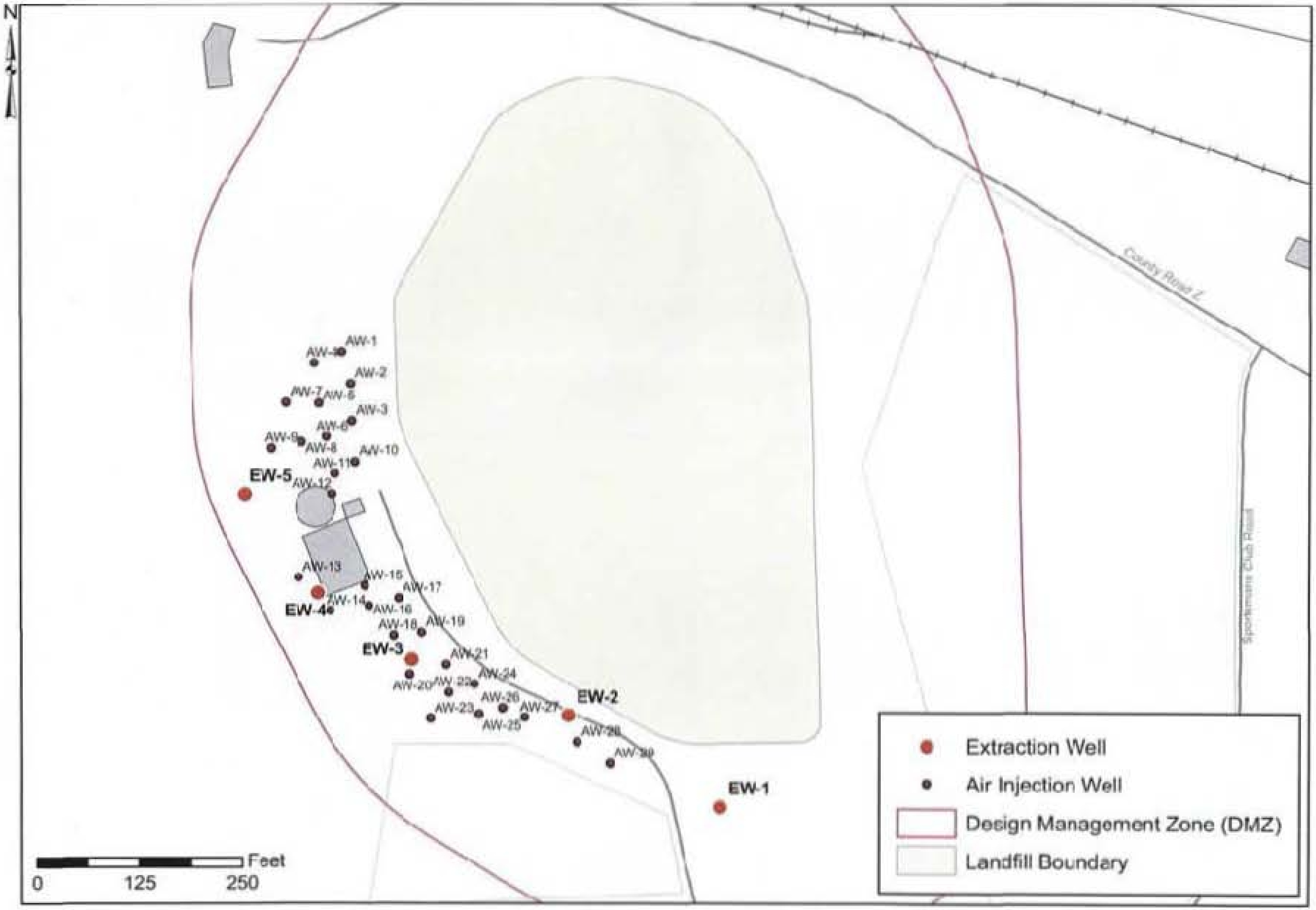


Figure 4 Remediation System Components, 1994 to 2001

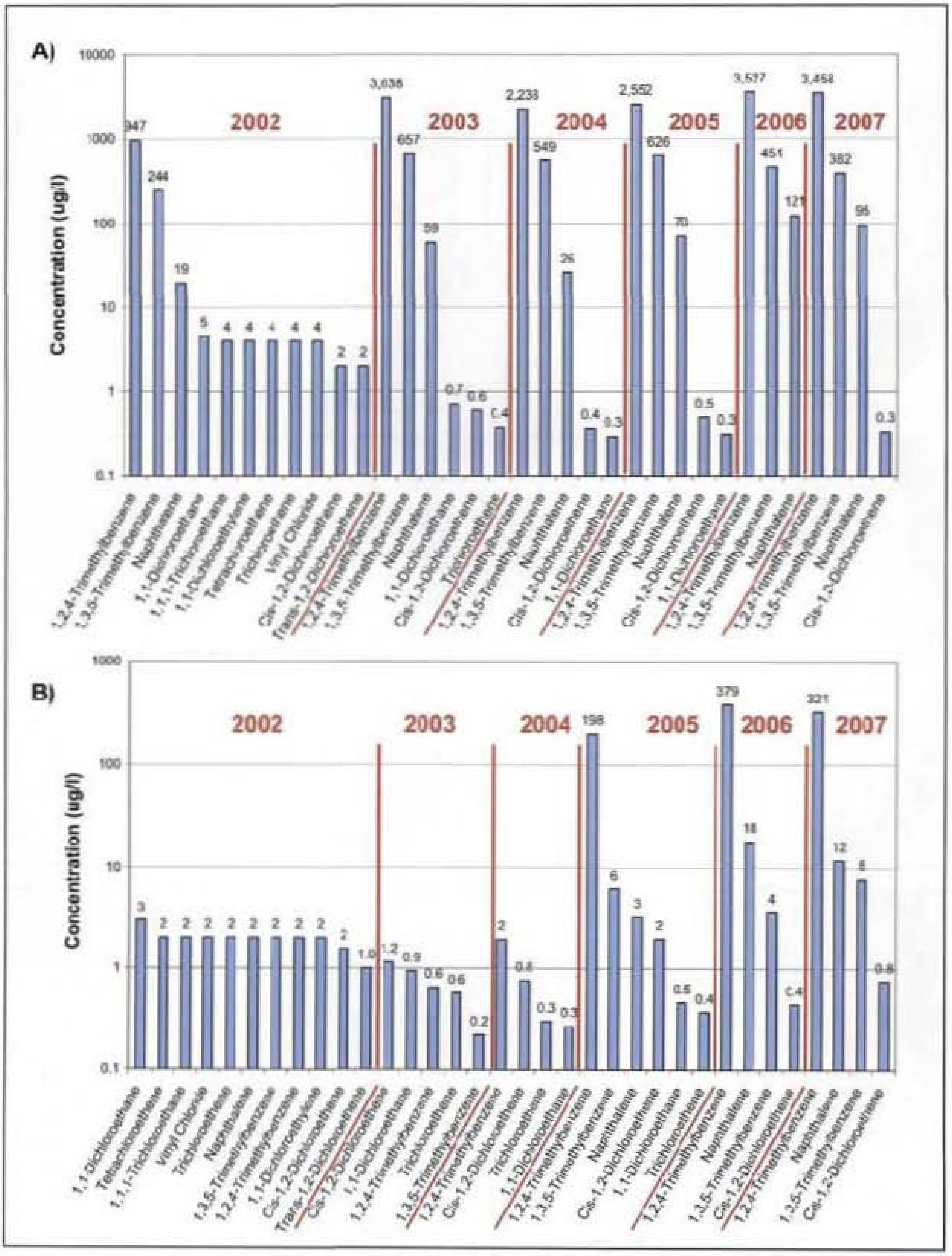


Figure 5 VOC Compounds Detected in Groundwater (excluding BTEX), Sums of Individual Well Annual Averages 2002 to 2007, in A) Shallow Wells, and B) Medium-Depth Wells

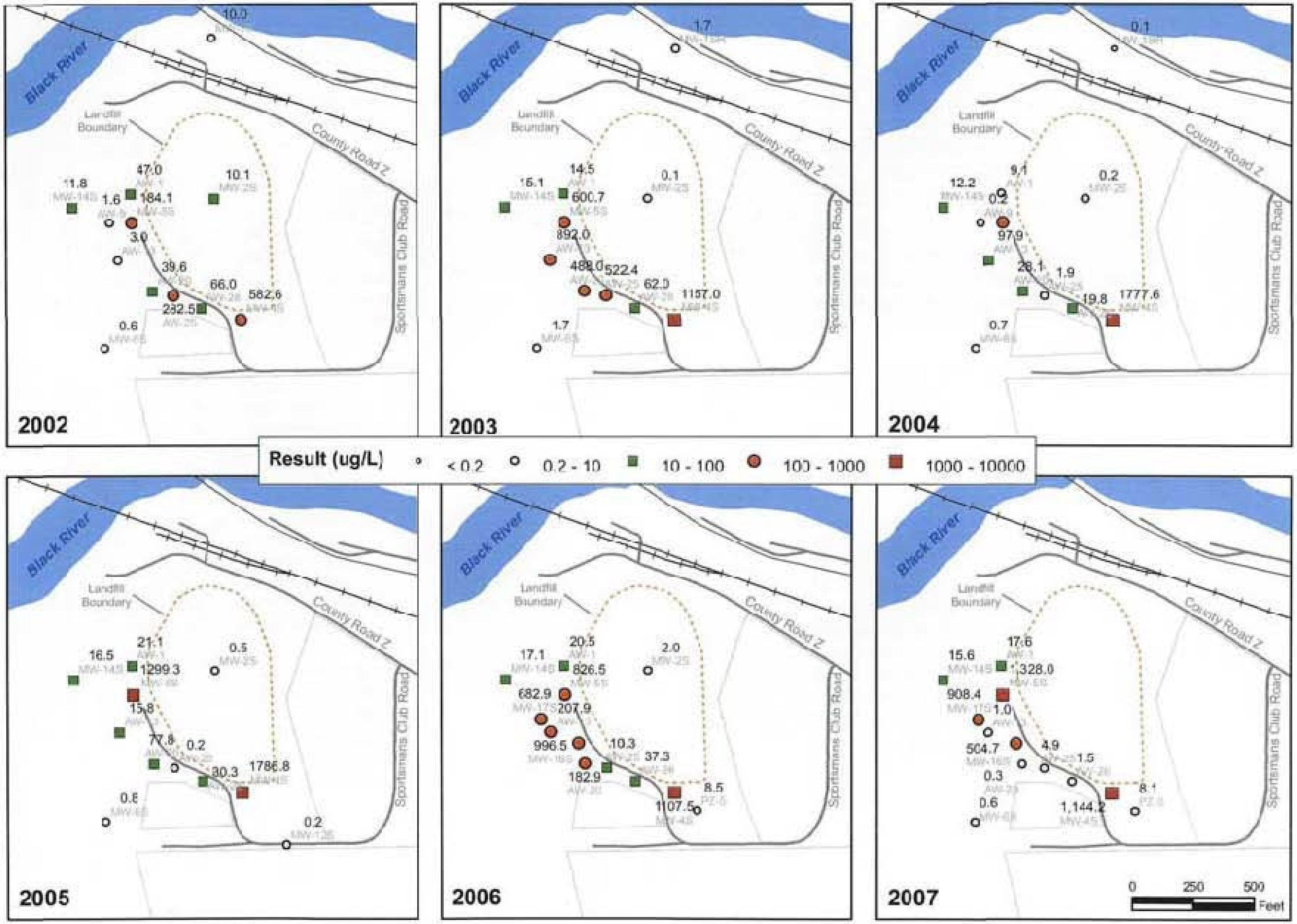


Figure 6 Total VOC Concentrations, 2002 to 2007, Shallow Wells

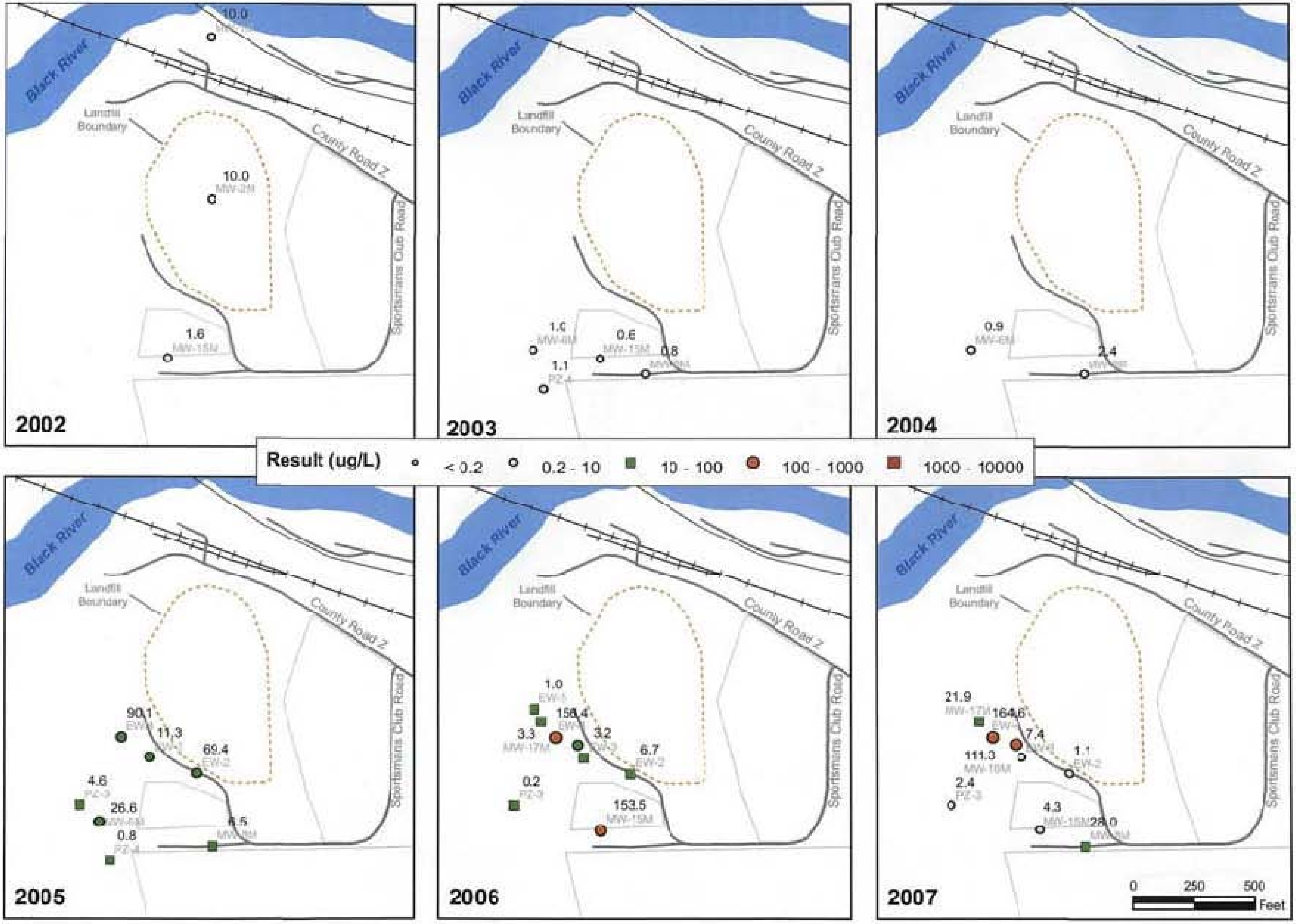


Figure 7 Total VOC Concentrations, 2002 to 2007, Medium-Depth Wells

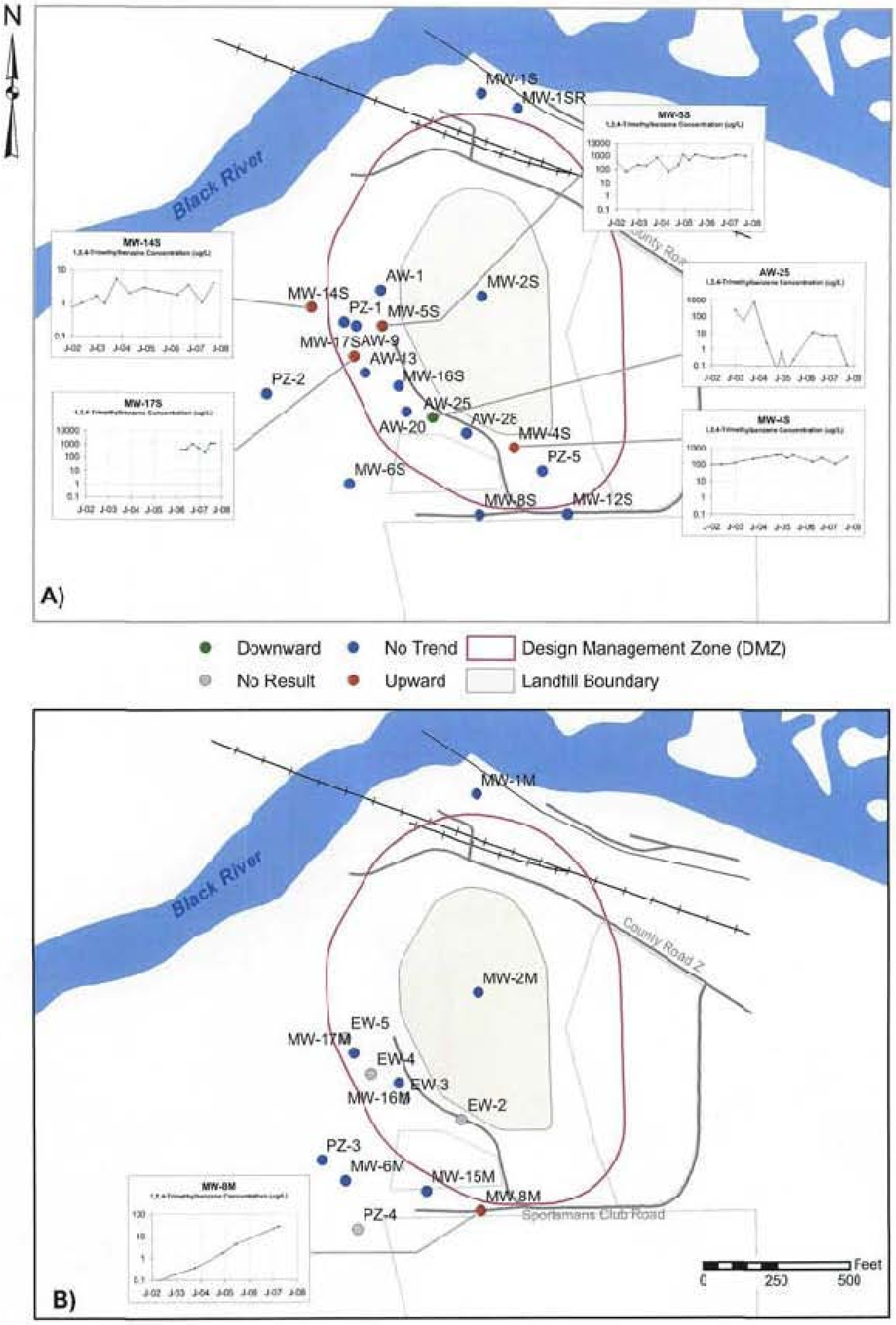


Figure 8 1,2,4-Trimethylbenzene Concentration Trends from PAM analysis for the A) Shallow Wells and B) Medium-Depth Wells

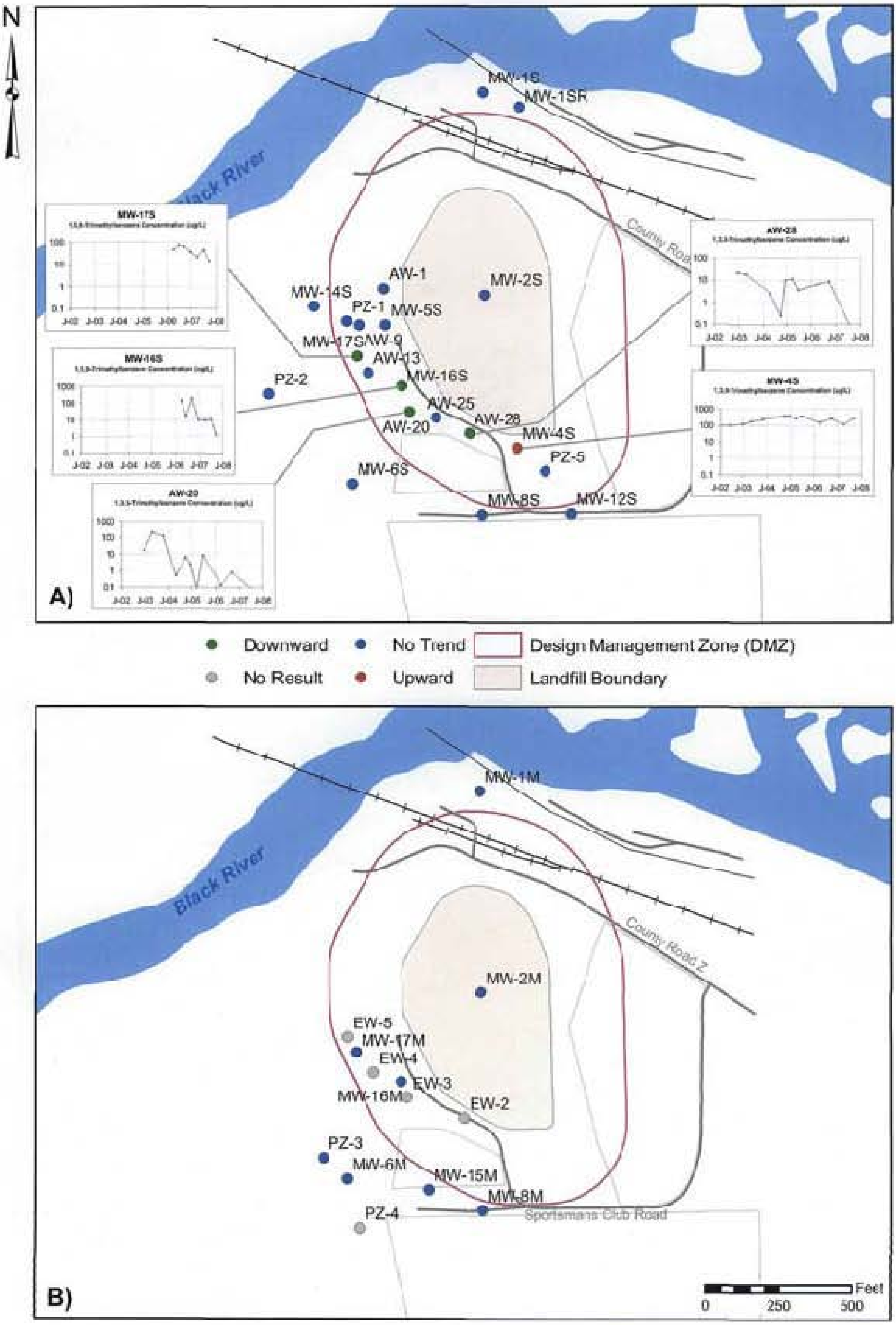


Figure 9 1,3,5-Trimethylbenzene Concentration Trends from PAM analysis for the A) Shallow Wells and B) Medium-Depth Wells

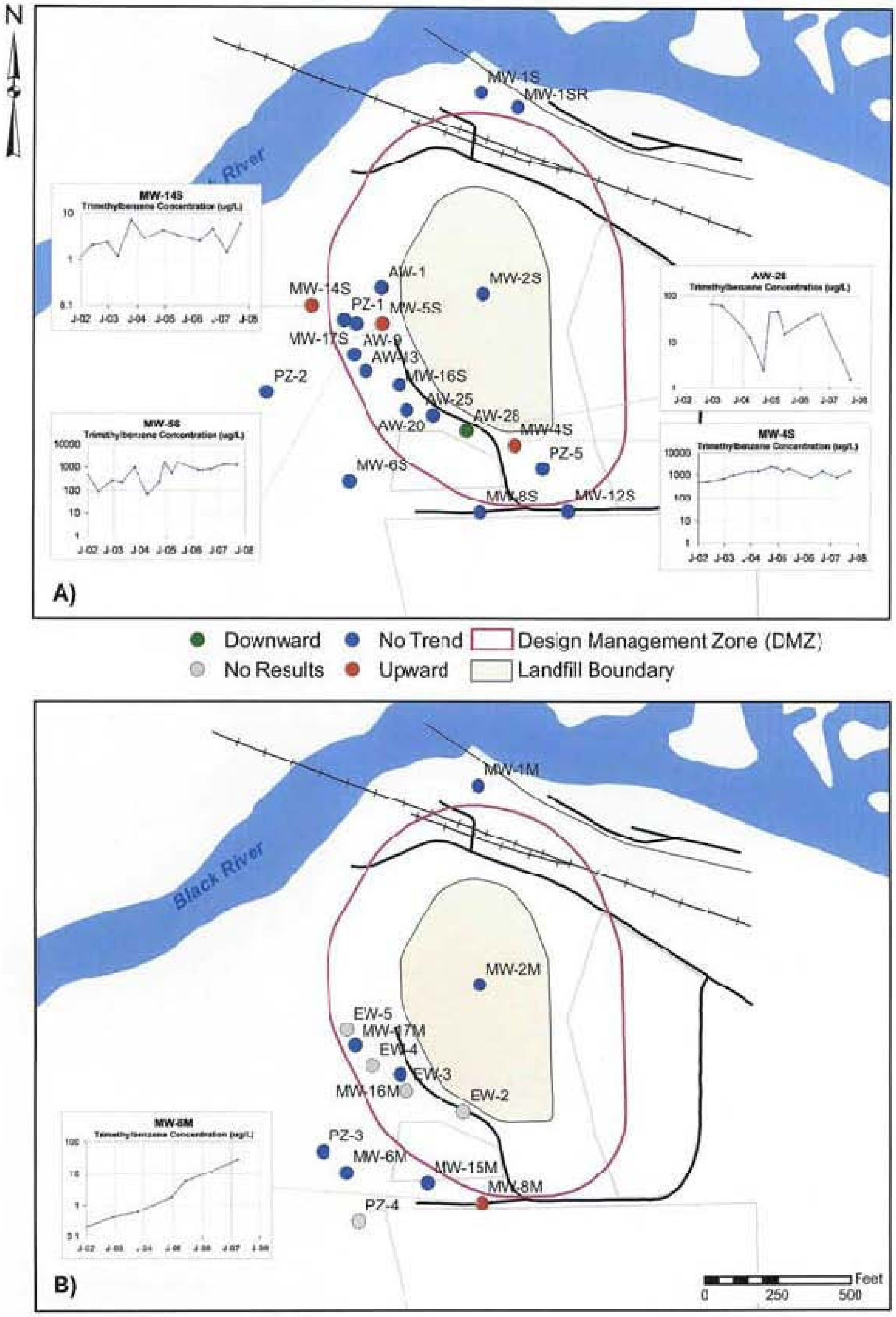


Figure 10 Total Trimethylbenzenes Concentration Trends from PAM analysis for the A) Shallow Wells and B) Medium-Depth Wells

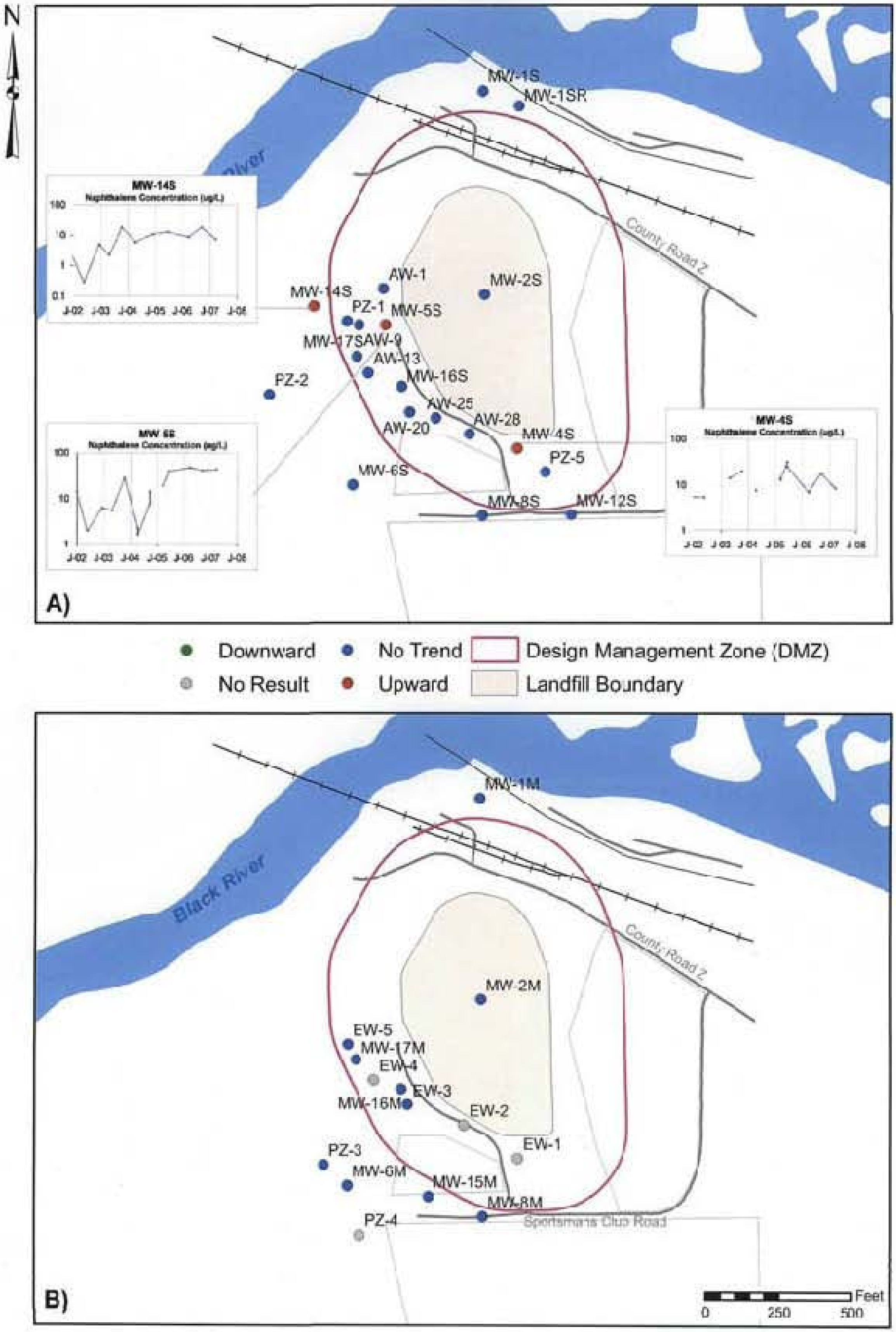


Figure 11 Naphthalene Concentration Trends from PAM analysis for the A) Shallow Wells and B) Medium-Depth Wells

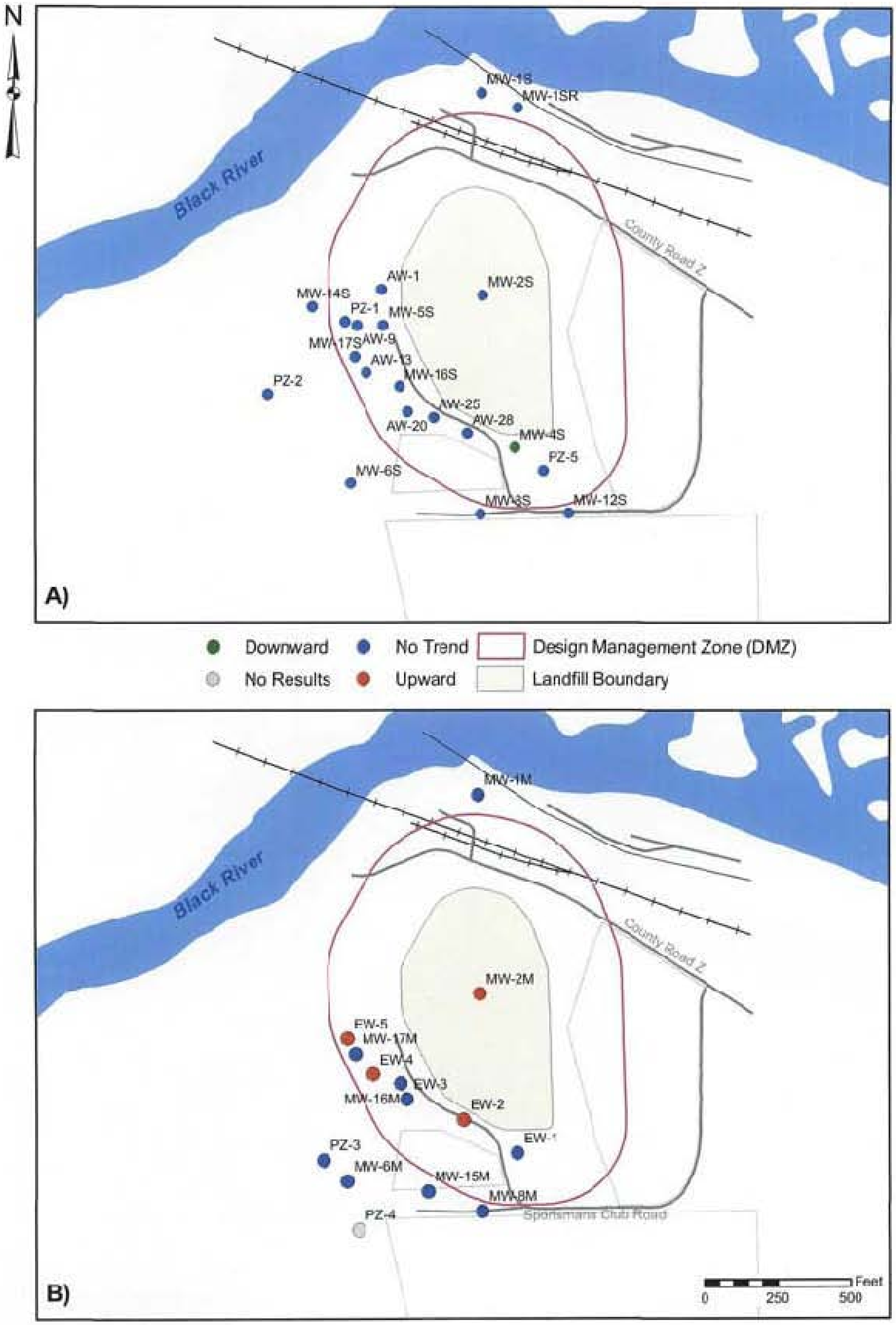


Figure 12 Dissolved Arsenic Concentration Trends from PAM analysis for the A) Shallow Wells and B) Medium-Depth Wells

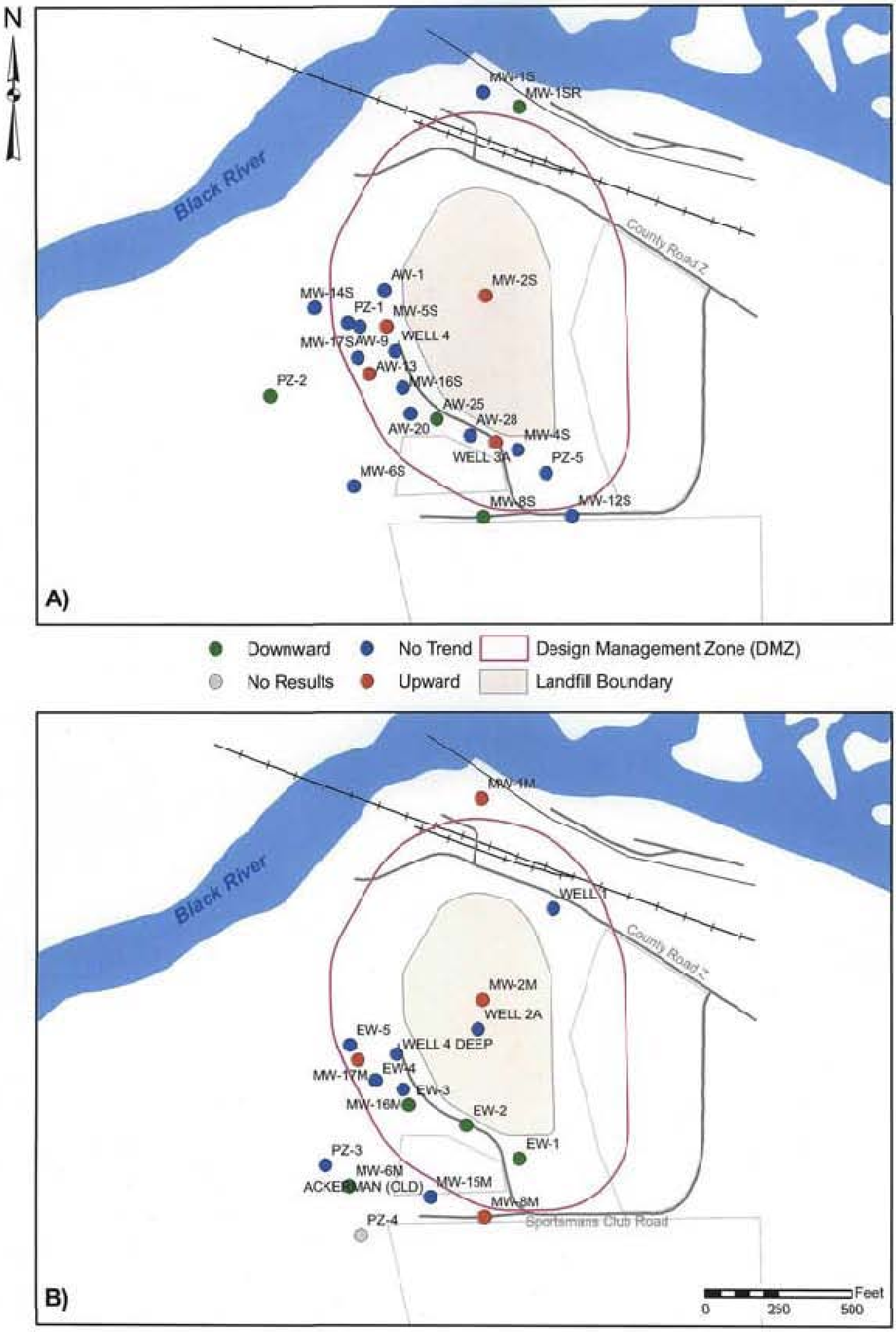


Figure 13 Dissolved Barium Concentration Trends from PAM analysis for the A) Shallow Wells and B) Medium-Depth Wells

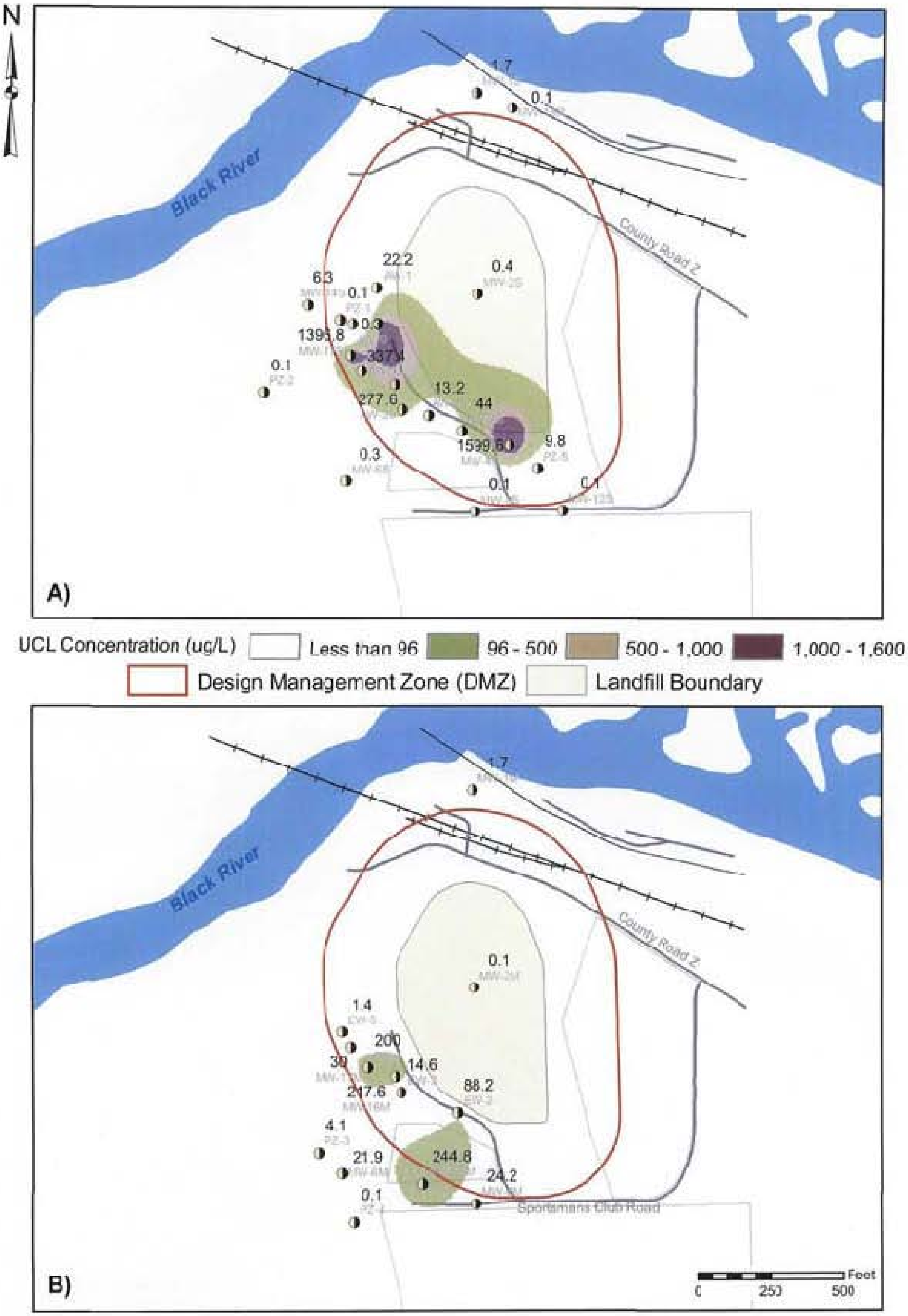


Figure 14 Map of UCL Target Zones for Total Trimethylbenzenes at A) Shallow Wells and B) Medium-Depth Wells

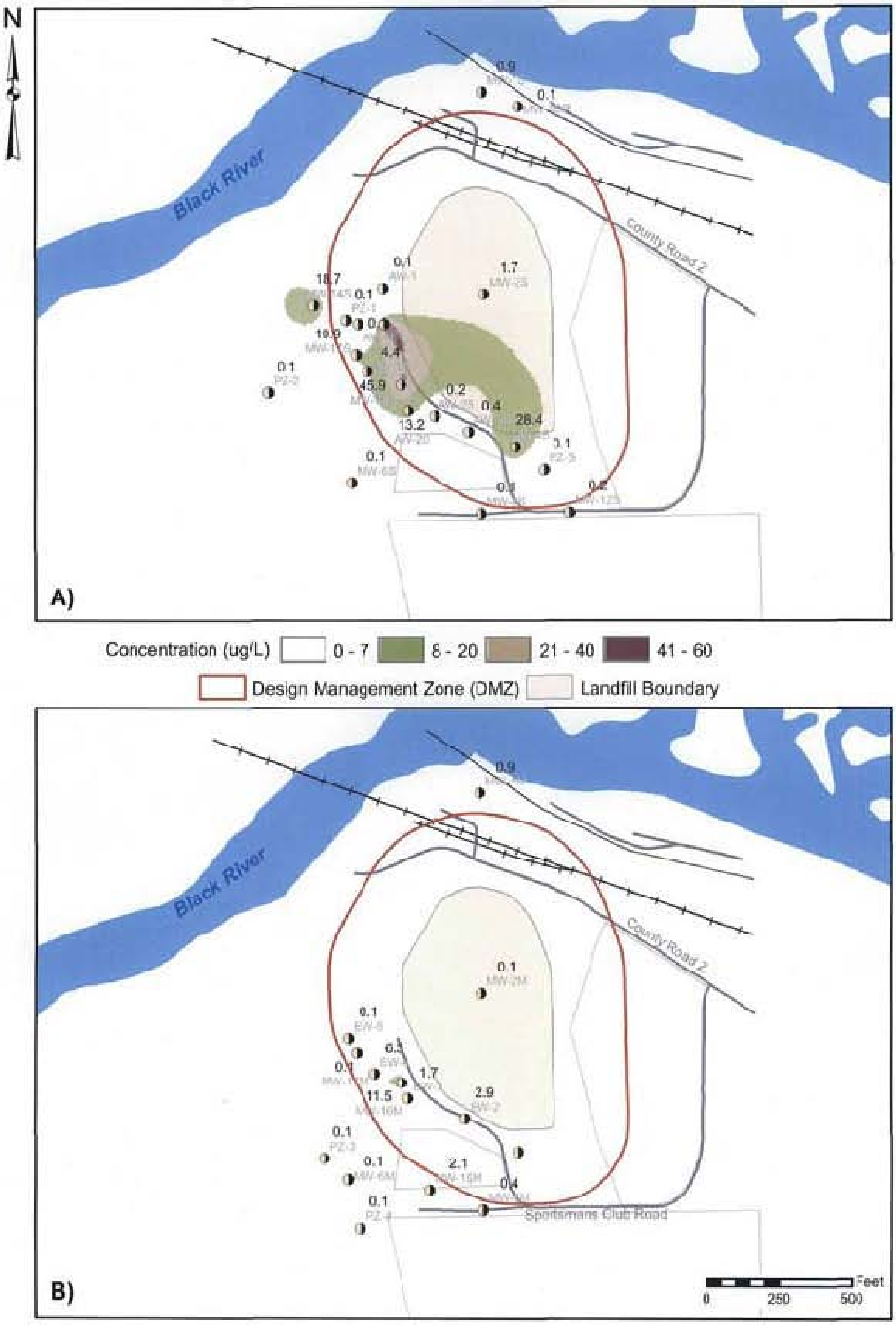


Figure 15 Map of UCL Target Zones for Naphthalene at A) Shallow Wells and B) Medium-Depth Wells

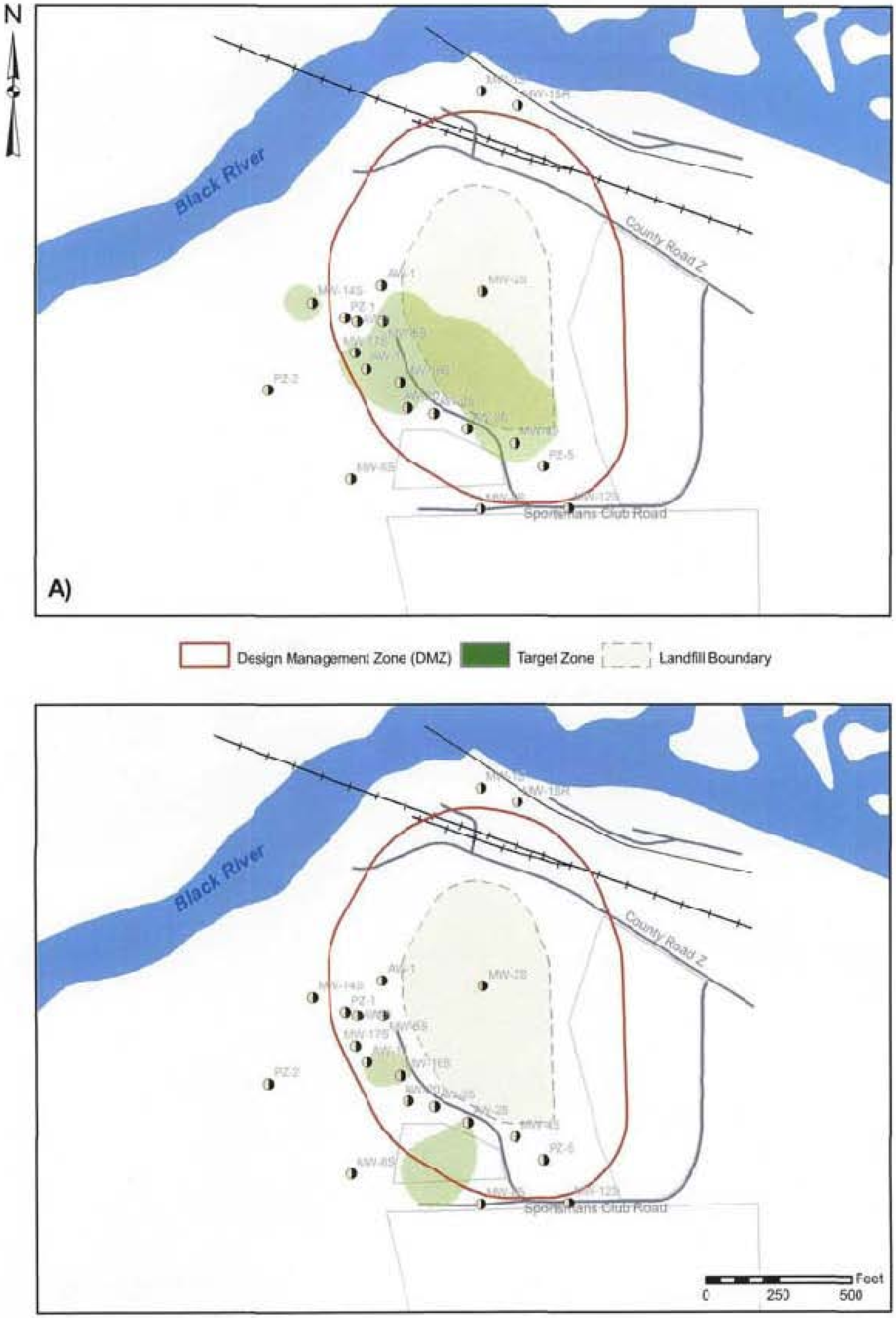
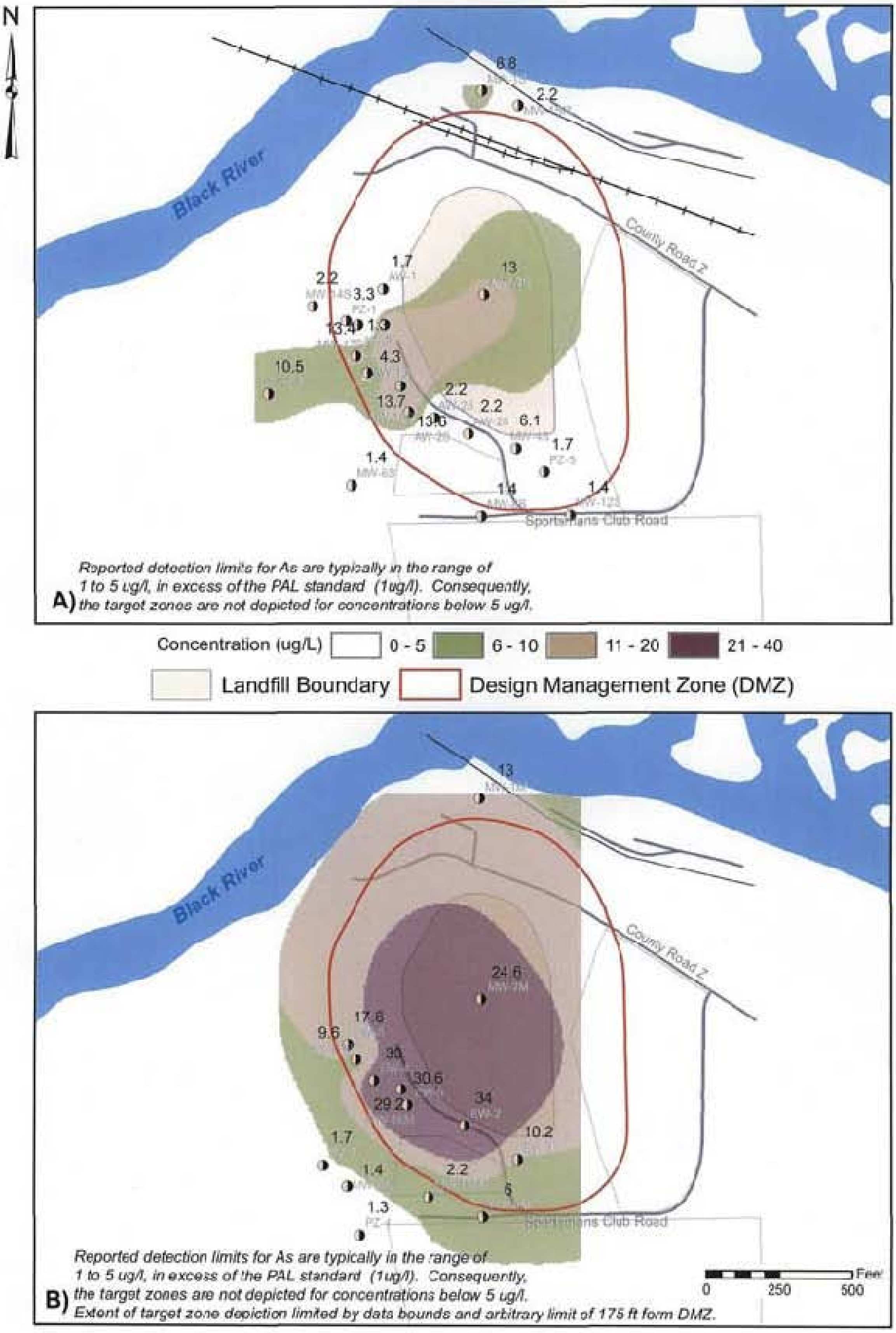


Figure 16 Map of Combined VOC UCL Target Zones for the A) Shallow Wells and B) Medium-Depth Wells



A) Reported detection limits for As are typically in the range of 1 to 5 ug/l, in excess of the PAL standard (1ug/l). Consequently, the target zones are not depicted for concentrations below 5 ug/l.

B) Reported detection limits for As are typically in the range of 1 to 5 ug/l, in excess of the PAL standard (1ug/l). Consequently, the target zones are not depicted for concentrations below 5 ug/l. Extent of target zone depiction limited by data bounds and arbitrary limit of 175 ft form DMZ.

Figure 17 Map of UCL Target Zones for Dissolved Arsenic at A) Shallow Wells and B) Medium-Depth Wells

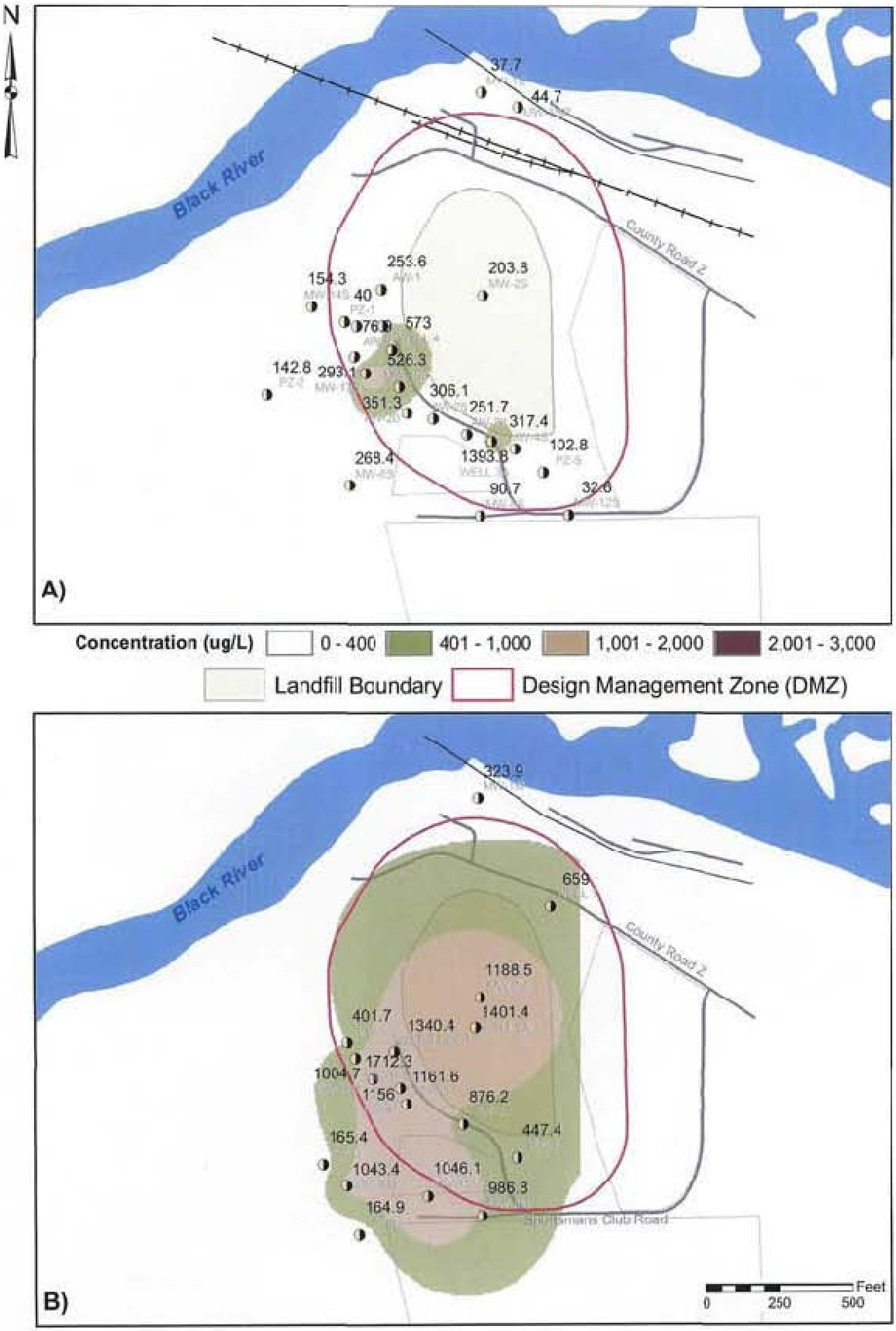


Figure 18 Map of UCL Target Zones for Dissolved Barium at A) Shallow Wells and B) Medium-Depth Wells

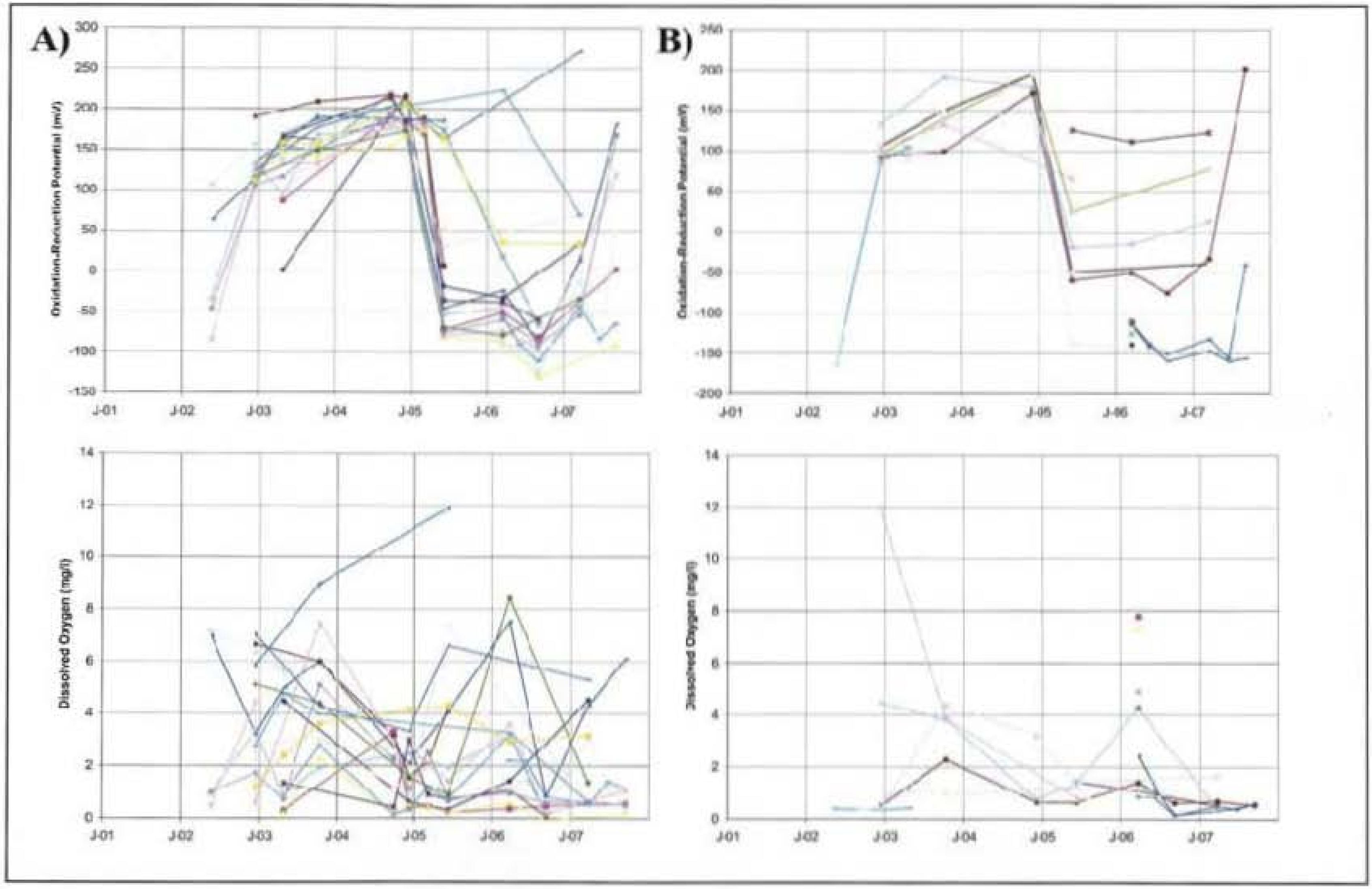


Figure 19 Oxidation-Reduction Potential (ORP) and Dissolved Oxygen in a) Shallow Monitoring Wells, and B) Medium-Depth Wells

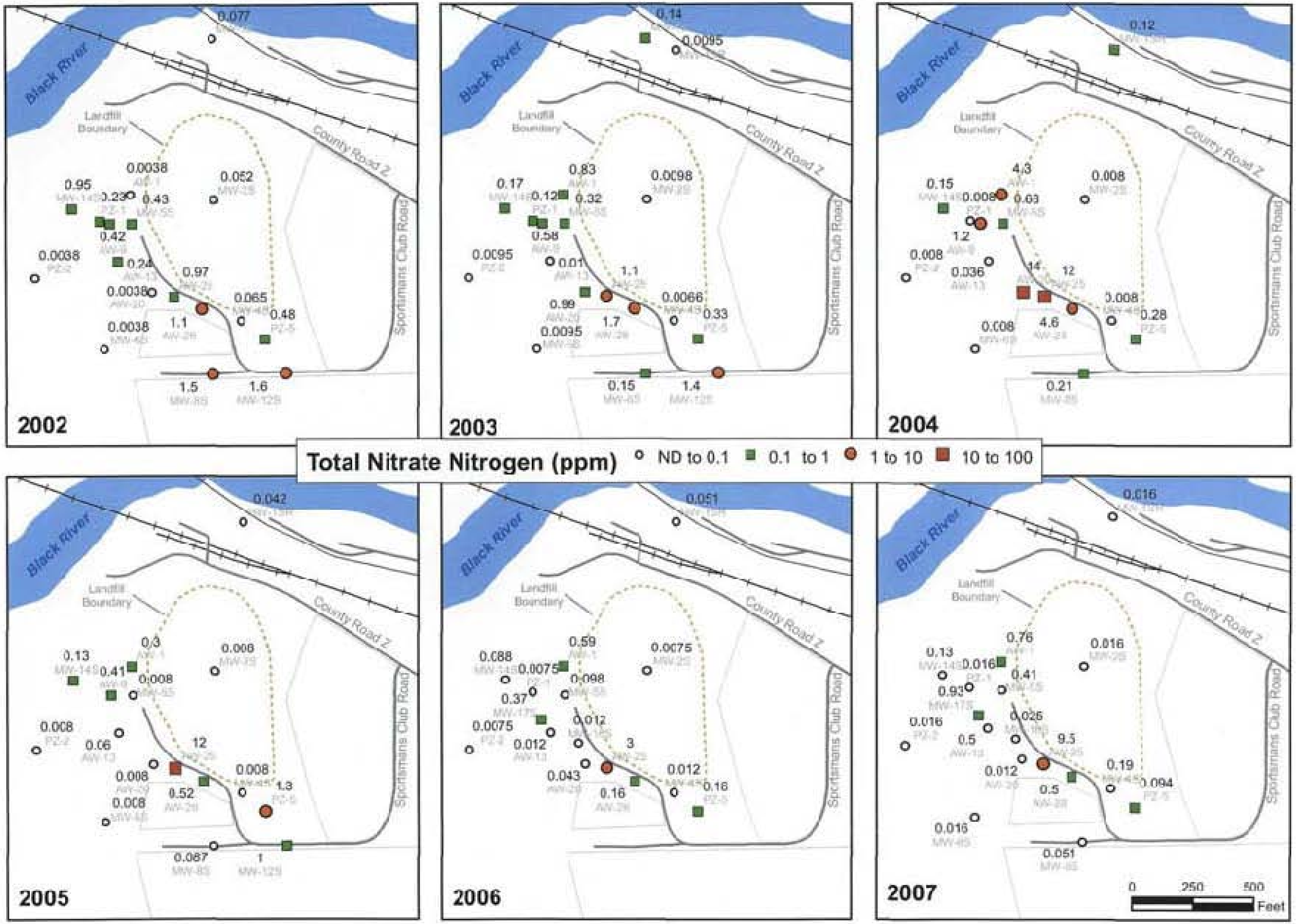


Figure 20 Nitrate Concentrations in Shallow Wells

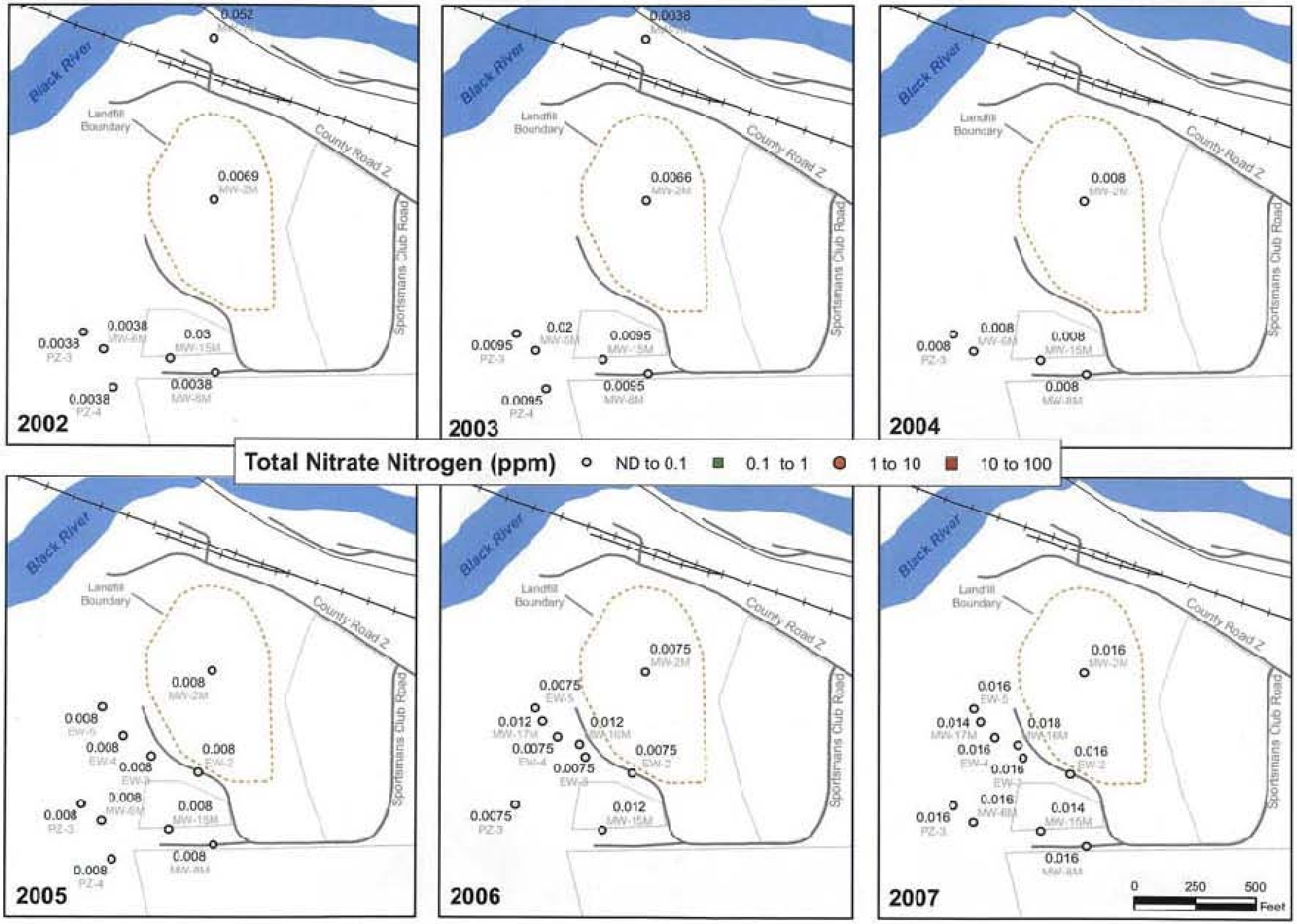


Figure 21 Nitrate Concentrations in Medium-Depth Wells

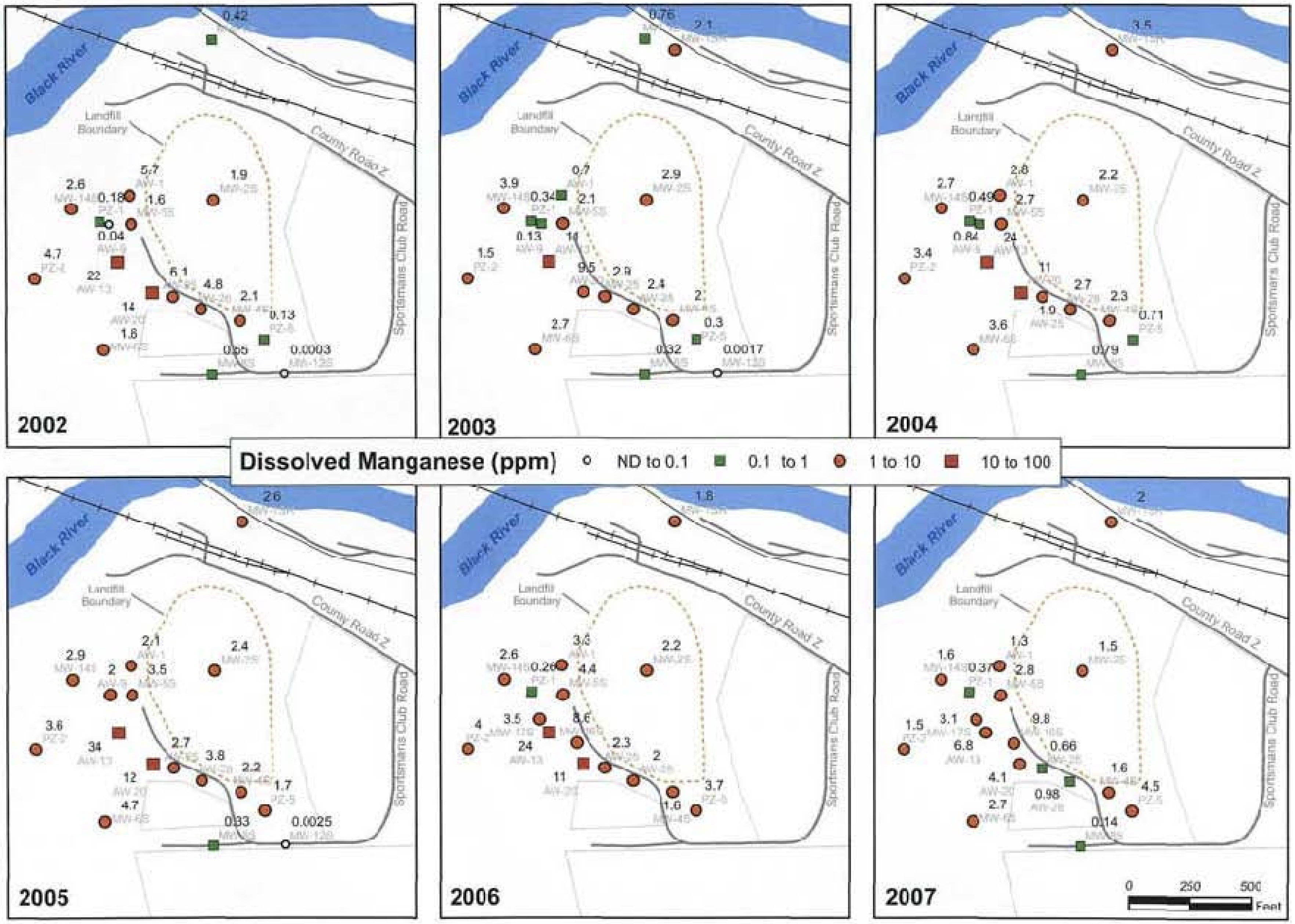


Figure 22 Dissolved Manganese Concentrations in Shallow Wells

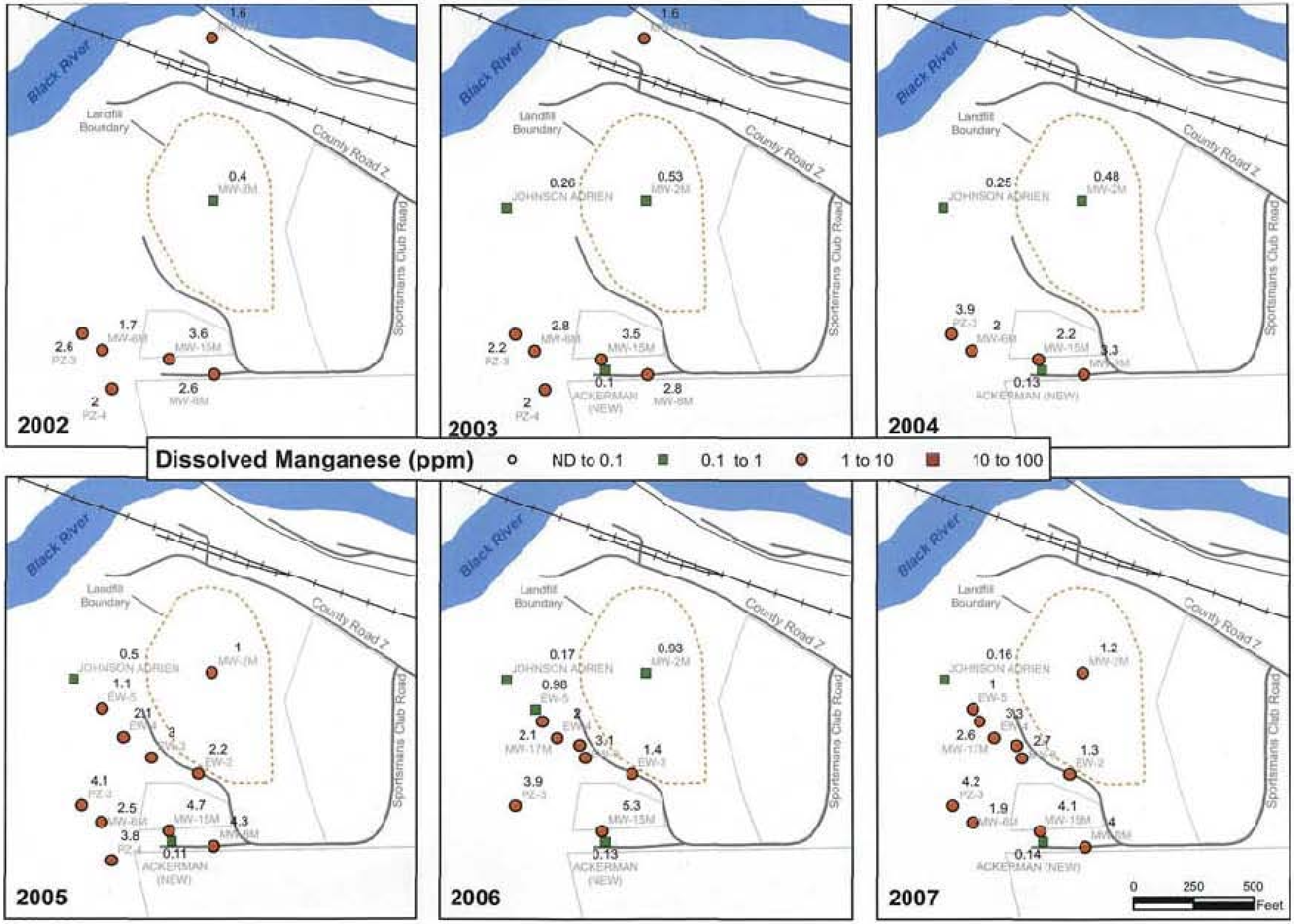


Figure 23 Dissolved Manganese Concentrations in Medium-Depth Wells

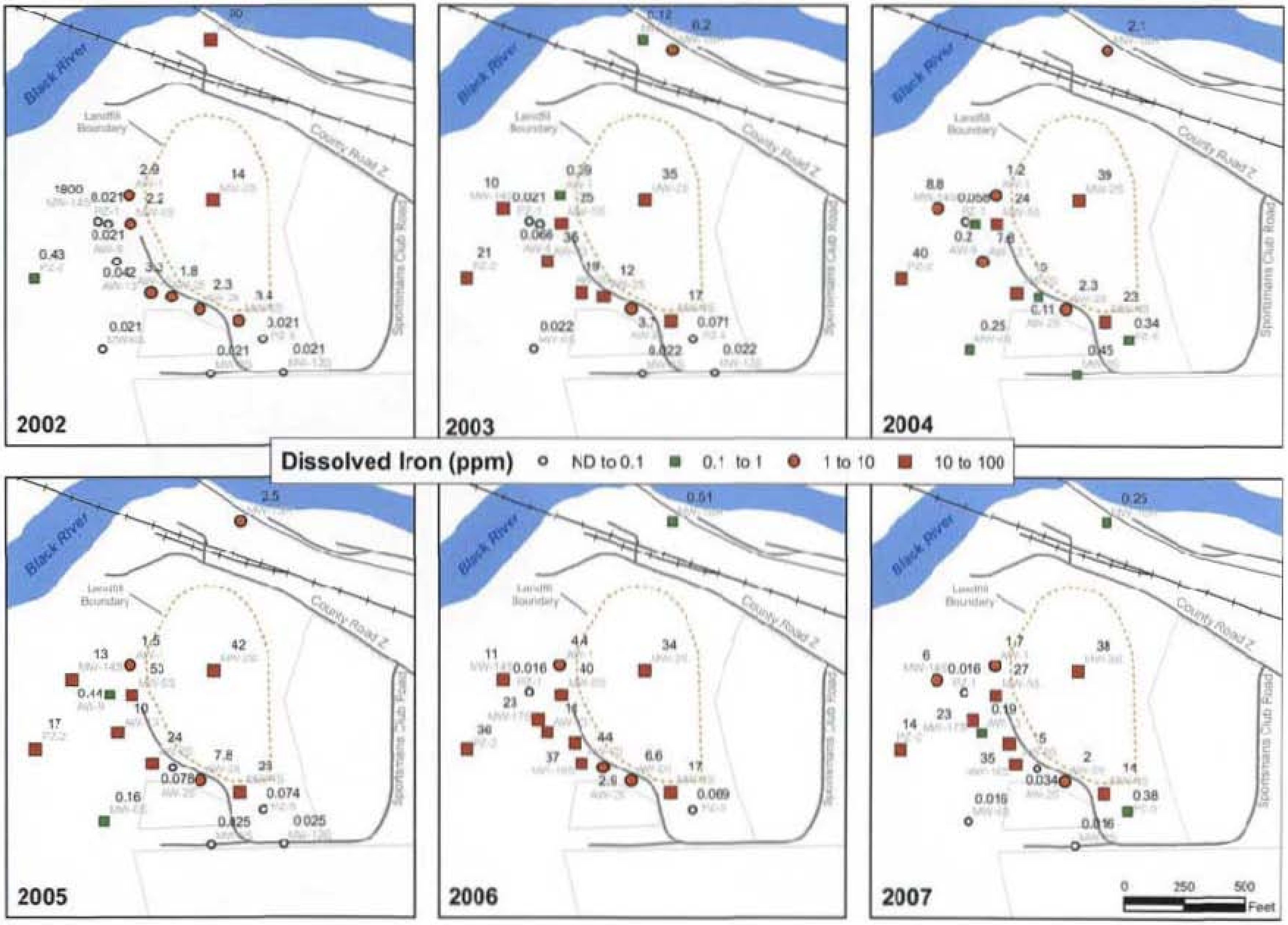


Figure 24 Dissolved Iron Concentrations in Shallow Wells

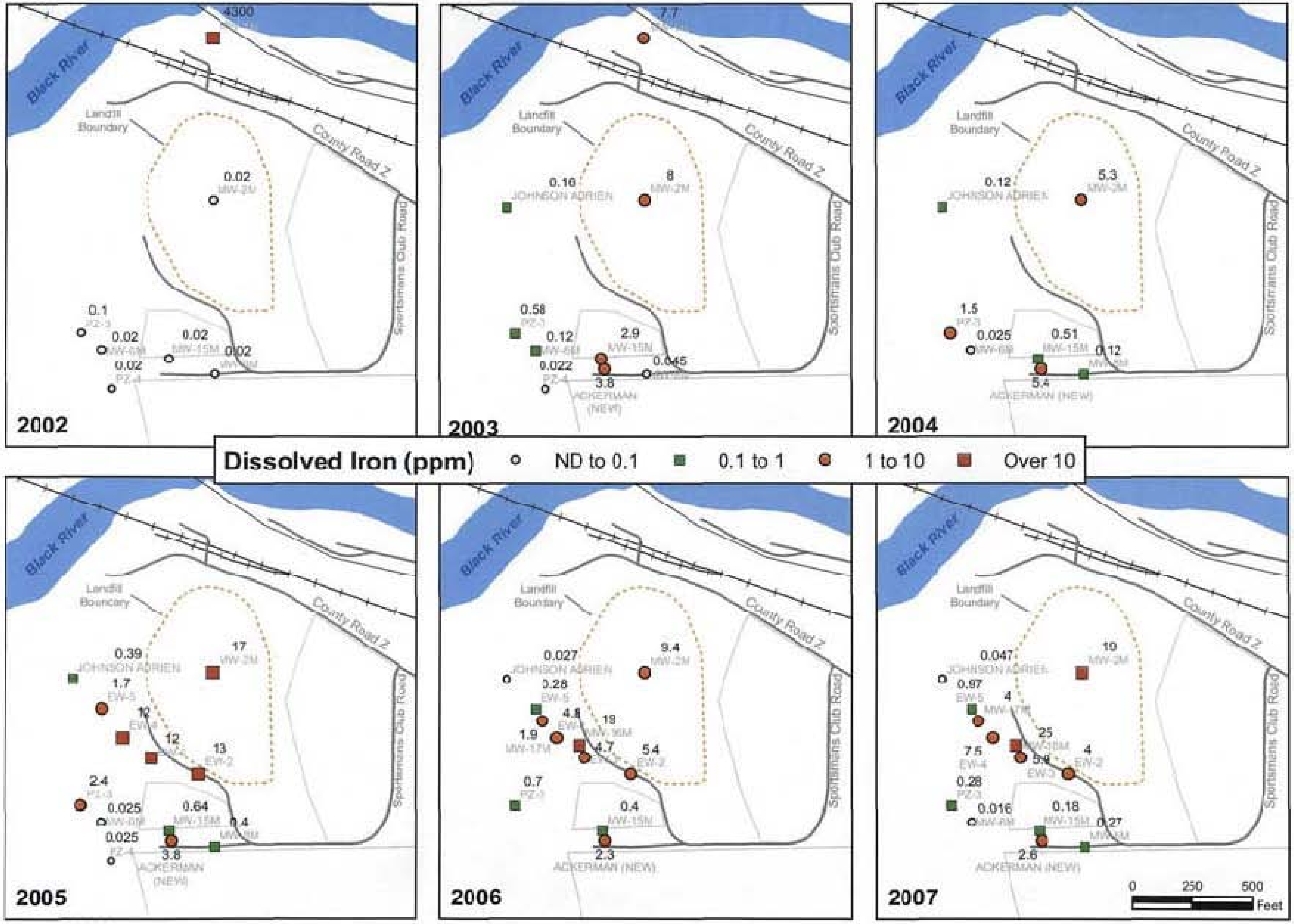


Figure 25 Dissolved Iron Concentrations in Medium-Depth Wells

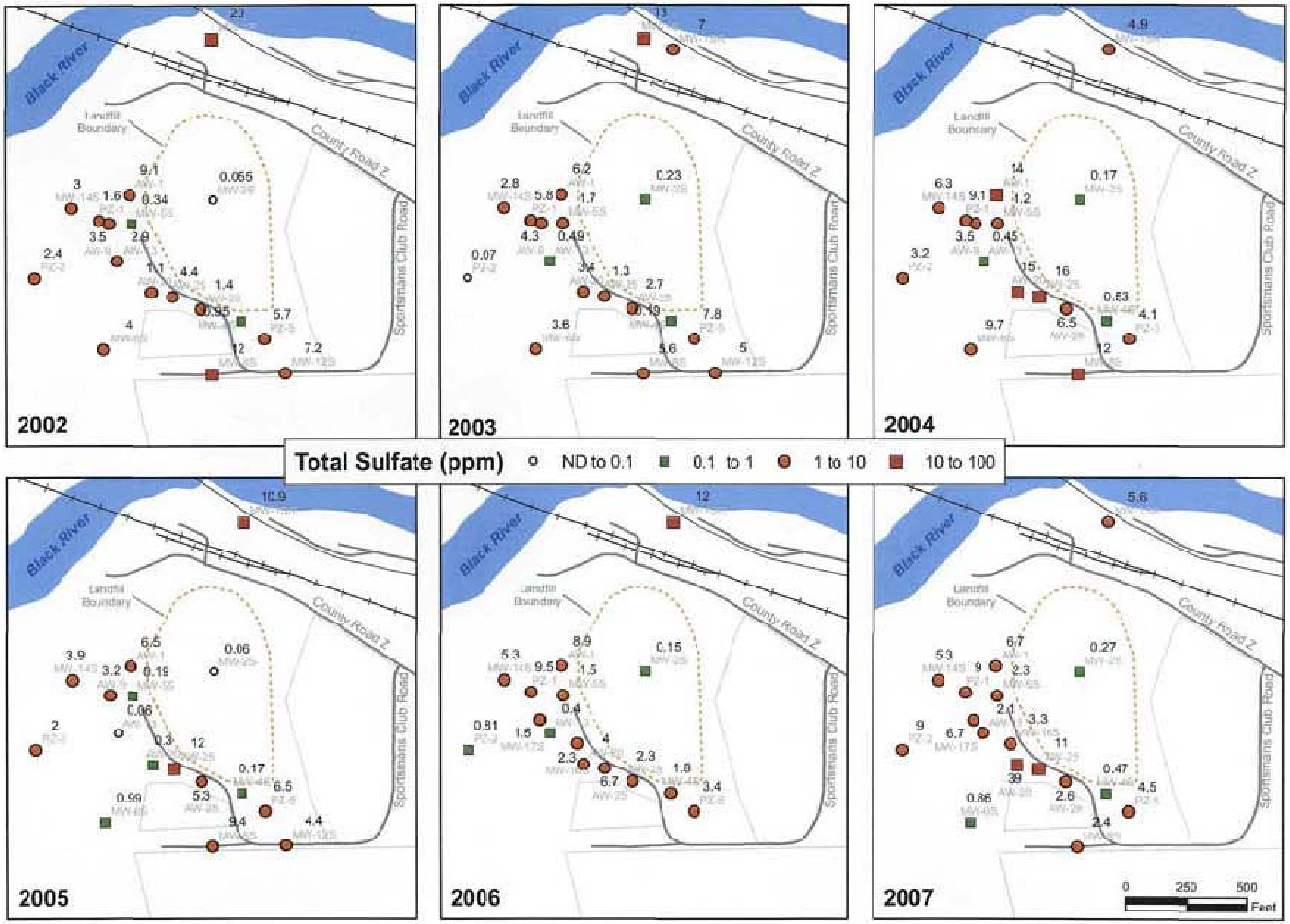


Figure 26 Sulfate Concentrations in Shallow Wells

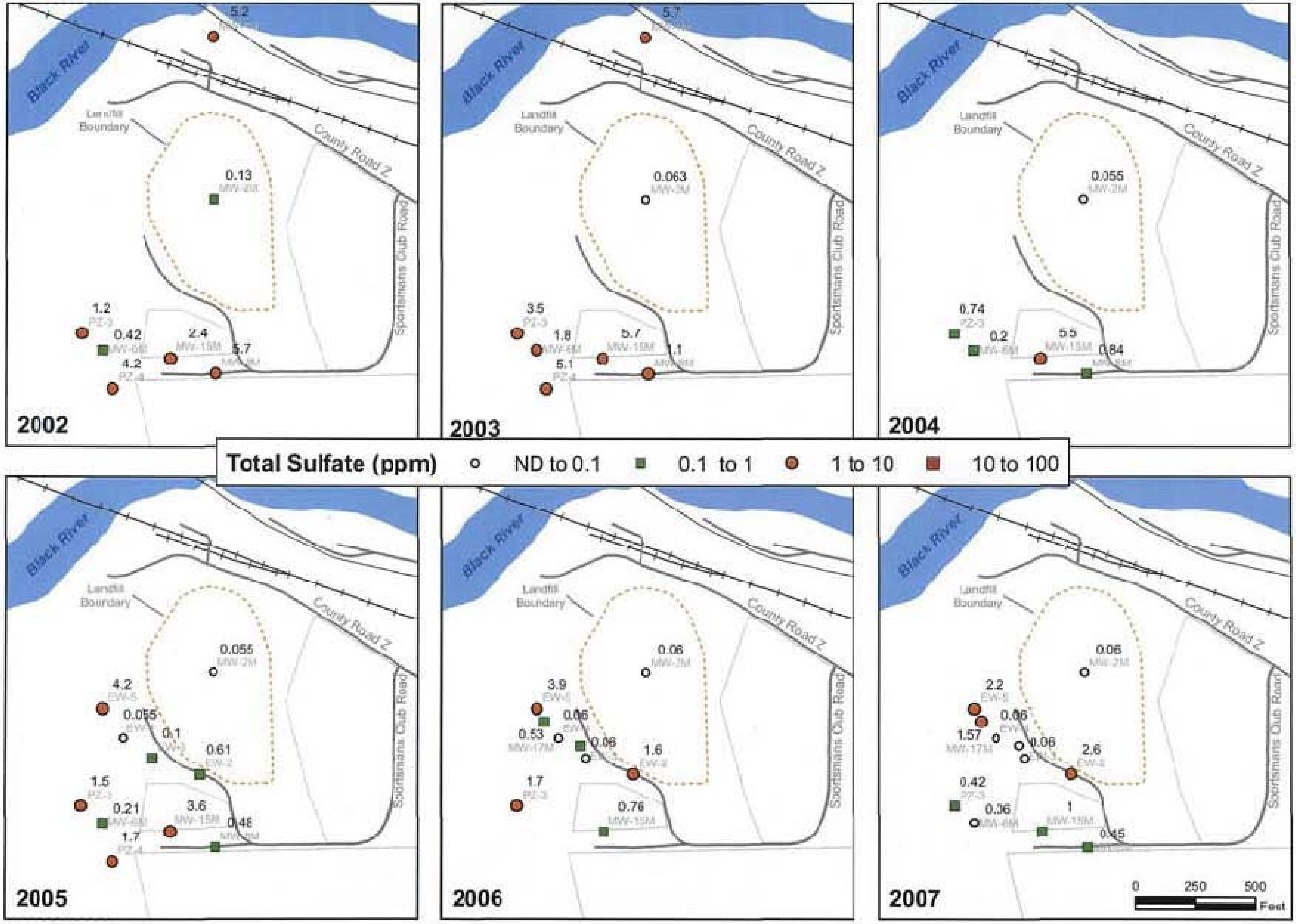


Figure 27 Sulfate Concentrations in Medium-Depth Wells

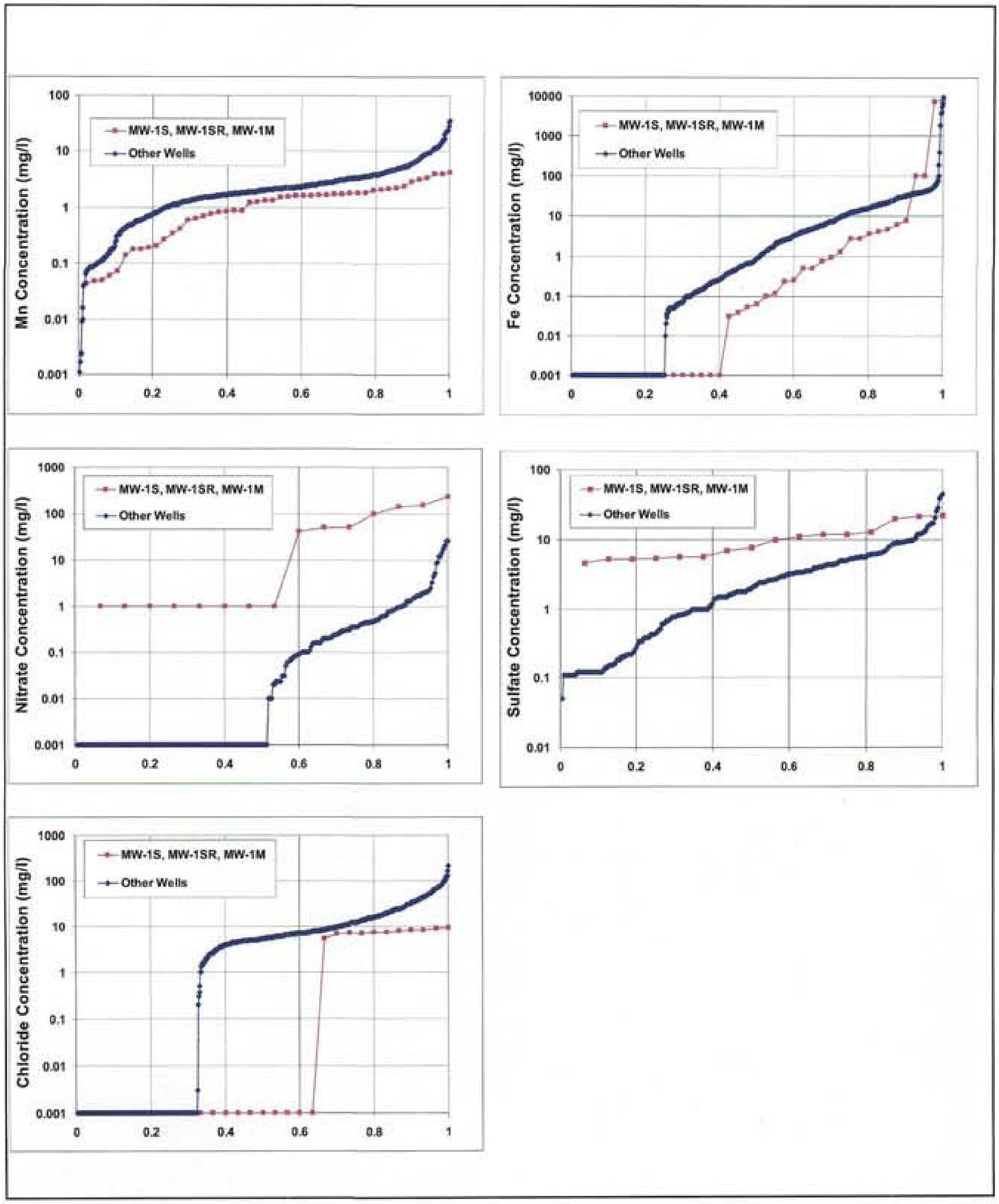


Figure 28 Cumulative Frequency Diagrams for MNA Parameters

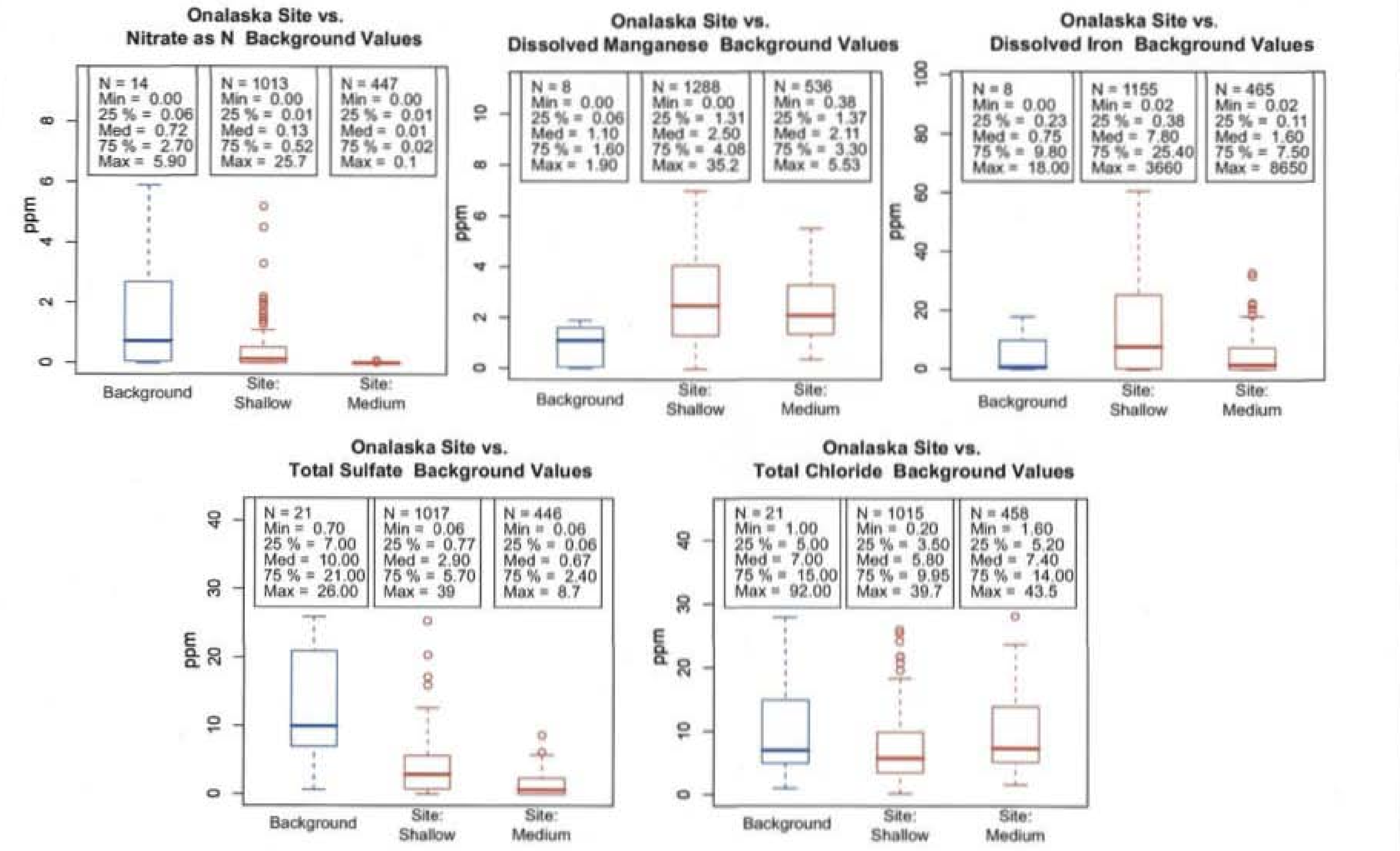


Figure 29 Comparison of Site Data to background Values in the Black River Watershed, Sand and Gravel Aquifer

TABLES

Table 1 Contaminants of Concern and Cleanup Standards

Contaminants	Wisconsin NR140 PAL [ug/L][1]	Wisconsin NR140 ES [ug/L]	Federal MCL [ug/L]
Organic Contaminants			
BTEX			
Benzene	0.5	5	5
Ethylbenzene	140	700	700
Toluene	200	1,000	1,000
Total Xylenes	1000	10,000	10,000
Chlorinated VOC[2]			
1,1-Dichioroethane	85	850	N.A.[3]
1,1-Dichloroethene	0.7	7	7
1,1,1-Trichloroethane	40	200	200
Cis-1,2-Dichloroethene	7	70	70
Trans-1,2-Dichloroethene	20	100	100
Trichloroethene	0.5	5	5
Tetrachloroethene	0.5	5	5
Methylene Chloride	0.5	5	N.A.
Vinyl Chloride (Chloroethene)	0.02	0.2	2
Other VOC			
Sum of 1,2,4-and1,3,5-Trimethylbenzene	96	480	N.A.
Naphthalene	8	40	N.A.
Metal Contaminants			
Arsenic	1	10	10
Barium	400	2,000	2,000
Iron	150	300	N.A.
Lead	1.5	15	15
Manganese	25	50	N.A.
Cadmium	0.5	5	5
Cobalt	8	40	N.A.
Mercury	0.2	2	2
Vanadium	6	30	N.A.

Source: Table 1-1, ENSR Corporation (2007). Annual Monitored Natural Attenuation Report for the Onalaska Municipal Landfill Site, Onalaska, Wisconsin, Wisconsin Department of Natural Resources.

Notes:

1. ug/L= micrograms per liter, equivalent to parts to billion
2. VOC = Volatile Organic Compounds
3. N A.= Not applicable

Table 2 Wells with Increasing and Decreasing Concentration Trends of VOCs

Well	1,2,4 - Trimethylbenzene	1,3,5 - Trimethylbenzene	Total Trimethylbenzenes	Naphthalene
AW-20		decreasing		
AW-25	decreasing			
AW-28		decreasing	decreasing	
MW-4S	increasing	increasing	increasing	increasing
MW-5S	increasing		increasing	increasing
MW-8M	increasing		increasing	
MW-14S	increasing		increasing	increasing
MW-16S		decreasing		
MW-17S	increasing	decreasing		

Table 3 Partial List of Wastes Deposited at Onalaska Landfill

Waste	Sources
High Flash Naphtha (metal cleaning waste)	Outers/Metallics
Mineral Spirits	Outers/Metallics
Gun Oil	Outers
Gun Cleaning Solvents	Outers
Paint Residues	Outers/Metallics
Asphaltum	Outers/Metallics
Water Soluble Solvents (Okite Materials)	Outers/Metallics
Lubricating Oils	Outers/Metallics
Synthetic Lubricant (PTL-1009) (amine soap)	Continental Can
Cannery wash (99 percent water)	Continental Can
Septic Tank Sludges	Septic Tank Sludge Haulers
Animal Carcasses, Hides, Intestines	Bly Rendering Works
Animal Manure	Bly Rendering Works
Transformers	Trempealeau Electric
Entire Rendering Works Building (4 stories)	Bly Rendering Works
Insecticides (DOT, etc.)	Unknown
Beer Cooling Units	Heileman's Brewing
Beer Cans (partially full and empty)	Heileman's Brewing
Cardboard, Wood, Paper Waste	St. Francis Hospital Outers/Metallics
Plastic Waste	St. Francis Hospital
Empty Drums	Outers/Metallics
Full Drums (Naphtha and Paint Wastes)	Outers/Metallics
Tank Truck (paint wastes) (500 gal)	Outers/Metallics
Municipal Rubbish	Town or City of: Onalaska, Medary, Campbell, French Island, West Salem
Tires	Tire Haulers

Source: Table 1-2, CH2M Hill, (1989). Remedial Investigation (RI) Report. Vol 1. (SDMS# 233292)

Table 4 Exceedances of Standards, 2007 Average Concentrations

Wells Outside DMZ (Regulatory Standard is PAL)					Wells Inside DMZ (Regulatory Standard is MCL/ES)				
Analyte	Location	Depth	2007 Average* (ug/l)	PAL Std (ug/l)	Analyte	Location	Depth	2007 Average* (ug/l)	MCL/ES Std (ug/l)
Arsenic, Dissolved	PRETASKY	D	6.60	1	Arsenic, Dissolved	EW-2	M	24.20	10
Arsenic, Dissolved	MW-8M	M	5.80	1	Arsenic, Dissolved	EW-3	M	21.40	10
Arsenic, Dissolved	MILLER-JOEL		5.18	1	Arsenic, Dissolved	EW-4	M	27.20	10
Barium, Dissolved	MW-8M	M	874.00	400	Arsenic, Dissolved	EW-5	M	16.80	10
Barium, Dissolved	MW-15M	M	756.50	400	Arsenic, Dissolved	MW-16M	M	22.43	10
Barium, Dissolved	MW-6M	M	744.00	400	Arsenic, Dissolved	MW-16S	S	11.57	10
Barium, Dissolved	MILLER-JOEL		416.00	400	Arsenic, Dissolved	MW-2M	M	22.60	10
Iron, Dissolved	PZ-2	S	13,500.00	150	Arsenic, Dissolved	MW-2S	S	12.80	10
Iron, Dissolved	MILLER-JOEL		9,550.00	150	Arsenic, Dissolved	MW-17S	S	11.65	10
Iron, Dissolved	MW-14S	S	5,950.00	150	Dichloromethane	MW-16S	S	25.41	5
Iron, Dissolved	PZ-3	M	280.00	150	Dichloromethane	MW-17S	S	46.94	5
Iron, Dissolved	MW-8M	M	270.00	150	Iron, Dissolved	ACKERMAN (NEW)	D	2,640.00	300
Iron, Dissolved	MW-1SR	S	250.00	150	Iron, Dissolved	AW-1	S	1,700.00	300
Iron, Dissolved	MW-15M	M	184.50	150	Iron, Dissolved	AW-20	S	15,100.00	300
Iron, Dissolved	PRETASKY	D	170.00	150	Iron, Dissolved	AW-28	S	2,000.00	300
Manganese, Dissolved	MILLER-JOEL		6,655.00	25	Iron, Dissolved	EW-2	M	4,000.00	300
Manganese, Dissolved	PZ-3	M	4,200.00	25	Iron, Dissolved	EW-3	M	5,900.00	300
Manganese, Dissolved	MW-15M	M	4,075.00	25	Iron, Dissolved	EW-4	M	7,500.00	300
Manganese, Dissolved	MW-8M	M	3,970.00	25	Iron, Dissolved	EW-5	M	970.00	300
Manganese, Dissolved	MW-6S	S	2,720.00	25	Iron, Dissolved	MW-16M	M	25,200.00	300
Manganese, Dissolved	MW-1SR	S	2,050.00	25	Iron, Dissolved	MW-16S	S	35,066.67	300
Manganese, Dissolved	MW-6M	M	1,900.00	25	Iron, Dissolved	MW-17M	M	3,966.67	300
Manganese, Dissolved	MW-14S	S	1,625.00	25	Iron, Dissolved	MW-17S	S	23,233.33	300
Manganese, Dissolved	MW-10M	M	1,520.00	25	Iron, Dissolved	MW-2M	M	18,700.00	300
Manganese, Dissolved	PZ-2	S	1,510.00	25	Iron, Dissolved	MW-2S	S	37,900.00	300
Manganese, Dissolved	PRETASKY	D	1,490.00	25	Iron, Dissolved	MW-4S	S	14,100.00	300
Manganese, Dissolved	JOHNSON ADRIEN		157.40	25	Iron, Dissolved	MW-5S	S	26,850.00	300
Manganese, Dissolved	MW-8S	S	135.00	25	Iron, Dissolved	PZ-5	S	380.00	300
Naphthalene	MW-14S	S	11.75	8	Manganese, Dissolved	ACKERMAN (NEW)	D	140.00	50
					Manganese, Dissolved	AW-1	S	1,320.00	50
					Manganese, Dissolved	AW-13	S	6,850.00	50
					Manganese, Dissolved	AW-20	S	4,080.00	50
					Manganese, Dissolved	AW-25	S	656.50	50
					Manganese, Dissolved	AW-28	S	977.00	50
					Manganese, Dissolved	EW-2	M	1,270.00	50
					Manganese, Dissolved	EW-3	M	2,670.00	50
					Manganese, Dissolved	EW-4	M	3,310.00	50
					Manganese, Dissolved	EW-5	M	1,030.00	50
					Manganese, Dissolved	MW-16M	M	1,495.00	50
					Manganese, Dissolved	MW-16S	S	9,796.67	50
					Manganese, Dissolved	MW-17M	M	2,603.33	50
					Manganese, Dissolved	MW-17S	S	3,093.33	50
					Manganese, Dissolved	MW-2M	M	1,170.00	50
					Manganese, Dissolved	MW-2S	S	1,490.00	50
					Manganese, Dissolved	MW-4S	S	1,560.00	50
					Manganese, Dissolved	MW-5S	S	2,820.00	50
					Manganese, Dissolved	PZ-1	S	371.00	50
					Manganese, Dissolved	PZ-5	S	4,460.00	50
					Trimethylbenzenes - Combined	MW-17S	S	907.00	480
					Trimethylbenzenes - Combined	MW-4S	S	1,125.00	480
					Trimethylbenzenes - Combined	MW-5S	S	1,290.00	480
					Vinyl Chloride	MW-5S	S	2.10	2

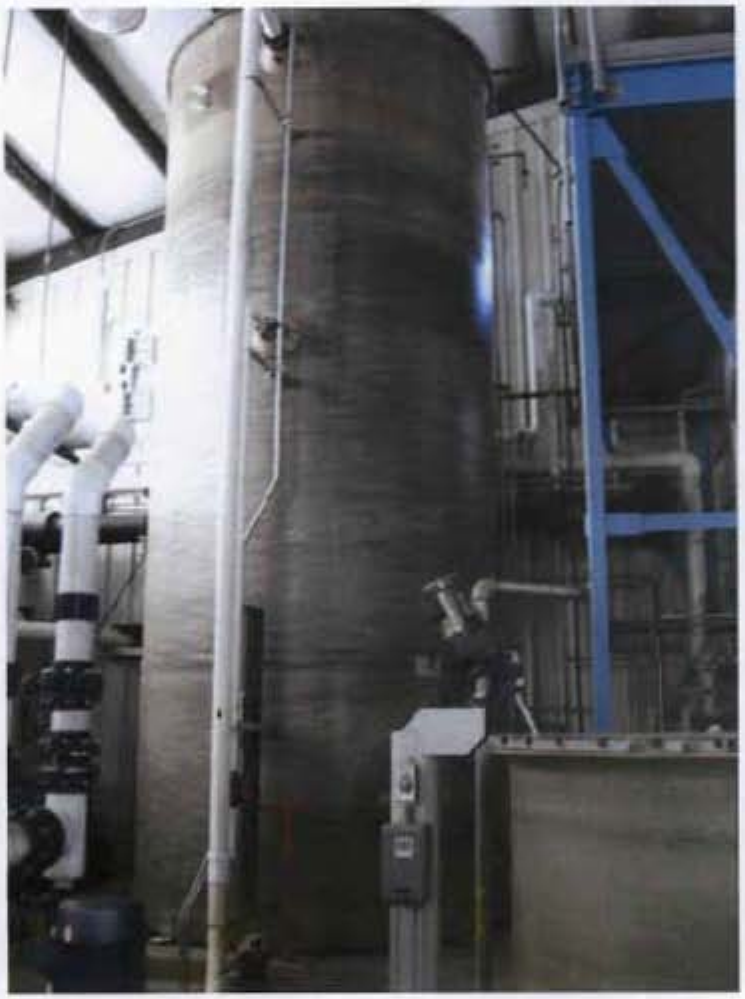
* Average calculated based upon detected value or half detection limit

ATTACHMENT 10

Photographs

Entrance to fenced remediation facility

Process Building



Sludge Holding Tank.

Diatomaceous earth filter tank

Caustic Tank

Compressor that produces air flow for the air stripping tower.

Alarm Panel

Part of electrical panel awaiting replacement of surge protector fuse. (Part on order)

One of two circuit breaker boxes.

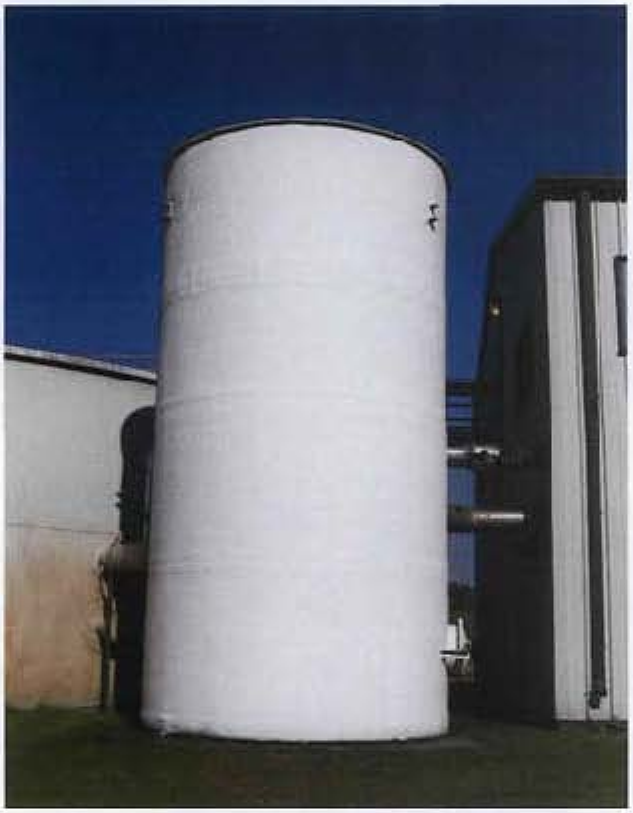
MW-5 – Protective top and new surface seal required.

Extraction Well EW-5

Back (west side) of treatment building. Clarifier tank at left and aerator tank at center.

Monitoring wells MW-17S and MW-17M.

Air Stripping Tower



Aerator Tank where air is injected prior to the water being pumped to the clarifier .

Groundwater Extraction Well EW-4

Air Injection Well

Passive Gas Vent Well
on Landfill Cap

Edge of Landfill Cap

MW-4S

Markings for desired easement for driveway to Prinsen Property at southern part of site.

Monitoring Well PZ-5

Monitoring Well
MW-12S

Monitoring Well Nest
MW-8S, MW-8M &
MW-8D

Monitoring Well Nest
MW-6S & MW-6M

Johnson Supply Well

Landfill Cap, Facing North, Monitoring Well Nest MW-2S, MW-2M and MW-2D in Center
Cap was recently mowed to facilitate inspection.

Sampling Port of
Landfill Passive Gas
Vent

Landfill Cap, Facing North, slight depression with no signs of water ponding.

Five-Year Review Report

Second Five-Year Review Report
for
Skinner Landfill Superfund Site
Butler County
West Chester, Ohio

March 2004

PREPARED BY:

United States Environmental Protection Agency
Region 5
Chicago, Illinois

Approved by:

for Richard C. Karl, Acting Director
Superfund Division

Date:

3/17/04

Table of Contents

Tables

Attachments

List of Acronyms

ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
EPA	United States Environmental Protection Agency
CFR	Code of Federal Regulations
DNAPL	Dense Non-aqueous Phase Liquid
FML	Flexible Membrane Liner
GCL	Geosynthetic Clay Liner
GIS	Groundwater Interception System
HDPE	High Density Polyethylene
LNAPL	Light Non-aqueous Phase Liquid
MCL	Maximum Contaminant Level
NCP	National Contingency Plan
NPL	National Priorities List
O&M	Operation and Maintenance
PCB	Polychlorinated Biphenyl
PRP	Potentially Responsible Party
RA	Remedial Action
RAO	Remedial Action Objective
RD	Remedial Design
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SVE	Soil Vapor Extraction
VOC	Volatile Organic Compound

Executive Summary

The five-year review of the Skinner Landfill site in West Chester, Ohio was completed in March 2004. The remedy is protective of human health and the environment in the short term. There are no current exposure pathways and the remedy appears to be functioning as designed. The landfill cap, the GIS and putting citizens on public water supply eliminates the source of contamination and has achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and prevent direct contact with, or ingestion of, contaminants in soils and sediments. A few deficiencies that do not immediately impact the protectiveness of the remedy were noted.

Both the Health and Safety Plan and the Contingency Plans are in place, sufficient to control risks, and properly implemented. The remedy for the Skinner Landfill Superfund Site (the site) includes a landfill cap/containment, access controls, institutional controls and a groundwater interception system (GIS).

The Ohio Environmental Protection Agency (Ohio EPA) in cooperation with the United States Environmental Protection Agency (EPA) completed oversight of all major construction activities for the site.

The site is located approximately 15 miles north of Cincinnati, Ohio near West Chester, Butler County, Ohio in Township 3, Section 22, Range 2. The site is comprised of approximately 78 acres of hilly terrain. The site was used in the past for the mining of sand and gravel, and was operated for the landfilling of a wide variety of materials from approximately 1934 through 1990. Materials deposited at the site include demolition debris, household refuse, and a variety of chemical wastes. The site is bordered on the east by a Norfolk Southern Railway Company right-of-way, on the south by the East Fork of Mill Creek, on the north by wooded and agricultural land, and on the west by a gravel driveway and Cincinnati-Dayton Road.

The site achieved construction completion in September 2001. The assessment of this five-year review found that the remedy was constructed in accordance with the requirements of the June 4, 1993, Record of Decision (ROD). The remedy is protective of human health and the environment in the short term and there are no current exposure pathways and the remedy appears to be functioning as designed. The landfill cap has been constructed over all the wastes, a GIS is operating, and a public water supply was provided to nearby residents.

Five-Year Review Summary Form

SITE IDENTIFICATION

Site name *(from WasteLAN)*: Skinner Landfill

EPA ID *(from WasteLAN)*: OHD063963714

Region: V | **State:** Ohio | **City/County:** West Chester/Butler

SITE STATUS

NPL status: ☒ Final ☐ Deleted ☐ Other (specify) ____________________

Remediation status (choose all that apply): ☐ Under Construction ☒ Operating ☐ Complete

Multiple OUs? YES X NO | **Construction completion date:** 9-27-01

Has site been put into reuse? ☐ YES ☒ NO

REVIEW STATUS

Reviewing agency: ☒ EPA X State ☐ Tribe ☐ Other Federal Agency ____________

Author name: Scott Hansen

Author title: Remedial Project Manager | **Author affiliation:** EPA Region V

Review period: 2/17/2004 - 3/17/2004

Date(s) of site inspection: 1/22/2004

Type of review:
☒ Statutory
☐ Policy (☐ Post-SARA ☐ Pre-Sara ☐ NPL-Removal only
☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead
☐ Regional Discretion)

Review number: ☐ 1(first) X 2 (second) ☐ 3 (third) ☐ Other (specify) ____________

Triggering action:
Actual RA Onsite Construction at OU # ___ ☐ Actual RA Start at OU# ___
☐ Construction Completion X Previous Five-Year Review Report
☐ Other (specify) ____

Triggering action date *(from WasteLAN)*: 3/17/1999

Due date *(five years after triggering action date)*: 3/17/2004

Five-Year Review Summary Form, cont'd.

Issue:

1) Institutional controls need to be implemented.

2) The creek bank on the East Fork of Mill Creek, southeast side of the site, has eroded.

3) The site fence needs to be installed where the creek bank has eroded.

4) Water is accumulating in Vault Box and Inspection Manhole.

5) Decide if upgradient groundwater control is required.

6) Security measures required.

Recommendations and Follow-up Actions:

1) Institutional controls will be implemented.

2) The creek bank will be stabilized (e.g. rip-rap, gabion wall, sheet-piling.).

3) Once the creek bank is stabilized the site fence will be installed.

4) Water will be pumped out of Vault Box and Inspection Manhole periodically.

5) Continue to monitor the elevation of the groundwater beneath the landfill cap area.

6) Make sure that site fence is in place and look for signs of trespassing.

Protectiveness Statement(s):

The remedy is protective of human health and the environment in the short term. There are no current exposure pathways and the remedy appears to be functioning as designed. The landfill cap and putting citizens on public water supply eliminates the source of contamination and has achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and prevent direct contact with, or ingestion of, contaminants in soils and sediments. Long-term protectiveness of the of the remedial action will be achieved when cleanup goals are met.

Other Comments:

At this time, the institutional controls portion of the remedy has not been implemented. There has been a dispute over who will be the grantee of the institutional controls.

SKINNER LANDFILL SITE
WEST CHESTER, OHIO
FIVE YEAR REVIEW REPORT

I. INTRODUCTION

The purpose of the five-year review is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review reports. In addition, Five-Year Review reports identify issues found during the review, if any, and identify recommendations to address them.

EPA is preparing this Five-Year Review report pursuant to CERCLA §121 and the National Contingency Plan (NCP). CERCLA §121 states:

If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgement of the President that action is appropriate at such site in accordance with section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.

EPA interpreted this requirement further in the NCP; 40 CFR §300.430(f)(4)(ii) states:

If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.

EPA, Region 5, is conducting this five-year review of the remedy implemented at the Skinner Landfill Superfund Site in West Chester, Ohio. This review was conducted by the Remedial Project Manager (RPM) for the site. This report documents the results of the review.

The triggering action for this statutory review is the previous five-year review which was completed on March 17, 1999. The five-year review is required due to the fact that hazardous substances, pollutants, or contaminants remain at the site at levels which do not allow for unlimited use and unrestricted exposure.

II. SITE CHRONOLOGY

Table 1 - Chronology of Site Events

EVENT	*DATE*
Initial Discovery of Problem	**1976**
Proposed on NPL	**December 30, 1982**
Listed on NPL	**September 8, 1983**
RI/FS (entire site)	**September 26, 1984 - June 4, 1993**
Interim ROD	**September 30, 1992**
Unilateral Administrative Order	**December 9, 1992**
ROD (entire site)	**June 4, 1993**
RD	**March 29, 1994 - June 18, 1996**
RA Start	**June 18, 1996**
First Five-Year Review	**March 1999**
RA Construction Start	**April 2, 2001**
RA Completed	**September 30, 2003**
Final Inspection of Entire Site	**March 27, 2003**
PCOR	**September 27, 2001**
O&M Activities Began	**June 30, 2003**
Next Five-Year Review	**March 2009**

III. BACKGROUND

Physical Characteristics

The site is located approximately 15 miles north of Cincinnati, Ohio near West Chester, Butler County, Ohio in Township 3, Section 22, Range 2. The site is bordered on the east by a Norfolk Southern Railway Company right-of-way, on the south by the East Fork of Mill Creek, on the north by wooded and agricultural land, and on the west by a gravel driveway and Cincinnati-Dayton Road. A map of the site is provided in Attachment 1.

The approximately 10.5 acre landfill site is fenced on all sides with locked access gates on the south and west sides of the site The only structures on site are the metal electrical box located near the south entrance gate and the gas vents. A gravel access road is located inside the fence on the south and west sides of the site.

The site is located in a highly dissected area that slopes from a till-mantled-bedrock upland to a broad, flat-bottomed valley that is occupied by the main branch of Mill Creek. Elevations on the site range from a high of nearly 800 feet above mean sea level (MSL) in the northeast, to a low of 645 feet above MSL near the confluence of Skinner Creek and the East Fork of Mill Creek. Both Skinner Creek and the East Fork of Mill Creek are small, intermittent shallow streams. Both of these streams flow to the southwest from the site toward Mill Creek, which in turn flows into the Ohio River.

In general, the site is underlain by relatively thin glacial drift over inter-bedded shale and limestone of Ordovician age. The composition of the glacial drift ranges from intermixed silt, sand and gravel, to silty sandy clays with a thickness ranging from zero to over forty feet. The sand and gravel deposits comprise the hills and ridges and are encountered near the surface of the central portion of the site. The silts and clays usually occur as lenses in the sands and gravel or directly overlie bedrock.

Land and Resource Use

The property was originally developed as a sand and gravel mining operation and was subsequently used as a landfill from 1934 to 1990.

History of Contamination

In 1976, in response to a fire on the site and reports of observations of a black, oily liquid in a waste lagoon on the site, the Ohio EPA began an investigation of the site. Before Ohio EPA could complete the investigation, the site owner/operator covered the waste lagoon with a layer of demolition debris, thereby hindering the investigation. Albert Skinner, the site owner at the time, dissuaded the Ohio EPA from accessing the lagoon area by claiming that nerve gas, mustard gas, incendiary bombs, phosphorus, flame throwers, cyanide ash, and other explosive devices were buried at the landfill. This prompted Ohio EPA to request the assistance of the U.S.

Army. Albert Skinner, in the presence of Ohio EPA attorneys and the U.S. Army investigators, subsequently retracted his claims of the presence of ordnance. The U.S. Army and Ohio EPA then dug several trenches into the buried waste lagoon, and found black and orange liquids and a number of barrels of waste. Subsequently, records searches have been performed by the U.S. Army, and have indicated that there is no evidence of munitions of any sort having been disposed at the site.

Based on the initial studies, materials deposited at the site include demolition debris, household refuse and a wide variety of chemical wastes. The waste disposal areas include a now buried former waste lagoon near the center of the site and a landfill. The buried lagoon was used for the disposal of paint wastes, ink wastes, creosote, pesticides, and other chemicals. The landfill area, located north and northeast of the buried lagoon, received predominantly demolition debris.

Initial Response

In 1982, the EPA conducted a limited investigation of the site for the purpose of scoring the site for inclusion on the NPL.. The investigation showed that groundwater southeast of the buried waste lagoon was contaminated with VOCs. The site was proposed for the NPL in December 1982.

The EPA completed a search for potentially responsible parties (PRPs) in April 1983. The results of that search were later supplemented by information requests under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 104(e) and by administrative depositions.

In 1986, the U.S. EPA began a Phase I Remedial Investigation (RI), with the sampling of groundwater, surface water, and soils. A biological survey of the East Fork of Mill Creek and Skinner Creek was also performed.

In 1989, the U.S. EPA began its Phase II RI, to further investigate the site groundwater, surface water, soils, and sediments. Overall, more than 400 samples from the site were analyzed.

In August 1990, through a legal proceeding, the Ohio EPA closed the site to all further landfilling activities.

The Phase II RI was completed in May 1991. Both a Baseline Risk Assessment and Feasibility Study (FS) were completed in 1992.

The results of the two-phased RI are summarized below.

The former dump area was used for the disposal of a variety of wastes, including demolition debris, household refuse and assorted scrap. Chemical wastes were also disposed in this area. The total volume of wastes within the former dump was estimated at 120,000 cubic yards. Water samples collected during the Phase I RI indicated that the most concentrated groundwater contamination found at the site was in the area beneath the former dump. Site records and deposition testimony of waste haulers indicated that large quantities of chemical wastes were disposed in the waste lagoon. These wastes included creosote, paint wastes, ink wastes, and pesticides. The total volume of contaminated materials in the lagoon were estimated in the RI/FS to be 107,000 cubic yards. The total volume of lagoon waste materials that exceeded the risk-based protective levels was estimated in the FS to be 17,000 cubic yards.

Basis for Taking Action

Contaminants

Hazardous substances that have been released at the site in each media include:

Soil
Toluene
Xylenes
Ethylbenzene
1,1,2-Trichloroethane
1,2-Dichloropropane
Benzene
Naphthalene
2-Methylnaphthalene
Phenanthrene
Bis(2-ethylhexyl)phthalate
Benzoic acid
Fluoranthene
Pyrene
Hexachlorobenzene
Flourene
Phenol
Butylbenzylphthalate
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachlorobutadiene
Acenaphthene
Benzo(a)anthracene
Chrysene
Hexachlorocyclopentadiene
Heptachlor
Endrin ketone
Gamma Chlordane
Antimony
Cadmium
Lead

Groundwater
Benzene
Ethylbenzene
Xylenes
Phenol
2-Methyl phenol
4-Methyl phenol
Acetone
1,2-Dichloroethane
Chlorobenzene
2-Hexanone
Methylene chloride
Toluene
1,1,2,2-Tetrachloroethylene
1,1,2-Trichloroethane
1,1-Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
Chloroethane
Chloroform
Trichloroethene
Vinyl Chloride
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzoic acid
Bis(chloroethyl)ether
Naphthalene

Silver
Thallium

Leachate
Benzene
Chloroethane
1,1-Dichloroethane
Bis(2-chloroethyl)ether
Hexachlorobutadiene

Exposure to soil and groundwater is associated with significant human health risks due to exceedances of EPA's risk criteria for the reasonable maximum exposure scenarios. The carcinogenic risks were highest for exposure to contaminated groundwater from a possible future ingestion pathway. Soil contaminants posed the greatest non-carcinogenic risk to human health through dermal contact and ingestion by children and future workers.

IV. REMEDIAL ACTIONS

Remedy Selection

EPA organized the remedial action at the site into two phases, or "operable units." The first operable unit was an interim action to protect human health from any potential immediate risks. The ROD for the first Operable Unit Interim Action was signed on September 30, 1992. A Unilateral Administrative Order (UAO) for the first operable unit, which included site fencing, connections to the Butler County public water system for potentially affected local users of groundwater, and groundwater monitoring, was issued to the PRPs on December 9, 1992. Several PRPs complied with the UAO.

The ROD for the second and final operable unit was signed on June 4, 1993. The final operable unit addressed potential future migration of site contaminants into groundwater and limited direct exposure to site contaminants to humans through source control measures. The remedial action addressed the source of the contamination by intercepting and treating on-site groundwater. The function of this action is to control the landfill site as a source of groundwater contamination, to reduce the risks associated with the site and reduce exposure to contaminated materials, and to prevent untreated leachate from running off site. The groundwater response action includes long-term monitoring with site-specific groundwater trigger levels. If site-specific groundwater trigger levels are exceeded in downgradient groundwater monitoring wells, EPA will consider whether additional remedial actions are necessary to address groundwater conditions. The ROD also required an investigation to determine the feasibility for soil vapor extraction (SVE) in the granular soil adjacent to the buried lagoon.

The major components of the selected remedy included:

- Construction of a RCRA cap over the waste materials;

- Interception, collection, and treatment of contaminated groundwater;
- Diversion of upgradient groundwater flow, if necessary;
- Monitoring;
- Institutional controls; and
- Soil vapor extraction.

Remedy Implementation

A Remedial Design (RD) Investigation was performed in 1994 to collect data required to assess the feasibility of the SVE and to design the multi-media cap and the groundwater extraction/treatment system. Based on the RD investigation, the installation of a SVE system was determined to be infeasible.

The Remedial Action Consent Decree for the final operable unit was entered by the court on April 2, 2001. The PRP group constructed the landfill cap and the GIS under the requirements of the CD. Construction began in April 2001.

Landfill Cap

The general profile of the cap from top down includes vegetative cover materials, geocomposite drainage layer, flexible geomembrane liner (FML) primary barrier layer, geosynthetic clay liner (GCL) secondary barrier layer, geocomposite gas venting layer and the prepared subgrade.

Site preparation included clearing and grubbing, preparing the GIS working platform, and removing portions of the fence. The on-site borrow material was used to construct the south sidehill fill area and the landfill cap subgrade. The fill material was transported to the application areas by off-road dump trucks and applied to fill areas in lifts with a dozer. The grade was maintained by using a laser and grade rod and staking grade levels in a grid layout. The grade was spot checked with the grade rod throughout the application process and verified after completion by surveyors. Each section of subgrade was inspected by the Construction Quality Assurance (CQA) consultant and the liner subcontractor to verify that the subgrade was acceptable for placement of the geomembrane panels.

The first geosynthetic layer above the subgrade is a geocomposite consisting of a HDPE geonet with a 6-ounce non woven geotextile heat bonded on both sides. The geocomposite layer is used for collecting landfill gas and was incorporated with gas vent stubs, which allowed for ease of attachment of the gas vents prior to the installation of the overlying cap layers. The geocomposite was installed manually by the geosynthetic installation contractor. Deployment generally proceeded from a higher elevation to a lower elevation to minimize wrinkles. The geonet was overlapped at least four inches and affixed together with plastic ties with the geotextile sewn together with hand-held sewing machines.

The secondary barrier layer, a Geosynthetic Clay Liner (GCL), serves as a backup barrier for the primary barrier. The GCL consists of a 0.75 pound per square foot bentonite clay layer bonded to a non-woven geotextile backing. The GCL was unrolled and pulled into place and overlapped at least six inches edge to edge and, two feet end to end. Installation of the GCL was conducted in a manner that provided immediate coverage of the GCL by the Flexible Membrane Liner (FML) at the end of each working day to prevent hydration of the GCL.

The primary barrier of the landfill cap, the FML, consists of a 60 ml thick low linear density polyethylene FML textured on both sides. The FML was placed directly on top of the GCL immediately following deployment of the GCL. Placement and seaming of the FML was completed in a timely fashion to minimize weather exposure to the GCL. Field seaming the FML panels was the most critical phase of the landfill cap construction and required the most rigorous CQA documentation activities. All major seaming was performed using double-tracked fusion welders. Where fusion welding was not possible, such as joints and around gas vents and piezometers, an extrusion weld was used. Both fusion and extrusion welds were tested by non-destructive test methods to ensure a completed seal.

After sections of the FML were accepted, the drainage layer was installed over the FML to serve two purposes: 1) the geonet facilitates drainage of water that infiltrates through the vegetative cover materials, and 2) the geocomposite affords protection for the liner system during placement of the vegetative cover materials. The drainage layer is a geocomposite consisting of an HDPE geonet with a 6-ounce non-woven geotextile heat bonded to both sides (similar material as the geocomposite gas venting layer).

A minimum of 24 inches of soil was placed over the geosynthetic materials. An excavator was used to cast material out ahead of the leading edge of the cap soil so that no wrinkling developed in the liner/drainage system materials. The cap soil was then pushed with a low ground pressure (LGP) dozer over the in-place drainage layer. Grade was maintained using PVC tubes as grade stakes, so as not to harm the underlying liner materials. No LGP equipment was allowed to be on top of the cap material without a minimum thickness of 18 inches of soil. A minimum of 3 feet was required to be beneath the excavator and dump trucks. To accomplish the minimum thickness requirements, temporary haul roads were installed to enable access to the location where filling occurred. After the application of the cap soil layer was complete, seeding and fertilizing was conducted with a hydro-seeder. Erosion matting was used on slopes, affixed in place with aluminum hooks, to help hold the seed in place.

Surface water drainage control is achieved for the site through the construction of a network of interceptor ditches, drainage letdowns, and culverts. The purpose of the controls is to manage surface water infiltration into the landfill, minimize landfill surface erosion, and direct infiltration away from known disposal areas.

Ten gas probes were constructed around the perimeter of the landfill to monitor landfill gas migration.

Groundwater Interception System

The Groundwater Interception System (GIS) was installed to intercept and capture groundwater migrating from the landfill to the East Fork of Mill Creek. The GIS consists of a of a single cut-off wall of soil-bentonite keyed into bedrock, three gravel filled trenches each with a single groundwater extraction well and a force main system to convey the groundwater to the local sanitary sewer system.

The cut-off wall consists of a soil-bentonite slurry mixture and is capped with native clay to provide protection and a surface for site access. The wall extends from two to three feet below the ground surface (bgs) to where it is keyed into the bedrock. The cut-off wall was constructed by excavating a trench using an extended boom excavator equipped with a 24-inch wide bucket with ripping teeth. The trench was constructed by excavating to bedrock (ranging from approximately 10 feet to 30 feet below grade) and placing the trench spoils to the side. Bentonite clay and water was mixed to create a slurry in a self-contained mixing plant. The bentonite slurry was mixed with the trench spoils to create a soil-bentonite slurry backfill. The bentonite slurry and trench spoils were mixed alongside the trench on the up-gradient side. The majority of the trench spoils were reincorporated into the cut-off wall, with excess soils being used as subgrade for the landfill cap.

The interceptor trench was installed in three separate sections between the landfill and the cut-off wall to create a vertical zone of high permeability gravel extending from two to three feet bgs to approximately four or five feet below the lowest significant sand/gravel seam. The interceptor trenches were generally installed parallel to the cut-off wall. Each trench was excavated to the specified depth (ranging from 14 to 23 feet below grade) prior to placement of geotextile filter fabric along the bottom and sides of the trench. The geotextile fabric was overlapped four feet lengthwise to ensure complete coverage of the trench. The purpose of the geotextile is to filter out fines from the groundwater that may clog the gravel and pumps.

A bio-polymer slurry was placed in the trench bottom prior to placing the geotextile and backfilling to ensure sidewall integrity of the excavation. The slurry allowed for the placement of the geotextile, the granular material and the observation well components. As backfill was placed, extraction and observation wells were installed in accordance with the design specifications. The groundwater extraction pumps were installed in the extraction well of each interceptor trench. The pumps consist of 4" diameter submersibles rated at 25 gpm at 55 feet of total dynamic head. The pumps discharge via a pitless adapter approximately 3 feet bgs. The discharge is transported through a vertical discharge line that is connected to the force main. The force main consists of a 2 inch diameter HDPE pipe approximately 30 inches bgs extending from Extraction Well #1 to the Gravity Manhole. The PRP group has a permit with Butler County Department of Environmental Services to discharge groundwater to the Butler County sewer system.

Other Issues

Two contaminated soil areas located outside the landfill area, but within the limits of the site, Area BP01/BP02 and Area GW-38, were excavated and moved to the on-site landfill and incorporated under the landfill cap. After excavation of the areas, confirmation soil samples were collected and analyzed from each location to ensure that all the contaminated soil was excavated.

Monitoring wells and piezometers were installed in and around the landfill to: 1) monitor the groundwater elevation under the cap to determine contact with buried waste, and 2) assess the long-term performance of the groundwater interception system (interception trench and cut-off wall) in accordance with the Long Term Performance Plan (O&M). Nine new groundwater monitoring wells and one replacement groundwater well were installed during the RA construction activities. Twelve piezometers were installed, four of which are installed through the landfill cap in order to monitor the groundwater/waste contact status.

The remedy also includes physical access restriction with a six-foot high fence with barbed wire at the top, around the entire site sufficient to prevent the public from easily entering the site. The fence is posted with numerous visible warning signs to inform the public of potential site hazards.

A public water supply was supplied to nearby residences located southwest of the site in order to eliminate the groundwater exposure pathway to those persons consuming groundwater.

The site achieved construction completion in September 2001. A Preliminary Close Out Report (PCOR) was completed on September 27, 2001.

System Operations/Operation and Maintenance (O&M)

The groundwater extraction system consists of approximately 770 lineal feet of interceptor trench in three sections and 985 lineal feet of cut-off wall. Located at the low point of the three sections of the interceptor trenches are three extraction wells. Each of the three extraction wells has a submersible pump in it. The pump discharge is tied to a force main that transfers the groundwater from the wells to an existing sanitary sewer which goes to the Butler County POTW for treatment. The pumps have three level controls, one for "pump on", one for "pump off", and one for high level "alarm". If a "pump on" signal is continuous for a predetermined amount of time, an alarm condition occurs. Each pump is connected to a run timer that records the run time.

All of the pumps operate independently. They are connected to a main control panel, which is located at the west end of the GIS. The panel contains run indicator lights for the pumps as well as depth of water in each extraction well with respect to the depth transducer. Additionally, the panel includes a telephone auto dialer that calls a minimum of four predetermined numbers in the event of an alarm situation. The auto dialer has prerecorded messages indicating the alarm condition and location. The system is designed to be monitored remotely, without the need for routine operator interface. However, sampling of the effluent from the GIS is part of the discharge conditions required by BCDES Industrial Discharge Permit (see Attachment 3).

The pumps, valves, settings of the pump control and alarm, flow measurement device, and continuous sampler are the primary components requiring maintenance on the GIS. During the first six months of operation, the O&M tasks related to the GIS were performed on a monthly basis. After the first 6 months, the O&M activities are conducted on a quarterly basis.

The O&M plan provides for inspection and repair of the physical components of the site after closure. Maintenance activities for the final cap include mowing, earthwork activities to correct erosion and sedimentation problems, re-vegetation of disturbed or distressed areas, regrading in settlement areas as determined necessary, and localized repairs due to intrusion, vandalism, etc. The final cap is inspected quarterly for signs of damage. The O&M activities are planned to occur for 30 years after construction completion.

Operation, maintenance, and monitoring activities are performed by Earth Tech, a contractor for the PRP Group. In addition, Butler County has personnel performing activities associated with operation and maintenance.

The Long Term Performance Plan (LTPP) provides the mechanism to ensure that the RA meets the long-term performance standards set forth in the ROD. Sampling and chemical analysis of groundwater, surface water, and the measurement of groundwater elevations will occur as part of O&M activities following completion of the RA. A description of these field activities is provided below.

Groundwater Sampling Plan

The point of compliance for the downgradient groundwater control system is the line of monitoring wells between the GIS alignment and the East Fork of Mill Creek. Groundwater samples are collected from 11 monitoring wells located between the GIS and the East Fork of Mill Creek. The monitoring wells are sampled quarterly. The samples are analyzed for the parameters shown in Tables 7 and 8 (see Attachment 4). However, the PRPs may petition EPA and Ohio EPA to modify the parameter list and sampling frequency based on the results of groundwater monitoring conducted on a quarterly basis for two years after completion of the landfill cap and GIS. Three monitoring wells installed during the RI are located outside the fenced area. These wells are sampled and tested annually to monitor groundwater quality around the landfill. In addition, measurements of water levels and the presence or absence of DNAPLs will be recorded for all existing piezometers, monitoring wells and select gas probes. The measurements are used to evaluate the potentiometric surface and to monitor for DNAPLs in the vicinity of the landfill cap and GIS.

Surface Water Monitoring Plan

Surface water samples are collected for analysis from three monitoring points along the East Fork of Mill Creek and three run-off outfall locations. Monitoring points were chosen to allow impacts from site run-off to be evaluated and include water entering the site upgradient of the landfill, points at and downstream of surface water discharges from the site, and water leaving the site. The samples are collected quarterly and will be analyzed for parameters found in Tables 7 and 8 (see Attachment 4). The PRPs may petition EPA and Ohio EPA to modify the parameter list and sampling frequency based on the results of groundwater monitoring conducted on a quarterly basis for two years after completion of the landfill cap and GIS.

Groundwater Waste Monitoring Plan (GWMP)

The purpose of this plan is to monitor the elevation of groundwater beneath the landfill cap area with respect to the maximum depth of buried waste. The GWMP provides a mechanism to evaluate whether waste material underneath the cap is in contact with site groundwater and whether the landfill cap is affecting the groundwater elevations beneath the landfill. The plan provides for quarterly measurements of the groundwater elevation and flow direction for two years (subsequent to the RA completion) or until the groundwater data have stabilized for at least four consecutive quarters, whichever is longer. The trigger date for the start of the two year monitoring period is September 30, 2003, which is the date EPA approved the RA construction completion report. The data derived from the quarterly sampling events is used to evaluate whether or not the waste material underneath the cap is in contact with site groundwater. The monitoring is implemented in conjunction with the quarterly groundwater sampling at the points of compliance to assess effectiveness of the GIS and the potential need to construct an upgradient groundwater control system.

If after two years of consecutive monitoring, EPA is not able to make a determination as to whether the elevation of the groundwater is below the waste material under the cap, quarterly monitoring will be conducted for an additional year. If EPA determines that the elevation of the groundwater is in contact with the waste material underneath the cap and may reasonably be expected to remain in contact with the waste material for more than three years after completion of the groundwater monitoring period, the PRP group will, within 60 days of EPA's determination or some other longer time period agreed to by EPA, submit to EPA a plan and schedule to construct the upgradient groundwater control. If the upgradient groundwater control plan is submitted, it will be incorporated in the O&M Plan. The points to be measured for the GWMP will be 12 piezometers, 15 monitoring wells, and 2 gas probes within and around the landfill cap.

The ROD estimated that the annual O&M costs will be $397,000. Since O&M activities are conducted by the PRPs, EPA does not have access to the actual expenditures.

Institutional Controls

The remedy includes institutional controls to limit the future use of all areas of the site where RA construction has occurred. These areas include the area covered by the cap, slurry wall, interceptor trenches, extraction wells, etc. The restrictions must prevent the use of this portion of the site for any activity which will interfere with the performance of the remedy, or which will result in the exposure of contaminants to humans or the environment. Such restrictions include, but are not limited to, drilling, digging, building, or the installation, construction, removal, or use of any buildings, wells, pipes, roads, ditches, or any other structures on the capped area. EPA will need to prevent all individuals from traversing the cap, so that the cap is not damaged. In addition, deed restrictions need to be in place as a means to impose limitations on the use of the property. In the event that institutional controls cannot be implemented effectively, EPA and Ohio EPA will consider additional actions as necessary to ensure that the remedy remains effective on a long-term basis.

V. PROGRESS SINCE THE LAST FIVE-YEAR REVIEW

The remedy was implemented since the last five-year review.

VI. FIVE-YEAR REVIEW PROCESS

Administrative Components

Ohio EPA was notified of the initiation of the five-year review in January 2004. The Skinner Landfill Five-Year Review team was led by Scott Hansen of EPA, RPM for the site, and included the Ohio EPA (Chuck Mellon, Project Manager), Ron Roelker of Earth Tech, contractor for the PRP Group, and Ben Baker of Dow Chemical, representative of the PRP Group.

This five-year review consisted of the following activities: a review of relevant documents (see Attachment 2); interviews with local government officials; a local citizen and representatives of the construction and the operations contractors; and a site inspection. In addition, a notice regarding the forthcoming review was placed in the local newspaper. The completed report will be placed in the information repository. Notice of completion will be placed in the local newspaper which will include a summary of the Review findings.

Community Involvement

Activities to involve the community in the five-year review process were initiated in January 22, 2004 with a notification to the local newspaper for the Skinner Landfill Superfund site stating that a five-year review is being conducted at the site. The announcement publicized the start of the five-year review and invited citizens to get involved in the process.

Since the January 22, 2004, notice, no members of the community have expressed any interest or opinion concerning the five-year review process.

Document Review

This five-year review consisted of a review of relevant documents including O&M Plan, RA construction completion report, evaluation reports, and monitoring data (see Attachment 2). Site-specific groundwater trigger levels, as listed in the 1993 ROD, were reviewed.

Data Review

The O&M Plan was submitted by the PRPs in February 2002. Also, a Quality Assurance Project Plan for groundwater sampling was submitted at that time. After considerable review and discussions with the PRPs and their contractor, EPA accepted the plans in June 2003.

Prior to the start of the Long-term Performance activities (O&M), all of the site groundwater monitoring wells and surface water locations were sampled in March 2002. All of the samples were analyzed for metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, and PCBs. All monitoring wells, piezometers, and gas probes were in good condition, with no maintenance needed. No DNAPLs or LNAPLs were encountered in any of the wells or piezometers during the sampling event. The results are discussed below.

VOC and SVOC Results for Groundwater and Surface Water

Bis (2-ethylhexyl) phthalate was detected at 474 ug/L in groundwater at monitoring well GW-64, however it is qualified with a 'B' flag, indicating that the compound was detected in the method blank. This compound is known to be a common laboratory artifact.

VOCs were below detection limits in all surface water samples collected at the site. SVOCs were below detection limits in all surface water samples collected at the site, except for the field blank, which contained phenol at 14.9 ug/L.

Inorganic Results for Groundwater and Surface Water

Barium, Chromium, Copper, Iron, Lead, Nickel, Silver, Thallium and Zinc were detected in groundwater at various sampling locations, however, none of the detections exceeded the trigger levels. Barium, Copper, Iron, Lead, Nickel, Silver and Zinc were also detected in the method field blank. PCBs were not detected in any of the sampling locations.

Barium, Copper, Iron, Nickel, Silver and Zinc were detected in surface water at various sampling locations, however, none of the detections were above trigger levels. Iron, Silver, and Zinc were detected in the method field blank. PCBs were not detected at any of the locations. Cyanide was detected in the matrix spike sample at 109 ug/L, however, it was not seen in the original sample location and is most likely the result of a laboratory artifact.

Groundwater-Waste Monitoring Results

The groundwater elevations under the landfill cap indicate that groundwater levels have dropped below the buried waste at piezometers P-11 and P-12.

Conclusion

Of the twelve groundwater samples collected in March 2002, one trigger level exceedance was measured at MW-64. The exceedance at MW-64 is for bis (2-ethylhexyl) phthalate and is the result of a laboratory artifact. The four surface water samples collected did not exhibit a trigger level exceedance.

As of February 2003, the GIS has pumped approximately 7,654,570 gallons and has resulted in a lowering of the groundwater table below the landfill such that groundwater is no longer in contact with the waste at two of the four monitoring locations.

Site Inspections

Site inspections took place in November 2001, March, June, and December 2002, March 2003 and January 2004. During the site inspections, the landfill cap was inspected and GIS was observed. The inspection evaluated the landfill cap, the GIS, the surface water drainage system, and site fencing.

The landfill cap was found to be in good condition. The vegetative cover was adequate and continuing to improve or mature, with no distressed areas, trees or shrubs. No noticeable depressions, excessive cracks, leachate seeps, odors, or other indications of distress were noted. No significant ponding has been observed on the cap. There was some evidence of erosion on the creek bank on the southeast side of the site. The erosion is not located on the landfill cap, therefore, it does not affect the performance or integrity of the cap system.

The 10.5-acre site is wire fenced on all sides with locked access gates on the west and southwest boundary. The wire fence needs repairs in some areas, particularly the southeastern boundary near the erosion area, and allows easy access to anyone wishing to walk on site. The PRP contractor is repairing the fence and erosion in the spring 2004. If the landfill cap is damaged, repairs are usually pursued in the spring or fall to enhance revegetation efforts. The PRP contractor is also making periodic checks for trespassers.

No other deficiencies of the cap system or appurtenant structures, including drainage channels and access roads, were noted. With the exception of the erosion to the creek bank no intrusive activities were noted on the cap system and no landfill waste or other contaminants were exposed or appeared likely to be exposed. The GIS was found to be operating and functioning properly. All monitoring well covers are intact and locked and show no signs of damage.

Interviews

The following individuals were contacted by telephone as part of the five-year review:

- Ron Roelker, Earth Tech, PRP contractor (Interviewed January 2004)

- Chuck Martin, local citizen, lives near the site (Interviewed November 2003)

- Chuck Mellon, Ohio EPA, project manager (Interviewed January 2004)

- Paula Wyrick, West Chester Township (Interviewed January 2004)

Mr. Roelker, Mr. Mellon, and Ms. Wyrick stated that there are no serious issues related to the site. They also stated that community interest about the site remains low. Ms. Wyrick stated that West Chester Township had received a copy the RA construction completion report. Mr. Martin called EPA to report possible activities at the site. EPA informed Mr. Roelker of the citizen's concern. Mr. Roelker conducted a site inspection and informed EPA that the site was not disturbed. Mr. Roelker confirmed that no changes in land use were planned for the site, and that institutional controls need to be implemented at the site.

VII. TECHNICAL ASSESSMENT

Question A: Is the remedy functioning as intended by the decision documents? Yes.

The review of documents, applicable or relevant and appropriate requirements (ARARs), risk assumptions, and the results of the site inspection indicates that the remedy is functioning as intended by the ROD. The cap has been completed, citizens are on public water supply and the GIS is in place, and these factors have achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and prevent direct contact with, or ingestion of, contaminants in soils and sediments.

HASP/Contingency Plan: Both the HASP and the Contingency Plan are in place, sufficient to control risks, and properly implemented.

Implementation of Institutional Controls and Other Measures: The City provides security services for the site to prevent trespassing. The fence needs to be maintained. As previously discussed, the institutional controls have not been implemented. The institutional controls would include a restrictive easement which will prevent the use of the capped area of the site for any activity that interferes with the performance of the remedy, or which will result in the exposure of contaminants to humans or the environment. Such restrictions include, but are not limited to, drilling, digging, building, or the installation, construction, removal, or use of any buildings, wells, pipes, roads, ditches, or any other structures on the capped area. This issue needs to be resolved.

Remedial Action Performance: The landfill cap system has been effective in isolating waste and contaminants. As previously discussed, some erosion has occurred on the creek bank near the site but it does not affect the performance or integrity of the cap system. The GIS is intercepting and capturing groundwater. Groundwater monitoring shows that the landfill cap and GIS are functioning properly. These factors indicate that the remedial actions continue to be effective and operating and functioning as designed.

System Operations/O&M: System operations procedures are consistent with requirements.

Cost of System Operations/O&M: As previously discussed, the O&M activities are conducted by the PRPs, EPA does not have access to their actual expenditures.

Opportunities for Optimization: Given the adequate performance at the site, this five-year review does not identify a need for optimization at this time.

Early Indicators of Potential Remedy Failure: No early indicators of potential remedy failure were noted during the review.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of the remedy selection still valid? Yes.

There have been no changes in the physical conditions of the Skinner Landfill site that would affect the protectiveness of the remedy.

Changes in Standards and To be Considers

As the remedial work has been completed, most ARARs for sediment, soil and debris contamination cited in the ROD have been met. There have been no changes in these ARARs and no new standards or "to be considered" (TBCs) requirements affecting the protectiveness of the remedy.

Changes in Exposure Pathways, Toxicity, and Other Contaminant Characteristics

There have been no changes in the toxicity factors for the contaminants of concern that were used in the baseline risk assessment. These assumptions are considered to be conservative and reasonable in evaluating risk and developing risk-based cleanup levels. No change to these assumptions, or the cleanup levels developed from them is warranted. There has been no change to the standardized risk assessment methodology that could affect the protectiveness of the remedy. The remedy is progressing as expected.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy? No.

No other events have affected the protectiveness of the remedy and there is no other information that calls into question the short term and long term protectiveness of the remedy.

Technical Assessment Summary

According to the data reviewed and the site inspections, the remedy is functioning as intended by the ROD. There have been no changes in the physical conditions of the site that would affect the protectiveness of the remedy. ARARs for soil, groundwater and sediment contamination cited in the ROD have been met. There have been no changes in the toxicity factors for the contaminants of concern that were used in the baseline risk assessment, and there have been no changes to the standardized risk assessment methodology that could affect the protectiveness of the remedy. There is no other information available that calls into question the protectiveness of the remedy.

VIII. ISSUES

The primary operation performed at the site is the removal of groundwater to the Butler County sewer system. As mentioned before, the pumps, valves, settings for the pump control and alarm, flow measurement device, and continuous sampler are the primary GIS components requiring maintenance. During scheduled O&M maintenance activities, the PRP contractor will need to ensure that all the components of the GIS system are functioning properly. All general O&M maintenance will be conducted for the next 30 years.

The O&M plan provides for quarterly measurements of the groundwater elevation and flow direction for two years (subsequent to the RA completion of September 2003) or until the groundwater data have stabilized for at least four consecutive quarters, whichever is longer. The data derived from the quarterly sampling events, will be used to evaluate whether or not the waste material underneath the cap is in contact with site groundwater. If after two years of consecutive monitoring (September 2005), EPA is not able to make a determination as to whether the elevation of the groundwater is below the waste material under the cap, quarterly monitoring will be conducted for an additional year. If EPA determines that the elevation of the groundwater is in contact with the waste material underneath the cap and may reasonably be expected to remain in contact with the waste material for more than three years after completion of the groundwater monitoring period, the PRP group will, within 60 days of EPA's determination or some other longer time period agreed to by EPA, submit to EPA a plan and schedule to construct the upgradient groundwater control. The monitoring will be implemented in conjunction with the quarterly groundwater sampling at the points of compliance to assess effectiveness of the GIS and the potential need to construct an upgradient groundwater control system.

In addition, the institutional controls need to be implemented at the site. The institutional controls may include a restrictive easement or some other type of proprietary control, which will prevent the use of the capped area of the site for any activity that interferes with the performance of the remedy, or which will result in the exposure of contaminants to humans or the environment. Such restrictions include, but are not limited to, drilling, digging, building, or the installation, construction, removal, or use of any buildings, wells, pipes, roads, ditches, or any other structures on the capped area.

Table 2 - Issues

Issue	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
Institutional Controls - Not implemented	N	Y
Creek bank has eroded	N	Y

Issue	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
Site fence missing at creek bank erosion area	N	Y
Water accumulating in Vault Box and Inspection Manhole	N	Y
Upgradient groundwater control	N	Y
Security Measures required	N	Y

IX. RECOMMENDATIONS AND FOLLOW-UP ACTIONS

Table 3 - Recommendations and Follow-Up Actions

Issue	Recommendations/ Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
Institutional Controls	Need to be implemented	PRP Group and EPA	EPA	ASAP	N	Y
Creek bank erosion	Install gabion wall	PRP Group	EPA	Spring 2004	N	Y
Site fence missing at eroded creek bank	Install site fence after creek bank stabilization	PRP Group	EPA	Spring 2004	N	Y
Water accumulation in Vault Box and Inspection Manhole	Water will be pumped out periodically	PRP Group	EPA	As needed	N	Y

Issue	Recommendations/ Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness? (Y/N)	
					Current	Future
Upgradient groundwater control	Quarterly measurements of groundwater elevations	PRP Group	EPA	Fall 2005	N	Y
Security Measures	Repair fence where needed and put up more warning signs where trespassing is likely to occur.	PRP Group	EPA	Next 30 years	N	Y

It is recommended that inspections be performed after extreme meteorological events, such as tornados or extreme rainfall, to ensure the integrity of the access road or cap has not been compromised. The site fencing, gates, and the existing control panel will be inspected at the same frequency as the cap system, at least 3-4 times a year. Repairs should be performed when determined through inspection.

The passive landfill gas management system consists of vent pipes located throughout the area of final cap system installation. These vents will be inspected at the same frequency and duration as the cap system.

X. PROTECTIVENESS STATEMENT

The remedy is protective of human health and the environment in the short term. There are no current exposure pathways and the remedy appears to be functioning as designed. The landfill cap, the GIS, public water supply for nearby residents and groundwater monitoring have achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and prevent direct contact with, or ingestion of, contaminants in soils and sediments.

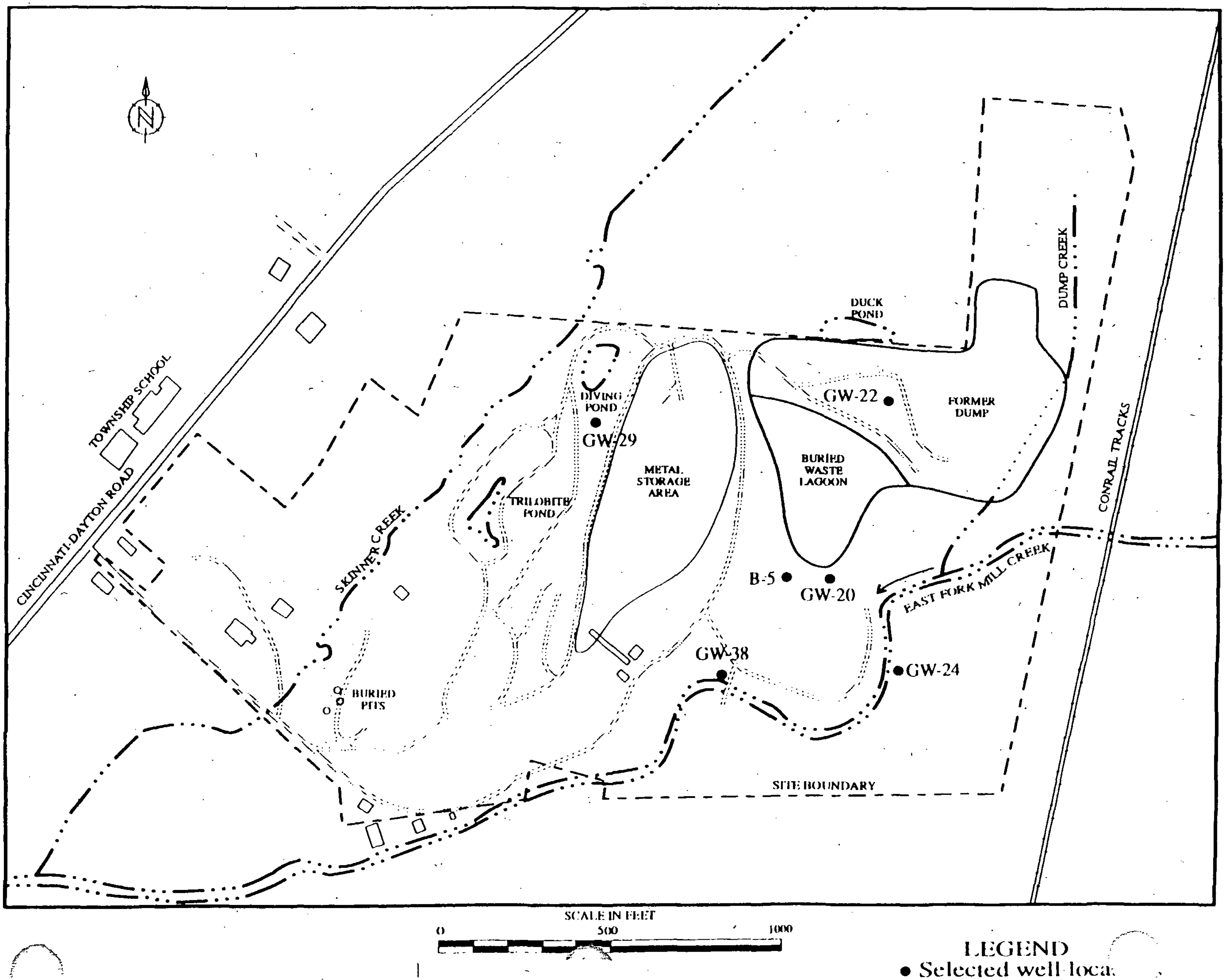
Long-term protectiveness of the remedial action will be achieved when cleanup goals are met.

XI. NEXT REVIEW

The next five-year review for the Skinner Landfill site is required by March 2009, five years from the date of this review.

ATTACHMENTS

Attachment 1: Skinner Site Map



LEGEND
● Selected well loca
as referred to in text

ATTACHMENT 2

List of Documents Reviewed

- Final Operation and Maintenance - Long Term Performance Plan
- Final Remedial Construction Completion Report
- CERCLA - Record of Decision
- Results of Groundwater Monitoring 2002

ATTACHMENT 3

Butler County Department of Environmental Services

Water • Wastewater • Solid Waste • Recycling & Litter Prevention

Commissioners:
Courtney E. Combs
Charles R. Furmon
Michael A. Fox

SPECIAL WASTEWATER DISCHARGE PERMIT

March 17, 2003

The Skinner Landfill Site Work Group
c/o The Dow Chemical Company
Attn: Ben Baker
Remediation Leader
The Dow Chemical Company
4520 E. Ashman
Midland, MI 48674

Re: Skinner Landfill Consent Decree
Permit # 150-01
Permit Fee $200.00
Effective Date: 3/11/2003
Expiration Date: 9/30/2003

In accordance with the provisions of the agreement reached with Butler County Department of Environmental Services (hereafter "BCDES") in May 1996, this Special Wastewater Discharge Permit is hereby granted to The Skinner Landfill Site Work Group, c/o The Dow Chemical Company Attn: Ben Baker Remediation Leader 4520 E. Ashman Midland, Michigan 48674 (hereafter called "Permittee") on this 17th day of March, 2003. **This permit supersedes the permit originally issued on 03/11/2003, and is retroactive to 03/11/2003.** Permittee is authorized to discharge into the Butler County Sewer System in a manner approved by BCDES under the following conditions of this draft permit:

BCDES has agreed to accept the groundwater discharge from Skinner Landfill Site, only based on the understanding that a Special Discharge Permit would be issued by BCDES with site-specific conditions for connection, monitoring, compliance, and user fees. BCDES proposes to handle this discharge in a unique way because (a) groundwater is a prohibited discharge according to the BCDES Sewer Use Rules (hereafter "Rules"), (b) the pollutant concentrations and flows may fluctuate and (c) there is no control or pretreatment system in place. This Draft Special Discharge Permit will be subject to a 14 day public notification process prior to consideration by the Butler County Board of Commissioners.

The permit shall contain special conditions of the discharge and shall expire on September 30, 2003. Subsequent permits shall be effective for up to five (5) years. BCDES will use the sampling vault to collect flow proportional samples. Grab samples will be obtained from the next downstream manhole from the sampling vault. The discharge will have a flow monitoring system. BCDES requires all dischargers to execute a flow monitoring agreement and have an effective O&M and calibration program in place so that BCDES is assured reliable flow data.

The monthly usage fee shall be established at 200% of the standard discharge fee/1000 gallons based on the potentially hazardous content of the waste.

Except as provided in this Special Permit, Permittee shall at all times remain subject to all provisions of the Rules. This Permit does not constitute a waiver by BCDES or the Board of County Commissioners of the right to seek any lawful remedy or penalty for any such violation of this Permit or Rules.

Section 9.6A of the Rules provides that any person who violates a permit condition is subject to a civil penalty in an amount not to exceed $10,000.00 per day of such violation (Section 9.6A). Consequently, should Permittee violate this Special Wastewater Discharge Permit or any Rule, the County, acting through its Director of BCDES, shall have the authority to assess civil penalties of up to $10,000.00 per violation per day. A violation of this permit is subject to such penalties as may be provided by law.

In addition to civil and criminal liability, the Permittee violating this permit, or causing damage to or otherwise materially inhibiting the Upper Mill Creek wastewater disposal system shall be liable to the BCDES for any expense, loss, or damage caused by such violation or discharge. The BCDES shall bill the Permittee for the costs incurred by the BCDES for any cleaning, repair, or replacement work caused by the violation or discharge. Refusal to pay the assessed costs shall constitute a separate violation of Section 9.6B of the Rules.

This permit may be modified by agreement of the Permittee and BCDES in accordance with provisions of the Rules or as lawfully required by the United States EPA, Ohio EPA or agencies thereof. Should BCDES and Permittee be unable to come to terms on a modification of this Permit, BCDES may cancel any remaining term of this Permit upon 180 days notice to Permittee.

Failure on the part of the Permittee to fulfill any of the specified conditions may be sufficient cause for immediate revocation of this permit per Section 5.7 of the Rules. This permit is further subject to termination upon thirty (30) days written notice to the Permittee by an authorized representative of BCDES.

It is the responsibility of the Permittee to submit to an Application for Special Wastewater Discharge Permit to BCDES at least ninety (90) days prior to the expiration date of this permit.

This permit may be assigned or transferred to another discharger per provisions of Section 5.6 of the Rules, which require approval of the Director. Such assignment will not be unreasonably withheld. Notice of changes in the point of discharge, in the number or location of extraction points or other changes that may impact the quality or quantity of the effluent must be provided to and acceptable to BCDES per Section 6.5 of the Rules.

Incidental discharges resultant from monitoring, and/or operation and maintenance of the Skinner Landfill Site as of the effective date of the Special Permit Issuance may be accepted upon notification to BCDES per the Rules.

James A. Parrott

James A. Parrott
Director

SPECIAL PERMIT CONDITIONS

1) Except as otherwise provided in this Special Permit, the Permittee shall comply with the Rules and with the U.S. v Skinner Consent Decree. Where inconsistency exists between the Rules and the Consent Decree, an understanding shall be reached between BCDES and Permittee, with court approval where necessary, as to the terms of this Special Permit before discharges are accepted. In the event of a dispute between the Permittee and BCDES after the Permit is granted, the parties agree to attempt to resolve the dispute first through mediation using a mediator acceptable to both parties, and including U.S. EPA in the mediation if requested by the Permittee.

2) The Permittee shall allow BCDES personnel, upon presentation of their credentials or other documents as may be required by law, to: enter the Skinner Site premises and have access to, inspect, and copy, at reasonable times, any records located at any facility that are deemed necessary by such personnel to determine Permittee's compliance with this Permit. Permittee shall have the right to claim business confidentiality, trade secret, or privileges recognized by state or federal law on the face of any document sought to be copied by BCDES personnel. Should any other person attempt, under the Ohio Public Records Law, to obtain a copy of material from BCDES which Permittee claims to be protected from disclosure, BCDES shall notify Permittee of the request and allow Permittee to defend its claim of entitlement to exclusion before a judge of the Butler County Court of Common Pleas and no material shall be released except in accordance with the final ruling of an Ohio court upon the question. The Permittee shall allow BCDES personnel to inspect at reasonable times any facilities, equipment, practices, or operations regulated or required under this permit; BCDES may sample or monitor, for the purposes of assuring permit compliance, any relevant substances or parameters at any location; and inspect any storage area where pollutants, regulated under this permit, could originate, be stored, or be discharged to the sewer system. Should BCDES be denied access to records it seeks to determine compliance with the terms and conditions of this Permit, then a responsible official of the Permittee shall provide BCDES with an affidavit attesting to Permittee's full and complete compliance with the terms of this Permit under penalty of perjury. Should BCDES be denied access to information it seeks or be denied an acceptable affidavit in lieu of access, BCDES may terminate this Permit upon thirty (30) days prior notice to Permittee.

3) BCDES will conduct regular discharge monitoring to determine that constituents in the effluent from Skinner Landfill Site do not exceed local limits or site-specific limits or pose a threat to the wastewater treatment facility, the collection system, County employees or the receiving stream. The inorganic and organic discharges shall not be in excess of local or site specific limits (see attached maximum discharge limit chart). Should sampling indicate violations of these limits, BCDES reserves the right to suspend the discharge and/or require pretreatment prior to accepting additional flow.

4) Due to the nature and source of the discharge, BCDES will aggressively monitor local limit parameters until the County feels that it has representative data, at which time a normal schedule may be adopted of monthly local limits monitoring. However, BCDES has the right to sample, with or without notice, as frequently as it determines necessary. The costs associated with sampling will be billed back to the discharger along with any surcharge fees associated with high strength acceptable waste. Any prohibited waste in excess of site specific limits will be subject to the enforcement provisions of the Rules and the Enforcement Response Plan. BCDES understands that seasonal variations may have an impact on water quality parameters, and we want to be assured that the concentrations we are given are within the Publicly Owned Treatment Works (POTW's) ability to safely handle.

5) The Permittee shall report to the BCDES any significant changes in location, operational conditions, the quality or quantity of discharges or chemical storage procedures as provided in Section 6.5 of the Rules.

6) The Permittee shall notify the BCDES immediately after Permittee's knowledge of the occurrence of an accidental discharge of substances or slug loads or spills that may enter the public sewer. BCDES should be notified by telephone at (513) 887-3686.

The notification shall include location of discharge, date and time thereof, type of waste, including concentration and estimated volume, and corrective actions taken (Section 6.6A). The Permittee's notification of accidental releases in accordance with this section does not relieve it of other reporting requirements that arise under local, State, or Federal laws or the U.S. v Skinner Consent Decree.

Within 5 days of the verbal notification of a discharge, a complete written report must be submitted detailing the quantity and quality of discharge, reason for discharge, and steps taken to prevent further occurrences.

7) The Permittee shall keep on file at a location of Permittee's choosing, all records, documents, reports, and correspondence pertaining to effluent monitoring, sampling, and chemical analysis made by or prepared for the Permittee. Said records, reports, documents and correspondence shall be kept on file for a minimum of three (3) years.

8) Particular attention should be given to the following: (Note: This section will be utilized to reflect the categorical standards and limits (40 CFR 433) if applicable).

(a) From effective date of the permit through September 30, 2003, the Permittee's effluent wastewater discharged to the County Sewer System shall not exceed the following limits based on flow rates provided in the application.

BCDES Special Permit Limits for Skinner Landfill Site

Skinner Landfill Applicable Parameters	Applicable Limit	Allowable Mass Loading Limits(1) (lbs/day)
TTO	Site Specific	0.53
Arsenic	Local Limit	0.04
Cadmium	Local Limit	0.02
Chromium, Total	Local Limit	0.88
Chromium, Hexavalent	Local Limit	0.13
Copper	Local Limit	0.35
Lead	Local Limit	0.13
Mercury	Local Limit	<0.00009
Molybdenum	Local Limit	0.17
Nickel	Local Limit	0.31
Selenium	Local Limit	0.03
Silver	Local Limit	0.01
Cyanide, Total	Local Limit	0.03
Zinc	Local Limit	0.25
Ammonia	Local Limit	9.17
BOD_5	Local Limit	366.96
COD	Local Limit	917.40
Oil & Grease	Local Limit	18.35
TSS	Local Limit	229.35

(1) Based upon 11,000 gallons per day discharge rate. The method detection limit (MDL) for mercury is 0.2 ug/l. Ohio EPA defined practical quantification limit (PQL) is 5 times the MDL. To determine compliance with this permit, results below the mdl will be reported as BDL. Results between the MDL and the PQL shall be reported as an analytical result.

9) The conditions for renewal of the permit will be that 90 days prior to expiration of the permit, the Permittee shall provide a analysis of the discharge, including operational schedule and anticipated flows, concentrations and an evaluation of the discharge needs for the following 4 years. Additionally, any anticipated significant operational changes shall be reported at any time there is an anticipated significant change during the course of the agreement.

10) The Permittee must verbally notify BCDES within 24 hours of becoming aware of any violation found in any self-monitoring. BCDES will require the Permittee to re-sample every 30 days until the Permittee's discharge is in compliance with limits established in this permit. In addition, the Permittee must submit all effluent and monitoring well data collected in accordance with the self-monitoring requirements in 40 CFR Part 136 (as applicable) or the analytical requirements approved by U.S. EPA pursuant to the U.S. v. Skinner Consent Decree, as appropriate. This includes any samples the County may split with the Permittee.

11) This permit allows discharge of up to 324,000 gallons per month from the Skinner Landfill Site. Flows greater than 324,000 gallons per month will be assessed peaking surcharges as established in the County's Sewer Rate Resolution 02-1-103, or any subsequent rate schedule. Additionally, due to the nature of this special discharge, any peaking charges are subject to be billed at the 200% standard discharge fee that is established this Special Permit.

Should additional flow need to be discharged from the Skinner Landfill Site, then a letter requesting allocation of additional capacity will need to be sent to the Director. Since groundwater is a prohibited flow except as provided by this Special Permit, then separate approval and agreement will be needed regarding additional ERU allocation.

12) BCDES may make an additional 23 ERUs ("Additional ERU") available for Permitee's use with the understanding that the charges for the 23 ERUs will be paid by Permittee at the rate currently in effect at the time of purchase. It is also required that Permittee will surrender to BCDES one or more Additional ERU(s) assigned to Permittee when the groundwater flow from the Skinner Landfill Site decreases such that each Additional ERU/capacity allocation is no longer needed by Permittee. An Additional ERU will be deemed to be no longer needed after a period of two (2) years in which the peak flow in any one month does not exceed 110% of the additional assigned capacity. For example, if the peak monthly flow in 2004 is 450,000 gallons, then each Additional ERU in excess of that needed for the 495,000 gallon capacity allocation would be considered to be an Additional ERU to be surrendered in 2006. For the purposes of determining the surrender of an Additional ERU, a review will be conducted by BCDES and Permittee in January of each year with a surrender of an Additional ERU, if any, to occur in January two (2) years later. Should data during the intervening two (2) years indicate Permittee's need for the Additional ERU, then a letter requesting deferral of the surrender will be submitted to BCDES. Consent for such deferral will not be unreasonably withheld by BCDES. Notwithstanding the ERU review example provided above, at no time shall the Additional ERU review require the Skinner Landfill Site to surrender any of the original 27 ERUs (324,000 gallons per month) authorized under this permit.

ATTACHMENT 4

TABLE 7

TARGET COMPOUND LIST

		Quantitation Limits (1)
Volatiles	CAS Number	Water (ug/L)
1. Chloromethane	74-87-3	1.0
2. Bromomethane	74-83-9	1.0
3. Vinyl Chloride	75-01-4	1.0
4. Chloroethane	75-00-3	1.0
5. Methylene Chloride	75-09-2	1.0
6. Acetone	67-64-1	1.0
7. Carbon Disulfide	75-15-0	1.0
8. 1,1-Dichloroethene	75-35-4	1.0
9. 1,1-Dichloroethane	75-35-3	1.0
10. 1,2-Dichloroethane (total)	540-59-0	1.0
11. Chloroform	67-66-3	1.0
12. 1,2-Dichloroethane	107-06-2	1.0
13. 2-Butanone	78-93-3	1.0
14. 1,1,1-Trichloroethane	71-55-6	1.0
15. Carbon Tetrachloride	56-23-5	1.0
16. Bromodichloromethane	75-27-4	1.0
17. 1,2-Dichloropropane	78-87-5	1.0
18. cis-1,3-Dichloropropene	10061-01-5	1.0
19. Trichloroethene	79-01-6	1.0
20. Dibromochloromethane	124-48-1	1.0
21. 1,1,2-Trichloroethane	79-00-5	1.0
22. Benzene	71-43-2	1.0
23. trans-1,3-Dichloropropene	10061-02-6	1.0
24. Bromoform	75-25-2	1.0
25. 4-Methyl-2-pentanone	108-10-1	1.0
26. 2-Hexanone	591-78-6	1.0
27. Tetrachloroethene	127-18-4	1.0
28. Toluene	108-88-3	1.0
29. 1,1,2,2-Tetrachloroethane	79-34-5	1.0
30. Chlorobenzene	108-90-7	1.0
31. Ethyl benzene	100-41-4	1.0
32. Styrene	100-42-5	1.0
33. Xylenes (total)	1330-20-7	1.0

TABLE 7 (cont.)

TARGET COMPOUND LIST

		Quantitation Limits (1)	
Semi-volatiles (2, 3)	CAS Number	Water (ug/L)	Soil/Sediment (mg/kg)
34. Phenol	108-95-2	10	330
35. bis(2-Chloroethyl) ether	111-44-4	10	330
36. 2-Chlorophenol	95-57-8	10	330
37. 1,3-Dichlorobenzene	541-73-1	10	330
38. 1,4-Dichlorobenzene	106-46-7	10	330
39. 1,2-Dichlorobenzene	95-50-1	10	330
40. 2-Methylphenol	95-48-7	10	330
41. 2,2'-oxybis-(1-Chlororpropane)#	108-60-1	10	330
42. 4-Methylphenol	106-44-5	10	330
43. N-Nitroso-di-n-dipropylamine	621-64-7	10	330
44. Hexachloroethane	67-72-1	10	330
45. Nitrobenzene	98-95-3	10	330
46. Isophorone	78-59-1	10	330
47. 2-Nitrophenol	88-75-5	10	330
48. 2,4-Dimethylphenol	105-67-9	10	333
49. bis(2-Chloroethoxy) methane	111-91-1	10	330
50. 2,4-Dichlorophenol	120-83-2	10	330
51. 1,2,4-Trichlorobenzene	120-82-1	10	330
52. Naphthalene	91-20-3	10	330
53. 4-Chloroaniline	106-47-8	10	330
54. Hexachlorobutadiene	87-68-3	10	330
55. 4-Chloro-3-methyphenol	59-50-7	10	330
56. 2-Methylynaphthalene	91-57-6	10	330
57. Hexachlorocyclopentadiene	77-47-4	10	330
58. 2,4,6-Trichlorophenol	88-06-2	10	330
59. 2,4,5-Trichlorophenol	95-95-4	25	800
60. 2-Chloronaphthalene	91-58-7	10	330
61. 2-Nitroaniline	88-74-4	25	800
62. Dimethylphthalate	131-11-3	10	330
63. Acenaphthlene	208-96-8	10	330
64. 2,6-Dinitrotoluene	606-20-2	10	330
65. 3-Nitroaniline	99-09-2	50	800
66. Acenaphthene	83-32-9	10	330
67. 2,4-Dinitrophenol	51-28-5	25	800
68. 4-Nitrophenol	100-02-7	25	800
69. Dibenzofuran	132-64-9	10	330
70. 2,4-Dinitrotoluene	121-14-2	10	330
71. Diethylphthalate	84-66-2	10	330
72. 4-Chlorophenyl-phenyl ether	7005-72-3	10	330
73. Fluorene	86-73-7	10	330

TABLE 7 – (Cont.)

TARGET COMPOUND LIST

		Quantitation Limits (1)	
Semi-volatiles (2, 3)	CAS Number	Water (ug/L)	Soil/Sediment (mg/kg)
74. 4-Nitroaniline	100-01-6	25	800
75. 4,6-Dinitro-2-methylphenol	534-52-1	25	800
76. N-Nitrosodiphenylamine	86-30-6	10	330
77. 4-Bromophenyl-phenyl ether	101-55-3	10	330
78. Hexachlorobenzene	118-74-1	10	330
79. Pentachlorophenol	87-86-5	25	800
80. Phenanthrene	85-01-8	10	330
81. Anthracene	120-12-7	10	330
82. Carbazole	86-74-8	10	330
83. Di-n-butyl phthalate	86-74-2	10	330
84. Fluoranthene	206-44-0	10	330
85. Pyrene	129-00-0	10	330
86. Butyl benzyl phthalate	85-68-7	10	330
87. 3,3'-Dichlorobenzidine	91-94-1	10	330
88. Benz(a)anthracene	56-55-3	10	333
89. Chrysene	218-01-9	10	330
90. bis(2-Ethylhexyl)phthalate	117-81-7	10	330
91. Di-n-Octylphthalate	117-84-0	10	330
92. Benzo(b)fluoranthene	205-99-2	10	330
93. Benzo(k)fluoranthene	207-08-9	10	330
94. Benzo(a)pyrene	50-32-8	10	330
95. Indeno(1,2,3-cd)pyrene	193-39-5	10	330
96. Dibenzo(a,h)anthracene	53-70-3	10	330
97. Benzo(g,h,i)perylene	191-24-2	10	330

\# Previously known by the name bis(2-Chloroisopropyl) ether

(1) Quantitation Limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, as required by the protocol, will be higher.

TABLE 7 (cont.)

TARGET COMPOUND LIST

		Quantitation Limits (1)	
Pesticides/Aroclors	CAS Number	Water (ug/L)	Soil/Sediment (mg/kg)
98. alpha-BHC	319-84-6	0.05	1.7
99. beta-BHC	319-85-7	0.05	1.7
100. delta-BHC	319-86-8	0.05	1.7
101. gamma-BHC (Lindane)	58-89-9	0.05	1.7
102. Heptachlor	76-44-8	0.05	1.7
103. Aldrin	309-00-2	0.05	1.7
104. Heptachlor epoxide	1024-57-3	0.05	1.7
105. Endosulfan I	959-98-8	0.05	1.7
106. Dieldrin	60-57-1	0.10	3.3
107. 4,4'-DDE	72-55-9	0.10	3.3
108. Endrin	72-20-8	0.10	3.3
109. Endosulfan II	33213-65-9	0.10	3.3
110. 4,4'-DDD	72-54-8	0.10	3.3
111. Endosulfan sulfate	1031-07-8	0.10	3.3
112. 4,4'-DDT	50-29-3	0.10	3.3
113. Methoxychlor	72-43-5	0.50	17.0
114. Endrin ketone	53494-70-5	0.10	3.3
115. Endrin aldehyde	7421-36-3	0.10	3.3
116. alpha-Chlordane	5103-71-9	0.05	1.7
117. gamma-Chlordane	5103-74-2	0.05	1.7
118. Toxaphene	8001-35-2	5.0	170.0
119. AROCLOR-1016	12674-11-2	1.0	33.0
120. AROCLOR-1221	11104-28-2	0.5	67.0
121. AROCLOR-1232	11141-16-5	0.5	33.0
122. AROCLOR-1242	53469-21-9	1.0	33.0
123. AROCLOR-1248	12672-29-6	1.0	33.0
124. AROCLOR-1254	11097-69-1	1.0	33.0
125. AROCLOR-1260	11096-82-5	1.0	33.0

(1) Quantitation Limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, as required by the protocol, will be higher.

TABLE 8

TARGET ANALYTE LIST

Analyte	Contract Required (1, 2, 3) Detection Limit (ug/L)
Aluminum	200
Antimony	60
Arsenic	10
Barium	200
Beryllium	5
Cadmium	5
Calcium	5000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Lead	3
Magnesium	5000
Manganese	15
Mercury	0.2
Nickel	40
Potassium	5000
Selenium	5
Silver	10
Sodium	5000
Thallium	10
Vanadium	50
Zinc	20
Cyanide	10

(1) Higher detection limits may only be used if the sample concentration exceeds five times the detection limit of the instrument or method in use. The value may be reported even though the instrument or method detection limit may not equal the CRQL. This is illustrated in the example where the value of 220 may be reported even though the instrument detection limit is greater than the CRQL.

For lead:

Method in use = ICP
Instrument Detection Limit (IDL) = 40
Sample Concentration = 220
CRQL = 3

(2) The CRQLs are the instrument detection limits obtained in pure water. The detection limits for samples may be considerably higher depending on the sample matrix.

(3) The CRQLs for soils = 200 times CRQL's for water.

THIRD FIVE-YEAR REVIEW REPORT

SKINNER LANDFILL SUPERFUND SITE

Butler County
West Chester, Ohio

PREPARED BY:

United States Environmental Protection Agency
Region 5
Chicago, Illinois

Approved by: Date:

3/17/09

Richard C. Karl
Director
Superfund Division, Region 5

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Acronyms

ARARs	Applicable or Relevant and Appropriate Requirements
BCDES	Butler County Department of Environmental Services
bgs	below ground surface
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CQA	Construction Quality Assurance
DNAPL	Dense Non Aqueous Phase Liquid
EPA	United States Environmental Protection Agency
FML	Flexible Geomembrane Liner
FS	Feasibility Study
GCL	Geosynthetic Clay Liner
GIS	Groundwater Interception System
gpm	gallons per minute
GWMP	Groundwater Waste Monitoring Plan
IC	Institutional Control
LGP	Low Ground Pressure
LTPP	Long Term Performance Plan
MCL	Maximum Contaminant Level
MSL	mean sea level
NCP	National Contingency Plan
NPL	National Priorities List
O&M	Operation and Maintenance
Ohio EPA	Ohio Environmental Protection Agency
PCBs	Polychlorinated Biphenyls
PCOR	Preliminary Close Out Report
POTW	Publicly Owned Treatment Works
ppm	parts per million
PRPs	Potentially Responsible Parties
RA	Remedial Action
RD	Remedial Design
RI	Remedial Investigation
RI/FS	Remedial Investigation/ Feasibility Study
ROD	Record of Decision
Site	Skinner Landfill Superfund Site
SVE	Soil Vapor Extraction
SVOCs	Semi-Volatile Organic Compounds
UAO	Unilateral Administrative Order
UECA	Uniform Environmental Covenants Act
VOCs	Volatile Organic Compounds

Executive Summary

EPA completed the third five-year review of the Skinner Landfill site in West Chester, Ohio, in March 2009. The assessment of this five-year review found that the remedy is protective of human health and the environment. There are no current exposure pathways and the remedy appears to be functioning as designed. The landfill cap, the groundwater interception system (GIS) and the connection of nearby residents to the public water supply eliminate the source of contamination and have achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and to prevent direct contact with, or ingestion of, contaminants in soils and sediments. Institutional controls (ICs), in the form of an environmental covenant under the Ohio version of the Uniform Environmental Covenants Act (UECA), have been implemented to protect the remedy components, and to protect against improper use of site land and groundwater resources. Compliance with effective ICs will be ensured through long-term stewardship by implementing, maintaining, monitoring and enforcing effective ICs as well as maintaining the site remedy components. To that end, the current title commitment and site survey map will be reviewed to ensure that the environmental covenant remains effective and long-term stewardship procedures will be reviewed. EPA noted a few deficiencies that do not immediately impact the protectiveness of the remedy.

Both the Health and Safety Plan and the Contingency Plans are in place, sufficient to control risks, and properly implemented. The remedy for the Skinner Landfill Superfund Site (the site) includes a landfill cap/containment, access controls, ICs and a GIS.

The Ohio Environmental Protection Agency (Ohio EPA) in cooperation with the United States Environmental Protection Agency (EPA) completed oversight of all major construction activities for the site.

The site is located approximately 15 miles north of Cincinnati, Ohio, near West Chester, Butler County, Ohio, in Township 3, Section 22, Range 2. The site is comprised of approximately 78 acres of hilly terrain. The site was used in the past for the mining of sand and gravel, and was operated for the landfilling of a wide variety of materials from approximately 1934 through 1990. Materials deposited at the site include demolition debris, household refuse, and a variety of chemical wastes. The site is bordered on the east by a Norfolk Southern Railway Company right-of-way, on the south by the East Fork of Mill Creek, on the north by wooded and agricultural land, and on the west by a gravel driveway and Cincinnati-Dayton Road.

The site achieved construction completion in September 2001. The assessment of this five-year review found that the remedy was constructed in accordance with the requirements of the June 4, 1993, Record of Decision (ROD). The landfill cap has been constructed over all the wastes, a GIS is operating, and a public water supply was provided to nearby residents.

Five-Year Review Summary Form

SITE IDENTIFICATION

Site name (from WasteLAN): Skinner Landfill Superfund Site

EPA ID (from WasteLAN): EPA ID# OHD063963714

Region: 5 | State: OH | City/County: West Chester, Butler County

SITE STATUS

NPL status: _X_ Final __ Deleted __ Other (specify)

Remediation status (choose all that apply): __ Under Construction X Operating _ Complete

Multiple OUs? __YES X_NO | Construction completion date: 9/27/01

Has site been put into reuse? _ YES X NO

REVIEW STATUS

Lead agency: _X EPA _ State _ Tribe _ Other Federal Agency

Author name: Scott Hansen

Author title: Remedial Project Manager | Author affiliation: U.S.EPA, Region 5

Review period: 09 / 17 / 2008 to March 2009

Date(s) of site inspection: 01 / 28 / 2009

Type of review:
_X Post-SARA _ Pre-SARA _ NPL-Removal only
_ Non-NPL Remedial Action Site _ NPL State/Tribe-lead
_ Regional Discretion

Review number: 1 (first) _ 2 (second) _X 3 (third) _ Other (specify) ______

Triggering action:
_ Actual RA Onsite Construction at OU #____ _ Actual RA Start at OU#_NA___
_ Construction Completion _X Previous Five-Year Review Report
_ Other (specify)

Triggering action date (from WasteLAN): 03 / 17 / 2004

Due date (five years after triggering action date): 03 / 17 / 2009

Five-Year Review Summary Form, cont'd.

Issues:

- Security measures (site fence repair and control illegal dumping)
- The need for upgradient groundwater control must be evaluated
- Institutional controls: Location of some existing easements and their relationship to remedy components is unknown
- Institutional controls: Ensure long-term stewardship

Recommendations and Follow-up Actions:

- Repair fence where needed and control illegal dumping
- Continued quarterly measurements of groundwater elevations
- Institutional controls: Update title commitment and site survey map; check all easements of record to make sure there is no interference with site remedy components
- Institutional controls: Review long-term stewardship procedures and update if necessary

Protectiveness Statement:

The assessment of this five-year review found that the remedy at the Skinner Landfill Superfund site is protective of human health and the environment. There are no current exposure pathways and the remedy appears to be functioning as designed. The landfill cap, the GIS and the connection of nearby residents to the public water supply eliminate the source of contamination and have achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and to prevent direct contact with, or ingestion of, contaminants in soils and sediments. Institutional controls, in the form of an environmental covenant under the Ohio version of the Uniform Environmental Covenants Act, have been implemented to protect the remedy components, and to protect against improper use of site land and groundwater resources. Compliance with effective ICs will be ensured through long-term stewardship by implementing, maintaining, monitoring and enforcing effective ICs as well as maintaining the site remedy components.

1.0 INTRODUCTION

The EPA, Region 5, has conducted a five-year review of the remedial actions implemented at the Skinner Landfill Superfund Site in Butler County, Ohio. The review was conducted between September 2008 and March 2009. This report documents the results of the five-year review. The purpose of five-year reviews is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of the review are documented in the five-year review reports. In addition, five-year review reports identify issues found during the review, if any, and make recommendations to address them.

This review is required by statute. EPA must implement five-year reviews consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). CERCLA 121(c), as amended, states:

> If a remedial action is selected that results in any hazardous substances, pollutants, or contaminants remaining at the site, the remedial action shall be reviewed no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented.

The NCP part 300.430(f)(4)(ii) of the Code of Federal Regulations (CFR) states:

> If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.

This is the third five-year review for the Skinner Landfill Site. The first five-year review report was completed and signed in March 1999, and the second report was signed in March 2004. Due to the fact that hazardous substances, pollutants, or contaminants remain at the site above levels that allow for unlimited use and unrestricted exposure, this five-year review is required.

2.0 SITE CHRONOLOGY

Table 1. Chronology of Site Events

Date	Event
1976	Initial Discovery of Problem
09/1983	National Priorities List (NPL) Listing
09/1984 – 06/1993	RI/FS (entire site)
09/30/1992	Interim ROD
12/09/1992	Unilateral Administrative Order (UAO)
06/04/1993	ROD (entire site)
03/1994 – 06/1996	RD
06/18/1996	RA start
04/02/2001	Consent Decree for RA
04/02/2001	RA construction start
09/27/2001	Preliminary Close Out Report (PCOR)
03/27/2003	Final inspection of site
09/30/2003	RA completed
03/17/1999	First five-year review
03/17/2004	Second five-year review
12/24/2006	Environmental covenant under the UECA recorded in site land records
12/2006 – 01/2007	Abandoned damaged piezometers and installed new piezometers
06/2008	Removal action

3.0 BACKGROUND

3.1 Physical Characteristics

The Skinner Landfill site is located approximately 15 miles north of Cincinnati, Ohio, near West Chester, Butler County, Ohio, in Township 3, Section 22, Range 2. The site is bordered on the east by a Norfolk Southern Railway Company right-of-way, on the south by the East Fork of Mill Creek, on the north by wooded and agricultural land, and on the west by a gravel driveway and Cincinnati-Dayton Road. A map of the site is provided in Attachment 1.

The approximately 10.5-acre landfill site is fenced on all sides with locked access gates on the south and west sides of the site. The only structures on site are the metal electrical box located near the south entrance gate and the gas vents. A gravel access road is located inside the fence on the south and west sides of the site.

The site is located in a highly dissected area that slopes from a till-mantled-bedrock upland to a broad, flat-bottomed valley that is occupied by the main branch of Mill Creek. Elevations on the site range from a high of nearly 800 feet above mean sea level (MSL) in the northeast, to a low of 645 feet above MSL near the confluence of Skinner Creek and the East Fork of Mill Creek. Both Skinner Creek and the East Fork of Mill Creek are small, intermittent shallow streams. Both of these streams flow to the southwest from the site toward Mill Creek, which in turn flows into the Ohio River.

In general, the site is underlain by relatively thin glacial drift over inter-bedded shale and limestone of Ordovician age. The composition of the glacial drift ranges from intermixed silt, sand and gravel, to silty sandy clays with a thickness ranging from zero to over forty feet. The sand and gravel deposits comprise the hills and ridges and are encountered near the surface of the central portion of the site. The silts and clays usually occur as lenses in the sands and gravel or directly overlie bedrock.

3.2 Land and Resource Use

The property was originally developed as a sand and gravel mining operation and was subsequently used as a landfill from 1934 to 1990.

3.3 History of Contamination

In 1976, in response to a fire at the site and reports of observations of a black, oily liquid in a waste lagoon on the site, the Ohio EPA began a site investigation. Before Ohio EPA could complete the investigation, the site owner/operator covered the waste lagoon with a layer of demolition debris, thereby hindering the investigation. Albert Skinner, the site owner at the time, dissuaded the Ohio EPA from accessing the lagoon area by claiming that nerve gas, mustard gas, incendiary bombs, phosphorus, flame throwers, cyanide ash, and other explosive devices were buried at the landfill. This prompted Ohio EPA to request the assistance of the U.S. Army. Albert Skinner, in the presence of Ohio EPA attorneys and the U.S. Army investigators, subsequently retracted his claims of the presence of ordnance. The U.S. Army and Ohio EPA then dug several trenches into the buried waste lagoon, and found black and orange liquids and a number of barrels of waste. Subsequently, the U.S. Army performed records searches; these have indicated that there is no evidence of munitions of any sort having been disposed at the site.

Based on the initial studies, materials deposited at the site include demolition debris, household refuse and a wide variety of chemical wastes. The waste disposal areas include a now buried former waste lagoon near the center of the site and a landfill. The buried lagoon was used for the disposal of paint wastes, ink wastes, creosote, pesticides, and other chemicals. The landfill area, located north and northeast of the buried lagoon, received predominantly demolition debris.

3.4 Initial Response

In 1982, the EPA conducted a limited site investigation for the purpose of scoring the site for inclusion on the National Priorities List (NPL). The investigation showed that groundwater southeast of the buried waste lagoon was contaminated with volatile organic compounds (VOCs). The site was proposed for the NPL in December 1982.

The EPA completed a search for potentially responsible parties (PRPs) in April 1983. The results of that search were later supplemented by information requests under CERCLA Section 104(e) and by administrative depositions.

In 1986, the EPA began a Phase I Remedial Investigation (RI) with the sampling of groundwater, surface water, and soils. A biological survey of the East Fork of Mill Creek and Skinner Creek was also performed. In 1989, the EPA began its Phase II RI, to further investigate the site groundwater, surface water, soils, and sediments. Overall, more than 400 samples from the site were analyzed. In August 1990, through a legal proceeding, the Ohio EPA closed the site to all further landfilling activities. EPA completed the Phase II RI in May 1991 and both a Baseline Risk Assessment and Feasibility Study (FS) in 1992.

The results of the two-phased RI are summarized below.

The former dump area was used for the disposal of a variety of wastes, including demolition debris, household refuse and assorted scrap. Chemical wastes were also disposed in this area. The total volume of wastes within the former dump was estimated at 120,000 cubic yards. EPA's water samples collected during the Phase I RI indicated that the most concentrated groundwater contamination found at the site was in the area beneath the former dump. Site records and deposition testimony of waste haulers indicated that large quantities of chemical wastes were disposed in the waste lagoon. These wastes included creosote, paint wastes, ink wastes, and pesticides. The RI/FS estimated that the total volume of contaminated materials in the lagoon was 107,000 cubic yards. The FS estimated that 17,000 cubic yards of lagoon waste materials exceeded the risk-based protective levels.

3.5 Basis for Taking Action

Based on sampling results, the hazardous substances that have been released at the site in each media include:

Soil
Toluene
Xylenes
Ethylbenzene
1,1,2-Trichloroethane
1,2-Dichloropropane
Benzene

Groundwater
Benzene
Ethylbenzene
Xylenes
Phenol
2-Methyl phenol
4-Methyl phenol

Naphthalene
2-Methylnaphthalene
Phenanthrene
Bis(2-ethylhexyl)phthalate
Benzoic acid
Fluoranthene
Pyrene
Hexachlorobenzene
Flourene
Phenol
Butylbenzylphthalate
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Hexachlorobutadiene
Acenaphthene
Benzo(a)anthracene
Chrysene
Hexachlorocyclopentadiene
Heptachlor
Endrin ketone
Gamma Chlordane
Antimony
Cadmium
Lead
Silver
Thallium

Acetone
1,2-Dichloroethane
Chlorobenzene
2-Hexanone
Methylene chloride
Toluene
1,1,2,2-Tetrachloroethylene
1,1,2-Trichloroethane
1,1 -Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
Chloroethane
Chloroform
Trichloroethene
Vinyl Chloride
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzoic acid
Bis(chloroethyl)ether
Naphthalene

Leachate
Benzene
Chloroethane
1,1-Dichloroethane
Bis(2-chloroethyl)ether
Hexachlorobutadiene

In addition, the risk assessment concluded that the potential routes of current and future exposure above safe levels included: ingestion of and direct contact with contaminated soils; ingestion of affected groundwater; dermal contact with groundwater; inhalation of chemicals that volatilize from groundwater to air during showering; and ingestion of and direct contact with surface water and sediments during recreational activities. Inhalation of fugitive dust and volatile chemicals was also evaluated qualitatively as a potential exposure route but did not warrant a quantitative assessment because emissions from surface soil would likely be low. This is because the most contaminated portion of the site, the buried waste lagoon, is covered by up to 40 feet of demolition debris and is not considered a source of air risk under the current conditions.

4.0 REMEDIAL ACTIONS

4.1 Remedy Selection

EPA organized the remedial action at the site into two phases, or "operable units." The first operable unit was an interim action to protect human health from any immediate potential risks. EPA's ROD for the first Operable Unit Interim Action was signed on September 30, 1992. A Unilateral Administrative Order (UAO) for the first operable unit, which included site fencing, connections to the Butler County public water system for potentially affected local users of groundwater, and groundwater monitoring, was issued to the PRPs on December 9, 1992. Several PRPs complied with the UAO.

EPA signed the ROD for the second and final operable unit on June 4, 1993. The remedial action objectives for the final operable unit addressed potential future migration of site contaminants into groundwater and limited direct exposure to site contaminants to humans through source control measures. The remedial action addressed the source of the contamination by intercepting and treating on-site groundwater. The function of this action was to control the landfill site as a source of groundwater contamination; to reduce the risks associated with the site and reduce exposure to contaminated materials; and to prevent untreated leachate from running off site. The groundwater response action includes long-term monitoring with site-specific groundwater trigger levels. If site-specific groundwater trigger levels are exceeded in downgradient groundwater monitoring wells, EPA will consider whether additional remedial actions are necessary to address groundwater conditions. The ROD also required an investigation to determine the feasibility for soil vapor extraction (SVE) in the granular soil adjacent to the buried lagoon.

The major components of the selected remedy included:

- Construction of a hazardous waste landfill cap over the waste
- Interception, collection, and treatment of contaminated groundwater by a system known as the Groundwater Interception System or GIS;
- Diversion of upgradient groundwater flow, if necessary;
- Monitoring;
- Institutional controls; and
- Soil vapor extraction.

The selected remedy uses permanent treatment systems to eliminate the principal threat posed to human health and the environment by extracting the contaminated groundwater.

4.2 Remedy Implementation

A Remedial Design (RD) Investigation was performed in 1994 to collect data required to assess the feasibility of the SVE and to design the multi-media cap and the groundwater extraction/treatment system. Based on the RD investigation, EPA determined that the installation of a SVE system was infeasible.

Judge Weber of the Federal District Court in Cincinnati, Ohio, signed the Remedial Action Consent Decree (CD) for the final operable unit on April 2, 2001. The PRP group constructed the landfill cap and the GIS under the requirements of the CD. Construction began in April 2001.

Landfill Cap

The general profile of the cap from top down includes vegetative cover materials, geocomposite drainage layer, flexible geomembrane liner (FML) primary barrier layer, geosynthetic clay liner (GCL) secondary barrier layer, geocomposite gas venting layer and the prepared subgrade.

Site preparation included clearing and grubbing, preparing the GIS working platform, and removing portions of the fence. The PRPs used on-site borrow material to construct the south sidehill fill area and the landfill cap subgrade. The fill material was transported to the application areas by off-road dump trucks and applied to fill these areas in lifts with a bulldozer. The grade was maintained by using a laser and grade rod and staking grade levels in a grid layout. The grade was spot-checked with the grade rod throughout the application process and verified after completion by surveyors. The Construction Quality Assurance (CQA) consultant and the liner subcontractor inspected each section of subgrade to verify that the subgrade was acceptable for placement of the geomembrane panels.

The first geosynthetic layer above the subgrade is a geocomposite consisting of a HOPE geonet with a 6-ounce non-woven geotextile, which is heat bonded on both sides. The geocomposite layer is used for collecting landfill gas. It was installed with gas vent stubs, which allowed for ease of attachment of the gas vents prior to the installation of the overlying cap layers. The geosynthetic installation contractor manually installed the geocomposite layer. Installation of the geocomposite generally proceeded from a higher elevation to a lower elevation to minimize wrinkles. The geonet was overlapped at least four inches and affixed together with plastic ties, with the geotextile sewn together with hand-held sewing machines.

The secondary barrier layer, a GCL, serves as a backup barrier for the primary barrier. The GCL consists of a 0.75 pound per square foot bentonite clay layer bonded to a non-woven geotextile backing. The installation contractor unrolled the GCL and pulled it into place; it was overlapped at least six inches edge to edge and two feet end to end. Installation of the GCL was conducted in a manner that provided immediate coverage of the GCL by the Flexible Membrane Liner at the end of each working day to prevent hydration of the GCL.

The primary barrier of the landfill cap, the FML, consists of a 60 ml thick low linear density polyethylene FML textured on both sides. The FML was placed directly on top of the GCL immediately following installation of the GCL. The PRP's contractor completed the placement and seaming of the FML in a timely fashion to minimize weather exposure to the GCL. Field seaming the FML panels was the most critical phase of the landfill cap construction and required the most rigorous CQA documentation activities. All major seaming was performed using double-tracked fusion welders. Where fusion welding was not possible, such as at joints and around gas vents and piezometers, an extrusion weld was used. The CQA consultant tested both the fusion and extrusion welds by nondestructive test methods to ensure a completed seal.

After the CQA consultant determined that sections of the FML were of acceptable quality, the drainage layer was installed over the FML. The drainage layer is a geocomposite consisting of an HOPE geonet with a 6-ounce non-woven geotextile heat bonded to both sides (similar material as the geocomposite gas venting layer). The drainage layer was installed over the FML to serve two purposes: 1) the geonet facilitates drainage of water that infiltrates through the vegetative cover materials, and 2) the geocomposite affords protection for the liner system during placement of the vegetative cover materials.

A minimum of 24 inches of soil was placed over the geosynthetic materials. The PRPs' contractor used an excavator, which casts material out ahead of the leading edge of the cap soil so that no wrinkling developed in the liner/drainage system materials. The cap soil was then pushed with a low ground pressure (LGP) bulldozer over the in-place drainage layer. Grade was maintained using PVC tubes as grade stakes, so as not to harm the underlying liner materials. No LGP equipment was allowed to be on top of the cap material without a minimum thickness of 18 inches of soil. The CQA consultant required that there was always a minimum of 3 feet of soil beneath the excavator and dump trucks. To accomplish the minimum thickness requirements, temporary haul roads were installed to enable access to the location where filling occurred. After the application of the cap soil layer was complete, seeding and fertilizing was conducted with a hydro-seeder. Erosion matting was used on the slopes, and affixed in place with aluminum hooks to help hold the seed in place.

The PRPs achieved surface water drainage control for the site through the construction of a network of interceptor ditches, drainage letdowns, and culverts. The purpose of the controls is to manage surface water infiltration into the landfill, minimize landfill surface erosion, and direct infiltration away from known disposal areas.

Ten gas probes were constructed around the perimeter of the landfill to monitor landfill gas migration from the site.

Groundwater Interception System

The GIS was installed to intercept and capture groundwater migrating from the landfill to the East Fork of Mill Creek. The GIS consists of a single cutoff wall of soil-bentonite keyed into bedrock, three gravel-filled trenches each with a single groundwater extraction well, and a force main system to convey the groundwater to the Butler County sanitary sewer system. The groundwater is tested to make sure the contaminant levels in groundwater discharged to the sewer system are within the limits of the PRP's Industrial Discharge Permit from the Butler County Department of Environmental Services (BCDES) (see Attachment 3).

The cut-off wall consists of a soil-bentonite slurry mixture; it is capped with native clay to provide protection and a surface for site access. The wall extends from two to three feet below ground surface (bgs) to where it is keyed into the bedrock. The PRPs constructed the cut-off wall by excavating a trench using an extended boom excavator equipped with a 24-inch wide bucket with ripping teeth. The trench was constructed by excavating to bedrock (ranging from approximately 10 feet to 30 feet below grade) and placing the trench spoils to the side. Bentonite clay and water were mixed to create a slurry in a self-contained mixing plant. The bentonite slurry was mixed with the trench spoils to create a soil-bentonite slurry backfill. The bentonite slurry and trench spoils were mixed alongside the trench on the up-gradient (upstream) side. The PRPs reincorporated the majority of the trench spoils into the cut-off wall, with excess soils being used as subgrade for the landfill cap.

The PRPs installed the interceptor trench in three separate sections between the landfill and the cut-off wall. They created a vertical zone of high permeability gravel extending from two to three feet bgs to approximately four or five feet below the lowest significant sand/gravel seam. The interceptor trenches were generally installed parallel to the cut-off wall. Each trench was excavated to the specified depth (ranging from 14 to 23 feet below grade). The PRPs placed a bio-polymer slurry in the trench bottom prior to placing the geotextile and backfilling, in order to ensure the integrity of the excavation sidewalls. The slurry allowed for the placement of the geotextile, the granular material, and the observation well components. Prior to placement of the slurry, a geotextile filter fabric was installed along the bottom and sides of the trench. The geotextile fabric was overlapped four feet lengthwise to ensure complete coverage of the trench. The purpose of the geotextile is to filter out fines from the groundwater that may clog the extraction well pumps.

As backfill was placed around the interceptor trench, the PRPs installed extraction and observation wells in accordance with the design specifications. The groundwater extraction pumps were installed in the extraction well of each interceptor trench. The pumps consist of 4" diameter submersibles rated at 25 gallons per minute (gpm). The pumps' discharge is transported through a vertical discharge line that is connected to the force main. The force main consists of a 2-inch diameter HOPE pipe approximately 30 inches bgs extending from Extraction Well #1 to the Gravity Manhole, at which point it is discharged into the Butler County public sanitary sewer system.

Other Issues

Soils from two contaminated soil areas located outside the landfill area, but within the limits of the site, Area BP01/BP02 and Area GW-38, were excavated and moved to the on-site landfill and incorporated under the landfill cap. After excavation of these areas, the PRPs collected and analyzed confirmation soil samples from each location to ensure that all the contaminated soil was excavated.

Monitoring wells and piezometers were installed in and around the landfill to: 1) monitor the groundwater elevation under the cap to determine contact with buried waste, and 2) assess the long-term performance of the groundwater interception system (interception trench and cut-off wall) in accordance with the Long Term Performance Plan (LTPP) (part of operation and maintenance, O&M). During the remedial action (RA) construction activities, the PRPs installed nine new groundwater monitoring wells and one replacement groundwater well.

Twelve piezometers were installed, four of which are installed through the landfill cap in order to monitor whether the groundwater is in contact with landfill waste.

The remedy also restricts physical access to the site with a six-foot high fence with barbed wire at the top, around the entire site perimeter. The fence is sufficient to prevent the public from easily entering the site. The fence is posted with numerous visible warning signs to inform the public of potential site hazards.

Nearby residences located southwest of the site were connected to a public water supply in order to prevent these residents from potential exposure to contaminated groundwater.

The RA construction was completed at the site in September 2001. A Preliminary Close Out Report (PCOR) was completed on September 27, 2001.

In August 2007, Ohio EPA was notified via a complaint that assorted electronic waste (e-waste) was being stored in open containers along the southwestern portion of the fence surrounding the Skinner Landfill. Ohio EPA investigated the complaint and identified 78 one-cubic-yard cardboard containers of crushed computer glass and a roll-off container of assorted computer parts, including intact monitors and hard drives. The waste was being stored in an uncovered location and the weather was causing the containers to deteriorate rapidly.

Ohio EPA sampled the waste material and determined it to be hazardous waste based on its high lead content. In February 2008, Ohio EPA issued Notices of Violation to the waste generator and to Skinner Demolition requiring abatement of the illegal storage of hazardous waste. Neither party submitted a compliance plan to Ohio EPA. In March 2008, Ohio EPA requested assistance from EPA with the assessment, removal, and disposal of the hazardous waste.

EPA confirmed that the waste exceeded hazardous waste regulatory limits for lead. After both parties failed to submit a response to EPA's Notice of Liability, EPA initiated a time-critical removal of the hazardous waste. EPA and its contractors began the cleanup on June 9, 2008. Approximately 131 tons of hazardous waste, including crushed cathode ray tubes, e-waste, and contaminated soil were disposed of at the Michigan Disposal Waste Treatment Plant in Belleville, Michigan. EPA completed this removal action on June 11, 2008.

4.3 System Operations/Operation and Maintenance (O&M)

O&M activities are performed by Earth Tech/AECOM , a contractor for the PRP group. In addition, Butler County has personnel performing activities associated with O&M.

The groundwater extraction system consists of approximately 770 lineal feet of interceptor trench in three sections and 985 lineal feet of cut-off wall. Located at the low point of the three sections of the interceptor trenches are three extraction wells. Each of the three extraction wells has a submersible pump in it. The pump discharge is tied to a force main that transfers the groundwater from the wells to an existing sanitary sewer, and from there to the Butler County sewage treatment plant (Publicly Owned Treatment Works or POTW).

The pumps have three level controls, one for "pump on," one for "pump off," and one for high level "alarm." If a "pump on" signal is continuous for a predetermined amount of time, the off-site system operators are advised of this condition via an automatic alarm. Each pump is connected to a run timer that records the time a pump has been operating.

All of the pumps operate independently. They are connected to a main control panel, which is located at the west end of the GIS. The panel contains run indicator lights for the pumps as well as depth of water indicators in each extraction well with respect to the depth transducer. Additionally, the panel includes a telephone auto dialer that calls a minimum of four predetermined numbers in the event of an alarm situation. The auto dialer has prerecorded messages indicating the alarm condition and location. The system is designed to be monitored remotely, without the need for the routine presence of an operator.

The pumps, valves, settings of the pump control and alarm, flow measurement device, and continuous sampler are the primary components requiring maintenance on the GIS. During the first six months of operation, the O&M tasks related to the GIS, such as routine maintenance and calibrating the GIS equipment, were performed on a monthly basis. After the first 6 months, the O&M activities have been conducted on a quarterly basis.

The O&M plan provides for inspection and repair of the physical components of the site after closure. Maintenance activities for the final cap include mowing, earthwork activities to correct erosion and sedimentation problems, re-vegetation of disturbed or distressed areas, regrading in settlement areas as determined necessary, and localized repairs due to intrusion, vandalism, etc. The final cap is inspected quarterly for signs of damage. The O&M activities are planned to occur for 30 years after construction completion.

The LTPP provides the mechanism to ensure that the RA meets the long-term performance standards set forth in the ROD. Sampling and chemical analysis of groundwater, surface water, and the measurement of groundwater elevations have occurred as part of O&M activities since the RA was completed. A description of these field activities is provided below.

Groundwater Sampling Plan

A line of monitoring wells between the GIS alignment and the East Fork of Mill Creek aims to demonstrate that contaminated groundwater is not being discharged to Mill Creek. Earth Tech/AECOM collects quarterly groundwater samples from these 11 monitoring wells, known as the point of compliance. The samples are analyzed for the parameters shown in Attachment 4. However, the approved remedial design document provides that the PRPs may petition EPA and Ohio EPA to modify the parameter list and sampling frequency based on the results of groundwater monitoring conducted on a quarterly basis for two years after completion of the landfill cap and GIS.

Three monitoring wells installed during the RI are located outside the fenced area. Earth Tech/AECOM samples and tests these wells annually to monitor groundwater quality around the landfill. In addition, Earth Tech/AECOM records the measurements of water levels and the presence or absence of Dense Non Aqueous Phase Liquids (DNAPLs), dense organic chemicals that are not soluble in water, from all existing piezometers, monitoring wells and select gas probes. The measurements are used to evaluate the water table and to monitor for DNAPLs in the vicinity of the landfill cap and GIS.

Surface Water Monitoring Plan

Earth Tech/AECOM collects surface water samples for analysis from three monitoring points along the East Fork of Mill Creek and three run-off outfall locations. Monitoring points were chosen to allow impacts from site run-off to be evaluated. Water entering the site upgradient (uphill) of the landfill and water leaving the site are monitored. Also monitored are points where site water is discharged into streams and points downstream of these discharges. Earth Tech/AECOM collects these samples quarterly and analyzes them for the parameters shown in Attachment 4. The PRPs may petition EPA and Ohio EPA to modify the parameter list and sampling frequency based on the results of groundwater monitoring conducted on a quarterly basis for two years after completion of the landfill cap and GIS. The PRP group recently submitted a petition to EPA to modify the parameter list and sampling frequency. EPA anticipates making a decision on this petition in 2009.

Groundwater Waste Monitoring Plan (GWMP)

The GWMP provides a mechanism to evaluate whether the waste material underneath the cap is in contact with site groundwater and whether the landfill cap is affecting the groundwater elevations beneath the landfill. The plan provides for quarterly measurements of the groundwater elevation and flow direction for two years (subsequent to the RA completion) or until the groundwater data have stabilized for at least four consecutive quarters, whichever is longer. The points that have been measured under the GWMP are 12 piezometers, 15 monitoring wells, and 2 gas probes within and around the landfill cap.

This monitoring began in September 2001, which is the date that EPA approved the RA construction completion report. The data derived from the quarterly sampling events is used to evaluate whether or not the waste material underneath the cap is in contact with site groundwater. Earth Tech/AECOM implements this monitoring in conjunction with the quarterly groundwater sampling at the 11 monitoring wells that are the points of compliance. The data are used to assess the effectiveness of the GIS and the potential need to construct an upgradient slurry wall.

In 2006, it was necessary to replace four inoperable piezometers. Piezometers P-9 to P-12 were used to monitor groundwater levels beneath the landfill cap, with respect to whether groundwater is in contact with the bottom level of the waste. Subsurface settlement caused the original piezometers to warp, which restricted access to the groundwater level measurement probes. The former piezometers were replaced with Piezometers P-9R to P-12R, using a larger diameter stainless steel casing to minimize future constriction of the well casings.

The Corrective Action Work Plan for Piezometer Replacement was approved by EPA on May 23, 2006. The piezometer replacement took place between December 5, 2006, and January 22, 2007. The corrective measures were performed in accordance with the EPA-approved Work Plan, with the exception of the locations of piezometers P-9R and P-12R. The P-9R boring location was placed approximately 10 feet to the north of its proposed location, due to the inability to drill down more than approximately 7 feet bgs at the proposed original boring location. P-12R was installed 20 feet to the northeast of the proposed location, due to errors in the field measurement caused by the slope in topography at this location. P-10R and P-11R are located within 5 feet of the original proposed locations (see Figure 1). Since the original groundwater–waste monitoring piezometers were damaged and new piezometers had to be installed, EPA approved an extension of the monitoring period regarding the determination of whether an upgradient slurry wall is required at the site.

The RA consent decree provides that EPA will examine the data obtained through the GWMP. If EPA determines that the elevation of the groundwater is in contact with the waste material underneath the cap and may reasonably be expected to remain in contact with the waste material for an additional three years after completion of the two-year groundwater monitoring period, the PRP group will submit to EPA a plan and schedule to construct the upgradient groundwater slurry wall. After the installation of the new piezometers (Piezometers P-9R to P-12R) in 2006, two years of groundwater monitoring was completed in the fall of 2008. EPA expects to make a decision on the need for the upgradient slurry wall in 2009.

4.4 Institutional Controls

Institutional controls (ICs) are non-engineered instruments, such as administrative and legal controls, that help to minimize the potential for exposure to contamination and that protect the integrity of the remedy. ICs are required to assure long-term protectiveness for any areas which do not allow for unlimited use or unrestricted exposure. ICs are also required to maintain the integrity of the remedy. The 1993 ROD included the imposition of proprietary restrictions and other institutional controls to prevent the future development of the site and assure the integrity of the remedial action and prohibit the potable use of site groundwater.

Analysis of Existing ICs: On January 24, 2006, an environmental covenant for the site under the Ohio version of UECA was signed by the site owners and was recorded in Butler County on February 14, 2006 (see Attachment 5). The environmental covenant was intended to prevent the development and use of land within the site boundary, to assure the integrity of the landfill cap and other components of the remedial action, and to prevent the potable use of site groundwater. The environmental covenant implements the requirements set forth in the 1993 final ROD.

At the time the environmental covenant was implemented, EPA reviewed a site title commitment. For this five-year review, EPA re-analyzed this title commitment, along with a topographic map and a site survey that included the mapping of utility easements, to insure that existing easements would not impact the landfill cap and other remedy components. This analysis revealed that there were two easements identified in the 2005 title commitment that had not been shown on the site survey map. The PRPs have already agreed to obtain a current title commitment and redo the site survey map, which will be submitted to EPA for analysis. EPA will review the current title commitment and site survey map to ensure that the environmental covenant remains in place and is effective.

***Current compliance*:** Based on site inspections and interviews, EPA finds there is no evidence of a cap breach and the existing use is consistent with the objectives of the landfill cap and land use restrictions.

Long-Term Stewardship: Long-term protectiveness at the Site requires compliance with use restrictions to assure the remedy continues to function as intended. The regular inspections are provided for in the O&M plan, and constitute long-term stewardship at the site. However, the O&M plan does not provide for an annual certification to EPA that there is no existing land or resource use at the site that is inconsistent with the implemented environmental covenant. To assure proper maintenance and monitoring of effective ICs, long-term stewardship procedures will be reviewed and the O&M plan revised if needed. Additionally, use of a communications plan and use of a one-call system should be explored for long-term stewardship.

Table 2. Institutional Controls Summary Table

Media, Engineered Controls & Areas that Do Not Support UU/UE* @ Current Conditions	IC Objective	IC Instrument Implemented
RA Components such as wells, and Groundwater Interception System	Prohibits use of land underlying the site, and assures integrity of remedy components	Environmental Covenant
Landfill Cap	Prohibits use of land underlying the site, and assures integrity of landfill	Environmental Covenant
Groundwater-area that exceeds cleanup levels	Prohibits use of groundwater	Environmental Covenant

* unlimited use/unrestricted exposure

5.0 PROGRESS SINCE LAST FIVE-YEAR REVIEW

This is the third five-year review for the Skinner Landfill Site. The second five-year review was completed and signed in March 2004. The second five-year review protectiveness statement concluded the following: that the remedy is protective of human health and the environment in the short term; that there are no current exposure pathways and the remedy appears to be functioning as designed; that the landfill cap, the GIS, public water supply for nearby residents and groundwater monitoring have achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and prevent direct contact with, or ingestion of, contaminants in soils and sediments; and that long-term protectiveness of the remedial action will be achieved when cleanup goals are met. Issues during the 2004 review included the following:

- ICs need to be implemented

- Creek bank was eroded
- Site fence missing near eroded creek bank
- Water accumulation in vault box and inspection manhole
- The need for upgradient groundwater control must be evaluated
- Security measures: Site fence in disrepair in certain areas, allowing easy access to anyone wishing to trespass

The follow-up work to address the issues of the 2004 five-year review included:

- Environmental Covenant was recorded in Butler County on February 14, 2006
- Gabion (rock) wall was installed to eliminate creek bank erosion
- Site fence was added after gabion (rock) wall was completed
- 4-inch drain line was installed to allow water from Vault Box to drain back into GIS
- Groundwater elevations have been measured and reported quarterly. Four piezometers extending through cover system and waste became inoperable, and were replaced with stainless steel casings
- Periodic checks have been made for trespassers and fence has been repaired when necessary

Table 3 summarizes the issues, recommendations and follow-up actions from the 2004 five-year review.

Table 3. Issues, Recommendations and Follow-up Actions from 2004 Five-Year Review

Issues from 2004 Review	Recommendations/ Follow-up Actions	Party Responsible	Milestone Date	Action Taken and Outcome	Date of Action
Institutional controls need to be implemented	Implement ICs	PRPs	NA	Environmental Covenant was recorded in land records	Jan. 24, and Feb. 14, 2006
Creek bank eroded	Install gabion (rock) wall	PRPs	Spring 2004	Gabion wall installed	May 2004
Site fence missing near eroded bank	Install fence after creek bank stabilization	PRPs	Spring 2004	Fence installed	June 2004
Water accumulation in vault box and inspection manhole	Pump water out periodically	PRPs	As needed	Drain line installed	April 2006
Possible upgradient groundwater control	Quarterly measurements of groundwater elevations	PRPs	Fall 2005	Continued groundwater elevation measurements	Decision will be made in 2009
Security measures	Repair fence where needed and put up more warning signs where trespassing might occur	PRPs	Next 30 years	Fence has been repaired when necessary	ongoing

While the PRPs are responsible for implementing all recommended follow-up actions, all recommendations are completed under EPA and Ohio EPA oversight.

6.0 FIVE-YEAR REVIEW PROCESS

6.1 Administrative Components

The Skinner Landfill five-year review was prepared by Scott Hansen, EPA Remedial Project Manager for the Site. Chuck Mellon, State Project Manager with the Ohio EPA, also assisted in the review. This five-year review consisted of the following activities: a review of relevant documents (see Attachment 2); interview with government official and representatives of the construction and operations contractors; and a site inspection. The completed report will be available in the site information repository for public view.

6.2 Community Notification and Involvement

The completed third five-year review report and background data will be available in the site information repository and on the EPA website for public view. An advertisement notice regarding the five year-review process was placed in the Pulse-Journal newspaper for public review on January 15, 2009 (see Attachment 7). EPA received no public comments regarding the five-year review.

Community relations activities ongoing at the Site include reporting on the comprehensive operation and maintenance sampling program currently being carried out, to assure that human health and the environment continue to be protected.

6.3 Document Review

EPA personnel reviewed Skinner Landfill site documents in preparing this five-year review report. They include the following:

- Second Five-Year Review Report, March 2004
- RA Consent Decree, April 2001
- Record of Decision, June 1993
- Skinner Landfill Quarterly Monitoring reports, 2004-2008
- 2005 Title Commitment, Site Survey, and Site Topographic Map

6.4 Data Review

Groundwater monitoring has been occurring at this site since August 2003. The Quarterly Groundwater Monitoring reports, March 2004 – September 2008, were the comprehensive reports that EPA reviewed as part of this five-year review. These reports include the most recent results from the site groundwater monitoring wells, along with groundwater elevation data.

The PRP conducted quarterly sampling from 2003 to the present. Samples are analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs) and metals. Several metals (arsenic, selenium, chromium, mercury, cyanide) and one VOC (benzene) were detected above trigger levels at various groundwater sample locations; however, the quarterly analytical results before and after the detections were either below the trigger levels or non-detect. Attachment 10 includes the groundwater test results summaries. Several metals (arsenic, chromium, and zinc) and SVOCs (fluoranthene, naphthalene, phenanthrene, and phenol) were detected above trigger levels at various surface water sample locations; however, the quarterly analytical results before and after the detections were either below the trigger levels or non-detect. Attachment 9 includes the surface water test results summaries. Based on the quarterly baseline sample results (October 2001 – August 2003), the quarterly monitoring results from 2003 to 2008 indicate that the target compounds (Attachment 4) have declined or remained stable. Since the installation of the new piezometers, the groundwater elevations under the landfill cap indicate that groundwater levels have dropped below the buried waste at piezometer P-12R. Attachment 8 includes the groundwater-waste monitoring summary.

Landfill cap maintenance involves the inspection and repair of any soil burrowing or erosion locations, and mowing of the landfill surface as needed.

The PRP group has an Industrial Discharge permit with BCDES to discharge groundwater to the Butler County sewer system. Sampling of the effluent from the GIS is part of the conditions required by the BCDES discharge permit (see Attachment 3). Historically the discharge has been in compliance with the permit.

6.5 Site Inspection

The inspection at the site was conducted on January 29, 2009, by Scott Hansen, EPA, and Alex Maginnis and Ron Roelker, Earth Tech/AECOM. The purpose of the inspection was to assess the protectiveness of the remedy, including the presence of fencing to restrict access, the integrity of the landfill cap, and the general conditions of the GIS and monitoring wells.

The inspectors walked around the surface of the landfill. Site access is available through locked gates which enclose the site landfill and other components of the remedy (GIS, monitoring wells). The Site Inspection Checklist is in Attachment 6. The landfill cap over most of the site was covered with about 6 to 8 inches of snow so it was difficult to determine whether the cap was in good condition.

The only issue found during the five-year review site inspection was that the fence needs minor repairs.

6.6 Interviews

The following individuals were contacted by telephone as part of the five-year review:

- Ron Roelker, Earth Tech/AECOM, PRP contractor (Interviewed January 2009)
- Chuck Mellon, Ohio EPA, project manager (Interviewed January 2009)

Mr. Roelker and Mr. Mellon stated that there are no serious issues related to the site. They also stated that community interest about the site remains low. As discussed in Section 4.2 of this report, in 2007, Ohio EPA was contacted about waste being left on the site. Chuck Mellon subsequently conducted a site inspection and informed EPA that waste was being illegally stored at the site, and EPA conducted a removal action in June 2008. Mr. Roelker confirmed that no changes in land use are planned for the site, and that institutional controls are in place.

7.0 TECHNICAL ASSESSMENT

7.1 Question A: Is the remedy functioning as intended by the decision documents? Yes

RA Performance: The remedies selected in the 1992 ROD for the first operable unit interim action and the 1993 final ROD have been implemented and remain functional, operational and effective. As long as the site hazardous waste cap and GIS continue to be maintained and monitored, and the security perimeter fence is maintained, the source area remedies will ensure that the site remains protective.

Cost of System Operations/O&M: Current annual O&M costs are not available since the PRPs conduct the O&M. The 1993 ROD estimated the annual O&M costs would be approximately $397,000.

Opportunities for Optimization: Given the adequate performance of the remedy at the site, this five-year review does not identify a need for optimization at this time.

Early Indicators of Potential Remedy Failure: No early indicators of potential remedy failure were noted during the review. Based on the quarterly baseline sample results (October 2001 – August 2003), the quarterly monitoring results from 2003 to 2008 indicate that the target compounds (Attachment 4) have declined or remained stable. Maintenance activities have been consistent with expectations.

Implementation of Institutional Controls and Other Measures: The 1993 ROD remedy included the implementation of proprietary restrictions and other institutional controls to prevent future development of the site, assure the integrity of the remedial action, and prohibit the use of site groundwater as a drinking water source. These restrictions were required to protect the integrity of the landfill cap, the GIS, and all other components of the RA. On February 14, 2006, an environmental covenant, under the Ohio version of the UECA, was recorded in the land records for the site. The environmental covenant implements the ROD requirements.

EPA reviewed a title commitment before the environmental covenant was recorded in 2006. As part of this five-year review, the PRPs have agreed to obtain a current title commitment and to redo the site survey map, which will be submitted to EPA for analysis. EPA will review the current title commitment and site survey map to ensure that the environmental covenant remains in place and is effective.

7.2 Question B: Are the assumptions used at the time of remedy selection still valid? Yes

Changes in Standards and To Be Considered: Requirements contained in environmental laws and regulations, which were outlined in the 1993 ROD and the 2004 Five-Year Review Report, are still valid at the Skinner Landfill site.

Changes in Exposure Pathways: No changes in the site conditions that affect human or environmental exposure to contaminants were identified as part of the five-year review. There are no current or known planned changes in the site land use.

Changes in Risk Assessment Methodologies: Changes in risk assessment methodologies since the second five-year review are not significant and do not call into question the protectiveness of the remedy.

7.3 Question C: Has any other information come to light that could call into question the protectiveness of the remedy? No

No other events have affected the protectiveness of the remedy and there is no other information that calls into question the short-term and long-term protectiveness of the remedy.

Technical Assessment Summary

According to the data reviewed and the site inspection, the remedy, including the recorded site environmental covenant, is functioning as intended by the 1993 ROD. There have been no changes in the physical conditions of the site, clean-up standards, contaminant toxicity or exposure pathways that would affect the protectiveness of the remedy. No additional information has been identified that would call into question the protectiveness of the remedy.

8.0 ISSUES

The following issue was identified during the five-year review site inspection but does not impact the protectiveness of the remedy:

- The site fence needs minor repairs

The following issues were identified during the five-year review process and could impact the protectiveness of the remedy as indicated in Table 4.

- Security measures (site fence repair and control illegal dumping)
- The need for upgradient groundwater control must be evaluated

- Institutional controls: Location of some existing easements and their relationship to remedy components is unknown
- Institutional controls: Ensure long-term stewardship

Table 4. Issues that Impact Protectiveness

Issue	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
Security measures	N	Y
Upgradient groundwater control	N	Y
Institutional controls: Location of some existing easements and their relationship to remedy components is unknown	N	Y
Institutional controls: Ensure Long-term stewarship.	N	Y

Y=yes; N=no

9.0 RECOMMENDATIONS AND FOLLOW-UP ACTIONS

Table 5. Recommendations and Follow-up Actions

Issue	Recommendations/ Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness (Y/N)	
					Current	Future
Security measures	Repair fence where needed and control illegal dumping	PRPs	EPA	As needed	N	Y
Upgradient groundwater control	Continued quarterly measurements of groundwater elevations	PRPs	EPA	September 2009	N	Y
Institutional controls: Location of some existing easements and their relationship to remedy components is unknown	Update title commitment and site survey map; check all easements of record to make sure there is no interference with site remedy components	PRPs will obtain title commitment and updated site survey map	EPA	September 2009	N	Y
Institutional controls: Ensure long-term stewarship	Review long-term stewardship procedures and update if necessary.	PRPs	EPA	March 2010	N	Y

Y=yes; N=no

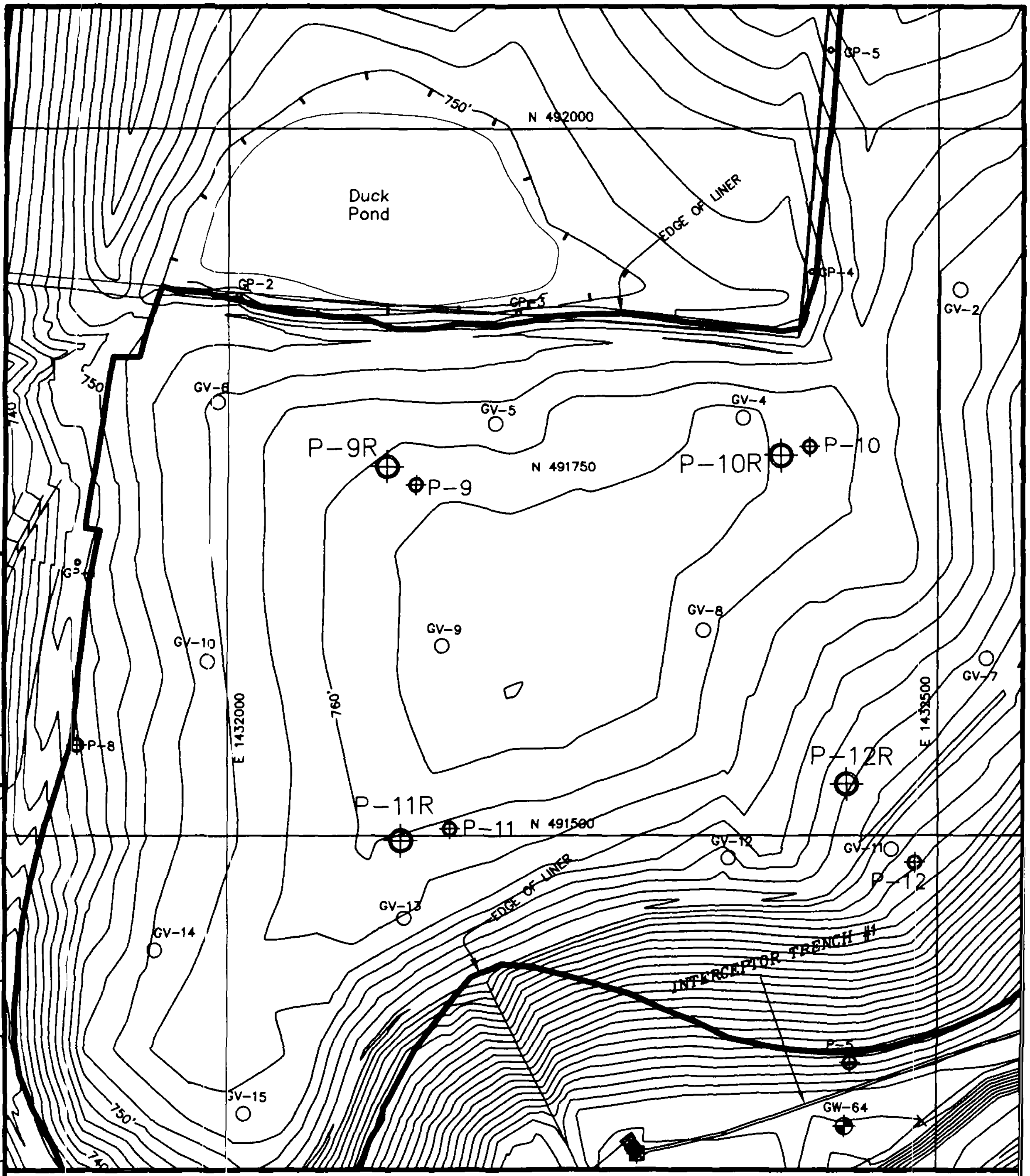
10.0 PROTECTIVENESS STATEMENT(S)

The assessment of this five-year review found that the remedy at the Skinner Landfill Superfund site is protective of human health and the environment. There are no current exposure pathways and the remedy appears to be functioning as designed. The landfill cap, the GIS and the connection of nearby residents to the public water supply eliminate the source of contamination and have achieved the remedial objectives to minimize the migration of contaminants to groundwater and surface water and to prevent direct contact with, or ingestion of, contaminants in soils and sediments. Institutional controls, in the form of an environmental covenant under the Ohio version of the Uniform Environmental Covenants Act, have been implemented to protect the remedy components, and to protect against improper use of site land and groundwater resources. Compliance with effective ICs will be ensured through long-term stewardship by implementing, maintaining, monitoring and enforcing effective ICs as well as maintaining the site remedy components.

11.0 NEXT REVIEW

EPA performs statutory reviews on remedies selected that result in hazardous substances, pollutants or contaminants remaining at sites above levels that allow for unlimited use and unrestricted exposure. Since hazardous substances, pollutants or contaminants are contained at the site and will potentially remain above EPA and State of Ohio regulatory standards in the future, the Skinner Landfill Site will require ongoing Five-Year Reviews. Therefore, another report is scheduled to be completed in 2014, five years after the current five-year review. The completion date of the current five-year review is the signature date shown on the cover attached to the front of this report.

FIGURES



REPLACEMENT PIEZOMETER LOCATION MAP

SKINNER LANDFILL
BUTLER COUNTY, OHIO

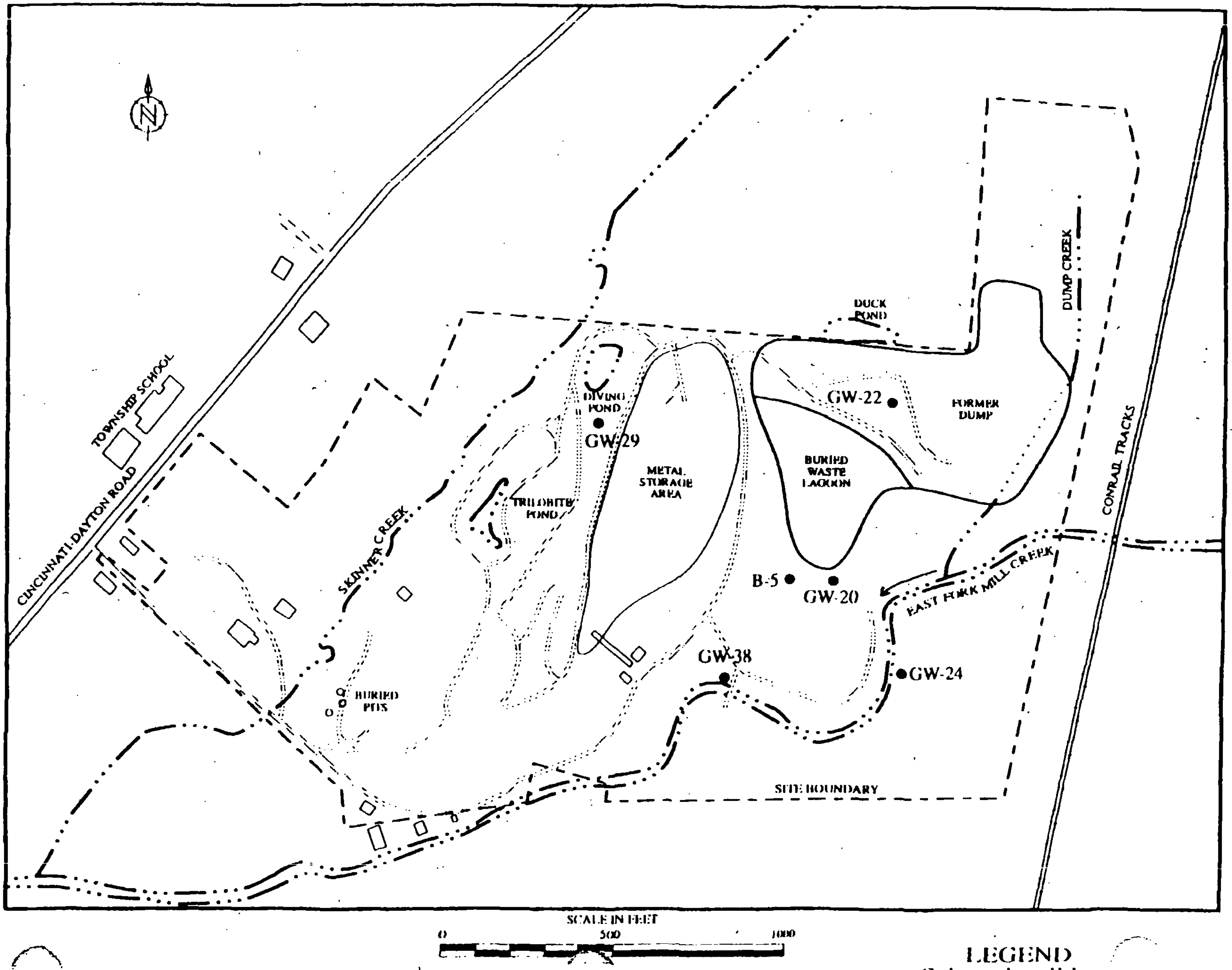
FIGURE 1

EarthTech
A tyco International Ltd. Company

03-01-2007 54280\PZ Replacement\Corrective Action Completion Report - Piezometer Replacement\Figure1-ReplacementPiezometerLocations.dwg

ATTACHMENT 1

Attachment 1: Skinner Site Map



LEGEND
● Selected well loca
as referred to in text

ATTACHMENT 2

List of Skinner Landfill Site Documents Reviewed for Five-Year Review Report

- Second Five-Year Review Report, March 2004
- RA Consent Decree, April 2001
- Record of Decision, June 1993
- Skinner Landfill Quarterly Monitoring reports, 2004-2008
- 2005 Title Commitment, Site Survey, and Site Topographic Map

ATTACHMENT 3

Butler County Department of Environmental Services

Water • Wastewater • Solid Waste • Recycling & Litter Prevention

Commissioners:
Courtney E. Combs
Charles R. Furmon
Michael A. Fox

SPECIAL WASTEWATER DISCHARGE PERMIT

March 17, 2003

The Skinner Landfill Site Work Group
c/o The Dow Chemical Company
Attn: Ben Baker
Remediation Leader
The Dow Chemical Company
4520 E. Ashman
Midland, MI 48674

Re: Skinner Landfill Consent Decree
Permit # 150-01
Permit Fee $200.00
Effective Date: 3/11/2003
Expiration Date: 9/30/2003

In accordance with the provisions of the agreement reached with Butler County Department of Environmental Services (hereafter "BCDES") in May 1996, this Special Wastewater Discharge Permit is hereby granted to The Skinner Landfill Site Work Group, c/o The Dow Chemical Company Attn: Ben Baker Remediation Leader 4520 E. Ashman Midland, Michigan 48674 (hereafter called "Permittee") on this 17th day of March, 2003. **This permit supersedes the permit originally issued on 03/11/2003, and is retroactive to 03/11/2003.** Permittee is authorized to discharge into the Butler County Sewer System in a manner approved by BCDES under the following conditions of this draft permit:

BCDES has agreed to accept the groundwater discharge from Skinner Landfill Site, only based on the understanding that a Special Discharge Permit would be issued by BCDES with site-specific conditions for connection, monitoring, compliance, and user fees. BCDES proposes to handle this discharge in a unique way because (a) groundwater is a prohibited discharge according to the BCDES Sewer Use Rules (hereafter "Rules"), (b) the pollutant concentrations and flows may fluctuate and (c) there is no control or pretreatment system in place. This Draft Special Discharge Permit will be subject to a 14 day public notification process prior to consideration by the Butler County Board of Commissioners.

The permit shall contain special conditions of the discharge and shall expire on September 30, 2003. Subsequent permits shall be effective for up to five (5) years. BCDES will use the sampling vault to collect flow proportional samples. Grab samples will be obtained from the next downstream manhole from the sampling vault. The discharge will have a flow monitoring system. BCDES requires all dischargers to execute a flow monitoring agreement and have an effective O&M and calibration program in place so that BCDES is assured reliable flow data.

The monthly usage fee shall be established at 200% of the standard discharge fee/1000 gallons based on the potentially hazardous content of the waste.

Except as provided in this Special Permit, Permittee shall at all times remain subject to all provisions of the Rules. This Permit does not constitute a waiver by BCDES or the Board of County Commissioners of the right to seek any lawful remedy or penalty for any such violation of this Permit or Rules.

Section 9.6A of the Rules provides that any person who violates a permit condition is subject to a civil penalty in an amount not to exceed $10,000.00 per day of such violation (Section 9.6A). Consequently, should Permittee violate this Special Wastewater Discharge Permit or any Rule, the County, acting through its Director of BCDES, shall have the authority to assess civil penalties of up to $10,000.00 per violation per day. A violation of this permit is subject to such penalties as may be provided by law.

In addition to civil and criminal liability, the Permittee violating this permit, or causing damage to or otherwise materially inhibiting the Upper Mill Creek wastewater disposal system shall be liable to the BCDES for any expense, loss, or damage caused by such violation or discharge. The BCDES shall bill the Permittee for the costs incurred by the BCDES for any cleaning, repair, or replacement work caused by the violation or discharge. Refusal to pay the assessed costs shall constitute a separate violation of Section 9.6B of the Rules.

This permit may be modified by agreement of the Permittee and BCDES in accordance with provisions of the Rules or as lawfully required by the United States EPA, Ohio EPA or agencies thereof. Should BCDES and Permittee be unable to come to terms on a modification of this Permit, BCDES may cancel any remaining term of this Permit upon 180 days notice to Permittee.

Failure on the part of the Permittee to fulfill any of the specified conditions may be sufficient cause for immediate revocation of this permit per Section 5.7 of the Rules. This permit is further subject to termination upon thirty (30) days written notice to the Permittee by an authorized representative of BCDES.

It is the responsibility of the Permittee to submit to an Application for Special Wastewater Discharge Permit to BCDES at least ninety (90) days prior to the expiration date of this permit.

This permit may be assigned or transferred to another discharger per provisions of Section 5.6 of the Rules, which require approval of the Director. Such assignment will not be unreasonably withheld. Notice of changes in the point of discharge, in the number or location of extraction points or other changes that may impact the quality or quantity of the effluent must be provided to and acceptable to BCDES per Section 6.5 of the Rules.

Incidental discharges resultant from monitoring, and/or operation and maintenance of the Skinner Landfill Site as of the effective date of the Special Permit Issuance may be accepted upon notification to BCDES per the Rules.

James A. Parrott

James A. Parrott
Director

SPECIAL PERMIT CONDITIONS

1) Except as otherwise provided in this Special Permit, the Permittee shall comply with the Rules and with the U.S. v Skinner Consent Decree. Where inconsistency exists between the Rules and the Consent Decree, an understanding shall be reached between BCDES and Permittee, with court approval where necessary, as to the terms of this Special Permit before discharges are accepted. In the event of a dispute between the Permittee and BCDES after the Permit is granted, the parties agree to attempt to resolve the dispute first through mediation using a mediator acceptable to both parties, and including U.S. EPA in the mediation if requested by the Permittee.

2) The Permittee shall allow BCDES personnel, upon presentation of their credentials or other documents as may be required by law, to: enter the Skinner Site premises and have access to, inspect, and copy, at reasonable times, any records located at any facility that are deemed necessary by such personnel to determine Permittee's compliance with this Permit. Permittee shall have the right to claim business confidentiality, trade secret, or privileges recognized by state or federal law on the face of any document sought to be copied by BCDES personnel. Should any other person attempt, under the Ohio Public Records Law, to obtain a copy of material from BCDES which Permittee claims to be protected from disclosure, BCDES shall notify Permittee of the request and allow Permittee to defend its claim of entitlement to exclusion before a judge of the Butler County Court of Common Pleas and no material shall be released except in accordance with the final ruling of an Ohio court upon the question. The Permittee shall allow BCDES personnel to inspect at reasonable times any facilities, equipment, practices, or operations regulated or required under this permit; BCDES may sample or monitor, for the purposes of assuring permit compliance, any relevant substances or parameters at any location; and inspect any storage area where pollutants, regulated under this permit, could originate, be stored, or be discharged to the sewer system. Should BCDES be denied access to records it seeks to determine compliance with the terms and conditions of this Permit, then a responsible official of the Permittee shall provide BCDES with an affidavit attesting to Permittee's full and complete compliance with the terms of this Permit under penalty of perjury. Should BCDES be denied access to information it seeks or be denied an acceptable affidavit in lieu of access, BCDES may terminate this Permit upon thirty (30) days prior notice to Permittee.

3) BCDES will conduct regular discharge monitoring to determine that constituents in the effluent from Skinner Landfill Site do not exceed local limits or site-specific limits or pose a threat to the wastewater treatment facility, the collection system, County employees or the receiving stream. The inorganic and organic discharges shall not be in excess of local or site specific limits (see attached maximum discharge limit chart). Should sampling indicate violations of these limits, BCDES reserves the right to suspend the discharge and/or require pretreatment prior to accepting additional flow.

4) Due to the nature and source of the discharge, BCDES will aggressively monitor local limit parameters until the County feels that it has representative data, at which time a normal schedule may be adopted of monthly local limits monitoring. However, BCDES has the right to sample, with or without notice, as frequently as it determines necessary. The costs associated with sampling will be billed back to the discharger along with any surcharge fees associated with high strength acceptable waste. Any prohibited waste in excess of site specific limits will be subject to the enforcement provisions of the Rules and the Enforcement Response Plan. BCDES understands that seasonal variations may have an impact on water quality parameters, and we want to be assured that the concentrations we are given are within the Publicly Owned Treatment Works (POTW's) ability to safely handle.

5) The Permittee shall report to the BCDES any significant changes in location, operational conditions, the quality or quantity of discharges or chemical storage procedures as provided in Section 6.5 of the Rules.

6) The Permittee shall notify the BCDES immediately after Permittee's knowledge of the occurrence of an accidental discharge of substances or slug loads or spills that may enter the public sewer. BCDES should be notified by telephone at (513) 887-3686.

The notification shall include location of discharge, date and time thereof, type of waste, including concentration and estimated volume, and corrective actions taken (Section 6.6A). The Permittee's notification of accidental releases in accordance with this section does not relieve it of other reporting requirements that arise under local, State, or Federal laws or the U.S. v Skinner Consent Decree.

Within 5 days of the verbal notification of a discharge, a complete written report must be submitted detailing the quantity and quality of discharge, reason for discharge, and steps taken to prevent further occurrences.

7) The Permittee shall keep on file at a location of Permittee's choosing, all records, documents, reports, and correspondence pertaining to effluent monitoring, sampling, and chemical analysis made by or prepared for the Permittee. Said records, reports, documents and correspondence shall be kept on file for a minimum of three (3) years.

8) Particular attention should be given to the following: (Note: This section will be utilized to reflect the categorical standards and limits (40 CFR 433) if applicable).

(a) From effective date of the permit through September 30, 2003, the Permittee's effluent wastewater discharged to the County Sewer System shall not exceed the following limits based on flow rates provided in the application.

BCDES Special Permit Limits for Skinner Landfill Site

Skinner Landfill Applicable Parameters	Applicable Limit	Allowable Mass Loading Limits[1] (lbs/day)
TTO	Site Specific	0.53
Arsenic	Local Limit	0.04
Cadmium	Local Limit	0.02
Chromium, Total	Local Limit	0.88
Chromium, Hexavalent	Local Limit	0.13
Copper	Local Limit	0.35
Lead	Local Limit	0.13
Mercury	Local Limit	<0.00009
Molybdenum	Local Limit	0.17
Nickel	Local Limit	0.31
Selenium	Local Limit	0.03
Silver	Local Limit	0.01
Cyanide, Total	Local Limit	0.03
Zinc	Local Limit	0.25
Ammonia	Local Limit	9.17
BOD_5	Local Limit	366.96
COD	Local Limit	917.40
Oil & Grease	Local Limit	18.35
TSS	Local Limit	229.35

(1) Based upon 11,000 gallons per day discharge rate. The method detection limit (MDL) for mercury is 0.2 ug/l. Ohio EPA defined practical quantification limit (PQL) is 5 times the MDL. To determine compliance with this permit, results below the mdl will be reported as BDL. Results between the MDL and the PQL shall be reported as an analytical result.

9) The conditions for renewal of the permit will be that 90 days prior to expiration of the permit, the Permittee shall provide a analysis of the discharge, including operational schedule and anticipated flows, concentrations and an evaluation of the discharge needs for the following 4 years. Additionally, any anticipated significant operational changes shall be reported at any time there is an anticipated significant change during the course of the agreement.

10) The Permittee must verbally notify BCDES within 24 hours of becoming aware of any violation found in any self-monitoring. BCDES will require the Permittee to re-sample every 30 days until the Permittee's discharge is in compliance with limits established in this permit. In addition, the Permittee must submit all effluent and monitoring well data collected in accordance with the self-monitoring requirements in 40 CFR Part 136 (as applicable) or the analytical requirements approved by U.S. EPA pursuant to the U.S. v. Skinner Consent Decree, as appropriate. This includes any samples the County may split with the Permittee.

11) This permit allows discharge of up to 324,000 gallons per month from the Skinner Landfill Site. Flows greater than 324,000 gallons per month will be assessed peaking surcharges as established in the County's Sewer Rate Resolution 02-1-103, or any subsequent rate schedule. Additionally, due to the nature of this special discharge, any peaking charges are subject to be billed at the 200% standard discharge fee that is established this Special Permit.

Should additional flow need to be discharged from the Skinner Landfill Site, then a letter requesting allocation of additional capacity will need to be sent to the Director. Since groundwater is a prohibited flow except as provided by this Special Permit, then separate approval and agreement will be needed regarding additional ERU allocation.

12) BCDES may make an additional 23 ERUs ("Additional ERU") available for Permitee's use with the understanding that the charges for the 23 ERUs will be paid by Permittee at the rate currently in effect at the time of purchase. It is also required that Permittee will surrender to BCDES one or more Additional ERU(s) assigned to Permittee when the groundwater flow from the Skinner Landfill Site decreases such that each Additional ERU/capacity allocation is no longer needed by Permittee. An Additional ERU will be deemed to be no longer needed after a period of two (2) years in which the peak flow in any one month does not exceed 110% of the additional assigned capacity. For example, if the peak monthly flow in 2004 is 450,000 gallons, then each Additional ERU in excess of that needed for the 495,000 gallon capacity allocation would be considered to be an Additional ERU to be surrendered in 2006. For the purposes of determining the surrender of an Additional ERU, a review will be conducted by BCDES and Permittee in January of each year with a surrender of an Additional ERU, if any, to occur in January two (2) years later. Should data during the intervening two (2) years indicate Permittee's need for the Additional ERU, then a letter requesting deferral of the surrender will be submitted to BCDES. Consent for such deferral will not be unreasonably withheld by BCDES. Notwithstanding the ERU review example provided above, at no time shall the Additional ERU review require the Skinner Landfill Site to surrender any of the original 27 ERUs (324,000 gallons per month) authorized under this permit.

ATTACHMENT 4

TABLE 7

TARGET COMPOUND LIST

		Quantitation Limits (1)
Volatiles	CAS Number	Water (ug/L)
1. Chloromethane	74-87-3	1.0
2. Bromomethane	74-83-9	1.0
3. Vinyl Chloride	75-01-4	1.0
4. Chloroethane	75-00-3	1.0
5. Methylene Chloride	75-09-2	1.0
6. Acetone	67-64-1	1.0
7. Carbon Disulfide	75-15-0	1.0
8. 1,1-Dichloroethene	75-35-4	1.0
9. 1,1-Dichloroethane	75-35-3	1.0
10. 1,2-Dichloroethane (total)	540-59-0	1.0
11. Chloroform	67-66-3	1.0
12. 1,2-Dichloroethane	107-06-2	1.0
13. 2-Butanone	78-93-3	1.0
14. 1,1,1-Trichloroethane	71-55-6	1.0
15. Carbon Tetrachloride	56-23-5	1.0
16. Bromodichloromethane	75-27-4	1.0
17. 1,2-Dichloropropane	78-87-5	1.0
18. cis-1,3-Dichloropropene	10061-01-5	1.0
19. Trichloroethene	79-01-6	1.0
20. Dibromochloromethane	124-48-1	1.0
21. 1,1,2-Trichloroethane	79-00-5	1.0
22. Benzene	71-43-2	1.0
23. trans-1,3-Dichloropropene	10061-02-6	1.0
24. Bromoform	75-25-2	1.0
25. 4-Methyl-2-pentanone	108-10-1	1.0
26. 2-Hexanone	591-78-6	1.0
27. Tetrachloroethene	127-18-4	1.0
28. Toluene	108-88-3	1.0
29. 1,1,2,2-Tetrachloroethane	79-34-5	1.0
30. Chlorobenzene	108-90-7	1.0
31. Ethyl benzene	100-41-4	1.0
32. Styrene	100-42-5	1.0
33. Xylenes (total)	1330-20-7	1.0

TABLE 7 (cont.)

TARGET COMPOUND LIST

		Quantitation Limits (1)	
Semi-volatiles (2, 3)	CAS Number	Water (ug/L)	Soil/Sediment (mg/kg)
34. Phenol	108-95-2	10	330
35. bis(2-Chloroethyl) ether	111-44-4	10	330
36. 2-Chlorophenol	95-57-8	10	330
37. 1,3-Dichlorobenzene	541-73-1	10	330
38. 1,4-Dichlorobenzene	106-46-7	10	330
39. 1,2-Dichlorobenzene	95-50-1	10	330
40. 2-Methylphenol	95-48-7	10	330
41. 2,2'-oxybis-(1-Chlororpropane)#	108-60-1	10	330
42. 4-Methylphenol	106-44-5	10	330
43. N-Nitroso-di-n-dipropylamine	621-64-7	10	330
44. Hexachloroethane	67-72-1	10	330
45. Nitrobenzene	98-95-3	10	330
46. Isophorone	78-59-1	10	330
47. 2-Nitrophenol	88-75-5	10	330
48. 2,4-Dimethylphenol	105-67-9	10	333
49. bis(2-Chloroethoxy) methane	111-91-1	10	330
50. 2,4-Dichlorophenol	120-83-2	10	330
51. 1,2,4-Trichlorobenzene	120-82-1	10	330
52. Naphthalene	91-20-3	10	330
53. 4-Chloroaniline	106-47-8	10	330
54. Hexachlorobutadiene	87-68-3	10	330
55. 4-Chloro-3-methyphenol	59-50-7	10	330
56. 2-Methylynaphthalene	91-57-6	10	330
57. Hexachlorocyclopentadiene	77-47-4	10	330
58. 2,4,6-Trichlorophenol	88-06-2	10	330
59. 2,4,5-Trichlorophenol	95-95-4	25	800
60. 2-Chloronaphthalene	91-58-7	10	330
61. 2-Nitroaniline	88-74-4	25	800
62. Dimethylphthalate	131-11-3	10	330
63. Acenaphthlene	208-96-8	10	330
64. 2,6-Dinitrotoluene	606-20-2	10	330
65. 3-Nitroaniline	99-09-2	50	800
66. Acenaphthene	83-32-9	10	330
67. 2,4-Dinitrophenol	51-28-5	25	800
68. 4-Nitrophenol	100-02-7	25	800
69. Dibenzofuran	132-64-9	10	330
70. 2,4-Dinitrotoluene	121-14-2	10	330
71. Diethylphthalate	84-66-2	10	330
72. 4-Chlorophenyl-phenyl ether	7005-72-3	10	330
73. Fluorene	86-73-7	10	330

TABLE 7 – (Cont.)

TARGET COMPOUND LIST

		Quantitation Limits (1)	
Semi-volatiles (2, 3)	CAS Number	Water (ug/L)	Soil/Sediment (mg/kg)
74. 4-Nitroaniline	100-01-6	25	800
75. 4,6-Dinitro-2-methylphenol	534-52-1	25	800
76. N-Nitrosodiphenylamine	86-30-6	10	330
77. 4-Bromophenyl-phenyl ether	101-55-3	10	330
78. Hexachlorobenzene	118-74-1	10	330
79. Pentachlorophenol	87-86-5	25	800
80. Phenanthrene	85-01-8	10	330
81. Anthracene	120-12-7	10	330
82. Carbazole	86-74-8	10	330
83. Di-n-butyl phthalate	86-74-2	10	330
84. Fluoranthene	206-44-0	10	330
85. Pyrene	129-00-0	10	330
86. Butyl benzyl phthalate	85-68-7	10	330
87. 3,3'-Dichlorobenzidine	91-94-1	10	330
88. Benz(a)anthracene	56-55-3	10	333
89. Chrysene	218-01-9	10	330
90. bis(2-Ethylhexyl)phthalate	117-81-7	10	330
91. Di-n-Octylphthalate	117-84-0	10	330
92. Benzo(b)fluoranthene	205-99-2	10	330
93. Benzo(k)fluoranthene	207-08-9	10	330
94. Benzo(a)pyrene	50-32-8	10	330
95. Indeno(1,2,3-cd)pyrene	193-39-5	10	330
96. Dibenzo(a,h)anthracene	53-70-3	10	330
97. Benzo(g,h,i)perylene	191-24-2	10	330

\# Previously known by the name bis(2-Chloroisopropyl) ether

(1) Quantitation Limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, as required by the protocol, will be higher.

TABLE 7 (cont.)

TARGET COMPOUND LIST

		Quantitation Limits (1)	
Pesticides/Aroclors	CAS Number	Water (ug/L)	Soil/Sediment (mg/kg)
98. alpha-BHC	319-84-6	0.05	1.7
99. beta-BHC	319-85-7	0.05	1.7
100. delta-BHC	319-86-8	0.05	1.7
101. gamma-BHC (Lindane)	58-89-9	0.05	1.7
102. Heptachlor	76-44-8	0.05	1.7
103. Aldrin	309-00-2	0.05	1.7
104. Heptachlor epoxide	1024-57-3	0.05	1.7
105. Endosulfan I	959-98-8	0.05	1.7
106. Dieldrin	60-57-1	0.10	3.3
107. 4,4'-DDE	72-55-9	0.10	3.3
108. Endrin	72-20-8	0.10	3.3
109. Endosulfan II	33213-65-9	0.10	3.3
110. 4,4'-DDD	72-54-8	0.10	3.3
111. Endosulfan sulfate	1031-07-8	0.10	3.3
112. 4,4'-DDT	50-29-3	0.10	3.3
113. Methoxychlor	72-43-5	0.50	17.0
114. Endrin ketone	53494-70-5	0.10	3.3
115. Endrin aldehyde	7421-36-3	0.10	3.3
116. alpha-Chlordane	5103-71-9	0.05	1.7
117. gamma-Chlordane	5103-74-2	0.05	1.7
118. Toxaphene	8001-35-2	5.0	170.0
119. AROCLOR-1016	12674-11-2	1.0	33.0
120. AROCLOR-1221	11104-28-2	0.5	67.0
121. AROCLOR-1232	11141-16-5	0.5	33.0
122. AROCLOR-1242	53469-21-9	1.0	33.0
123. AROCLOR-1248	12672-29-6	1.0	33.0
124. AROCLOR-1254	11097-69-1	1.0	33.0
125. AROCLOR-1260	11096-82-5	1.0	33.0

(1) Quantitation Limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, as required by the protocol, will be higher.

TABLE 8

TARGET ANALYTE LIST

Analyte	Contract Required (1, 2, 3) Detection Limit (ug/L)
Aluminum	200
Antimony	60
Arsenic	10
Barium	200
Beryllium	5
Cadmium	5
Calcium	5000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Lead	3
Magnesium	5000
Manganese	15
Mercury	0.2
Nickel	40
Potassium	5000
Selenium	5
Silver	10
Sodium	5000
Thallium	10
Vanadium	50
Zinc	20
Cyanide	10

(1) Higher detection limits may only be used if the sample concentration exceeds five times the detection limit of the instrument or method in use. The value may be reported even though the instrument or method detection limit may not equal the CRQL. This is illustrated in the example where the value of 220 may be reported even though the instrument detection limit is greater than the CRQL.

For lead:

Method in use = ICP
Instrument Detection Limit (IDL) = 40
Sample Concentration = 220
CRQL = 3

(2) The CRQLs are the instrument detection limits obtained in pure water. The detection limits for samples may be considerably higher depending on the sample matrix.

(3) The CRQLs for soils = 200 times CRQL's for water.

ATTACHMENT 5

200600009454
Filed for Record in
BUTLER COUNTY, OHIO
DANNY N CRANK
02-14-2006 At 09:22:24 am.
AGREEMENT 212.00
OR Book 7699 Page 953 - 977

BK: 7699 PG: 953

To be recorded with Deed Records - ORC § 317.08

9/15/05

ENVIRONMENTAL COVENANT

This Environmental Covenant is made as of the 24TH day of JANUARY, 200~~5~~6, by and among Owners Elsa Skinner-Morgan and David Morgan (as further identified below) and Holders, Elsa Skinner-Morgan and David Morgan (as further identified below) pursuant to Ohio Revised Code ("ORC") §§ 5301.80 to 5301.92 for the purpose of subjecting the Site and the Restricted Area (described below) to the activity and use limitations and to the rights of access described below.

Whereas, pursuant to Section 105 of the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"), 42 U.S.C. § 9605, the United States Environmental Protection Agency ("EPA"), placed the Skinner Landfill Site ("Site") on the National Priorities List, set forth at 40 C.F.R. Part 300, Appendix B, by publication in the Federal Register, 48 Fed. Reg. 40658 (September 8, 1983); and

Whereas, in a Remedial Action/Feasibility Study (RI/FS) completed on June 4, 1993, EPA found the following contaminants had been released into the soil at the Site: toluene, xylenes, ethylbenzene, 1,1,2-trichloroethane, 1,2-dichlororopane, benzene, naphthalene, 2-methylnapthalene, phenanthrene, bis(2-ethylhexyl)phthalate, benzoic acid, fluoranthene, pyrene, hexachlorobenzene, flourene, phenol, butylbenzlphthalate, 1,3-dichlorobenzene, 1,4-dichlorobenzene, hexachlorobutadiene, acenapthene, benzo(a)anthracene, chrysene, hexachlorocyclopentadiene, heptachlor, endrin ketone, gamma chlordane, antimony, cadmium, lead, silver and thallium. In the same RI/FS, EPA found the following contaminants had been released into the groundwater at the Site: benzene, ethylbenzene, xylenes, phenol, 2-methyl phenol, 4-methyl phenol, acetone, 1, 2-dichloroethane, chlorobenzene, 2-hexanone, methylene chloride, toluene, 1,1,2,2,-tetrachlorothylene, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,2-dichloroethene 1,2-dichloropropane, chloroethane, chloroform, trichloroethene, vinyl chloride, 1,3-dichlorobenzene, 1,4-dichlorobenzene, benzoic acid, bis(chloroethyl)ether, and naphthalene; and

Whereas, EPA issued a Record of Decision (ROD) for the Operable Unit Interim Action on September 30, 1992, which provided for Site fencing, and connections to the Butler County public water system for potentially affected local users of groundwater, and groundwater monitoring, and whereas EPA issued a final ROD on June 4, 1993 which called for the construction of a RCRA cap over the waste materials; interception, collection, and treatment of contaminated groundwater; diversion of upgradient groundwater flow, if necessary; monitoring; soil vapor extraction; and institutional controls to limit the future use of the property where remedial construction has occurred and to protect the performance of the remedy, and to prevent the exposure of humans or the environment to contaminants; and

TRANSFER NOT NECESSARY
KAY ROGERS
BY 2/14/R. Bal DEPT
AUDITOR, BUTLER CO., OHIO

Whereas on December 9, 1992, a EPA issued a Unilateral Administrative Order to various potentially responsible parties, and on April 2, 2001, a Remedial Action Consent Decree was entered which provided for the implementation of the remedial action selected in the June 4, 1993 ROD, and whereas with the exception of the diversion of the upgradient groundwater (which has not yet been determined to be necessary) and the institutional controls, the remedial action has been implemented at the Site; and

Whereas, the parties hereto have agreed: 1) to grant a permanent right of access over the Site to the Access Grantees (as hereafter defined) for purposes of implementing, facilitating and monitoring the remedial action, and 2) to impose on the Site activity and use limitations as covenants that will run with the land for the purpose of protecting human health and the environment; and

Now therefore, Owners and EPA agree to the following:

1. Environmental Covenant. This instrument is an environmental covenant executed and delivered pursuant to §§ 5301.80 to 5301.92 of the Ohio Revised Code.

2. Site; Restricted Area. The three (3) parcels of real property which together contain 78.29 acres located in Union Township, Butler County, Ohio (the "Site") which are subject to the environmental covenants set forth herein are described on Exhibit A attached hereto and hereby by reference incorporated herein. Part of the Site which is subject to certain activity and use limitations in Paragraph 5 below is described on Exhibit B attached hereto and hereby incorporated herein, and is hereafter referred to as the "Restricted Area." The Site is outlined by heavy black line on the copy of the Butler County, Ohio Auditor's tax map (the "Map") attached hereto as Exhibit C-1 and the Restricted Area is shown by diagonal lines on the copy of the Map attached hereto as Exhibit C-2.

3. Owner. Elsa Skinner-Morgan ("Owner") who resides at 8750 Cincinnati Dayton Road, West Chester, Ohio 45069 is the owner of the Site. David Morgan, ("Morgan") of the same address, who is the husband of Owner, joins in this Environmental Covenant in order to subject his dower/courtesy interest and any other interest in the Site which he may now or hereafter hold to the terms of this instrument. Owner and David Morgan are the Settling Owner/Operator Defendants named in the Consent Decree (described in Paragraph 10 below).

4. Holders. Elsa Skinner-Morgan and David Morgan, whose address appears in Paragraph 3 above.

5. Activity and Use Limitations on the Restricted Area and on the Site.

(a) Owner agrees for herself and her successors in title not to permit the Site to be used in any manner that would interfere with or adversely affect the integrity or protectiveness of the remedial action which has been implemented or which will be implemented pursuant to the Consent Decree unless the written consent of the EPA to such use is first obtained. Owner's agreement to restrict the use of the Site shall include, but not be limited to, not permitting any drilling, digging, building, or the installation, construction, removal or use of any buildings, wells, pipes, roads, ditches, or any other structures on the Restricted Area unless the written consent of EPA to such use or activity is first obtained. Further, Owner agrees for herself and her successors in title to refrain from bringing, and to refuse to grant permission to any other person to bring, Waste Material or Scrap Metal onto the Site, except in accordance with any federal, state or local permit or the Consent Decree.

(b) Owner covenants for herself and her successors and assigns, that the Restricted Area, shall be used solely for Commercial/Industrial Activities only in accordance with an EPA-approved plan for re-use of the Restricted Area as required under Paragraph 5(a) and the Restricted Area shall not be used for Residential and Other Prohibited Activities. Owner acknowledges and agrees that the Restricted Area has been remediated only for commercial/industrial uses. The term "Commercial/Industrial Activities" includes: (i) wholesale and retail sales and service activities including, but not limited to retail stores, and automotive fuel, sales and service facilities; (ii) governmental, administrative and general office activities, (iii) manufacturing, processing, and warehousing activities, including, but not limited to, production, storage and sales of durable goods and other non-food chain products; and (iv) activities which are consistent with or similar to the above listed activities; together with related parking areas and driveways, but excludes Residential and Other Prohibited Activities. The term "Residential and Other Prohibited Activities" includes: (i) single and multi-family dwellings and transient residential units; (ii) day care centers and preschools; (iii) public and private elementary and secondary schools; (iv) hospitals, assisted living facilities and other extended care medical facilities and medical and dental offices; (v) food preparation and food service facilities, including food stores, restaurants, banquet facilities and other food preparation or sales facilities; and (vi) indoor or outdoor entertainment and recreational facilities.

(c) Owner covenants for herself and her successors and assigns that there shall be no consumptive use of Site groundwater, either on or off the Site.

6. Running with the Land. This Environmental Covenant shall be binding upon the Owner and all assigns and successors in interest, including any Transferee, and shall run with the land, pursuant to ORC § 5301.85, subject to amendment or termination as set forth herein. The term "Transferee," as used in this Environmental Covenant, shall mean any future owner of any interest in the Site or any portion thereof, including, but not limited to, owners of an interest in fee simple, mortgagees, easement holders, and/or lessees.

7. Requirements for Notice to EPA Following Transfer of a Specified Interest in, or Concerning Proposed Changes in the Use of, Applications for Building Permits for, or Proposals for any Site Work Affecting Contamination on, the Restricted Area. Neither Owner nor any Holder shall transfer any interest in the Restricted Area or make proposed changes in the use of the Restricted Area, or make applications for building permits for, or proposals for any work in the Restricted Area without first providing notice to EPA and

obtaining any approvals or consents thereto which are required under Sections VII, VIII, X or XIII of the Consent Decree.

8. Access to the Site. Pursuant to Section X of the Consent Decree, Owner agrees that EPA and the Settling Generator/Transporter Defendants, their successors and assigns, and their respective officers, employees, agents, contractors and other invitees (collectively, "Access Grantees") shall have and hereby grants to each of them an unrestricted right of access to the Site to undertake the Permitted Uses described in Paragraph 9 below and, in connection therewith, to use all roads, drives and paths, paved or unpaved, located on the Site or off the Site ("off-site") and rightfully used by Owner and Owner's invitees for ingress to or egress from portions of the Site (collectively, "Access Roads"). The Site and the Access Roads are shown on the Survey. The off-site Access Roads referred to in the preceding sentence are located on the parcels described on Exhibits D and E attached hereto. The right of access granted under this Paragraph 8 shall be irrevocable while this Covenant remains in full force and effect. The Settling Generator/Transporter Defendants are named on Exhibit F attached hereto.

9. Permitted Uses. The right of access granted under Paragraph 8 of this Environmental Covenant shall provide Access Grantees with access at all reasonable times to the Site, or such other property, for the purpose of conducting any activity related to the Consent Decree or the purchase of the Site, including, but not limited to, the following activities:

a) Monitoring the Work;

b) Verifying any data or information submitted to the United States or the State;

c) Conducting investigations relating to contamination at or near the Site;

d) Obtaining samples;

e) Assessing the need for, planning, or implementing response actions at or near the Site;

f) Implementing the Work pursuant to the Consent Decree;

g) Inspecting and copying records, operating logs, contracts, or other documents maintained or generated by Owner or her agents, consistent with Section XXXI (Access to Information) of the Consent Decree;

h) Assessing Settling Generator/Transporter Defendants' compliance with the Consent Decree;

i) Determining whether the Site or other property is being used in a manner that is prohibited or restricted or that may need to be prohibited or restricted by or pursuant to the Consent Decree; and

j) Surveying and making soil tests of the Site, locating utility lines, and assessing the obligations which may be required of a Prospective Purchaser (as defined in the Consent Decree) by EPA under the Consent Decree.

10. Administrative Record.

(a) Owner is the Defendant in an action filed by EPA under federal programs governing environmental remediation of the Site under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. § 9601 et seq. in the United States District Court for the Southern District of Ohio, Western Division, Civil Action No., C-1-00-424 and has executed and delivered a Consent Decree dated April 2, 2001, (the "Consent Decree") settling such lawsuit. A certified copy of the Consent Decree has been recorded in the Office of the Butler County Recorder at OR Book 6658, Pages 413-613. The Consent Decree constitutes an environmental response project as defined by ORC § 5301.80(E) and authorizes and requires certain remedial action to be taken by the Settling Generator/Transporter Defendants. On June 4, 1993, EPA issued a Record of Decision (ROD) which set forth EPA's determination of the appropriate remedial action to be implemented at the Site to address Site contamination. Pursuant to this ROD, EPA approved a Remedial Design and Remedial Action work plan which has been implemented as described in the fourth "Whereas" clause at the beginning of this instrument. EPA's ROD was based upon an administrative record. Copies of the EPA administrative record for the Skinner Landfill Site are maintained at the following locations: EPA Region 5; Superfund Records Center (7th Floor); 77 W. Jackson; Chicago, Illinois 60604; Union Township Library, 7900 Cox Road, West Chester, Ohio 45069; and Union Township Hall, 9113 Cincinnati-Dayton Road, West Chester, Ohio 45069.

(b) Under Section X, Paragraphs 27 and 28 of the Consent Decree, Owner has agreed to provide the institutional controls with respect to the Site that are set forth in this Environmental Covenant. Owner has executed and delivered this Environmental Covenant to satisfy and implement her agreements to provide such institutional controls under the Consent Decree and as herein provided. All capitalized terms in this Environmental Covenant which are not defined herein shall have the same meaning as set forth in the Consent Decree or in Sections 5301.80 to 5301.90 Ohio Revised Code.

11. Notice upon Conveyance. Each instrument hereafter conveying any interest in the Site or Restricted Area or any portion of the Site or Restricted Area shall contain a notice of the activity and use limitations, and grants of access set forth in the Environmental Covenant, and provide the recorded location of this Environmental Covenant. For instruments conveying any interest in the Site or any portion thereof other than the Restricted Area, the notice shall be

substantially in the form set forth in Exhibit G. For instruments conveying any interest any interest in the Restricted Area or any portion thereof, the notice shall be substantially in the form set forth in Exhibit H.

12. Amendments; Early Termination. This Environmental Covenant may be modified or amended or terminated while Owner owns the property only by a writing signed by Owner and, EPA with the formalities required for the execution of a deed in Ohio which is recorded in the Office of the Recorder of Butler County, Ohio. Upon transfer of all or any portion of the Site, Owner waives any rights that she might otherwise have under Section 5301.90 of the Ohio Revised Code to withhold her consent to any amendments, modifications, or termination of this Environmental Covenant, to the extent that she has transferred her interest in that portion of the Site affected by said modification, amendment or termination. The rights of Owner's successors in interest as to a modification, amendment or termination of this Environmental Covenant are governed by the provisions of Section 5301.90 of the Ohio Revised Code.

13. Other Matters.

(a) Representations and Warranties of Owner and Morgan. Owner and Morgan represent and warrant; that Owner is the sole owner of the Site; that Owner holds fee simple title to the Site which is free, clear and unencumbered except for the Consent Decree; that Owner and Morgan have the power and authority to make and enter into this Agreement as Owner and Holder, to grant the rights and privileges herein provided and to carry out all obligations of Owner, Morgan and Holder hereunder; that this Agreement has been executed and delivered pursuant to the Consent Decree; and, that this Agreement will not materially violate or contravene or constitute a material default under any other agreement, document or instrument to which Owner or Morgan is a party or by which Owner or Morgan may be bound or affected.

(b) Right to Enforce Agreement Against Owner and Morgan; Equitable Remedies. In the event that Owner, Morgan or any other person should attempt to deny the rights of access granted under Paragraph 8 or should violate the restrictions on use of the Site set forth in Paragraph 5, then, in addition to any rights which EPA may have under the Consent Decree, EPA or any Settling Generator/Transporter Defendant that is adversely affected by each denial (for example, any Settling Generator/Transporter Defendant that is prevented from conducting its remedial obligations under the Consent Decree) or by such violation shall have the right to immediately seek an appropriate equitable remedy and any court having jurisdiction is hereby granted the right to issue a temporary restraining order and/or preliminary injunction prohibiting such denial of access or use in violation of restrictions upon application by EPA or by such adversely affected Settling Generator/Transporter Defendant without notice or posting bond. Owner and each subsequent owner of the Site by accepting a deed thereto or to any part thereof waives all due process or other constitutional right to notice and hearing before the grant of a temporary restraining order and/or preliminary injunction pursuant to this Subsection 13(b).

(c) Future Cooperation; Execution of Supplemental Instruments. Owner agrees to cooperate fully with EPA and/or the Settling Generator/Transporter Defendants and to assist them in implementing the rights granted them under this Environmental Covenant and, in furtherance thereof, agrees to execute and deliver such further documents as may be requested by EPA to supplement or confirm the rights granted hereunder.

(d) Cumulative Remedies; No Waiver. All of the rights and remedies set forth in this Environmental Covenant or otherwise available at law or in equity are cumulative and may be exercised without regard to the adequacy of, or exclusion of, any other right, remedy or option available hereunder or under the Consent Decree or at law. The failure to exercise any right granted hereunder, to take action to remedy any violation by Owner or Morgan of the terms hereof or to exercise any remedy provided herein shall not be deemed to be a waiver of any such right or remedy and no forbearance on the part of EPA and no extension of the time for performance of any obligations of Owner or Morgan hereunder shall operate to release or in any manner affect EPA's rights hereunder.

(e) Severability. If any provision of this Environmental Covenant is found to be unenforceable in any respect, the validity, legality, and enforceability of the remaining provisions shall not in any way be affected or impaired.

(f) Recordation. Within thirty (30) days after the date of the final required signature upon this Environmental Covenant, Owner shall file this Environmental Covenant for recording, in the same manner as a deed to the Site, with the Butler County Recorder's Office.

(g) Effective Date. The effective date of this Environmental Covenant shall be the date upon which the fully executed Environmental Covenant has been recorded as a deed record for the Site with the Butler County Recorder.

(h) Distribution of Environmental Covenant/Other Notices. The Owner shall distribute a file-stamped and date-stamped copy of the reorded Environmental Covenant to: Ohio EPA, Butler County, each person holding a recorded interest in the Site, and the Settling Generator/Transporter Defendants. All notices, requests, demands or other communications required or permitted under this Environmental Covenant shall be given in the manner and with the effect set forth in the Consent Decree.

(f) Notices – All notices, requests, demands or other communications required or permitted under this Environmental Covenant shall be given in the manner and with the effect set forth in the Consent Decree.

(g) Governing Law. This Environmental Covenant shall be construed according to and governed by the laws of the State of Ohio and the United States of America.

(h) Captions. All paragraph captions are for convenience of reference only and shall not affect the construction of any provision of this Environmental Covenant.

(i) Time of the Essence. Time is of the essence of each and every performance obligation of Owner and Morgan under this Environmental Covenant.

[SIGNATURE PAGE TO FOLLOW]

IN WITNESS WHEREOF, Owner, Morgan and EPA have executed and delivered this Environmental Covenant as of the date first above written.

OWNER

Elsa M Skinner-Morgan

Elsa M. Skinner-Morgan, a/k/a
Elsa M. Skinner

David Morgan

David Morgan

STATE OF OHIO)
) SS.
COUNTY OF BUTLER)

The foregoing instrument was acknowledged before me this 16th day of November, 2005, by Elsa M. Skinner-Morgan, a/k/a Elsa M. Skinner and David Morgan, wife and husband.

Notary Public

UNITED STATES OF AMERICA
On behalf of the Administrator of the
United States Environmental Protection Agency

By: Richard C Karl

Richard C. Karl, Director,
Superfund Division, Region 5

STATE OF ILLINOIS)
) SS.
COUNTY OF COOK)

The foregoing instrument was acknowledged before me this 24th day of JANUARY, 200~~5~~6, by Richard C. Karl, Director, Superfund Division, Region 5 of the United States Environmental Protection Agency, on behalf of the United States of America.

Joseph H Kruth
My Commission Expires 07/24/06

Joseph H Kruth

Notary Public

EXHIBIT A

Legal Description of the "Site"

PARCEL I

Situated in and being in Section 22, Town 3, Range 2 and in Union Township, Butler County, Ohio, and is bounded and described as follows:

Beginning at the Northwest corner of the Southeast Quarter of said Section 22, Town 3, Range 2; thence along the north line of the southeast quarter section, South 86° 09' East, 300.40 feet to an old stone; thence North 4° 18' 45" East, 726.56 feet to an iron pipe; thence South 85° 57' 45" East, 406.26 feet to the old right of way for the C.C.C. & St. L. Railroad; thence along said old right of way line South 15° 10' 45" East, 163.00 feet to a point in the present right of way line for the C.C.C. & St. L. Railroad; thence along said present Railroad right of way line, South 11° 49' West, 1865.17 feet to an iron pipe; thence South 89° 03' West, 512.03 feet; (witnessed by an iron pipe, North 89° 03' East, 2.00 feet); thence North 3° 59' East, 1318.92 feet to an iron pipe and the point of beginning; containing 24.852 acres of land, more or less.

M5610-023-000-015

PARCEL II

Situate in Section 22, Town 3, Range 2, Union Township, Butler County, Ohio and being part of the property conveyed to Elsa M. Skinner by deed recorded in Deed Book 1236, Page 337, in the Butler County Recorder's Office, and being more particularly described as follows:

Commencing at the intersection of the west line of Section 22 and the half section line; thence along said half section line, South 87° 01' 55" East, 982.76 feet to the centerline of Cincinnati-Dayton Road; thence leaving said half section line and along said centerline, South 39° 59' 08" West, 861.28 feet to the western most corner of said Skinner lands; thence along said centerline, North 39° 59' 08" East, 198.15 feet to the point of beginning of this tract; thence along said centerline, North 39° 59' 08" East, 263.98 feet; thence leaving said centerline and with said Skinner lines, South 50° 00' 52" East, 363.10 feet; thence North 39° 59' 08" East, 171.00 feet; thence North 29° 42' 05" East, 279.68 feet; thence South 50° 02' 05" East, 175.77 feet; thence North 23° 00' 00" East, 328.48 feet; thence South 86° 06' 05" East, 66.89 feet; thence South 85° 38' 15" East, 292.00 feet; thence by new division line, South 40° 49' 19" West, 848.97 feet; thence South 35° 31' 36" West, 225.23 feet; thence South 36° 05' 41" West, 269.24 feet; thence South 43° 12' 11" West, 99.54 feet; thence North 46° 47' 50" West, 339.63 feet; thence North 39° 59' 08" East, 188.51 feet; thence North 50° 00' 52" West, 363.10 feet to the said centerline and the point of beginning of this parcel.

Containing 11.507 acres of land, more or less.

A plat of survey prepared by Joseph M. Allen Co. is recorded in Volume 22, Page 175 of the Butler County Engineer's Records of Land Surveys.

PARCEL III

Situate in Section 22, Town 3, Range 2, Union Township, Butler County, Ohio and being part of the property conveyed to Elsa M. Skinner by deed recorded in Deed Book 1236, Page 337 in the Butler County Recorder's Office, and being more particularly described as follows:

Commencing at the intersection of the west line of Section 22 and the half section line; thence along said half section line, South 87° 01' 55" East, 982.76 feet to the centerline of Cincinnati-Dayton Road; thence leaving said half section line and along said centerline, South 39° 59' 08" West, 861.28 feet to the westernmost corner of said Skinner lands, being the point of beginning of this tract; thence along said centerline, North 39° 59' 08" East, 198.15 feet; thence by new division line, South 50° 00' 52" East, 363.10 feet; thence South 39° 59' 08" West, 188.51 feet; thence South 46° 47' 50" East, 339.63 feet; thence North 43° 12' 11" East, 99.54 feet; thence North 36° 05' 41" East, 269.24 feet; thence North 35° 31' 36" East, 225.23 feet; thence North 40° 49' 19" East, 848.97 feet to said Skinner line; thence with said Skinner line, South 85° 38' 15" East, 802.73 feet; thence South 4° 16' 10" West, 1319.05 feet; thence South 89° 08' 10" West, 549.50 feet to the east line of Ray A. Skinner as conveyed by deed recorded in Deed Book 1475, Page 656 in the Butler County Recorder's Office; thence with said Ray Skinner line, North 7° 08' 10" East, 58.61 feet; thence North 75° 27' 20" West, 225.36 feet; thence South 6° 48' 51" West, 118.98 feet to said Elsa Skinner line; thence with said line, South 82° 52' 15" West, 530.95 feet; thence North 5° 52' 15" West, 108.95 feet; thence North 46° 47' 50" West, 1007.50 feet to the centerline of Cincinnati-Dayton Road and the point of beginning; excepting therefrom the 0.401 acres of land of Charles S. and Rosella M. Wallen as conveyed by deed recorded in Deed Book 721, Page 251 of the Butler County Recorder's Office.

Containing 41.938 acres of land, more or less.

A plat of survey prepared by Joseph M. Allen Co. is recorded in Volume 22, Page 175 of the Butler County Engineer's Records of Land Surveys.

M5610-023-000-055

Property Address: 8750 Cincinnati Dayton Road, West Chester, OH
Tax ID No.: M5610-023-000-015; -025; -055

EXHIBIT B

Legal Description of the "Restricted Area"

PARCEL I

Situated in and being in Section 22, Town 3, Range 2 and in Union Township, Butler County, Ohio, and is bounded and described as follows:

Beginning at the Northwest corner of the Southeast Quarter of said Section 22, Town 3, Range 2; thence along the north line of the southeast quarter section, South 86° 09' East, 300.40 feet to an old stone; thence North 4° 18' 45" East, 726.56 feet to an iron pipe; thence South 85° 57' 45" East, 406.26 feet to the old right of way for the C.C.C. & St. L. Railroad; thence along said old right of way line South 15° 10' 45" East, 163.00 feet to a point in the present right of way line for the C.C.C. & St. L. Railroad; thence along said present Railroad right of way line, South 11° 49' West, 1865.17 feet to an iron pipe; thence South 89° 03' West, 512.03 feet; (witnessed by an iron pipe, North 89° 03' East, 2.00 feet); thence North 3° 59' East, 1318.92 feet to an iron pipe and the point of beginning; containing 24.852 acres of land, more or less.

Excepting from the above described 24.852 acre parcel that part thereof which adjoins the centerline of Cincinnati-Dayton Road to a depth of 702.34 feet measured southeasterly from and at a right angle to the centerline of Cincinnati-Dayton Road.

PARCEL III

Situate in Section 22, Town 3, Range 2, Union Township, Butler County, Ohio and being part of the property conveyed to Elsa M. Skinner by deed recorded in Deed Book 1236, Page 337 in the Butler County Recorder's Office, and being more particularly described as follows:

Commencing at the intersection of the west line of Section 22 and the half section line; thence along said half section line, South 87° 01' 55" East, 982.76 feet to the centerline of Cincinnati-Dayton Road; thence leaving said half section line and along said centerline, South 39° 59' 08" West, 861.28 feet to the westernmost corner of said Skinner lands, being the point of beginning of this tract; thence along said centerline, North 39° 59' 08" East, 198.15 feet; thence by new division line, South 50° 00' 52" East, 363.10 feet; thence South 39° 59' 08" West, 188.51 feet; thence South 46° 47' 50" East, 339.63 feet; thence North 43° 12' 11" East, 99.54 feet; thence North 36° 05' 41" East, 269.24 feet; thence North 35° 31' 36" East, 225.23 feet; thence North 40° 49' 19" East, 848.97 feet to said Skinner line; thence with said Skinner line, South 85° 38' 15" East, 802.73 feet; thence South 4° 16' 10" West, 1319.05 feet; thence South 89° 08' 10" West, 649.50 feet to the east line of Ray A. Skinner as conveyed by deed recorded in Deed Book 1475, Page 656 in the Butler County Recorder's Office; thence with said Ray Skinner line, North 7° 08' 10" East, 58.61 feet; thence North 75° 27' 20" West, 225.36 feet; thence South 6° 48' 51" West, 118.98 feet to said Elsa Skinner line; thence with said line, South 82° 52' 15" West, 530.95 feet; thence North 5° 52' 15" West, 108.95 feet; thence North 46° 47' 50" West, 1007.50 feet to the centerline of Cincinnati-Dayton Road and the point of beginning; excepting therefrom the 0.401 acres of land of Charles S. and Rosella M. Wallen as conveyed by deed recorded in Deed Book 721, Page 251 of the Butler County Recorder's Office.

Containing 41.938 acres of land, more or less.

A plat of survey prepared by Joseph M. Allen Co. is recorded in Volume 22, Page 175 of the Butler County Engineer's Records of Land Surveys.

M5610-023-000-055

Property Address: 8750 Cincinnati Dayton Road, West Chester, OH
Tax ID No.: M5610-023-000-015; -025; -055

EXHIBIT C-1

Drawing of Site

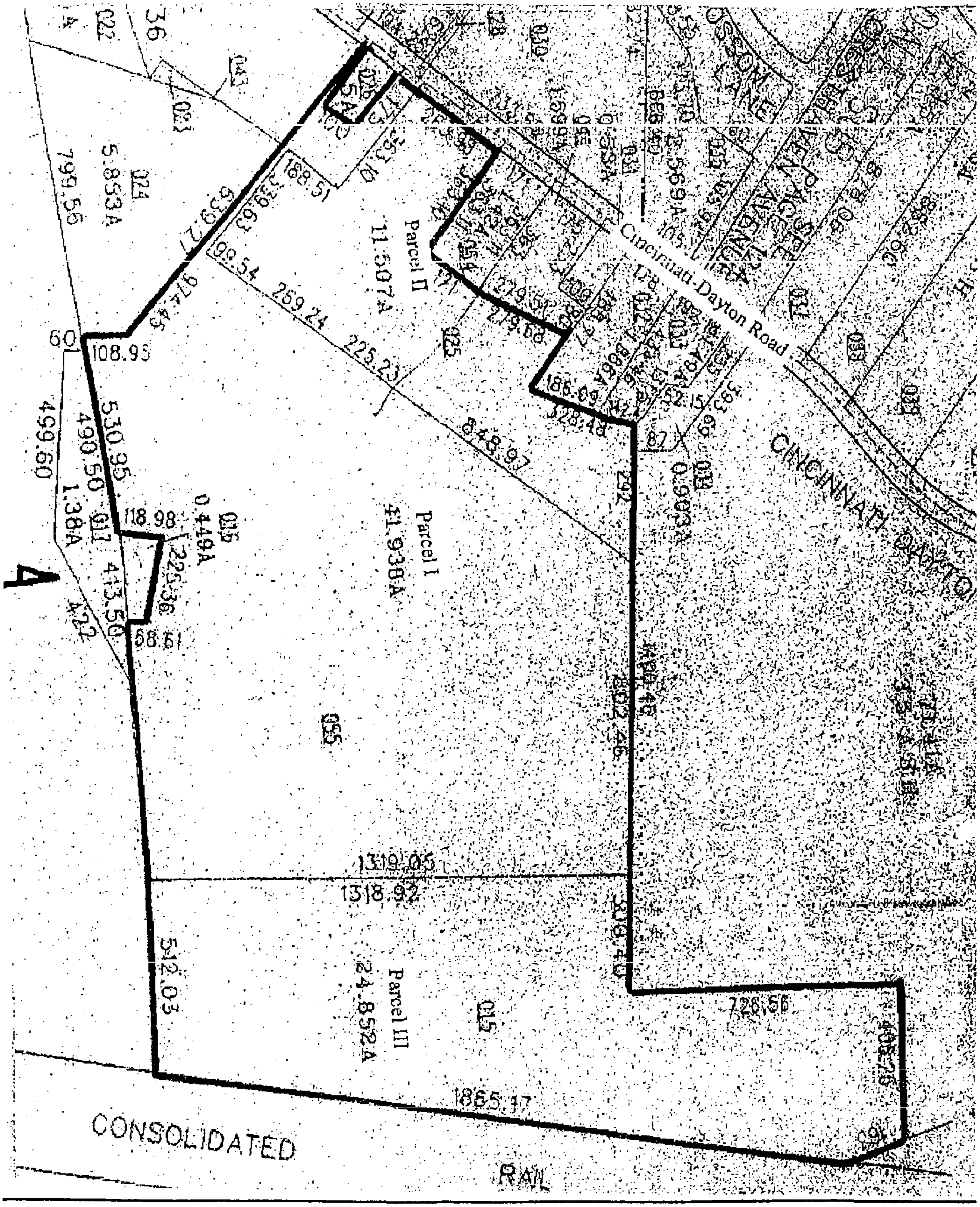


EXHIBIT C-2

Drawing of Restriction Area

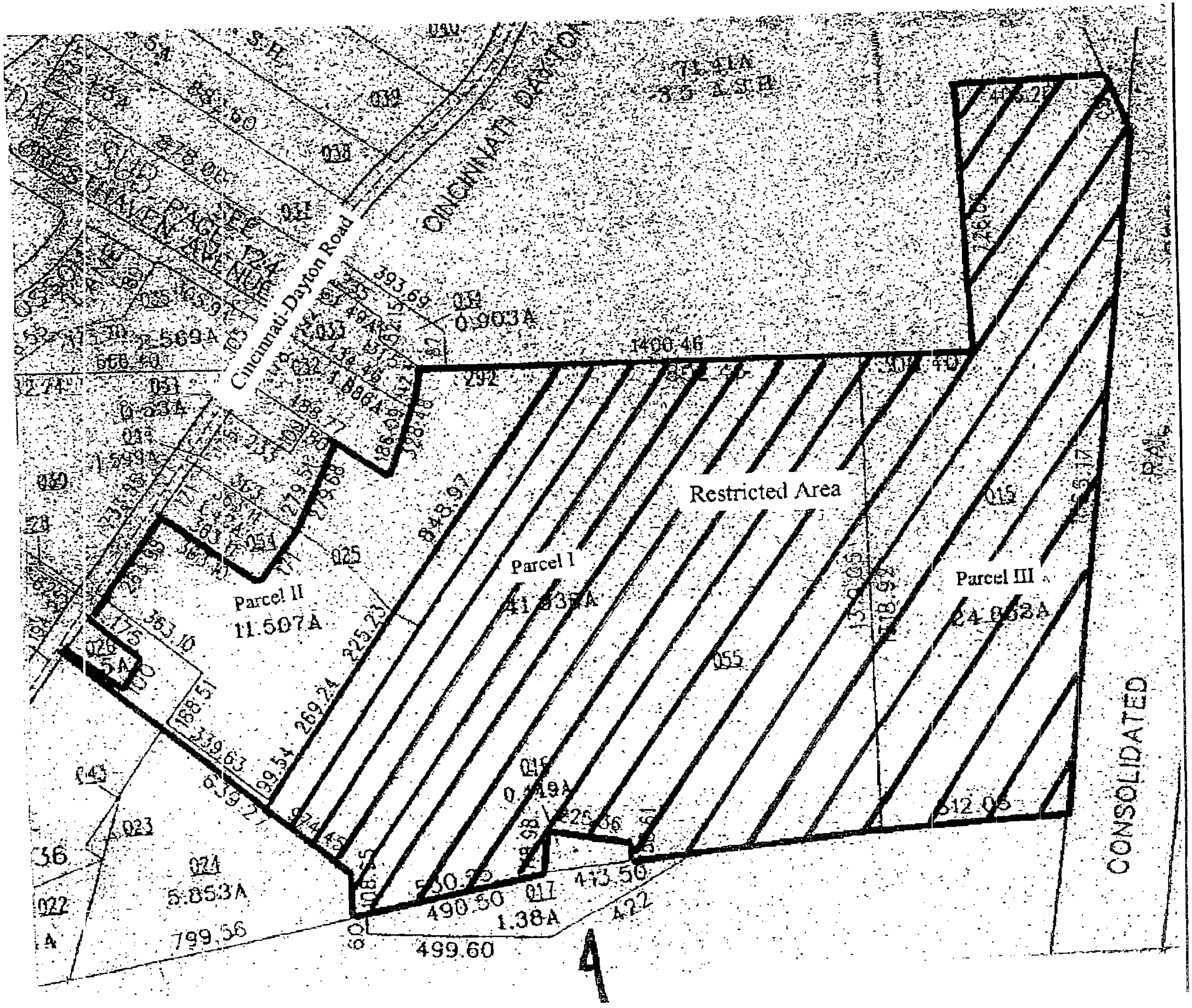
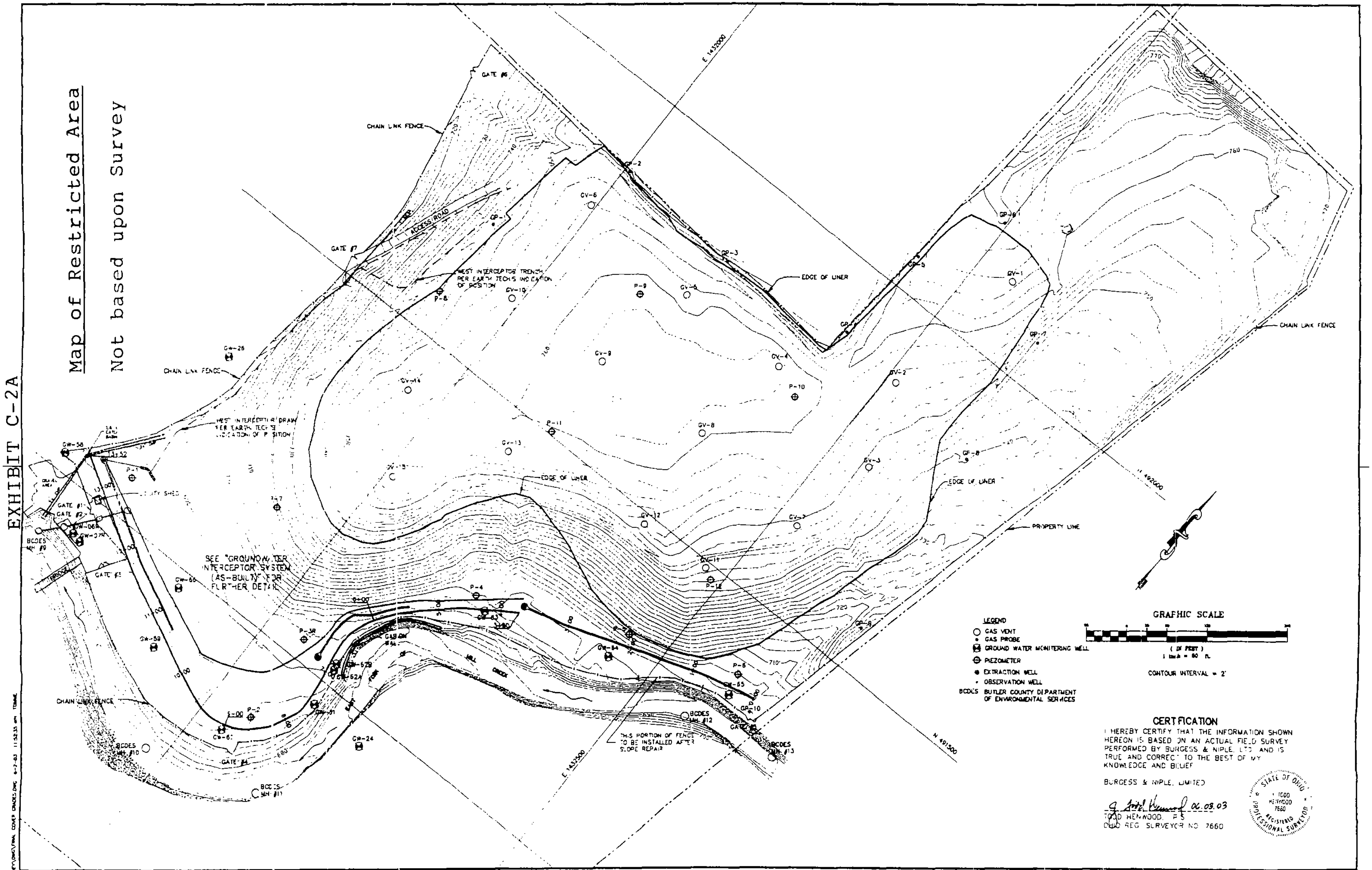


EXHIBIT C-2A

Map of Restricted Area

Not based upon Survey



LEGEND

- ○ GAS VENT
- • GAS PROBE
- GROUND WATER MONITORING WELL
- PIEZOMETER
- ● EXTRACTION WELL
- • OBSERVATION WELL
- BCDES BUTLER COUNTY DEPARTMENT OF ENVIRONMENTAL SERVICES

GRAPHIC SCALE

(IN FEET)
1 inch = 60 ft.

CONTOUR INTERVAL = 2'

CERTIFICATION

I HEREBY CERTIFY THAT THE INFORMATION SHOWN HEREON IS BASED ON AN ACTUAL FIELD SURVEY PERFORMED BY BURGESS & NIPLE, LTD. AND IS TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF

BURGESS & NIPLE, LIMITED

J. Todd Henwood 06.03.03
TODD HENWOOD, P.S.
OHIO REG. SURVEYOR NO. 7660

TODD HENWOOD 7660

NO.	REVISIONS	DATE	BY	CHK.
1	REVISIONS PER EARTH TECH	4/03	JLT	JTH
2	REVISIONS PER EARTH TECH	5/03	JLT	JTH

Burgess & Niple, Limited CINCINNATI, OHIO

BURGESS & NIPLE

EARTH TECH
A TYCO INTERNATIONAL LTD. COMPANY

JOB NO.	30435
DESIGNED BY:	
DRAWN BY:	JLT
CHECKED BY:	JTH
APPROVED BY:	RFR
DATE	5 15 03

SKINNER LANDFILL SUPERFUND SITE
REMEDIAL ACTION COMPLETION REPORT
FINAL COVER GRADES (AS-BUILT)

Scale
1" = 60'

RECORD DRAWING 3

EXHIBIT D

Legal Description of 1.38-Acre Access Easement Parcel

Being part of lot number four (4) and part of Lot Number Eleven (11) in Section 22, Town 3, Range 2, in Union Township, Butler County, Ohio, and as recorded in Land Book #1, page 62, of the Butler County Ohio Recorder's Records, and more particularly described as follows:

Lying and being in Section 22, Town 3, Range 2, in Union Township, Butler County, Ohio, and beginning at the northeast corner of said lot #4, thence north 83-1/2 degrees east a distance of four hundred and thirteen and five-tenths (413.5) feet to a point, thence south 70 degrees west a distance of four hundred and twenty-two (422) feet to a point, thence south 86-1/2 degrees west a distance of two hundred and thirty nine and six-tenths (239.6) feet to a point, thence south 88 degrees west a distance of two hundred and sixty feet to a point; thence north ½ degree west a distance of sixty (60) feet to a point, thence north 87 degrees east a distance of four hundred and ninety and five-tenths (490.5) feet to the place of beginning, containing one and thirty-eight hundredths (1.38) acres of land; being the same premises conveyed by Anna Mae Skinner to William J. Skinner by deed dated February 14, 1938, recorded in Volume 327 page 137, Butler County, Ohio Deed Records.

EXHIBIT E

Legal Description of .449-Acre Access Easement Parcel

Situated and lying in Section 22, Town 3, Range 2, Union Township, Butler County, Ohio. Commencing at the southwest corner of Section 22, Town 3, Range 2 in Union Township, thence north 1 degree 45' east 1042.8 feet; thence north 78 degrees 00' east 1798.5 feet to a stone at the southwest corner of tract herein transferred; thence north 83 degrees 30' east 225 feet to an iron pin; thence north 1 degree 30' east 58.61 feet to an iron pipe; thence north 81 degrees 05-1/2' west 225.36 feet to a stone; thence south 2 degrees 25' west to the place of beginning, containing .449 of an acre.

EXHIBIT F

APPENDIX D

SETTLING GENERATOR/TRANSPORTER DEFENDANTS

Anchor Hocking Corporation

Chemical Leaman

The Dow Chemical Company

Ford Motor Company

Formica Corporation

Henkel Corporation

GE Aircraft Engines

General Motors Corporation

King Wrecking Company, Inc.

King Container Services, Inc.

Monsanto Company

Oxy USA Inc

Velsicol Chemical Corporation

EXHIBIT G

Notice upon Conveyance of Site or any Portion thereof other than the Restricted Area

THE INTEREST CONVEYED HEREBY IS SUBJECT TO A CONSENT DECREE DATED APRIL 2, 2001, WHICH WAS RECORDED IN THE OFFICE OF THE BUTLER COUNTY RECORDER, OR BOOK 6658, Pages 413-613, AND WHICH RESTRICTS THE INTEREST CONVEYED AS SET FORTH IN THIS NOTICE AND AN ENVIRONMENTAL COVENANT, DATED __________, 200_, RECORDED IN THE DEED OR OFFICIAL RECORDS OF THE BUTLER COUNTY RECORDER ON ________________, 200_, in BOOK _____, Page _____, THE ENVIRONMENTAL COVENANT CONTAINS THE FOLLOWING ACTIVITY AND USE LIMITATIONS AND ACCESS RIGHTS:

Activity and Use Limitations on the Site.

(a) The Site shall not be used in any manner that would interfere with or adversely affect the integrity or protectiveness of the remedial action which has been implemented or which will be implemented pursuant to the Consent Decree unless the written consent of the EPA to such use is first obtained. No person shall bring any Waste Material or Scrap Metal onto the Site, except in accordance with any federal, state or local permit or the Consent Decree.

(b) There shall be no consumptive use of Site groundwater, either on or off the Site.

Access to the Site. Pursuant to Section X of the Consent Decree and the Environmental Covenant, EPA and the Settling Generator/Transporter Defendants, their successors and assigns, and their respective officers, employees, agents, contractors and other invitees (collectively, "Access Grantees") shall have an unrestricted right of access to the Site to undertake the Permitted Uses described below and, in connection therewith, to use all roads, drives and paths, paved or unpaved, located on the Site or off the Site ("off-site") and the "Access Roads." The Site and the Access Roads are shown on the Survey, which is recorded in Volume 22, Page 175 of the Butler County Engineer's Records of Land Surveys. The off-site Access Roads referred to in the preceding sentence are located on the parcels described on Exhibits D and E of the Environmental Covenant referred to above, from which this Notice proceeds. The right of access set forth above shall be irrevocable while the Environmental Covenant remains in full force and effect. The Settling Generator/Transporter Defendants are named on Exhibit F of the Environmental Covenant.

Permitted Uses. The right of access granted under the Environmental Covenant shall provide Access Grantees with access at all reasonable times to the Site, or such other property, for the purpose of conducting any activity related to the Consent Decree or the purchase of the Site, including, but not limited to, the following activities:

a) Monitoring the Work;

b) Verifying any data or information submitted to the United States or the State;

c) Conducting investigations relating to contamination at or near the Site;

d) Obtaining samples;

e) Assessing the need for, planning, or implementing response actions at or near the Site;

f) Implementing the Work pursuant to the Consent Decree;

g) Inspecting and copying records, operating logs, contracts, or other documents maintained or generated by Owner or her agents, consistent with Section XXXI (Access to Information) of the Consent Decree;

h) Assessing Settling Generator/Transporter Defendants' compliance with the Consent Decree;

i) Determining whether the Site or other property is being used in a manner that is prohibited or restricted or that may need to be prohibited or restricted by or pursuant to the Consent Decree; and

j) Surveying and making soil tests of the Site, locating utility lines, and assessing the obligations which may be required of a Prospective Purchaser (as defined in the Consent Decree) by EPA under the Consent Decree.

EXHIBIT H

Notice upon Conveyance of Restricted Area or any Portion thereof

THE INTEREST CONVEYED HEREBY IS SUBJECT TO A CONSENT DECREE DATED APRIL 2, 2001, WHICH WAS RECORDED IN THE OFFICE OF THE BUTLER COUNTY RECORDER, OR BOOK 6658, Pages 413-613, AND WHICH RESTRICTS THE INTEREST CONVEYED AS SET FORTH IN THIS NOTICE, AND AN ENVIRONMENTAL COVENANT, DATED __________, 200_, RECORDED IN THE OFFICIAL RECORDS OF THE BUTLER COUNTY RECORDER ON ________________, 200_, in BOOK _____, Page ______, THE ENVIRONMENTAL COVENANT CONTAINS THE FOLLOWING ACTIVITY AND USE LIMITATIONS AND ACCESS RIGHTS:

Activity and Use Limitations on the Restricted Area.

(a) The Restricted Area shall not be used in any manner that would interfere with or adversely affect the integrity or protectiveness of the remedial action which has been implemented or which will be implemented pursuant to the Consent Decree unless the written consent of the EPA to such use is first obtained. There shall be no drilling, digging, building, or the installation, construction, removal or use of any buildings, wells, pipes, roads, ditches, or any other structures on the Restricted Area unless the written consent of EPA to such use or activity is first obtained. No person shall bring any Waste Material or Scrap Metal onto the Restricted Area, except in accordance with any federal, state or local permit or the Consent Decree.

(b) The Restricted Area, shall be used solely for Commercial/Industrial Activities only in accordance with an EPA-approved plan for re-use of the Restricted Area as required under Paragraph 5(a) of the Environmental Covenant and the Restricted Area shall not be used for Residential and Other Prohibited Activities. The Restricted Area has been remediated only for commercial/industrial uses. The term "Commercial/Industrial Activities" includes: (i) wholesale and retail sales and service activities including, but not limited to retail stores, and automotive fuel, sales and service facilities; (ii) governmental, administrative and general office activities, (iii) manufacturing, processing, and warehousing activities, including, but not limited to, production, storage and sales of durable goods and other non-food chain products; and (iv) activities which are consistent with or similar to the above listed activities; together with related parking areas and driveways, but excludes Residential and Other Prohibited Activities. The term "Residential and Other Prohibited Activities" includes: (i) single and multi-family dwellings and transient residential units; (ii) day care centers and preschools; (iii) public and private elementary and secondary schools; (iv) hospitals, assisted living facilities and other extended care medical facilities and medical and dental offices; (v) food preparation and food service facilities, including food stores, restaurants, banquet facilities and other food preparation or sales facilities; and (vi) indoor or outdoor entertainment and recreational facilities.

(c) There shall be no consumptive use of Restricted Area groundwater, either on or off the Restricted Area.

Requirements for Notice to EPA Following Transfer of a Specified Interest in, or Concerning Proposed Changes in the Use of, Applications for Building Permits for, or Proposals for any Site Work Affecting Contamination on, the Restricted Area. No transferee in interest may make changes in the use of the Restricted Area, or may make applications for building permits for, or proposals for any work in the Restricted Area without first providing notice to EPA and obtaining any approvals or consents thereto which are required under Sections VII, VIII, X or XIII of the Consent Decree.

Access to the Restricted Area. Pursuant to Section X of the Consent Decree and the Environmental Covenant, EPA and the Settling Generator/Transporter Defendants, their successors and assigns, and their respective officers, employees, agents, contractors and other invitees (collectively, "Access Grantees") shall have an unrestricted right of access to the Restricted Area to undertake the Permitted Uses described below and, in connection therewith, to use all roads, drives and paths, paved or unpaved, located on the Restricted Area or off the Restricted ("off-site") and the Access Roads. The Site and the Access Roads are shown on the Survey which is recorded in Volume 22, Page 175 of the Butler County Engineer's Records of Land Surveys. The right of access granted under this Paragraph shall be irrevocable while this Environmental Covenant remains in full force and effect. The Settling Generator/Transporter Defendants are named on Exhibit F of the Environmental Covenant.

Permitted Uses. The right of access granted under the Environmental Covenant shall provide Access Grantees with access at all reasonable times to the Restricted Area, or such other property, for the purpose of conducting any activity related to the Consent Decree or the purchase of the Restricted Area, including, but not limited to, the following activities:

a) Monitoring the Work;

b) Verifying any data or information submitted to the United States or the State;

c) Conducting investigations relating to contamination at or near the Restricted Area;

d) Obtaining samples;

e) Assessing the need for, planning, or implementing response actions at or near the Restricted Area;

f) Implementing the Work pursuant to the Consent Decree;

g) Inspecting and copying records, operating logs, contracts, or other documents maintained or generated by Owner or her agents, consistent with Section XXXI (Access to Information) of the Consent Decree;

h) Assessing Settling Generator/Transporter Defendants' compliance with the Consent Decree;

i) Determining whether the Restricted Area or other property is being used in a manner that is prohibited or restricted or that may need to be prohibited or restricted by or pursuant to the Consent Decree; and

j) Surveying and making soil tests of the Restricted Area, locating utility lines, and assessing the obligations which may be required of a Prospective Purchaser (as defined in the Consent Decree) by EPA under the Consent Decree.

ATTACHMENT 6

Site Inspection Checklist

I. SITE INFORMATION

Site name: Skinner Landfill

Date of inspection: 1/29/09

Location and Region: West Chester, OH Region 5

EPA ID: OHD063963714

Agency, office, or company leading the five-year review: EPA

Weather/temperature: Cloudy 22°

Remedy Includes: (Check all that apply)

☑ Landfill cover/containment
☑ Access controls
☑ Institutional controls
☑ Groundwater pump and treatment
☑ Surface water collection and treatment
☑ Other Slurry Wall

☐ Monitored natural attenuation
☑ Groundwater containment
☑ Vertical barrier walls

Attachments: ☐ Inspection team roster attached ☐ Site map attached

II. INTERVIEWS (Check all that apply)

1. **O&M site manager** Ronald F. Roelker — Project Manager — 1/29/09
Name Title Date
Interviewed ☑ at site ☐ at office ☐ by phone Phone no. ______
Problems, suggestions; ☐ Report attached ______

2. **O&M staff** Alex Maginnis — Project Engineer — 1/29/09
Name Title Date
Interviewed ☑ at site ☐ at office ☐ by phone Phone no. ______
Problems, suggestions; ☐ Report attached ______

3. **Local regulatory authorities and response agencies** (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Agency Ohio EPA
Contact Chuck Mellon Project Manager ______ 937) 285-6036
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached

Agency
Contact
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached

Agency
Contact
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached

Agency
Contact
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached

4. **Other interviews** (optional) ☐ Report attached.

III. ON-SITE DOCUMENTS & RECORDS VERIFIED (Check all that apply)

1. **O&M Documents**
☑ O&M manual ☐ Readily available ☐ Up to date ☑ N/A
☑ As-built drawings ☐ Readily available ☐ Up to date ☑ N/A
☑ Maintenance logs ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

2. **Site-Specific Health and Safety Plan** ☐ Readily available ☐ Up to date ☑ N/A
☐ Contingency plan/emergency response plan ☐ Readily available ☐ Up to date ☐ N/A
Remarks ______________________________

3. **O&M and OSHA Training Records** ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

4. **Permits and Service Agreements**
☐ Air discharge permit ☐ Readily available ☐ Up to date ☐ N/A
☑ Effluent discharge ☐ Readily available ☐ Up to date ☑ N/A
☑ Waste disposal, POTW ☐ Readily available ☐ Up to date ☑ N/A
☐ Other permits ____________ ☐ Readily available ☐ Up to date ☐ N/A
Remarks ______________________________

5. **Gas Generation Records** ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

6. **Settlement Monument Records** ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

7. **Groundwater Monitoring Records** ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

8. **Leachate Extraction Records** ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

9. ***Discharge Compliance Records***
☐ Air ☐ Readily available ☐ Up to date ☐ N/A
☑ Water (effluent) ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

10. **Daily Access/Security Logs** ☐ Readily available ☐ Up to date ☑ N/A
Remarks ______________________________

IV. O&M COSTS

1. **O&M Organization**

☐ State in-house
☐ PRP in-house
☐ Federal Facility in-house
☐ Other ____________________

☐ Contractor for State
☑ Contractor for PRP
☐ Contractor for Federal Facility

2. **O&M Cost Records**

☐ Readily available ☐ Up to date
☐ Funding mechanism/agreement in place
Original O&M cost estimate ____________ ☐ Breakdown attached

Total annual cost by year for review period if available

From ________ To ________ ____________ ☐ Breakdown attached
Date Date Total cost
From ________ To ________ ____________ ☐ Breakdown attached
Date Date Total cost
From ________ To ________ ____________ ☐ Breakdown attached
Date Date Total cost
From ________ To ________ ____________ ☐ Breakdown attached
Date Date Total cost
From ________ To ________ ____________ ☐ Breakdown attached
Date Date Total cost

3. **Unanticipated or Unusually High O&M Costs During Review Period**

Describe costs and reasons: ____________________

V. ACCESS AND INSTITUTIONAL CONTROLS ☑ Applicable ☐ N/A

A. Fencing

1. **Fencing damaged** ☐ Location shown on site map ☑ Gates secured ☐ N/A

Remarks Top of fence damaged at one location

B. Other Access Restrictions

1. **Signs and other security measures** ☐ Location shown on site map ☐ N/A

Remarks Signs are in place

C. Institutional Controls (ICs)

1. **Implementation and enforcement**

Site conditions imply ICs not properly implemented ☐ Yes ☑ No ☐ N/A
Site conditions imply ICs not being fully enforced ☐ Yes ☑ No ☐ N/A

Type of monitoring (*e.g.*, self-reporting, drive by) Self - reporting
Frequency Quarterly
Responsible party/agency PRP
Contact Ron Roelker Project Manager (859) 442-2311
Name Title Date Phone no.

Reporting is up-to-date ☑ Yes ☐ No ☐ N/A
Reports are verified by the lead agency ☑ Yes ☐ No ☐ N/A

Specific requirements in deed or decision documents have been met ☑ Yes ☐ No ☐ N/A
Violations have been reported ☐ Yes ☑ No ☐ N/A
Other problems or suggestions: ☐ Report attached

2. **Adequacy** ☑ ICs are adequate ☐ ICs are inadequate ☐ N/A
Remarks

D. General

1. **Vandalism/trespassing** ☐ Location shown on site map ☑ No vandalism evident
Remarks

2. **Land use changes on site** ☑ N/A
Remarks

3. **Land use changes off site** ☑ N/A
Remarks

VI. *GENERAL SITE CONDITIONS*

A. Roads ☑ Applicable ☐ N/A

1. **Roads damaged** ☐ Location shown on site map ☑ Roads adequate ☐ N/A
Remarks

B. Other Site Conditions

Remarks

VII. LANDFILL COVERS ☑ Applicable ☐ N/A

A. Landfill Surface

1. **Settlement** (Low spots) ☐ Location shown on site map ☑ Settlement not evident
   Areal extent________ Depth________
   Remarks Site covered with 6 to 8 inches of snow, therefore it was difficult to see cover

2. **Cracks** ☐ Location shown on site map ☑ Cracking not evident
   Lengths________ Widths________ Depths________
   Remarks Same remark as above

3. **Erosion** ☐ Location shown on site map ☑ Erosion not evident
   Areal extent________ Depth________
   Remarks Same remark as above

4. **Holes** ☐ Location shown on site map ☑ Holes not evident
   Areal extent________ Depth________
   Remarks Same remark as above

5. **Vegetative Cover** ☐ Grass ☐ Cover properly established ☑ No signs of stress
   ☐ Trees/Shrubs (indicate size and locations on a diagram)
   Remarks Same remark as above

6. **Alternative Cover (armored rock, concrete, etc.)** ☑ N/A
   Remarks

7. **Bulges** ☐ Location shown on site map ☑ Bulges not evident
   Areal extent________ Height________
   Remarks Same remark as above

8. **Wet Areas/Water Damage** ☑ Wet areas/water damage not evident
   ☐ Wet areas ☐ Location shown on site map Areal extent________
   ☐ Ponding ☐ Location shown on site map Areal extent________
   ☐ Seeps ☐ Location shown on site map Areal extent________
   ☐ Soft subgrade ☐ Location shown on site map Areal extent________
   Remarks Same remark as above

9. **Slope Instability** ☐ Slides ☐ Location shown on site map ☑ No evidence of slope instability
Areal extent____________
Remarks Same as remark on previous page

B. Benches ☑ Applicable ☐ N/A
(Horizontally constructed mounds of earth placed across a steep landfill side slope to interrupt the slope in order to slow down the velocity of surface runoff and intercept and convey the runoff to a lined channel.)

1. **Flows Bypass Bench** ☐ Location shown on site map ☑ N/A or okay
Remarks____________

2. **Bench Breached** ☐ Location shown on site map ☑ N/A or okay
Remarks____________

3. **Bench Overtopped** ☐ Location shown on site map ☑ N/A or okay
Remarks____________

C. Letdown Channels ☑ Applicable ☐ N/A
(Channel lined with erosion control mats, riprap, grout bags, or gabions that descend down the steep side slope of the cover and will allow the runoff water collected by the benches to move off of the landfill cover without creating erosion gullies.)

1. **Settlement** ☐ Location shown on site map ☑ No evidence of settlement
Areal extent____________ Depth____________
Remarks____________

2. **Material Degradation** ☐ Location shown on site map ☑ No evidence of degradation
Material type____________ Areal extent____________
Remarks____________

3. **Erosion** ☐ Location shown on site map ☑ No evidence of erosion
Areal extent____________ Depth____________
Remarks____________

4. **Undercutting** ☐ Location shown on site map ☑ No evidence of undercutting
Areal extent____________ Depth__________
Remarks____

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5. **Obstructions** Type__________________ ☑ No obstructions
☐ Location shown on site map Areal extent____________
Size__________
Remarks____

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6. **Excessive Vegetative Growth** Type_________________
☑ No evidence of excessive growth
☐ Vegetation in channels does not obstruct flow
☐ Location shown on site map Areal extent____________
Remarks____

D. Cover Penetrations ☑ Applicable ☐ N/A

1. **Gas Vents** ☐ Active ☑ Passive
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☑ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance
☐ N/A
Remarks____

2. **Gas Monitoring Probes**
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance ☑ N/A
Remarks____

3. **Monitoring Wells** (within surface area of landfill)
☑ Properly secured/locked ☑ Functioning ☑ Routinely sampled ☑ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance ☐ N/A
Remarks____

4. **Leachate Extraction Wells**
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition
☐ Evidence of leakage at penetration ☐ Needs Maintenance ☑ N/A
Remarks____

5. **Settlement Monuments** ☐ Located ☐ Routinely surveyed ☑ N/A
Remarks____

E. Gas Collection and Treatment ☑ Applicable ☐ N/A

1. **Gas Treatment Facilities**
☐ Flaring ☐ Thermal destruction ☐ Collection for reuse
☑ Good condition ☐ Needs Maintenance
Remarks______________________________

2. **Gas Collection Wells, Manifolds and Piping**
☑ Good condition ☐ Needs Maintenance
Remarks______________________________

3. **Gas Monitoring Facilities** (*e.g.*, gas monitoring of adjacent homes or buildings)
☐ Good condition ☐ Needs Maintenance ☑ N/A
Remarks______________________________

F. Cover Drainage Layer ☑ Applicable ☐ N/A

1. **Outlet Pipes Inspected** ☐ Functioning ☑ N/A
Remarks______________________________

2. **Outlet Rock Inspected** ☐ Functioning ☑ N/A
Remarks______________________________

G. Detention/Sedimentation Ponds ☐ Applicable ☑ N/A

1. **Siltation** Areal extent____________ Depth____________ ☑ N/A
☐ Siltation not evident
Remarks______________________________

2. **Erosion** Areal extent____________ Depth____________
☑ Erosion not evident
Remarks______________________________

3. **Outlet Works** ☐ Functioning ☑ N/A
Remarks______________________________

4. **Dam** ☐ Functioning ☑ N/A
Remarks______________________________

H. Retaining Walls ☐ Applicable ☑ N/A

1. **Deformations** ☐ Location shown on site map ☐ Deformation not evident
Horizontal displacement__________ Vertical displacement__________
Rotational displacement__________
Remarks__________

2. **Degradation** ☐ Location shown on site map ☐ Degradation not evident
Remarks__________

I. Perimeter Ditches/Off-Site Discharge ☑ Applicable ☐ N/A

1. ***Siltation*** *☐ Location shown on site map ☑ Siltation not evident*
Areal extent__________ Depth__________
Remarks__________

2. **Vegetative Growth** ☐ Location shown on site map ☐ N/A
☑ Vegetation does not impede flow
Areal extent__________ Type__________
Remarks__________

3. **Erosion** ☐ Location shown on site map ☑ Erosion not evident
Areal extent__________ Depth__________
Remarks__________

4. **Discharge Structure** ☑ Functioning ☐ N/A
Remarks__________

VIII. VERTICAL BARRIER WALLS ☑ Applicable ☐ N/A

1. **Settlement** ☐ Location shown on site map ☑ Settlement not evident
Areal extent__________ Depth__________
Remarks__________

2. **Performance Monitoring** Type of monitoring Inspections
☐ Performance not monitored
Frequency Quarterly ☐ Evidence of breaching
Head differential__________
Remarks__________

IX. GROUNDWATER/SURFACE WATER REMEDIES [✓ Applicable] N/A

A. Groundwater Extraction Wells, Pumps, and Pipelines Applicable N/A

1. **Pumps, Wellhead Plumbing, and Electrical**
[✓ Good condition] [✓ All required wells properly operating] Needs Maintenance N/A
Remarks______________________________

2. **Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
[✓ Good condition] Needs Maintenance
Remarks______________________________

3. **Spare Parts and Equipment**
Readily available [✓ Good condition] Requires upgrade Needs to be provided
Remarks______________________________

B. Surface Water Collection Structures, Pumps, and Pipelines Applicable [✓ N/A]

1. **Collection Structures, Pumps, and Electrical**
Good condition Needs Maintenance
Remarks______________________________

2. **Surface Water Collection System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
Good condition Needs Maintenance
Remarks______________________________

3. **Spare Parts and Equipment**
Readily available Good condition Requires upgrade Needs to be provided
Remarks______________________________

C. Treatment System ☑ Applicable ☐ N/A

1. **Treatment Train** (Check components that apply)
☐ Metals removal ☐ Oil/water separation ☐ Bioremediation
☐ Air stripping ☐ Carbon adsorbers
☐ Filters
☐ Additive (*e.g.*, chelation agent, flocculent)
☐ Others
☑ Good condition ☐ Needs Maintenance
☑ Sampling ports properly marked and functional
☑ Sampling/maintenance log displayed and up to date
☑ Equipment properly identified
☑ Quantity of groundwater treated annually
☐ Quantity of surface water treated annually
Remarks

2. **Electrical Enclosures and Panels** (properly rated and functional)
☐ N/A ☑ Good condition ☐ Needs Maintenance
Remarks

3. **Tanks, Vaults, Storage Vessels**
☐ N/A ☑ Good condition ☐ Proper secondary containment ☐ Needs Maintenance
Remarks

4. **Discharge Structure and Appurtenances**
☐ N/A ☑ Good condition ☐ Needs Maintenance
Remarks

5. **Treatment Building(s)**
☐ N/A ☑ Good condition (esp. roof and doorways) ☐ Needs repair
☐ Chemicals and equipment properly stored
Remarks

6. **Monitoring Wells** (pump and treatment remedy)
☑ Properly secured/locked ☑ Functioning ☑ Routinely sampled ☑ Good condition
☐ All required wells located ☐ Needs Maintenance ☐ N/A
Remarks

D. Monitoring Data

1. Monitoring Data
☑ Is routinely submitted on time ☑ Is of acceptable quality

2. Monitoring data suggests:
☑ Groundwater plume is effectively contained ☑ Contaminant concentrations are declining

D. Monitored Natural Attenuation

1. **Monitoring Wells** (natural attenuation remedy)
☐ Properly secured/locked ☐ Functioning ☐ Routinely sampled ☐ Good condition
☐ All required wells located ☐ Needs Maintenance ☑ N/A
Remarks

X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy. An example would be soil vapor extraction.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

The remedy is functioning as intended.

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

C. Early Indicators of Potential Remedy Problems

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future.

D. Opportunities for Optimization

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

ATTACHMENT 7

LAKOTA EAST HIGH SCHOOL INAUGURATION

Students to experience history

By Lindsey Hilty
Staff Writer

If Lakota East senior Lilly Appelfeller had the chance to meet President-Elect Barack Obama and his family, she said she would launch herself forward, pen outstretched with the request, "Here, can you sign my face?"

Well, maybe she wouldn't launch herself, she said, considering security at the Inauguration will be tighter than spandex on a hippo.

But if she does see him during her tour of Washington, D.C. next week, she said she would be thrilled.

"I'm looking forward to it, and maybe if I see Obama, I would shake his hand or something," she said.

East Senior Kara Ruder said she figures the group of 34 Lakota students won't even come close to the action Jan. 20 with the millions of spectators.

"I want to see the (first) kids from a distance, at least," she said. "I figure there'll be so much security it will be ridiculous."

East history teachers Carolyn Smardon and Jennifer Reid said this is their third Presidential Inauguration, and they were able to get tickets through House Minority Leader John Boehner's office. However, with the first black president taking office, this Inauguration will be different, Smardon said.

With an average temperature close to freezing and the chance of snow and rain, she said it will not be for the faint of heart as students stand outside for five hours with more than five million people.

Although students might be far away from the president, depending on where their tickets place them in the crowd, Reid said there will be giant televisions broadcasting the action and students may take binoculars.

"You're there with this enormous crowd of Americans witnessing history and it's very electric," she said. "It's still a thrilling experience, even if you're not in the front row."

Jessica R. Towhey, press secretary for Boehner's office, said because the congressman is on the Joint Congressional Committee on Inaugural Ceremonies, he was given extra tickets to fill requests.

"We really made the effort to fulfill every request that came in from our district," she said. "We had a lot of requests. This is a historic event that people are very interested in attending."

Contact this reporter at (513) 755-5067 or lhilty@coxohio.com.

Read all about it

Both Lilly Appelfeller and Kara Ruder will update area readers on their adventures in Washington, D.C., through daily blog updates and photo galleries at www.pulsejournal.com/inauguration.

Their tour will include visits to historic monuments, museums and memorials as well as an informal inaugural ball for teens.

Parents, staff weigh options for curriculum

By Lindsey Hilty
Staff Writer

Several hundred Lakota residents and staff members attended a mathematics open house at Liberty Early Childhood School on Tuesday, Jan. 13, to weigh in on what curriculum should be used district-wide.

Each building, and sometimes each teacher, has chosen which math curriculum to use in the past. With the implementation of a new unified program, students will see an increased algebraic focus and a shift in the way they are taught.

"The materials will align to the curriculum units," said Lon Stettler, assistant superintendent of elementary education.

No matter which building a student attends, he or she will receive math up to Lakota standards, which he said will be higher than state standards.

"I think it was an essential piece of the process, because it allowed us to hear of past experiences, ways we can improve our math curriculum, and learn what's important to parents in the math curriculum," said district spokeswoman Laura Kursman. "This is a really big decision for the district."

The only choice for grades seven and eight is Glencoe's Math Connects Math Scape Courses 2-3. For the younger grades, there is Pearson's Investigations in Number, Data and Space 2-[illegible] and Everyday Mathematics [illegible] by Wright Group.

After compiling parent suggestions, a committee of administrators will make a recommendation to the Student Success Committee, which will send a formal proposal to Superintendent Mike Taylor. The goal is for the board to approve the program in time to get materials to teachers this spring.

Investigations has a three-prong approach, with textbook, inquiry-based learning and investigation.

Jack Heun of the Wright Group said his program is assessment driven, so parents and teachers know exactly where a child fares on the path to achieving state standards. With a continual progression of topics, he said students will see the same lessons repeated in increasing difficulty and the same games and exercises. There are student journals, online references, tutorials for parents and an interactive audio component for visual or auditory learners. The method of teaching has been developed from three decades of research and application that is teacher friendly and structured, teaching students to think differently about math, he said.

"The goal is that each child in the classroom is comfortable seeing a problem they've never seen before and knowing ways to attack it," he said.

›› On the Web
Lakota school news, issues
pulsejournal.com/lakotashoolnews

Local singer reported to be in top 50 on 'Idol'

By Richard O. Jones
Staff Writer

Season eight of "American Idol," the popular singing competition, began at 8 p.m. Tuesday, Jan. 13, on Fox, and fans of the local band Instereo will be tuning in to see how far singer Ryan P.A. Johnson makes it.

Ryan Johnson

According to his agreement with the producers and the Fox television network, Johnson isn't allowed to speak to the media until he is eliminated or wins the competition.

But sources close to the band say that Johnson traveled to California last fall for taping after winning a local competition and a regional audition in Louisville.

Also, Internet "spoiler" sites are reporting that Johnson has at least made it to the top 50 performers.

Audition rounds will be broadcast through Jan. 29. Hollywood rounds will be broadcast through Feb. 11.

Live broadcasts with season eight finalists begin Feb. 18. Locally, "American Idol" is broadcast at 8 p.m. on WXIX-TV.

For more information on Johnson, visit Instereo's Web site at www.instereoband.com.

Contact this reporter at (513) 820-2168 or rjones@coxohio.com

ATTACHMENT 8

TABLE 2

Groundwater-Waste Monitoring Summary

Skinner Landfill
West Chester, Ohio

Piezometer ID		**P-9R**	**P-10R**	**P-11R**	**P-12R**	
Grade Elevation (feet)		760.12	761.87	760.39	750.11	
Bottom of Waste Elevation (MSL-feet)		**731.92**	**729.87**	**728.00**	**722.61**	
Depth to Bottom of Waste (feet)		28.20	32.00	32.39	27.50	Comments
Groundwater Elevation (ft):	**22-Jan-07**	747.70	739.52	734.04	721.24	**BASELINE**
	02-Mar-07	748.03	740.60	735.68	718.17	1rst Q 2007
	11-Jun-07	746.34	751.34*	737.08	716.70	2nd Q 2007
	04-Sep-07	736.49	737.73	733.49	712.61	3rd Q 2007
	17-Dec-07	745.36	736.92	731.13	714.31	4th Q 2007
	10-Mar-08	747.61	739.04	733.71	717.42	1st Q 2008
	02-Jun-08	748.06	740.44	739.15	719.10	2nd Q 2008
	16-Sep-08	743.09	738.64	735.98	714.85	3rd Q 2008

Notes:

Bottom-of-Waste elevations determined during installation of new piezometers from 12/6/06 through 12/11/06.
Shaded cells indicate water level elevations below the elevation of waste.
* Groundwater Elevation suspect.

ATTACHMENT 9

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2004

Sample ID	**VOCs**	**SVOCs**	**Dissolved Metals****	**Pesticides/PCBs**
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	-	-	-	-

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2004

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	*	*	*	*

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Fourth Quarter 2004

Sample ID	**VOCs**	**SVOCs**	**Dissolved Metals****	**Pesticides/PCBs**
SW-50	-	-	*arsenic, selenium*	-
SW-51	-	-	*arsenic*	-
SW-52	-	-	**arsenic**	-
SWD-1	*	*	*	*
SWD-2	-	-	**arsenic**	-
SWD-3	-	-	**arsenic**, *zinc*	-

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2005

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	*arsenic*	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	-	-	-	-

\- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2005

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	**chromium**	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	*	*	*	*

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2005

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	*	*	*	*

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Fourth Quarter 2005

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	-	-	-	-

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2006

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	-	-	*Zinc*	-
SWD-2	-	-	*Zinc*	-
SWD-3	-	-	-	-

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2006

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	*	*	*	*

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2006

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	*Zinc*	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	-	-	*Zinc*	-

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

Table 4

Surface Water Summary

Skinner Landfill
West Chester, Ohio
Fourth Quarter 2006

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	-	-	-	-

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

TABLE 4

Surface Water Test Results Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	-	-	-	-
SWD-3	-	-	-	-

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

TABLE 4

Surface Water Test Results Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	-	-	-	-
SW-51	-	-	-	-
SW-52	-	-	-	-
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	-	-	-	-

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

TABLE 4

Surface Water Test Results Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	—	—	—	—
SW-51	—	—	—	—
SW-52	—	—	—	—
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	*	*	*	*

Notes:

— : all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* : Insufficient sample volume or location dry.

** : Dissolved metals for analytes that have a corresponding trigger level.

TABLE 4

Surface Water Test Results Summary

Skinner Landfill
West Chester, Ohio
Fourth Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	—	—	—	—
SW-51	—	—	—	—
SW-52	—	—	—	—
SWD-1	—	—	—	—
SWD-2	—	—	—	—
SWD-3	—	—	—	—

Notes:

— : all parameters below report limits
italic : above Contract Required Quantitation Levels (CRQL's)
bold : above trigger level
* : Insufficient sample volume or location dry.
** : Dissolved metals for analytes that have a corresponding trigger level.

TABLE 4

Surface Water Test Results Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2008

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	—	—	—	—
SW-51	—	—	—	—
SW-52	—	—	—	—
SWD-1	—	—	*Zinc*	—
SWD-2	—	—	—	—
SWD-3	—	—	—	—

Notes:

-- : all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* Insufficient sample volume or location dry.

** : Dissolved metals for analytes that have a corresponding trigger level.

TABLE 4

Surface Water Test Results Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2008

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	—	—	—	—
SW-51	—	—	—	—
SW-52	—	—	*Zinc*	—
SWD-1	—	—	***Zinc***	—
SWD-2	—	*Acenaphthene* *2,4-Dimethylphenol* ***Fluoranthene*** ***Naphthalene*** ***Phenanthrene*** ***Phenol***	—	—
SWD-3	—	—	—	—

Notes:

— all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* Insufficient sample volume or location dry

** Dissolved metals for analytes that have a corresponding trigger level

EarthTech
A Tyco International Ltd. Company

TABLE 4

Surface Water Test Results Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2008

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
SW-50	—	—	—	—
SW-51	—	—	—	—
SW-52	—	—	*Lead*	—
SWD-1	*	*	*	*
SWD-2	*	*	*	*
SWD-3	*	*	*	*

Notes:

— : all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* Insufficient sample volume or location dry.

** : Dissolved metals for analytes that have a corresponding trigger level.

ATTACHMENT 10

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2004

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	*iron*	-
GW-07R	-	-	-	-
GW-58	not sampled	not sampled	not sampled	not sampled
GW-59	-	-	-	-
GW-60	-	-	-	-
GW-61	-	-	*iron*	-
GW-62A	-	-	-	-
GW-62B	**benzene**	*	*	*
GW-63	-	-	*iron*	-
GW-64	-	-	-	-
GW-65	-	-	*	*

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.
GW-58 not sampled due to wasp nest in standpipe.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2004

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	*barium*	-
GW-07R	-	-	-	-
GW-58	*	*	*	*
GW-59	-	-	-	-
GW-60	*	*	*	*
GW-61	-	-	*iron*	-
GW-62A	-	-	-	-
GW-62B	*	*	*	*
GW-63	-	-	*iron*	-
GW-64	-	-	-	-
GW-65	*	*	*	*

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Fourth Quarter 2004

Sample ID	**VOCs**	**SVOCs**	**Dissolved Metals****	**Pesticides/PCBs**
GW-06R	-	-	**arsenic**, *iron*	-
GW-07R	-	-	**arsenic, selenium**	-
GW-24	-	-	*arsenic, iron*	-
GW-26	-	-	*arsenic, barium, selenium*	-
GW-30	-	-	*arsenic, barium, iron*	-
GW-58	-	-	*arsenic, iron, selenium*	-
GW-59	-	-	**arsenic**	-
GW-60	-	-	**arsenic**, *selenium*	-
GW-61	-	-	**arsenic**, *iron*	-
GW-62A	-	-	*arsenic*	-
GW-62B	-	-	*	*
GW-63	-	-	**arsenic**, *iron, selenium*	-
GW-64	-	-	**arsenic**	-
GW-65	-	*	*	*

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2005

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	-	-
GW-07R	-	-	-	-
GW-58	-	-	-	-
GW-59	-	-	-	-
GW-60	-	-	-	-
GW-61	-	-	*arsenic*	-
GW-62A	-	-	*iron*	-
GW-62B	-	*	*	*
GW-63	-	-	*arsenic , iron*	-
GW-64	-	-	-	-
GW-65	*	*	*	*

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2005

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	-	-
GW-07R	-	-	**chromium**	-
GW-58	-	-	-	-
GW-59	-	-	-	-
GW-60	-	-	-	-
GW-61	-	-	*iron*	-
GW-62A	-	-	-	-
GW-62B	-	*	*	*
GW-63	-	-	*iron*	-
GW-64	-	-	-	-
GW-65	*	*	*	*

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2005

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	*barium*	-
GW-07R	-	*	*	*
GW-24	-	-	*iron*	-
GW-26	-	-	*barium, iron*	-
GW-30	-	-	*barium, iron*	-
GW-58	-	-	-	-
GW-59	-	-	-	-
GW-60	*	*	*	*
GW-61	-	-	**chromium**, *iron*	-
GW-62A	-	-	-	-
GW-62B	-	*	*	*
GW-63	-	-	*iron, zinc*	-
GW-64	-	-	*iron*	-
GW-65	-	*	*	*

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner *Landfill*
West Chester, Ohio
Fourth Quarter 2005

Sample ID	**VOCs**	**SVOCs**	**Dissolved Metals****	**Pesticides/PCBs**
GW-06R	-	-	-	-
GW-07R	-	*	*	*
GW-58	-	-	-	-
GW-59	-	-	-	-
GW-60	-	*	*	*
GW-61	*	*	*	*
GW-62A	-	-	-	-
GW-62B	*	*	*	*
GW-63	-	-	*Iron*	-
GW-64	-	-	-	-
GW-65	*	*	*	*

- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2006

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	-	-
GW-07R	-	-	*Iron*	-
GW-58	-	-	*Barium, Iron,* **Mercury**	-
GW-59	-	-	-	-
GW-60	-	-	-	-
GW-61	*2-Butanone*	-	*Iron*	-
GW-62A	-	-	*	-
GW-62B	*2-Butanone*	-	*	*
GW-63	-	-	-	-
GW-64	*2-Butanone*	-	-	-
GW-65	-	*	*	*

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2006

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	*Barium, Iron*	-
GW-07R	-	-	-	-
GW-58	-	-	*Barium, Iron*	-
GW-59	-	-	-	-
GW-60	-	-	*	-
GW-61	-	-	*Iron*	-
GW-62A	-	-	-	-
GW-62B	*	*	*	*
GW-63	-	-	*Iron*	-
GW-64	-	-	-	-
GW-65	*	*	*	*

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2006

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	*Barium, Iron*	-
GW-07R	-	-	*Iron,* ***Cyanide*** $(_{1})$	-
GW-58	-	-	***Cyanide*** $(_{1})$	-
GW-59	-	-	-	-
GW-60	-	-	*	*
GW-61	-	-	*Iron*	-
GW-62A	-	-	-	-
GW-62B	-	*	*	*
GW-63	-	-	*Iron*	-
GW-64	-	-	***Cyanide*** $(_{1})$	-
GW-65	-	-	*	-
GW-24	-	-	*Iron*	-
GW-26	-	-	*Barium, Iron*	-
GW-30	-	-	*Barium, Iron*	-

\- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

$_{(1)}$ Total Cyanide

Table 3

Groundwater Summary

Skinner Landfill
West Chester, Ohio
Fourth Quarter 2006

Sample ID	**VOCs**	**SVOCs**	**Dissolved Metals****	**Pesticides/PCBs**
GW-06R	-	-	*Barium, Iron*	-
GW-07R	-	-	*Iron*	-
GW-58	-	-	-	-
GW-59	-	-	-	-
GW-60	-	-	-	-
GW-61	-	-	*Iron*	-
GW-62A	-	-	-	-
GW-62B	*	*	*	*
GW-63	-	-	*Iron*	-
GW-64	-	-	-	-
GW-65	-	*	*	*
GW-24	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-26	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-30	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume.
** - Dissolved metals for analytes that have a corresponding trigger level.
(1) The concentration of Cyanide has been reported from the total fraction because the CLP SOW ILM04.0 only specifies for the analysis of Total Cyanide.

TABLE 3

Groundwater Test Results Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	*Barium, Iron*	-
GW-07R	-	-	*Iron*	-
GW-58	-	-	*Barium, Iron*	-
GW-59	-	-	-	-
GW-60	-	-	-	-
GW-61	-	-	*Iron*	-
GW-62A	-	-	-	-
GW-62B	*	*	*	*
GW-63	-	-	-	-
GW-64	-	-	-	-
GW-65	-	*	*	*
GW-24	-	-	*Iron*	-
GW-26	-	-	*Barium*	-
GW-30	-	-	*Iron*	-

\- all parameters below report limits

italic - above Contract Required Quantitation Levels (CRQL's)

bold - above trigger level

* - Insufficient sample volume.

** - Dissolved metals for analytes that have a corresponding trigger level.

(1 The concentration of Cyanide has been reported from the total fraction because the CLP SOW ILM04.0 only specifies for the analysis of Total Cyanide.

TABLE 3

Groundwater Test Results Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	-	-	*Barium, Iron*	-
GW-07R	-	-	-	-
GW-58	-	-	*Zinc*	-
GW-59	-	-	*Iron*	-
GW-60	-	-	*	*
GW-61	-	-	*Zinc*	-
GW-62A	-	-	*Zinc*	-
GW-62B	*	*	*	*
GW-63	-	-	*Iron*	-
GW-64	-	-	-	-
GW-65	-	-	*	*
GW-24	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-26	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-30	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			

- all parameters below report limits
italic - above Contract Required Quantitation Levels (CRQL's)
bold - above trigger level
* - Insufficient sample volume
** - Dissolved metals for analytes that have a corresponding trigger level

EarthTech

TABLE 3

Groundwater Test Results Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	—	—	*Barium, Iron*	—
GW-07R	—	*	*	*
GW-58	—	—	—	—
GW-59	—	—	—	—
GW-60	*	*	*	*
GW-61	—	—	—	—
GW-62A	—	—	*Iron*	—
GW-62B	*	*	*	*
GW-63	—	—	***Cyanide*** (1)	—
GW-64	—	—	—	—
GW-65	*	*	*	*
GW-24	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-26	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-30	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			

Notes:

— all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* : Insufficient sample volume or location dry

** Dissolved metals for analytes that have a corresponding trigger level

(1) Total Cyanide

TABLE 3

Groundwater Test Results Summary

Skinner Landfill
West Chester, Ohio
Fourth Quarter 2007

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	—	—	*Iron*	—
GW-07R	—	—	*Iron*	—
GW-58	—	—	—	—
GW-59	—	—	—	—
GW-60	—	—	—	—
GW-61	—	—	*Iron*	—
GW-62A	—	—	*Iron*	—
GW-62B	—	—	*	—
GW-63	—	—	—	—
GW-64	—	—	—	—
GW-65	—	—	*	—
GW-24	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-26	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-30	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			

Notes:

— all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* Insufficient sample volume or location dry.

** : Dissolved metals for analytes that have a corresponding trigger level

(1) Total Cyanide

TABLE 3

Groundwater Test Results Summary

Skinner Landfill
West Chester, Ohio
First Quarter 2008

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	—	—	—	—
GW-07R	—	—	—	—
GW-58	—	—	—	—
GW-59	—	—	*Zinc*	—
GW-60	—	—	—	—
GW-61	—	—	—	—
GW-62A	—	—	—	—
GW-62B	—	—	*Zinc*	—
GW-63	—	—	—	—
GW-64	—	—	—	—
GW-65	—	—	*Iron*	—
GW-24 (Perimeter Well)	—	—	*Iron*	—
GW-26 (Perimeter Well)	—	*bis(2-ethylhexyl)phthalate*	*Barium*	—
GW-30 (Perimeter Well)	—	—	*Iron*	—

Notes:

— all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* Insufficient sample volume or location dry

** Dissolved metals for analytes that have a corresponding trigger level

(1) Total Cyanide.

TABLE 3

Groundwater Test Results Summary

Skinner Landfill
West Chester, Ohio
Second Quarter 2008

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	—	—	*Barium, Iron*	--
GW-07R	—	*bis(2-ethylhexyl)phthalate*	—	--
GW-58	—	—	—	--
GW-59	—	—	—	--
GW-60	—	*bis(2-ethylhexyl)phthalate*	—	--
GW-61	—	—	*Iron, Lead, Zinc*	--
GW-62A	—	—	—	--
GW-62B	—	—	*Lead, Zinc*	--
GW-63	—	—	*Iron*	--
GW-64	—	—	*Lead*	--
GW-65	—	—	—	--
GW-24 (Perimeter Well)	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-26 (Perimeter Well)	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-30 (Perimeter Well)	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			

Notes:

-- : all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* : Insufficient sample volume or location dry.

** : Dissolved metals for analytes that have a corresponding trigger level

EarthTech
A Tyco International Ltd Company

TABLE 3

Groundwater Test Results Summary

Skinner Landfill
West Chester, Ohio
Third Quarter 2008

Sample ID	VOCs	SVOCs	Dissolved Metals**	Pesticides/PCBs
GW-06R	—	—	—	—
GW-07R	—	—	*Iron*	—
GW-58	—	—	—	—
GW-59	—	—	—	—
GW-60	*	*	*	*
GW-61	—	—	—	—
GW-62A	—	—	—	—
GW-62B	—	—	*Iron and Zinc*	—
GW-63	—	—	—	—
GW-64	—	—	—	—
GW-65	*	*	*	*
GW-24 (Perimeter Well)	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-26 (Perimeter Well)	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			
GW-30 (Perimeter Well)	Monitoring Well Outside Fenced area sampled annually (not sampled this quarter)			

Notes:

-- : all parameters below report limits

italic : above Contract Required Quantitation Levels (CRQL's)

bold : above trigger level

* Insufficient sample volume or location dry.

** : Dissolved metals for analytes that have a corresponding trigger level

First Five-Year Review Report

for

Solvents Recovery Service of New England, Inc. Superfund Site

Southington, Hartford County, Connecticut

September 2010

Prepared by

U.S. Environmental Protection Agency
Region 1

Boston, Massachusetts

James T. Owens, III, Director
Office of Site Remediation and Restoration
United States Environmental Protection Agency
Region 1

9/29/10
Date

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Acronyms and Abbreviations

ADAFs	Age-Dependent Adjustment Factors
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substance and Disease Registry
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CL&P	Connecticut Light & Power
CTDEP	Connecticut Department of Environmental Protection
CTDPH	Connecticut Department of Public Health
DOJ	United States Department of Justice
EPA	United States Environmental Protection Agency
ft bgs	feet below ground surface
HCTS	Hydraulic Containment and Treatment System
IMS	Interim Monitoring and Sampling
IRIS	Integrated Risk Information System
ISTR	In-situ Thermal Remediation
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	Monitored Natural Attenuation
NAPL	non-aqueous phase liquid
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTCRA	Non-Time-Critical Removal Action
O&M	Operations and Maintenance
OIS	On-Site Interceptor System
OSWER	Office of Solid Waste and Emergency Response
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	perchloroethylene
PIPP	Pre-ISTR Preparation Plan
PRGs	Preliminary Remediation Goals
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RDWP	Remedial Design Work Plan
RD/RA	Remedial Design/Remedial Action
ROD	Record of Decision
RSRs	Connecticut Remediation Standard Regulations
SOW	Statement of Work
SRSNE	Solvents Recovery Service of New England, Inc.
SVOCs	semi-volatile organic compounds
TCE	trichloroethylene
ug/L	micrograms per liter
$\mu g/m^3$	micrograms per meter cubed
UV/ox	ultraviolet/oxidation
VOCs	volatile organic compounds

Executive Summary

This five-year review report was prepared for the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site, located in Southington, Hartford County, Connecticut. The Site, which encompasses the former Operations Area and the extent of impacted groundwater, is approximately 42 acres. Land use in the immediate vicinity of the SRSNE Site is mixed residential, commercial and light industrial, and has not changed since the Record of Decision (ROD) was issued in 2005. Public water is available to all downgradient properties.

The SRSNE facility began operating in Southington in 1955. Spent solvents were received from customers and distilled to remove impurities until the facility's closure in 1991. During processing, numerous spills to bare ground occurred, and two unlined lagoons were used for part of the operational period for storage of still bottoms. As a result, soil and groundwater are impacted above acceptable risk levels, primarily by solvents. Non-aqueous phase liquids (NAPL) are present in the overburden and fractured bedrock.

Migration of contaminated groundwater is controlled by two Non-Time-Critical Removal Actions (NTCRAs) that were implemented at the Site in the 1990's and became part of the final Site remedy with issuance of the ROD. Contaminated groundwater in both the overburden and bedrock aquifers is hydraulically contained and treated on site.

The remedy selected by EPA for the Site was set forth in the September 2005 ROD. Key elements of the remedy are as follows:

- In-situ thermal treatment of contaminants in the overburden aquifer NAPL area until site-specific NAPL performance standards are achieved;
- Excavate, consolidate and cap soil and wetland soil (including river sediment) that exceeds cleanup levels (see Table 6);
- Capture and on-site treatment of contaminated groundwater in both the overburden and bedrock aquifers, until federal safe drinking water standards and other risk-based levels are achieved;
- Over time, modification of the configuration of the on-site groundwater extraction and treatment system, as appropriate, based on expected reductions in contamination;
- Monitor natural attenuation of the groundwater plume including a) groundwater outside the capture zone of the extraction and treatment system until groundwater cleanup levels are achieved and b) contaminants in the NAPL area of the bedrock aquifer until groundwater cleanup levels are achieved (see Table 5);
- Implement restrictions on uses of the Site in perpetuity to prevent human exposure to contaminants in the subsurface soils and to prohibit activities that might harm the cap.

Implement institutional controls to prevent human exposure to contaminated groundwater and NAPL areas until appropriate levels are met. These restrictions will also prohibit construction above that portion of the groundwater plume that exceeds federal and state volatilization criteria, if studies conducted during remedial design confirm the need for such restrictions;

- Maintain the cap in the long term; and
- Perform reviews at least every five years to ensure that the remedy remains protective of human health and the environment.
- Contingent remedy – In the event that the Southington Water District decides to re-activate municipal production wells located near the Site prior to attainment of federal drinking water standards and other risk-based levels throughout the Site, additional groundwater containment is required.

Pursuant to a Consent Decree entered on March 26, 2009, by the United States District Court for the District of Connecticut, a group of potentially responsible parties (SRSNE Site Group) agreed to conduct the cleanup of the Site as set forth in the ROD. Since entry of the Consent Decree, monitored natural attenuation of groundwater is ongoing and remedial design activities, sampling and continued operations of the NTCRA groundwater containment systems have been undertaken by the SRSNE Site Group.

This is the first five-year review for the Site. The requirement for conducting five-year reviews is incorporated in Section 121(c) of CERCLA 42 § 9621(c). Depending on the selected remedial action, the five-year review may be required by statute or conducted as a matter of EPA policy. This is a statutory review, conducted five years from the issuance of the ROD in September 2005.

Based upon a review of the ROD, remedial design documents, data collected during sampling events, operation and maintenance reports, and an inspection of the Site, the remedy at the SRSNE Site is expected to be protective of human health and the environment upon completion of the remedy, and in the interim, exposure pathways that could result in unacceptable risks are being controlled.

Access control in the form of fencing and paving are in place, and currently limit exposure to soil that presents an unacceptable human-health risk. In addition, groundwater beneath and down gradient of the Site is not currently used as drinking water. Finally, although the vapor intrusion investigation is not yet complete, there are currently no structures without vapor controls above the area where groundwater presents possible vapor intrusion issues. As a result, this possible exposure pathway is not complete.

Excavation of wetland soils and river sediment at the culvert outfall that pose an ecological risk, and, consolidation in the Operations Area where the contaminated material will be covered with clean fill is underway and will be completed by December 2010.

However, in order for the remedy to be protective in the long-term, the following actions need to be taken to ensure long-term protectiveness: major components of the remedy need to be implemented including in-situ thermal treatment of contaminants in groundwater; excavation, consolidation and capping of soil; vapor intrusion investigation and, if required, mitigation; and institutional controls. In addition, if 1, 4-dioxane is found in concentrations that exceed EPA's risk-screening level in that portion of the groundwater plume that is not contained, the monitored natural attenuation approach for addressing this contaminant in that portion of the plume may need to be re-evaluated.

Five-Year Review Summary Form

SITE IDENTIFICATION

Site name: Solvents Recovery Service of New England, Inc Superfund Site

EPA ID: CTD009717604

Region: 1 **State:** CT **City/County:** Southington/Hartford County

SITE STATUS

NPL status: ■ Final ☐ Deleted ☐ Other (specify)

Remediation status (choose all that apply): ■ Under Construction ☐ Operating ☐ Complete

Multiple OUs? ☐ YES ■ NO **Construction completion date:** N/A

Has site been put into reuse? ☐ YES ■ NO ☐ N/A

REVIEW STATUS

Lead agency: ■ EPA ☐ State ☐ Tribe ☐ Other Federal Agency __________________

Author name: Karen Lumino

Author title: RPM **Author affiliation:** EPA Region 1

Review period: 1/6/10 to 9/24/10

Date(s) of site inspection: 6/2/10

Type of review:
■ Post-SARA ☐ Pre-SARA ☐ NPL-Removal only
☐ Non-NPL Remedial Action Site ☐ NPL State/Tribe-lead
☐ Regional Discretion ☐ Policy ☐ Statutory

Review number: ■ 1 (first) ☐ 2 (second) ☐ 3 (third) ☐ Other (specify)_________

Triggering action:
☐ Actual RA Onsite Construction at OU #
☐ Construction Completion
■ Other (specify): Record of Decision
☐ Actual RA Start at OU#
☐ Previous Five-Year Review Report

Triggering action date ***(from WasteLAN)***: 9/30/05

Due date ***(five years after triggering action date)***: 9/30/10

Does the report include recommendation(s) and follow-up action(s)? ■ yes ☐ no
Is human exposure under control? ■ yes ☐ no
Is contaminated groundwater under control? ■ yes ☐ no ☐ not yet determined
Is the remedy protective of the environment? ■ yes ☐ no ☐ not yet determined
Acres in use or available for use: **restricted:** 42 **unrestricted: 0**

Five-Year Review Summary Form, cont'd.

Issues, Recommendations, and Follow-Up Actions

1) Although significant progress has been made, major components of the remedy need to be implemented including in-situ thermal treatment of contaminants in the overburden aquifer; excavation, consolidation and capping of soil; vapor intrusion investigation and possible mitigation; and institutional controls.

Preparation of the site for the in-situ thermal treatment began on September 13, 2010, and will be completed by December 2010. The contaminated soil in the railroad right-of-way and drainage ditch, as well as contaminated wetland soil and river sediment at the culvert outfall will be excavated during this phase of construction and used as fill material in the re-grading of the Operations Area. Startup of the in-situ thermal component is anticipated for early 2012. Upon completion of thermal treatment in 2014, the remaining soil targeted for excavation will be moved to the thermally-treated area and capped.

Groundwater data collected for the vapor intrusion investigation is undergoing validation and will be reviewed by EPA and CTDEP later this year; additional data may be needed for a multiple-lines-of-evidence analysis. Institutional controls are required by the ROD to prevent unacceptable exposure to groundwater, soil, subsurface NAPL, and possibly vapor intrusion in the future but have not yet been put in place. Completion of the vapor intrusion investigation triggers submission of a plan and schedule for implementing institutional controls.

2) If 1,4-dioxane is found in concentrations that exceed EPA's risk-screening level in that portion of the groundwater plume that is not contained, the monitored natural attenuation approach for addressing this contaminant in that portion of the plume may need to be re-evaluated.

Groundwater data collected this summer is undergoing validation and will be reviewed by EPA and CTDEP later this year.

Five-Year Review Summary Form, cont'd.

Protectiveness Statement

Based upon a review of the ROD, remedial design documents, data collected during sampling events, operation and maintenance reports and an inspection of the Site, the remedy at the SRSNE Site is expected to be protective of human health and the environment upon completion of the remedy, and in the interim, exposure pathways that could result in unacceptable risks are being controlled.

Access controls in the form of fencing and pavement are in place, and currently limit exposure to soil that presents an unacceptable human-health risk. In addition, groundwater beneath and downgradient of the Site is not currently used as drinking water. Finally, although the vapor intrusion investigation is not yet complete, there are currently no structures without vapor barriers above the area where groundwater presents possible vapor intrusion issues. As a result, this possible exposure pathway is not complete.

Excavation of wetland soil and river sediment at the culvert outfall that pose an ecological risk, and, consolidation in the Operations Area where the contaminated material will be covered with clean fill is underway and will be completed by December 2010.

However, in order for the remedy to be protective in the long term, the following actions need to be taken to ensure long-term protectiveness: major components of the remedy need to be implemented including in-situ thermal treatment of contaminants in the overburden aquifer; excavation, consolidation and capping of soil; vapor intrusion investigation and potential remediation; and institutional controls. In addition, if 1,4-dioxane is found in that portion of the groundwater plume that is not contained in concentrations that exceed EPA's risk-screening level, the monitored natural attenuation approach for addressing this contaminant in the portion of the plume may need to be re-evaluated.

FIVE-YEAR REVIEW REPORT

SECTION 1.0
INTRODUCTION

The purpose of the five-year review is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in Five-Year Review Reports. In addition, Five-Year Review Reports identify issues found during the review, if any, and identify recommendations to address them.

The United States Environmental Protection Agency (EPA) is preparing this Five-Year Review Report pursuant to CERCLA §121 and the National Contingency Plan. CERCLA §121 states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

40 CFR §300.430(f)(4)(ii) states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

EPA, Region 1, conducted this first five-year review of the remedy implemented at the Solvents Recovery Service of New England, Inc. (SRSNE) Site ("the Site"), located in the Town of Southington, Hartford County, Connecticut. This five-year review was conducted by EPA Remedial Project Manager Karen Lumino. The review was conducted in accordance with the *Comprehensive Five-Year Review Guidance* (OSWER Directive 9355.7-03B-P, June 2001). This report documents the results of the review, and will become part of the administrative record for the Site.

A five-year review is required at this Site due to the fact that hazardous substances, pollutants, or contaminants remain at the Site above levels that allow for unlimited use and unrestricted exposure.

In accordance with EPA's five-year review guidance, this first statutory five-year review is triggered by the date the Record of Decision (ROD) for the Site was signed and issued which occurred on September 30, 2005.

Based upon a review of the ROD, remedial design documents, data collected during sampling events, operation and maintenance reports, and an inspection of the Site, the remedy at the SRSNE Site is expected to be protective of human health and the environment upon completion of the remedy, and in the interim, exposure pathways that could result in unacceptable risks are being controlled.

Access control in the form of fencing and paving are in place, and currently limit exposure to soil that presents an unacceptable human-health risk. In addition, groundwater beneath and down gradient of the Site is not currently used as drinking water. Finally, although the vapor intrusion investigation is not yet complete, there are currently no structures without vapor controls above the area where groundwater presents possible vapor intrusion issues. As a result, this possible exposure pathway is not complete.

Excavation of approximately 1300 total cubic yards of wetland soils and river sediment at the culvert outfall that pose an ecological risk, and, consolidation in the Operations Area where the contaminated material will be covered with clean fill is underway and will be completed by December 2010.

However, in order for the remedy to be protective in the long-term, the following actions need to be taken to ensure long-term protectiveness: major components of the remedy need to be implemented including in-situ thermal treatment of contaminants in groundwater; excavation, consolidation and capping of soil; vapor intrusion investigation and, if required, mitigation; and institutional controls. In addition, if 1,4-dioxane is found at concentrations that exceed EPA's risk-screening level in that portion of the groundwater plume that is not being contained, the monitored natural attenuation approach for addressing that contaminant in the portion of that plume may need to be re-evaluated.

SECTION 2.0
SITE CHRONOLOGY

Table 1 (attached) summarizes the site-related events from discovery to date. Additional events and details are provided in Section 3.0, Background.

SECTION 3.0
BACKGROUND

3.1 Physical Characteristics and Land and Resource Use

The SRSNE Site is located on approximately 14 acres along Lazy Lane in Southington, Hartford County, Connecticut, approximately 15 miles southwest of the City of Hartford (Figure 1). The physical setting of the Site – including the regional geology, overburden geology, bedrock geology, hydrogeology, groundwater use and classification, drainage, and surface water use and classification – is summarized below.

The SRSNE Site encompasses portions of several properties/areas that include the former SRSNE Operations Area, the former Boston & Maine railroad right-of-way, the former Cianci Property, and the Town of Southington municipal well field. The Site includes all areas where contamination, which includes a broad range of volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), metals, pesticides and polychlorinated biphenyls (PCBs), has come to be located. There are no areas of architectural or historical importance within the Site.

These areas are shown on Figure 2, and further described below.

- **Former SRSNE Operations Area:** The former SRSNE Operations Area ("Operations Area") comprises approximately 2.5 paved acres on a 3.7-acre lot, south of Lazy Lane in the Quinnipiac River basin, approximately 600 feet west of the Quinnipiac River channel. This is the area where SRSNE historically performed solvent recovery and related operations. The Operations Area is bordered on the east (downhill) by an abandoned railroad right-of-way and the former Cianci Property; to the north by commercial businesses; to the west (uphill) by private property; and to the south by private property, the Connecticut Light & Power (CL&P) electrical transmission line easement, and the Town of Southington municipal well field.

- **Railroad Right-of-Way:** The railroad right-of-way is an approximately 50-foot wide corridor running north-south that separates the Operations Area (to the west) from the former Cianci Property (to the east). The railroad was historically owned and operated by Boston & Maine, but is presently abandoned and the rails have been removed. Connecticut Department of Environmental Protection (CTDEP) purchased the right-of-way in this area in support of extending the Farmington Canal Heritage Trail, a rails-to-trails greenway, from New Haven to the Massachusetts border.

- **Former Cianci Property:** The former Cianci Property is a 10-acre parcel located immediately east of the Operations Area and railroad right-of-way. The Quinnipiac River borders the eastern edge of the former Cianci Property. Lazy Lane is to the north, and the Town Well Field Property borders the property to the south.

- **Town of Southington Municipal Well Field:** The Town of Southington municipal well field ("Town Well Field") consists of approximately 28 acres of undeveloped land south of the Cianci Property and southeast of the Operations Area. The well field is bounded to the east by the Quinnipiac River and to the south by the Quinnipiac River and Curtiss Street. The railroad right-of-way and the Delahunty property border its western perimeter and the CL&P easement runs northwest-southeast through the northern portion of the Town Well Field.

Soil and/or groundwater contamination above acceptable levels has been found on/below these properties. Soil contamination above acceptable levels has been identified on the Operations Area, railroad right-of-way, and Cianci Property. Groundwater contamination (dissolved phase and NAPL) has been identified in both the overburden and bedrock aquifers (Figures 3A and 3B, respectively). A groundwater extraction and treatment system that was installed in the 1990's to prevent the migration of groundwater that exceeds federal safe drinking water standards and other risk-based levels continues to operate, and is described in greater detail in Section 3.3.

Geology, Hydrogeology, Land and Resource Use

Geology. The Site is located within the Connecticut Valley Lowland section of the New England physiographic province. The Connecticut Valley Lowland occupies a regional, structural rift basin, which is characterized by block-faulted and tilted bedrock strata. The geology of the region, in general, consists of the Upper Triassic New Haven Arkose bedrock, overlain by Wisconsin-age unconsolidated deposits formed when glaciers eroded and smoothed the bedrock hills.

The depth to bedrock varies throughout the Site, from approximately 15 to 40 feet below ground surface (ft bgs) at the Operations Area, to approximately 25 to 45 ft bgs, on the Cianci property, to approximately 80 to 100 ft bgs at the Town Well Field. Core samples and drilling observations indicate that the upper five feet of the bedrock is severely weathered and partially decomposed, and that the degree of weathering generally decreases with depth.

The overburden geology beneath the Operations Area and Cianci Property consists primarily of two unconsolidated layers. The upper layer, called outwash, extends from ground surface to approximately 10 to 25 ft bgs and consists of reddish-brown silty sand and gravel deposits, interbedded with discontinuous layers of silt and relatively well-sorted sand and gravel. The lower layer consists of glacial till, a generally unstratified unit consisting of reddish-brown clay, silt, sand, gravel, cobbles and boulders, but also including isolated, discontinuous sandy seams. Fill materials are present above the outwash in portions of the Operations Area and Cianci Property, where grading operations reworked the upper few feet of soil and filled low areas. Fill materials (ballast) are also observed along the railroad right-of-way. The overburden in the Town Well Field grades to a coarser distribution of sand and gravel, lacking fines.

Hydrogeology. Groundwater is present in the overburden and bedrock units. In the overburden, depth to the water table generally ranges from 0 to 10 ft bgs throughout the Site. The overburden and bedrock groundwater is recharged primarily via precipitation, although groundwater underflow also occurs from the north within the saturated zone in the vicinity of the Quinnipiac River.

Essentially all overburden and bedrock groundwater within the monitored geologic zones ultimately discharges to the Quinnipiac River and associated wetlands. The overburden and bedrock units are hydraulically connected. Where the till layer is relatively thick, it may limit the rate of groundwater flow between them. In areas where till is anomalously thin or absent, or lacks fine-grained material, more groundwater flow may occur between the overburden and bedrock.

Surface Water Hydrology. Surface water from precipitation falling within the Operations Area generally drains to the east, with surface runoff collected in a ditch on the west side of the existing railroad right-of-way. This ditch also collects runoff from areas to the north of the Operations Area, including areas north of Lazy Lane. An existing 30-inch culvert conveys water from this ditch easterly to the Quinnipiac River (BBL and EPA 2005).

The former Cianci property currently drains by overland flow to the east towards the Quinnipiac River and adjoining wetland and low-lying areas. The Town Well Field also drains by overland flow towards the east, although an intermittent stream collects some runoff in the eastern and central portions of the property (BBL and EPA 2005).

Land and Resource Use. Land use in the immediate vicinity of the SRSNE Site is mixed residential, commercial and light industrial, and has not changed since the issuance of the ROD in 2005.

Currently, use of the Site is limited to activities that support the cleanup activities selected in the ROD. There are no anticipated future uses for the Operations Area and Cianci Property other than those needed to perform the long-term components of the remedy (e.g., operation and maintenance on the cap, groundwater monitoring, etc).

With respect to the railroad right-of-way, the reasonably anticipated future use of this parcel is for recreational purposes, specifically, to redevelop this property to create a multi-purpose public path, known as a "rails-to-trails greenway."

Groundwater at the Site is not currently being used for drinking water. The on-site treatment building, the commercial/residential properties adjacent to and north of the Operations Area, the Southington police headquarters across the street from the Cianci Property, and the commercial/light industrial properties along Route 10 are all on public water. Approximately 85 residences on Lazy Lane, Melcon Street, Curtiss Street, Juniper Road, Little Fawn Road and Carrier Court are on domestic supply wells, but these properties are all to the west of and hydraulically upgradient from the SRSNE Site.

The potential beneficial use of groundwater at the Site and surrounding areas is for drinking water. Groundwater within the Site is currently classified by CTDEP as GA, GA-degraded or GAA. The State's goal for this aquifer is to maintain or restore the groundwater to its natural quality, suitable for drinking or other domestic uses without treatment.

The Quinnipiac River is not used as a drinking water supply. Adjacent to and south of the SRSNE Site there is limited access, as the river is a narrow, shallow meander bordered by steep banks along Queen Street to the east and the Town Well Field and fenced Cianci Property to the west. Seasonally low water and lack of access leads to little to no recreational use of the river in the vicinity of the Site.

Surface water along the Quinnipiac River adjacent to the Site is currently classified by CTDEP as Class C/B. This means that the state's goal for this surface water is Class B, although it is currently degraded to Class C. Class B surface waters are designated for recreational use, fish and wildlife habitat, agricultural and industrial supply, and other legitimate uses including navigation. Conditions that result in a Class C designation are usually correctable, and commonly relate to combined sewer overflows, urban runoff, inadequate municipal or industrial waste water treatment, and community-wide septic system failures.

Based on the State's classification, the potential beneficial use of the surface water is recreational use, fish and wildlife habitat, agricultural and industrial supply, and other legitimate uses including navigation.

3.2 History of Contamination

The SRSNE facility began operating in Southington in 1955 (ATSDR 1992). From approximately 1955 until the facility's closure in 1991, spent solvents were received from customers and distilled to remove impurities, and the recovered solvents were returned to the customer or sold to others for reuse.

Liquid wastes processed at the SRSNE facility included unrecoverable or spent solvent-based fuels, spent chlorinated solvents, and wastes generated from fuel-blending operations. Contact and non-contact distillation stream generated during the facility's distillation process were discharged into a subsurface drain pipe that discharged into a ditch along the west side of the Operations Area. From 1957 to approximately 1967, the non-recoverable portion of distilled solvents, consisting of distillation or still-bottom sludge, was stored in two unlined lagoons located in the Operations Area.

After the closure of the lagoons in 1967, wastes, including still-bottom sludge and flammable liquids, were incinerated in an open pit on site or disposed of off site. The open-pit incinerator burned approximately 1,000 gallons of solvent sludge per day between 1966 and 1974, when it was decommissioned (ATSDR 1992). The solvent-burning and fuel-blending operations involved handling, storage, and transfer activities that resulted in leaks and spills to bare ground within the Operations Area.

In 1976, VOCs were detected at the Town of Southington's Production Well No. 4, forcing its closure. Water-supply pumping shifted to Production Well No. 6 until 1979 when it too was closed due to the presence of VOCs (HNUS 1994). Subsequent environmental investigations revealed that the SRSNE Site was a major source of VOC contamination to the groundwater in the Town Well Field.

In 1983, EPA and SRSNE executed a Consent Decree that required the installation of a groundwater interceptor system along the downgradient property line of the Operations Area. The on-site interceptor system (OIS) was installed in 1985 and began operating in 1986 with the intended purpose of capturing overburden groundwater migrating from the Operations Area. Between 1986 and 1991, the OIS was used to extract and treat contaminated groundwater. The OIS used a cooling tower on the roof of the operations building that was converted to an air stripper to capture contamination, with treated groundwater discharging via a subsurface pipe to the ditch along the railroad tracks east of the Operations Area.

The 1983 Consent Decree also required modifications to SRSNE's solvent handling practices and the performance of subsurface investigations to assess environmental impacts associated with the Site. Between 1983 and the facility's closure in 1991, SRSNE made some improvements including spill control measures, paving the Operations Area, fire protection measures, and installation of a groundwater treatment system but did not meet other requirements.

In 1988, the three batch stills were removed, and spent solvents received by SRSNE were transferred to other facilities for the remainder of SRSNE's period of operations. An EPA Resource Conservation and Recovery Act (RCRA) inspection in February 1989 documented 75 cases of solvent releases from drums, tank trucks, hoses, and other solvent containers and transfer equipment during the previous year (EPA 1989).

Additional EPA and CTDEP enforcement orders were subsequently issued to compel SRSNE to perform further cleanup work at the facility. The facility ceased operating in March 1991 and was closed down in May 1991.

3.3 Initial Response

Pre-1994 Response Actions

Key regulatory milestones prior to 1994 are as follows:

- 1983: EPA adds SRSNE to the National Priorities List, thereby designating it a Superfund Site; SRSNE signs a Consent Decree with EPA to install an on-site groundwater interceptor system and propertly store/manage hazardous waste on site.
- 1983-1988: EPA and the State of Connecticut take enforcement actions to require cleanup of the facility operations and the property.

- 1989 – 1990: Site paving and control measures were installed in accordance with a RCRA Corrective Measures Plan.

- 1991: SRSNE operations cease.

- 1990 – 1994: EPA conducts the remedial investigation in three phases.

- 1992: EPA takes emergency actions to remove contaminated soils from the railroad grade drainage ditch and some chemicals stored in buildings in the Operations Area for proper off-site disposal.

- 1992 – 1994: CTDEP operates the on-site groundwater interceptor system and an ultra-violet/oxidation (UV/ox) treatment system.

Post-1994 Response Actions

NTCRA 1 Groundwater Extraction System. In 1994, the SRSNE Site Group entered into a settlement with EPA that required construction and operation of a pump and treat system to contain the contaminated groundwater in the overburden ("NTCRA 1"). Pumping from the NTCRA 1 system began in July 1995 and continues to operate today. The NTCRA 1 system is located on the Cianci Property (Figure 4). It consists of a 700-foot long by 30-foot deep steel sheetpile wall through the overburden to the top of bedrock, and 12 overburden groundwater extraction wells (RW-1 through RW-12) on the upgradient side of the wall. Contaminated groundwater is extracted from the wells to maintain hydraulic gradient reversal across the sheetpile wall, which prevents its migration. Other work conducted under this settlement included the construction of a mitigation wetland in the northeast corner of the Cianci Property, a full-scale phytoremediation study within the sheetpile wall, and extension of public water to three buildings immediately adjacent to the Site.

NTCRA 2 Groundwater Extraction System. In 1997, EPA and the SRSNE Site Group entered into a second settlement that expanded the groundwater containment system ("NTCRA 2"). The NTCRA 2 groundwater extraction system consists of three extraction wells (two in the deep overburden (RW-13 and 14) and one in the bedrock (RW-1R)) just north of the CL&P easement (Figure 4). The purpose of these wells is to prevent the migration of contaminated groundwater in the bedrock aquifer. It, too, continues to operate. Other work conducted under this settlement included the completion of a remedial investigation/feasibility study (described below in greater detail) and the decontamination, demolition and removal of the remaining buildings and tanks from the Operations Area.

On-site Groundwater Treatment System. Groundwater extracted from the NTCRA 1 and 2 systems is treated on site using a process that consists of the following: metals pretreatment, filtration, UV/ox, and granular activated carbon adsorption. Vapor phase carbon adsorption is also used to capture contaminants that volatize during treatment. The system precipitates and extracts metals, reduces suspended solids, and captures and destroys VOCs. Treated water is discharged to the Quinnipiac River in accordance with the Revised CTDEP Substantive Requirements for Discharge of Pre-Treated Groundwater, issued November 5, 1995.

The SRSNE Site Group continues to operate the overburden and bedrock groundwater containment systems and on-site treatment system which, following entry of the Consent Decree in 2009, became part of the groundwater remedy specified in the ROD. Those systems are now collectively referred to as the Hydraulic Containment and Treatment System (HCTS). Since 1995, 196 million gallons of contaminated groundwater have passed through the HCTS, removing 16,000 pounds of VOCs from the Site.

Remedial Investigation/Feasibility Study. As part of the 1997 settlement, the SRSNE Site Group also agreed to complete the remedial investigation/feasibility study (RI/FS) which they did in 2004. Based on the RI/FS, EPA issued a proposed cleanup plan for the Site (June 2005), held a public comment period (June 9, 2005 to August 8, 2005) and ultimately selected a final cleanup plan with the issuance of the ROD on September 30, 2005.

3.4 Basis for Taking Action

This section summarizes the extent of contamination found at the Site and the human-health and ecological risks associated with exposure to that contamination.

Site Contamination

Soil. The distribution of contaminants in soil covers much of the Operations Area. This suggests that solvent VOCs and other contaminants entered the surface and subsurface soil in varying quantities at many locations within the Operations Area. Likely known entry points include two unlined lagoons, drum storage areas, and truck loading/unloading areas. Overflow from the lagoons drained into a ditch east of the Operations Area, alongside the railroad tracks and into a concrete culvert that crosses the Cianci Property and discharges directly to the Quinnipiac River.

Groundwater. The plume of contamination in the overburden aquifer that is associated with the SRSNE Site extends deep into the Town Well Field (Figure 3A). The highest contaminant concentrations are found in the Operations Area, particularly in the area where the unlined lagoons were located. The plume in the bedrock aquifer does not extend as far into the well field but does extend into the northern portion of the Cianci Property (Figure 3B). It is believed that a production well on the Cianci Property pulled the plume in the bedrock to its current location, which is hydraulically upgradient of the Operations Area. Groundwater that exceeds federal drinking water standards and other risk-based levels is contained and treated on site.

NAPL Zones. Waste oil and solvents in the form of non-aqueous phase liquid (NAPL) are present in the unconsolidated deposits in the overburden aquifer and in the fractured sandstone in the bedrock aquifer.

Surface Water and Wetlands Soil. Surface water and wetland soils, including river sediment, at the outlet of the concrete culvert to the Quinnipiac River have been impacted by runoff from the two unlined lagoons that were located on the Operations Area, and, contaminated groundwater infiltrating the cracked and leaky concrete culvert.

Summary of Risk Assessments

Human-Health Risk Assessment. In 1994, a baseline human-health risk assessment was performed that evaluated both current and future risks from exposure to contamination under a variety of different exposure scenarios. Approximately 40 of the more than 80 chemicals detected in groundwater and approximately 30 of the more than 65 chemicals detected in soils at the Site were identified as contaminants of potential concern and evaluated for possible adverse health effects to human receptors to determine the total cancer and total non-cancer hazards present.

With respect to groundwater, the baseline risk assessment assumed a future residential exposure scenario and evaluated risks from ingestion, dermal contact and inhalation of VOCs and SVOCs emitted from showers, toilets, dishwashers, washing machines and other turbulent water-use sources. With respect to soil, surface water and river sediment, the baseline risk assessment considered residential, recreational and trespasser exposure scenarios. Exposure pathways included direct contact with soil, surface water and river sediment, as well as inhalation of soil particulates and vapors.

In 1999, portions of the risk assessment were updated to incorporate new data and to reflect new risk assessment guidance issued by EPA the previous year. The update re-evaluated the potential risks and hazards associated with incidental ingestion and dermal contact with surface and subsurface soils for residential, recreational and commercial/industrial land uses and re-evaluated the potential risks and hazards associated with hypothetical future ingestion of groundwater (see Table 2).

Neither risk assessment looked at the potential for impacts from volatile chemicals emanating from the groundwater plume into overlying buildings that may be constructed in the future. The vapor intrusion pathway was addressed in the 2005 ROD with a requirement that the remedy include a study to determine the extent of impacts, if any, and the imposition of institutional controls and/or mitigation systems on those parcels where risk was determined to be present.

Ecological Risk Assessment. Surface water and soil/wetland soil to depths of 10 feet were considered for the ecological risk assessment. The chemicals considered in the exposure assessment based on occurrence, distribution, toxicity, persistence and bioaccumulation potential were:

- benzene
- xylenes
- phthalate esters
- polycyclic aromatic hydrocarbons (PAHs)
- 1,2,4-trichlorobenzene
- PCBs or Aroclors
- dioxin
- several pesticides
- metals (cadmium, copper, lead, mercury, nickel, selenium, zinc)

These chemicals persist, undergo bioaccumulation and biomagnify though food webs. Although plants and invertebrates are at potential risk from the contaminants present at the Site, species at higher levels received special emphasis. The selection of indicator species to assess the potential effects of contaminant exposure on wildlife was based on observations in the field, feeding habits, food webs and routes of exposure. The indicator species used for the ecological risk assessment were raccoon, red-tailed hawk, mallard duck, eastern garter snake, and green frog.

Summary of Site Risks

Groundwater Risk. Contaminants in groundwater exceed both cancer and non-cancer EPA target risk requirements and state and federal regulatory requirements assuming that the groundwater is used for potable use in the future. The highest calculated groundwater ingestion risks are related to the Operations Area, the Cianci Property, and the northern portion of the Town Well Field. Groundwater in these areas is not currently used for drinking water or other domestic purposes.

Soil and Wetland Soil Risk. Soil in the Operations Area and railroad right-of-way presented unacceptable cancer and/or non-cancer risks to adults and children who might live on the property in the future (residential scenario) and workers (industrial scenario). Although the future use scenario for the Site is expected to be recreational, per Connecticut law, areas used for recreational purposes must meet cleanup standards for residential use. In addition, soil in the Operations Area, railroad right-of-way, isolated areas on the Cianci Property, and the drainage ditch north of the culvert exceed Connecticut remediation standards for pollutant mobility criteria and/or direct exposure criteria. Wetland soil (including river sediment) at the culvert outfall also exceeds Connecticut remediation standards for direct exposure criteria and presents an unacceptable ecological risk from PCBs.

River Sediment and Surface Water Risk. The total cancer risk and non-cancer risk calculated for accidental ingestion and dermal contact with surface waters and sediment in the Quinnipiac River indicate that surface water and sediment do not present an unacceptable risk to human health. Surface water and river sediment at the outlet of the 30-inch concrete culvert pose an unacceptable risk to ecological receptors from PCBs and PAHs.

SECTION 4.0
REMEDIAL ACTIONS

4.1 Remedy Selection

Remedial action objectives (RAOs) were established based on types of constituents, environmental media of concern (e.g., soil, groundwater) and potential exposure pathways. The RAOs were developed to guide plans to mitigate, restore, and/or prevent existing and future potential threats to human health and/or the environment from soil and wetland soil, overburden and bedrock groundwater, and NAPL in the overburden and bedrock aquifers; and to meet applicable or relevant and appropriate requirements (ARARs).

The specific RAOs presented in the ROD issued on September 30, 2005, are summarized in the following table.

Remedial Action Objectives

Site Area/ Medium	Protection of Human Health	Protection of the Environment
Former SRSNE Operations Area/ Railroad Soil	• Prevent potential human exposure (dermal contact, ingestion and inhalation) to soil with contaminants that exceed an excess carcinogenic risk of 10^{-4} to 10^{-6}, that pose a non-carcinogenic Hazard Index greater than 1, or that exceed ARARs. • Prevent migration of contaminants from soils to groundwater that would result in groundwater concentrations in excess of ARARs or which otherwise present an unacceptable risk in groundwater.	• Prevent migration of contaminants from soils to groundwater that would result in groundwater concentrations in excess of ARARs.
Former Cianci Property Soil	• Same as Former SRSNE Operations Area/Railroad Soil Area.	• Prevent ecological risks associated with SRSNE-related contaminants.

Site Area/ Medium	Protection of Human Health	Protection of the Environment
Overburden NAPL Area	• Reduce or stabilize contaminants in the NAPL area that would otherwise result in groundwater concentrations that pose a carcinogenic risk in excess of 10^{-4} to 10^{-6}, non-carcinogenic Hazard Index greater than 1, or that exceed ARARs.	• Reduce contaminants in the NAPL area to achieve one or more of the following: - Shorten the timeframe that groundwater standards are exceeded - Shrink the size of the groundwater plume - Reduce groundwater constituent concentrations - Prevent the migration of NAPL
Overburden Groundwater	• Prevent potential human exposure (dermal contact, ingestion and inhalation) to groundwater in the overburden aquifer with contaminants that pose an excess carcinogenic risk of 10^{-4} to 10^{-6}, non-carcinogenic Hazard Index greater than 1, or that exceed ARARs.	• Restore groundwater quality to meet ARARs.
Bedrock NAPL Area	• Minimize expansion of the extent of impacted bedrock groundwater due to further NAPL migration.	• Minimize expansion of the extent of impacted bedrock groundwater due to further NAPL migration.
Bedrock Groundwater	• Prevent potential human exposure (dermal contact, ingestion and inhalation) to groundwater in the bedrock aquifer with contaminants that pose an excess carcinogenic risk of 10^{-4} to 10^{-6}, non-carcinogenic Hazard Index greater than 1, or that exceed ARARs.	• Prevent continuing migration of contaminants that exceed ARARs; and restore bedrock groundwater to meet ARARs once VOC residuals are depleted.

Key elements of the selected remedy are summarized as follows:

- In-situ thermal treatment of contaminants in the overburden aquifer NAPL area until site-specific NAPL performance standards are achieved;
- Excavate, consolidate and cap soil and wetland soil that exceeds cleanup levels (see Table 6);

- Capture and on-site treatment of contaminated groundwater in both the overburden and bedrock aquifers, until federal safe drinking water standards and other risk-based levels are achieved;

- Over time, modification of the configuration of the on-site groundwater extraction and treatment system, as appropriate, based on expected reductions in contamination;

- Monitor natural attenuation of the groundwater plume including a) groundwater outside the capture zone of the extraction and treatment system until groundwater cleanup levels are achieved and b) contaminants in the NAPL area of the bedrock aquifer until groundwater cleanup levels are achieved (see Table 5);

- Implement restrictions on uses of the Site in perpetuity to prevent human exposure to contaminants in the subsurface soils and to prohibit activities that might harm the cap. Implement institutional controls to prevent human exposure to contaminated groundwater and NAPL areas until appropriate levels are met. These restrictions will also prohibit construction above that portion of the groundwater plume that exceeds federal and state volatilization criteria, if studies conducted during remedial design confirm the need for such restrictions;

- Maintain the cap in the long term; and

- Perform reviews at least every five years to ensure that the remedy remains protective of human health and the environment.

- Contingent remedy – In the event that the Southington Water District decides to re-activate municipal production wells located near the Site prior to attainment of federal drinking water standards and other risk-based levels throughout the Site, additional groundwater containment is required.

4.2 Remedy Implementation

Pursuant to a Consent Decree entered on March 26, 2009 by the United States District Court for the District of Connecticut, the SRSNE Site Group agreed to conduct the cleanup of the Site as set forth in the ROD. The Consent Decree included a Statement of Work (SOW) that sets out the framework for conducting the remedy selected in the ROD. In the 18 months that have passed since entry of the Consent Decree, remedy implementation has consisted primarily of remedial design activities, sampling, and continued operation of the groundwater containment and treatment system. This section summarizes the remedial activities that have been undertaken by the SRSNE Site Group to date, and provides a status report on implementation of the other key components of the remedy.

Remedial Design. Significant remedial design field activities conducted include:

- Comprehensive monitoring well evaluation (June and July 2009)

- Baseline habitat survey and wetlands delineation (June 2009)
- Negotiation and agreement for access to ten properties not controlled by the SRSNE Site Group (August to November 2009)
- Overburden NAPL Area delineation (July to November 2009)
- Soil sampling in railroad right-of-way (July 2009)
- Monitoring well abandonment, installation and development program (November 2009 to May 2010)
- First round of groundwater sampling to support vapor intrusion assessment (February 2010)
- Soil sampling on Cianci Property (May 2010)
- First comprehensive groundwater sampling program (May and June 2010)
- Survey of existing and new wells (June and July 2010)

Remedial design activities have also included submissions to EPA and CTDEP of the following documents:

- Draft Memorandum of Agreement between EPA, CTDEP, the SRSNE Site Group and the Town of Southington/Southington Water Department, submitted for EPA review on September 16, 2009, and resubmitted based upon EPA comments on June 23, 2010.
- *Annual State of Compliance Report #1* submitted on December 4, 2009.
- *In-Situ Thermal Remedial (ISTR) Conceptual Design* submitted on April 15, 2010.
- *Pre-ISTR Preparation Plan (PIPP) Final Design and Remedial Action Work Plan* on April 15, 2010.
- *Independent Quality Assurance Team Plan* on April 15, 2010.

A public information web site was launched on August 28, 2009 (www.srsnesite.com). An open house was held at the Site on July 10, 2010, satisfying the SOW requirement for a pre-construction public meeting prior to the PIPP activities which began on September 13, 2010.

No noteworthy difficulties or delays have occurred during the remedial design process.

Capture and on-site treatment of contaminated groundwater. As discussed above, the NTCRA 1 and NTCRA 2 groundwater containment and treatment systems are now known as the Hydraulic Containment and Treatment System (HCTS). In the five-year period covered by this review, the HCTS has operated in compliance with the Demonstration of Compliance requirements first in the 1994 and 1997 NTCRA settlements and subsequently, the 2009 Consent Decree. Since 1995, more than 196 million gallons of groundwater have been recovered and treated, with 16,000 pounds of VOCs removed. During the five-year period since the ROD was issued (September 2005 to August 2010), the HCTS has pumped and treated 70,495,000 gallons of contaminated groundwater and removed 3,487 pounds of VOCs.

No noteworthy problems have occurred during operation and maintenance (O&M) of the HCTS. Costs for work since the ROD was issued, including pre-remedial design, remedial design and HCTS O&M are provided in Table 3.

In-situ thermal treatment of Overburden NAPL Area. Site preparation which started on September 13, 2010, will include significant earthworks; installation of thermal infrastructure (new gas, sewer, power); re-routing of a major AT&T optics line; and removing and replacing the existing concrete culvert. The conceptual design for the in-situ thermal treatment system is under EPA and CTDEP review. Construction on the thermal component is scheduled to being in the summer of 2011, with operation start-up anticipated for early 2012.

Excavation, consolidation and capping soils. Contaminated soils that run along the railroad right-of-way will be excavated and used as fill during re-grading of the Operations Area this fall during the ISTR site preparations. The wetland soils and river sediments at the outfall of the existing culvert will also be excavated and consolidated in the Operations Area. The outlet will be reconfigured to enhance the functions and value of the habitat in that area. The remaining, isolated areas of contaminated soil on the Cianci Property will be excavated after the in-situ thermal treatment and placed in the Operations Area prior to capping which is scheduled for 2014.

Monitored natural attenuation and vapor intrusion. New monitoring wells were needed to further refine the delineation of the groundwater plumes in the overburden and bedrock aquifers for purposes of monitoring natural attenuation in 3-D and the vapor intrusion study. The wells were installed over fall/winter of 2009 and spring 2010. Data collected from new and existing monitoring wells across the entire 42-acre site is currently undergoing validation and will be submitted for EPA review later this year. Additional data may be needed for a multiple-lines-of-evidence analysis concerning vapor intrusion.

Implementation of institutional controls. Institutional controls are required by the ROD to prevent unacceptable exposure to groundwater, soil, subsurface NAPL, and possibly vapor intrusion in the future but have not yet been put in place. A process to identify and implement necessary controls was set forth in the SOW and the SRSNE Site Group is making satisfactory progress towards implementing controls. The next step in implementing controls is completion of the vapor intrusion investigation, which triggers submission of an Institutional Controls Plan.

SECTION 5.0
PROGRESS SINCE THE LAST FIVE-YEAR REVIEW

This section is not applicable because this is the first five-year review for the Site.

SECTION 6.0
FIVE-YEAR REVIEW PROCESS

6.1 Community Notification and Involvement

EPA, Region 1, published a notice in both the Meriden Record Journal (daily newspaper) and the Southington Citizen (weekly publication) on March 5, 2010, notifying the community of the start of the five-year review process. The notice indicated that EPA would be conducting a five-year review of the SRSNE Site to ensure that it is protective of public health and the environment and that the implemented components of the remedy are functioning as designed. It also indicated that once the five-year review is completed, the results will be made available in a final report. A similar notice will be published when the review is completed. A copy of the public notice announcing the start of the review process is included as Attachment 1.

In addition, the newspaper display ad encouraged local citizens to contact EPA if they had any questions about the SRSNE Site or if they wanted to be interviewed as part of the five-year review process. No citizens contacted EPA to be interviewed. Interviews were conducted by EPA with the Southington Town Manager and the Southington Director of Public Works/Town Engineer in April 2010 (see Section 6.5).

A Superfund Community Update was mailed to approximately 1500 Southington households in June 2010. The update included information about ongoing and upcoming activities at the Site and announced an open house for the public scheduled for July 10, 2010. The update included a paragraph explaining the five-year review process and soliciting community interviewees.

The Five-Year Review Report will be provided to the Town and a press release will be issued to announce its availability.

6.2 Document Review

Table 4 (attached) summarizes the documents, data, and information reviewed during the development of this first five-year review.

6.3 Data Review

Data reviewed include the HCTS monitoring data found in *Annual Demonstration of Compliance Reports #57, 58 and 59* (covering the time period January 2005 to December 2007) and the *Annual State of Compliance Report #1* (covering October 2008 to October 2009).

The performance standards developed for the NTCRA 1 and 2 containment systems now apply to the HCTS. With respect to the plume in the overburden, groundwater on both sides of the NTCRA 1 sheetpile wall must flow in the direction of the twelve recovery wells. With respect to the plume in the bedrock, three NTCRA 2 recovery wells located in the vicinity of the CL&P easement must maintain a capture zone beyond which all groundwater must meet federal drinking water standards and other risk-based levels set forth in the ROD. Contaminated groundwater from all the recovery wells is treated on site with an UV/ox/oxidation process and must meet requirements of a NPDES permit equivalency issued by CTDEP before it is discharged to the Quinnipiac River. The HCTS monitoring data indicate continued compliance with discharge limits, reversal of groundwater gradient across the NTCRA 1 sheetpile wall, and consistent maintenance of the NTCRA 2 bedrock capture zone, with no excessive system downtime noted. Since HCTS startup in 1995, more than 196 million gallons of groundwater have been pumped and treated, removing 16,000 pounds of VOCs from the Site. During the five-year period since the ROD was issued (September 2005 to August 2010), the system has pumped and treated 70,495,000 gallons of contaminated groundwater and removed 3,487 pounds of VOCs from the Site.

The data collected for the vapor intrusion study (February, May and June 2010) and during the first comprehensive groundwater monitoring event to demonstrate that natural attenuation processes continue to reduce contaminant concentrations within the plumes, and, verify plume capture in 3-D (June and July 2010) is undergoing validation and will be included in deliverable to be submitted to EPA and CTDEP later this year. This data has not been evaluated for purposes of this five-year review. However, with respect to vapor intrusion, there are currently no structures without vapor controls above the area where groundwater presents possible vapor intrusion issues[1].

6.4 Site Inspection

A SRSNE Site was inspected for this five-year review on June 2, 2010. Those in attendance included Karen Lumino, Ryan Santos (CTDEP Project Manager), the SRSNE Site Group's Project Coordinator, Bruce Thompson of *de maximis, inc.*, John Hunt of *de maximis, inc.*, and Jeffrey Holden from ARCADIS (the SRSNE Site Group's remedial design consultant).

The site inspection checklist is included as Attachment 2.

6.5 Interviews

Two in-person interviews were conducted by EPA on April 27, 2010, with Mr. John Weichsel (Southington Town Manager) and Mr. Anthony Traquillo (Southington Town Engineer and Director of Public Works). Neither interviewee expressed any major concerns regarding the Site and the effectiveness of the remedy. In general, both were pleased with the level of communication from the EPA and SRSNE Site Group concerning activities at the Site. Reports of these interviews are included as Attachment 3.

The Town Manager stated that the Site appears to be in pretty good shape. He stated that the nearby residences have become less nervous about the presence of the Site and he feels

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[1] The only structure in this area is the HCTS building which was constructed with a vapor barrier in the slab foundation as a precautionary measure.

that the Town is well informed about site events and work. The Town is pleased that the SRSNE Site Group has committed to complete that section of the rails-to-trails project that crosses the Site since the presence of that recreational corridor has been a very positive development for Southington.

The Town Engineer noted that there is some community concern about the potential for vapors to be released during the planned remediation. He also thought that there is some general frustration over the length of time that it has taken to decide on and then implement the cleanup. The Town Engineer views the work at the SRSNE Site to be very well done and professional.

Telephone interviews were conducted with two local residents following the open house. Two additional residents contacted EPA's Community Involvement Coordinator with comments.

The major concern expressed by all the citizens was that while the information about the Site is usually very helpful and useful in understanding site developments, it is not always timely. Specifically, although the open house was advertized in the local weekly paper by the SRSNE Site Group, EPA's postcard announcing the meeting was received either the day of or the day following the event, or as was the case with some citizens in the neighboring vicinity, not at all. That said, a dozen citizens did attend the open house including Albert Natelli, a councilman for the Town of Southington.

A second issue raised by two of the citizens is that there continues to be concern about the possible emission of vapors during next year's in-situ thermal remediation. The concern is primarily based on the history of releases when the facility was in operation, and it was recommended that EPA continue to explain how the community will be protected during the operation of the thermal treatment process. The citizen who did attend the open house said that she was satisfied that her concerns about potential emissions and noise had been well addressed by the SRSNE Site Group's project manager and remedial design consultant.

Two citizens recommended that EPA prepare another brief update prior to major activity at the Site in 2011 and provide a clear description of what they can expect to see, including pictures of what the structures might look like. There was general agreement that although the open house was not well attended by community members, there should be a similar event next year so that interested citizens can get a firsthand look at site activity.

None of the citizens had any concerns regarding the operation of the existing groundwater containment and treatment system. None were aware of any negative events or incidents at the Site such as trespassing or emergency responses from local authorities.

SECTION 7.0
TECHNICAL ASSESSMENT

7.1 Question A: Is the remedy functioning as intended by the decision documents?

Yes. Ecological risk related to wetland soil, surface water and river sediment is in the process of being addressed with the excavation of approximately 1300 total cubic yards of wetland soil and river sediment at the culvert outlet to the Quinnipiac River and replacement of the existing leaky concrete culvert. This phase of construction began on September 13, 2010 and will be completed by December 2010.

Other components of the selected remedy are functioning as intended. The HCTS portion of the remedy is performing as expected, meeting hydraulic containment requirements and successfully treating extracted groundwater to meet NPDES-equivalent discharge limits set by CTDEP. The SRSNE Site Group continues to implement O&M of the HCTS, which will maintain the effectiveness of this component of the remedy.

Access controls in the form of fencing and paving are in place limiting current exposure to soil that presents an unacceptable human-health risk, while the remedial design/remedial action process to address those areas of the Site continues towards implementation. Groundwater that has been impacted by the Site is currently not used as drinking water or for any industrial uses. Finally, although the vapor intrusion investigation in not yet complete and additional data may be needed to conduct a multiple-lines-of-evidence analysis, there are currently no structures without vapor controls above the area where groundwater presents possible vapor intrusion issues. As a result, this possible exposure pathway is not complete nor is expected to be complete in the foreseeable future.

In addition to the vapor intrusion investigation, there are other components of the selected remedy that have not been fully implemented: in-situ thermal treatment of contaminants in the overburden aquifer; excavation, consolidation and capping of soil; and demonstration that monitored natural attenuation is ongoing. Vapor intrusion and monitored natural attenuation sampling has occurred and the results will be evaluated by EPA later this year. In-situ thermal treatment is still in design however, site preparation for next year's thermal installation has started and will be completed by December 2010. Isolated hotspots of contaminated soil on the Cianci Property that are not being addressed this year will be excavated and placed in the Operations Area for capping upon completion of the in-situ thermal treatment in 2014.

Institutional controls are required by the ROD to prevent unacceptable exposure to groundwater, soil, subsurface NAPL, and possibly vapor intrusion in the future but have not yet been put in place. A process to identify and implement necessary controls was set forth in the SOW and the SRSNE Site Group is making satisfactory progress towards implementing controls. The next step in implementing controls is completion of the vapor intrusion investigation, which triggers submission of an Institutional Controls Plan.

7.2 Question B: Are the exposure assumptions, toxicity data, cleanup levels, and remedial action objectives (RAOs) used at the time of remedy selection still valid?

No. However, the changes are not expected to affect the selected remedy.

7.2.1 Review of Human Heath and Ecological Risk Assessments and Toxicity Factors Serving as the Basis for the Remedy

Land use on and near the Site has not changed. The physical site conditions have not changed. Human health and ecological routes of exposure have not changed, therefore none of these issues call into question the protectiveness of the remedy. However, there have been developments with respect to 1,4-dioxane, trichloroethylene (TCE), perchloroethylene (PCE), PAHs, vinyl chloride, chromium and dioxin that must be considered.

1,4-dioxane. EPA's Integrated Risk Information System (IRIS) has recently published an external peer review draft of a toxicological review of 1,4-dioxane. This review has found that 1,4-dioxane is 17 times more potent than previously believed. There is currently no federal standard for 1,4-dioxane. EPA's risk-based screening level for 1,4-dioxane in water is 6.1 µg/L based on target risk level of $1x10^{-6}$. However, this level might become 17 times lower or more stringent as a result of the IRIS toxicological review.

The UV/ox/oxidation process in the HCTS is sufficient to treat this contaminant, which has been detected in groundwater at the Site. However, studies have shown that the monitored natural attenuation approach to solvent contamination is unlikely to achieve degradation of 1,4-dioxane since it is very persistent in water. Data show that it is infinitely soluble in water and a volatilization half-life cannot be estimated. As a result, if after review of the first round of comprehensive groundwater monitoring data later this year, 1,4-dioxane is found outside of the HCTS containment area at concentrations that exceed EPA's risk-screening level, the monitored natural attenuation approach for that portion of the plume may need to be re-evaluated.

TCE , PCE, PAHs and vinyl chloride. The toxicity assessments for TCE and PCE are currently under external peer review. The assessments found these chemicals to be more toxic than previously characterized hence using this information to re-evaluate risk from these contaminants would result in higher risks than the results in the ROD. EPA has determined that the carcinogenic PAHs and vinyl chloride can cause cancer via the mutagenic mode of action and has developed specific toxicity values for vinyl chloride and guidance to address early-life exposure to carcinogens. Using this updated risk methodology would result in higher risks for vinyl chloride and carcinogenic PAHs.

A qualitative assessment has been conducted for this five-year review and concluded that these changes or potential changes would not affect the selected remedy and its protectiveness. PAHs are not found in that portion of the groundwater plume that is outside the capture/treatment zone. For the qualitative assessment of the other three contaminants, the highest concentrations found in the wells which are outside the capture/treatment zone were used: TCE (0.2 µg/L), PCE (1.0 µg/L) and vinyl chloride (non-detect). The ingestion risk was doubled to account for inhalation, and ½ the detection limit was used for the non-detect. The total risk was $1x10^{-5}$ which is within EPA's acceptable risk range.

Chromium. EPA has concluded that the weight of evidence on chromium VI supports the conclusion that it may act through a mutagenic mode of action following exposure via drinking water, and, recommends that Age-Dependent Adjustment Factors (ADAFs) be applied when assessing cancer risks from early-life exposure (< 16 years of age) to reflect EPA's 2005 *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens*. Application of ADAFs for all exposure pathways would result in more health-protective screening levels and higher risk results. For chromium VI, EPA suggests use of the oral cancer slope factor of 5×10^{-1} $(mg/kg\text{-}day)^{-1}$ developed by New Jersey Department of Environmental Protection. For chromium VI inhalation unit risk, IRIS shows a value of 1.2×10^{-2} $(\mu g/m^3)^{-1}$. Using the conservative assumption that all chromium existed is chromium VI, EPA suggests chromium VI inhalation unit risk of 8.4×10^{-2} $(\mu g/m^3)^{-1}$ by multiplying the IRIS value by 7, assuming a chromium VI to chromium III ratio of 1:6.

A qualitative assessment has been conducted for this five-year review and concluded that these changes or potential changes would not affect the selected remedy and its protectiveness. Chromium is not found in that portion of the groundwater plume that is outside the capture/treatment zone.

Dioxin. Dioxin has been identified as a contaminant of concern in soil at the Site. EPA's dioxin reassessment has been developed and undergone review over many years with the participation of scientific experts in EPA and other federal agencies, as well as scientific experts in the private sector and academia. EPA followed current cancer guidelines and incorporated the latest data and physiological/biochemical research into assessment. The results of the assessment have currently not been finalized and have not been adopted into state or federal standards. EPA anticipates that a final revision to the dioxin toxicity numbers may be released by the end of 2010. In addition, EPA has proposed to revise the interim preliminary remediation goals (PRGs) for dioxin and dioxin-like compounds, based on technical assessment of scientific and environmental data. However, EPA has not made any final decisions on interim PRGs at this time. Therefore, the dioxin toxicity re-assessment for this Site will be updated during the next five-year review.

7.2.2 ARARs Review

No changes have been made to the standards identified in the ROD. No new standards have been promulgated. No changes have been made to the "To Be Considered" standards used in selecting cleanup levels that could affect the protectiveness of the remedy. CTDEP has published a lower detection limit for 1,2,4-trichlorobenzene of 0.5 ug/L, compared to the prior value of 2 ug/L. To satisfy CTDEP regulations, the SRSNE Site Group will treat this as the new cleanup level for that contaminant (see Table 5).

7.2.3 Remedial Action Objectives

The RAOs incorporated into the ROD are still appropriate, and the remedy is progressing as expected. Protection of human health is currently being achieved with fencing, pavement and the fact that that no one is drinking the groundwater. The HCTS which contains and treats all groundwater that exceeds federal drinking water standards and other risk-based levels coupled with the contingent remedy for additional containment will prevent the consumption of contaminated groundwater should the Southington Water Department at some point in the future make the decision to re-activate existing and/or drill new municipal production wells in the Town Well Field. The components that will address the remaining RAOs are currently in remedial design.

The RAOs for prevention of ecological risks associated with SRSNE-related contaminants are expected to be met once wetland soils and river sediments at the outfall of the concrete culvert are excavated and consolidated in the Operations Area during the earthworks that are underway, and the areas are restored. This phase of the remedy began on September 13, 2010, and will be completed by December 2010.

7.3 Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

No. There is no other information that calls into question the protectiveness of the remedy.

On August 6, 2010, CTDEP notified EPA that two state species of special concern, Eastern Box Turtle and Eastern Hognose Snake, occur in the vicinity of the SRSNE Site. Neither species has been observed directly on site, however, suitable habitat does exist and will be enhanced by the remedy. During construction, precautions such as the creation of and regular inspection for trapped animals inside silt-fence exclusion zones will be taken to reduce the risk of harming these state-listed species.

7.4 Technical Assessment Summary

Based upon the results of the five-year review, the remedy selected for the Site is expected to be protective of human health and the environment upon completion of the remedy, and in the interim, exposure pathways that could result in unacceptable risks to human health are being controlled.

SECTION 8.0
ISSUES

Based on the activities conducted during this five-year review, the issues identified in the following table have been noted.

Issue	Affects Current Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
Major components of the remedy need to be implemented: in-situ thermal treatment of contaminants in the overburden aquifer; excavation, consolidation and capping of soil; vapor intrusion investigation and potential remediation; and institutional controls.	No	Yes
If 1,4-dioxane is found above EPA's risk-screening level in groundwater that is not being contained, the monitored natural attenuation approach for addressing this contaminant in that portion of the plume may need to be re-evaluated.	No	Yes

SECTION 9.0
RECOMMENDATIONS AND FOLLOW-UP ACTIONS

Issue	Recommendations and Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectiveness	
					Current	Future
Many key elements of the remedy are still in design.	Implement in-situ thermal treatment	SRSNE Site Group	EPA	2011	No	Yes
	Excavate, consolidate and cap soil.	SRSNE Site Group	EPA	2014		
	Complete vapor intrusion study and determine need for mitigation controls.	SRSNE Site Group	EPA	December 2010		
	Implement institutional controls.	SRSNE Site Group	EPA	2011		
Monitored natural attenuation for 1,4-dioxane may need to be re-evaluated if found in that portion of the plume that is not hydraulically contained.	Review groundwater monitoring data to determine if 1,4-dioxane is a) present and b) above EPA's risk-screening level.	SRSNE Site Group	EPA	December 2010	No	Yes

SECTION 10.0
PROTECTIVENESS STATEMENT

Based upon a review of the ROD, remedial design documents, data collected during sampling events, operation and maintenance reports and an inspection of the Site, the remedy at the SRSNE Site is expected to be protective of human health and the environment upon completion of the remedy, and in the interim, exposure pathways that could result in unacceptable risks are being controlled.

Access controls in the form of fencing and pavement are in place, and currently limit exposure to soil that presents an unacceptable human-health risk. In addition, groundwater beneath and downgradient of the Site is not currently used as drinking water. Finally, although the vapor intrusion investigation is not yet complete, there are currently no structures without vapor barriers above the area where groundwater presents possible vapor intrusion issues. As a result, this possible exposure pathway is not complete.

Excavation of approximately 1300 total cubic yards of wetland soils and river sediment at the culvert outfall that pose an ecological risk, and, consolidation in the Operations Area where the contaminated material will be covered with clean fill is underway and will be completed by December 2010.

However, in order for the remedy to be protective in the long term, the following actions need to be taken to ensure long-term protectiveness: major components of the remedy need to be implemented including in-situ thermal treatment of contaminants in the overburden aquifer; excavation, consolidation and capping of soil; vapor intrusion investigation and potential remediation; and institutional controls. In addition, if 1,4-dioxane is found in that portion of the plume that is not hydraulically contained in concentrations that exceed EPA's risk-screening level, the monitored natural attenuation approach for addressing this contaminant in that portion of the plume may have to be re-evaluated.

SECTION 11.0
NEXT REVIEW

Since hazardous substances, pollutants or contaminants remain at the SRSNE Superfund Site which do not allow for unlimited use or unrestricted exposure, in accordance with 40 CFR 300.430 (f) (4) (ii), the site shall be reviewed no less often than every five years. EPA will conduct another five-year review on or before September 2015.

Table 1
Chronology of Site Events

Event	Date
Solvents Recovery Service of New England (SRSNE) facility begins operations	1955
Use of on-site lagoons for sludge disposal terminates	1967
EPA files suit against SRSNE under RCRA	1979
Town Production Wells No. 4 & No. 6 close when they are found to contain VOCs	1979-1980
Investigations by EPA of Town Well Field property initiated	1980
EPA lawsuit under RCRA amended to include claims under CERCLA	1982
EPA lists SRSNE Site on Superfund National Priorities List	1983
On-site interceptor system (OIS) installed along with 25 groundwater extraction wells to capture contaminated groundwater	1985
SRSNE paves site and installs control measures in accordance with a RCRA Corrective Measures Plan	1986-1990
EPA initiates the remedial investigation for the Site	1990
CTDPH initiates a public health assessment for the SRSNE Site under cooperative agreement with ATSDR	1990-1997
SRSNE facility closes	1991
CTDEP takes over operation of OIS, upgrades treatment to use UV/oxidation	1991-1995
EPA conducts an emergency removal of contaminated soils from the drainage ditch and chemicals stored at the property	1992
SRSNE Site Group enters into a settlement with EPA to construct overburden aquifer containment and treatment system (NTCRA 1)	1994
NTCRA 1 construction completed and operations began; OIS terminated	1995
SRSNE Site Group constructs a mitigation wetland on the Cianci Property to compensate for the potential impact from constructing/operating the NTCRA 1 system	1996
SRSNE Site Group enters into second settlement with EPA to construct bedrock aquifer containment, complete remedial investigation and prepare feasibility study	1997
SRSNE Site Group submits Remedial Investigation Report; implements phytoremediation study in NTCRA 1 containment area	1998
NTCRA 2 begins operating	1999
SRSNE Site Group decontaminates, demolishes and removes all remaining site structures, tanks, and distillation towers	1999
SRSNE Site Group conducts a field investigation to delineate the extent of NAPL in overburden	2003
SRSNE Site Group completes Feasibility Study Report	2005
EPA issues the Record of Decision which sets forth the remedy for the Site and will form the basis for all remedial design/remedial action (RD/RA) activities	2005
EPA/DOJ lodges RD/RA Consent Decree with the U.S. District Court in Connecticut	2008
Consent Decree entered by the U.S District Court	2009
SRSNE Site Group submits remedial design work plan (RDWP) and Project Operations Plan; begins remedial design activities	2009
Overburden NAPL area delineation refined (RDWP Attachment A)	2009
Pre-construction wetland delineation performed (RDWP Attachment H)	2009

Soil sampling performed along railroad right-of-way to delineate capping limits (RDWP Attachment M)	2009
Operation and maintenance performed on ~160 monitoring wells across the Site (RDWP Attachment N)	2009
Groundwater sampling for vapor intrusion study performed (RDWP Attachment K)	2010
A drilling event including the installation of 29 new monitoring wells, the abandonment of 43 existing monitoring wells and a site-wide well rehabilitation program is completed (RDWP Attachment N)	2010
Initial comprehensive groundwater sampling event completed; consists of sampling of 110 monitoring wells and taking water-level measurements of ~160 wells (RDWP Attachment N)	2010
Sampling of wetland soil and river sediment removal areas on the Cianci Property to define limits for excavation (RDWP Attachment I)	2010

Table 2
Summary of Human-Health Risks (RA Update 1999)

The baseline risk assessment (1994) was updated in 1999 to incorporate new soil and groundwater data and new EPA guidance on performing risk assessments. A summary of the potential risks from direct contact and/or inhalation of particles under residential, recreational and commercial/industrial exposure scenarios is presented below.

Location Receptor	Surface Soils		Subsurface Soils	
	Total Excess Lifetime Cancer Risk	**Total Noncancer Hazard Index**	**Total Excess Lifetime Cancer Risk**	**Total Noncancer Hazard Index**
North Cianci				
Adult Resident	3×10^{-6}	0.01	-	-
Child Resident	7×10^{-6}	0.1	-	-
Total Residential Risk (30 year)	1×10^{-5}	0.1		
Recreational/Trespasser	3×10^{-7}	0.002	-	-
Worker	2×10^{-6}	0.009	-	-
South Cianci				
Adult Resident	5×10^{-6}	0.08	-	-
Child Resident	1×10^{-5}	0.8	-	-
Total Residential Risk (30 year)	2×10^{-5}	0.9		
Recreational/Trespasser	5×10^{-7}	0.02	-	-
Worker	4×10^{-6}	0.06	-	-
Operations Area/Railroad Property				
Adult Resident	-	-	5×10^{-4}	2.0
Child Resident	-	-	1×10^{-3}	20
Total Residential Risk (30 year)	-	-	2×10^{-3}	20
Worker	-	-	3×10^{-4}	2.0

A summary of the potential risks from hypothetical future ingestion of groundwater is presented below.

Location	Bedrock Groundwater		Overburden Groundwater	
	Total Excess Lifetime Cancer Risk	**Total Noncancer Hazard Index**	**Total Excess Lifetime Cancer Risk**	**Total Noncancer Hazard Index**
Operations Area Plume	2×10^{0}	1000	1×10^{0}	1000
Queen Street Plume	7×10^{-5}	0.08	NO COPC	NO COPC
Up gradient Area	1×10^{-4}	20	6×10^{-4}	10

Table 3

Post-ROD, Pre-RD/RA Costs

Task Name	Amount Expended from ROD through Consent Decree Lodging (October 30, 2008)
NTCRA O&M Costs	
Final Quarter 2005	$117,844
2006	$454,703
2007	$648,988
2008	$403,750
RD/RA Negotiation Support (Contractor)	
2006	$114,106
2007	$66,223
Project Management / RD/RA Negotiation Support	
Final Quarter 2005	$ 53,192
2006	$218,527
2007	$119,249
2008	$108,523
Total from ROD through Consent Decree Lodging	**$2,305,105**

RD/RA Costs to Date

Task Name	Amount Expended from Consent Decree Lodging through June 2010
Settlement Costs	
EPA Past Costs	$2,234,000
Future Oversight Costs Subaccount Funding	$5,700,000
Groundwater Natural Resource Damage Costs	$2,625,000
SWD Settlement Cost	$500,000
Sediment Natural Resource Damage Costs	$200,000
NTCRA 1&2 Interim O&M Costs	$857,876
2001 - 2008 Trustee Costs	$187,070
Administrative Costs	
Legal Support	$130,960
Trustee	$81,678
TC Advisor	$12,559

Financial Advisor	$8,292
Taxes Paid (Federal and State)	$32,364
Future Response Costs	$176,705
Subtotal- Settlement + Admin	**$12,746,604**
Technical Costs	
Project Management	$703,487
Soils Remedy (Ops Area Cap + Drainage Pathways)	
Remedial Design (including Pre-Design Studies)	$396,155
In-Situ Thermal Remedy	
Remedial Design (including Pre-Design Studies)	$446,326
Remedial Action	$138,889
Groundwater Remedy	
Remedial Design (including Pre-Design Studies)	$1,027,370
Access Agreements	$6,500
Groundwater Monitoring	$126,332
Subtotal - Technical	**$2,791,634**
Total - Settlement + Admin + Technical	**$15,538,237**

Table 4

Documents, Data and Information Reviewed for the Five-Year Review

Inspection Report: Solvents Recovery Service of New England (SRSNE), EPA	February 1989
Public Health Assessment, Agency for Toxic Substances and Disease Registr	July 1992
Final Remedial Investigation Report: Remedial Investigation/Feasibility Study, SRSNE Site, Southington, Connecticut, Halliburton NUS (HNUS)	May 1994
Remedial Investigation Report, Blasland, Bouck & Lee (BBL)	June 1998
Preliminary Reuse Assessment, EPA	September 2003
Feasibility Study Report, BBL and EPA	May 2005
Interim Monitoring and Sampling Report No. 14, BBL	June 27, 2005
Record of Decision, EPA Region 1	September 30, 2005
Non-Time Critical Removal (NTCRA) Action No.1 and 2 – Annual Demonstration of Compliance Report #57 (January – December 2005), Weston Solutions, Inc.	February 28, 2006
NTCRA No.1 and 2 – Annual Demonstration of Compliance Report #58 (January – December 2006), Weston Solutions, Inc.	March 16, 2007
NTCRA No.1 and 2 – Annual Demonstration of Compliance Report #59 (January – December 2007), Weston Solutions, Inc.	November 5, 2008
Remedial Designt/Remedial Action (RD/RA) Monthly Progress Reports #1-20, *de maximis, inc.*	November 2008-June 2010
RD/RA Consent Decree, United States District Court for the District of Connecticut in connection with Civil Actions No. 3:08cv1509 (SRU) and No. 3:08cv1504 (WWE).	Entered March 26, 2009
RD Work Plan and Project Operations Plan, ARCADIS	April 21, 2009
Draft Memorandum of Agreement between EPA, CTDEP, SRSNE Site Group and Town of Southington/Southington Water Department	September 16, 2009
Annual State of Compliance Report #1 (October 2008 – October 2009), *de maximis, inc.*	April 15, 2010
In-Situ Thermal Remediation (ISTR) Conceptual Design, TerraTherm, Inc.	April 15, 2010
Pre-ISTR Preparation Plan Final RD/RA Work Plan, ARCADIS	April 15, 2010
Independent Quality Assurance Team Plan, *de maximis, inc.*	April 15, 2010
EPA guidance for conducting five-year reviews and other guidance and regulations to determine if any new Applicable or Relevant and Appropriate Requirements relating to the protectiveness of the remedy have been developed since EPA issued the ROD.	

TABLE 5

INTERIM CLEANUP LEVELS FOR GROUNDWATER [1]

Chemical Name	Units	Interim Cleanup Level [1]	Basis of Interim Cleanup Level
1,1,1-Trichloroethane	ug/l	0.5	CT RSR
1,1,1,2-Tetrachloroethane	ug/l	0.5	CT RSR
1.1.2-Trichloroethane	ug/l	0.5	CT RSR
1,1-Dichloroethane	ug/l	0.5	CT RSR
1,1-Dichloroethene	ug/l	0.5	CT RSR
1,2-Dibromo-3-chloropropane	ug/l	0.05	CT RSR
1,2-Dichlorobenzene	ug/l	0.5	CT RSR
1,2-Dichloroethane	ug/l	0.5	CT RSR
1,4-Dichlorobenzene	ug/l	0.5	CT RSR
2-Butanone	ug/l	5	CT RSR
2-Hexanone	ug/l	5	CT RSR
4-Methyl-2-pentanone	ug/l	5	CT RSR
Acetone	ug/l	5	CT RSR
Benzene	ug/l	0.5	CT RSR
Bromomethane	ug/l	0.5	CT RSR
Carbon Disulfide	ug/l	0.5	CT RSR
Carbon tetrachloride	ug/l	0.5	CT RSR
Chlorobenzene	ug/l	0.5	CT RSR
Chloroethane	ug/l	0.5	CT RSR
Chloroform	ug/l	0.5	CT RSR
Chloromethane	ug/l	0.5	CT RSR
cis-1,2-Dichloroethene	ug/l	0.5	CT RSR
Ethylbenzene	ug/l	0.5	CT RSR
Methylene chloride	ug/l	0.5	CT RSR
Styrene	ug/l	0.5	CT RSR
Tetrachloroethene	ug/l	0.5	CT RSR
Tetrahydrofuran	ug/l	0.5	CT RSR
Toluene	ug/l	0.5	CT RSR
trans-1,2-Dichloroethene	ug/l	0.5	CT RSR
trans-1,3-Dichloropropene	ug/l	0.5	CT RSR
Trichloroethene	ug/l	0.5	CT RSR
Vinyl chloride	ug/l	0.5	CT RSR
Xylenes	ug/l	0.5	CT RSR
1,2,4-Trichlorobenzene	ug/l	0.5 * ~~2~~	CT RSR
2,4-Dimethylphenol	ug/l	10	CT RSR
2-Methylphenol	ug/l	10	CT RSR
4-Methylphenol	ug/l	10	CT RSR
Benzoic Acid	ug/l	10	CT RSR
bis(2-Ethylhexyl)phthalate	ug/l	10	CT RSR
Di-n-butyl phthalate	ug/l	10	CT RSR
Di-n-octyl phthalate	ug/l	10	CT RSR
Hexachlorobutadiene	ug/l	0.45 [2]	CT RSR
Isophorone	ug/l	10	CT RSR
Napthalene	ug/l	0.5 [3]	CT RSR
Phenol	ug/l	10	CT RSR
Aroclor-1254	ug/l	0.5	CT RSR
Aroclor-1260	ug/l	0.5	CT RSR

TABLE 5

INTERIM CLEANUP LEVELS FOR GROUNDWATER [1]

Chemical Name	Units	Interim Cleanup Level [1]	Basis of Interim Cleanup Level
Aluminum	ug/l	(1)	CT RSR
Antimony	ug/l	(1)	CT RSR
Arsenic	ug/l	(1)	CT RSR
Barium	ug/l	(1)	CT RSR
Beryllium	ug/l	(1)	CT RSR
Cadmium	ug/l	(1)	CT RSR
Chromium (Total)	ug/l	(1)	CT RSR
Cobalt	ug/l	(1)	CT RSR
Copper	ug/l	(1)	CT RSR
Iron	ug/l	(1)	CT RSR
Lead	ug/l	(1)	CT RSR
Manganese	ug/l	(1)	CT RSR
Nickel	ug/l	(1)	CT RSR
Silver	ug/l	(1)	CT RSR
Thallium	ug/l	(1)	CT RSR
Vanadium	ug/l	(1)	CT RSR
Zinc	ug/l	(1)	CT RSR
4,4'-DDD	ug/l	0.1	CT RSR
Aldrin	ug/l	0.05	CT RSR
Ethanol	ug/l	1000	CT RSR
Isopropanol	ug/l	1000	CT RSR
Methanol	ug/l	1000	CT RSR
Sec-Butanol	ug/l	1000	CT RSR

Notes:

1. CT Remediation Standards Regulation requires that "Remediation of groundwater in a GA area shall result in reduction of each substance therein to a concentration equal to or less than the background concentration for groundwater of such substance...." (RCSA 22a-133k-3(a)(2). Where background concentrations are reported as non-detects, the analytical detection level as defined in the CT RSRs shall be the remedial goal. Background levels for metals will be established based on future field sampling and laboratory analyses.

2. A special request to the laboratory is needed to provide an analytical detection limit of 0.45 ug/l for hexachlorobutadiene.

3. The analytical detection limit for napthalene is 0.5 ug/l via EPA Test Method 8260.

* Detection limit for 1,2,4-trichlorobenzene modified to reflect the value specified in CTDEP's Reasonable Confidence Protocol for Method 8260 (Version 3.0, July 2006)

TABLE 6 SOIL AND WETLAND SOIL CLEANUP LEVELS FOR THE PROTECTION OF HUMAN HEALTH AND THE AQUIFER[1]

Chemical Name	Connecticut Residential Direct Exposure Criteria (mg/kg)	Connecticut GA, GAA Pollutant Mobility Criteria (mg/kg) [2]	Soil Cleanup Level (mg/kg) [1]	Basis of Cleanup Level	Carcinogenic Risk [3]	Non-Carcinogenic Hazard Quotient [3]	Non-cancer Target Endpoint
1,1,1-Trichlorethane	500	4	4	CT RSR	-	NA	-
1,1,2,2-Tetrachloroethane	3.1	0.01	0.01	CT RSR	2.E-08	1.E-05	liver
1.1.2-Trichloroethane	11	0.1	0.1	CT RSR	1.E-07	3.E-03	blood
1,1-Dichloroethane	500	1.4	1.4	CT RSR	-	3.E-03	kidney
1,1-Dichloroethene	1	0.14	0.14	CT RSR	-	1.E-03	liver
1,2-Dichloroethene, Total	500	1.4	1.4	CT RSR	-	3.E-02	blood
1,2-Dichloropropane	9	0.1	0.1	CT RSR	3.E-07	NA	-
2-Butanone	500	8	8	CT RSR	-	4.E-03	fetal weight
4-Methyl-2-pentanone	500	7	7	CT RSR	-	1.E-03	liver/ kidney
Acetone	500	14	14	CT RSR	-	1.E-03	kidney
Benzene	21	0.02	0.02	CT RSR	3.E-08	1.E-03	blood
Carbon tetrachloride	4.7	0.1	0.1	CT RSR	4.E-07	5.E-02	liver
Chlorobenzene	500	2	2	CT RSR	-	1.E-02	liver
Chlorodibromomethane	7.3	0.01	0.01	CT RSR	9.E-09	3.E-04	liver
Chloroform	100	0.12	0.12	CT RSR	6.E-07	2.E-03	liver
Ethylbenzene	500	10.1	10.1	CT RSR	-	5.E-03	liver
Methylene chloride	82	0.1	0.1	CT RSR	1.E-08	5.E-05	liver
Styrene	500	2	2	CT RSR	-	5.E-04	blood/ immune
Tetrachloroethene	12	0.1	0.1	CT RSR	2.E-07	3.E-03	liver
Toluene	500	20	20	CT RSR	-	3.E-02	liver/kidney
Trichloroethene	56	0.1	0.1	CT RSR	2.E-06	6.E-03	liver/ kidney/ developmental
Vinyl chloride	0.32	0.04	0.04	CT RSR	5.E-07	1.E-03	liver
Xylenes, Total	500	19.5	19.5	CT RSR	-	7.E-02	body weight
2-Methylnapthalene	474	0.98	0.98	CT RSR	NA	NA	-
4-Chloroaniline	270	1	1	CT RSR	-	4.E-03	spleen
4-Methylphenol	340	0.7	0.7	CT RSR	-	2.E-03	nervous system
Benzo(a)anthracene	1	1	1	CT RSR	2.E-06	-	-
Benzo(a)pyrene	1	1	1	CT RSR	2.E-05	-	-
Benzo(b)fluoranthene	1	1	1	CT RSR	2.E-06	-	-
Benzo(k)fluoranthene	8.4	1	1	CT RSR	2.E-07	-	-
bis(2-Ethylhexyl)phthalate	44	1	1	CT RSR	3.E-08	1.E-03	liver
Chrysene	84	1	1	CT RSR	2.E-08	-	-
Dibenzofuran	270	1	1	CT RSR	-	7.E-03	kidney
Di-n-butyl phthalate	1000	14	14	CT RSR	-	2.E-03	mortality
Di-n-octyl phthalate	1000	2	2	CT RSR	-	8.E-04	liver/thyroid

TABLE 6 SOIL AND WETLAND SOIL CLEANUP LEVELS FOR THE PROTECTION OF HUMAN HEALTH AND THE AQUIFER[1]

Chemical Name	Connecticut Residential Direct Exposure Criteria (mg/kg)	Connecticut GA, GAA Pollutant Mobility Criteria (mg/kg) [2]	Soil Cleanup Level (mg/kg) [1]	Basis of Cleanup Level	Carcinogenic Risk [3]	Non-Carcinogenic Hazard Quotient [3]	Non-cancer Target Endpoint
Fluoranthene	1000	5.6	5.6	CT RSR	-	2.E-03	liver
Indeno(1,2,3-cd)pyrene	1	1	1	CT RSR	2.E-06	-	-
Phenanthrene	1000	4	4	CT RSR	NA	NA	-
Pyrene	1000	4	4	CT RSR	-	2.E-03	kidney
2,3,7,8 TCDD -TEQ	NA [4]	NA [4]	lower of 0.001 mg/kg or background [4]	EPA Policy [4]/ background	To be determined	-	-
PCBs Total	1	0.0005 mg/l [2]	1 mg/kg and 0.0005 mg/l [2]	CT RSR	5.E-06	9.E-01	immune
Antimony	27	0.006 mg/l [2]	27 mg/kg and 0.006 mg/l [2]	CT RSR	-	9.E-01	mortality/ blood
Arsenic	10	0.05 mg/l [2]	10 mg/kg and 0.05 mg/l [2]	CT RSR	3.E-05	5.E-01	skin
Barium	4700	1 mg/l [2]	4700 mg/kg and 1 mg/l [2]	CT RSR	-	9.E-01	kidney
Beryllium	2	0.004 mg/l [2]	2 mg/kg and 0.004 mg/l [2]	CT RSR	1.E-09	1.E-02	small intestine
Cadmium	34	0.005 mg/l [2]	34 mg/kg and 0.005 mg/l [2]	CT RSR	2.E-08	9.E-01	kidney
Chromium^{+3}	3900	0.05 mg/l [2,5]	3900 mg/kg and 0.05 mg/l [2,5]	CT RSR	-	3.E-02	none
Chromium^{+6}	100	0.05 mg/l [2,5]	100 mg/kg and 0.05 mg/l [2,5]	CT RSR	3.E-06	5.E-01	none
Lead	500	0.015 mg/l [2]	400 mg/kg [6] and 0.015 mg/l [2]	EPA Policy [6]/ CT RSR	NA	NA [6]	nervous system

Total Cancer Risk[7] =	7.E-05

Cumulative HI by Target Endpoint

kidney	2.E+00
immune	9.E-01
mortality	9.E-01
skin	5.E-01
other endpoints	HI below 1

TABLE 6

SOIL AND WETLAND SOIL CLEANUP LEVELS F THE PROTECTION OF HUMAN HEALTH AND THE AQUIFER[1]

Notes:

NA = Not Available or Not Applicable

1. Soil Cleanup levels are the more stringent of the Connecticut Residential Direct Exposure Criteria (RDEC) or Pollutant Mobility Criteria (PMC) for those depths of soil where both RDEC and PMC apply, and where both RDEC and PMC are expressed in mass concentrations (e.g. mg/kg). Cleanup levels for those substances where PMC are leachate concentrations (see footnote 3), both RDEC and PMC apply except for lead where the cleanup level is based on EPA policy (see footnote 7) and the CT PMC for lead. Cleanup levels may revert to background concentrations if adequate documentation is provided.

2. For inorganics and PCBs, the Pollutant Mobility Criteria are based on leachate concentrations (expressed in mg/l) as obtained via either the SPLP or TCLP leaching procedures.

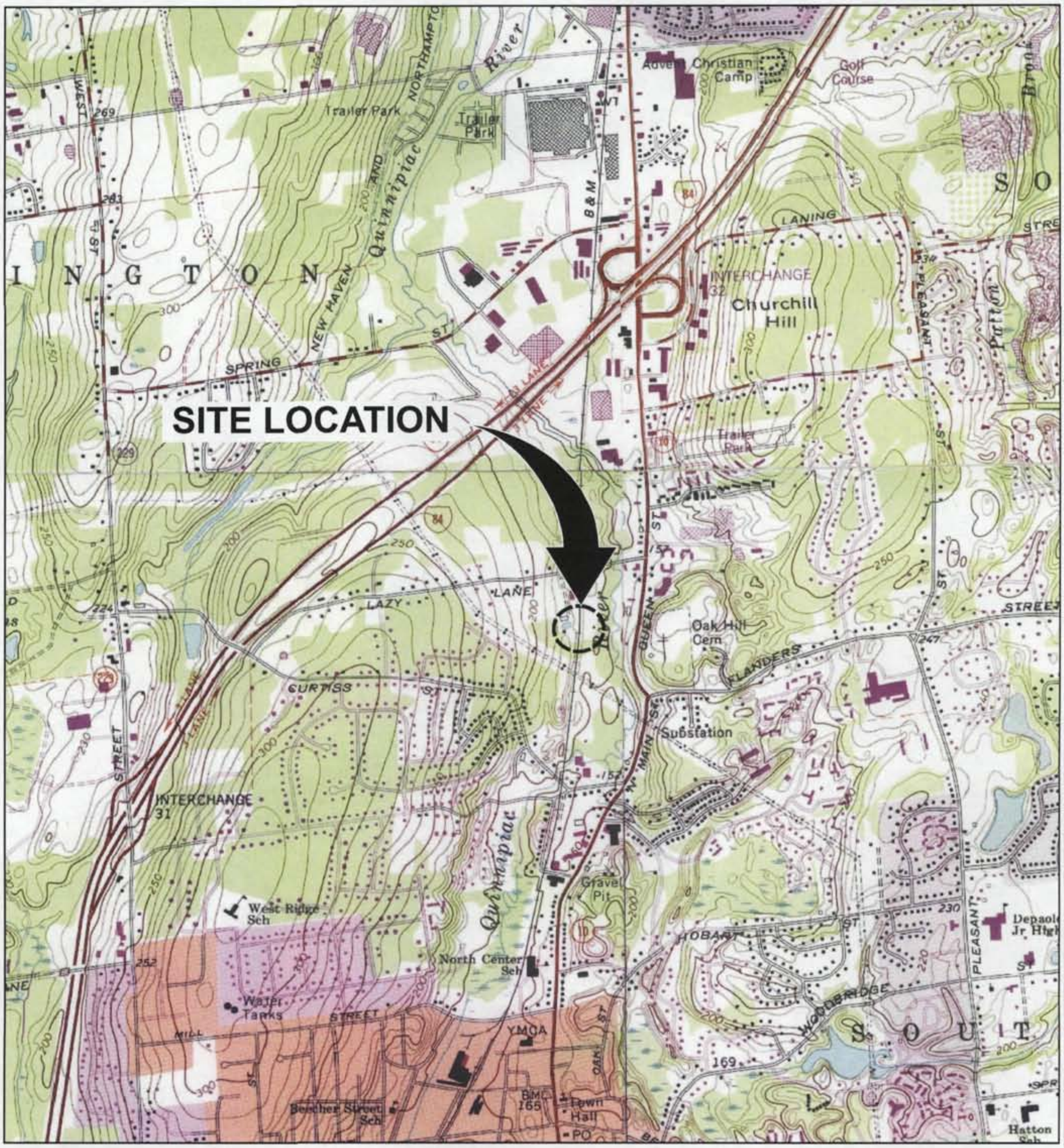
3. Cancer risk and non-cancer hazard are based on residential exposure and assume exposure parameters consistent with EPA Region 9 Preliminary Remediation Goals which reflect ingestion, dermal contact, and inhalation of the soil medium. Values for PCBs and inorganics reflect risk or hazard for cleanup levels expressed as a soil concentration (mg/kg).

4. There are no CT residential DEC or PMC for 2,3,7,8 TCDD-TEQ (Dioxin) in the CT RSRs. EPA and CT DEP have agreed that the cleanup level for 2,3,7,8-TCDD TEQ will be the lower of the EPA policy for residential sites (0.001 mg/kg per OSWER Directive # 9200.4-26 April 1998) and the background concentration which will be determined based on future field study, or another concentration consistent with CT RSRs, but not lower than background.

5. The PMC based cleanup levels for chromium (both trivalent and hexavalent) are based on a total chromium concentration.

6. The value of 400 mg/kg lead protects 95% of the exposed population from blood lead levels in excess of 10 ug/dl consistent with EPA's policy for lead (OSWER Directive #9355.4-12 July 14, 1994).

7. The total cancer risk does not include the risk attributed to 2,3,7,8 TCDD-TEQs as the cleanup level will be determined during remedial design.



REFERENCE: SOUTHINGTON, CONN. USGS QUAD. 1968 PR 1992, MERIDEN, CONN. USGS QUAD. 1966 PR 1984, NEW BRITAIN, CONN. USGS QUAD. 1966 PR 1984, & BRISTOL, CONN. USGS QUAD 1967 PR 1984

2000' 0 2000'

APPROX. SCALE: 1" = 2000'

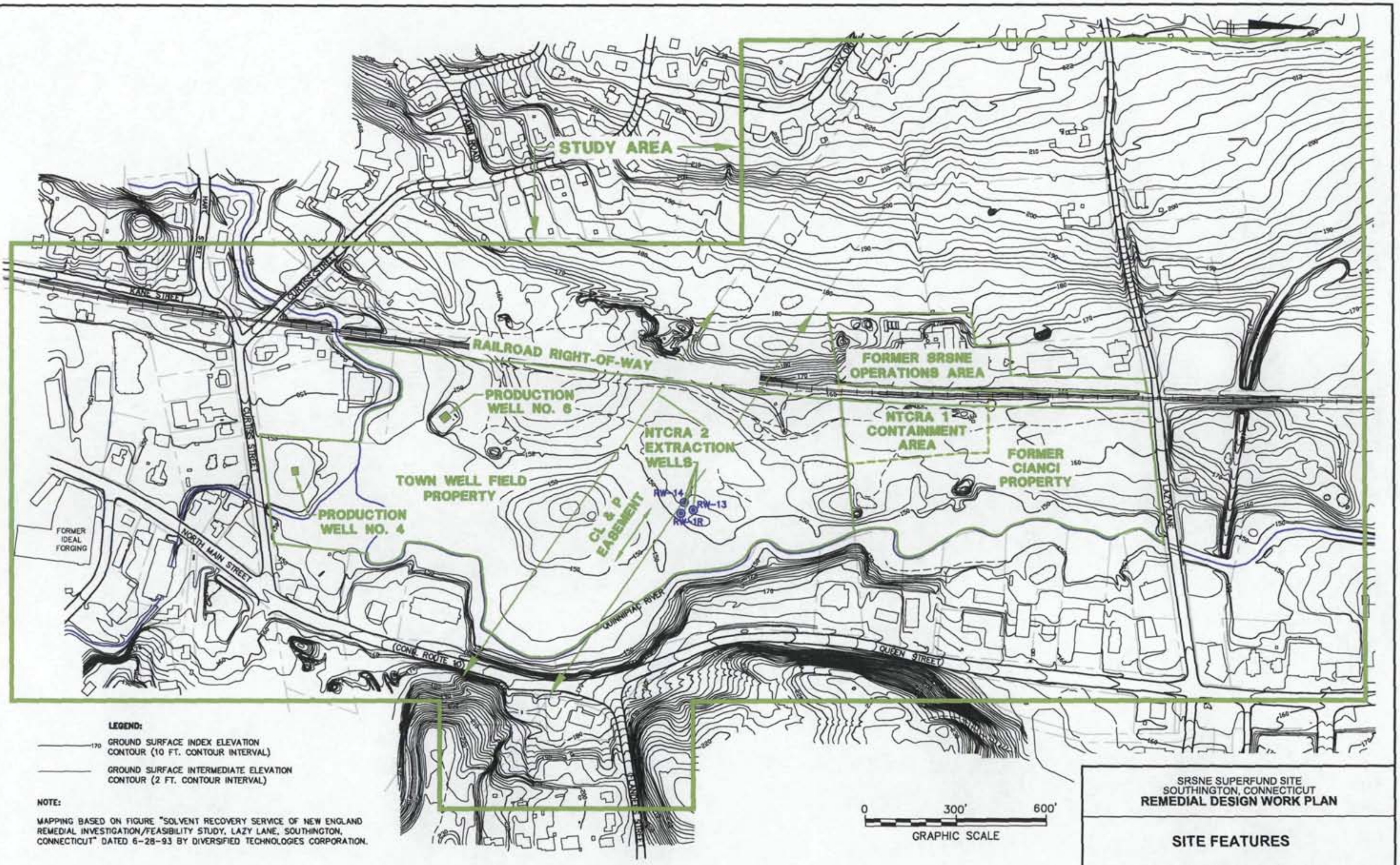
QUADRANGLE LOCATION

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL DESIGN WORK PLAN

SITE LOCATION MAP

ARCADIS

FIGURE
1



LEGEND:

170 GROUND SURFACE INDEX ELEVATION CONTOUR (10 FT. CONTOUR INTERVAL)

GROUND SURFACE INTERMEDIATE ELEVATION CONTOUR (2 FT. CONTOUR INTERVAL)

NOTE:

MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONNECTICUT" DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

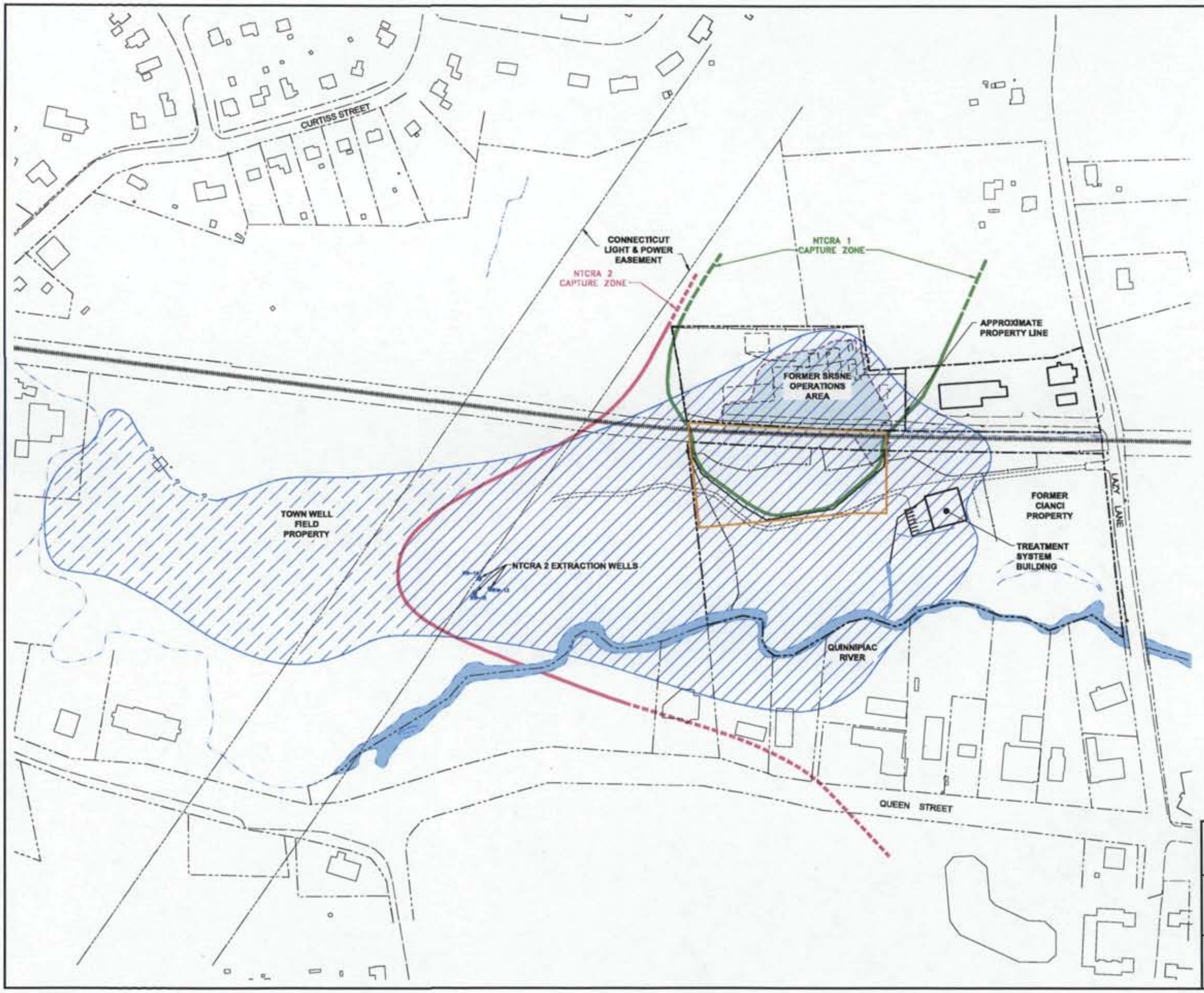
XREFS: 54634X01 IMAGES: PROJECTNAME: —

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL DESIGN WORK PLAN

SITE FEATURES

ARCADIS

FIGURE
2



LEGEND:

- PROPERTY LINE
- PROPERTY LINE – ADJOINER
- BUILDING
- BUILDING – ADJOINER
- FORMER BUILDING
- RAILROAD
- ROAD
- GRAVEL ROAD
- DRAINAGE SWALE
- RIVER
- EASEMENT
- CHAINLINK FENCE
- SHEETPILE
- NTCRA 1 CONTAINMENT AREA
- OVERBURDEN GROUNDWATER AREA (FROM FIGURE 2-4 OF FEASIBILITY STUDY [BBL AND USEPA 2005])
- SEVERED PLUME (FROM FIGURE 2-4 OF FEASIBILITY STUDY [BBL AND USEPA 2005])
- OVERBURDEN NAPL AREA (FROM FIGURE 2-3 OF FEASIBILITY STUDY [BBL AND USEPA 2005])

NOTES:

1. BASEMAP INFORMATION OBTAINED FROM A FIGURE CREATED BY CONKLIN & SOROKA, INC., ENTITLED "TOPOGRAPHIC SURVEY" DATED 1/13/09 AT A SCALE OF 1"=50'.
2. ALL LOCATIONS ARE APPROXIMATE.
3. THIS FIGURE PRESENTS AN OVERLAY OF THE ESTIMATED EXTENTS OF THE GROUNDWATER PLUME IN THREE MONITORED OVERBURDEN ZONES, BASED ON PLUME DELINEATION LIMITS PRESENTED IN THE FEASIBILITY STUDY (BBL AND USEPA 2005).

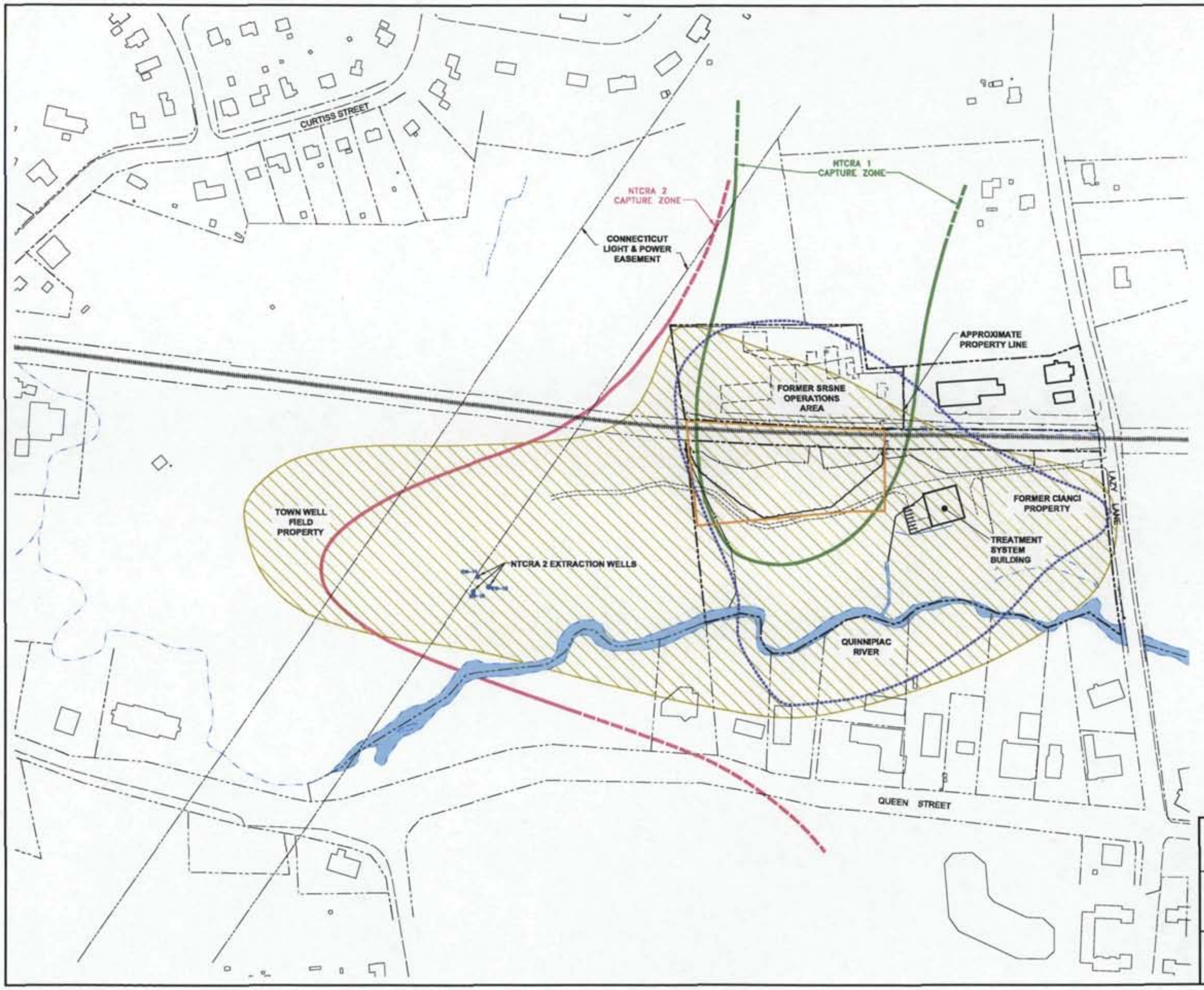
0 120' 240'
GRAPHIC SCALE

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL DESIGN WORK PLAN

ESTIMATED GROUNDWATER PLUME AND NAPL AREAS - OVERBURDEN

ARCADIS

FIGURE
3A



LEGEND:

- PROPERTY LINE
- PROPERTY LINE - ADJOINER
- BUILDING
- BUILDING - ADJOINER
- FORMER BUILDING
- RAILROAD
- ROAD
- GRAVEL ROAD
- DRAINAGE SWALE
- RIVER
- EASEMENT
- CHAINLINK FENCE
- SHEETPILE
- NTCRA 1 CONTAINMENT AREA
- BEDROCK NAPL AREA (FROM FIGURE 2-5 OF FEASIBILITY STUDY [BBL AND USEPA 2005])
- BEDROCK GROUNDWATER AREA (FROM FIGURE 2-6 OF FEASIBILITY STUDY [BBL AND USEPA 2005])

NOTES:

1. BASEMAP INFORMATION OBTAINED FROM A FIGURE CREATED BY CONKLIN & SOROKA, INC., ENTITLED "TOPOGRAPHIC SURVEY" DATED 1/13/09 AT A SCALE OF 1"=50'.
2. ALL LOCATIONS ARE APPROXIMATE.
3. THIS FIGURE PRESENTS AN OVERLAY OF THE ESTIMATED EXTENTS OF THE GROUNDWATER PLUME IN TWO MONITORED BEDROCK ZONES, BASED ON PLUME DELINEATION LIMITS PRESENTED IN THE FEASIBILITY STUDY (BBL AND USEPA 2005).

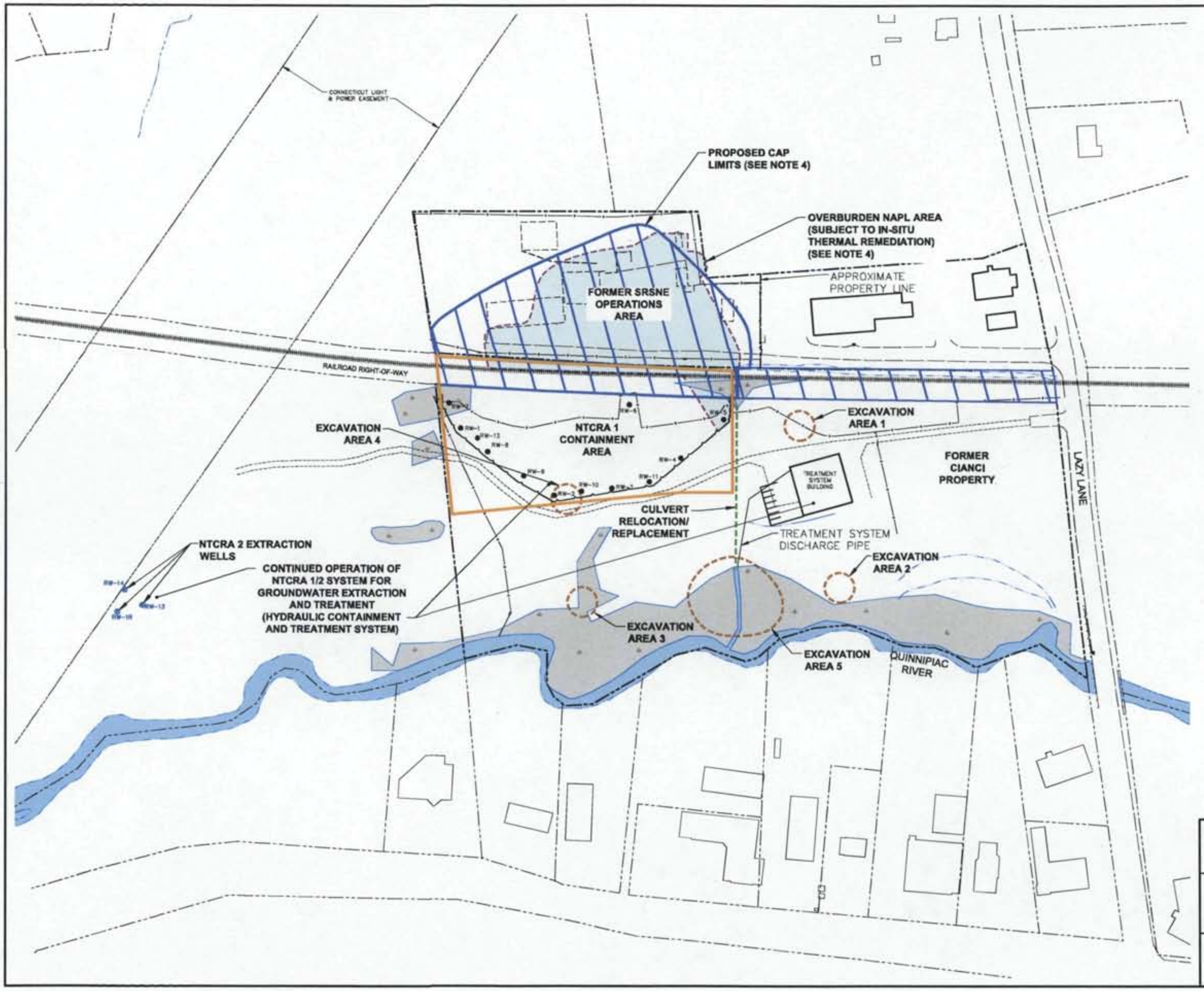
0 120' 240'
GRAPHIC SCALE

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL DESIGN WORK PLAN

ESTIMATED GROUNDWATER PLUME AND NAPL AREAS - BEDROCK

ARCADIS

FIGURE
3B



NOTES:

1. SITE PLAN TAKEN FROM DIVERSIFIED TECHNOLOGIES CORP., 556 WASHINGTON AVE., NORTH HAVEN, CT, DATED 6/93. TOPOGRAPHY REPORTED TO HAVE BEEN DIGITIZED FROM TOWN OF SOUTHINGTON TOPOGRAPH MAPS G-7, G-8, G-9; PHOTOGRAPHY DATED NOV. 1978, SCALE: 1"=100', PROPERTY LINES REPORTED TO HAVE BEEN DIGITIZED AND LOT NUMBERS TAKEN FROM "PROPERTY MAP, TOWN OF SOUTHINGTON" MAPS 134 & 147, SCALE: 1"=100' BY DIVERSIFIED TECHNOLOGIES CORPORATION.
2. BENCHMARK #1 IS AT ELEVATION 164.03. PK NAIL; S'LY SIDE; POLE #9049.
3. WETLAND AREAS WERE TAKEN FROM THE FINAL REMEDIAL INVESTIGATION REPORT (HNUS 1994).
4. THE LIMITS OF REMEDIAL ACTIVITIES ARE PRELIMINARY AND ARE SUBJECT TO CONFIRMATION/MODIFICATION BASED ON REMEDIAL DESIGN ACTIVITIES.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
REMEDIAL DESIGN WORK PLAN

PLANNED REMEDIAL ACTIVITIES

ARCADIS

FIGURE
4

Attachment 1 Public Notice of Five-Year Review

Soldier returns from Iraq

Army National Guard Chief Warrant Officer 2 Christopher R. Mattson is returning to the U.S. after a deployment to Iraqi in support of Operations Iraqi Freedom.

The soldier returns to Fort Dix, N.J. for debriefing, evaluations and out-processing procedures before returning to his regularly assigned Army National Guard unit.

The chief warrant officer served in support of Operation Iraqi Freedom in the Iraq Theater of Operations.

Mattson, a CH-47 pilot, is a member of Company B, 104th General Support Aviation Battalion, based in Windsor Locks. He has 12 years of military service.

He is the son of Richard A.E. and Alice Mattson of Golden Road, Uncasville.

His wife, Kristen, is the daughter of Fredrick K. Anderson, and Mary E. Anderson, both of Southington.

In 1998, he graduated from Montville High School, Oakdale, Conn.

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United States Environmental Protection Agency New England

Solvents Recovery Service of New England Superfund Site Five-Year Review

1149906

The United States Environmental Protection Agency (EPA) has begun its first five-year review at the Solvents Recovery Service of New England, Inc. Superfund Site on Lazy Lane in Southington, Connecticut. This review is being performed five years following selection of the final cleanup plan and issuance of the Record of Decision in 2005. The review is a comprehensive assessment of the performance of the groundwater cleanup systems which began operating in 1995. EPA will also talk with Southington officials and citizens to gain a better understanding of any local concerns related to the Superfund site.

The review team will evaluate the information gathered and then make a determination as to whether the remedy is protective or not protective of public health and the environment. After completion of these activities, EPA will issue a Five-Year Review Report summarizing the findings with respect to the site.

From 1955 to 1991, Solvents Recovery Service (SRS) operated as a spent solvent processing and reclamation facility at the Lazy Lane site. Millions of gallons of waste solvents and oils were handled, stored and processed at the facility. Past operating practices, such as the use of lagoons and a leach field, contributed to contamination at SRS and surrounding properties. Poor housekeeping from a variety of practices, including the unloading and loading of tank trucks, the transfer of spent solvents to storage tanks, as well as the improper handling and storage of drums, resulted in numerous leaks and spills to the bare ground which also contributed to contamination of the underlying aquifer.

The 2005 cleanup plan selected by EPA is projected to cost approximately $29 million and includes heating, capturing, and treating waste oils and solvents in the subsurface; excavating, consolidating and capping contaminated soil and wetland soil onsite; and continuing to pump and treat contaminated groundwater. There will also be restrictions on uses of the site property and groundwater, and long term monitoring of the cap and groundwater to ensure that the cleanup remains protective of human health and the environment for the future.

Preliminary activities will begin at the site this year and major cleanup work is being planned for 2011. EPA plans to keep the community informed of the status of activities at the site and will announce opportunities for community participation later this year. In the meantime, anyone who has questions or who would like to be interviewed as part of the five-year review, may contact Jim Murphy, EPA's Community Involvement Coordinator at 617-918-1028 or murphy.jim@epa.gov.

More information about cleanup activities at the Solvents Recovery Services Superfund Site may be found on the EPA New England web site at www.epa.gov/region1/superfund/sites/srs.

Obituaries

William Shearstone II

William Charles Shearstone II, 68, of the Plantsville section of Southington died Feb. 27, 2010, at the Hospital of Central Connecticut at Bradley Memorial. He was beloved husband of Barbara (Pelsinski) Shearstone for 49 years.

He was born July 13, 1941, in Ashland, Pa., to the late William Charles Shearstone Jr. and the late Alice (Winters) Shearstone he had lived in Southington for many years. He retired from the Travelers Insurance Company and will be fondly remembered for being a big Dodgers fan.

In addition to his wif, he is survived by his son, William Shearstone III and his wife, Leslie, of Roswell, Ga.; two daughters, Jennifer Shearstone, of Northampton, Mass. and Angeline Shearstone of Durham, N.C.; two sisters, Alice Oshman and Rosemary Beaver; and three grandchildren: William, Amanda and Matthew. He was predeceased by his brother, John Shearstone.

The funeral was held March 3, 2010, at the Plantsville Funeral Home, Plantsville with a Mass at St. Aloysius Church, Plantsville. Burial followed in St. Thomas Cemetery, Southington. Memorial donations may be made to The American Cancer Society, 825 Broad St., Rocky Hill, CT 06067 or to the National Emphysema Foundation, 128 East Ave., Norwalk, CT 06850.

Nancy Peterson

Nancy (Hornkohl) Peterson, 76, of Southington, widow of Harvey E. Peterson, died Feb. 28, 2010.

She was born in New Britain, and had been a Southington resident since 1957. She was a graduate of Teachers College (now Central Connecticut State University) and was employed as a nursery school teacher at Grace United Methodist Church in Southington for many years. Besides being a member of the church, she was a member of the Southington Festival Choir.

She is survived by her two sons, Mark Peterson, of Southington and Todd Peterson and his wife, Rosemarie, of Plainville; a sister, Joyce Brotherton, of Southington; two grandchildren, Nathan H. Peterson and Victoria Lynn Peterson; several nieces and nephews; and a grand puppy, Lilly.

The funeral was held March 4, 2010, at the Carlson Funeral Home, New Britain. Burial was in Oak Hill Cemetery, Southington. Memorial donations may be made to the Connecticut Humane Society, Russell Road, Newington, CT 06111.

More obituaries on page 22

Attachment 2 Five-Year Review Site Inspection Checklist

I. SITE INFORMATION

Site name: Solvents Recovery Service of New England, Inc	**Date of inspection:** June 2, 2010
Location and Region: Southington, CT / Region 1	**EPA ID:** CTD009717604
Agency, office, or company leading the five-year review: EPA Region 1	**Weather/temperature:** 75-80°, Sunny

Remedy Includes: (Check all that apply)

√ Landfill cover/containment
√ Access controls
√ Institutional controls
√ Groundwater pump and treatment
☐ Surface water collection and treatment
√ Other: In-situ Thermal Treatment

√ Monitored natural attenuation
√ Groundwater containment
√ Vertical barrier walls

Attachments: ☐ Inspection team roster attached √ Site map attached

II. INTERVIEWS (Check all that apply)

1. **O&M site manager** John Hunt, *de maximis, inc* Project Manager June 2, 2010
Name Title Date
Interviewed √ at site ☐ at office ☐ by phone Phone no. 860-651-1196
Problems, suggestions; ☐ Report attached: None

2. **O&M staff** ________ ________ ________
Name Title Date
Interviewed ☐ at site ☐ at office ☐ by phone Phone no. ________
Problems, suggestions; ☐ Report attached ________

3. **Local regulatory authorities and response agencies**

Agency: CT Department of Environmental Protection
Contact: Ryan Santos Project Manager June 2, 2010 860-424-3865
Name Title Date Phone no.
Problems; suggestions; ☐ Report attached : None

Agency: Town of Southington
Contact: John Weichsel Town Manager April 27, 2010 860-276-6200
Name Title Date Phone no.
Problems; suggestions; √ Report attached

Agency: Town of Southington
Contact: Anthony Traquillo Town Engineer/Director Public Works April 27, 2010 860-276-6231
Name Title Date Phone no.
Problems; suggestions; √ Report attached

4. **Other interviews** (optional) ☐ Report attached

See discussion in Section 6.5

III. ON-SITE DOCUMENTS & RECORDS VERIFIED (Check all that apply)

1. **O&M Documents**
☐ O&M manual √ Readily available √ Up to date ☐ N/A
☐ As-built drawings √ Readily available √ Up to date ☐ N/A
☐ Maintenance logs √ Readily available √ Up to date ☐ N/A
Remarks: None

2. **Site-Specific Health and Safety Plan** ☐ Readily available ☐ Up to date ☐ N/A
☐ Contingency plan/emergency response plan ☐ Readily available ☐ Up to date ☐ N/A
Remarks: RPM did not review

3. **O&M and OSHA Training Records** ☐ Readily available ☐ Up to date ☐ N/A
Remarks: RPM did not review

4. **Permits and Service Agreements**
☐ Air discharge permit ☐ Readily available ☐ Up to date √ N/A
☐ Effluent discharge √ Readily available √ Up to date ☐ N/A
☐ Waste disposal, POTW √ Readily available √ Up to date ☐ N/A
☐ Other permits____________________ ☐ Readily available ☐ Up to date √ N/A
Remarks: None

5. **Gas Generation Records** ☐ Readily available ☐ Up to date √ N/A
Remarks____________________

6. **Settlement Monument Records** ☐ Readily available ☐ Up to date √ N/A
Remarks____________________

7. **Groundwater Monitoring Records** √ Readily available √ Up to date ☐ N/A
Remarks: None

8. **Leachate Extraction Records** ☐ Readily available ☐ Up to date √ N/A
Remarks: None

9. **Discharge Compliance Records**
☐ Air ☐ Readily available ☐ Up to date √ N/A
☐ Water (effluent) √ Readily available √ Up to date ☐ N/A
Remarks: None

10. **Daily Access/Security Logs** ☐ Readily available ☐ Up to date ☐ N/A
Remarks: RPM did not review

IV. O&M COSTS

1. **O&M Organization**
☐ State in-house ☐ Contractor for State
☐ PRP in-house √ Contractor for PRP

☐ Federal Facility in-house ☐ Contractor for Federal Facility
☐ Other

2. **O&M Cost Records**
☐ Readily available √ Up to date
☐ Funding mechanism/agreement in place
Original O&M cost estimate ☐ Breakdown attached

Total annual cost by year for review period if available: See Table 3

3. **Unanticipated or Unusually High O&M Costs During Review Period**
Describe costs and reasons: None

V. ACCESS AND INSTITUTIONAL CONTROLS √ Applicable ☐ N/A

A. Fencing

1. **Fencing damaged** √ Location shown on site map √ Gates secured ☐ N/A
Remarks: None

B. Other Access Restrictions

1. **Signs and other security measures** ☐ Location shown on site map √ N/A
Remarks

C. Institutional Controls (ICs) This component of the remedy has not been implemented yet.

D. General

1. **Vandalism/trespassing** ☐ Location shown on site map √ No vandalism evident
Remarks: None

2. **Land use changes on site** √ N/A
Remarks

3. **Land use changes off site** √ N/A
Remarks

VI. GENERAL SITE CONDITIONS

A. Roads √ Applicable ☐ N/A

1. **Roads damaged** √ Location shown on site map √ Roads adequate ☐ N/A
Remarks: None

B. Other Site Conditions

Remarks: None

VII. LANDFILL COVERS This component of the remedy has not been implemented yet.

VIII. VERTICAL BARRIER WALLS √ Applicable ☐ N/A

1. **Settlement** √ Location shown on site map √ Settlement not evident
Areal extent: 700 feet long Depth: 30 feet
Remarks: None

2. **Performance Monitoring** Type of monitoring : Groundwater elevations
☐ Performance not monitored
Frequency: varies (daily, weekly, monthly) ☐ Evidence of breaching
Head differential: minimum requirement of 0.3 feet
Remarks: None

IX. GROUNDWATER/SURFACE WATER REMEDIES √ Applicable ☐ N/A

A. Groundwater Extraction Wells, Pumps, and Pipelines √ Applicable ☐ N/A

1. **Pumps, Wellhead Plumbing, and Electrical**
☐ Good condition ☐ All required wells properly operating ☐ Needs Maintenance ☐ N/A
Remarks: RPM did not inspect

2. **Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
☐ Good condition ☐ Needs Maintenance
Remarks: RPM did not inspect

3. **Spare Parts and Equipment**
☐ Readily available ☐ Good condition ☐ Requires upgrade ☐ Needs to be provided
Remarks: RPM did not inspect

B. Surface Water Collection Structures, Pumps, and Pipelines ☐ Applicable √ N/A

C. Treatment System √ Applicable ☐ N/A

1. **Treatment Train** (Check components that apply)
☐ Metals removal ☐ Oil/water separation ☐ Bioremediation
☐ Air stripping √ Carbon adsorbers
☐ Filters______________________________
☐ Additive (*e.g.*, chelation agent, flocculent)________________________
√ Others: UV/oxidation
√ Good condition ☐ Needs Maintenance
☐ Sampling ports properly marked and functional
☐ Sampling/maintenance log displayed and up to date
☐ Equipment properly identified
√ Quantity of groundwater treated annually (Sept 2005 to August 2010): 14 million (average)
☐ Quantity of surface water treated annually____________________
Remarks: None

2. **Electrical Enclosures and Panels** (properly rated and functional)
☐ N/A ☐ Good condition ☐ Needs Maintenance
Remarks: RPM did not inspect

3. **Tanks, Vaults, Storage Vessels**
☐ N/A ☐ Good condition ☐ Proper secondary containment ☐ Needs Maintenance
Remarks: RPM did not inspect

4. **Discharge Structure and Appurtenances**
☐ N/A ☐ Good condition ☐ Needs Maintenance
Remarks: RPM did not inspect

5. **Treatment Building(s)**
☐ N/A √ Good condition (esp. roof and doorways) ☐ Needs repair
☐ Chemicals and equipment properly stored
Remarks: None

6. **Monitoring Wells** (pump and treatment remedy)
√ Properly secured/locked √ Functioning √ Routinely sampled √ Good condition
☐ All required wells located ☐ Needs Maintenance ☐ N/A
Remarks: None

D. Monitoring Data

1. Monitoring Data
√ Is routinely submitted on time √ Is of acceptable quality

2. Monitoring data suggests
√ Groundwater plume is effectively contained √ Contaminant concentrations are declining

E. Monitored Natural Attenuation

1. **Monitoring Wells** (natural attenuation remedy)
√ Properly secured/locked √ Functioning √ Routinely sampled √ Good condition
☐ All required wells located ☐ Needs Maintenance ☐ N/A
Remarks: None

X. OTHER REMEDIES

In-situ thermal treatment – this component of the remedy has not been implemented yet.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

Groundwater containment and on-site treatment is functioning as designed. MNA portion of that plume that meets federal drinking water standards but not ARARs (background) is occurring. Access is controlled by fencing and no one is currently drinking the groundwater. Excavation of wetland soils and river sediment that posed a ecological risk are being excavated in the phase of construction that began September 13, 2010, to be completed by December 2010. Remaining components of the remedy will be implemented before next five-year review (2015).

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

O&M of the groundwater containment and on-site treatment system is performed regularly, with no significant issues or problems reported.

C. Early Indicators of Potential Remedy Problems

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs that suggest that the protectiveness of the remedy may be compromised in the future.

No such issues or observations noted.

D. Opportunities for Optimization

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

Under the terms of the 2009 Consent Decree, the SRSNE Site Group is required to perform an optimization study of the containment/treatment system after the in-situ thermal component of the remedy, which is expected to be completed in 2015.

Attachment 3 Interview Reports

INTERVIEW RECORD – Town Manager of Southington

Site Name: Solvents Recovery Services of New England (SRSNE)

EPA ID No.:

Subject: First Five-Year Review (2010)

Time: 11:00

Date: 4/27/10

Type: ☐ Telephone ☒ Visit ☐ Other
Location of Visit: Town Offices

☐ Incoming ☐ Outgoing

Contact Made By:

Name: Jim Murphy

Title: Community Involvement Coordinator

Organization: US EPA

Individual Contacted:

Name: John Weichsel

Title: Town Manager

Organization: Town of Southington

Telephone No: 860-276-6200
Fax No: 860-628-4727
E-Mail Address: weichselj@southington.org

Street Address: Town Hall, 75 Main Street
City, State, Zip: Southington, CT 06489

Summary Of Conversation

Q1: What is your overall impression of the project and site?
A1: The site is well managed by the responsible party group as well as the EPA. The Town is pleased that the SRSNE site group has committed to complete the section of the rails to trails project that crosses the site as thr rails to trails project has been a vert positive recreational development in town.

Q2: What effects have site operations had on the surrounding community?
A2: While there was an impact on the community along Lazy Lane over the years, that has eased over time as the remediation work has progressed.

Q3: Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
A3: As the Town is not really involved in the operation and management of the site, he does not focus general site issues and is not aware of any community concers relative to the site.

Q4: Has there been any significant changes in the O&M activities or a chance to optimize the O&M?
A4: Not aware of any.

Q5: Do you feel that information related to the site is readily available?
A5: He feels appropriately informed on the issues and events by the site group and US E.P.A; there haven't been any real surprises.

Q6: Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details.
A6: No incidents or emergency response activities have occurred at the Site.

Q7: Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
A7: Nothing at this time.

INTERVIEW RECORD – Southington Town Engineer

Site Name: Solvents Recovery Services of New England (SRSNE)
EPA ID No.:
Subject: First Five-Year Review (2010)
Time: 12:00
Date: 4/27/10
Type: ☐ Telephone ☒ Visit ☐ Other
Location of Visit: Town Offices
☐ Incoming ☐ Outgoing

Contact Made By:

Name: Jim Murphy
Title: Community Involvement Coordinator
Organization: US EPA

Individual Contacted:

Name: Anthony J. Tranquillo, P.E.
Title: Dir. Of Public Works / Town Engineer
Organization: Town of Southington
Telephone No: 860-276-6231
Fax No: 860-628-8669
E-Mail Address: tranquiloa@southington.org
Street Address: Town Hall, 75 Main Street
City, State, Zip: Southington, CT 06489

Summary Of Conversation

Q1: What is your overall impression of the project and site?
A1: In contrast to the OSL site where the Town plays an active role, including the scheduled mowing of the site, there is very little involvement with the SRS site and very little information that comes into the Town that he is aware of.

Q2: What effects have site operations had on the surrounding community?
A2: The area around the site is still generally depressed due to the stigma.

Q3: Are you aware of any community concerns regarding the site or its operation and administration? If so, please give details.
A3: There is some community concern about the potential for vapors to be released during the planned remediation. There is also some general frustration over the length of time that it has taken to decide on and then implement the cleanup.

Q4: Has there been any significant changes in the O&M activities or a chance to optimize the O&M?
A4: Not aware of any.

Q5: Do you feel that information related to the site is readily available?
A5: He believes the Town Offices are moderately well informed, but he doesn't always get information in the Engineering Department.

Q6: Are you aware of any events, incidents, or activities at the site such as vandalism, trespassing, or emergency responses from local authorities? If so, please give details.
A6: No incidents or emergency response activities have occurred at the Site.

Q7: Do you have any comments, suggestions, or recommendations regarding the site's management or operation?
A7: There are some internal issues with delivering the information to the necessary people and departments and he suggests the Assistant Town Manager be the point of contact and that relevant information also be sent directly to Mr. Tranquillo.

EPA/600/R-99/107
February 2000

Introduction to Phytoremediation

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

The EPA through its ORD produced this document. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technicological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

Phytoremediation is the name given to a set of technologies that use different plants as a containment, destruction, or an extraction technique. Phytoremediation as a remediation technology that has been receiving attention lately as the results from field trials indicate a cost savings compared to conventional treatments.

The U.S. EPA has a dual role in which it seeks to protect human health and the environment associated with hazardous waste sites, while encouraging development of innovative technologies that might more efficiently clean up these sites.

This Introduction is intended to provide a tool for site regulators, owners, neighbors, and managers to evaluate the applicability of phytoremediation to a site. This document defines terms and provides a framework to understand phytoremediation applications. It is a compilation of research and remediation work that has been done to date. The format is intended to be accessible to EPA RPMs, state regulators, and others who need to choose between alternate technologies, as well for site owners, consultants, contractors, and students who are interested in basic information. It is not a design manual, and is not intended to provide enough information to choose, engineer, and install a phytoremediation application.

This work may also be used to help guide research, development, and regulation. Areas of needed research have been identified. By compiling the published and unpublished work, research repetition can be avoided, and areas of opportunity that need attention should be clear.

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Acronyms

AAP	Army Ammunition Plant
ACAP	Alternative Cover Assessment Program (U.S. EPA)
ALCD	Alternative Landfill Cover Demonstration
ANOVA	Analysis of Variance
APG	Aberdeen Proving Grounds
ARARs	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C_o	Original Concentration
DEPH	Diethylhexylphthalate
DNAPL	Dense Nonaqueous Phase Liquid
DOD	Department of Defense
DOE	Department of Energy
EPA	Environmental Protection Agency
ERT	U.S. EPA Emergency Response Team
FFDCA	Federal Food, Drug, and Cosmetic Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GC/MS	Gas Chromatography/Mass Spectroscopy
HCB	Hexachlorobenzene
K_{ow}	octanol-water partition coefficient
LNAPL	Light Nonaqueous Phase Liquid
MCL	Maximum Contaminant Level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List (Superfund)
NRMRL	National Risk Management Research Laboratory
OSC	On-Scene Coordinator
ORD	U.S. EPA Office of Research and Development
OSWER	U.S. EPA Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PCE	Perchloroethylene, tetrachloroethene
PCP	Pentachlorophenol
PRP	Potentially Responsible Party
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RPM	Remedial Project Manager
ROD	Record of Decision
RTDF	Remediation Technologies Development Forum
SITE	Superfund Innovative Technology Evaluation Program (EPA)
TCA	Tetrachloroethane
TCAA	Trichloroacetic acid
TCE	Trichloroethylene
TIO	U.S. EPA Technology Innovation Office
TNT	Trinitrotoluene

Acronyms (continued)

TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act
USDA	U.S. Department of Agriculture
UXO	Unexploded Ordinance
VOC	Volatile Organic Compounds

Chapter 6
Case Studies

The six case studies presented in this chapter illustrate specific field applications of phytoremediation. Site descriptions, design considerations, monitoring recommendations, status, and cost of various phytoremediation processes are presented. The completeness of the information provided varies based on the status of the project (i.e., complete costs or degree of contaminant removal may not be fully defined because the project is ongoing).

6.1 Edgewood Area J-Field Toxic Pits Site Aberdeen Proving Grounds Edgewood, Maryland

Site name:	Edgewood Area J-Field Toxic Pits Site
Location:	Aberdeen Proving Grounds, Edgewood, Maryland
Media:	Groundwater (8 ft bgs)
Primary contaminants and maximum concentration:	1,1,2,2-tetrachloroethane (1122-TCA), 170 ppm Trichloroethylene (TCE), 61 ppm
Type of plant:	*Populus tricocarpa x deltoides* (Hybrid poplar)
Area of planting:	1 acre
Date of planting:	March/April 1996

6.1.1 Site Description

The Aberdeen Proving Grounds (APG) in Maryland began serving as a U.S. Army weapons testing facility in 1918. Military weapons testing and past disposal activities over the years have caused extensive pollution throughout the soil and groundwater of the Proving Grounds. As a result, the entire Edgewood area of Aberdeen appears on the Superfund National Priority List (NPL). The Department of Defense (DOD) and the U.S. Environmental Protection Agency (EPA) are jointly funding field-scale applications of innovative treatment technologies around the facility. At the J-Field Site in the Edgewood Area, EPA's Environmental Response Team (ERT) coordinated the planting of hybrid poplars over a shallow plume of chlorinated solvents in an effort to hydraulically contain the contaminants and treat the groundwater.

J-Field is located at the tip of Gunpowder Neck, in the Edgewood Area of APG. Two pits measuring 10 x 15 x 200 feet were used for the disposal of chemical warfare agents, munitions, and industrial chemicals from the 1940s to the 1980s. Disposal methods included open burning of waste material such as high explosives, nerve agents, mustard agents, and smoke-producing materials. Wood and fuel were used to feed the fire. Decontaminating agents used in the operations were solvent-based. During this burning process, large volumes of various chlorinated solvents were discharged. As a result, a plume of chlorinated solvents formed in the aquifer below the burning pits. The predominant solvents in the groundwater are 1,1,2,2-tetrachloroethane (1122-TCA) and trichloroethylene (TCE), with maximum concentrations in the groundwater of 170 ppm and 61 ppm, respectively. Total volatile organic compound (VOC) concentrations in the groundwater range up to 260 ppm.

6.1.2 Design, Goals, and Monitoring Approaches

Several technologies were considered for cleaning the soil and groundwater at the site. Soil washing, vapor extraction, and capping were considered for cleaning up soils, while pump-and-treat and air sparging were considered for remediating the groundwater. These technologies were eliminated from consideration for a number of reasons. Technologies that involved a rigid installation design were eliminated because of the potential for unexploded bombs buried on site. Pumping and treating the water would be difficult because of the high concentrations of contaminants and strict discharge regulations. Thus, the pump-and-treat system would need to remove high concentrations of contaminants from large volumes of groundwater, and then discharge the groundwater after it had been treated. Soil excavation was eliminated from consideration due to the presence of unexploded ordnance (UXO) and its high cost. After eliminating the other possibilities, project managers decided the J-Field site was a candidate for a pilot-scale phytoremediation system.

Based on site conditions and the possible presence of UXO at the J-Field Toxic Pits Site of APG, phytoremediation was deemed a viable remedial alternative to hydraulically contain the contaminants and treat the groundwater. Applied Natural Sciences, Inc., was subcontracted to design and install the phytoremediation system. The phytoremediation strategy employed at the J-Field site began in September 1995 with a phytotoxicity assessment of on-site pollutants to determine any nutrient deficiencies that would hinder tree growth. Four planting areas were designated at the J-Field site, totaling approximately 1-acre. Holes were augered to a depth of 8 feet to allow homogenization of soil layers. Soil samples were collected and analyzed for VOCs, metals, and chloride. The design was based on the location of the toxic pits, various wells which would be utilized in monitoring the system, and the flow of contaminated groundwater.

In March and April 1996, 184 bare-root hybrid poplars (*P. trichocarpa x deltoides* [HP-510]) were purchased from a tree farm in Pennsylvania and planted 2 to 6 feet below ground surface (bgs) in the areas of highest pollutant concentration around the leading edge of the plume. These trees were planted in an attempt to intercept groundwater, thus preventing further contamination of the nearby marsh. The phytoremediation planting area covers approximately 1 acre southeast of the toxic pits, and is surrounded by wooded areas and scattered thickets. Groundwater flows from the toxic pit area to the south and southeast. Perched groundwater in the planting area varies throughout the year from 2 to 8 feet below ground surface (bgs). To promote growth down to the saturated zone, each tree was planted with a plastic pipe around its upper roots. A long piece of rubber tubing was also added from the surface to the deeper roots in order to provide oxygen. A drainage system was installed in May 1996 to remove rainwater and thus encourage the plants' roots to seek groundwater. A sweetgum tree growing on site prior to installation of the phytoremediation system was left standing. It will be monitored along with the poplars.

Since the Aberdeen project involves a new treatment strategy, extensive monitoring is taking place to determine the fates of the pollutants, the transpiration rates of the trees, and the best methods for monitoring phytoremediation sites. Groundwater contaminant levels, water levels, tree growth, tree transpiration rates, tree transpirational gas and condensate water contaminant levels, soil community, and tree tissue contaminant levels were monitored over the second year growing season to determine the effectiveness of this emerging technology. The monitoring approaches are summarized in Table 6-1. The sampling design of the site involves collecting soils, transpiration gases, and tree tissues from the roots, shoots, stems, and leaves. Results will help determine the concentrations of contaminants and their metabolites along each step of the translocation pathway.

Nine wells were located in the surficial aquifer near the study area at the time of tree planting. To determine the effects of the phytoremediation study on groundwater, an additional five wells and four lysimeters were installed in November 1996. Monitoring wells were screened from 4 to 14 feet bgs. Two sets of two lysimeters were installed near the new monitoring wells. The lysimeters were placed in pairs and set at depths of 4 and 8 feet bgs. These depths allow for coverage of the capillary zone during seasonal highs and lows. Groundwater and lysimeters were monitored on a quarterly basis for VOCs, metals, and chloride. The data obtained from the lysimeters are currently being compared with the surrounding tree tissue and transpirational gas data to determine the degree of success of the study.

Table 6-1. Monitoring Approaches at the J-Field Site.

Type of Analysis or Observation Used	Parameters Tested or Methods
Plant growth measurements and visual observations	Diameter, height, health, pruning, replacement
Groundwater and vadose zone sampling and analysis	14 wells and 4 lysimeters to sample for VOCs, metals, and nutrients
Soil sampling and analysis	Biodegradation activity, VOCs, metals
Tissue sampling and analysis	Degradation products, VOCs
Plant sap flow measurements	Correlate sap flow data to meteorological data
Transpirational gas sampling and analysis	Explore various methods

Source: Tobia and Compton (1997)

6.1.3 Results and Status

Plant tissue samples were taken from certain trees and analyzed for VOCs and metals. Results have shown parent compounds and degradation products increasing in concentration through mid-growing season and waning in the fall.

Weather parameters were measured by an on-site meteorological station, correlated with tree data, and were utilized to estimate seasonal, daily, and yearly water uptake. These parameters included precipitation, incident solar radiation, temperature, humidity, and wind speed. All of these factors play a role in transpiration rates and sap flow.

Tree sap flow rates are being monitored in order to determine the pumping rates of the trees. A noninvasive technique was used to measure sap flow on certain trees during the various sampling seasons. The Dynamax Flow32™ Sap Flow System was used to measure the water flux of the trees in grams of water/hour/tree by utilizing the heat balance method.

Transpiration gas sampling was performed by placing a 100-L Tedlar™ bag over a section of branch on each of the selected trees. Air was drawn from the sealed branch by using a carbon Tenax tube, summa canister, Sciex Trace Atmospheric Gas Analyzer, and on-site Viking Gas Chromatograph/Mass Spectrometer (GC/MS). The most reliable results were obtained by collection into the summa canister, then analysis by laboratory GC/MS. The results show similar patterns to those found in the leaf tissue. The parent compounds of 1122-TCA and TCE were detected at increasing levels through the mid-growing season (maximum 2,000 ppb), with subsequent decreasing concentrations in the fall. Condensate water was collected from the bags and analyzed for VOCs. There was a strong correlation (0.92) between condensate water and transpiration gas, with a maximum concentration of 640 ppb of 1122-TCA in the condensate water.

Soil samples were collected from the rhizosphere of the selected trees. These samples were analyzed for VOCs, chloride, and metals, and utilized for soil community comparisons. There were noteworthy changes to the nematode functional group populations. The nematode community appears to have increased, both in diversity and concentration, from previous samples taken from the area before the trees were planted. Studies are planned to assess chlorinated solvent degradation by soil microbes.

Growth measurements, visual observations, and maintenance were performed on all trees during planting and at the end of each growing season to monitor tree growth and health. Tree diameter and height were measured and tree health observed, including monitoring of insect damage, chlorosis, and wilting. Approximately 10% of the trees have been killed by frost, deer rub during rutting season, and insect predation.

Sap flow rate data indicate that on a daily scale, maximum flow occurs in the morning hours. In addition, increasing amounts of solar radiation seem to increase sap flow rates, as would be expected in a tree. Groundwater monitoring data from May 1997 indicate that the trees are pumping large amounts of groundwater. Data indicate that there is roughly a 2-foot depression in the water table beneath the trees in comparison to data from April 1996. Tree tissue samples indicate the presence of trichloroacetic acid (TCAA), a breakdown product of TCE. These data correlate with the results from University of Washington greenhouse scale studies that also found TCAA in plant tissues in both axenic poplars cell cultures and hybrid poplar tissues. Site managers at Aberdeen are also finding that chlorinated solvents (TCE and 1,1,2,2-tetrachloroethane) are being evapotranspirated by the trees. To date, no mass balance studies have been performed to quantitatively determine the different fates of chlorinated solvents in this treatment system. Future monitoring of the site will hopefully answer some of the questions about solvent fate. To accomplish this, additional types of monitoring will be employed, such as on-site infrared spectrometry and on-site GC/MS.

Based on tree containment measurements, the results of the second growing season show that the trees are removing contaminants from the groundwater and transpiring parent compounds and their degradation products. The groundwater table has been lowered by tenths of feet in the planting area at the end of the growing season, indicating possible groundwater withdrawal by the trees for containment of the contaminated groundwater in future growing seasons. The trees are utilizing the groundwater at rates of 2 to 10 gpd/tree.

6.1.4 Costs

Tree installation cost is about $80/tree, or approximately $15,000 for the installation of 184 trees. The costs of monitoring are highly varied due to the numerous monitoring techniques employed at the site.

6.1.5 Conclusions

Phytoremediation using trees to clean up groundwater contaminated with volatile organic compounds may be an ideal choice for this site and others due to the low cost, low maintenance, and low impact associated with the technology. Much more work needs to be performed to further confirm: (1) the correlation between transpiration gas and condensate water; (2) soil community contaminant degradation rate; (3) soil flux rate of VOCs; (4) contaminant exposure to the root zone versus sap and condensate water; (5) leaf litter exposure pathway; and (6) microwells to determine the zone of contamination.

The environment benefits from the presence of trees regardless of whether or not the technology is effective in removing contamination. These environmental benefits include habitat for wildlife, protection of the soil against wind and water erosion, reduction of rainwater infiltration and flushing, an increase in organic matter, and an increase in soil aeration and microbial activity.

6.1.6 Contacts

Harry Compton
US EPA Environmental Response Team
Edison, NJ 00837
(732) 321-6751

Steve Hirsh
US EPA Region 3
Philadelphia, PA 19103
(215) 814-3352

6.2 Carswell Site
Fort Worth, Texas

Site name:	Former Carswell Air Force Plant
Location:	Fort Worth, Texas
Media:	Groundwater (12 ft bgs)
Primary contaminant and maximum concentration:	Trichloroethylene (TCE), <1,000 ppb
Type of plant:	*Populus deltoides* (Eastern Cottonwood)
Area of planting:	1 acre
Date of planting:	April 1996

6.2.1 Site Description

The efficacy and cost of phytoremediation with respect to the cleanup of shallow trichloroethylene (TCE) contaminated groundwater are being evaluated at the field scale in a multiagency demonstration project in Fort Worth, Texas. This U.S. Air Force project, which is being conducted as part of the Department of Defense's (DOD) Environmental Security Technology Certification Program (ESTCP), as well as the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program, entails the planting and cultivation of Eastern Cottonwood (*Populus deltoides*) trees above a dissolved TCE (<1,000 ppb maximum concentration) plume in a shallow aerobic aquifer to investigate the ability of these trees to control and degrade the plume. The plume is located near Air Force Plant 4 at the Naval Air Station Ft. Worth, also known as the Carswell Air Force Base. Data are being collected to determine the ability of trees planted as short-rotation woody crops to perform as a natural pump-and-treat system.

6.2.2 Design, Goals, and Monitoring Approaches

The U.S. Air Force (USAF) Acquisition and Environmental Management Restoration Division and the EPA National Risk Management Research Laboratory (NRMRL) carried out the design and implementation of the phytoremediation strategy at Carswell Site. In April 1996, the USAF planted 660 cottonwoods in an effort to contain and remediate a plume of dissolved TCE located in a shallow alluvial aquifer (<12 feet below ground surface). The species *P. deltoides* was chosen over a hybridized species of poplar because it is indigenous to the region. Therefore it has proven its ability to withstand the Texas climate, local pathogens, and other localized variables that may affect tree growth and health.

Two sizes of trees were planted: whips and 5-gallon buckets. The whips were approximately 3/4 inch in diameter and were about 18 inches long at planting. The whips were planted so that about 2 inches remained above ground and the rest of the tree was below ground to take root. The 5-gallon bucket trees were about 1 inch in diameter and 7 feet tall when planted. The 5-gallon bucket trees were estimated to have about twice as much leaf mass as the whips when planted, and thus they were expected to have higher evapotranspiration rates.

The layout for the project (see Figure 6-1) involved planting a separate plot of trees for the whips and the 5-gallon buckets, with both plots perpendicular to the contaminant plume. The plume is moving to the southeast, so the plots were laid out on a northeast axis. The whips section was planted to the northwest of the 5-gallon buckets, so that the plume would first travel through the root zone of the whips and then through the root zone of the 5-gallon buckets. A control area with monitoring wells was placed to the northwest of the whips, and another in between the whips and the 5-gallon buckets, along with monitoring wells throughout the treatment site. These control areas enable data to be collected on the amount of contaminant that enters each of the treatment areas (whips and 5-gallon buckets), so that

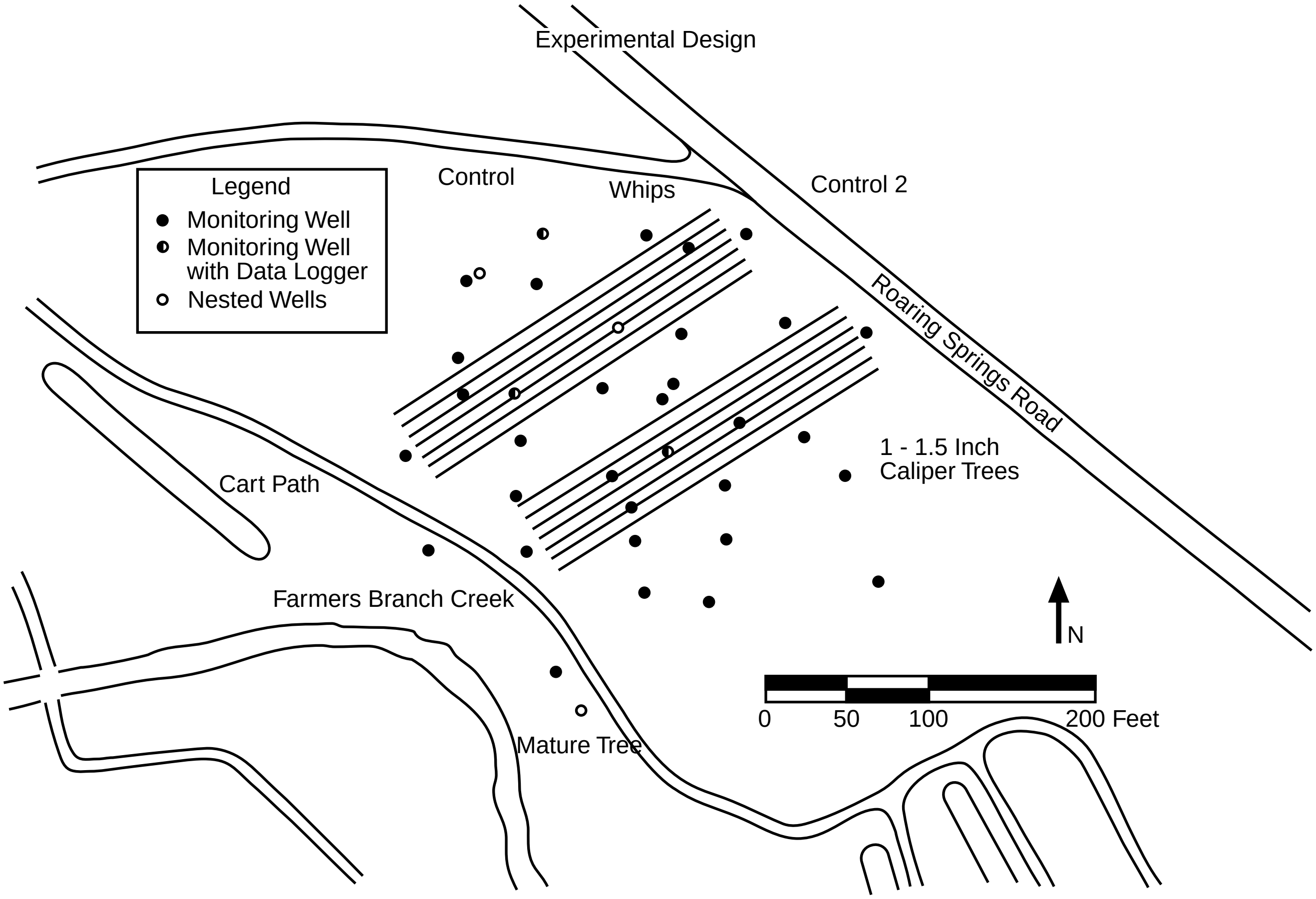

Figure 6-1. Experimental Design

a comparison of the performance of each type of tree can be made.

One unique aspect of Carswell Site is the 19-year-old mature cottonwood growing on the site. This 70-foot-tall tree is located just southeast of the planting area on the other side of a cart path. Groundwater monitoring wells were installed around this tree, and it has been sampled in a similar manner to the planted cottonwoods to see how well a mature tree functions in this phytoremediation system.

6.2.3 Results and Status

Seventeen months after the trees were planted (summer 1997), several trenches were dug adjacent to selected trees, and it was determined that the tree roots had reached the water table (Hendrick 1997). Although the trees are pumping water from the contaminated aquifer, they have not yet begun to hydraulically control the plume. Combined results of a transpiration model and a groundwater flow model will be used to determine when hydraulic control of the plume might occur. Transpiration measurements indicate that the largest planted trees pumped approximately 3.75 gpd during summer 1997; the mature 19-year-old cottonwood tree near the planted trees was determined to pump approximately 350 gpd (Vose 1997).

Some analytical work has been done on the tree tissues at the site, but this type of information is still in the early stages of collection. Data from November 1996 indicated TCE in the whips that were planted over an area where the groundwater was the shallowest. This indicates that the young trees were capable of evapotranspirating TCE after just one growing season. Qualitatively, both types of trees were capable of evapotranspiring TCE, and the 5-gallon trees are evapotranspiring more water than the whips. This was to be expected because of the greater total surface area of the leaves of the 5-gallon trees. In addition, the transpiration rates were generally higher in June than May, which is likely due to a combination of warmer weather and more fully developed leaves. There also appeared to be a midday decline in transpiration during June, indicating that the plants were experiencing water stress during the hottest part of the day in the summer months. Thus, the water demand for the tree exceeded the supply during that time. There was also a notable difference in transpiration rates between days in June, with cloudier days resulting in lower transpiration rates. In addition to evapotranspiration information, some tree growth data have also been collected. In 16 months the whips grew about 20 feet, and the 5-gallon bucket trees have grown faster than the whips. Now that the trees have been on site for over an entire growing season, site managers at Carswell Site have increased monitoring at the site to include a whole suite of water, soil, air, and tree tissue sample analysis. Some of the more unique data they are collecting (in relation to the other case study sites) are analyses of microbial populations and assays of TCE-degrading enzymes in the trees.

Laboratory experiments conducted on root samples from the site show the disappearance of perchloroethylene (PCE) in the presence of roots from the cottonwood trees. The products of degradation are anaerobic in the rhizosphere and aerobic (haloacetic acids and carbon dioxide) in the canopy. Increased amounts of vinyl chloride and a trace of TCE as well as iron- and sulfur-reducing conditions in the rhizosphere were detected at the end of these experiments (Harvey 1998). The disappearance of PCE in the presence of roots from a willow tree near the site was even more remarkable (Wolfe 1997). These experiments indicate that cottonwoods and willows produce enzymes that can degrade PCE and TCE. Researchers trying to determine how the trees change the geochemistry of an aerobic aquifer contaminated with TCE and its breakdown product found that labile organic matter from the cottonwoods and several other species of trees is promoting reducing conditions conducive to the degradation of TCE (Harvey 1998).

Groundwater samples had been collected from the 29 monitoring wells and analyzed on three occasions as of August 1997. Concentrations of TCE, cis-DCE, trans-DCE, and vinyl chloride were determined from these samples. They ranged from 2 to 930 ppb TCE in the groundwater, with most samples falling in the 500- to 600-ppb range (see Figure 6-2). Average concentrations of the contaminants on the three sampling dates are provided in Table 6-2, with the exception of vinyl chloride. Vinyl chloride was only detectable in a handful of samples and generally at low levels; thus, an average concentration was not determined.

TCE concentrations in groundwater samples collected beneath the 19-year-old cottonwood tree during summer 1997 were about 80% less than concentrations in groundwater beneath the planted trees, and cis-1,2 DCE (byproduct of TCE degradation) concentrations were about 100% greater. These data, along with additional geochemistry data from the site, are consistent with microbial degradation of TCE beneath the mature tree (Lee 1997). Microbes with the ability to readily degrade TCE require an environment that is low in dissolved oxygen and high in an appropriate source of organic carbon. These conditions, which are often lacking at sites contaminated with TCE, exist in the aquifer under the mature tree and are likely due to the introduction of organic matter from tree-root activity. Once the planted cottonwood trees have established more mature root systems, an environment could develop in the aquifer beneath the trees that would promote biodegradation and result in an additional mechanism for attenuation of TCE. The effect of other mature trees such as willows, oaks, junipers, mesquite, ashes, and sycamores on the geochemistry of the groundwater in the winter and spring is also being explored.

6.2.4 Costs

Some rough estimates of cost for the Carswell Site have been provided by site managers. These estimates can be found in Table 6-3. Since this site involves an innovative treatment technology, these costs are substantially inflated due to the heavy monitoring taking place at the site. Also, long-term projected costs and/or total project costs are not available because the time involved in remediating the site is uncertain. In addition to the costs in the table, $200,000

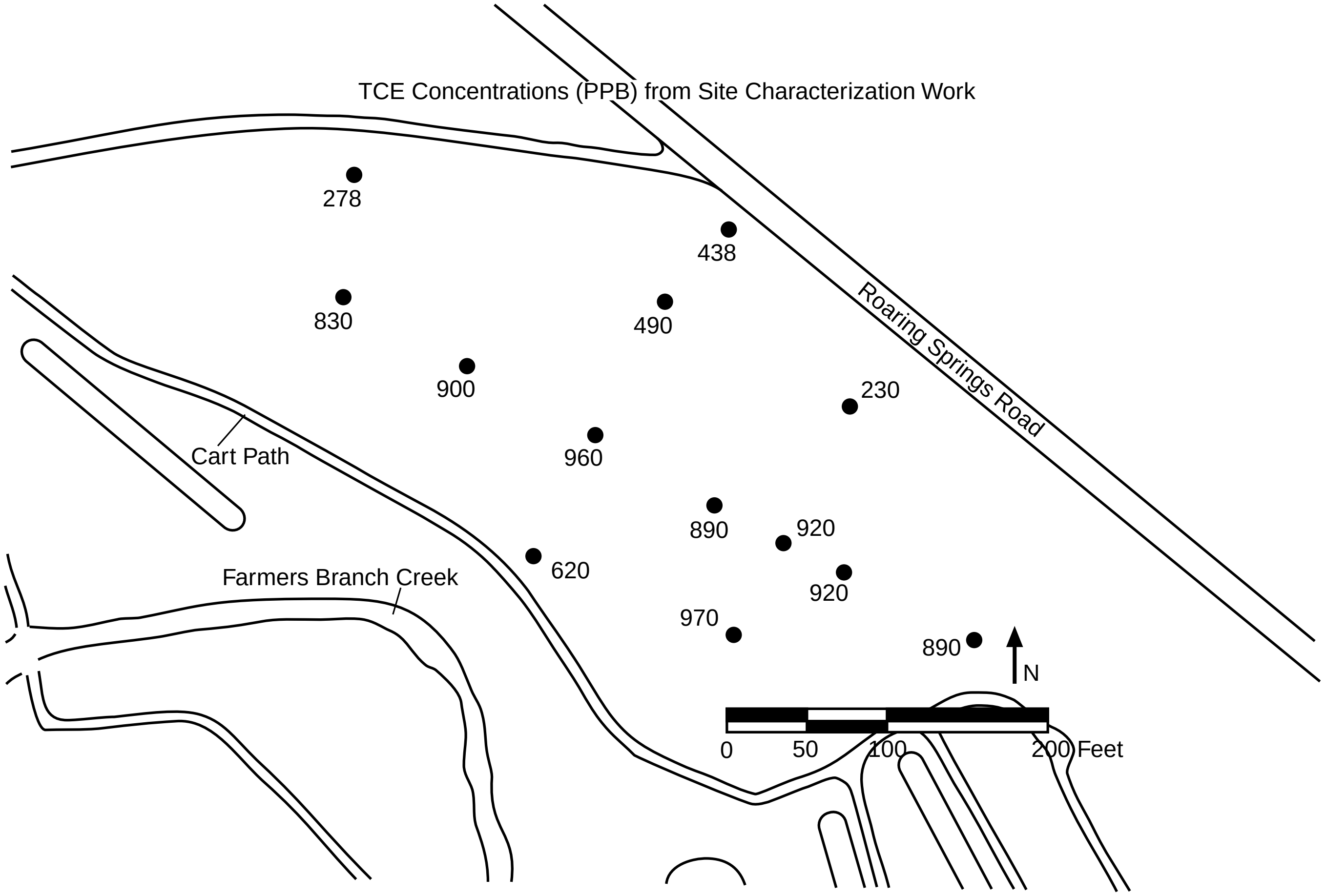

Figure 6-2. TCE Concentrations

Table 6-2. Average Concentrations of TCE, cis-DCE, and trans-DCE at Carswell Site.

Contaminant	Average Concentration (ppb)		
	December 1996	May 1997	July 1997
TCE	610	570	550
cis-DCE	130	140	170
trans-DCE	4	2	4

Table 6-3. Estimated Cost of Phytoremediation at the Carswell Site.

Activity	Estimated Cost
Wholesale cost of trees (does not tree include delivery or installation costs)	$8/tree for 5-gallon bucket $0.20/tree for whips
29 wells (including surveying, drilling and testing)	$200,000
Subsurface fine biomass study (the vertical and lateral extent of tree roots less than 2 mm in diameter)	$60,000

will be spent for extensive site monitoring that would not normally be associated with a phytoremediation system; thus, this amount was not included in the cost estimates.

More extensive cost and performance data from the demonstration are being compiled to assist others in selecting phytoremediation as a treatment technology. The subsurface fine biomass study will also define the volume of soil exploited by the trees at any given point in time. A typical poplar plantation grown as a short rotation woody crop can produce up to 50,000 to 75,000 miles of fine roots per acre. Also, a groundwater flow and transport model of the site is planned to help determine the relative importance of various attenuation processes in the aquifer to guide data collection at future sites. The model will also be used to help predict the fate of TCE at the demonstration site in an effort to gain regulatory acceptance of this remedial action.

6.2.5 Conclusions

There are over 900 Air Force sites with TCE contamination within 20 feet of land surface that could be reviewed for potential application of phytoremediation by use of poplar trees (Giamonna 1997). Costs may be 10 to 20% of those for mechanical treatments. Scale-up costs for large scale applications of phytoremediation can be minimized by exploiting the body of data developed for the Department of Energy on the planting and cultivation of poplar trees for the purpose of biomass production.

6.2.6 Contacts

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6.3 Edward Sears Properties Site New Gretna, New Jersey

Site name:	Edward Sears Properties Site
Location:	New Gretna, New Jersey
Media:	Groundwater (9 ft bgs)
Primary contaminant and maximum concentration:	Trichloroethylene (TCE), <400 ppb
Type of plant:	*Populus charkowiieensis x incrassata* (Hybrid Poplar)
Area of planting:	1/3 acre
Date of planting:	December 1996

6.3.1 Site Description

From the mid-1960's to the early 1990's, Edward Sears repackaged and sold expired paints, adhesives, paint thinners, and various military surplus materials out of his backyard in New Gretna, NJ (see Figure 6-3). As a result, toxic materials were stored in leaking drums and containers on his property for many years. The soil and groundwater were contaminated with numerous hazardous wastes, including methylene chloride, tetrachloroethylene, trichloroethylene, trimethylbenzene, and xylene. After his death, no one could be found responsible for the site or its cleanup; thus, On-Scene Coordinators (OSC) from EPA's Region 2 Removal Action Branch were called in to remove the leaking drums of hazardous materials, including off-specification paints and solvents. Soil sampling indicated that two areas, 35 x 40 feet and 15 x 20 feet, were very heavily contaminated with solvents. These soils were removed to 8 feet below ground surface (bgs) (just above the water table). Further excavation could not be achieved without pumping and treating large volumes of groundwater. The excavated areas were backfilled with clean sand and the OSC activated the EPA's Environmental Response Team (ERT) of Edison, NJ to determine the extent of groundwater and deep soil contamination.

Using innovative hydraulic-push groundwater sampling techniques, the ERT investigation revealed localized, highly contaminated groundwater. Based on this information, a limited number of monitoring wells (see Figure 6-4) were installed to determine vertical contaminant migration and to conduct aquifer tests necessary to evaluate pump-and-treat options. A pilot test for a pump-and-treat system with air stripping and activated carbon was then conducted. The aquifer tests revealed a high yield aquifer, which would require severe over pumping to create any substantial cone of influence around the pumping wells. Contaminants trapped in the silty-clay lens beneath the site would be difficult to extract in this manner because the transfer rate of contaminants into the groundwater is slow. As a result, large volumes of groundwater would need to be pumped to the surface for treatment, and this water would contain low concentrations of contaminant. Also, neighbors of the property would be disturbed by the noise created by a pump-and-treat system.

Based on these results, a pump-and-treat option would be expensive and inefficient for the Edward Sears site. Site managers then moved to consider a phytoremediation option. This site was judged as a potential candidate for a phytoremediation system due to the nature of the soils and groundwater. There is a highly permeable sand layer about 4 to 5 feet bgs, but below that exists a much-less-permeable layer of sand, silt, and clay from 5 to 18 feet bgs. This silt, sand, and clay layer acts as a semiconfining unit for water and contaminants percolating down toward an unconfined aquifer from 18 to 80 feet bgs. This unconfined aquifer is composed primarily of sand and is highly permeable. The top of the aquifer is about 9 feet bgs, which lies in the less-permeable sand, silt, and clay layer. Most of the contamination is confined from 5 to 18 feet bgs; thus, site managers decided to plant hybrid poplars in order to prevent further migration of the contaminants and ultimately remove contaminants from the groundwater.

Samples were taken from temporary well points throughout the site. Data from these sampling efforts indicated trichloroethylene (TCE) concentrations in the groundwater ranged from 0 to 390 ppb. Most of the TCE was concentrated in a small area on the site. Seven monitoring wells were installed based on the information obtained from the temporary well points. Monitoring Well 1 was installed in the area of highest TCE contamination. Little or undetectable TCE was found in the groundwater samples from the other six wells.

6.3.2 Design, Goals, and Monitoring Approaches

Under the Response Engineering and Analytical Contract (REAC), a pilot phytoremediation test was conducted at the Sears site to determine whether hybrid poplar trees can be used to reduce soil and groundwater VOC contamination levels in the planted area and to prevent further offsite migration of contaminated groundwater. In October and November 1996, the site was cleared of debris and a 4-inch clay layer was placed approximately 1 foot bgs to prevent penetration of rainwater into the upper root zone, thus promoting root growth into the underlying aquifer. This was followed by the replacement and grading of the native surface soil.

Thomas Consultants, Inc. of Cincinnati, OH were subcontracted to lay out the phytoremediation design. In December 1996, 118 hybrid poplar saplings (*Populus*

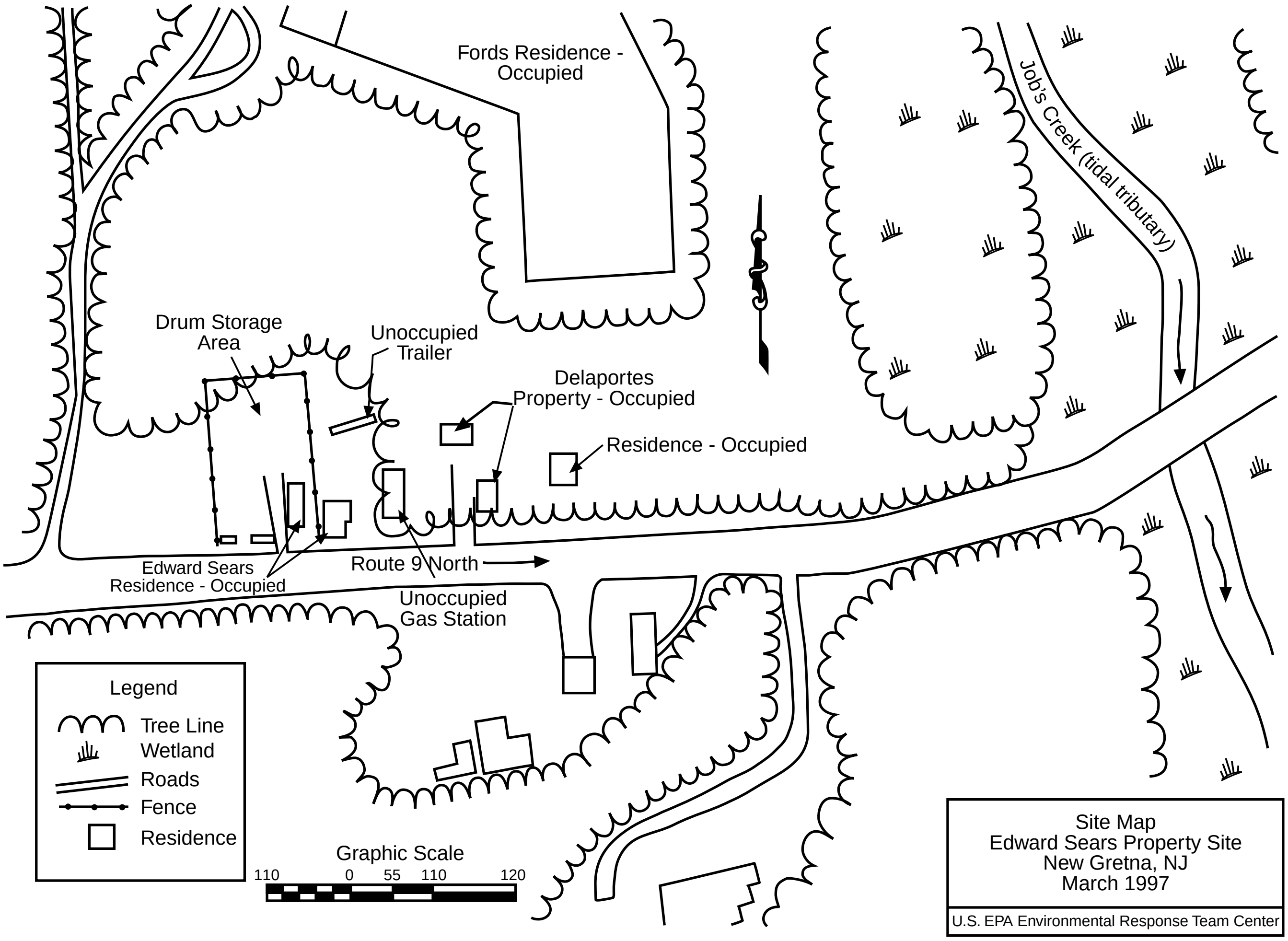

Figure 6-3. Site Map

charkowiieensis x incrassata, NE 308) were planted by ERT, REAC, and Thomas Consultants personnel in a 1/3-acre plot. The trees were planted 10 feet apart on the axis running from north to south and 12.5 feet apart on the east-west axis.

A process called deep rooting was used to plant the trees. In deep rooting, the roughly 12-foot trees were buried 9 feet so that only about 2 to 3 feet remained on the surface. Deep rooting the trees involved drilling 12-inch-diameter holes to a depth of 13 feet. These holes were then back filled to 5 feet below ground surface with amendments such as peat moss, sand, limestone, and phosphate fertilizer. This backfill was installed to provide nutrients to the roots as they penetrated down through the soils. Waxed cardboard cylinders 12 inches in diameter and 4 feet long were installed above the backfill to promote root growth down into the groundwater. These barriers settled about 1 foot into the planting holes; therefore, 5-gallon buckets with the bottoms cut out were placed on top of the cylinders to create a 5-foot bgs root barrier. The trees were placed in the cylinders and the remaining 5 feet to surface was filled with clays removed during the boring process.

About 90 poplars still remained after the deep rooting was completed. These extra trees were planted along the boundary to the north, west, and east sides of the site. These trees were only planted to a depth of 3 feet, or shallow rooted. The shallow-rooted trees were added to prevent rainwater infiltration from off site and to replace any loss of deep-rooted trees. These trees were planted very close together (about 3 feet apart) under the assumption that natural thinning would take place over subsequent growing seasons. A surface water control system was then installed by planting grasses over the entire site. These grasses came from commercially available seeds purchased from a lawn and garden store.

ERT is conducting an ongoing maintenance and monitoring program at Edward Sears. Monitoring of the site includes periodic sampling of groundwater, soils, soil gas, plant tissue, and evapotranspiration gas. Continued growth

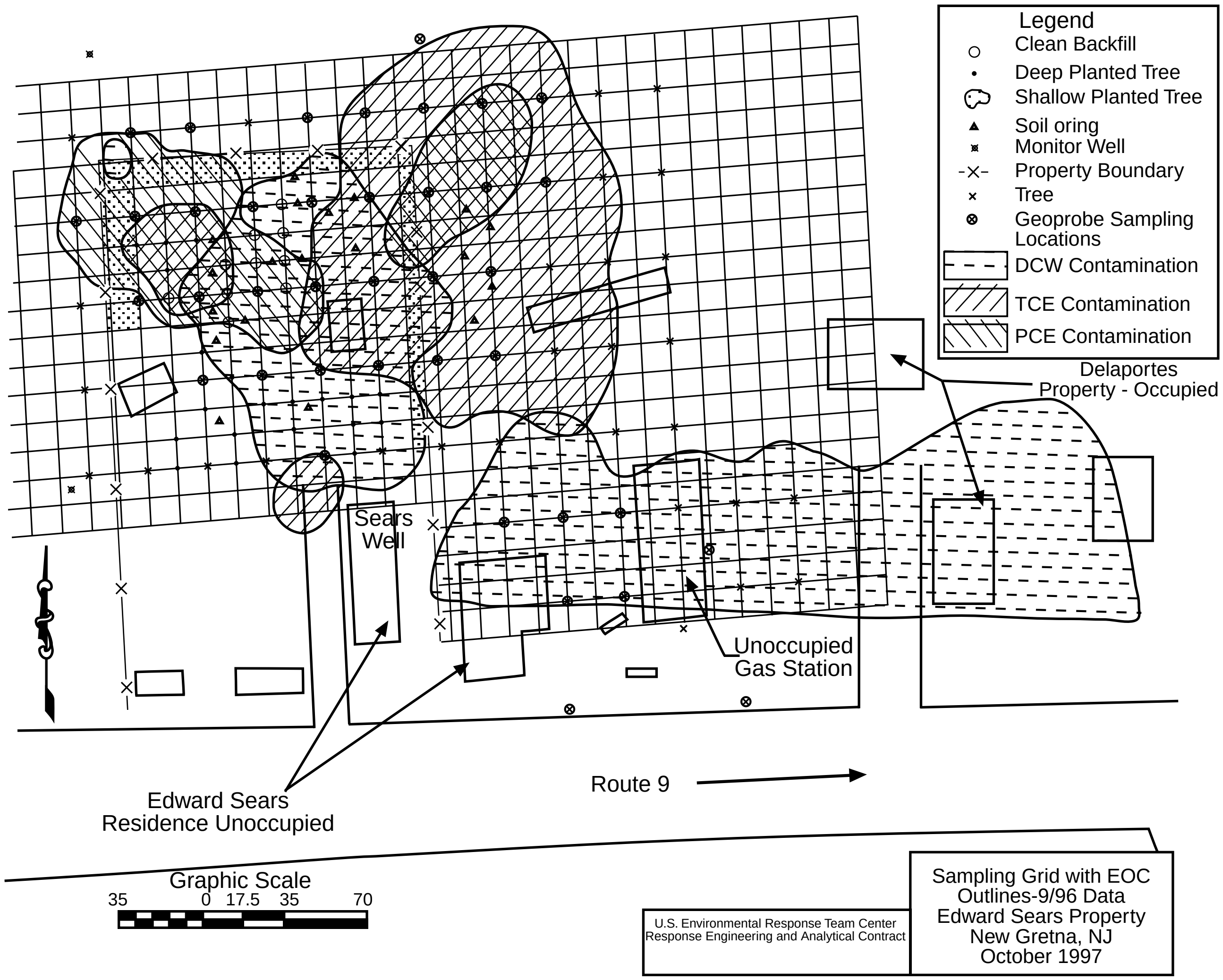

Figure 6-4. Sampling Grid

measurements will also be made as the trees mature. In the fall of 1997, the surface water control system was replaced due to a summer drought that killed much of the grass. Site maintenance also involves the prevention of deer and insect damage. Bars of soap were hung from the trees to deter deer from rubbing their antlers on the trees. Some damage was inflicted by an insect larva known as the poplar leaf caterpillar. This caterpillar lives on poplar trees and makes its cocoon by rolling itself in a poplar leaf. A spray containing *Bacillus thuringesis*, a bacteria that produces toxins specific to various insects, was applied to the site. This spray has been effective in killing most of the caterpillars living on the trees.

6.3.3 Results and Status

Because the trees had only one full growing season, very little performance data are available; however more data are expected in the next growing season. Evapotranspiration gas was sampled by placing Tedlar™ bags over entire trees. Data from these air samples suggest that the trees are evapotranspirating some of the VOC's. However, the VOC concentration in the Tedlar™ bags matches the background concentrations of VOCs in control samples. This could be due to VOCs volatilizing from the soils, or it could be due to evapotranspirated VOCs that may have gotten into the control samples. Future sampling designs will attempt to determine accurate background VOC concentrations. The trees have grown about 30 inches since planting. Site managers plan to sacrifice one tree either after or during the next growing season to determine the extent of root growth.

6.3.4 Costs

The total cost for the installation of 118 deep-rooted and 90 shallow-rooted trees was approximately $25,000. Additionally, installation of the surface water control system and one year of on-site maintenance totaled about $15,000.

ANL/ES/RP-66172

317/319 Phytoremediation Site Monitoring Report - 2009 Growing Season

Energy Systems Division

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317/319 Phytoremediation Site Monitoring Report - 2009 Growing Season

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February 2, 2010

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317/319 Phytoremediation Site Monitoring Report
2009 Growing Season

By

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Argonne 317/319 Phytoremediation Site
Monitoring Report
2009 Growing Season

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Abstract:

In 1999, Argonne National Laboratory (Argonne) designed and installed a series of engineered plantings consisting of a vegetative cover system and approximately 800 hybrid poplars and willows rooting at various predetermined depths. The plants were installed using various methods including Applied Natural Science's TreeWell® system. The goal of the installation was to protect downgradient surface and groundwater by intercepting the contaminated groundwater with the tree roots, removing moisture from the upgradient soil area, reducing water infiltration, preventing soil erosion, degrading and/or transpiring the residual volatile organic compounds (VOCs), and removing tritium from the subsoil and groundwater. This report presents the results of the monitoring activities conducted by Argonne's Energy Systems (ES) Division in the growing season of 2009.

Monitoring of the planted trees began soon after the trees were installed in 1999 and has been conducted every summer since then. As the trees grew and consolidated their growth into the contaminated soil and groundwater, their exposure to the contaminants was progressively shown through tissue sampling. During the 2009 sampling campaign, VOC concentrations found in the French Drain area were in general consistent with or slightly lower than the 2008 results. Additionally, closely repeated, stand wide analyses showed contaminant fluctuations that may indicate short-term contaminant depletion in the area of interest of roots. This data will be useful to determine short-term removal rate by the trees. As in previous years, levels in the Hydraulic Control Area were close to background levels except for a few exceptions.

Introduction:

The 317/319 Area at Argonne (approximately 2 hectares of surface) contains several release sites used in the past to dispose of solid and liquid waste from various laboratory activities. Because of these past activities, VOCs and tritium have been released in the groundwater at depths of approximately 6-9 m and have been detected in groundwater offsite. The U.S. Department of Energy (DOE) has funded Argonne to deploy a phytoremediation system as it was deemed more cost effective and better suited to achieve project goals than current baseline technologies (mechanical extraction wells, currently removing groundwater as an interim measure, and an asphalt cap).

As part of the deployment efforts, approximately 800 hybrid poplars and willows were planted in the summer of 1999 in the 317/319 Area at varying, predetermined depths as an engineered plantation (see Figure 1). An additional 142 trees were planted in 2003 in areas that were not accessible in 1999. All trees were planted so that root development targets the areas of soil and groundwater contamination, using methods that include the TreeWell® and TreeMediation® system patented by Applied Natural Sciences, Inc. In addition, a vegetative cover of herbaceous plants was seeded among the trees to control soil erosion and minimize water infiltration. In the upgradient VOC source area French Drain (FD) hybrid willow trees were planted so that their roots could freely explore the contaminated soil from the surface throughout the 9 m depth and take up excess water and entrained chemicals. A few TreeWell® poplars were also planted at the southernmost edge of the FD area to contain the contaminated groundwater. In the downgradient area of groundwater contamination (hydraulic control area, or HC), hybrid poplars were planted using the TreeWell® technology so that their roots were isolated from clean surficial aquifers and forced to extend downwards to the deeper, contaminated groundwater. Background control cells have been set up at the Argonne greenhouse area (a clean area on site nearby) to represent clean groundwater/soil conditions.

The 2009 monitoring efforts conducted by ES Division personnel had the purpose of contributing to the determination the system's effectiveness in achieving the remediation objectives. Activities involved:

- Determining the uptake of the volatile contaminants in tree tissue to document source reduction and contact with groundwater.
- Determining tree water uptake and movement within the tree by measuring sap flow at two different depths of wood.
- Determining temporal variations on contaminant concentrations in tree tissue and groundwater over a six-day time period.

Monitoring Protocols:

1) Site-wide VOC monitoring::

Site-wide monitoring conducted in years past presented a valuable picture of the contaminant plume in the phytoremediation system. In 2009 we monitored contaminant levels in the tree tissue following methods established in previous years. As branch concentrations typically begin to be reliably measurable after mid-June, we performed the 2009 field campaign on July 7th, 9th and the 13th. The purpose of the repeated sampling was to determine stand-wide concentration fluctuations over a short time interval. These, in turn, would be useful to determine any localized contaminant removals that are not noticeable in longer timeframes and/or when monitoring groundwater. Because of the presence of a contaminant source, any removal by the trees is masked by continuous redissolution of contaminants from the source into the soil water/groundwater. Based on results from years past, we hypothesized that the short-term fluctuations we found in tree concentrations could signal a temporary depletion of contaminants due to strong water use. This year we tested this hypothesis on a stand-basis (i.e., across the entire tree stand).

Plant tissue from the study area was sampled to determine the presence of VOCs. Finding VOCs above background levels in leaf and/or branch tissue, sap or wood cores provides a clear indication that the trees are taking up the contaminants from soil or groundwater and translocating it to the aboveground tissues. In principle, by multiplying contaminant concentrations in the sap (ng/mL) by sap flow (L/day), a quantitative measure of contaminant removal by plant uptake can be obtained. Plant uptake of contaminants from the soil solution and the resulting concentration in tissue are dependent on many factors, including soil properties, the contaminant distribution coefficient between soil and soil water, its octanol-water partitioning coefficient (K_{ow}, a measure of a chemical's lipophilicity, and indirectly of its ability to be taken up by plants); the rate of microbial degradation in the rhizosphere, the contaminant's transpiration stream concentration factor (TSCF, or the ratio of the concentration in the transpiration stream of the plant to the concentration in soil water – empirically related to the log K_{ow}), and the rate of diffusion of the contaminant from the plant tissue to the air. In order to properly predict plant uptake and its spatial and temporal variations, these factors need to be properly understood.

Sampling and analytical methods were described in previous years' reports. In 2009 analytes were trichloroethene (TCE), tetrachloroethene (PCE), carbon tetrachloride (CT) and chloroform (CF). Detection limits were 3 ng/g for chloroform and TCE, 0.04 ng/g for PCE, and 2.6 ng/g for CT. Monitoring of 1,1,1, trichloroethane (TCA) was discontinued due to its very limited detection in tree tissue in past years. Trichloroacetic acid (TCAA, a degradation product of TCE, PCE) is measured as chloroform after thermal decarboxylation and thus is not distinguishable from it.

Samples were collected from approximately every sixth tree (willows and poplars) at the 317 FD area, and downgradient hydraulic control area, starting with tree A10W and through row V. A total of 81 trees/day were sampled during the main campaign, for a total of three different days. In most cases, two branch samples were collected from each sampled tree. Two samples of leaves growing on the sampled branch were also collected from selected trees. While the current SOP calls for sampling the lowest available branch, low branches suitable for sampling have become limited in recent years, thus our samples had to be collected either from branches at a higher insertion point in the main trunk, or from the distal portion of large, low branches, which may have contributed to overall concentrations differences compared to the first growth years. Repeated sampling over the three-day period was done on branches from the same height and orientation of each tree. To ensure that the samples from each tree were as similar as possible, three contiguous branches of similar height and orientation were pre-selected and marked with field ribbon before starting the sample collection on the first day. Samples on all three days were collected at approximately the same time each day in the late morning period (between 10am and noon).

2) Sap Flow Measurements:

Since sap flow remains the best estimate of tree water uptake, measurement of sap flow using the thermal dissipation method is commonly used on trees due to its ease and relatively low cost to set up. The thermal dissipation method described by Granier (1985, 1987) utilizes two needles (probes) imbedded in sapwood, one pulse-heated and the other a reference, spaced at a known vertical distance. The reference needle gives a baseline temperature to compare with the heated needle's temperature dissipation caused by sap flow. When sap flow increases, the difference in temperature between the two probes decreases. The maximum temperature difference is at little to no flow. By measuring the difference in temperature between the heated and reference needle (via differences in voltage between thermocouples in each needle), sap velocity can be measured.

$$\mathbf{dT\ (°C) = thermocouple\ differential\ voltage\ (in\ mV) * 25}$$

Where dT is the differential temperature between heated and reference needle.

Using the differential temperature (**dT**) and the maximum differential temperature (**dTM**) when there is no sap flow, Granier defined a dimensionless constant, **K** as:

$$\mathbf{K = (dTM - dT) / dT}$$

When dT = 0, $K = \infty$. If dT = dTM (no sap flow), then K = 0.

Granier found that average sap flow velocity (**V**, in cm/sec) could be related to K by the following relationship:

$$\mathbf{V = 0.0119 * K^{1.231}}$$

Furthermore, sap flow rate (**F**, in cm^3/hour or grams/hour) can be derived from the following equation:

$$\mathbf{F = A * V * 3600}$$

Where **A** is the sapwood area (cm^2).

The sap flow monitoring system (Dynamax, Inc., Houston, TX) acquired in August of 2007 was used again this year and installed on thirteen poplar trees by ES personnel in the vicinity of MW 319171 in the Spring of 2009. New to this monitoring season was the use of longer (80 mm) probes to ascertain the sap flow within the more water-saturated heartwood of the trees. These two different types of thermal dissipation probes (TDP-30 and TDP-80) were installed on each tree again at breast height. Data from the probes were averaged to estimate total sap flow for sapwood area measured, assuming that flow is homogeneous. Data was recorded by a CR1000 datalogger in a weather-resistant housing. The sap flow system was powered by a solar panel with marine battery backup. This year, two batteries were used to help supply power to the more demanding long probes. Data collection ran from the period of May 8 to July 9, 2009, a similar period as in 2008. Four newly purchased TDP-80 probes, in addition to two from late last year, were installed on June 5 on five trees. One tree (S392P) was replicated with four 30 mm probes and two 80 mm probes to assess validity of the sap flow data being collected.

Tree diameters were taken for determination of basal area within the stand where sap flow was measured. Due to the relative genetic uniformity of trees planted, reasonably accurate stand level estimates of water use could be made for this season. Currently there are 542 poplar trees in the 317 and 319 Areas, covering approximately 1.15 hectares. Live stem counts, average diameter at breast height (DBH) and health of the willows in the 317 FD Area were not determined this year. Also, annual and perennial weed growth was excessive again this year especially within the willow stand of the 317 FD Area.

Results:

1) Site-wide VOC monitoring:

Figure 2 presents the contaminant plume map drawn using the tree branch samples collected during the years 2007 through 2009. The VOC tissue analysis results for contaminants in the hotspot near the vault area were compared for three years and the results are presented in Table 1. The full set of data collected from field sampling is reported in Appendix 1.

VOC concentration levels in leaf samples are also presented in Appendix 1. Once again overall leaf contaminant levels in both areas were very close to background levels (i.e., collected in the clean groundwater/soil background cells near Bldg. 485) further indicating that leaf data are primarily driven by background levels and not by uptake from soil or groundwater.

VOC data in branch tissue followed the established trend of being highest in the French Drain area and near the storage vaults (the source area), and decreasing as distance from the source area increased. This trend was similar for all years as seen from the contaminant maps.

The hydraulic control areas showed some non-detects but in general results in this area were in the 2-digit ppb range, with a few notable exceptions, such as those found in the north-eastern portion of the M row in the HC area within the fence. Results for PCE found in trees M296P (a new sampling point within the suspected hot spot) and M312P were in the 1000 ppb range this year. Carbon tetrachloride levels were almost twice as high near this hot spot this year than last year as well, whereas PCE levels were only slightly lower. In addition, higher levels of PCE than before were found in the O and P row trees near these two trees. This data further reinforces the probability of a nearby presence of a DNAPL pool.

During the sampling period, the ESQ Long-Term Stewardship program was operating pumps in the wells within the French drain area. These pumps removed between 500 and 1600 gallons of groundwater from each of the four wells. This groundwater extraction should have depressed the groundwater elevation near the wells, which may have changed the distribution of soil moisture and contaminants within the root zones of some of the trees, with some influence on the uptake of contaminants in 2009. During late 2008 similar pumps were installed on two of the four wells.

As previously discussed, many factors could contribute to the low values of VOCs found in the HC: low contamination levels in the groundwater, retardation by the backfill medium, and possibly biodegradation in the rhizosphere. None of these possible explanations has been thoroughly studied at this time. Because VOCs may be adsorbed and/or degraded in the organic-richer backfill rhizosphere of the TreeWell® trees before they actually reach the roots, non-detects do not necessarily imply that the roots have not reached the groundwater. Likewise, some of the low levels found do not necessarily prove contact with groundwater as they are not different from background concentrations. Background concentrations of TCE, PCE and CCl_4 were notably high on a few days this year in both leaf and branch samples, possibly leading to further confounding of estimation of the phytoremediation system's soil decontamination.

Differences in branch VOC concentrations may have many reasons. Since the height of sample collection influences contaminant concentrations (the lower the branch, the higher the concentration), and since with time low branches have become scarcer, samples collected in recent years may not compare well with those collected in earlier years when low branches were almost exclusively sampled. Other differences in branch concentrations may be caused by dilution and diffusion (as the trees grow larger, the contaminants may be diluted in the larger biomass volume. In addition, as branches grow large, samples must be taken from distal branch portions, where there are more opportunities for VOCs to escape by diffusion). An additional possible reason for differences in branch concentration is the temporal variability in soil and groundwater concentrations (supply and equilibrium), resulting in different concentrations in the tree branches depending on the day when samples were collected. Finally, phytotoxicity may locally depress transpiration rates and thus uptake. This may play a role locally, considering that many French Drain Area willow trees have appeared to become quite stressed and unhealthy in recent years as the summer progressed. Without soil and root samples being collected, reasons for the willow trees' midsummer decline are debatable.

The site-wide temporal series analysis provided interesting results: a high level of variability was found in the branch concentrations within a few days. This short-term variability was most pronounced in the hotspots where levels can fluctuate by an order of magnitude (see Figure 3). Where the concentrations were low, the variability was present but it was within sampling and analytical error. This seems to tell us that the interactions between soil processes for the contaminants (TCE, PCE and CCl_4) and plant root interactions are the primary factors responsible for the fluctuation.

Because of the close similarity among the three samples from each tree, and in light of our greenhouse and hydroponic experiments in previous years, we hypothesize that the primary reason for the variability is the partitioning, desorption and uptake processes between the soil water and the roots. Under this hypothesis, it would appear that the trees are drawing out the soil water faster than the lag between the desorption of the TCE in the soil particles and the replenishment of the soil water. How that affects the rhizospheric bacteria and the degradation of TCE in the soil is an open question. Importantly however, these concentration fluctuations point at a localized, short-term depletion of contaminants in the area of interest of tree roots. This data is important as it may allow us to estimate how much contaminant the trees are capable of removing – which, in turn, will give us an estimate of the performance of the phytoremediation system. In short, the short-term variability will let us know how much of a slug of TCE/PCE is being removed within a couple of days by the trees. Coupled with the sap flow rates data, it will allow us to calculate stand-wide removal rates.

2) Sap Flow Measurements:

Since measuring sap flow is currently the best estimate of tree water usage, it is commonly used to estimate hydraulic control by a phytoremediation installation. For 2009, sap flow was measured on many of the same poplar trees in the vicinity of MW 319171 as the previous two years. Sap flow data in the 319 Area is of interest because this site has the greatest number of trees of the largest diameter, hence should exact the greatest hydraulic control.

For the 319 Area, thirteen hybrid poplar trees in the vicinity of MW 319171 were monitored from May 8 to July 9, 2009, from the beginning to the height of the transpirative period. All of these trees were the same used in 2008, but several of them had multiple probes installed at varying heights and orientation to test system accuracy**.** Sap flow data was quite similar on trees with multiple probes mounted at varying heights and direction (see Figure 5). Trees measured for sap flow in this area had aDBH of 23 cm, four cm larger compared to 2008, which was only one cm greater than 2007. Average monthly temperatures for May and June were respectively 1.6°C and 5°C higher than last year. Monthly total precipitation for May and June was -3 and +5 mm respectively for 2009 compared to 2008.

The health of the trees has not changed significantly since last year, although many of the HP 510 (=NE 41) variety in the 317 HC area are more greatly affected by canker and winter-kill. For the HP 308 (=NE 308) variety, most of the trees have canker-killed lower branches. Several of the trees also have broken tops from wind damage of canker-weakened wood. The prevalence of dead branches from disease and/or shading only increases disease reinoculation within the site and may ultimately affect long-term performance. Generally the trees that have shown the lowest sap flow and flux have had the most canker and dead branches around the area probed as well as being the smallest DBH.

Collecting sap flow measurements in the 319 Area for 2009 offered perhaps more accurate data compared to previous years', because we were able to measure heartwood sap flow. Average sap flow, flux and tree diameters for the thirteen trees measured in the 319 Area for 2008-09 are shown in Table 2. A few cores were taken again this year to ascertain the extent of the sapwood area. In the six samples taken, all the trees showed active, moist live wood inside the bark layer to the center. Four of the six trees cored actively hissed and dripped copious amounts of sap when the sapwood-heartwood boundary was reached. The outer, drier sapwood comprises roughly 76% of the total wood area (minus bark). Analyzing data collected this year, this sapwood has an average flow of 42% greater and an average flux of 60% greater than that of the inner, more saturated heartwood

The inner heartwood has been shown in the past to hold roughly twice as much water by weight via oven drying cores. Since previously we did not have the ability to measure sap flow within this deeper wood, we had either estimated assuming it had sap velocity equal to that of the outer sap wood, or assumed it was not actively transporting any significant amount of water, but rather just storing it. The data collected this year confirmed that the inner sapwood is less actively transporting water.

Comparing diurnal sap flow between the two different depths of wood measured (see Table 3), mean sap flow at 15 mm deep (from bark face) generally peaked at about 2 to 3 pm and was minimal at 1 to 2 am. Maximum sap flow was recorded by the 70mm deep probes a few hours later (5 to 6 pm), the minimum at 3 to 8 am (see Figure 6). This lag time between the two different depths may partly be explained by the tree's roots not being able to take up water fast enough during peak daytime transpiration. Therefore the tree may be radially redistributing water from the deeper, wetter heartwood outwards to keep up with transpiration, as this water may be more easily accessible than vadose water (via shallow roots) or groundwater (via sinker roots). In other words, during the day, the trees may not be able to meet all transpiration demand via direct root uptake of water but rather may be taking excess water stored in the deeper xylem. This deeper xylem may be recharged at night then (as shown by sapflow data) restoring water potential gradients. Poplars in this setting would not be significantly closing stomata at night (a typical dark response) nor during the day (typical drought response) ensuring that the tree is always removing water from the ground. Note that tree night transpiration may actually be quite high, from of 5-30% of total transpiration (from other studies).

Interestingly, on a 24 hour basis sap never completely ceased flowing in the heartwood. Nighttime flow in the heartwood suggests a cyclic recharge of this deeper wood occurring, regardless of decreases in vapor pressure deficit and transpiration during the night. Similar tree sap flow studies have shown water recharge of deeper xylem to occur during the night (Fischer et al 2007). Hydraulic redistribution may also be an indirect contribution to nighttime sap flow, but the marked decrease in outer wood sap flow during the night may contradict this, unless the trees are separating xylem water dynamics around the soil line.

In 2008 we assumed that the total stem area minus bark was actively moving water, therefore a typical poplar tree in the site transpired 108 L/day on average, to a maximum of 176 L/day. This was calculated by using the measured sap flux multiplied by total wood area (not including bark). In 2009, using combined measured sap flow from sapwood (outer xylem) and heartwood (inner xylem) we estimate that each tree transpired an average of 163 L/day up to a maximum of 253 L/day. The last two days of sap flow data collection (July 8-9) yielded the highest daily total flows of the season: 176 and 186 L/day/tree average up to a maximum of 327 and 348 L/day/tree respectively.

For the 319 HC Area as a whole, the ca. 160 poplar trees therefore removed an average of 26 kL/day up to a maximum of 46.5 kL/day for this 62 day period. For a stand estimation, assuming a 200 day growing season (April 20 – Nov 6) and a stand density of 472 trees/ha, poplars in the 319 HC Area may have removed an average of 600 mm/yr, up to a maximum of 1.7 m/yr.

For the 317 HC Area the ca. 382 trees removed an average of 62.1 kL/day up to a maximum of almost 96.6 kL/day. Again, assuming a 200 day growing season and above stand density, the 317 HC poplars may have removed an average of 1.4 m/yr up to a maximum of 2.2 m/yr. High variability in measured sap flow, low sample size and lack of tree data, especially for willows (stem count, DBH, health) in the FD Area prevents accurate stand estimations for water removal at this time.

Using extrapolated poplar data, the entire installation of 542 poplar trees in both the 317 and 319 HC Areas may have transpired an approximate average of 88.2 kL/day, up to a maximum of 137kL/day. Again assuming a 200 day growing season, the poplar stands in the 317 and 319 HC Areas combined may have transpired an average of 2.0 m/year, up to a maximum of 3.1 m/yr

Conclusions:

As the 317 and 391 Area trees completed their tenth growing season in the field, a significant amount of information has been collected to assess their performance at achieving the remedial objectives. From this data, the trees appear to be influencing the cleanup area. Quantitative assessments of this influence need to be evaluated in concert with other parts of the monitoring efforts.

Based on this year's monitoring results, the following conclusions can be drawn:

- VOC data in branch tissue during the 2009 season tended to be comparable or slightly lower than data from 2008. The only exception for 2009 is an overall increase in average CCl_4. VOCs were highest in the French Drain (source) area, and decreased as distance from the source area increased. VOC leaf data once again was very close to background, further indicating that leaf uptake is data are primarily driven by background levels and not by uptake from soil or groundwater.
- Over a period of only six days, branch concentrations of VOCs showed marked fluctuations in the trees sampled. This short-term variability was found to be most pronounced in the hotspots where levels fluctuated by an order of magnitude. Where the concentrations were low, the variability was still present but within sampling and analytical error. This seems to tell us that the interactions between soil processes for TCE and plant root interactions are the primary factors responsible for the fluctuations recorded.
- Most of the willow trees once again have grown poorly this year, with more decline and death, for reasons still uninvestigated. Whether it is from lack of water, direct soil toxicity from VOC's or VOC breakdown by-products is unknown.
- Poplars grew on average four cm DBH since last year in the 319 Area, compared to one cm between 2007 and 2008. Higher monthly average temperatures, solar radiation and precipitation for both May and June 2009 are most likely the cause.
- Measured sap flow (of outer wood) in the 319 HC Area was 47% higher in 2009 than 2008 for the period June 4 to July 9. For 2009, measured whole tree flow (all wood) was 34% higher than the 2008 whole tree estimate. Sap flow was 53% greater at 15mm depth than at the 70mm depth, and sap flux was 75% greater at 15mm than 70mm with only a 24% difference in wood area. Mean daily sap flow generally peaked at 2-3 pm at 15mm depth probe and peaked at 5-6 pm for the 70mm deep probe. Sap flow in the deeper wood occurred around the clock, possibly indicating that the trees are continually depleting and recharging this water-saturated wood. How much this flow may be affected by night transpiration or soil hydraulic redistribution is unknown.

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References:

Fisher, J., Baldocchi, D., Misson, L., Dawson, T. and Goldstein, A. (2007) *What the towers don't see at night: nocturnal sap flow in trees and shrubs at two AmeriFlux sites in Calfifornia.* Tree Phys., 27:597-610.

Gopalakrishnan G, M.C. Negri, B.S. Minsker and C.J. Werth (2007). *Monitoring Subsurface Contamination Using Tree Branches.* Groundwater Monitoring and Remediation 27 (1) pp. 65-74.

Granier, A. (1985) Une nouvelle méthode pour la mesure du flux de sève brute dans le tronc des arbres. Annal. Sci. Forest. 42, 193–200.

Granier, A. 1987. *Evaluation of transpiration in a Douglas fir stand by means of sap flow measurements.* Tree Phys., 3:309-320.

Hinckley, T., Brooks, J., Cermak, J., Ceulemans, R., Kucera, J., Meinzer, F., *et al*. (1994) *Water flux in a hybrid poplar stand*. Tree Physiology 14:1005-18.

Howard, A., Iersel, M., Richards, J. and Donovan, L. (2009) *Night-time transpiration can decrease hydraulic redistribution.* Pl. Cell & Env. 32:1060-1070.

Ma, X., and J.C. Burken (2003), *TCE Diffusion to the Atmosphere in Phytoremediation Applications.* Environ. Sci. Technol. 37, 2534-2539.

Newman L.A., X. Wang, I.A. Muiznieks, G. Ekuan, M. Ruszaj, R. Cortellucci, D. Domroes, G. Karescig, T. Newman, R.S. Crampton, R.A. Hashmonay, M.G. Yost, P.E Heilman, J. Duffy, M. Gordon, and S.E. Strand (1999), *Remediation of Trichloroethylene in an Artificial Aquifer with Trees: A Controlled Field Study*, Environ. Sci Technol. 33:2257-2265.

Newman, L.A., S.E. Strand, N. Choe, J. Duffy, G. Ekuan, M. Ruszaj, B.B. Shurtleff, J. Wilmoth, P. Heilman, and M. Gordon (1997), *Uptake and Transformation of Trichloroethylene by Hybrid Poplars*, Env. Sci. Technol. 31, 4:1062:1067.

Nietch C.T., J.T. Morris, and D.A. Vroblesky (1999) *Biophysical Mechanisms of Trichloroethene Uptake and Loss in Baldcypress Growing in Shallow Contaminated Groundwater*, Environ. Sci. Technol. 33:2899-2904.

Nzengung, V.A. (2001), *Sequestration, Phytoreduction, and Phytooxidation of Halogenated Organic Chemicals by Aquatic and Terrestrial Plants*, Int. J. of Phyto. 3, 1:13-40.

Phillips, N., Oren, R. and Zimmermann, R. (1996) *Radial patterns of xylem sap flow in non-, diffuse- and ring-porous tree species.* Pl. Cell Env. 19:983-990.

Schroth, G. & F.L. Sinclair, Eds. (2003) *Trees, Crops and Soil Fertility: Concepts and Research Methods.* CABI Publishing, Wallingford.

Vroblesky D.A., C.T. Nietch, and J.T. Morris (1999), *Chlorinated Ethenes from Groundwater in Tree Trunks*, Environ. Sci Technol. 33:510-515.

Vose, J., Swank, W., Harvey, G., Clinton, B. and Sobek, C. (2000) *Leaf water relations and sap flow in Eastern cottonwood (P. deltoides) Trees planted for phytoremediation of a groundwater pollutant.* Int. J. Phytorem. 2, 1: 53-73.

Vose, J., Harvey, G., Elliott, K. and Clinton, B. (2003) *Measuring and modeling tree and stand level transpiration.* In: McCutcheon & Schnoor, eds. Phytoremediation: transformation and control of contaminants. Wiley, New York.

Wullschleger, S. and King, A. (2000) *Radial variation in sap velocity as a function of stem diameter and sapwood thickness in yellow-poplar trees.* Tree Phys. 20: 511-518.

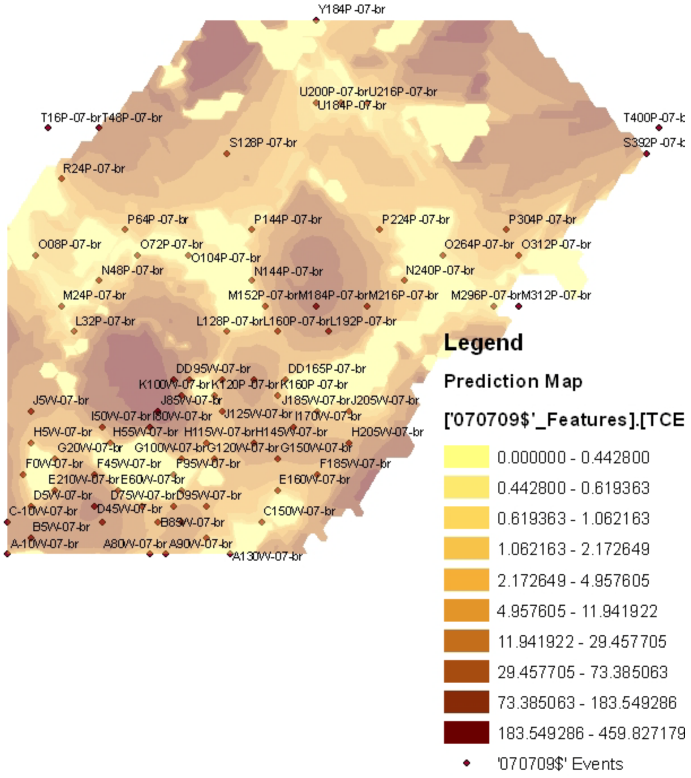
Zalesny, R.A. Jr, Wiese, A.H, Bauer, E.O. and Riemenschneider, D.E. (2006) *Sap flow of hybrid poplar (Populus nigra L.×P. maximowiczii A. Henry 'NM6') during phytoremediation of landfill leachate.* Biomass and Bioenergy**.** 30, 8-9: 784-793.

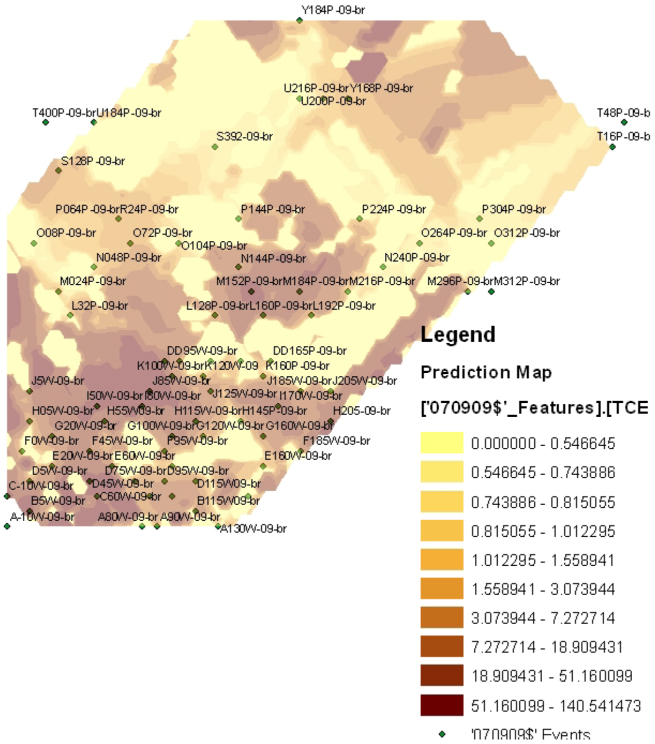
Searching for groundwater,
10 m deep into a glacial
subsoil at Argonne:
a multidisciplinary effort.

Figure 1: Aerial Pictures of the 317/319 Area, 2001 and 2006. Each tree in this area was given a specific coordinate number composed of row lettering and a numbering. Row lettering start from top row (N) and numbering increases from left to right (W to E).

Figure 2: TCE and PCE Contaminant plume maps from tree branch tissue in the 317 Area for 2009.

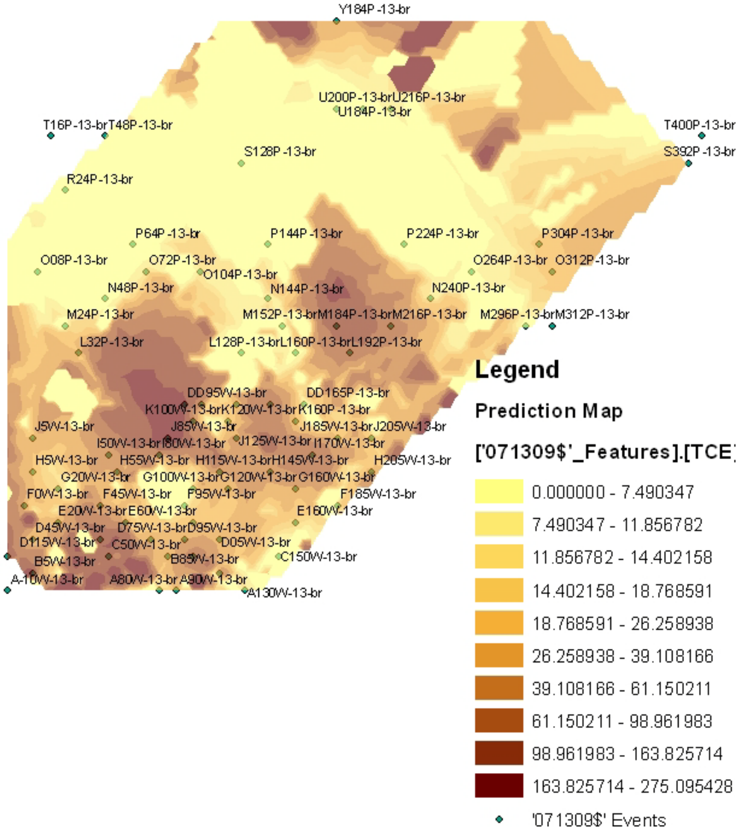
TCE plume map for 7/7/09

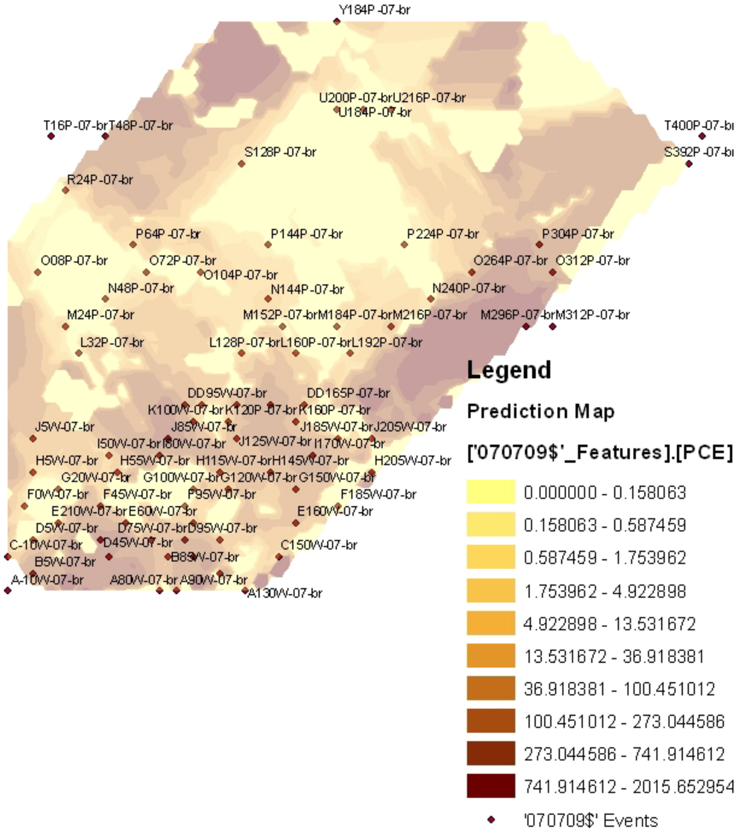




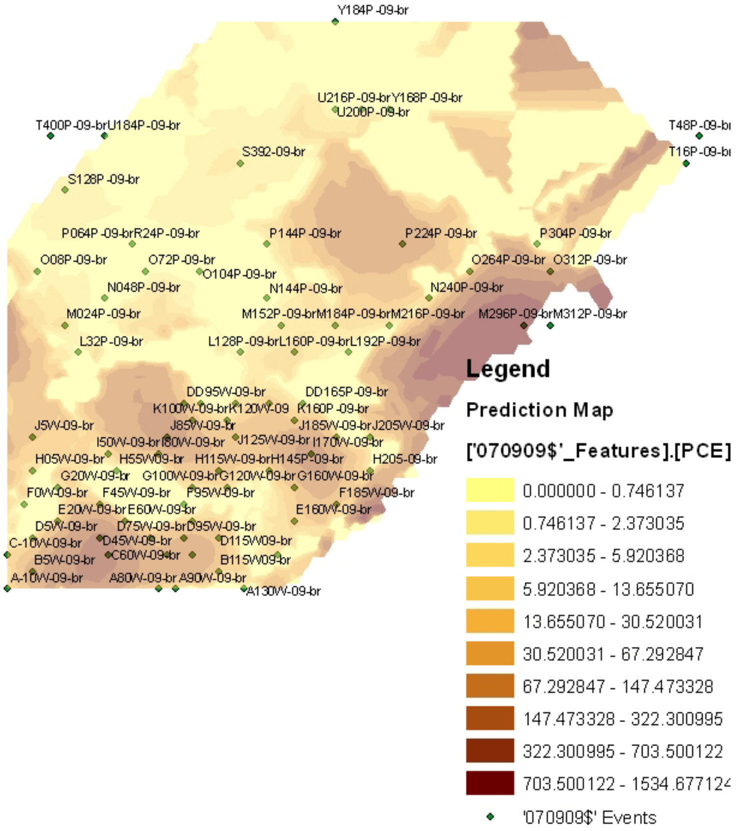
TCE plume map 7/9/09

TCE plume map 7/13/09

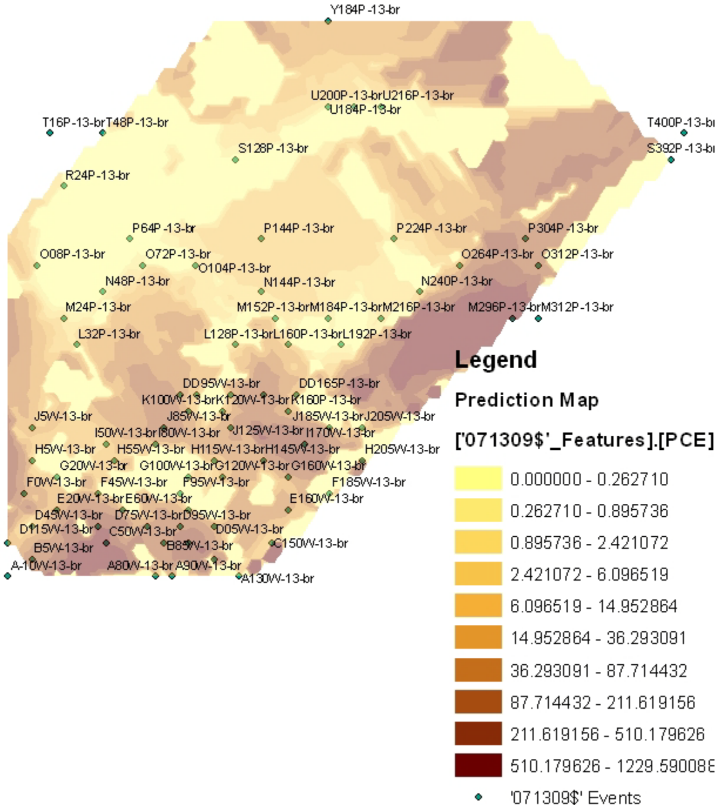




PCE plume map 7/7/09



PCE plume map 7/9/09



PCE plume map 7/13/09

Figure 3 a,b,c: Mean VOC branch levels of trees growing in hot spots near 317 vaults on three vegetation sampling dates in July 2009.

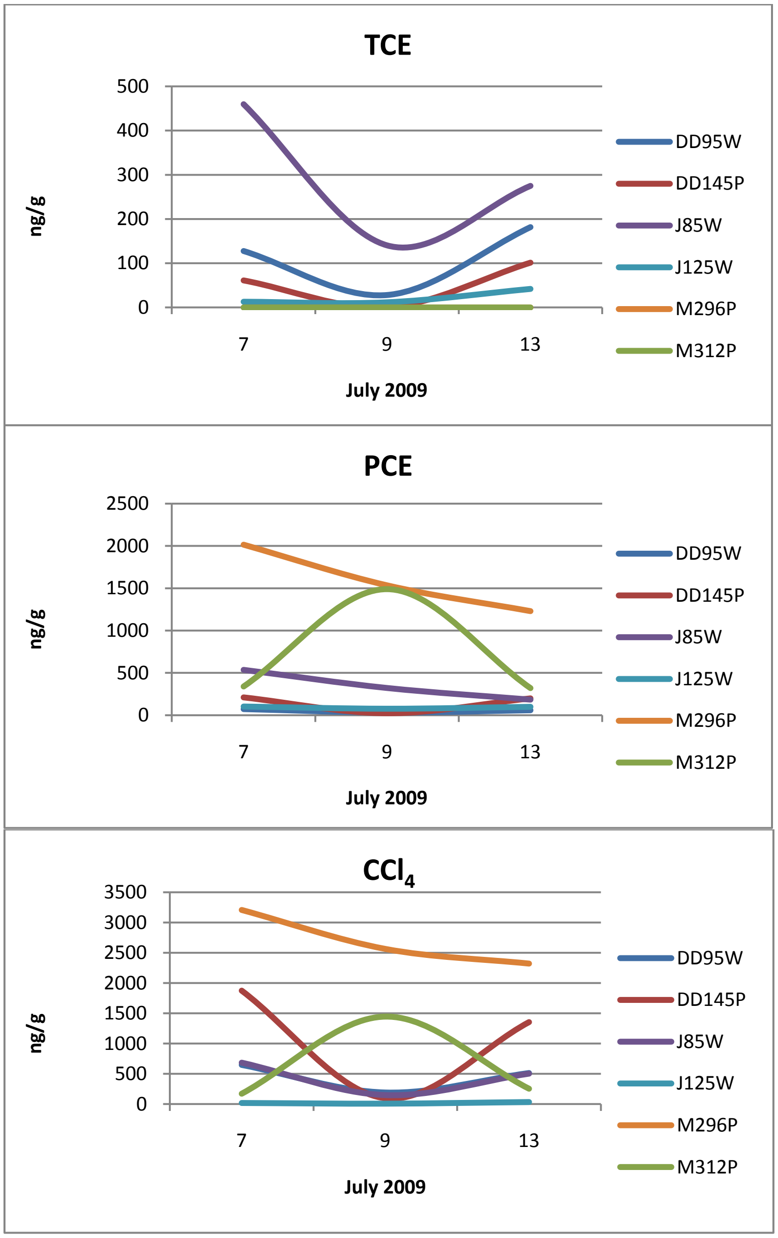


Figure 4. Selected daily average meteorological data from Argonne weather station for July 1 - 13, 2009.

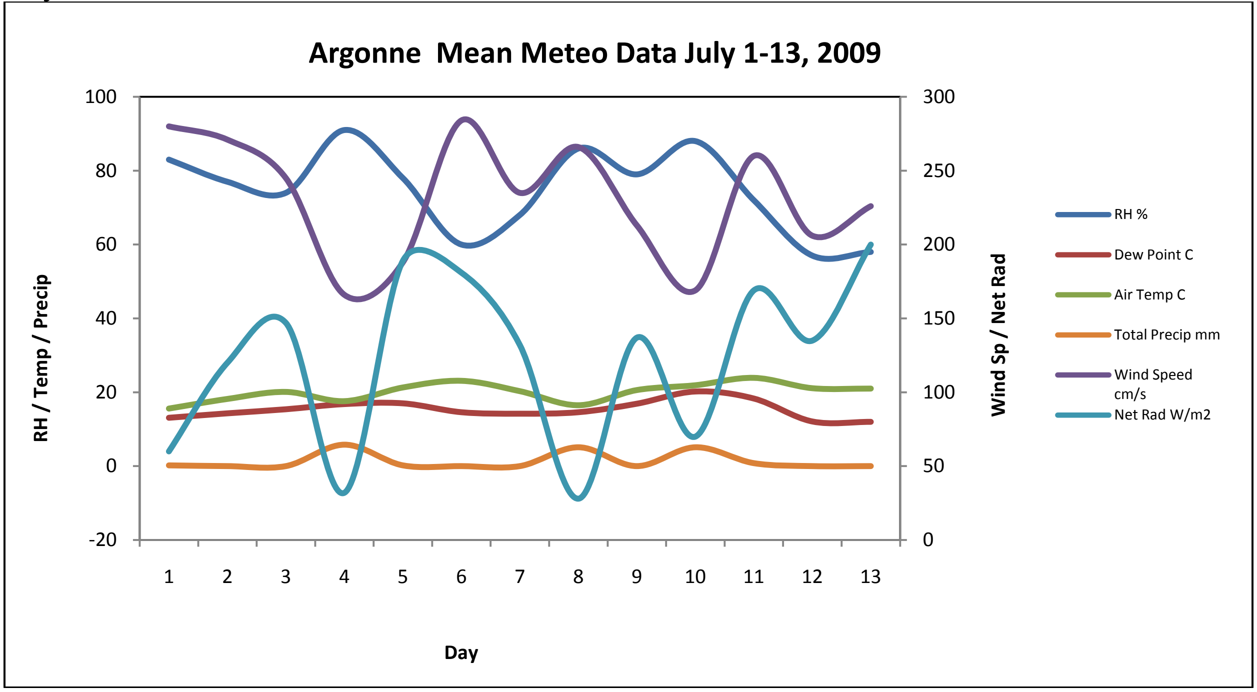


Figure 5: Comparison of diurnal sap flow over eight days for three TDP30 probes (15mm depth) mounted at three different heights and orientation on hybrid poplar tree in 319 HC Area. Time period is June 4-11, 2009.

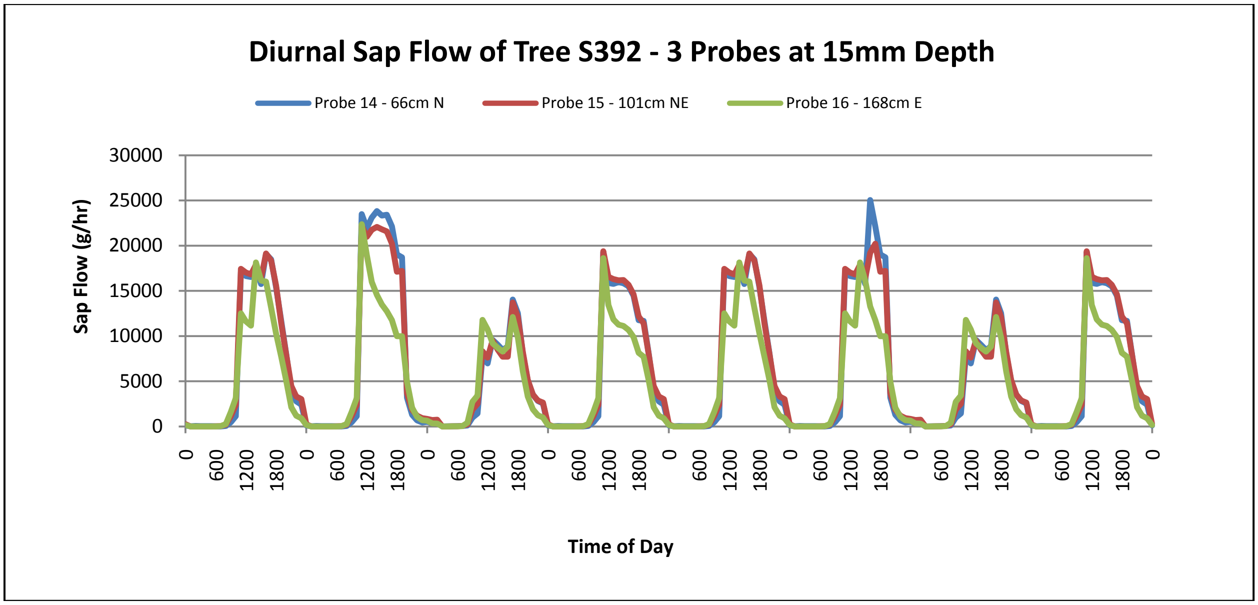


Figure 6: Typical diurnal sap flow showing difference in flow and timing between shallower and deeper woods of a hybrid poplar in 319 HC Area. Time period is June 4-11, 2009.

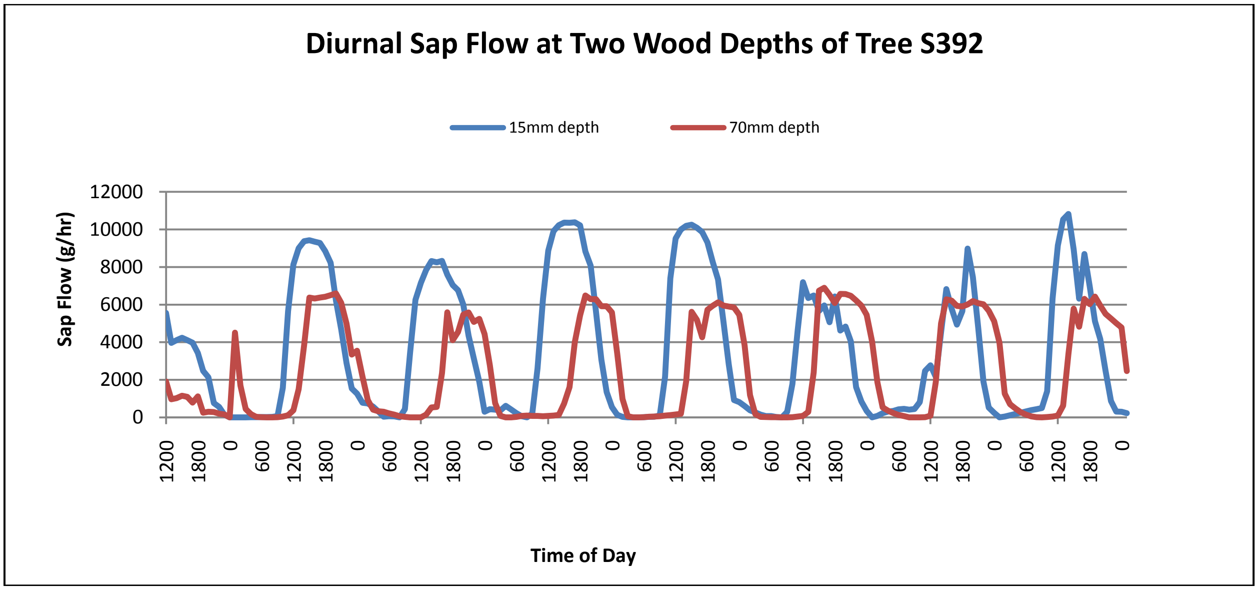


Table 1: Mean VOC concentrations in branch samples collected from trees in two hot spots in the 317 Area. Control is in vicinity of Bldg 485*.

Year	**2007 (ng/g)**				**2008 (ng/g)**				**2009 (ng/g)**			
Sample ID	TCE	PCE	1,1,1 TCA	CCl4	TCE	PCE	1,1,1 TCA	CCl4	TCE	PCE	1,1,1 TCA	CCl4
DD145W	7	7	0	0	92	249	0	301	54	144	0	1109
DD95W	106	35	0	123	250	98	0	85	112	54	0	452
J85W	81	20	0	56	108	229	0	211	292	347	0	445
K100W	36	17	0	15	53	83	0	68	32	32	0	13
K120W	9	4	0	3	0	2	0	0	8	4	0	9
M296P	-	-	-	-	-	-	-	-	0	1593	0	2698
M312P	3	125	0	145	8	1940	0	1473	0	716	0	625
Control	*4*	*0*	*0*	*2*	*0*	*1*	*0*	*0*	*13*	*73*	*0*	*6*

*As seen from the biomaps in Figure 2, there are significant differences between contaminant concentrations based on the day that the samples were collected. Thus, this table illustrates the areas where the contaminant hotspots are present; values of contaminant concentrations are inherently uncertain as a result of the temporal variability and may differ significantly from year-to-year.

Table 2: DBH, mean sap flows and sap flux for thirteen hybrid poplar trees in the 319 Area sampled from June 4-July 9, 2008 and 2009.

	2008			2009		
Tree	**DBH (cm)**	**Total Wood Sap Flow (L/day)**	**Sap Flux (g/d-cm^2)**	**DBH (cm)**	**Total Wood Sap Flow (L/day)**	**Sap Flux (g/d-cm^2)**
Q392	18.2	70.1	12.6	21.6	156.7	19.6
Q408	15.9	109.5	26.2	18.4	181.1	31.7
R384	20.6	156.2	21.6	23.5	192.4	20.2
R400	18.8	51.8	8.7	22.0	123.8	14.9
R416	22.9	131.2	14.5	29.3	216.7	14.4
S360	17.3	57.3	11.4	19.0	76.8	12.6
S376	18.5	188.3	32.6	21.5	248.8	31.4
S392	19.8	188.4	28.3	22.8	183.6	20.5
S408	20.1	91.6	13.3	26.2	203.7	22.3
S424	20.6	193.5	26.7	23.0	181.0	15.1
T400	21.0	82.3	10.9	22.0	148.6	17.9
T416	18.3	82.6	14.6	22.2	142.6	16.8
T432	17.3	144.5	28.9	21.0	203.1	26.9
Mean	**19.2**	**121.7**	**19.6**	**23.2**	**173.7**	**20.3**
Min	**15.9**	**34.4**	**6.2**	**18.4**	**76.8**	**12.6**
Max	**22.9**	**219.8**	**32.7**	**29.3**	**248.4**	**31.7**
StDev	*3.5*	*57.5*	*9.0*	*2.7*	*44.3*	*6.3*

Note: Total wood sap flow is estimated sap flow for whole tree diameter minus bark. Sap flux is mean measured flux by probes. For 2008, total sap flow was estimated using total wood area and measured flux; for 2009 total sap flow is sum of outer and inner woods' flows.

Table 3: Comparison of mean daily sap flow and sap flux at two different wood depths, June 4-July 9, 2009.

	15 mm depth (n=25)			**70 mm depth (n=5)**		
	Wood Area (cm2)	**Mean Sap Flow (L/day)**	**Sap Flux (g/cm^2-hr**	**Wood Area (cm2)**	**Mean Sap Flow (L/day)**	**Sap Flux (g/cm^2-hr)**
Mean	244.1	114.8	20.1	181.2	48.0	12.2
Min	152.2	42.3	10.2	127.1	34.3	11.2
Max	402.6	174.8	34.5	238.9	78.0	14.4
StDev	*62.6*	*34.9*	*6.6*	*51.2*	*18.4*	*1.3*

Appendix 1 - Summer 2009 Field Data: VOCs in plant tissue from field samples (ng/g dry weight).

Branch Samples Tree ID	**Date**	**TCAA+ CHCl$_3$**	**TCE**	**PCE**	**CCl4**
A-10W-07-br	7/7/2009	7	1	5	2
A-10W-09-br	7/9/2009	2	0	4	1
A-10W-13-br	7/13/2009	0	17	3	21
A130W-07-br	7/7/2009	5	1	1	2
A130W-09-br	7/9/2009	17	1	0	3
A130W-13-br	7/13/2009	0	11	1	16
A80W-07-br	7/7/2009	9	1	4	3
A80W-09-br	7/9/2009	8	1	2	3
A80W-13-br	7/13/2009	0	18	3	13
A90W-07-br	7/7/2009	11	5	9	2
A90W-09-br	7/9/2009	8	1	2	2
A90W-13-br	7/13/2009	0	21	4	23
B115W-07-br	7/7/2009	3	0	10	1
B115W09-br	7/9/2009	10	1	8	1
B115W-13-br	7/13/2009	0	20	17	17
B5W-07-br	*7/7/2009*	*13*	*47*	*123*	*1*
B5W-09-br	*7/9/2009*	*7*	*41*	*104*	*1*
B5W-13-br	*7/13/2009*	*82*	*74*	*120*	*21*
B85W-07-br	7/7/2009	10	4	38	2
B85W-09-br	7/9/2009	8	7	73	13
B85W-13-br	7/13/2009	64	28	80	18
C100W-07-br	*7/7/2009*	*14*	*36*	*324*	*1*
C100W-09-br	*7/9/2009*	*12*	*20*	*189*	*2*
C100W-13-br	*7/13/2009*	*82*	*88*	*490*	*17*
C-10W-07-br	7/7/2009	52	69	17	1
C-10W-09-br	7/9/2009	34	65	18	1
C-10W-13-br	7/13/2009	163	135	21	21
C150W-07-br	7/7/2009	16	1	5	2
C150W-09-br	7/9/2009	13	1	2	2
C150W-13-br	7/13/2009	171	0	3	25
C50W-07-0br	*7/7/2009*	*21*	*50*	*477*	*2*
C50W-09-br	*7/9/2009*	*7*	*36*	*386*	*2*
C50W-13-br	*7/13/2009*	*74*	*122*	*742*	*20*
D115W-07-br	7/7/2009	14	7	30	2
D115W09-br	7/9/2009	12	8	40	2
D115W-13-br	7/13/2009	81	36	68	20
D45W-07-br	*7/7/2009*	*22*	*115*	*473*	*1*
D45W-09-br	*7/9/2009*	*12*	*83*	*422*	*3*

Branch Samples Tree ID	**Date**	**TCAA+ $CHCl_3$**	**TCE**	**PCE**	**CCl4**
D45W-13-br	*7/13/2009*	*82*	*169*	*521*	*16*
D5W-07-br	7/7/2009	9	1	1	2
D5W-09-br	7/9/2009	10	1	0	2
D5W-13-br	7/13/2009	68	22	2	24
D75W-07-br	*7/7/2009*	*17*	*13*	*104*	*2*
D75W-09-br	*7/9/2009*	*16*	*4*	*52*	*5*
D75W-13-br	*7/13/2009*	*72*	*40*	*120*	*22*
D95W-07-br	*7/7/2009*	*16*	*11*	*99*	*3*
D95W-09-br	*7/9/2009*	*7*	*6*	*83*	*1*
D95W-13-br	*7/13/2009*	*60*	*35*	*127*	*23*
DD105P-07-br	7/7/2009	62	6	6	8
DD105P-09-br	7/9/2009	37	3	4	5
DD105P-13-br	7/13/2009	150	33	5	27
DD125P-09-br	7/9/2009	343	1	10	30
DD125P-07-br	7/7/2009	2304	16	45	271
DD125P-13-br	7/13/2009	690	25	17	80
DD145P-07-br	*7/7/2009*	*6352*	*61*	*210*	*1876*
DD145P-09-br	*7/9/2009*	*473*	*1*	*22*	*96*
DD145P-13-br	*7/13/2009*	*6183*	*101*	*199*	*1355*
DD165P-07-br	7/7/2009	307	0	14	174
DD165P-09-br	7/9/2009	69	1	2	9
DD165P-13-br	7/13/2009	882	818	11	830
DD95W-07-br	7/7/2009	1429	128	72	649
DD95W-09-br	7/9/2009	485	28	32	192
DD95W-13-br	7/13/2009	1337	182	58	514
E100W-07-br	7/7/2009	10	1	24	2
E100W-09-br	7/9/2009	8	1	8	3
E100W-13-br	7/13/2009	68	25	12	25
E160W-07-br	7/7/2009	3	0	42	1
E160W-09-br	7/9/2009	13	1	22	3
E160W-13-br	7/13/2009	0	16	41	26
E20W-07-br	7/7/2009	9	1	0	2
E20W-09-br	7/9/2009	11	1	0	1
E20W-13-br	7/13/2009	62	35	40	7
E60W-07-br	7/7/2009	0	1	7	4
E60W-09-br	7/9/2009	11	4	7	4
E60W-13-br	7/13/2009	0	29	12	26
F0W-07-br	7/7/2009	11	1	0	2
F0W-09-br	7/9/2009	11	1	0	1
F0W-13-br	7/13/2009	69	41	74	22
F185W-07-br	7/7/2009	23	8	26	8

Branch Samples Tree ID	**Date**	**TCAA+ CHCl$_3$**	**TCE**	**PCE**	**CCl4**
F185W-09-br	7/9/2009	30	10	41	6
F185W-13-br	7/13/2009	73	21	15	17
F45W-07-br	7/7/2009	17	26	24	3
F45W-09-br	7/9/2009	1260	19	25	6
F45W-13-br	7/13/2009	54	45	14	19
F95W-07-br	7/7/2009	0	1	0	3
F95W-09-br	7/9/2009	18	8	4	2
F95W-13-br	7/13/2009	12	11	2	11
G100W-07-br	7/7/2009	14	1	6	1
G100W-09-br	7/9/2009	0	24	2	25
G100W-13-br	7/13/2009	0	15	1	16
G120W-07-br	7/7/2009	13	7	34	1
G120W-09-br	7/9/2009	14	1	7	3
G120W-13-br	7/13/2009	44	34	19	28
G160W-07-br	7/7/2009	103	12	47	13
G160W-09-br	7/9/2009	65	7	31	12
G160W-13-br	7/13/2009	0	33	34	35
G20W-07-br	7/7/2009	11	1	0	1
G20W-09-br	7/9/2009	22	15	1	23
G20W-13-br	7/13/2009	0	14	0	20
H115W-07-br	7/7/2009	14	1	7	0
H115W-09-br	7/9/2009	9	0	3	1
H115W-13-br	7/13/2009	69	35	3	24
H145P-09-br	7/9/2009	8	18	42	0
H145W-07-br	7/7/2009	12	20	47	13
H145W-13-br	7/13/2009	59	49	69	0
H205-09-br	7/9/2009	0	1	0	2
H205W-07-br	7/7/2009	6	13	29	2
H205W-13-br	7/13/2009	349	37	27	0
H55W-07-br	7/7/2009	10	4	8	2
H55W09-br	7/9/2009	113	56	4	32
H55W-13-br	7/13/2009	0	33	13	28
H5W-07-br	7/7/2009	9	1	3	2
H5W-09-br	7/9/2009	61	24	1	28
H5W-13-br	7/13/2009	0	25	1	30
I170W-07-br	*7/7/2009*	*39*	*34*	*185*	*2*
I170W-09-br	*7/9/2009*	*32*	*32*	*247*	*3*
I170W-13-br	*7/13/2009*	*129*	*104*	*550*	*17*
I50W-07-br	7/7/2009	12	11	7	3
I50W-09-br	7/9/2009	83	62	10	25
I50W-13-br	7/13/2009	77	46	4	14

Branch Samples Tree ID	**Date**	**TCAA+ CHCl$_3$**	**TCE**	**PCE**	**CCl4**
I80W-07-br	7/7/2009	8	5	6	2
I80W-09-br	7/9/2009	84	35	5	17
I80W-13-br	7/13/2009	0	34	3	19
J125W-07-br	*7/7/2009*	*1653*	*13*	*102*	*18*
J125W-09-br	*7/9/2009*	*920*	*12*	*77*	*8*
J125W-13-br	*7/13/2009*	*976*	*42*	*99*	*33*
J185W-07-br	7/7/2009	13	1	5	2
J185W-09-br	7/9/2009	8	1	3	2
J185W-13-br	7/13/2009	27	21	1	13
J205W-07-br	7/7/2009	16	1	4	3
J205W-09-br	7/9/2009	9	1	4	2
J205W-13-br	7/13/2009	52	21	3	13
J5W-07-br	7/7/2009	20	18	35	5
J5W-09-br	7/9/2009	9	14	34	1
J5W-13-br	7/13/2009	66	28	19	11
J85W-07-br	*7/7/2009*	*3686*	*460*	*536*	*685*
J85W-09-br	*7/9/2009*	*798*	*141*	*322*	*148*
J85W-13-br	*7/13/2009*	*3194*	*275*	*184*	*503*
K100W-07-br	7/7/2009	106	19	29	2
K100W-09-br	7/9/2009	84	19	40	2
K100W-13-br	7/13/2009	237	58	26	35
K120P-07-br	7/7/2009	21	1	9	3
K120W-09-br	7/9/2009	7	1	0	2
K120W-13-br	7/13/2009	74	22	2	23
K160P-07-br	7/7/2009	347	1	38	45
K160P-09-br	7/9/2009	208	2	28	23
K160P-13-br	7/13/2009	370	27	26	57
L128P-07-br	7/7/2009	1	2	5	7
L128P-09-br	7/9/2009	7	1	1	2
L128P-13-br	7/13/2009	0	0	2	77
L160P-07-br	7/7/2009	0	3	0	23
L160P-09-br	7/9/2009	0	6	8	169
L160P-13-br	7/13/2009	0	0	1	16
L192P-07-br	7/7/2009	0	35	0	3
L192P-09-br	7/9/2009	7	3	0	1
L192P-13-br	7/13/2009	42	76	0	7
L32P-07-br	7/7/2009	0	1	0	7
L32P-09-br	7/9/2009	18	1	0	8
L32P-13-br	7/13/2009	42	28	3	36
M152P-07-br	7/7/2009	3	1	2	2
M152P-09-br	7/9/2009	11	1	3	3

Branch Samples Tree ID	**Date**	**TCAA+ $CHCl_3$**	**TCE**	**PCE**	**CCl4**
M152P-13-br	7/13/2009	0	0	1	13
M184P-07-br	*7/7/2009*	*46*	*103*	*0*	*9*
M184P-09-br	*7/9/2009*	*46*	*97*	*2*	*5*
M184P-13-br	*7/13/2009*	*70*	*133*	*1*	*18*
M216P-07-br	7/7/2009	0	23	19	3
M216P-09-br	7/9/2009	6	43	5	2
M216P-13-br	7/13/2009	66	89	1	48
M24P-07-br	7/7/2009	0	0	0	2
M24P-09-br	7/9/2009	9	1	0	2
M24P-13-br	7/13/2009	31	17	1	22
M296P-07-br	*7/7/2009*	*1275*	*0*	*2016*	*3208*
M296P-09-br	*7/9/2009*	*1314*	*0*	*1535*	*2564*
M296P-13-br	*7/13/2009*	*1184*	*0*	*1230*	*2321*
M312P-07-br	*7/7/2009*	*95*	*0*	*339*	*172*
M312P-09-br	*7/9/2009*	*480*	*0*	*1489*	*1447*
M312P-13-br	*7/13/2009*	*232*	*0*	*320*	*255*
N144P-07-br	7/7/2009	1	1	8	4
N144P-09-br	7/9/2009	4	0	0	0
N144P-13-br	7/13/2009	29	13	2	27
N240P-07-br	7/7/2009	6	1	0	5
N240P-09-br	7/9/2009	4	1	0	5
N240P-13-br	7/13/2009	66	8	2	16
N48P-07-br	7/7/2009	6	1	0	2
N48P-09-br	7/9/2009	9	1	0	1
N48P-13-br	7/13/2009	21	0	0	21
O08P-07-br	7/7/2009	1	1	0	3
O08P-09-br	7/9/2009	4	0	0	1
O08P-13-br	7/13/2009	0	0	0	19
O104P-07-br	7/7/2009	0	0	2	16
O104P-09-br	7/9/2009	9	1	0	4
O104P-13-br	7/13/2009	73	14	1	23
O264P-07-br	7/7/2009	2	1	12	4
O264P-09-br	7/9/2009	10	0	6	1
O264P-13-br	7/13/2009	60	6	5	29
O312P-07-br	*7/7/2009*	*52*	*3*	*126*	*21*
O312P-09-br	*7/9/2009*	*51*	*1*	*114*	*25*
O312P-13-br	*7/13/2009*	*139*	*23*	*111*	*50*
O72P-07-br	7/7/2009	0	0	1	5
O72P-09-br	7/9/2009	26	3	0	11
O72P-13-br	7/13/2009	47	14	1	20
P144P-07-br	7/7/2009	1	1	0	3

Branch Samples Tree ID	**Date**	**TCAA+ CHCl$_3$**	**TCE**	**PCE**	**CCl4**
P144P-09-br	7/9/2009	15	4	0	9
P144P-13-br	7/13/2009	278	0	6	80
P224P-07-br	7/7/2009	0	3	0	14
P224P-09-br	7/9/2009	5	1	0	1
P224P-13-br	7/13/2009	61	0	3	86
P304P-07-br	*7/7/2009*	*0*	*7*	*107*	*36*
P304P-09-br	*7/9/2009*	*46*	*0*	*93*	*17*
P304P-13-br	*7/13/2009*	*539*	*22*	*114*	*34*
P64P-07-br	7/7/2009	7	1	0	1
P64P-09-br	7/9/2009	8	1	0	2
P64P-13-br	7/13/2009	0	0	0	22
R24P-07-br	7/7/2009	15	3	1	15
R24P-09-br	7/9/2009	11	0	0	1
R24P-13-br	7/13/2009	0	0	0	76
S128P-07-br	7/7/2009	20	9	0	20
S128P-09-br	7/9/2009	6	3	2	6
S128P-13-br	7/13/2009	31	0	0	65
S392-09-br	7/9/2009	7	1	2	2
S392P-07-br	7/7/2009	5	1	0	3
S392P-13-br	7/13/2009	44	24	0	12
T16P-07-br	7/7/2009	5	1	3	4
T16P-09-br	7/9/2009	5	1	0	3
T16P-13-br	7/13/2009	58	14	11	13
T400P-07-br	7/7/2009	0	32	0	13
T400P-09-br	7/9/2009	25	5	0	13
T400P-13-br	7/13/2009	22	10	0	20
T48P-07-br	7/7/2009	26	34	151	5
T48P-09-br	7/9/2009	10	1	0	3
T48P-13-br	7/13/2009	43	0	0	32
U184P-07-br	7/7/2009	56	1	0	4
U184P-09-br	7/9/2009	3	1	0	2
U184P-13-br	7/13/2009	62	0	0	26
U200P-07-br	7/7/2009	7	1	0	3
U200P-09-br	7/9/2009	11	0	0	2
U200P-13-br	7/13/2009	49	0	0	11
U216P-07-br	7/7/2009	5	0	0	1
U216P-09-br	7/9/2009	10	1	0	0
U216P-13-br	7/13/2009	43	9	0	10
Y168P-09-br	7/9/2009	42	2	0	5
Y184P-07-br	7/7/2009	10	0	3	4
Y184P-09-br	7/9/2009	8	1	0	1

Branch Samples Tree ID	**Date**	**TCAA+ $CHCl_3$**	**TCE**	**PCE**	**CCl4**
Y184P-13-br	7/13/2009	83	34	32	14
GHCP-07-br	7/7/2009	9	0	5	2
GHCP-09-0br	7/9/2009	42	23	94	4
GHCP-13-br	7/13/2009	117	15	121	12
Leaf Samples Tree ID	**Date**	**TCAA**	**TCE**	**PCE**	**CCl4**
B5W-lf	7/13/2009	138	0	0	21
DD95W-lf	7/13/2009	371	75	0	48
DD105P-lf	7/13/2009	274	45	0	27
K100W-lf	7/13/2009	242	53	0	31
L32P-lf	7/13/2009	0	37	0	24
GHCP-lf	7/13/2009	107	41	12	31

Samples highlighted in italics represent the samples taken in areas of higher concentration

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COST AND PERFORMANCE REPORT

Phytoremediation at Aberdeen Proving Grounds
Edgewood Area J-Field Site
Edgewood, MD

May 2002

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

Phytoremediation at Aberdeen Proving Grounds, Edgewood Area J-Field Site, Edgewood, MD

Excerpted from: NATO CCMS Pilot Study; 2001 Annual Report
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Project Completed 1999

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1. INTRODUCTION

The efficacy and cost of phytoremediation to clean up shallow groundwater contaminated with chlorinated solvents (primarily trichloroethylene), is being evaluated at the field scale in demonstration projects at Aberdeen Proving Grounds Edgewood Area J-Field Site in Edgewood, Maryland, the Edward Sears site in New Gretna, New Jersey, and Carswell Air Force Base in Fort Worth, Texas. These projects will demonstrate the use of hybrid poplars to hydraulically control the sites and ultimately to remove the volatile organic compounds (VOCs) from the groundwater. When completed, these projects will allow a comparison of phytoremediation at three sites under varied conditions within different climatic regions.

2. SUMMARY AND LATEST OBSERVATIONS

At the Aberdeen Proving Ground site, a process called deep rooting is being used to achieve hydraulic influence. Hybrid poplar trees were initially planted in the spring of 1996 at five to six feet below ground surface to maximize groundwater uptake. The field demonstration and evaluation will be for a five year period. The U.S. Geological Survey has estimated that hydraulic influence will occur when 7,000 gallons of water per day are removed from the site.

Several trees were excavated in the fall of 1998 to determine root growth. The tree roots were found to be confined to the hole in which they were placed. In an attempt to increase root depth and width, new trees were planted in holes of varying sizes and depths.

The latest field data indicates that hydraulic influence is occurring. Current tree uptake is 1,091 gallons (4,129 liters) per day and is expected to increase to 1,999 gallons (7,528 liters) at the end of 30 years. Contaminant uptake is minimal at this time but is expected to improve as the trees mature. Groundwater sampling indicates that the contaminated plume has not migrated off-site during the growing season and sampling data showed non-detectable emissions from transpiration gas. There are several on-going studies to determine if deleterious compounds retained in the leaves and soil could pose risks to environmental receptors.

3. SITE DESCRIPTION

Aberdeen Proving Grounds is located at the tip of the Gunpowder Neck Peninsula in Maryland, which extends into the Chesapeake Bay. The Army practiced open trench (toxic pits) burning/detonation of munitions containing chemical agents and dunnage from the 1940s to the 1970s. Large quantities of decontaminating agents containing solvents were used during the operation. The surficial groundwater table had been contaminated with solvents (1,1,2,2-TCA, TCE, DCE) at levels up to 260 parts per million (ppm). The contamination is 5 to 40 ft (3.5 to 13 m) below ground surface. The plume is slow-moving due to tight soils and silty sand. The impacted area is a floating mat-type fresh water marsh approximately 500 ft (160 m) southeast. A low environmental threat is presented by the contaminant plume.

4. DESCRIPTION OF THE PROCESS

Phytoremediation was selected to provide both hydraulic influence of the groundwater plume and mass removal of contaminants.

The plantation area being monitored is approximately 2034 m^2 and contains 156 viable poplars. 1,1,2,2-TCA and TCE are 90 percent of the contaminants (total approximately 260 ppm solvents). USGS estimated 7000 gals/day removal would achieve hydraulic influence. The duration of evaluation will be five years.

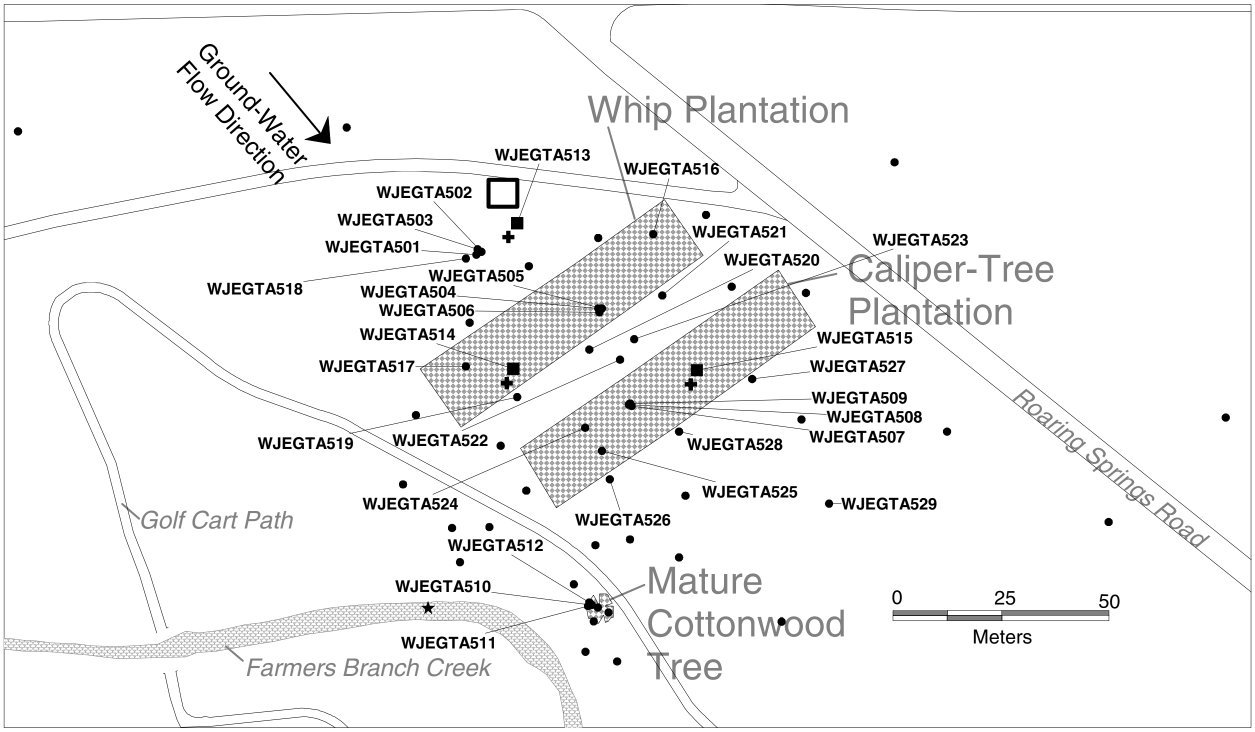
Process Description —
After agronomic assessment, two-year-old hybrid poplar 510 trees were planted 5 to 6 ft (1.6 to 2 m) deep in the spring of 1996. Surficial drainage system was installed to remove precipitation quickly and allowed trees to reach groundwater.

Various sampling methods were employed during the 1998 growing season to determine if project objectives are being met. The methodologies which yielded the most valuable data include: groundwater sampling; sap flow monitoring; tree transpiration gas and condensate sampling; and exposure pathway assessments. In addition to field sampling activities, new trees were planted on the site in October 1998 to increase the phytoremediation area and assess the usefulness of native species for phytoremediation.

5. RESULTS AND EVALUATION

1. Examination of groundwater level data revealed an area of depression within the poplar plantation indicating that hydraulic influence is occurring. Currently, the trees are removing approximately 1,091 gallons per day (4,129 L/day) and at the end of 30 years are expected to remove approximately 1,999 gallons per day (7,528 L/day).
2. Groundwater sampling indicated that the contaminated plume has not migrated off-site during the growing seasons.
3. There are no ecological impacts that are attributable to the plantation area. Sampling data have shown non-detectable off-site migration of emissions from transpiration gas.
4. Peak transpiration is estimated to occur in approximately 10 to 15 years.
5. Limitations include depth of contamination, but there are no limitations for concentrations of up to 260 ppm for solvents. Weather and growing season are the most influential factors.
6. Contaminant uptake is minimal at this time but is expected to improve as the trees mature.

Figure 1: Aberdeen Proving Grounds, Maryland



EXPLANATION

• MONITORING WELL: Well number indicates well was sampled throughout the entire location

i STREAM-STAGE GAGE

[TENSIOMETER NEST

Ó MONITORING WELL WITH WATER-LEVEL RECORDER

 WEATHER STATION

7. A groundwater model is under development to quantify the degree of containment generated by the trees. The model requires an accurate estimate of water withdrawal rates by the trees to determine if phytoremediation will work as a remedial alternative for the site.
8. This demonstration project is on-going and will be further evaluated for efficacy and costs.

Groundwater samples and elevations were collected, seasonally from the on-site wells to determine VOC concentrations and if trees were facilitating hydraulic influence of the plume. Results indicated that an area of drawdown exists within the tree zone during the spring and summer when tree transpiration is the greatest. In 1998, additional wells were installed using a Geoprobe® in order to more accurately assess VOC concentrations and groundwater elevation. A groundwater model is currently being developed to predict potential VOC removal by the trees and when complete hydraulic influence may be attained. Given the success of the groundwater sampling, sampling objectives for 1999 included groundwater elevation monitoring and sampling and a continued effort to refine the groundwater model.

Sap flow monitoring was performed to determine the amount of water being removed by individual trees. In order to increase monitoring accuracy, new sap flow probes were purchased which are placed directly into the tree tissue as opposed to resting on the trunk of the tree. Comparison of new equipment with previous methods indicates that the new methodology provides an even more accurate estimation of net transpiration rate with less data interference or “noise.” Future sampling objectives for the site include continued seasonal sap flow monitoring for the purposes of estimating transpiration rates.

Seasonal tree transpiration gas and condensate sampling continued in the 1998 sampling season to assess the release of VOCs from the trees. Previous methods consisted of placing a 100-liter Tedlar® bag over a section of branch and then sampling the gas and any condensate trapped within the bag. This method was modified in 1998 with the addition of a cold trap which would potentially remove excess moisture from the bag and keep the leaves in a more ambient temperature. Comparison of the two methods, with and without cold trap, indicates that the cold trap apparatus may not be powerful enough to sufficiently cool the temperature within the bag. Future transpiration gas monitoring was planned for the 1999 sampling season with the addition of a modified cold trap attachment.

Several studies were designed which examined exposure pathways. Leaves and soil were collected from the phytoremediation area and a reference area for a leaf degradation study. The study is designed to determine whether or not there are deleterious compounds retained within the study leaves or within the associated soil which could pose risk to an environmental receptor. The results of this study are still being analyzed. Additional studies involved nematode analyses which examined the trophic assemblage of the nematode community. Data collected in 1997 indicated that the nematode community was enhanced in the phytoremediation area as compared with data collected prior to the tree planting.

No trees were planted in the 1999 sampling season. The objectives were: 1) to assess the phytoremediation capabilities of native Maryland species, tulip trees and silver maples, in addition to hybrid poplar trees; 2) to increase the area of hydraulic influence; 3) to diversify the age of trees to ensure continued containment and contaminant removal; and 4) to assess new planting methods. The last objective relates to the three tree excavations performed in the fall of 1998. Three trees were excavated and replanted in their same areas on the site to examine root depth and structure and whether or not the trees were utilizing groundwater. Examinations revealed that most tree roots appeared to be confined to the hole in which they were placed and did not appear to radiate extensively from this area. It did appear however, that the tree roots were deep enough to access the groundwater. Three new planting methods (i.e., hole sizes and widths) were employed for the new trees in an attempt to provide the tree roots with either increased depth, increased width or a combination of increased width and depth. Monitoring of these new trees during the 1999 sampling season attempted to discern the phytoremediation capabilities of the native species versus the hybrid poplars and to assess the growth of the new trees given the various planting methods employed for each.

6. COSTS

Site Preparation (?):	$5,000
Capital:	$80,000 for UXO clearance of soil during planting; $80/tree.

Operation and maintenance: $30,000 due to no established monitoring techniques

7. REFERENCE

Eberts, S., G. Harvey, S. Jones, and S. Beckman, In press. A Multiple Process Assessment of Phtoremediation of a Chlorinated Solvent Plume at a Subhumid Field Site, John Wiley and Sons.

COST AND PERFORMANCE REPORT

Phytoremediation at Edward Sears Site
New Gretna, NJ

May 2002

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

Phytoremediation at Edward Sears Site, New Gretna, NJ
Excerpted from: NATO CCMS Pilot Study; 2001 Annual Report
EPA 542-R-02-001; January 2002
Project Completed 1999

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1. INTRODUCTION

The efficacy and cost of phytoremediation to clean up shallow groundwater contaminated with chlorinated solvents (primarily trichloroethylene), is being evaluated at the field scale in demonstration projects at Aberdeen Proving Grounds Edgewood Area J-Field Site in Edgewood, Maryland, the Edward Sears site in New Gretna, New Jersey, and Carswell Air Force Base in Fort Worth, Texas. These projects will demonstrate the use of hybrid poplars to hydraulically control the sites and ultimately to remove the volatile organic compounds (VOCs) from the groundwater. When completed, these projects will allow a comparison of phytoremediation at three sites under varied conditions within different climatic regions.

2. SUMMARY AND LATEST OBSERVATIONS

At the Edward Sears site, deep rooting was used to maximize groundwater uptake. Beginning in December 1996, hybrid poplar trees were planted nine feet below ground surface. In addition, some trees were planted along the boundary of the site at depth of only 3 feet to minimize groundwater and rainwater infiltration from off-site. Groundwater monitoring will continue in 2000. A November sampling is scheduled to determine if contaminant concentrations recover during the dormant season.

There were substantial reductions in dichloromethane and trimethylbenzene concentrations during the 1998 growing season. For example, dichloromethane was reduced to 615 parts per billion (ppb) from 490,000 ppb at one location and to a non-detect level from up to 12,000 ppb at another location; trimethylbenzene was reduced to 50 ppb from 1,900 at one location. There is also indication of anaerobic dechlorination in the root zone as the level of PCE dropped and TCE increased.

There seems to have been an adverse impact on tree growth in areas with high VOCs concentrations during the initial two growing seasons. However, in the third growing season, the rate of growth has increased significantly but the trees have yet to achieve the height and diameter of trees planted in uncontaminated areas. Evapotranspiration gasses were collected in sampling bags during the hottest periods of the day and were analyzed for target compounds. Only low levels of toluene (8 to 11 ppb) were detected. Soil gas flux measurements indicated that no contaminants are released into the air from the soil.

3. SITE DESCRIPTION

From the mid-1960s to the early 1990s, Edward Sears repackaged and sold expired paints, adhesives, paint thinners, and various military surplus materials out of his backyard in New Gretna, NJ. As a result, toxic materials were stored in leaky drums and containers on his property for many years. The soil and groundwater were contaminated with numerous hazardous wastes, including dichloromethane (up to 490,000 ppb), tetrachloroethylene (up to 160 ppb), trichloroethylene (up to 390 ppb), trimethylbenzene (up to 2,000 ppb), and xylenes (up to 2,700 ppb). There is a highly permeable sand layer from 0 to 5 ft (0 to 1.6 m) below ground surface (bgs). Below that exists a much less permeable layer of sand, silt, and clay from 5 to 18 (1.6 to 6 m) ft bgs. This silt, sand, and clay layer acts as a semi-confining unit for water and contaminants percolating down toward an unconfined aquifer from 18 to 80 ft (6 to 26 m) bgs. This unconfined aquifer is composed primarily of sand and is highly permeable. The top of the aquifer is about 9 ft (3 m) bgs, which lies in the less permeable sand, silt, and clay layer. The top of the aquifer is relatively shallow and most of the contamination is confined from 5 to 18 ft 1.6 to 6 m) bgs.

4. DESCRIPTION OF THE PROCESS

In December 1996, 118 hybrid poplar saplings (*Populus charkowiiensis x incrassata*, NE 308) were planted in a plot approximately one-third of an acre in size.

Poplar trees that were left over after the deep rooting was completed were planted to a depth of 3 ft (1 m), or shallow rooted. These trees were planted along the boundary of the site to the north, west, and east sides of the site. These trees will minimize groundwater and rainwater infiltration from off-site.

Process Description—
The trees were planted 10 ft (3 m) apart on the axis running from north to south and 12.5 ft (4 m) apart on the east-west axis. The trees were planted using a process called deep rooting: 12-ft (4 m) trees were buried nine feet under the ground so that only about 2 to 3 ft (0.6 to 1 m) remained on the surface. This was done to enhance deep rooting of poplar trees in the zone of contamination, and to maximize uptake of groundwater compared to surface water.

Monitoring of the site includes semi-annual analysis of groundwater, soils, soil gas, and evapotranspiration gas. Continued growth measurements will also be made as the trees mature. Site maintenance also involves fertilization, and control of insects, deer and unwanted vegetation.

5. RESULTS AND EVALUATION

Over 40 direct push microwells were installed to monitor groundwater instead of temporary direct push wells. This will enable frequent, seasonal monitoring of groundwater, at specific locations for comparable costs.

Substantial reductions in dichloromethane identified after the second growing season in August 1998 have been sustained as of August 1999. Concentrations at four locations were reduced from 490,000 down to 615 ppb, 12,000 ppb to ND, 680 ppb to ND, and 420 to 1.2 ppb. At one location PCE dropped from 100 to 56 ppb, while TCE increased from 9 to 35 ppb. This may be indicative of anaerobic dechlorination in the root zone. At other locations TCE concentrations remained stable over the past three years, although a decrease from 99 to 42 ppb was noted at one well point. Trimethylbenzene (TMB) was reduced from 147 to 2 ppb, 246 to ND, 1900 to 50 ppb, and 8 to 1 ppb at four microwell points in the treated area. At another well point within the treated area, concentrations of TMB were relatively unaffected, 102 ppb in August 1997 compared to 128 in August 1999. Xylenes were also unaffected or slightly increased at this same location, 26 ppb in August 1997 compared to 34 ppb in August 1999. At two other locations, xylene concentrations dropped from 590 to 17 ppb, and from 56 to 1.4 ppb.

The groundwater monitoring program will continue in 2000, with samples being collected in May, August and November. November sampling is being added to see if concentrations recover slightly during the dormant season.

Sampling of evapotranspiration gases was conducted by placing Tedlar bags over branches on 6 selected trees. Five trees were in areas where groundwater was contaminated with different concentrations of target contaminants. The sixth tree was in an area known to be free of contamination. Evapotranspiration gasses were collected on an hourly basis, for four hours during the hottest period of the day. Low levels of toluene 8 to 11 ppb were detected in three of four samples from one tree and one of four discrete gas samples from another tree. No other target compounds were detected (DL of 8 ppb/v) in any other samples.

Soil gas flux measurements were collected in conjunction with the evapotranspiration gas study. Samples collected indicated no contaminants being released to the air from the soils.

During the initial two growing seasons, tree height and diameter were substantially lower in areas containing high concentrations of VOCs in groundwater. This adverse impact appears to have been reduced during the third (1999) growing season. Rate of growth increased significantly in the contaminated areas; however, these trees have yet to achieve the overall height and diameter of trees planted in uncontaminated areas. Overall the trees in August 1998 averaged 17 ft (22 m) in height with a range from 3.5 to 25 ft (1 to 8 m).

6. COSTS

Site Preparation:	$24,000
Planting:	$65,700
Maintenance:	$15,300
Total:	$105,000
1997 Maintenance:	$26,000
1998 Maintenance:	$14,000 (Maintenance cost will drop substantially after trees are established)

Monitoring/analysis: 50 groundwater stations, soil gas, soils, hydrogeological parameters, weather, transpiration gas, reports, etc. Monitoring costs should also reduce annually as study techniques become more refined.

1997:	$72,800
1998:	$61,600
1999:	$42,000

7. REFERENCE

Eberts, S., G. Harvey, S. Jones, and S. Beckman, In press. A Multiple Process Assessment of Phtoremediation of a Chlorinated Solvent Plume at a Subhumid Field Site, John Wiley and Sons.

COST AND PERFORMANCE REPORT

Phytoremediation at Naval Air Station – Joint Reserve Base Fort Worth
Fort Worth, TX

November 2005

Prepared by:

U.S. Environmental Protection Agency
Office of Superfund Remediation and Technology Innovation (OSRTI)

IDENTIFYING INFORMATION

Site Name: Naval Air Station – Joint Reserve Base Fort Worth (formerly known as Carswell Air Force Base)
Location: Fort Worth, TX

TECHNOLOGY APPLICATION

Technology: Phytoremediation
Period of operation: 1996 to present (expected demonstration project completion in 2006)

SITE LOGISTICS/CONTACTS

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BACKGROUND

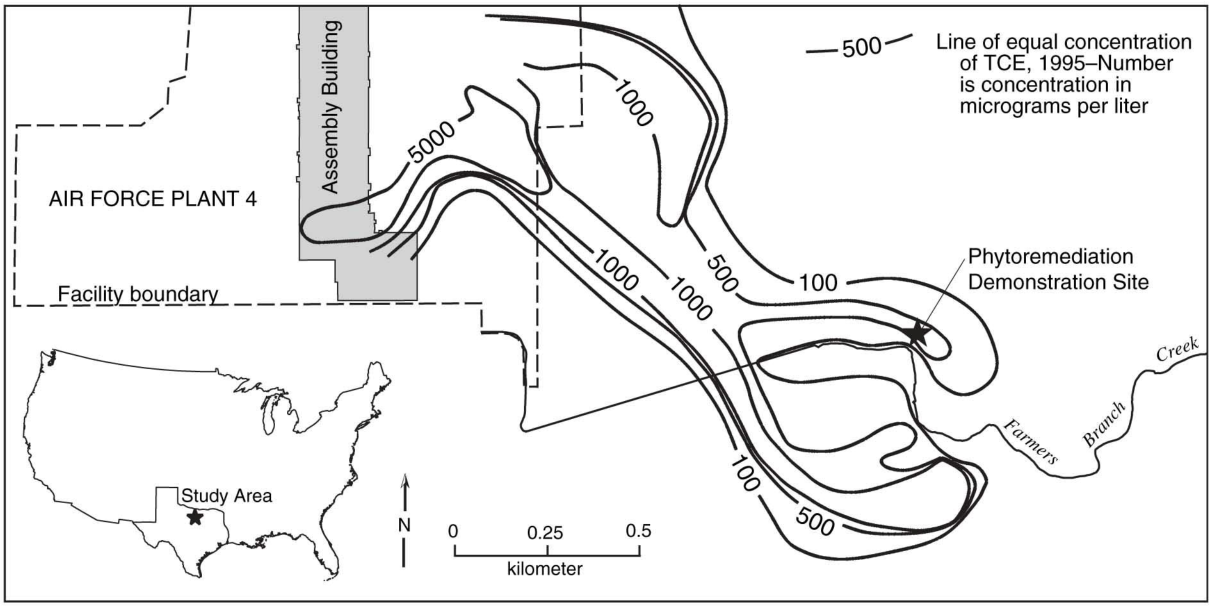
Waste Management Practice that Contributed to Contamination: Manufacture and assembly of military aircraft

Facility Operations [1,2,4,5,8]:

- The U.S. Air Force Plant 4 and adjacent Naval Air Station – Joint Reserve Base (NAS-JRB) Fort Worth, Texas (formerly known as Carswell Air Force Base) have sustained contamination in an alluvial aquifer through the use of chlorinated solvents in the manufacture and assembly of military aircraft.
- The plant was constructed in 1942 and currently produces F-16 aircraft, radar units, and various aircraft and missile components. Historically, the manufacturing processes at Plant 4 have generated an estimated 5,500 to 6,000 tons of waste per year, including waste solvents, oils, fuels, paint residues, and miscellaneous spent chemicals. Throughout most of the plant's history, the waste oil, solvents, and fuels were disposed in on-site landfills or burned in fire training exercises.
- Potential contamination was first noted in September 1982. Over time, it is suspected that trichloroethylene (TCE) leaked from the degreasing tanks in the assembly building at Plant 4 and migrated into the underlying aquifer. Dispersion and transport of TCE and its daughter products created a plume of contaminated groundwater.
- Previous use of a pump-and-treat system and steam-enhanced vacuum extraction addressed only a portion of the solvent-based source contamination at the site. Pump-and-treat was used to address a "finger" of the TCE plume that had migrated southeast of the central lobe.
- This report summarizes the phytoremediation demonstration project that began at the site in 1996. Figure 1 shows the location of NAS-JRB Fort Worth, the TCE groundwater plume, and the

phytoremediation demonstration site. The demonstration site is located over an approximately 70-meter-wide portion of the central lobe of the TCE groundwater plume, which originates approximately 1.5 kilometers upgradient of the demonstration area (near Plant 4).

Figure 1. Location of the phytoremediation demonstration site and TCE concentrations (μg/L) in the alluvial aquifer before system development, 1995 [5]



Source: Reproduced from Eberts, S. M., et al. 2005. Long-Term Changes in Ground Water Chemistry at a Phytoremediation Demonstration Site. Groundwater [5].

Project Background [1]:

The efficacy and cost of phytoremediation to clean up shallow groundwater contaminated with chlorinated solvents (primarily TCE) is being evaluated in field-scale demonstration projects at Aberdeen Proving Grounds Edgewood Area J-Field in Edgewood, Maryland; the Edward Sears site in New Gretna, New Jersey; and NAS-JRB Fort Worth (former Carswell Air Force Base) in Fort Worth, Texas. These projects will demonstrate the use of hybrid poplar trees to hydraulically control the sites and ultimately remove the volatile organic compounds (VOC) from the groundwater. When completed, these projects will allow a comparison of phytoremediation at three sites under varied conditions within different climatic regions.

At NAS-JRB Fort Worth, phytoremediation provides a low-cost, low-maintenance system that is consistent with a long-term contaminant reduction strategy. This project is led by the U.S. Air Force (USAF) and is being conducted as part of the U.S. Department of Defense (DOD) Environmental Security Technology Certification Program (ESTCP), as well as the U.S. EPA Superfund Innovative Technology Evaluation (SITE) Program. The phytoremediation system was designed to intercept and remediate a chlorinated ethene contaminant plume. The system relies on two mechanisms to achieve this goal: hydraulic removal of contaminated groundwater through tree transpiration and biologically mediated in situ reductive dechlorination of the contaminant. The tree root systems introduce labile organic matter into the aquifer system, which drives the microbial communities in the aquifer from aerobic to anaerobic communities that support the reductive dechlorination.

In addition to investigating changes in groundwater hydrology and chemistry, the trees are studied to determine important physiological processes such as rates of water usage, translocation and volatilization of volatile compounds, and biological transformation of chlorinated ethenes within the plant organs. Because planted systems may require many years to reach their full remediation potential, the study also makes use of transpiration and hydrologic predictive models to extrapolate findings to later years.

The demonstration study began in 1996 and is expected to be completed in 2006. This report presents available data through 2001, which includes the first six growing seasons. The growing season each year was from April through October, and the dormant season was from November through March.

MATRIX IDENTIFICATION

Soil and groundwater

CONTAMINANT CHARACTERIZATION

TCE is the main contaminant of concern at this site. Prior to the phytoremediation study, TCE concentrations in the groundwater approached 1,000 micrograms per liter (µg/L).

MATRIX CHARACTERISTICS AFFECTING TREATMENT COSTS OR PERFORMANCE [1,2,5]

The amount of hydraulic control that can be achieved by phytoremediation is a function of site-specific aquifer conditions. A planted system can be expected to have a greater hydrologic effect on an aquifer at a site that has an initially low volumetric flux of groundwater than at a site where the flux of contaminated groundwater is significantly greater. The volume of water stored in an aquifer will also affect system performance. The table below provides matrix characteristics for the phytoremediation system at this site.

Matrix Characteristic	Value/Description
Soil classification	Clayey sands and gravels
Groundwater velocity	0.5 meters per day
Groundwater flow direction	Southeast
Depth to groundwater	2.5 – 4 meters below ground surface
Average gradient	Greater than 2%
Saturated aquifer thickness	0.5 – 1.5 meters
Hydraulic conductivity (average)	6 meters per day

SITE HYDROGEOLOGY [1,4,5]

Surface soils at the site consist of 30 to 45 centimeters of silty clay and clayey silt. Groundwater has an estimated velocity of 0.5 meters per day (m/day). The underlying shallow aquifer consists of silty fine sands and hydraulically isolated lenses of coarser material.

PRIMARY TREATMENT TECHNOLOGY

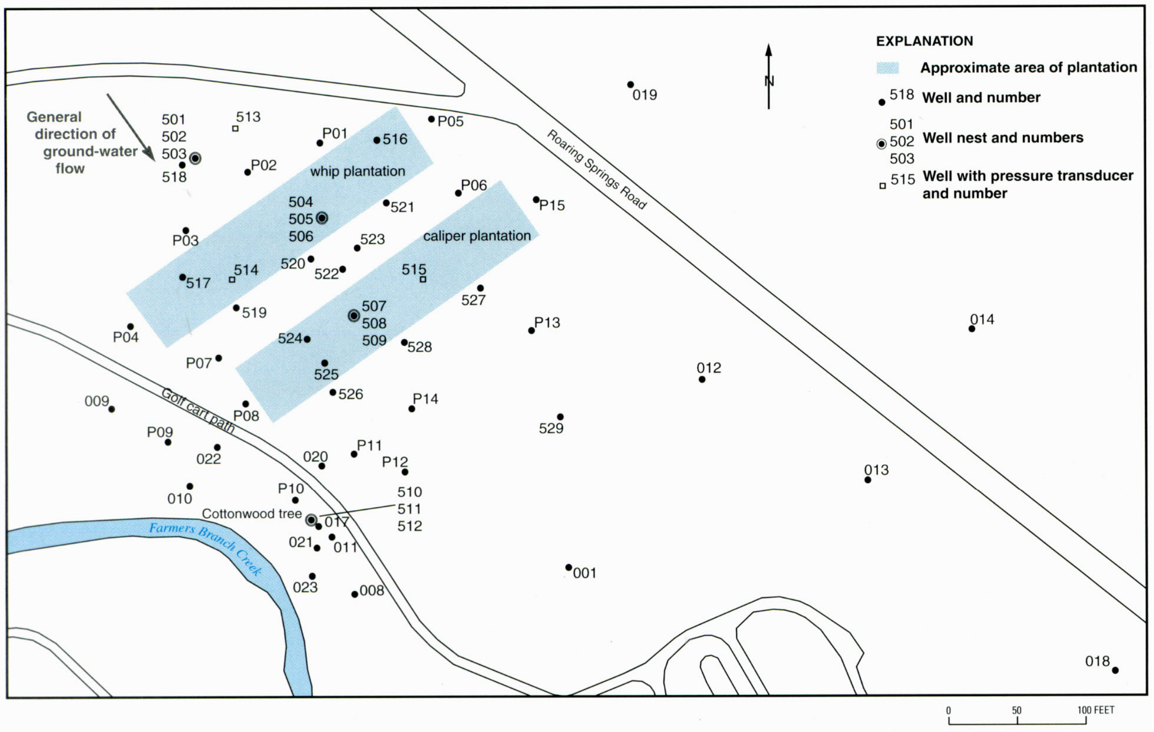
Phytoremediation

SYSTEM DESCRIPTION AND OPERATION [1,2,4,6]

This demonstration investigates the ability of eastern cottonwood (*Populus deltoides)* trees to remediate shallow TCE-contaminated groundwater in a subhumid climate. The study is determining the ability of the planted system to hydraulically control the migration of contaminated groundwater, as well as biologically enhance the subsurface environment to optimize in situ reductive dechlorination of the chlorinated ethenes.

In April 1996, the USAF planted 660 eastern cottonwoods at two plantations in a 4,000-square-meter area. The trees were planted as a short rotation woody crop employing standard techniques developed by the U.S. Department of Energy (DOE) to grow biomass for energy and fiber. Whips, which are sections of 1-year-old eastern cottonwood stems, were planted at one plantation. Caliper trees, which are more mature eastern cottonwoods with a 2.5- to 3.8-centimeter (cm) trunk diameter, were planted at the other plantation. Each plantation is approximately 15 by 75 meters and was designed so that the long side is generally perpendicular to the direction of the groundwater flow. Figure 2 shows the plantations, monitoring wells, and groundwater flow direction.

Figure 2. Location of cottonwood plantations and monitoring wells at phytoremediation demonstration site, Naval Air Station – Joint Reserve Base Fort Worth, Texas [6]



Source: Reproduced from U.S. Geological Survey. 2004. Demonstration-Site Development and Phytoremediation Processes Associated with Trichloroethene in Ground Water, Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas. USGS Fact Sheet 2004-3087. August [6].

Eastern cottonwoods were chosen because they are indigenous to the region and have proven their ability to withstand the Texas climate, local pathogens, and other localized variables that may affect tree growth and health. The caliper trees are expected to have higher evapotranspiration rates than the whips because of their larger leaf mass.

Soil preparation for planting included trenching seven rows spaced 2.4 meters apart in each of the plantations to a depth of 1 meter. The whips and caliper trees were placed 1.25 to 2.5 meters apart within the trenched rows. Irrigation lines were also installed in the trenched rows. A handful of fertilizer was applied around each whip and caliper tree. Following planting, fabric mulch and 10 cm of landscape mulch were placed along each row to minimize weed growth.

An extensive monitoring system was put in place to measure small incremental changes in site conditions over time. The monitoring system included the following:

- Sixty-seven (67) groundwater monitoring wells (wells) installed upgradient, within, downgradient, and surrounding the demonstration site
- Continuous water level recorders installed at three locations, including one upgradient of the tree plantations and two within the plantations
- Nine tensiometers installed upgradient or within the tree plantations
- A weather station installed to collect site-specific weather data
- A stream gauge installed on a creek adjacent to the site to record stream stages

- Tree collars or tree probes installed periodically during the growing season to measure sapflow in selected trees

A mature cottonwood tree (about 20 years old at the start of the demonstration) and section of the underlying aquifer located proximal to the study area were investigated to provide evidence of transpiration rates and geochemical conditions that eventually may be achieved at the site of the planted trees. Analyses were also conducted to evaluate the primary and secondary objectives of the project and to determine the ability of the trees to perform as a natural pump-and-treat system.

CLEANUP GOALS/OBJECTIVES [1,2,5,8]

Through the first three growing seasons (August 1996 through September 1998), this project was evaluated for its ability to reduce the mass of TCE transported across the downgradient end of the site (mass flux). The primary performance objectives were established: (1) a 30 percent reduction in the mass of TCE in the aquifer transported across the downgradient end of the site during the second growing season, as compared to baseline TCE mass flux; and (2) a 50 percent reduction in the mass of TCE in the aquifer transported across the downgradient end of the site during the third growing season, as compared to baseline TCE mass flux. To evaluate the primary objective, groundwater levels were monitored to evaluate hydraulic control, and samples were collected and analyzed for TCE over the course of the study.

Secondary objectives were addressed to help understand the processes that affect the downgradient migration of TCE in the aquifer, as well as to identify scale-up issues. These secondary objectives are as follows:

- Analyze the hydrologic effects of tree transpiration on the contaminated aquifer.
- Analyze contaminant uptake into plant organ systems.
- Evaluate TCE transformation kinetics in leaf samples of various mature trees in the local area.
- Evaluate microbial contributions to reductive dechlorination.
- Analyze tree transpiration rates to determine current and future water usage.
- Evaluate geochemical indices of subsurface oxidation-reduction processes.
- Determine tree growth rates and root biomass.
- Collect data to determine implementation and operation costs for the technology.

Groundwater monitoring for VOCs was continued through the sixth growing season (2001) to evaluate geochemical changes in the TCE plume. Biodegradation rates were correlated to the age of the tree plantations and associated increases in vegetative biomass by evaluating changes in redox conditions and accompanying changes in the in situ reductive dechlorination of TCE. Monitoring of groundwater redox conditions is ongoing.

PERFORMANCE DATA ASSESSMENT [1,2,5,7]

TCE Mass Flux and Hydraulic Control

As the trees in both plantations at the demonstration site began to use water from the aquifer, a measurable decrease was noted in the volumetric flux of contaminated groundwater leaving the demonstration site. The maximum reduction in the outflow of contaminated groundwater that could be attributed to the trees was approximately 12 percent of the volumetric flux rate. This 12 percent decrease was observed at the peak of the third growing season. At that time, the reduction in the mass flux of TCE across the downgradient end of the plantations was closer to 11 percent. Table 1 presents changes in volumetric and TCE mass flux through the first four growing seasons. During the first 3 years of the demonstration, the maximum water table fluctuation noted was a decrease by approximately 10 cm at the center of the demonstration site. During the fifth growing season (September 2000), the maximum observed drop in water level was about 29 cm, and the diameter of the water table depression for areas exceeding an 8-cm drop in water level was about 160 meters.

Table 1. Summary of results [2]

Event	Hydraulic Gradient Across Downgradient End of Planted Area[a]	Cross-Sectional Area Along Downgradient End of Planted Area[b] (m^2)	Volumetric Flux of Groundwater Across Downgradient End of Planted Area[c] (m^3/d)	Change in Volumetric Flux Across Downgradient End of Planted Area Attributed to Planted Trees (%)	Average TCE Concentration in Wells Along Downgradient End of Planted Area[d] (µg/L)	Mass Flux of TCE Across Downgradient End of Planted Area (g/d)	Change in Mass Flux of TCE Across Downgradient End of Planted Area Attributed to Planted Trees (%)
Baseline (1996)	0.0159	84	8.0	-	469	3.8	-
Peak[e] 2nd Season (1997)	0.0154	82	7.6	-5	535	4.1	8
Late[e] 2nd Season (1997)	0.0157	83	7.8	-2	-	-	-
Peak 3rd Season (1998)	0.0143	82	7.0	-12	483	3.4	-11
Late 3rd Season (1998)	0.0150	83	7.5	-6	473	3.5	-8
Peak 4th Season (1999)	0.0153	81	7.4	-8	-	-	-

Source: U.S. Environmental Protection Agency. 2003. Phytoremediation of Groundwater at Air Force Plant 4, Carswell, Texas [2].

Notes:

m^2	Square meter
m^3/d	Cubic meter per day
µg/L	Micrograms per liter
g/d	Grams per day
%	Percent
[a]	Gradient calculated between monitoring wells 522 and 529.
[b]	An aquifer width of 70 meters was used for the aquifer cross-sectional area calculations; aquifer thickness was the average of the saturated thickness in wells 526, 527, and 528 normalized to wells from the surrounding area to account for seasonal water table fluctuations unrelated to the planted trees.
[c]	A horizontal hydraulic conductivity of 6 meters per day was used for the volumetric flux calculations. This is the average of the hydraulic conductivity values determined for the study area.
[d]	TCE concentration is the average in wells 526, 527, and 528.
[e]	Peak growing season is end of June or beginning of July. Late growing season is end of September or beginning of October.

Trees are expected to achieve maximum hydraulic control once they are full grown. Because the phytoremediation system would not become fully mature during the demonstration period, MODFLOW, a groundwater model developed by the U.S. Geological Survey (USGS), was used to predict future hydraulic control. The model indicated that once the planted trees have achieved a closed canopy, the reduction in the volumetric flux of contaminated groundwater across the downgradient end of the site will likely be between 20 and 30 percent of the initial amount of water that flowed through the site. The actual amount of water that will be transpired from the aquifer by the trees will be between 50 and 90 percent of the volume of water that initially flowed through the site. The discrepancy between the volumetric outflow of groundwater and the volume of water transpired from the aquifer can be attributed to the predicted increase in groundwater inflow to the site and the release of water stored in the aquifer. No hydraulic control was observed as of the third dormant season (November 1998 to March 1999).

TCE Concentrations in Tree Samples

With respect to the fate of the contaminants taken up by the planted trees, TCE and its daughter products were detected in tissue samples of roots, stems, and leaves. Generally, the percentage of planted trees in which the compounds were detected increased over time. Stem tissue generally exhibited the greatest diversity and concentration of chlorinated compounds. The results also showed an increase over time in the percentage of trees containing chlorinated ethenes, as well as an increase in the average concentration. In October 1998, all five whip and five caliper trees sampled contained detectable levels of TCE in the stems, with an average concentration of 32.8 micrograms per kilogram (µg/kg) for whips and

24.6 µg/kg for caliper trees. Table 2 summarizes the average TCE and *cis*-1,2-dichloroethene (DCE) concentrations in whip and caliper tree samples collected during the first 3 years (1996 through 1998). Leaf and stem samples were collected from whips and caliper trees during each sampling event. Root samples were only collected during two events (October 1996 and June 1998). The table also summarizes average TCE and *cis*-1,2-DCE concentrations for leaf and stem samples taken from the mature cottonwood tree located proximal to the study area. Although the data indicate that the plantations are progressively translocating more contaminants from the subsurface over time, the fate of the contaminants within the plant tissues or volatilized to the air cannot be determined.

Table 2. Summary of tree sample results (µg/kg) [2]

Tree Type	Analyte	Plant Tissue	October 1996	July 1997	October 1997	June 1998	October 1998
Whips	TCE	Leaf	ND	ND	1.6 (2)	ND	ND
		Stem	26 (1)	ND	10.1 (3)	44 (1)	32.8 (5)
		Root	ND	NS	NS	140	NS
	cis-1,2-DCE	Leaf	ND	NS	ND	ND	ND
		Stem	ND	NS	1.9 (3)	14 (1)	13.5 (5)
		Root	ND	NS	NS	ND	NS
Calipers	TCE	Leaf	ND	ND	10.4 (3)	4.5 (2)	ND
		Stem	ND	ND	9.6 (3)	71 (1)	24.6 (5)
		Root	ND	NS	NS	13	NS
	cis-1,2-DCE	Leaf	ND	NS	ND	ND	ND
		Stem	ND	NS	1.6 (3)	15.7 (3)	8.9 (4)
		Root	ND	NS	NS	NS	NS
Mature cottonwood	TCE	Leaf	NS	ND	ND	ND	ND
		Stem	ND	ND	6.4	13	2.2
		Root	NS	NS	NS	NS	NS
	cis-1,2-DCE	Leaf	NS	NS	ND	ND	ND
		Stem	1.2	NS	10	ND	2.8
		Root	NS	NS	NS	NS	NS

Source: Adapted from U.S. Environmental Protection Agency. 2003. Phytoremediation of Groundwater at Air Force Plant 4, Carswell, Texas [2]

Notes:

Numbers in parentheses represent number of trees for which the analyte was detected.
Five whips and five caliper trees were sampled (except roots).
ND – Not detected
NS – Not sampled

TCE Transformation Kinetics

The kinetics of TCE transformation were evaluated using leaf samples collected from seven trees (cedar, hackberry, oak, willow, mesquite, cottonwood whip, and cottonwood caliper) growing at or near the demonstration site. Each of the plant species investigated appears to have properties effective in degrading TCE. Specifically, all leaf samples showed dehalogenase activity. Pseudo first-order rate constants were determined for the samples. The average and standard deviation for all seven rate constants is 0.049 ±0.02 per hour. This corresponds to a half life of about 14.1 hours. These kinetics are fast relative to other environmental transport and transformation processes except volatilization of TCE. Therefore, it is unlikely that degradation within the trees will be the rate-limiting step during phytoremediation. These data suggest that use of species native to a proposed site is sufficient, and genetically altered plants designed to enhance metabolism of TCE are not needed.

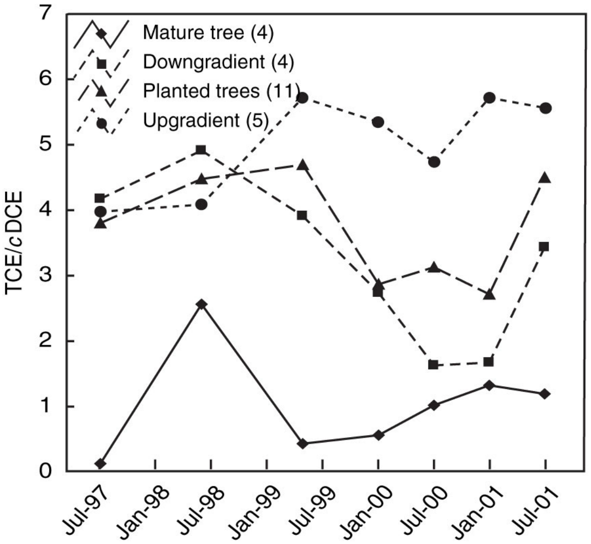
TCE Concentrations in Groundwater

With respect to biologically induced reductive dechlorination, there is evidence that the aquifer beneath the planted trees was beginning to support anaerobic microbial communities capable of TCE biodegradation within 3 years of planting. Specifically, microbial data from soil and groundwater samples indicate that the microbial community beneath the planted trees had begun to move toward an assemblage capable of supporting reductive dechlorination during the demonstration period. In addition, within 3 years of planting, dissolved oxygen (DO) concentrations decreased, and total iron concentrations increased at the southern end of the whip plantation where the water table is closest to land surface. Anaerobic conditions in the aquifer resulted in a reduced environment and some anaerobic bacteria reductive dechlorination processes. Based on 9 wells within the plantations, the ratio of TCE to *cis*-1,2-DCE also decreased within the first 3 years (December 1996 through September 1998), from 5.88:1 to 2.44:1, while the ratios upgradient and downgradient were 3.11:1 and 3.34:1, respectively, in September 1998. These ratios show subtle changes in the aquifer due to the transformation of TCE to *cis*-1,2-DCE. A decrease in this ratio suggests that biological anaerobic processes in the aquifer were beginning to biodegrade TCE beneath the plantations.

Data from the aquifer beneath a mature cottonwood tree near the plantations support the conclusion that reductive dechlorination can occur beneath cottonwood trees with established root systems. In September 1998, the ratio of TCE to *cis*-1,2-DCE beneath the mature tree (0.62:1) was one order of magnitude less than the ratio of TCE to *cis*-1,2-DCE elsewhere at the site during the demonstration period. The microbial population in the area of the mature cottonwood tree included a vibrant community that supported both hydrogen oxidizing and acetate fermenting methanogens. This active anaerobic population is believed to be responsible for the decrease in TCE concentration and the generation of daughter products beneath the mature cottonwood tree.

Average TCE concentrations decreased across the demonstration site from 532 µg/L (July 1997) to 182 µg/L (July 2001). Upgradient TCE concentrations also decreased, indicating the possibility that natural attenuation was occurring. To determine changes that were attributable to the tree plantations, the ratio of TCE to *cis*-1,2-DCE was evaluated. The average upgradient TCE to *cis*-1,2-DCE ratio since 1997 was greater than 4. The ratio for groundwater within the plantations and downgradient generally decreased. However, from January through July 2001, it increased from 2.7 to 4.5 (see following discussion on fluctuations in water table level and its effect on contaminant concentrations). Figure 3 shows the trend in the TCE to *cis*-1,2-DCE ratio between July 1997 and July 2001.

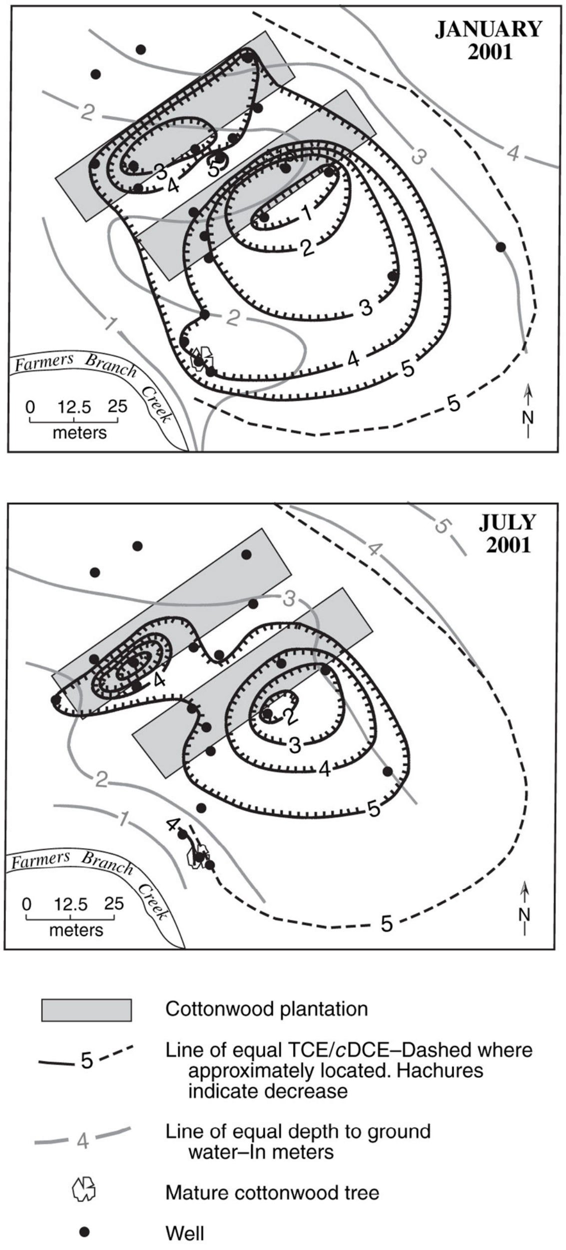
Figure 3. Average TCE to cis-1,2-DCE ratios in the alluvial aquifer (July 1997 to July 2001) [5]



Source: Reproduced from Eberts, S. M., et al. 2005. Long-Term Changes in Ground Water Chemistry at a Phytoremediation Demonstration Site. Groundwater [5].
Note: Numbers in parentheses are the number of wells used to compute the averages

Figure 4 shows the relationship between TCE and *cis*-1,2-DCE ratios and depth to groundwater. By the end of the fifth growing season (2000), the water table at wells with the lowest ratios was less than 3 meters below ground surface (bgs). These wells also had the highest dissolved organic carbon (DOC) concentrations (1.6 to 1.8 milligrams per liter [mg/L]) and lowest DO concentrations (0.93 to 1.7 mg/L). From January to July 2001, the water table was lower by 0.5 meter. This was the greatest drop in water level between two sampling events. During that period, the TCE to *cis*-1,2-DCE ratio increased from 2.7 to 4.5 likely because the deeper groundwater flow path was not in contact with the microbially active root zone. Additionally, the increase in TCE to *cis*-1,2-DCE ratio may have been due to the rapid change in groundwater level that left the microbial population stressed.

Figure 4. TCE to cis-1,2-DCE ratios in the alluvial aquifer and depth to ground water, January and July 2001 [5]



Source: Reproduced from Eberts, S. M., et al. 2005. Long-Term Changes in Ground Water Chemistry at a Phytoremediation Demonstration Site. Groundwater [5].

Also in July 2001 (sixth growing season), systematic flowpath changes were observed in the groundwater for the first time. Based on this observation, the BIOCHLOR model was used to estimate biodegradation rates attributable to the trees. Estimated biodegradation rate constants for sequential reductive dechlorination of TCE, *cis*-1,2-DCE, and vinyl chloride were 0.02/day, 0.04/day, and 0.82/day, respectively. These rates represent a notable increase when compared to baseline conditions in 1996 (0.0002/day for TCE, 0.0001/day for *cis*-1,2-DCE, and 0.0005/day for vinyl chloride), which suggests that reductive dechlorination continued to occur despite the temporary increase in the TCE to *cis*-1,2-DCE ratio between January and July 2001.

Transpiration Rates

A transpiration study was conducted at the site in 1997 (second growing season), and the average total daily transpiration rates were determined. The rates for whips ranged from 9.1 liters per tree per day in June to 1.6 liters per tree per day in October. For the caliper trees, total daily transpiration rates ranged from 14.7 liters per tree per day in July to 0.91 liters per tree per day in October. The total average daily transpiration rate was estimated at 1,872 liters per day for the caliper-tree plantation and 1,750 liters per day for the whip plantation. After five years, caliper trees transpired nearly four times the water (79 liters per tree per day) as the whip trees (19 liters per tree per day).

Groundwater Chemistry Parameters

Groundwater chemistry parameters, such as DO, nitrate, ferrous iron, alkalinity, and sulfide, were also measured to monitor changes in the redox conditions of the aquifer. Table 3 shows the average concentrations of selected water constituents and alkalinity at different areas of the site as of July 2001 (sixth growing season). Figure 5 shows the average DO concentrations over time. Decreases in DO and nitrate concentrations, along with increases in ferrous iron and alkalinity, indicate that reducing conditions were present in the subsurface. Sulfide concentrations were below detection limits or very low across most of the site until January 2000. Since that time, sulfide concentrations have ranged from 0.01 to 0.55 mg/L; however, no site-wide trend has been observed for sulfide.

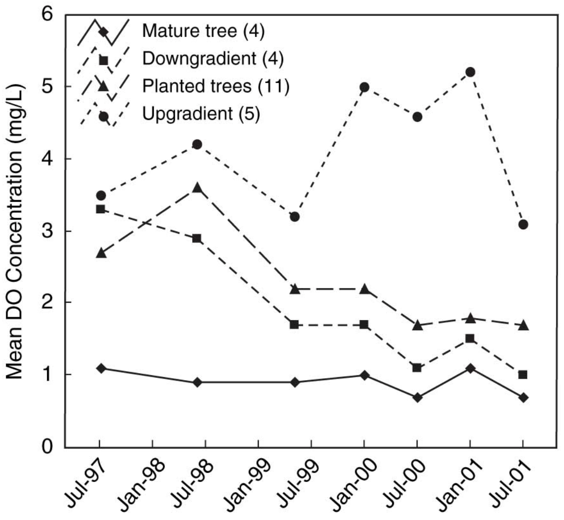
Table 3. Average concentrations of chemical parameters (as of July 2001) [5]

	Dissolved oxygen (mg/L)	Nitrate (mg/L)	Ferrous iron (mg/L)	Alkalinity (mg/L as bicarbonate)
Immediately upgradient of plantations	3.06	3.23	0.05	322
Beneath plantations	1.69	2.10	0.08	377
Downgradient of plantations	1.01	1.22	0.7	386
Beneath mature cottonwood tree	0.69	0.66	0.5	378

Source: Eberts, S. M., et al. 2005. Long-Term Changes in Ground Water Chemistry at a Phytoremediation Demonstration Site. Groundwater [5].

mg/L milligrams per liter

Figure 5. Average dissolved oxygen (DO) concentrations in the alluvial aquifer (July 1997 to July 2001) [5]



Source: Reproduced from Eberts, S. M., et al. 2005. Long-Term Changes in Ground Water Chemistry at a Phytoremediation Demonstration Site [5].
mg/L milligrams per liter

Note: Numbers in parentheses are the number of wells used to compute the averages.

Preliminary field data collected during the fifth dormant season (January 2001) indicate that the trees were having an effect on the geochemistry of the ground water year round. During this season, DO concentrations were above 4.5 mg/L in water from all upgradient wells and at one well between the tree plantations (well 522). At all other on-site wells, including wells located more than 50 meters downgradient of the plantations, DO levels were below 3.5 mg/L. The average DO concentration in water from all wells, excluding the upgradient wells and well 522, was 1.76 mg/L. The DO concentration in several wells located within the plantations was less than 1 mg/L. In addition, field data indicated that ferrous iron and sulfide concentrations were elevated at several locations within and immediately downgradient of the tree plantations. These data add to the evidence that the planted trees at the demonstration site can stimulate microbial activity resulting in the depletion of DO in the aquifer and the creation of local anaerobic conditions conducive to microbial reductive dechlorination.

Tree Parameters

A number of tree parameters were studied during the demonstration. In September 1997 (second growing season), root biomass and extent were examined in the whip and caliper-tree plantations. Four trees from each plantation were evaluated for fine root biomass and length and for coarse root biomass. Coarse root mass was significantly greater in the caliper trees, with root diameters in the range of 3 to 10 millimeters (mm), compared to the whips (458 grams per tree in the caliper trees and 240 grams per tree in the whips). Although the coarse root mass in roots with diameters greater than 10 mm also was greater in the caliper trees than the whips, the difference was not statistically significant. In addition, differences in the fine root biomass between the plantations were not statistically significant. Fine root length density in the upper 30 cm of soil was statistically greater in the caliper trees.

Also in the second growing season (September 1997), the roots of both the whips and caliper trees had reached the water table (275 cm for the whips and 225 cm for the caliper trees), and the depth distribution of the roots was comparable. Using the more expensive caliper trees did not appear to impart any substantial benefit with regard to root depth and biomass.

Tree-growth and root-growth data collected from the demonstration site are consistent with observations regarding hydraulic influence of the trees over the contaminated aquifer. Tree height, trunk diameter, and canopy diameter were measured for 52 whips and 51 caliper trees throughout the first three years (December 1996; May, July, and October 1997; and June and September 1998). Overall, trees in both plantations grew well and significantly increased in all physical parameters measured. Table 4 presents results of tree height and trunk diameter monitoring for the measurements taken in December 1996 and September 1998.

Table 4. Tree height and trunk diameter measurements [2]

	Whips		Caliper Trees	
Parameter	**December 1996**	**September 1998**	**December 1996**	**September 1998**
Tree height (meters)	2.27	5.52	3.77	6.64
Trunk diameter (centimeters)	1.41	5.31	3.83	8.12

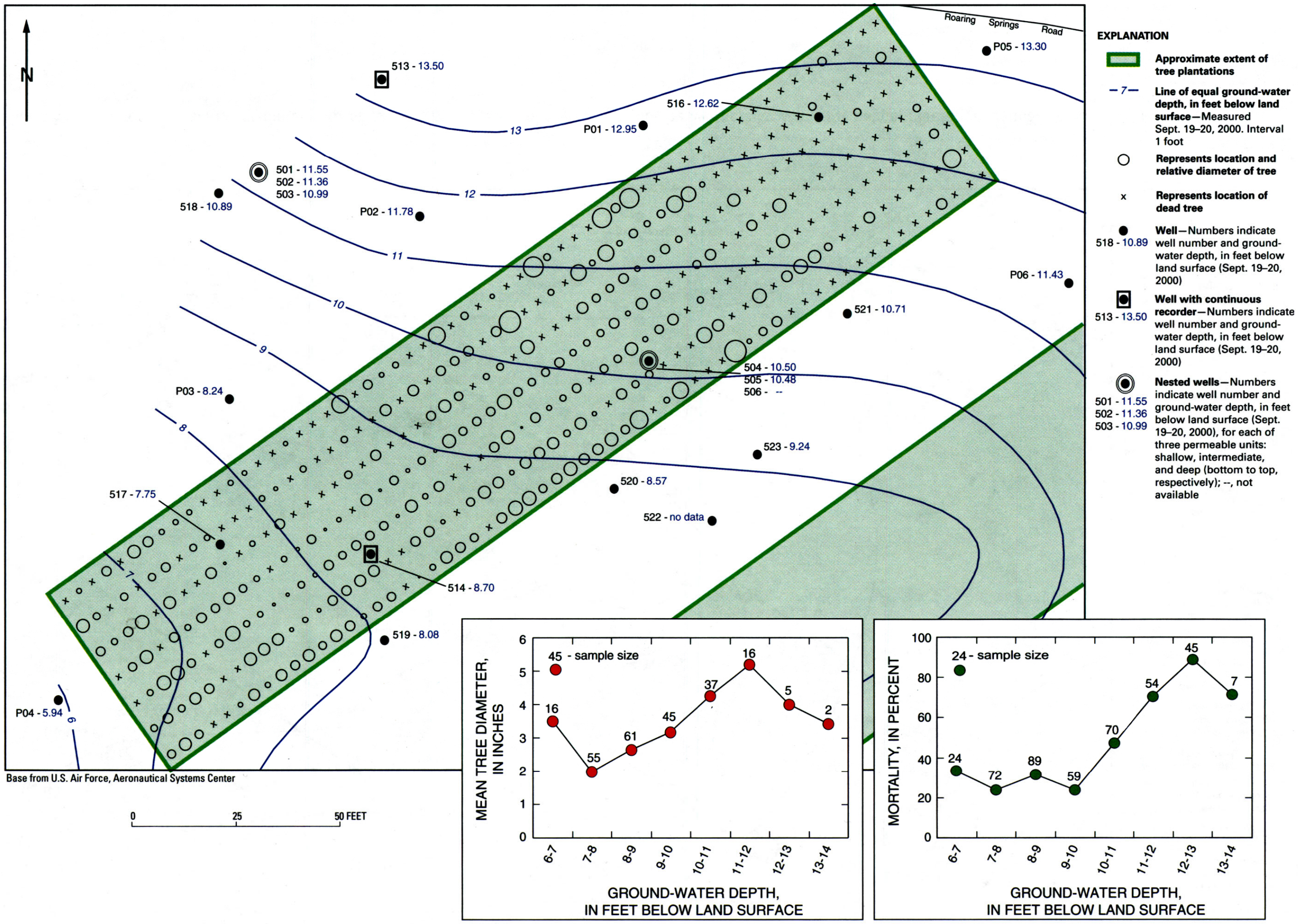
Source: U.S. Environmental Protection Agency. 2003. Phytoremediation of Groundwater at Air Force Plant 4, Carswell, Texas [2].

The average canopy diameter for the whips was 2.32 meters at the end of the third growing season (September 1998). These trees had been planted approximately 1.25 meters apart and were starting to approach canopy closure. A plantation approaches its maximum transpiration potential once it achieves a closed canopy because a closed canopy limits leaf area. This observation indicates that the trees were transpiring a significant amount of water at that time.

The average canopy diameter for caliper trees was 2.52 meters at the end of the third growing season (September 1998). The caliper trees were planted 2.5 meters apart and although the plantation was not as close to achieving a closed canopy, individual caliper trees transpired just over twice the water that individual whips transpired. As a result, the volume of water that was transpired by trees in the two plantations was similar because there were only half as many caliper trees as whips.

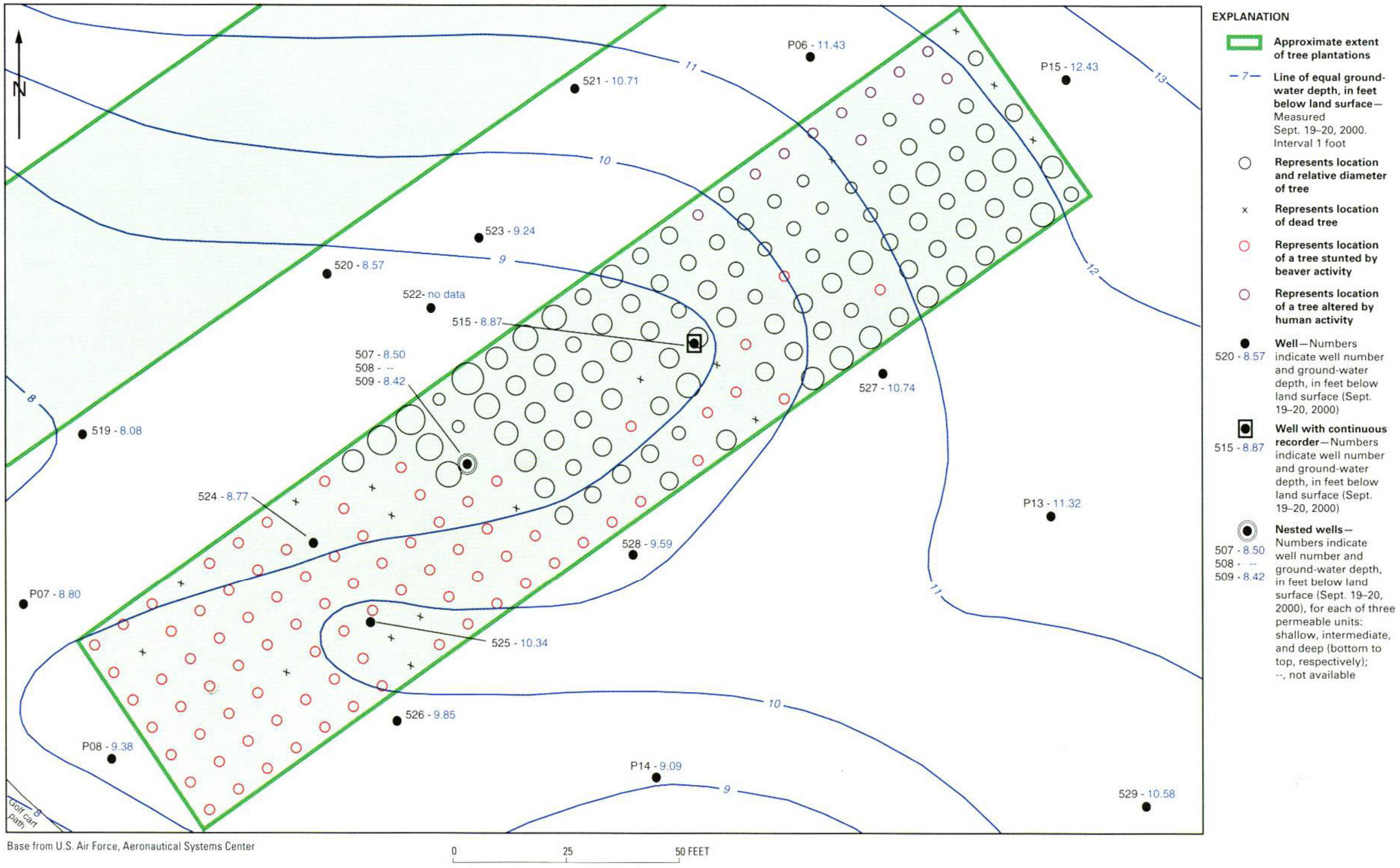
By January 2003 (seventh dormant season), some trees in both plantations had died, been stunted by beaver activity, or been altered by human activity. The groundwater level also affected the growth of trees. Tree mortality rates were relatively constant, near 25 percent where groundwater levels were less than 3 meters (10 feet) bgs but approaching 90 percent where groundwater levels were between 3.5 and 4 meters (12 and 13 feet) bgs. Figures 6 and 7 show groundwater levels, as well as the location and relative diameter of existing trees for both the whip and caliper plantations, respectively. The whips had both a higher mortality rate and a smaller relative diameter than the caliper trees.

Figure 6. Location and relative diameter of existing trees within the whip plantation (January 2003), and relations between average tree diameter and groundwater depth and between mortality and groundwater depth (September 2000) [7]



Source: Reproduced from U.S. Geological Survey. Water-Level Variations and Their Effects on Tree Growth and Mortality and on the Biogeochemical System at the Phytoremediation Demonstration Site in Fort Worth, Texas, 1996-2003 [7].

Figure 7. Location and relative diameter of existing trees within the caliper plantation, and locations of trees stunted by beaver activity (January 2003) [7]



Source: Reproduced from U.S. Geological Survey. Water-Level Variations and Their Effects on Tree Growth and Mortality and on the Biogeochemical System at the Phytoremediation Demonstration Site in Fort Worth, Texas, 1996-2003 [7].

COST INFORMATION [1,2,3,4]

Preparatory Work
Site Characterization: $12,000
Site Design: $10,000
Site Work
Monitoring (research level) well installation: $90,000
Development of Plantations – 4,000 square meters (includes landscaping costs): $41,000
Weather Station: $3,100
Survey: $25,000
Purchase of Trees
Whips ($0.20 each): $100
Calipers ($18 each): $2,000
Installation of Irrigation System: $10,000
Total Capital Cost: $193,200

Annual O&M
Landscaping: $2,000
Groundwater, soil, vegetation, transpiration, climate, soil moisture, and water-level monitoring (research level): $250,000
Total Annual O&M: $252,000

After Treatment Cost: None

The planting costs at NAS-JRB Fort Worth are significantly less than proprietary planting techniques employed by the vendors that involve auguring down to the capillary fringe and other engineered methods for individual tree planting. Based on the costs incurred at the demonstration site, a cost estimate was developed for an 18,600 square meter phytoremediation project. The estimated full-scale cost for this application is approximately $466,000, with a unit cost of $25 per square meter. Table 5 provides a breakdown of the full-scale estimate. Additional information about costs associated with planting and maintaining tree plantations is included in BIOCOST, a cost-estimating program available from Oak Ridge National Laboratory.

Table 5. Estimated full-scale cost for an 18,600 square meter hypothetical phytoremediation research model [2]

Category	Costs
Site preparation	$42,650
Permitting and regulatory requirements	$55,000
Capital equipment	$37,833
Startup and fixed costs	$3,783
Consumables and supplies	$19,480
Labor	$108,000
Utilities	$12,900
Effluent treatment and disposal	$0
Residual and waste shipping and handling	$7,500
Analytical services	$172,855
Maintenance and modifications	$5,000
Demobilization	$1,050
Estimated total cost for model site	**$466,051**

Source: Adapted from U.S. Environmental Protection Agency. Phytoremediation of Groundwater at Air Force Plant 4, Carswell, Texas [2].

OBSERVATIONS AND LESSONS LEARNED [2,4,5,8]

- During the first 3 years of the demonstration, the maximum observed reduction in the mass flux of TCE across the downgradient end of the demonstration site was 11 percent. This maximum occurred at the peak of the third growing season.

- When designing for hydraulic control during phytoremediation, it is important to keep the remediation goals in mind. In other words, it may not be desirable to achieve full hydraulic control at a site if full control would adversely affect the groundwater-surface water system downgradient of the site. At this site, the receptor is Farmers Branch Creek, which has a flow of less than 3 cubic centimeters per second (cm^3/sec) during the summer months (period of peak transpiration). At such a site, it may be desirable to prevent the contaminant plume from discharging into the creek without drying up the creek, particularly since hydraulic control is only one mechanism that contributes to the cleanup of a groundwater plume by phytoremediation. The use of an applicable groundwater flow model is recommended to predict flow movement at similar phytoremediation sites.

- TCE and its daughter products were detected in tissue samples of roots, stems, and leaves. In October 1998 (third growing season), all five whip and five caliper trees sampled contained detectable levels of TCE in the stems, with an average concentration of 32.8 µg/kg for whips and 24.6 µg/kg for the caliper trees.

- With respect to biologically induced reductive dechlorination, there is evidence that the aquifer beneath the planted trees was supporting anaerobic microbial populations capable of biodegrading TCE within 3 years of planting. Microbial data from soil and groundwater samples indicate that the microbial populations beneath the planted trees are capable of supporting reductive dechlorination.

- Average concentrations of TCE decreased across the demonstration site, from 532 µg/L in July 1997 to 182 µg/L in July 2001. To determine changes that were attributable to the tree plantations, the ratio of TCE to cis-1,2-DCE was evaluated; the ratio of the constituents in groundwater within the plantations and downgradient generally decreased until January 2001.

- Preliminary field data collected during the fifth dormant season (January 2001) indicate that the trees were beginning to have an effect on the geochemistry of the groundwater, with DO concentrations above 4.5 mg/L in groundwater from all upgradient wells and one well between the tree plantations (well 522). All other wells at the demonstration site, including wells more than 50 meters downgradient of the plantations, had DO levels below 3.5 mg/L. The average DO concentration in water from all wells, excluding the upgradient wells and well 522, was 1.76 mg/L. The DO concentration in several wells beneath the plantations was less than 1 mg/L.

Additional observations and lessons learned were noted in the ESTCP report:

- Trees can serve as a sustainable source of electron donors, supplying DOC to the underlying aquifer over the long term and thereby supporting in situ processes related to TCE degradation. Trees planted in areas where the depth to groundwater was less than 3 meters were able to deliver enough DOC to the aquifer to (1) lower DO concentrations, (2) create iron-reducing conditions along the plume centerline, (3) create sulfate-reducing or methanogenic conditions in localized areas, and (4) initiate in situ reductive dechlorination of TCE.

- After 6 growing seasons, in situ biodegradation was becoming the dominant process contributing to the reduction in the mass flux of TCE across the site, whereas transpiration directly from the aquifer was the dominant process during the first 3 years of the study.

- The presence of TCE and cis-1,2-DCE in tree cores can be indicators of subsurface contamination. Data imply that for each tree species, higher TCE concentrations in groundwater can produce higher TCE concentrations in tree cores. The comparison of tree cores to same-tree branches (for samples collected in 2001-2002) indicate that TCE concentrations in tree cores were often higher than concentrations found in the small branches.

REFERENCES

1. Eberts, S. M., et al. 2003. Multiple-Process Assessment for a Chlorinated Solvent Plume. Phytoremediation: Transformation and Control of Contaminants. Pages 589-633. September.

2. U.S. Environmental Protection Agency (EPA). 2003. Phytoremediation of Groundwater at Air Force Plant 4, Carswell, Texas. EPA/540/R-03/506. September.

3. North Atlantic Treaty Organization. 2002. Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater (Phase III), 2001 Annual Report. Number 250. EPA/542/R-02/001. January.

4. EPA. 2003. Phyto Demonstration Enters 7th Year at Carswell Naval Air Station. Technology News and Trends. September. http://www.cluin.org

5. Eberts, S. M., et al. 2005. Long-Term Changes in Ground Water Chemistry at a Phytoremediation Demonstration Site. Groundwater. Volume 43, No. 2. Pages 178-186. March-April.

6. U.S. Geological Survey (USGS). 2004. Demonstration-Site Development and Phytoremediation Processes Associated with Trichloroethene (TCE) in Ground Water, Naval Air Station-Joint Reserve Base Carswell Field, Fort Worth, Texas. USGS Fact Sheet 2004-3087. August.

7. USGS. 2004. Water-Level Variations and Their Effects on Tree Growth and Mortality and on the Biogeochemical System at the Phytoremediation Demonstration Site in Fort Worth, Texas, 1996-2003. Scientific Investigations Report 2004-5107.

8. Environmental Security Technology Certification Program. 2005. Air Force Plant 4 Carswell NAS Phytoremediation Cost and Performance Report. Draft.

9. Oak Ridge National Laboratory. 2005. BIOCOST: A tool to estimate energy crops costs on a PC. Accessed on October 7. Online Address: http://bioenergy.ornl.gov/papers/misc/biocost.html

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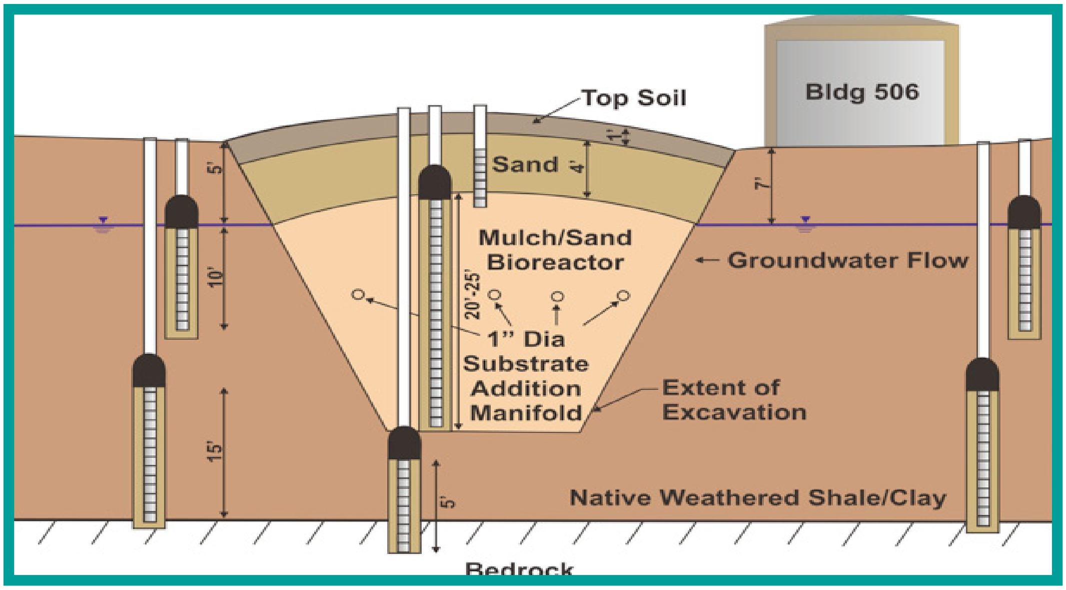
ESTCP
Cost and Performance Report

(ER-0019)



Impact of Landfill Closure Designs on Long-Term Natural Attenuation of Chlorinated Hydrocarbons

October 2008

ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

COST & PERFORMANCE REPORT

Project: ER-0019

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ACRONYMS AND ABBREVIATIONS

μg/L	micrograms per liter
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
bgs	below ground surface
CAH	chlorinated aliphatic hydrocarbon
CMS	Corrective Measures Study
DCE	dichloroethene
DNAPL	dense nonaqueous phase liquid
DO	dissolved oxygen
DOC	dissolved organic carbon
DoD	Department of Defense
DW	deeper well
ESTCP	Environmental Security Technology Certification Program
ET	evapotranspiration
ft/day	feet per day
ft/ft	foot per foot
ft/yr	feet per year
gpm	gallon(s) per minute
ID	inside diameter
LF-03	Landfill 3
LTM	long-term monitoring
mg/L	milligrams per liter
MNA	monitored natural attenuation
MSW	municipal solid waste
O&M	operation and maintenance
OM&M	operation, maintenance, and monitoring
ORP	oxidation-reduction potential
OU	operable unit
Parsons	Parsons Corporation
Parsons ES	Parsons Engineering Science
PCE	tetrachloroethene
PLFA	phospholipid fatty acids
PPE	personal protective equipment
PVC	polyvinyl chloride

ACRONYMS AND ABBREVIATIONS (continued)

QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
SW	shallow well
TCA	tetrachloroethane
TCE	trichloroethene
USEPA	U.S. Environmental Protection Agency
VC	vinyl chloride
VFA	volatile fatty acid
VOC	volatile organic compound
VMP	vapor monitoring point

ACKNOWLEDGEMENTS

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Technical material contained in this report has been approved for public release.

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1.0 EXECUTIVE SUMMARY

1.1 BACKGROUND

The subject of this cost and performance report is a pilot-scale field demonstration of a recirculation bioreactor at Landfill 3 (LF-03), Altus Air Force Base (AFB), Oklahoma. The purpose of constructing and operating the bioreactor was to demonstrate that a combination of organic material addition and accelerated leaching can rapidly reduce source area concentrations of chlorinated aliphatic hydrocarbons (CAH) in groundwater at unlined, closed landfills. Hundreds of landfills on Department of Defense (DoD) installations have generated CAH plumes in groundwater. Surface covers, which are intended to provide a barrier to prevent direct contact with waste material and minimize or eliminate infiltration of precipitation through the waste material (i.e., leachate formation), are the current method of choice to manage human and ecological risks at these sites (Bagchi, 1990). In some cases, impermeable covers may impede natural attenuation processes by reducing the quantity of organic-rich leachate that promotes the bioremediation of CAHs. The results of this project will provide environmental engineers with an additional perspective on treatment of dissolved volatile organic compound (VOC) plumes originating at unlined landfills (and at non-landfill source areas).

1.2 OBJECTIVES OF THE DEMONSTRATION

The bioreactor demonstration at Altus AFB had three primary objectives:

1. To demonstrate construction techniques and the instrumentation of two types of bioreactor cells that can be used for unlined and closed landfills:

    a. An active bioreactor that collects shallow groundwater and recirculates the groundwater through organic mulch to accelerate organic-rich leachate production and CAH biodegradation (Recirculation Bioreactor)

    b. A passive bioreactor that relies on natural groundwater flow and infiltration moving through an organic mulch layer to produce an organic-rich leachate (Passive Bioreactor).

2. To demonstrate that the bioreactor cells have a positive impact on the reductive dechlorination of CAH compounds as evidenced by trichloroethene (TCE) and dichloroethene (DCE) degradation without significant production or migration of vinyl chloride (VC). Leachate geochemistry and groundwater concentrations of CAHs were to be monitored beneath and immediately downgradient of each bioreactor to evaluate progress in achieving this objective.

3. To evaluate the longevity, potential costs, and benefits of landfill bioreactors for potential full-scale applications at Altus AFB and other DoD facilities.

1.3 DEMONSTRATON RESULTS

The primary regulatory driver for investigation and cleanup of hazardous waste at Altus AFB is Resource Conservation and Recovery Act (RCRA), Section 3008 (h). USEPA, Region 6, is the primary regulatory agency for the Base. LF-03, also referred to as Solid Waste Management Unit 7, was included in the base-wide RCRA Facility Investigation, Investigation Analysis, and Corrective Measures Study (CMS) (Earth Tech, 2002). The CMS recommended anaerobic bioremediation as the groundwater remediation alternative for the site. These regulatory considerations contributed to elimination of the passive bioremediation cell scenario as part of the final comparative bioreactor design, differing from the earlier bioreactor demonstration design discussed in the September 2003 Final Demonstration Work Plan.

The bioreactor was constructed by excavating a 30-ft by 30-ft by 11-ft-deep portion of the landfill near the suspected TCE source area and backfilling the excavation with a mixture of organic material and sand. A groundwater extraction trench was excavated into the shallow aquifer downgradient of the reactor cell and backfilled with gravel. Groundwater from the trench was extracted and distributed within the bioreactor cell using a drip irrigation system. Groundwater monitoring wells were installed within the bioreactor cell and in the aquifer adjacent to and beneath the test cell for monitoring concentrations of CAHs and geochemical/microbial indicator parameters. Five performance monitoring events were completed during the approximately 24-month pilot test.

During the five performance monitoring events, the bioreactor removal efficiencies for TCE and total chlorinated ethenes (sum of TCE, DCE, and VC) from recirculated groundwater ranged from 97 to 100% and 76 to 96%, respectively. A source of residual TCE in the subsurface upgradient of the bioreactor and above-average precipitation during a portion of the pilot test caused an influx of dissolved TCE, and an accumulation of TCE biodegradation daughter products (DCE and VC) in the monitored area adjacent to and beneath the bioreactor. Dissolved organic carbon (DOC) concentrations were elevated above the 20-milligram per liter (mg/L) threshold that is conducive for reductive dechlorination for approximately 6 months to a year in the deeper wells beneath the bioreactor, and for almost the entire 2-year duration of the pilot test in the shallow wells adjacent to the test cell. The presence of high sulfate concentrations in groundwater at LF-03 likely reduced the effectiveness of the bioreactor but did not prevent reductive dechlorination from occurring. Because of a continuing TCE source upgradient of the bioreactor and the accumulation of daughter products in the aquifer beneath and adjacent to the bioreactor, the objective of reducing CAH concentrations by 90% was not achieved.

1.4 IMPLEMENTATION ISSUES

Implementation of this technology requires excavation of vadose zone fill or waste, backfilling with a mulch/sand mixture, and installation of an infiltration gallery. In a full-scale implementation of this technology, it is likely that an area larger than the 900 sq ft tested in the pilot study would be excavated, and that a significant percentage of the soil/waste would require off-site disposal. In addition, if a vadose zone source area is removed, it is possible that a portion of the spoils would require disposal in a RCRA Subtitle C facility. Each of these conditions would affect the overall cost of the bioreactor technology. A cost analysis was performed to assess the impact of bioreactor size and off-site disposal requirements on the total net present value. The total net present value increases substantially with bioreactor size. For the small bioreactors evaluated (30 ft x 30 ft), the primary cost component was operation, maintenance, and monitoring (OM&M). For larger bioreactors, the capital costs contributed the most to the total net present value. In addition, the periodic cost of substrate replenishment represented a substantial portion of the total net present value. The greatest contributors to the capital cost were off-site disposal (transport and tipping fee) and bioreactor backfilling. If it is possible for the excavated soil to remain on site, then the capital costs would be substantially lower. However, it is expected that a technology which installs a bioreactor in a former source zone would result in off-site disposal of a significant percentage of the excavated material.

The cost analysis indicates that the mulch bioreactor technology has the potential for high costs to be incurred, depending on the size of the source area and the type of waste encountered. While this approach may be appropriate for well-defined, small, isolated source areas marked by shallow groundwater, it may not be the optimum approach for large landfills with multiple source areas.

Following completion of this demonstration project, Altus AFB has continued to operate the recirculation bioreactor and subsequently funded a project to add liquid carbon substrate and a bioaugmentation culture to the recirculation system. The goal of the follow-on project is to refresh the organic carbon supply and to determine if more complete and effective reductive dechlorination can be achieved.

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2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

Field and laboratory research over the past 10 years has discovered an important link between the rapidity and completeness of chlorinated aliphatic hydrocarbon (CAH) biodegradation and the quantity of dissolved organic carbon (DOC) that is comingled with CAH plumes (Wiedemeier et al., 1999). CAH plumes that are comingled with fuel spills and landfill-derived organics are much more likely to undergo biodegradation via the process of anaerobic reductive dechlorination. However, most military landfills containing CAH contaminants are over 30 years old and contain limited amounts of leachable organic material to continue the reductive dechlorination process.

The recirculation bioreactor installed for this project is an application of enhanced anaerobic bioremediation, which seeks to exploit anaerobic biodegradation processes to completely degrade contaminants to innocuous end products (Parsons, 2004). The bioreactor provides a source of leachable organic material for the CAH-contaminated aquifer, which is used by native microorganisms to create a highly reducing anaerobic treatment zone. It was intended that the leaching of organic carbon and bioremediation would be accelerated by the recirculation of groundwater through the bioreactor.

The carbon substrate used in the Landfill 3 (LF-03) bioreactor is primarily cellulose from a mixture of wood mulch and cotton gin trash. Sand was added to the mixture to improve hydraulic conductivity and reduce compaction in the test cell. Compared with soluble liquid carbon substrates (e.g., fructose, lactate, and molasses), solid carbon substrates, such as cellulose, are intended to be relatively long-lasting, slow-release sources of organic carbon.

The recirculation bioreactor at LF-03 was designed to promote direct anaerobic dechlorination of CAHs; however, it is likely that abiotic processes are also occurring. Biotic reductive dechlorination is the sequential removal of chlorine atoms and is the only common biological reaction known to degrade tetrachloroethene (PCE), TCE, tetrachloroethane (PCA), trichloroethane (TCA), carbon tetrachloride, and chlorinated benzenes with more than four chlorine atoms. Each chlorine atom that is removed in this process is replaced with a hydrogen atom. For example, chlorinated ethene reductive dechlorination proceeds sequentially from PCE (C_2Cl_4) to TCE (C_2HCl_3) to DCE ($C_2H_2Cl_2$) to VC (C_2H_3Cl) to ethene (C_2H_4).

2.2 PROCESS DESCRIPTION

Cross-sectional and plan views of the LF-03 recirculation bioreactor installed at Altus Air Force Base (AFB), LF-03, are shown on Figure 1. The recirculation bioreactor system is designed to extract approximately 2 to 3 gallons per minute (gpm) of water from the trench and distribute the water through a drip irrigation system equipped with approximately 120 drippers near the top of the bioreactor. Distributing the water through the mulch cell provides treatment of CAHs by anaerobic biodegradation processes within the bioreactor cell and increases the organic carbon concentration of water exiting the bioreactor to support enhanced bioremediation of CAHs in the aquifer.

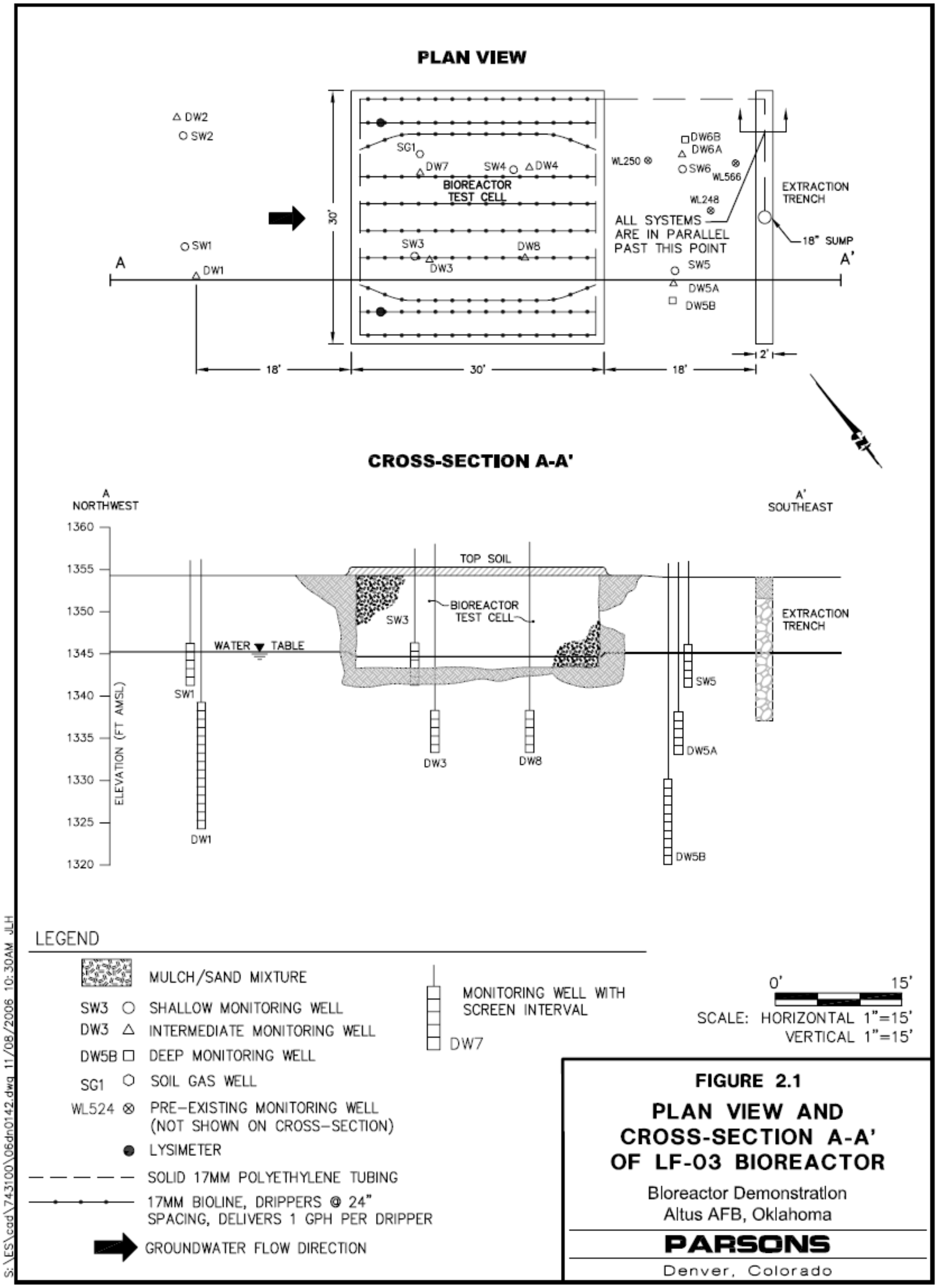

Figure 1. Plan View and Cross Section A-A' of LF-03 Bioreactore.

2.3 PREVIOUS TESTING OF THE TECHNOLOGY

Although the authors believe that the Altus AFB pilot bioreactor application that is the subject of this report is unique, the bioreactor concept is not new. “Bioreactor” is a generic term for a system that degrades contaminants using microorganisms. Bioreactors have been used in a wide variety of configurations to treat a variety of contaminants in multiple types of waste streams. Parsons (2006) provides a literature review that includes a summary of the bioreactor concept used 1) in municipal solid waste (MSW) landfills to accelerate the decomposition of waste and landfill gas generation; 2) for odor control from industrial, agricultural, and municipal sources of air emissions; 3) to biodegrade toxic compounds in liquid and vapor effluent streams from municipal and industrial processes and groundwater remediation systems; and 4) to treat CAH-contaminated groundwater in a passive, in situ biowall configuration.

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The application of a recirculation bioreactor for CAH source treatment as demonstrated at Altus AFB, LF-03, has several advantages over other remediation options and limitations that should be evaluated against the strengths of other applicable remediation technologies when choosing alternatives. These advantages and limitations are described below.

2.4.1 Advantages of the Technology

Recirculation bioreactors for CAH source treatment have several advantages over other remediation options, including:

- Excavation of contaminant source material during bioreactor construction can remove the majority of the contaminant mass present at the site if the location of the source material has been sufficiently defined.

- Groundwater is treated in situ by destructive processes rather than by a mechanical process such as air stripping that simply transfers contaminants to another medium.

- Recirculation allows enhanced dissolution of residual contaminant sources and increases the distribution of DOC. This is a significant benefit for heterogeneous, anisotropic subsurface environments such as the low permeability, fractured clay and shale present at LF-03.

- Delivery of organic carbon vertically through the bioreactor cell is more effective than through individual injection points in a fracture-flow environment because there is a higher likelihood of the organic substrate following the same migration pathways as the chlorinated solvents in a top-loaded system.

- The recirculation bioreactor provides both a water treatment system within the cell and an effective method for delivering organic carbon to the saturated zone.

The use of mulch as the carbon source utilizes locally available organic materials that are readily available and low cost.

- The bioreactor design demonstrated at Altus AFB, LF-03, had minimal operation and maintenance (O&M) requirements.

2.4.2 Limitations of the Technology

- The generation of relatively toxic daughter products, particularly VC, and the production of methane may be undesirable at some sites.

- The technology is best suited for sites with relatively shallow water tables where it is economical to excavate the source material in the vadose zone. However, it is feasible that this approach could also be successfully implemented at some sites with deeper water tables by allowing organic carbon-laden water to percolate through the vadose zone to the water table below the bottom of the bioreactor. This approach assumes that the organic carbon supply is not depleted (i.e., biodegraded) in the vadose zone prior to reaching the water table.

- The soluble organic carbon content in the mulch will decline over time and may need to be recharged (e.g., with a liquid organic substrate such as vegetable oil).

- The technology may not be well-suited for thick, sandy aquifers that require the removal of large volumes of water to control the contaminant plume and form a closed-loop system.

- When working in a landfill environment, there is an inherent possibility of encountering additional, previously unidentified contaminant source zones and hazardous materials. In such cases, increased contingency costs are to be expected.

- Conditions become less favorable for reductive dechlorination with increased distance vertically and laterally from the bioreactor cell. Site-specific conditions at LF-03 such as the high sulfate concentrations and shallow depth of the extraction trench likely contributed to this limitation. Other sites with more favorable geochemical conditions may have better performance at greater depths, but in general the technology demonstrated at LF-03 is better suited for sites where the desired remediation zone does not extend more than approximately 10 to 20 ft below the base of the bioreactor. An alternative technology such as organic substrate injection via vertical wells or temporary injection points may be better suited to remediate deeper zones.

3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

Groundwater analytical data for the bioreactor test cell were evaluated to determine the overall effectiveness of the bioreactor in reducing dissolved chlorinated ethene concentrations. Performance objectives for the bioreactor are described in Table 1. The bioreactor was a means for adding carbon substrate to the shallow groundwater at LF-03 and produced the reducing conditions that are necessary for reductive dechlorination to occur. The presence of high sulfate concentrations in groundwater at LF-03 likely reduced the effectiveness of the bioreactor but did not prevent reductive dechlorination from occurring. Because of a continuing TCE source upgradient of the bioreactor and the accumulation of daughter products in the aquifer beneath and adjacent to the bioreactor, the objective of reducing CAH concentrations by 90% was not achieved. The accumulation of DCE and VC in the shallow aquifer may likely be due to kinetic disparity where the intermediate dechlorination product is being generated faster than it is degraded, and not to an absence of appropriate dechlorinating microorganisms (Parsons, 2004).

Table 1. Performance Objectives, Bioreactor Demonstration, Altus AFB, Oklahoma.

Type of Performance Objective	Primary Performance Criteria	Expected Performance (Metric)
Quantitative	*Geochemical and Microbial Enhancement in LF-03 Saturated Zone:* Determine the chemical quality of leachate that can be produced when groundwater is recirculated through mulch material.	Reduced dissolved oxygen (DO), nitrate/nitrite, and sulfate concentrations; Increased DOC (including volatile fatty acids [VFA]), ferrous iron, and methane concentrations in the circulating groundwater; and evidence of microbial enhancement (via phospholipid fatty acid [PLFA] analyses).
Quantitative	*Contaminant Reduction*: Determine if the mulch bioreactor provides enough organic substrate to drive reductive dechlorination of CAHs as recirculated leachate passes through the bioreactor. Measured influent levels of TCE, DCE, VC, chloride, and ethene (as the leachate enters the top of the bioreactor) will be compared to levels of these constituents measured beneath and downgradient from the mulch bioreactor.	TCE being converted to DCE, and DCE being converted to VC, ethene, carbon dioxide, and chloride ions. Goal is a 90% reduction in the total CAH molar concentrations of groundwater in downgradient monitoring wells.
Quantitative	*Factors Affecting Technology Performance*: Identify how stratigraphy, groundwater geochemistry, changes in geochemistry during recirculation, and bioreactor design factors affect bioreactor performance.	Conclusions will be based on observations of groundwater mounding in the test cell, changes in groundwater geochemistry during recirculation, maintenance requirements, and bioreactor effectiveness.
Qualitative	*Reliability and Maintenance Requirements*: Evaluate reliability of solar pump and drip irrigation system for bioreactor applications.	Conclusions will be based on observations of solar pump and drip irrigation system reliability and O&M requirements.
Qualitative	*Scale-up Constraints and Technology Application*: Determine if the recirculation bioreactor design is appropriate for other landfills, both at Altus AFB and other DoD installations, and evaluate which types of climates, hydrogeologic settings, and landfill situations are best suited for this bioreactor design.	Conclusions will be based on 1) observations of bioreactor maintenance requirements and performance and 2) evaluation of any design modifications necessary or desirable for full-scale bioreactor implementation.

3.2 TEST SITE SELECTION

LF-03 in Operable Unit 1 (OU-1) at Altus AFB was selected as the landfill site for a recirculation bioreactor demonstration because of the favorable characteristics of the site and because Altus AFB personnel were receptive and supportive of the bioreactor pilot test and viewed it as a “win-win” situation for this ESTCP project and the base. Altus AFB personnel discussed this demonstration project with USEPA oversight personnel and obtained their support. However, the final bioreactor design, although favorable toward addressing the base’s regulatory goals and objectives, no longer included the original design features and objectives set forth in the ESTCP demonstration plan. Consequently, along with unanticipated contaminant source conditions, various ESTCP bioreactor demonstration performance objectives remain unresolved. Characteristics of an ideal candidate landfill site for the field pilot test are described in Table 2 along with the conditions present at Altus AFB, LF-03.

Table 2. Characteristics Leading to Selection of Altus AFB Site LF-03 for the Bioreactor Pilot Test, Bioreactor Demonstration, Altus AFB.

Desired Pilot Test Site Characteristic	Actual Condition at Altus AFB, LF-03
Dissolved CAH plume present in groundwater beneath the landfill, with a significant, continuing contaminant source in the landfill interior.	Available information suggested that the source area for the LF-03 CAH plume was located in the immediate vicinity of the current bioreactor test cell; therefore, this site provides an example of how a bioreactor can be installed in a limited landfill source-area “hotspot” excavation near the upgradient end of a substantial CAH plume.
PCE and/or TCE are primary risk-driver chemicals and are present in groundwater at relatively high concentrations (>100 micrograms per liter [µg/L]).	TCE is the primary contaminant of concern in groundwater beneath LF-03, with source area concentrations greater than 10,000 µg/L.
Remedial goals cannot be met within an acceptable time frame via monitored natural attenuation (MNA).	Reductive dechlorination of TCE was primarily limited to areas of OU-1 with commingled fuel hydrocarbon contamination (Parsons Engineering Science [Parsons ES], 1999). TCE biodegradation was not proceeding past the transformation to DCE, and VC was not detected. TCE is the primary component of the dissolved phase plume.
A final closure cover has not been designed or installed, or a vegetative (evapotranspiration [ET] type) cover is already in place.	Neither a final closure cover nor an ET cover is present at LF-03; the site is covered with native vegetation.
Remedial goals can be met with an ET cover (i.e., a low-permeability cover is not required). Either precipitation rates are sufficiently low that the infiltration-control properties of the ET cover would not be overwhelmed, or a significant portion of the contaminated waste lies below the average water table (i.e., infiltration is not the only source of water for plume generation).	There is no immediate plan to place an engineered cover on LF-03. It appears that a significant source of TCE remains in the subsurface. The vertical extent of the residual source is not known, but it appears to reside at least partially in the vadose zone.
Anaerobic conditions are present in the core of the dissolved plume, and the plume core can be contained at reasonable expense by extracting a flow that can be reapplied within the landfill (e.g., shallow depth to groundwater, limited-transmissivity aquifer). The presence of an existing groundwater collection system would be beneficial from a cost standpoint but is not required.	Background DO concentrations at the LF-03 bioreactor site averaged 0.8 mg/L (Parsons ES, 1999). The shallow depth to groundwater (6 to 9 ft below ground surface [bgs]), the limited thickness of the transmissive portion of the saturated zone (approximately 20 to 30 ft), and the fine-grained nature of the aquifer (clay and shaley clay) made it feasible to cost-effectively construct a shallow groundwater interceptor trench for leachate capture and recirculation.

3.3 TEST SITE HISTORY/CHARACTERISTICS

LF-03 is located in the northeastern portion of the base in a remote area adjacent to airfield taxiways. From 1956 through 1965, LF-03 received waste materials including garbage, wood, metal, paper, and shop wastes. After 1965, LF-03 received construction debris, concrete, brush, and several drums of paint waste. From 1956 to 1965, waste at LF-03 was buried in trenches with depths ranging from 6 to 8 ft bgs.

Shallow groundwater at the base occurs under unconfined conditions and generally flows to the southeast. Shallow groundwater in the LF-03 bioreactor area occurs at depths of 4 to 5 ft bgs during the wet winter and spring months and 5 to 9 ft bgs during the dry summer and fall months. The groundwater surface slopes toward the southeast with an average horizontal hydraulic gradient of approximately 0.003 foot per foot (ft/ft) (Parsons, 1999).

The hydraulic conductivity of the uppermost water-bearing zone was estimated to range from 8.4 to 20 feet per day (ft/day) in the fractured clay overburden (upper zone). Using this range of hydraulic conductivity values, a measured lateral hydraulic gradient of 0.003 ft/ft, and an estimated effective porosity (5%), the advective groundwater flow velocity in the overburden clay is calculated to range from 0.50 to 1.20 ft/day [183 to 438 feet per year (ft/yr)].

Since 1984, several remedial investigations have been completed at and downgradient of LF-03. Groundwater quality data indicate that TCE and *cis*-1,2-DCE are the most prevalent CAHs in OU-1 groundwater in terms of both areal extent and concentration. In March 2003, TCE and *cis*-1,2-DCE were detected at well WL250 at concentrations of 17,900 and 1,330 µg/L, near the suspected LF-03 source area. The TCE plume originates at LF-03 (in the vicinity of monitoring well WL250) and extends southeastward approximately 4,000 ft to the base's eastern boundary. The LF-03 bioreactor is located immediately upgradient of hot-spot well WL250, as this was believed to be the most likely location for CAH source material.

3.4 PHYSICAL SETUP AND OPERATION

The LF-03 recirculation bioreactor system consists of four primary components: an organic mulch cell excavated into the saturated zone, a groundwater collection trench, a groundwater recirculation system, and a monitoring network. Construction of the bioreactor system and monitoring network occurred over 10 days in October 2003. The bioreactor cell is a 30 ft by 30 ft square excavated to a depth of 11 ft bgs. Excavated soil containing landfill debris was segregated upon removal from the excavation. Landfill debris was encountered from near the ground surface to a depth of at least 8 ft bgs; however, there was no indication of CAH source material. Soil that did not contain landfill debris was spread adjacent to and on top of the bioreactor; a total of 142 tons of soil that contained landfill debris was characterized and disposed of as nonhazardous waste at a RCRA subtitle D landfill.

The backfill material placed in the cell was a mixture of 50% wood mulch, 40% sand, and 10% cotton burr trash, by volume. These three components were combined using a backhoe and front-end loader and used to backfill the cell from 11 to 12 ft bgs. Additional backfill was needed to fill the cell to grade and wood mulch (only) was utilized as it was the most readily available and least expensive component of the mixture. The cell was capped with two layers of geotextile fabric to prevent topsoil from migrating downward into the organic material. The groundwater distribution piping was installed between the geotextile layers. A 2-ft-thick layer of topsoil (set aside during the initial excavation) was placed over the cell and native grasses were allowed to reestablish themselves.

The groundwater collection trench was excavated 18 ft downgradient of the bioreactor cell using a backhoe. The trench is 2 ft wide, 30 ft long, and 18 ft deep in the center. An 18-inch inside diameter (ID), slotted, polyvinyl chloride (PVC) pipe was installed vertically in the middle of the trench to act as the sump. The entire trench was backfilled around the sump to within 2 ft of the surface with ½-inch plus washed angular gravel.

The groundwater distribution system consists of a solar-powered Grundfos submersible pump, instrumentation, valves, and duplicate distribution headers. The pump can produce a flow of 2 to 3 gpm during peak daylight hours and does not operate during the night or periods of low light. Water is discharged from the pump into a 1-inch poly tube and through a pressure relief valve, flow totalizer, strainer, and pressure gauge prior to reaching the distribution headers. The entire system is buried at least 2 ft bgs for freeze protection. The instrumentation and valves are accessible through a series of valve boxes.

System startup occurred immediately after completion of the baseline sampling event on November 16, 2003. Startup consisted of turning the pump on and ensuring that pressure and flow were within the desired ranges. No modifications to the system were necessary.

3.5 SAMPLING AND MONITORING

The monitoring network consists of 16 groundwater monitoring wells, one soil vapor monitoring point (VMP), two gravity lysimeters, and one distribution system sampling point (Figure 1). Shallow monitoring wells (SW) were installed upgradient, within, and downgradient of the cell. Deeper monitoring wells (DW) were installed upgradient, below, and downgradient of the cell. The bioreactor was designed to require minimal oversight and maintenance. The solar pump is the only mechanical equipment at the site. Altus AFB and Parsons personnel visited the site periodically to check that the pump was operating and record pressure and flow data. Performance monitoring groundwater sampling events were completed 3, 7, 13, 17, and 24 months after system start-up. Parsons operated, maintained, and monitored the bioreactor cell at LF-03 until the final sampling event on November 11, 2005. Altus AFB has continued to operate the system since November 11, 2005.

The sampling plan for the LF-03 bioreactor was developed following USEPA guidance for documenting the natural attenuation of CAHs (USEPA, 1998) and using prior experience monitoring enhanced bioremediation sites. The bioreactor was sampled to monitor the chemical and geochemical conditions in the groundwater impacted by the pilot test. The objective of this monitoring was to evaluate the impact of the bioreactor on the anaerobic dechlorination of CAHs in groundwater and the groundwater geochemistry near the LF-03 source area.

Groundwater samples were collected using a low-flow "micropurge" technique where water quality stabilization parameters were monitored prior to sampling. Soil gas samples were collected for fixed-base laboratory analysis using Summa canisters. The procedures used prior to and during each of the groundwater and soil gas monitoring events to ensure that representative samples were obtained are described in Appendix B of the Final Technical Report (Parsons, 2006).

Two lysimeters installed above the water table in the bark mulch bioreactor were used to verify that water was infiltrating into the bioreactor at the downstream ends of the drip lines. During each of the performance monitoring events the lysimeters were purged and were observed to recharge.

3.6 ANALYTICAL PROCEDURES

Groundwater samples were analyzed for VOC and a suite of geochemical and microbial indicator parameters. Groundwater samples, as well as the quality assurance/quality control (QA/QC) samples, were analyzed at both fixed-base commercial laboratories and in the field using field test kits (e.g., Hach® portable colorimeter or titration kits in accordance with manufacturer-specified procedures) and direct-reading meters. Soil gas samples were analyzed for VOCs, oxygen, carbon dioxide, and methane at a fixed-base commercial laboratory. The Quality Assurance Project Plan (QAPP) is available in Appendix C of the Final Technical Report (Parsons, 2006).

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4.0 PERFORMANCE ASSESSMENT

4.1 PERFORMANCE DATA

Table 3 summarizes the performance data collected during this demonstration. The analytical data that were collected include both direct and indirect biodegradation indicators. Analysis of chlorinated ethene concentrations provides direct evidence of contaminants being biodegraded. Concentrations of geochemical parameters that are widely recognized and accepted indicators of the degree to which groundwater geochemical conditions are conducive to biodegradation of chlorinated solvents (e.g., see the Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater [USEPA, 1998]) provide indirect evidence of biodegradation. In addition to these commonly targeted natural attenuation indicator parameters, more recently developed and relatively innovative biological indicator parameters (i.e., VFAs and PLFAs) were targeted for analysis. This section presents a summary of the primary performance data collected during the pilot test. A complete presentation of the data collected during the pilot test is available in Section 4 of the Final Technical Report (Parsons, 2006).

Table 3. Performance Data Summary Bioreactor Demonstration, Altus AFB.

Altus LF-03 Pilot-Scale Recirculation Bioreactor	
Types of samples collected	Groundwater samples were collected from monitoring wells installed within, beneath, and adjacent to the bioreactor.
Sample frequency and protocol	Baseline groundwater samples were collected prior to starting the recirculation system. Monitoring events occurred approximately 3, 7, 13, 18, and 24 months after recirculation started.
Quantity of material treated	Approximately 6.5 lb of TCE were removed from the 690,000 gal of groundwater recirculated through the bioreactor during the 2-year period. Additional TCE mass (estimated at 0.5 to 1 lb) was rapidly transformed within the bioreactor following bioreactor installation but prior to performance of the baseline sampling event and initiation of groundwater recirculation. The aquifer volume impacted during the pilot test is at least 11 times larger than the volume of the bioreactor. Calculating the total TCE mass removed in situ is problematic because the site is not a closed system.
Concentrations of untreated and treated contaminants	TCE concentrations in untreated groundwater ranged from 43 to 2,179 µg/L and from 0.1 to 20.2 µg/L in the treated groundwater. TCE concentrations decreased prior to the 2-year test. The total molar CAH concentration in shallow and deep monitoring wells remained relatively unchanged throughout the pilot test and ranged from approximately 15 to 29 micromolar. This was caused by the influx of new TCE mass from a nearby residual source into the monitored zone during the pilot test and the accumulation of TCE daughter products (DCE and VC).
Cleanup objective	90% reduction in total molar CAH concentration in shallow downgradient groundwater
Comparison with cleanup objectives	Geochemical conditions conducive to reductive dechlorination of CAHs were achieved, and biodegradation was enhanced. However, the cleanup objective was not met because of the presence of a residual TCE source area adjacent to the bioreactor that added new TCE mass to the monitored zone during the pilot test. The beneficial impact of the bioreactor decreased with increasing depth.
Method of analysis	VOCs were analyzed by a commercial fixed-base laboratory using USEPA Method SW8260B.
QA/QC	A QAPP was prepared for this project. Trip blanks, matrix spikes/matrix spike duplicates, and blind duplicates were collected.

4.1.1 TCE Concentration Trends

Figure 2 is a cross section of TCE concentrations in groundwater during the November 2003, June 2004, and November 2005 sampling events. Between November 2003 and June 2004, TCE concentrations decreased substantially at all wells in the vicinity of the bioreactor, including the upgradient wells. In December 2004, TCE concentrations began to rebound. It is hypothesized that this rebound reflects leaching of TCE from soil due to excessive rainfalls that occurred in October 2004 and November 2004. In June 2005, TCE concentrations at the shallow wells were low. For example, the TCE concentration at well SW5 was 5 µg/L in November 2005 as compared to 10,783 µg/L in November 2003. These data suggest that the bioreactor system affected the TCE contamination in the shallow groundwater zone. In November 2005, the TCE concentrations observed in the groundwater samples collected from the deep wells were of the same order of magnitude as the November 2003 results. The data indicate that the bioreactor had limited long-term impact on the TCE contamination in the deep groundwater zone.

In the end, bioreactor performance remains unresolved. To note, the bioreactor resulted in surprisingly rapid concentration changes. Relative to the baseline sampling event, TCE concentrations in shallow groundwater adjacent to the test cell were reduced by 96 to 99.9% during the five performance monitoring events. If the March 2003 TCE concentration (17,900 µg/L) for well WL250, located downgradient of the cell, reliably represents the downgradient groundwater quality immediately prior to bioreactor construction, then the bioreactor resulted in decreased TCE concentrations before the infiltration system became operational. The baseline sample from downgradient well SW5 had 10,783 µg/L TCE, which is approximately 60% of the March 2003 TCE concentration at well WL250. It is unclear whether the apparent change in the downgradient groundwater TCE concentration between March 2003 and November 2003 might be due to differences in the screened interval and pump placement during sampling or to natural temporal and spatial variability. With respect to long-term performance, an effective landfill bioreactor technology must be capable of addressing potential influx of upgradient contamination. The concentration rebound observed in the deeper wells suggests that the bioreactor cell was unable to address contaminant influx.

4.1.2 Total CAH Concentration Trends

Figure 3 shows the geometric mean total molar CAH concentrations in shallow groundwater adjacent to the bioreactor (wells SW1, 2, 5, and 6) over time. Shallow groundwater initially had a geometric mean total molar CAH concentration of 7,917 nanomolar (nM), and consisted of 49% TCE and 50% DCE. Over time, TCE was degraded; however, the total molar concentration of CAHs was higher than the baseline concentration during three of the five monitoring events, indicating an accumulation of TCE daughter products and influxes of new TCE mass into the shallow groundwater within the monitored area. During the first performance monitoring event in February 2004, the total molar CAH concentration in shallow groundwater adjacent to the bioreactor consisted of 99% DCE and less than 1% TCE and VC. By the second performance monitoring event in June 2004, the CAH content of shallow groundwater primarily consisted of VC (80%). From June 2004 to November 2005, VC consisted of 62 to 95% of the total molar CAH concentration in shallow groundwater.

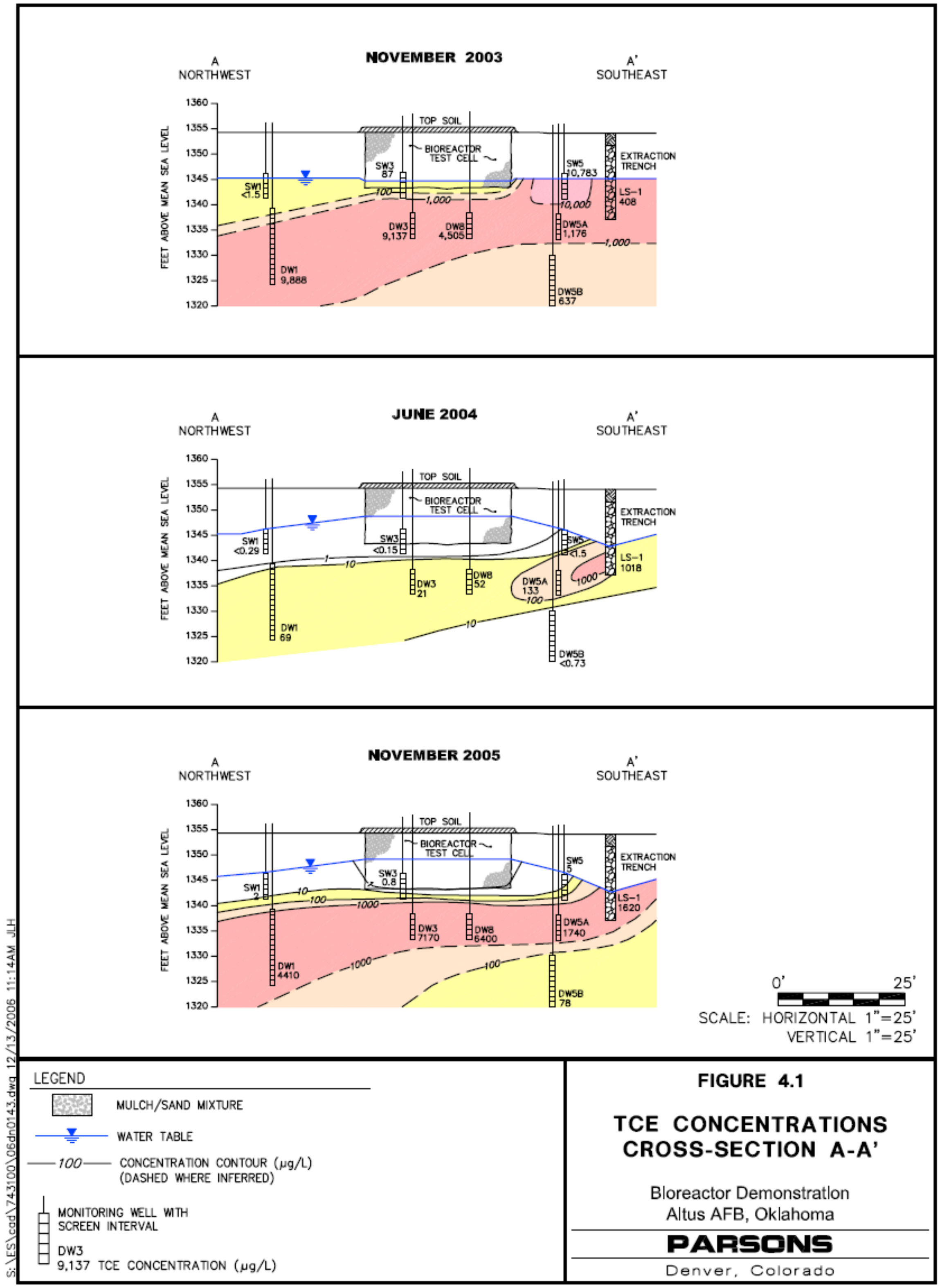

Figure 2. TCE Concentrations Cross Section A-A'.

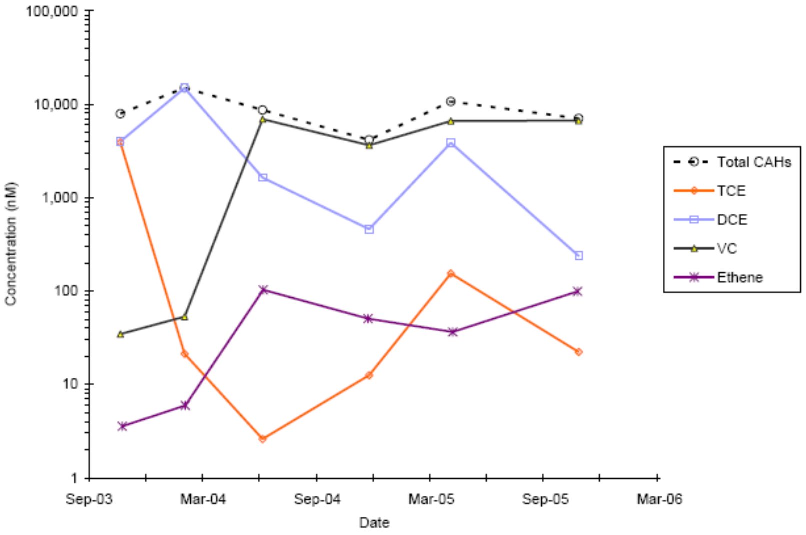

Figure 3. Molar Concentration Trends for Chlorinated Ethenes in Shallow Wells Adjacent to the Bioreactor.

Figure 4 shows the geometric mean chlorinated ethene concentrations through time for the deeper wells at the site (DW1, 2, 3, 4, 5A, 5B, 6A, 6B, 7, and 8). These wells were installed both adjacent to and through the bioreactor test cell, and are entirely screened below the base of the test cell. The total molar chlorinated ethene concentration in the deeper wells decreased by 52% from 13,406 nM in November 2003 to 6,420 nM in June 2004. A significant increase in TCE and total molar chlorinated ethene concentrations was observed after June 2004, suggesting that there was an influx of TCE into the area beneath the test cell after June 2004. The maximum geometric mean total chlorinated ethene concentration detected in the deeper wells was 20,084 nM in December 2004.

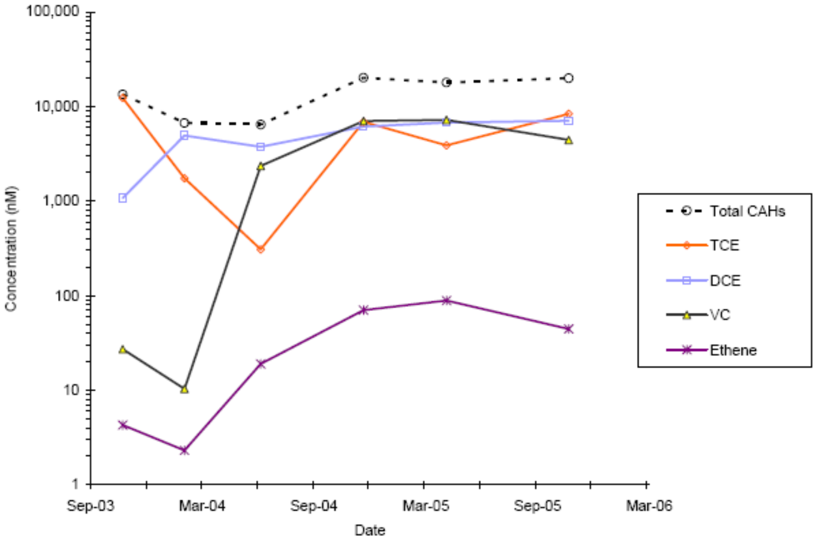

Figure 4. Molar Concentration Trends for Chlorinated Ethenes in Deeper Wells.

These data indicate that there is a continuing source of TCE in the vicinity of the bioreactor. The influx of TCE likely was caused by heavy precipitation that occurred in fall 2004, prior to the December 2004 groundwater monitoring event. The bioreactor test cell was virtually inundated with standing water during a visual inspection in November 2004. The accumulation of DCE and VC in the shallow aquifer is likely due to kinetic disparity where the intermediate dechlorination product is being generated faster than it is degraded, and not to an absence of appropriate dechlorinating microorganisms. These results highlight the importance of adequately delineating source areas prior to installing full-scale bioreactor systems, and indicate that soil excavation for source removal is a critical component of the technology.

4.1.3 Dissolved Organic Carbon Concentration Trends

Figure 5 is a graph showing the geometric mean DOC concentration trends for the recirculation system influent (LS-1), bioreactor interior (SW3 and 4), shallow aquifer adjacent to the bioreactor (SW1, 2, 5, and 6), and deeper aquifer adjacent to and beneath the bioreactor (all "DW" wells). The maximum DOC concentrations were observed in the bioreactor during the baseline sampling event, after installation of the mulch but prior to start-up of recirculation. The geometric mean DOC concentration measured in the bioreactor was 12,410 mg/L. The peak geometric mean DOC concentration for the shallow wells adjacent to the bioreactor was 114 mg/L, measured during the first performance monitoring event in February 2004. By the final performance monitoring event in November 2005, the geometric mean DOC concentrations in the bioreactor and adjacent shallow wells decreased to 32 and 19 mg/L, respectively. Figure 5 shows that the deeper wells had less of an increase in DOC and reached a maximum geometric mean DOC concentration of 30 mg/L in April 2005.

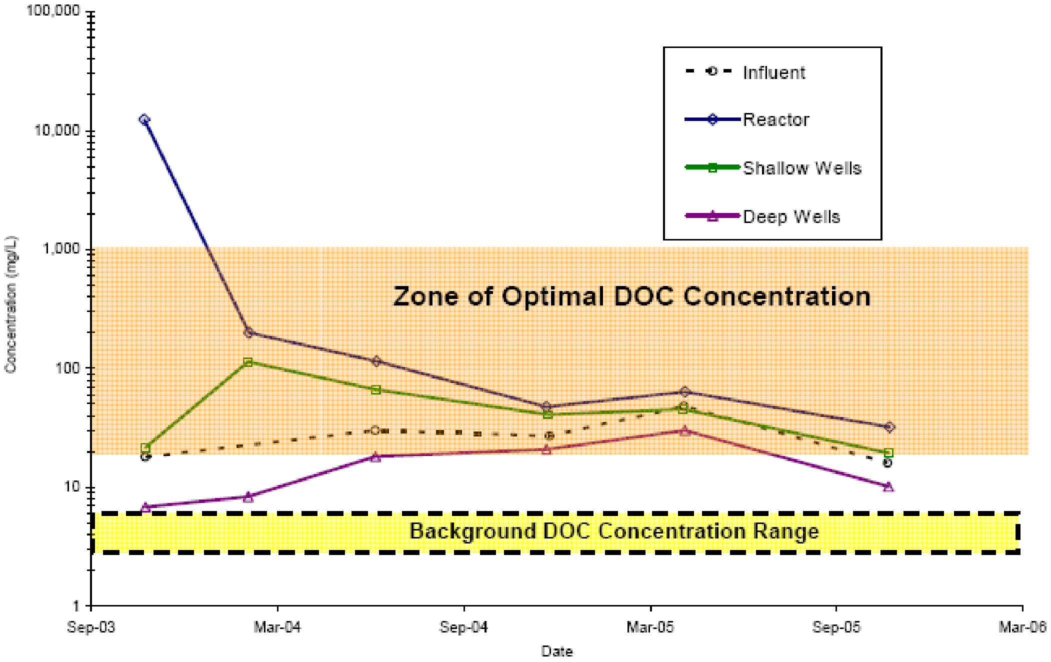

Figure 5. Dissolved Organic Carbon Concentration Temporal Trends.

Based on November 2003 (baseline) DOC concentrations in upgradient deeper wells, the background DOC concentration near the bioreactor is approximately 3 to 6 mg/L. DOC concentrations were elevated above the 20 mg/L threshold that is conducive to reductive dechlorination for approximately 6 months to a year in the deep wells beneath the bioreactor, and for almost the entire 2-year duration of the pilot test at the shallow wells adjacent to the test cell. These data suggest that, for this pilot test site, the pool of organic material required to maintain the DOC levels was depleted in approximately 2 years.

4.2 PERFORMANCE CRITERIA

The primary performance criteria for the evaluation of the recirculation bioreactor are contaminant reduction and geochemical/microbial enhancement in the saturated zone. The effectiveness of the bioreactor field demonstration was evaluated primarily using groundwater analytical results for samples collected from the monitoring wells installed up- and down-gradient from (based on the pre-recirculation groundwater flow direction), within, and beneath the test cell. The results from the five performance monitoring events were compared to the initial baseline sampling event and historical analytical data for nearby well WL250. The degree to which the bioreactor successfully enhanced the geochemical conditions of the saturated zone was assessed by comparing concentrations of the parent chlorinated ethene compound, TCE, and biodegradation daughter products over time, and by the degree to which concentrations of competing electron acceptors (e.g., sulfate) were reduced and microbial populations and concentrations of metabolic byproducts (e.g., methane, VFAs) and chloride were enhanced.

The secondary performance criteria were more qualitative and included identifying factors that affect the bioreactor performance, evaluation of system reliability and maintenance requirements, and evaluation of system scale-up constraints.

Table 4 presents the performance criteria and the actual versus expected performance for the demonstration.

4.3 DATA ASSESSMENT

Acceptable levels of data quality were achieved by following the sampling procedures outlined in “Procedures for Well Development and Sampling” (Appendix B) and the QAPP (Appendix C) in the Final Technical Report (Parsons, 2006).

Table 4. Expected Versus Actual Performance, Bioreactor Demonstration, Altus AFB.

Performance Criterion	Expected Performance Metric	Performance Confirmation Method	Actual
Geochemical and microbial enhancement in saturated zone	Reduction in DO, nitrate/nitrite, sulfate, and oxidation-reduction potential (ORP) levels and increases in methane, dissolved hydrogen, chloride, DOC, VFAs, PLFAs, alkalinity, ferrous iron, dissolved manganese, and hydrogen sulfide levels. Maintenance of near-neutral pH levels.	Comparison of performance monitoring results to baseline results; temporal trend analysis	• Increased DOC concentrations produced anaerobic, reducing conditions in the bioreactor and the aquifer. Increases in chloride, alkalinity, and metabolic by-products (methane, VFAs, dissolved manganese, ferrous iron) were observed. Sulfate concentrations were reduced. DOC concentrations suggest organic substrate depleted in approximately 2 years. • Biomass increased by as much as two orders of magnitude. • Increased concentration of anaerobic firmicutes bacteria that are responsible for fermentation of DOC and production of dissolved hydrogen.
Contaminant reduction	Reduction in parent solvent (i.e., TCE) concentrations, production of daughter products including ethene. The goal of this demonstration was a 90% reduction in the total molar concentration of CAHs as measured in the wells beneath and downgradient of the LF-03 test cell. Overall toxicity reduction in groundwater.	Comparison of performance monitoring results to baseline results; temporal trend analysis	• TCE reduced at well WL250, located between the bioreactor test cell and the groundwater collection trench and screened 8-18 ft bgs. • 96 to 99.9% geometric mean TCE removal efficiency for shallow wells outside the bioreactor during the five performance monitoring events. • 97 to 100% TCE removal efficiency within the bioreactor during the five performance monitoring events. • A 90% reduction in the total molar CAH concentration was not achieved in the wells beneath and downgradient of the LF-03 test cell. However, a 76 to 96% total molar CAH removal efficiency was achieved within the bioreactor during the five performance monitoring events. • In shallow monitoring wells adjacent to the test cell, the total molar chlorinated ethene concentrations were greater than the baseline concentrations during three of five performance monitoring events due to TCE daughter product formation (DCE and VC) and TCE influx from a continuing source.

Table 4. Expected Versus Actual Performance, Bioreactor Demonstration, Altus AFB (continued).

Performance Criterion	Expected Performance Metric	Performance Confirmation Method	Actual
Factors affecting technology performance	Excessive mounding in LF-03 test cell causing surface seeps. Evidence of aeration of collected groundwater in collection trench and/or distribution piping resulting in chemical precipitation and system fouling. Solar pump operates in a trouble-free fashion	Measurement of water levels in bioreactor; comparison of groundwater geochemistry between monitoring well samples and samples from collection trench sump and distribution line; observations of solar pump and recirculation system reliability	• Excessive mounding did not occur. • No chemical precipitation or system fouling was observed; however, in-line strainer required periodic cleaning to maintain flow of pumped water into recirculation lines. • Solar pump operated in a trouble-free fashion with no maintenance required. • Seasonally lowered groundwater temperatures in bioreactor appear to have resulted in decreased chlorinated ethene removal efficiency. • High sulfate concentrations likely decreased size of dechlorination treatment zone in aquifer and limited dechlorination effectiveness.
Reliability and maintenance	No breakdowns, routine periodic maintenance	Evaluation of operating parameters; experience from system operation, monitoring, and maintenance (OM&M)	• Solar pump operated without breakdown. • A leak in the recirculation system (from air release valve) was observed and fixed. Available data suggest that one or more additional small leaks were present and became more significant with time; this was alleviated by directing flow to the backup recirculation lines and cleaning the inline strainer. • No vendor or subcontractors were necessary for performing maintenance and repairs. Less than 2 hours per month of maintenance was required.

Table 4. Expected Versus Actual Performance, Bioreactor Demonstration, Altus AFB (continued).

Performance Criterion	Expected Performance Metric	Performance Confirmation Method	Actual
Scale-up Constraints and Technology Application	Readily scalable and applicable to other sites and contaminants	Experience from design and operation of the system	• Scale-up of this technology is feasible and would likely not pose significant problems. • Scale-up would likely require a longer and deeper extraction trench, multiple pumps, and larger piping. • More detailed hydrogeologic analysis may be necessary to ensure capture of potential daughter product plume without diluting the DOC concentrations. • Intermittent operation using a solar pump may not be desirable at some sites. Design may be modified to use a solar pump with battery array for longer pumping periods. • Solar pumping system not appropriate for areas with relatively low solar radiation or at sites where direct sun exposure is not possible. • Some landfills may be too hazardous to excavate. If necessary, the bioreactor design can be modified so that excavation does not extend into waste disposal zone. • This technology is not limited to landfill sites. It may be applied to source areas with contaminants other than CAHs. • Many sources of organic substrate are available. • Removal of source area is a critical component of this remedy, as evidenced by the influx of TCE during the pilot study. Full-scale implementation would require identification, delineation, and removal of source areas.

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5.0 COST ASSESSMENT

5.1 COST REPORTING

All relevant costs and related data were tracked and documented during the pilot demonstration to facilitate estimation of the full-scale costs of bioreactor design, installation, and OM&M. The total cost for the technology demonstration was $171,872. This cost includes $56,152 in start-up and capital costs, $2,880 in O&M costs, and $112,840 for monitoring during the 2-year demonstration.

Table 5 shows the estimated costs for construction and 2 years of OM&M of the 900-sq ft LF-03 recirculation bioreactor if operated as a full-scale implementation of the technology rather than a pilot test. For this estimate it is assumed that $50,000 would be spent on performing a preconstruction site characterization to define the TCE source location more accurately. The LF-03 pilot test demonstrated the importance of locating source areas to the success of the system. Groundwater monitoring could be reduced significantly for a full-scale application of the technology. It is estimated that the monitoring network could be sampled semiannually for $33,980 a year. The reduced OM&M costs would primarily result from reducing the number of wells monitored by approximately one-half, reducing the sampling frequency to semiannual, and limiting the target analytes to the primary indicators of the bioreactor performance (i.e., VOCs, and a limited number of geochemical parameters). Additional costs associated with the demonstration project such as the work plan preparation, ESTCP status reporting, and preparation of the final technical and cost and performance reports are not included in Table 5 as these costs would not normally apply to the full-scale implementation of this technology.

The major cost driver for the recirculation bioreactor technology is the size of the bioreactor cell, which directly impacts construction and material costs, and the disposal requirements for the excavated soil and debris. Equipment costs for the pilot recirculation system were approximately $4,000, a minimal component of the $171,000 capital and OM&M costs for the 900-sq ft bioreactor at Altus AFB. Approximately 40% of the capital costs incurred for the pilot bioreactor were for a construction subcontractor, labor for oversight and field engineering, soil disposal, and purchase of backfill materials. The single largest capital cost incurred was for installation of the performance monitoring network (34% of total capital costs).

The solar powered groundwater recirculation system used at LF-03 required very little maintenance and repair over the 2-year monitoring period. Similar results would be expected at other sites that use the same technology. Annual monitoring costs for a full- scale application of the recirculation bioreactor technology are expected to range from approximately $33,000 for a small system like the LF-03 bioreactor, to approximately $50,000 for a 1-acre system. Estimated monitoring costs assume semiannual sampling.

Table 5. Pilot Test Cost Summary, Bioreactor Demonstration, Altus AFB.

Cost Category	Sub-Category	Details	Total Cost ($)
Fixed Costs			
1. Capital costs	Planning/preparation	Review of historical data/site characterization	$50,000
	Mobilization/demobilization	Subcontractor mobilization, field crew travel costs	$4,450
	Design	Labor	$6,400
	Excavation of cell and trench	Subcontractor (370 CY cell and 30-ft-long trench)	$2,500
	Backfill of cell and trench	Subcontractor	$9,145
	Equipment purchase		
		Procurement	$500
		Groundwater pump	$1,055
		Solar power system	$1,225
		Pressure relief valve	$135
		Flow totalizer	$175
		Strainer	$10
		Pressure indicator	$30
		Piping (400 ft)	$350
		Vaults (4)	$80
		Lysimeter (2)	$60
	Field engineering		$4,800
	Disposal of soils	(175 CY)	$4,762
	Site cleanup		$675
	Performance monitoring network installation	16 wells, 1 soil vapor point	$16,800
			Subtotal: $103,152
Variable Costs			
2. Operation, maintenance, and monitoring	Year 1		$33,980
	Year 2		$33,980
			Subtotal: $67,960
		TOTAL:	**$171,112**

Notes: CY = cubic yard, ft = foot, hr = hour(s)

5.2 COST ANALYSIS

As noted in Section 5.1, the bioreactor cell dimensions and disposal requirements for the excavated soil/debris are expected to exert a substantial impact on the cost of full-scale implementation. To assess the potential cost impacts, the following scenarios were evaluated:

- Full-scale implementation scenario as shown in Table 5
    - Bioreactor dimensions of 30 ft x 30 ft x 11 ft
    - 175 cubic yards of soil disposed off site as nonhazardous waste (portion of soil excavated from the bioreactor cell location was retained on site)
    - 30-ft long, 2-ft wide, and 18-ft deep groundwater collection trench

- Scenario 1
    - Bioreactor and collection trench same dimensions as for pilot test
    - Offsite disposal of all soil excavated from the bioreactor cell footprint as nonhazardous waste

- Scenario 2
    - Bioreactor and collection trench same dimensions as for pilot test
    - Dense nonaqueous phase liquid (DNAPL) encountered in bottom 4 feet of bioreactor cell footprint (30 ft x 30 ft area). Excavation in this zone performed in Level C personal protective equipment (PPE), and associated soil/debris disposed offsite as hazardous waste
    - Offsite disposal of remainder of soil/debris excavated from bioreactor cell location as non-hazardous waste

- Scenario 3
    - Bioreactor dimensions are 100 ft x 100 ft x 11 ft
    - 100-foot long, 2-foot wide, and 18-foot deep groundwater collection trench
    - Offsite disposal of soil/debris excavated from bioreactor cell footprint as non-hazardous waste

- Scenario 4
    - Bioreactor dimensions are 100 ft x 100 ft x 11 ft
    - 100-foot long, 2-foot wide, and 18-foot deep groundwater collection trench
    - DNAPL zone with dimensions of 30 ft x 30 ft x 4 ft; excavation in this zone performed in Level C PPE, and associated soil/debris disposed of off site as hazardous waste
    - Off-site disposal of remainder of soil/debris excavated from bioreactor cell footprint as nonhazardous waste

- Scenario 5
    - Bioreactor dimensions are 200 ft x 200 ft x 11 ft

  - 200-ft long, 2-ft wide, and 18-ft deep groundwater collection trench
  - Offsite disposal of soil/debris excavated from bioreactor cell footprint as nonhazardous waste

- Scenario 6
  - Bioreactor dimensions are 200 ft x 200 ft x 11 ft
  - 200-ft long, 2-ft wide, and 18-ft deep groundwater collection trench
  - DNAPL zone with dimensions of 30 ft x 30 ft x 4 ft; excavation in this zone performed in Level C PPE, and associated soil/debris disposed of off site as hazardous waste
  - Off-site disposal of remainder of soil/debris excavated from bioreactor cell footprint as nonhazardous waste.

Scenarios 3 and 4 correspond to a bioreactor approximately one-quarter acre in size, while Scenarios 5 and 6 encompass slightly less than an acre.

Total net present value cost estimates for each scenario were developed with the following assumptions:

- Fifteen-year remedial time frame
- Replenishment of substrate with emulsified oil at Years 3 and 5 (based on the DOC data collected during the pilot test), followed by monitored natural attenuation to address residual contamination
- Annual OM&M costs based on the estimated cost of $33,980 per year (Table 5)
- Discount rate of 3.1 percent

The primary sources of unit costs were the 2005 RSMeans for Environmental Construction and the 2008 RSMeans for Heavy Construction. An inflation factor of 1.22, based on the Turner Construction Index was applied to unit rates obtained from the 2005 RSMeans. The total net present value calculated for each scenario is summarized in Table 6.

Table 6. Total Net Present Value of Bioreactor Scenarios.

Scenario	Total Net Present Value ($K)
Full-scale Implementation, Table 5	858
Scenario 1	967
Scenario 2	1,028
Scenario 3	3,144
Scenario 4	3,202
Scenario 5	9,587
Scenario 6	9,642

As shown in the above table, the total net present value increases substantially with bioreactor size, supporting the hypothesis that bioreactor cell dimensions are a primary cost factor.

Table 6 presents the breakdown of the total net present value into capital costs, OM&M costs, and periodic costs. With the 30 ft x 30 ft bioreactor cell dimensions, more than half of the total net present value is due to OM&M costs, while the capital cost is slightly greater than the total net present value of the periodic substrate replenishment. In Scenarios 3, 4, 5, and 6, OM&M costs are a minor component of the total net present value. While the primary cost component was the capital costs, the periodic costs of substrate replenishment also contributed substantially to the total net present value of these four scenarios. The cost analysis assumed two rounds of substrate replenishment. The degree to which substrate replenishment would be required during the O&M phase is likely to vary from site to site. The analysis indicates that this periodic cost, however, could contribute substantially to the total cost of the remedy.

The greatest contributors to the capital cost were off-site disposal (transport and tipping fee) and bioreactor backfilling. In Scenario 2, the assumed hazardous waste volume represented half of the soil identified for off-site disposal. The tipping fees and transportation costs associated with hazardous waste disposal increased the estimated capital costs by 24% as compared to Scenario 1 (same bioreactor dimensions; all soil/debris classified as nonhazardous). With Scenarios 4 and 6, the assumed hazardous waste volume represented a small fraction of the total volume identified for off-site disposal. Accordingly, the impact to the capital cost was less than in Scenario 2. The analysis emphasizes the importance of characterizing the bioreactor footprint prior to construction. If the source area is found to contain large quantities of soil/debris requiring off-site disposal as hazardous waste, capital costs could be higher than expected. On the other hand, if it is possible for the excavated soil to remain onsite, the capital costs could be substantially reduced.

This cost analysis indicates that the mulch bioreactor technology has the potential for incurring high costs, depending on the size of the source area and the type of waste encountered. While this approach may be appropriate for well-defined, small, isolated sources areas, it may not be the optimum approach for large landfills with multiple source areas.

5.3 INTEGRATION OF THE BIOREACTOR CELL INTO LANDFILL CLOSURE

The goal of this research was to investigate methods to accelerate the closure of unlined landfills. The bioreactor cell technology is intended to address a specific type of waste often encountered in landfills (i.e., chlorinated solvents). However, landfills typically contain other waste types in addition to chlorinated solvents. Unless the landfill contains only chlorinated solvent waste or the plan is to excavate the entire landfill during bioreactor cell construction, the technology cannot per se achieve landfill closure. For closure to be achieved, a cover would be required for any portions of the landfill where waste was left in place. In addition, the bioreactor cell technology may not treat all the potential groundwater contaminants. For example, groundwater beneath landfills often is contaminated with metals, such as arsenic and manganese, which are mobilized under reducing conditions. Until the substrate is depleted, the bioreactor cell could exacerbate commingled metals contamination.

The costing process for application of the bioreactor cell technology to a specific site should include the costs for the waste material outside the bioreactor cell footprint. If these costs are not included, the total landfill closure cost will be underestimated. Because of the need for any landfill remedy or corrective action to address all waste types, it is not expected that the bioreactor cell technology would decrease capital costs for landfill closure. The bioreactor cell technology must be implemented in conjunction with the excavation or covering of any waste material outside the bioreactor cell footprint. The potential cost benefit to be gained from the bioreactor cell would be decreased long-term monitoring (LTM) requirements if the dissolved phase contamination is dominated by chlorinated solvents or other contaminants amenable to remediation under anaerobic conditions. Even in this situation, a decrease in LTM requirements may not be realized due to the potential for commingled contaminants (e.g., arsenic, petroleum hydrocarbons) to linger under anaerobic conditions.

Because of the inability of the bioreactor cell technology to address commingled contamination, the technology may offer greater benefits at a non-landfill site with a well-defined chlorinated solvent source term and dissolved phase contamination.

6.0 IMPLEMENTATION ISSUES

6.1 COST OBSERVATIONS

Because the recirculation bioreactor was assembled with readily available components and conventional excavation techniques were used for construction, the actual costs incurred during the Altus AFB pilot test differed very little from the anticipated costs. Significantly higher costs would have been incurred if the excavated materials had been characterized as hazardous. Additionally, if hazardous or explosive conditions had been encountered during the excavation of the test cell, the cost would likely have been significantly higher than anticipated due to the need for implementation of contingency work procedures for health and safety reasons.

Analytical costs were a significant portion of the demonstration project budget and can be reduced for full-scale implementation of the technology. Analytical cost savings can be realized because 1) full-scale systems would not require the same density of groundwater monitoring points as the more research-oriented pilot-scale LF-03 bioreactor, and 2) the type and frequency of analyses for full-scale system performance monitoring can be reduced. At a minimum, the contaminants of concern and dissolved (or total) organic carbon should be analyzed to evaluate the remediation progress and strength/longevity of the carbon substrate. Less frequent (e.g., annual) monitoring of select geochemical parameters can reduce costs without sacrificing data quality objectives. Obtaining direct microbial evidence of biodegradation, including targeted gene analysis and PLFAs, is relatively expensive in terms of field labor and analytical costs and does not provide commensurate added-value for a long-term monitoring scenario. These specialized analyses should be reserved for troubleshooting system performance or other specific requirements rather than routine performance monitoring.

6.2 PERFORMANCE OBSERVATIONS

The original goal of the recirculation bioreactor was to reduce total CAH molar concentrations by 90% in shallow groundwater adjacent to the bioreactor. Because of the continuing upgradient TCE source and the slower biodegradation kinetics of VC and DCE compared to TCE, the CAH molar concentration increased over time. The organic mulch used in the bioreactor did provide a relatively long-lasting source of organic carbon (relative to soluble substrates such as fructose, lactate, or molasses) and produced conditions conducive to reductive dechlorination of TCE. The bioreactor was relatively effective at removing TCE and, to a lesser extent, DCE and VC, from the recirculated groundwater. A total CAH removal efficiency range of 76 to 96% was calculated for the five performance monitoring events.

The LF-03 pilot scale bioreactor at Altus AFB showed that the primary limitation for the technology was the inability to maintain significant levels of DOC and highly reducing conditions that are conducive to reductive dechlorination deeper than approximately 10 to 20 ft below the bioreactor. This limitation was likely due at least in part to the groundwater hydraulics at the site. The combination of the shallow depth of the extraction trench producing an upward hydraulic gradient and limited hydraulic head to produce a significant downward vertical gradient within the reactor caused the treatment zone at the site to be limited to shallower groundwater. Additionally, because the bioreactor was designed to be a long-lasting, slow-release source of organic carbon (i.e., relatively low DOC flux), the DOC was biodegraded (e.g., used to reduce high native sulfate levels) relatively close to the bioreactor cell rather than migrating deeper in the aquifer. Although it was intended that the mulch bioreactor provide a long-lasting source of DOC, the data indicated depletion of the leachable substrate in approximately 2 years.

In general, the reliability of the recirculation system during the 2-year operating period was good. The system as a whole was relatively simple, with few mechanical parts. The solar pump operated as planned with no mechanical problems. Operational data indicate that significant fouling of the drip irrigation system did not occur.

6.3 SCALE-UP

Scale-up of the recirculation bioreactor technology is feasible and, barring unforeseen conditions or circumstances, would likely not pose significant problems. The pilot-scale bioreactor installed at LF-03 was constructed with readily available off-the-shelf components. Each application of the bioreactor technology should be designed to site-specific factors such as depth to the water table (including seasonal or tidal fluctuations), and hydraulic conductivity of the aquifer. The carbon substrate for full-scale systems should make use of locally available organic materials to the extent practical. Scale-up would likely require a longer or deeper extraction trench, multiple pumps, and larger piping. More detailed hydrogeologic analysis may be necessary to ensure capture of potential daughter product plume without diluting the DOC concentrations. Consideration during the design of the bioreactor should be given to vehicle access to the site. Designated access roads may be desirable for larger-scale bioreactor systems and should be designed to avoid damage to the distribution lines. A significant scale-up constraint for the recirculation bioreactor technology may be the disposal of excavated materials from the site. The design of the bioreactor should be optimized by locating it within the source area in order to minimize construction and soil disposal costs.

6.4 OTHER SIGNIFICANT OBSERVATIONS

Full-scale implementation of the technology may include injecting amendments such as liquid carbon substrates (e.g., vegetable oil, lactate), nutrients, or bioaugmentation cultures. This can be readily accomplished via the recirculation system or dedicated injection piping. Design and construction of a bioreactor system with injection piping built into the system for adding amendments is more economical than retrofitting an existing system.

Vapor monitoring and potentially also vapor extraction may be required at sites located near buildings or utility corridors. Additional instrumentation that may be useful for evaluating the performance of the bioreactor cell and extraction trench are pressure transducers for automatic water level recording, thermocouples for monitoring temperatures in the cell, and a data acquisition system for remote monitoring of system parameters.

6.5 LESSONS LEARNED

The following bullets summarize the lessons learned for this demonstration project.

- Preconstruction site characterization, including adequate source area definition, is critical to the successful implementation of the technology.
- The technology may not be appropriate where the desired treatment zone extends more than approximately 10 to 20 ft below the water table.
- Persistent TCE source areas can lead to undesirable accumulation of daughter products (e.g., DCE and VC). This can potentially be remedied by bioaugmenting the bioreactor with a commercial microbial culture capable of completely degrading DCE and VC to ethene and periodically recharging the organic carbon content.
- Proper location and design of the groundwater extraction trench is a key component for preventing excessive downgradient migration of daughter products and for maximizing the vertical extent of the treatment zone in the aquifer.
- Although mulch is a relatively versatile and long-lasting carbon source, the relatively low rate of DOC flux from the mulch limits the distance the DOC can migrate from the bioreactor cell before it is biodegraded. The periodic addition of a liquid carbon substrate to the bioreactor (e.g., vegetable oil) may be an effective means of mitigating this limitation and extending the longevity of the carbon source. Spraying the mulch with a low-cost, slowly soluble, long-lasting substrate such as vegetable oil during bioreactor construction should be considered.
- The data indicated that the technology has limited ability to contain the dissolved contamination if source area(s) remain at the site.

6.6 END-USER ISSUES

The results of this project are directly applicable to future landfill and CAH spill site remediation decisions at Altus AFB and within the broader DoD and regulatory community. A full-scale recirculation bioreactor is funded for fiscal year 2007 construction at Altus AFB Site SS-17. The recirculation bioreactor concept is also being employed by the Army at Camp Stanley, Texas to introduce DOC into a fractured limestone aquifer contaminated with CAHs. The results of this pilot test may encourage the application of the bioreactor concept at additional DoD landfills as an alternative to traditional landfill closure techniques. To that end, it will be important to disseminate the results of this project within the DoD and USEPA. These findings could also have significant impact on the remediation and closure of thousands of industrial and municipal landfills that exhibit some level of CAH contamination. Publications in scientific and trade journals and presentations at industry and DoD conferences have been used to advance these concepts (Downey et al., 2004, 2005, and 2006).

Although the pilot-scale bioreactor was installed to test the technology at a TCE-impacted site at Altus AFB, LF-03, enhanced anaerobic bioremediation can also be applied to treat the following constituents (Parsons, 2004):

- Chlorobenzenes
- Chlorinated pesticides (e.g., chlordane) and polychlorinated biphenyls
- Chlorinated cyclic hydrocarbons (e.g., pentachlorophenol)

- Oxidizers such as perchlorate and chlorate
- Explosive and ordnance compounds
- Selected dissolved metals (e.g., hexavalent chromium)
- Nitrate and sulfate.

A primary concern for using a bioreactor or any enhanced bioremediation technology is the potential for production of toxic by-products such as VC at TCE- and PCE-contaminated sites. Therefore, adequate capture of more-toxic reductive dechlorination “daughter” products in groundwater exiting the bioreactor may be an important element of the bioreactor design process, depending on the prevailing reduction-oxidation conditions in the aquifer. The LF-03 bioreactor resulted in the production of daughter products; however, field demonstration results remain inconclusive as to whether there was an overall reduction in the toxicity of source area groundwater.

Additional concerns include the potential for subsidence of the mulch and accumulation of vapors in the vadose zone. The eventual subsidence of the mulch bioreactor may make this technology unsuitable for areas where future buildings and/or roads are planned. The potential for elevated concentrations of toxic or explosive vapors in the vadose zone should be addressed during the design of the bioreactor system.

6.7 APPROACH TO REGULATORY COMPLIANCE AND ACCEPTANCE

No special permits were required to install and operate the bioreactor at LF-03. However, digging permits were obtained from Altus AFB prior to intrusive activities, and Base access permits were obtained for the field personnel. In some states, permits may be required to re-inject extracted groundwater. Altus AFB personnel discussed this demonstration project with USEPA oversight personnel and obtained their support. Formal approval by the USEPA was not required.

7.0 REFERENCES

Bagchi, A. 1990. *Design, Construction, and Monitoring of Sanitary Landfills*. John Wiley & Sons, Inc. Canada.

Downey, Douglas C., J.R. Hicks, M. Krumholz, A. Leeson, A. Becvar, A. Wallon, and C. Butchee. 2004. Removing Chlorinated Hot Spots in Landfills Using In Situ Bioreactors. abstract. AFCEE Joint Service Environmental Management Conference. San Antonio, Texas.

Downey, Douglas C., J.R. Hicks, M. Krumholz, A. Leeson, A. Becvar, A. Wallon, and C. Butchee. 2005. Performance of a Recirculation Bioreactor at a Landfill Contaminated with Chlorinated Solvents. In Situ and On-Site Bioremediation. Eighth International Symposium. June.

Downey, Douglas C., B. Henry B., D. Griffiths J.R. Hicks, A. Becvar, S. Moore, and C. Butchee. 2006. Toxicity Reduction – A Key Metric for Enhanced Bioremediation of Chlorinated Solvents. Fifth International Conference on Remediation of Chlorinated and Recalcitrant Compounds. Monterey, California. May 22-25.

Earth Tech. 2002. RCRA Facilities Investigation (RFI)/Interim Action (IA)/Corrective Measures Study (CMS), Altus AFB, Oklahoma, Version 1.0. January 15.

Federal Remediation Technologies Roundtable. 1998. Guide to Documenting and Managing Cost and Performance Information for Remediation Projects (Revised Version). EPA 542-B-98-007. October 1998. www.frtr.gov.

Parsons Engineering Science, Inc. 1999. Remediation by Natural Attenuation Treatability Study Report, Operable Unit 1, Altus Air Force Base, Altus, Oklahoma. December.

Parsons Corp. (Parsons). 2002. Final Work Plan for In Situ Bioremediation of Chlorinated Solvents Using a Permeable Biowall at Operable Unit 1, Altus Air Force Base, Altus, Oklahoma. April.

Parsons. 2004. Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents. Final document prepared for Air Force Center for Environmental Excellence, Naval Facilities Engineering Service Center and Environmental Security Technology Certification Program. August.

Parsons. 2006. Bioreactor Demonstration at Landfill 3, Altus Air Force Base, Oklahoma. Final Report. Environmental Security Technology Certification Program Project No. 200019. 22 November.

USEPA. 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. EPA/600/R-98/128. September.

USEPA. 2001. Cost Analysis for Selected Groundwater Cleanup Projects: Pump and Treat Systems and Permeable Reactive Barriers. EPA-542-R-00-013. February.

Wiedemeier, T.H., H.S. Rifai, C.J. Newell, and J.T. Wilson. 1999. Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface. John Wiley & Sons, New York, New York.

APPENDIX A

POINTS OF CONTACT

Point of Contact	Organization	Phone Fax E-Mail	Role
John Hicks	1700 Broadway Suite 900 Denver, CO 80290	303-764-1941 John.hicks@parsons.com	Project Manager and Principal Investigator
Jason Bidgood, P.E.	1700 Broadway Suite 900 Denver, CO 80290	303-764-8836 jason.bidgood@parsons.com	Parsons Project Engineer
Chuck Butchee	97 CES/CEVR 401 L Avenue Altus AFB, OK 73523	580-481-5187 charles.butchee@altus.af.mil	Altus AFB Technical Point of Contact
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COST AND PERFORMANCE REPORT

In Situ Permeable Reactive Barrier for Contaminated Groundwater at the Moffett Federal Airfield Mountain View, California

September 1998

EPA

Prepared by:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

SITE INFORMATION

Identifying Information:

Moffett Federal Airfield
Mountain View, California

CERCLIS #: Not applicable

ROD Date: Not applicable

Treatment Application:

Type of Action: Pilot Test

Period of operation: April 1996 - Ongoing (Performance data collected through July 1997)

Quantity of material treated during application: 284,000 gallons of groundwater

Background [2]

Historical Activity that Generated Contamination at the Site: Service and support for Navy aircraft

Corresponding SIC Code: 3728 (Aircraft parts and Auxiliary Equipment)

Waste Management Practice That Contributed to Contamination: Leaking underground and aboveground storage tanks, waste sumps; on-site migration of contaminants from Silicon Valley plume

Location: Mountain View, California

Facility Operations [1, 2]:
- Moffett Federal Airfield (MFA) is a former Navy facility providing support, training, operation, and maintenance associated with Navy aircraft. Aircraft engine repairs and aircraft maintenance have been performed on site for many years. Cleanup and contaminant identification activities have been underway at MFA since 1987.

- This report addresses a Permeable Reactive Barrier (PRB) pilot study that, if effective, will be scaled up to remediate a large portion of the shallow aquifer at MFA. Currently, the PRB intercepts and treats contaminated groundwater immediately downgradient of a single source area at MFA. This site is complicated by the presence of a large groundwater plume that crosses MFA from off-site sources. The Navy is working with the responsible parties for the off-site sources to remediate the groundwater contamination.

- Remedial investigations were started in August 1990 and completed in April 1991 by International Technology Corporation and Tetra Tech EM, Inc.

- Contaminants in the area of the PRB consist primarily of chlorinated solvents. Specific activities that contributed to the source at MFA included dry cleaning operations.

- The Navy and Department of Defense Environmental Security Technology Certification Program (ESTCP) is funding this PRB as a pilot study for treating a portion of the large plume that crosses MFA.

- Remedial performance monitoring is being conducted by Tetra Tech EM and the PRB performance evaluation is being conducted by Battelle Memorial Institute (Columbus operations).

Regulatory Context:
The PRB was constructed as part of a voluntary pilot-scale study to demonstrate the effectiveness of the PRB for treating a groundwater plume of chlorinated solvents.

Groundwater Remedy Selection:
An *in situ* PRB was selected for a pilot study at this site.

SITE INFORMATION (CONT.)

Site Logistics/Contacts

Site Lead: U.S. Navy

Oversight: EPA

Treatment System Vendors:
Tim Mower*
Tetra Tech EM
1099 18th Street, Ste. 1960
Denver, CO 80202
303-312-8874

Chuck Reeter*
Naval Facilities Engineering Service Center
1100 23rd Ave., Code 411
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*Indicates primary contacts

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EPA Contact:
Lynn Suer
EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
415-744-2396

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Groundwater

Contaminant Characterization [2, 3]

Primary Contaminant Groups: Halogenated volatile organic compounds (VOCs)

- Contaminants detected near the location of the treatment wall include perchloroethene (PCE), trichloroethene (TCE), *cis-* and *trans*-1,2-dichloroethene (1,2-DCE), 1,1-dichloroethene (1,1-DCE), and 1,1-dichloroethane (1,1-DCA). Historically, 1,2-DCE and TCE are the predominant groundwater contaminants in the vicinity of the PRB.

- Maximum contaminant concentrations detected during 1991 investigations include 20,000 µg/L of TCE and 500 µg/L of PCE. In June 1996, TCE levels of over 5,000 µg/L were measured upgradient of the wall location. This may indicate that the plume originates from a continuous source.

- Figure 1 is a contour map that depicts TCE concentrations detected in February/March 1995. The 2,000 µg/L TCE contour line is closest to the treatment wall location.

- Dense nonaqueous phase liquid (DNAPL) presence is likely because of elevated concentrations detected in groundwater samples and processes known to have occurred at the facility. The maximum concentration of TCE detected was near 2% of its solubility limit.

- In 1991, the TCE plume was estimated to be over 10,000 feet long and 5,000 feet wide. Contaminants have been detected to a depth of 70 feet. The volume of the contaminant plume was estimated to be 5.6 billion gallons in the remedial investigation (RI) report. The PRB at MFA is treating a small part of this plume located in a shallow aquifer immediately downgradient of a source area.

MATRIX DESCRIPTION (CONT.)

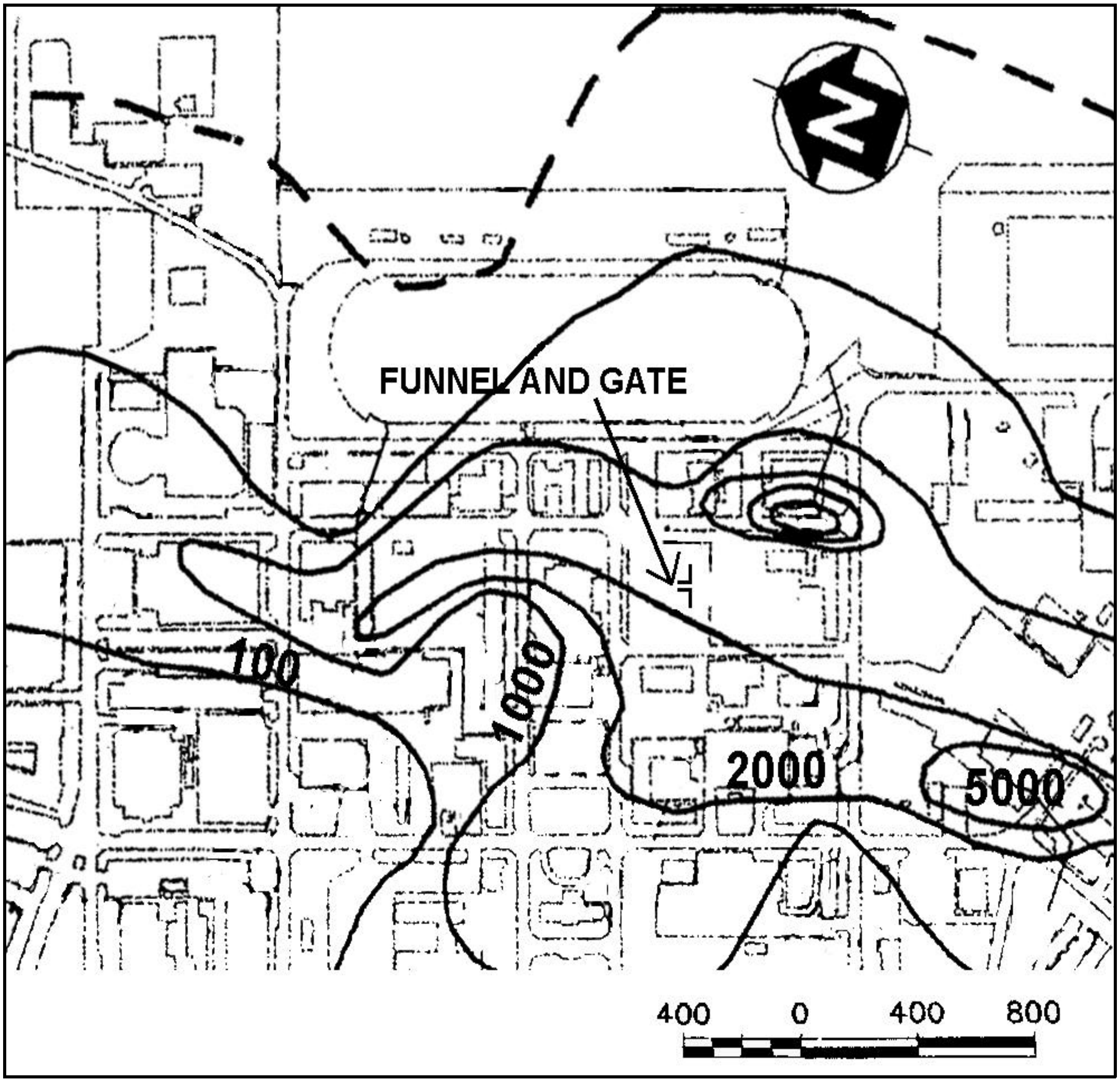

Figure 1. TCE Concentration (µg/L) (February/March 1995) [2]

MATRIX DESCRIPTION (CONT.)

Matrix Characteristics Affecting Treatment Costs or Performance [2]

Hydrogeology:

Five distinct hydrogeologic units have been identified beneath this site. Groundwater is found approximately five feet below ground surface. MFA lies on a relatively flat depression, known as Santa Clara Valley, present between the San Andreas and Hayward Faults. Regionally, the Santa Clara Valley contains up to 1,500 feet of interbedded alluvial, fluvial, and estuarine deposits. These sediments consist of varying combinations of clay, silt, sand, and gravel. Subsurface sediments have been divided into the A, B, and C aquifers. Most contaminants at MFA are found within the A aquifer, which includes two permeable zones. The PRB is designed to treat only those contaminants in the A1 unit.

Unit A1	Surficial Sediments	Fine- to coarse-grained material. Uppermost permeable zone, highly contaminated. A discontinuous confining bed is present beneath this unit. Upward hydraulic gradients are present between units A1 and A2.
Unit A2	Surficial Sediments	Fine- to coarse-grained material. Highly contaminated and having a continuous 5- to 7-foot thick clay aquitard beneath. Upward hydraulic gradients are present between the A and B aquifers.
Unit B1	Fluvial Sediments	Thin sand and gravel beds in a fine-grained matrix. Not contaminated, highly conductive (similar to A aquifer).
Unit B2	Fluvial Sediments	Thin sand and gravel beds in a fine-grained matrix.
Unit C	Estuarine Sediments	Fine to medium clayey and silty sand.

Tables 1 and 2 include technical aquifer information and technical wall data, respectively.

Table 1. Technical Aquifer Information

Unit	Thickness (ft)	Conductivity (ft/day)	Average Velocity (ft/day)	Flow Direction
A1	25	1 - 400	0.005 - 2	North
A2	40	30 - 200	0.15 - 1	North
B1	45	0.3 - 50	0.0014 - 0.22	North
B2	15	0.4 - 40	0.0018 - 0.18	North
C	>100	Not available	Not available	Not available

Source: [2]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology

Permeable Reactive Barrier (PRB)

Supplemental Treatment Technology

None

System Description and Operation

Table 2. Treatment Wall Data

Unit	Flow-Through Thickness	Conductivity (ft/day)	Material	Vertical Thickness
Flow Control Zone	2 feet	>1,000	Pea gravel	18 feet
Continuous Treatment Wall	6 feet	1,000	100% Granular iron	18 feet
Flow Control Zone	2 feet	>1,000	Pea gravel	18 feet

Source: [2,4]

System Description [2, 3, 4, 7]

- The PRB is a passive, *in situ* treatment technology that makes use of natural groundwater flow to carry contaminants through the reaction zone.

- The PRB, installed in 1996, is a funnel and gate iron treatment wall system. The components include two sheet pile walls, permeability zones upgradient and downgradient of the wall, and the reactive zone. Table 2 provides technical wall data. Figures 2 and 3 illustrate the layout and dimensions of the PRB.

- Two sheet pile walls measuring 20 feet in length extend at a 90^o angle from the wall (perpendicular to groundwater flow direction). These walls act as a funnel to force more of the contaminant plume through the PRB.

- The PRB is composed of 100% granular iron, has 6 feet of flow-through thickness, is 10 feet wide, and 18 feet high beginning 5 feet below ground surface. The flow control zones upgradient and downgradient of the wall are composed of pea gravel and have 2 feet of flow-through thickness.

- The PRB extends down through Unit A1, but is not keyed into the low conductivity unit comprised of clayey fine sand to silty clay that is found at a depth of approximately 23 to 25 feet below ground surface. This material is not classified as an aquitard; however, it is believed to inhibit contaminant transport to Unit A2. The iron filings begin at a depth of 5 feet below ground surface, which corresponds with the groundwater table. Native soil was backfilled above this depth. Two feet of concrete and bentonite were placed below the iron to prevent downward migration of contaminants.

- The PRB utilizes reactive zero-valent iron to dehalogenate the chlorinated compounds to chloride and ethylene.

- The actual residence time in the treatment zone for the dechlorination and reduction reactions has been estimated to be approximately 96 hours based on the highest concentration scenario. A minimal residence time of 48 hours is required to degrade contaminants to meet cleanup goals.

TREATMENT SYSTEM DESCRIPTION (CONT.)

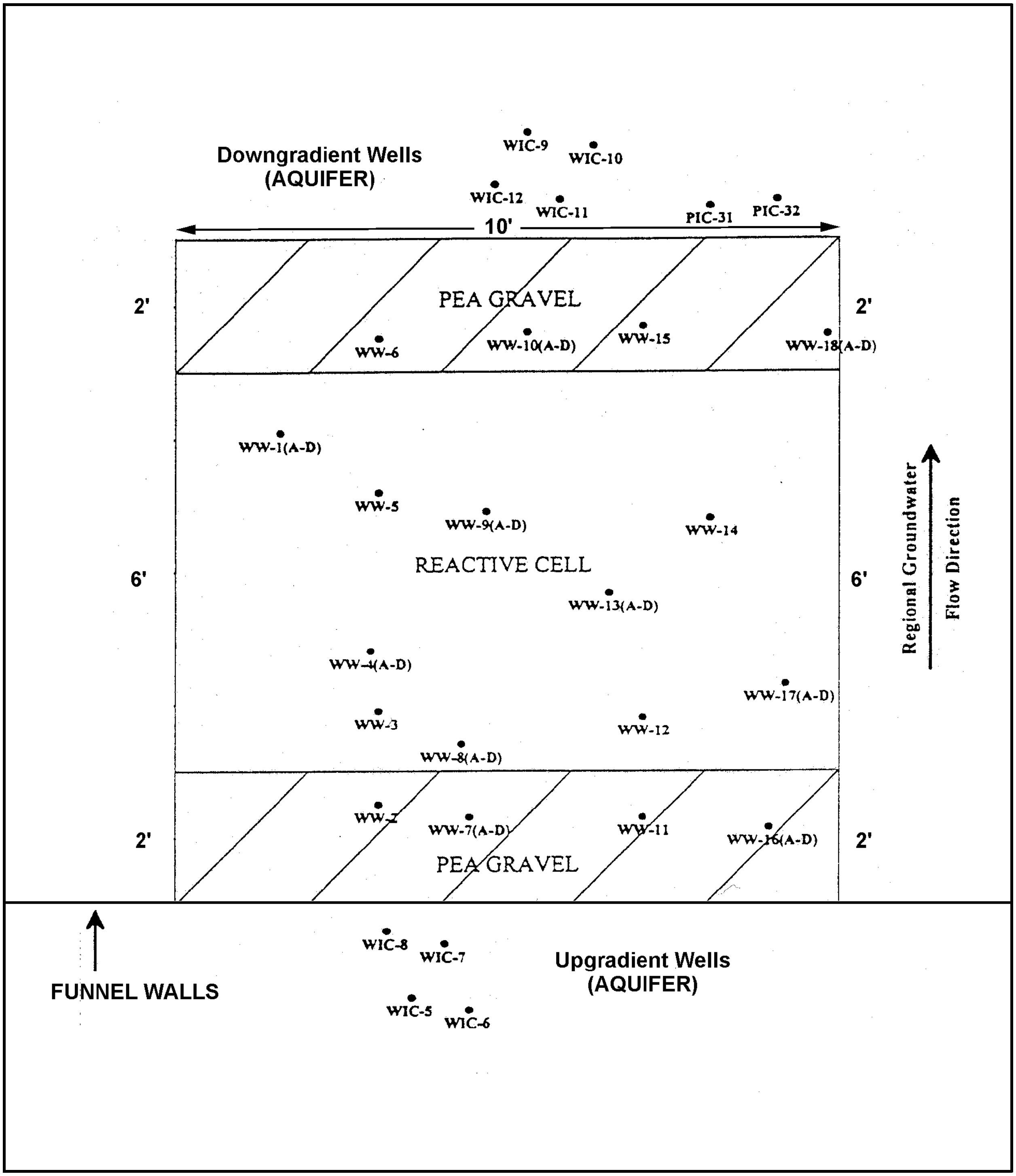

Figure 2. Funnel and Gate Plan View [3]

TREATMENT SYSTEM DESCRIPTION (CONT.)

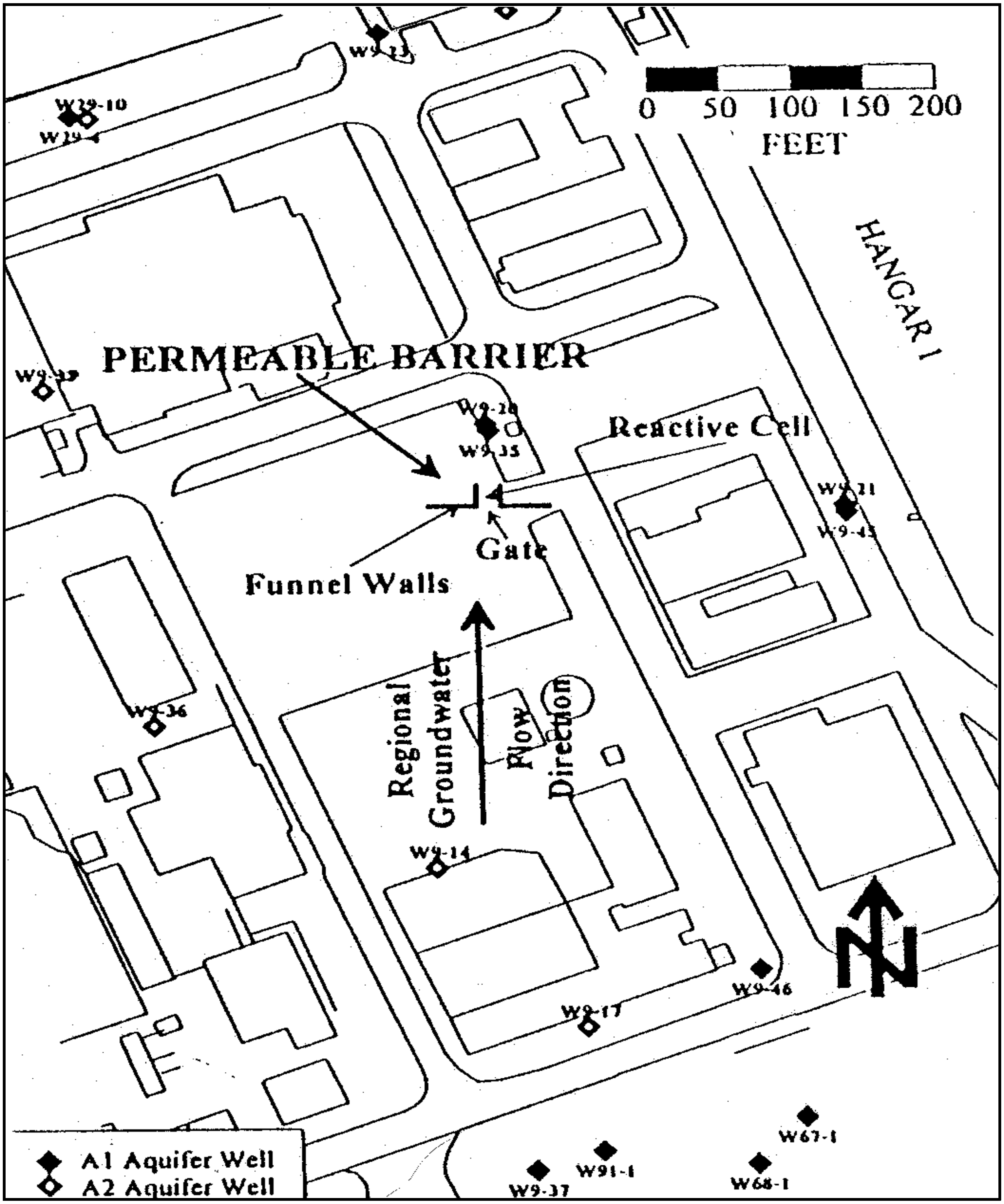

Figure 3. Site Plan [2]

TREATMENT SYSTEM DESCRIPTION (CONT.)

System Description and Operation Source (Cont.)

- Twenty-eight multi-level monitoring wells are located within the treatment zone. These wells are placed at 1 to 2 foot intervals to monitor contaminant concentration reduction through the wall. Four wells are located both upgradient and downgradient of the treatment zone to monitor influent and effluent concentrations.

System Operation [1, 2, 7-10]

- Quantity of groundwater treated:

Time Frame	Approximate Volume Treated
1996-1997	*284,000 gallons*

Based on average groundwater velocity of 0.5 ft/day, and dimensions of 10 feet wide and 18 feet deep [2].

- Since April 1996, the PRB has been 100% operational.

- There have been no maintenance requirements for the treatment wall to date. The reactive media may need to be replaced if the wall becomes clogged or ineffective. The monitoring plan requires monitoring of the wall for plugging and continued effectiveness. Sampling in December 1997 indicated no significant clogging.

- Monitoring wells and research sampling points are sampled quarterly, for piezometric head to evaluate groundwater velocity and flow direction through the treatment wall.

Operating Parameters Affecting Treatment Cost or Performance

Table 3 presents operating parameters affecting cost and performance for this technology.

Table 3: Performance Parameters

Parameter	Value
Average Flow Rate through Treatment Wall	0.5 ft/day [Estimate used for calculation purposes [9]]
Required Residence Time	48 hours

Source: [1]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Timeline

Table 4 presents a timeline for this pilot-scale project.

Table 4: Project Timeline

Start Date	End Date	Activity
4/95	8/95	Lab tests and column studies performed
8/95	1/96	Treatment wall designed
1/96	---	Procurement process begun
4/96	5/96	3-week construction period
6/96	---	First sampling event conducted
9/96	---	Second sampling event conducted
1/97	---	Third sampling event conducted
4/97	---	Fourth sampling event conducted
7/97	---	Fifth sampling event conducted (in conjunction with tracer test)
10/97	---	Sixth sampling event conducted

Source: [1]

TREATMENT SYSTEM PERFORMANCE

Treatment Performance Goals [1]

The objectives of the pilot project are to: (1) demonstrate and validate the PRB technology in remediating groundwater contaminated with chlorinated hydrocarbons; (2) evaluate the long-term effectiveness of the barrier from a hydraulic standpoint; and (3) develop cost and performance data [7].

Performance Data Assessment [3, 6]

- Data from sampling events in January, April, and July 1997 showed that chlorinated VOC concentrations were being reduced as the groundwater moves through the reactive zone. For example, TCE concentrations measured in upgradient wells during April 1997 were reduced to below the detection limit within the reactive zone. PCE and 1,2-DCE were also reduced to below the detection limit within the reactive zone.

- Figure 4 shows that *cis*-1,2-DCE and TCE concentrations decrease as the groundwater flows through the PRB. An average of the January 1997 and April 1997 data at specific intervals through the wall was used to generate this figure. TCE concentrations in the upgradient wells are near 1,000 µg/L; at 4 feet into the PRB, TCE concentrations are approximately 1 µg/L. *Cis-1,2*-DCE concentrations begin near 200 µg/L upgradient and decrease to less than 10 µg/L by the 4-foot interval.

- Figure 5 presents mass flux data calculated for the January, April, and July sampling events. This figure indicates that mass removed by the PRB has increased from .007 lbs/day to .0086 lbs/day over the three sampling events. TCE and *cis*-1,2-DCE concentrations were used for this calculation as they account for most of the total contaminant mass entering the PRB.

TREATMENT SYSTEM PERFORMANCE (CONT.)

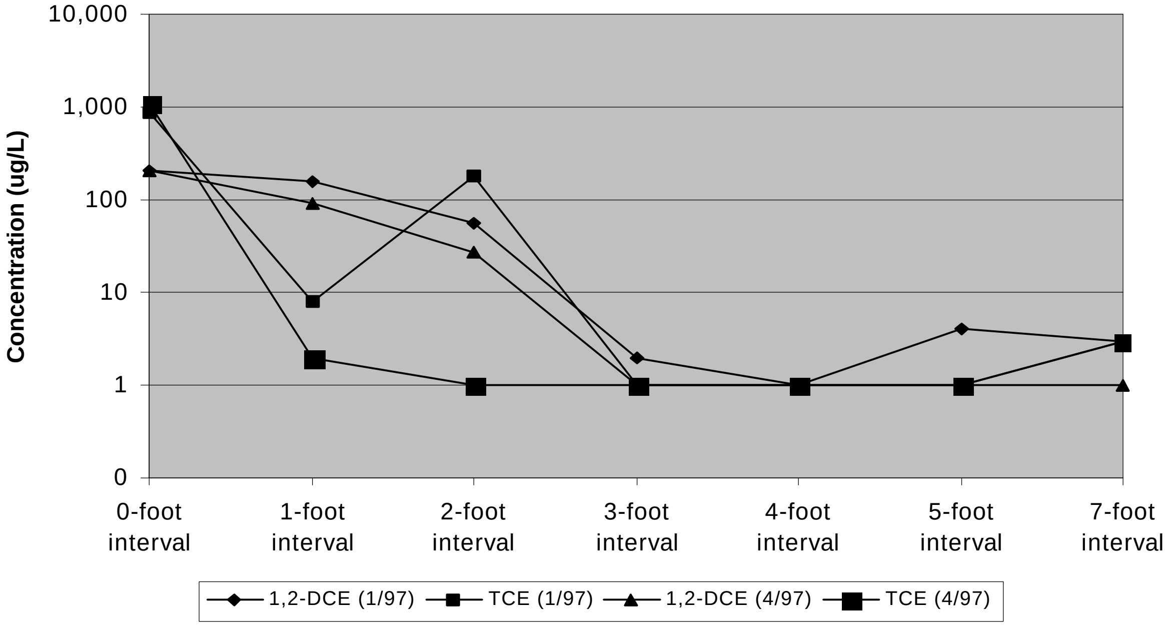

Figure 4. Concentration Reduction Through the PRB ***[3]***

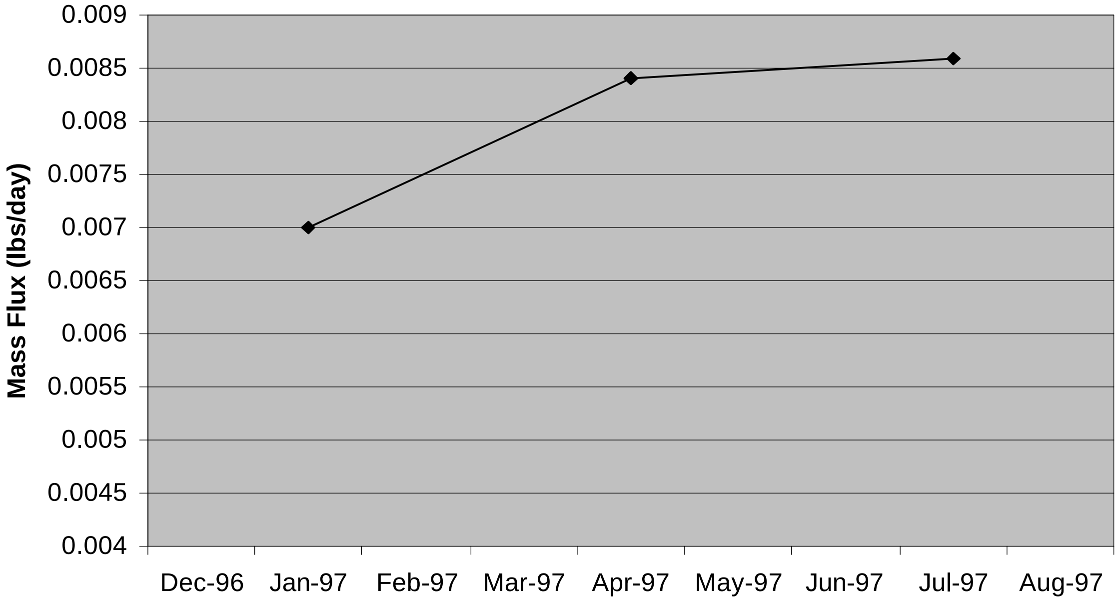

Figure 5. Mass Removal Through the PRB (January - July 1997) ***[3]***

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (Cont.)

- A tracer test was performed in July 1997 to assess performance of the PRB and to determine groundwater flow direction and velocity measurements within the treatment wall. The tracer test was performed using potassium bromide tracers. The results of the tracer test indicated that some lateral flow occurs within the wall and flow patterns appear to be rather complex (not always in straight lines). The flow patterns are attributed to the differential compaction of granular iron throughout the wall. Overall, flow velocities were lower than expected based on previous site characterization and modeling.

- Results from the tracer test indicate that flow velocity through the cell ranges from 0.05 to 0.45 ft/day. According to the contractor that performed the test (Battelle Columbus Operations), these flow velocities were much lower than were predicted by site characterization and modeling (about 3 ft/day), water level measurements (up to 5 ft/day), and downhole velocity measurement (1.1 to 6.1 ft/day) [6, 7].

- Cores of *in situ* iron were collected in December 1997 and analyzed for evidence of precipitates and corrosion materials that may reduce hydraulic and remedial effectiveness of the barrier. Microbial analysis of cored material also was conducted to assess presence of iron oxidizing or sulfate reducing bacteria [7].

Performance Data Completeness [1]

- Seventy-two monitoring wells are sampled quarterly. After one year of operation, the monitoring schedule may be adjusted if needed. The large number of wells are sampled for research purposes. According to Battelle, this number of wells exceeds the typical protocol necessary to demonstrate that the PRB is functioning properly and meeting treatment goals.

- Data from the January, April and July 1997 quarterly sampling events were available for this report. Additionally, a tracer test study was performed in July and also available for this report.

- In Figure 4, 2 µg/L is the detection limit. When data was reported as below detection limits, half the detection limit (1 µg/L) was used in the future.

Performance Data Quality

The QA/QC program used throughout the remedial action met the EPA and the State of California requirements. All monitoring was performed using EPA-approved methods, Method 353.1, Method N-601, SW-846 Method 8240, SW-846 Method 8020. Laboratory reports for the April 1997 sampling event indicated that detection limits were unacceptably high for the A1 aquifer zone wells and upgradient pea gravel wells due to excessive sampling dilution. The laboratory was asked to reanalyze samples. However, because the holding time had elapsed, the affected wells were resampled in July 1997.

The Navy is the lead for this site. MFA is responsible for on-site activities and oversight. EPA views the research activity as a means of remediating for a portion of the plume.

Cost Analysis

All costs for design, construction, and operation of the treatment system at this site are borne by the Navy and DoD.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Capital Costs

Remedial Construction	
System Installation	$323,000
Iron	$50,000
Total Remedial Construction	$373,000

Operating Costs

Monitoring/Analytical	$32,000[a]

[a] First annual monitoring and analytical contract

Cost Data Quality

Actual capital and operating and maintenance cost data are available from the Navy contact for this site.

OBSERVATIONS AND LESSONS LEARNED

- The cost for groundwater remediation at this site over one year was approximately $405,000 ($373,000 in capital costs and $32,000 in operating costs), corresponding to a unit cost of $1,400 per 1,000 gallons of groundwater treated.
- Based on sampling data from the January, April, and July sampling events, concentrations of PCE, TCE, and 1,2-DCE are being reduced as groundwater passes through the reactive zone.
- Data from monitoring points within the iron show that, by the fourth foot of iron, contaminant concentrations were reduced below detection limits.
- Mass flux was calculated from the quarterly data and an estimate of groundwater velocity from the tracer test conducted in July. Mass flux data have increased over the three sampling events indicating an increase in influent concentrations, while treatment goals continue to be met.
- ESTCP is sponsoring performance monitoring and cost data collection for technology certification and validation. Performance sampling is scheduled to continue on an annual basis for at least two more years. The final technology evaluation report is planned to be completed by August 1998. Proposals are being presented to continue the sampling process annually or semiannually.

REFERENCES

1. Draft Performance Monitoring Plan, Battelle Columbus Operations, Cleveland, Ohio, September 16, 1996.
2. Draft Operable Unit 4 Feasibility Study Report, PRC Environmental Management, Inc., Denver, Colorado, August 3, 1992.
3. April 1997 Monitoring Report for the Pilot Permeable Barrier at Moffett Federal Airfield, Battelle, September 1997.
4. Phone Conversations with Deidre O'Dwyer, June 21, 1997.
5. Phone Conversations with Tim Mower, Tetra Tech EM Inc., May 28, 1997.
6. Field Tracer Application to Evaluate the Hydraulic Performance of the Pilot-Scale Permeable Barrier at Moffett Federal Airfield, Battelle, October 1997.

REFERENCES (CONT.)

7. Permeable Reactive Wall Remediation of Chlorinated Hyrdocarbons in Groundwater at Moffett Federal Airfield, Mountain View, California, IBC Proceedings, January 1998.

8. Comments on draft report from Chuck Reeter, NFRSC, July 8, 1998.

9. Comments on draft report from Michael Gill, Region IX RPM, July 17, 1998.

10. Comments on draft report from Tim Mower, Tetra Tech EM Inc., July 17, 1998.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Eastern Research Group, Inc. and Tetra Tech EM Inc. under EPA Contract No. 68-W4-0004.

G-2050

FINAL

Report for Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater

Offutt Air Force Base, Nebraska
Building 301

Prepared for the Air Force Center for Environmental Excellence,
Brooks City-Base, TX and the
55th Civil Engineering Squadron, Offutt AFB, NE

Approved for Public Release, Distribution Unlimited

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Contract Number F41624-97-C-8020

Prepared By:
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FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

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FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

1.0 OVERVIEW

This report discusses the installation of a 500 ft mulch wall to remediate chlorinated hydrocarbon-impacted groundwater west of Building 301 at Offutt Air Force Base, Nebraska. The mulch wall was configured to extend southward approximately 400 feet from the existing pilot mulch wall to capture the complete width of the plume. The mulch wall was filled with coarse sand mixed with mulch produced at the Base. The mulch wall was designed to act as a permeable reactive wall, containing a slow-release long-lasting source of electron donor. The organic matter in the mulch ferments, producing hydrogen that can be used to stimulate reductive dechlorination of chlorinated hydrocarbons in groundwater passing through the wall.

The conceptual model for the stimulation of reductive dechlorination is that bioavailable organic constituents in the mulch act as a source of carbon for aerobic bacteria, thereby lowering the dissolved oxygen concentration and redox potential in the aquifer. Once anaerobic conditions are created, fermentation of the organic constituents generates hydrogen and acetate, which can be used to promote biological reductive dechlorination (Holliger et al., 1993; Carr and Hughes, 1998; He et al., 2002). Trichloroethylene (TCE) undergoes reductive dechlorination stepwise through cis-1,2-dichloroethylene (cis-DCE), vinyl chloride (VC), ethene, and ethane. Chlorinated solvent removal may also occur via sorption and other biological and abiotic processes.

2.0 SITE DESCRIPTION AND HYDROGEOLOGIC SETTING

Offutt AFB is located approximately five miles south of Omaha, Nebraska. Building 301 (B301) is located in the northwestern part of the Base, approximately 1500 ft from the railway tracks and 4300 ft from Papillion Creek (Figure 1).

B301 is situated on a dissected Pleistocene alluvial terrace remnant of the Missouri River with moderately sloping rolling hills. To the west of B301, the ground surface slopes steeply downward into the Papillion Creek alluvial valley. More gradual downward slopes are present to the south and east of the building. Much of the area surrounding B301 is paved for the numerous roadways and parking lots that serve B301 as shown in Figure 2.

The 500-ft mulch wall was installed about 150 feet east of MW-9S. In this area, the subsurface soil material consists of approximately 1-3 feet of fill, overlying either a stiff, black, low plastic, silty clay (topsoil) or a stiff to very stiff, light to reddish brown, low plastic, silty clay (Peoria and Loveland Loess). Near and west of the Base boundary, depth to groundwater is only 3 to 10 bgs. Depth to groundwater is approximately 6 ft bgs near MW-9S. A groundwater seep is located near the B301-MW-19 cluster at the west property boundary (Figures 2 and 3).

The groundwater flow is predominantly westward, toward Papillion Creek. The hydraulic conductivity in the alluvial silt and clay near MW-9S averaged 3.5 ft/day or 1.2 E-3 cm/sec (mean of 5 slug tests in alluvial silt and clay). The hydraulic gradient was 0.01 ft/ft. Using an assumed effective porosity of 0.15, the groundwater seepage velocity was calculated to be 0.23 ft/day or 85 ft/yr (Parsons Engineering Science, 1997). The measured hydraulic conductivity at MW-19S (located 300 ft south of MW-9S) in 1997 was 26 ft/day or 9 E-3 cm/sec. No north-south cross-sections of the area were available prior to wall installation.

3.0 AFFECTED ENVIRONMENTAL MEDIA

Groundwater quality data obtained during previous groundwater investigations at the site indicated that chlorinated solvents were the primary contaminants of concern in the groundwater. TCE was the most prevalent chlorinated solvent constituent in both extent and concentration in the groundwater at B301. The TCE distribution based on Spring 2000 long-term monitoring (LTM) and historical sample results are presented in Figure 2. The source of TCE contamination appeared to be located beneath the northwestern corner of B301, as evidenced by the relatively elevated TCE concentration (8,700 ug/L in the groundwater from MW-18I measured on 4/24/00). The plume extended westward approximately 3,300 ft from the suspected source area. An east-west cross-section of the plume is presented in Figure 3. The location of the cross-section corresponds to the A-A' transect shown on Figure 2.

4.0 PILOT-SCALE MULCH WALL RESULTS

In January, 1999, a pilot-scale mulch wall (100 ft long x 1 ft wide x 23 ft deep) was installed at Site B301, Offutt AFB, NE to evaluate the technology for its effectiveness for the treatment of TCE-contaminated groundwater. The mulch wall successfully turned the aerobic aquifer anaerobic and facilitated the treatment of TCE-impacted groundwater (GSI, 2001). TCE concentrations averaging 800 ug/L decreased 70%, with minimal generation of vinyl chloride, reduction in performance, or fouling. Because of these favorable results, a full-scale mulch wall was commissioned at Offutt AFB to treat the entire width and depth of the plume near the western Base boundary.

5.0 INSTALLATION OF FULL-SCALE MULCH WALL

5.1 Remedial Objectives

At the direction of the Air Force Center for Environmental Excellence, a full-scale mulch wall was commissioned to treat the entire width and depth of the plume just upgradient of the pilot wall location. The mulch wall was intended to be used as a polishing step in conjunction with an upgradient zero valent iron wall (Figure 3) to reduce chlorinated constituents to maximum contaminant level (MCL) concentrations at the Base boundary. The mulch wall was installed before the iron wall due to the availability of funding. Therefore, this report focuses on the performance of the mulch wall alone and the efficacy of it and the pilot wall on reducing concentrations in MW-9S near the Base boundary.

5.2 Mulch Wall Dimensions

A plan view of the mulch wall relative to the TCE plume is shown on Figure 4. The mulch wall was constructed to intercept the complete width and depth of the chlorinated hydrocarbon plume, based on data collected during the Spring 2000 LTM program (Figures 2 and 3) conducted by URS of Omaha, Nebraska. Accordingly, the mulch wall was constructed to a depth of 25 feet below existing grade, a width of 18 inches, and a length of 500 feet (which included full overlap with the existing 100-ft length pilot-test mulch wall). The overlap provided a double wall to increase treatment of the groundwater in the area where concentrations of chlorinated hydrocarbons were the greatest. At a minimum, the mulch wall was designed to intercept all groundwater with chlorinated hydrocarbons concentrations greater than 10 ug/L. The mulch wall was not extended north beyond the pilot wall as MW-25S (Figure 4) did not yield any water.

5.3 Mulch Wall Installation

The mulch wall was installed in July 2001 by DeWind Dewatering of Holland, Michigan with a trencher that cut and backfilled continuously. To attain the design depth of 25 feet below grade, the trenching contractor utilized the 25-feet depth cutting capacity of the trencher. A plan view of the mulch wall with its associated monitoring wells is shown on Figure 4. A schematic wall construction diagram can be found in Figure 5.

Equal volumes of coarse sand and mulch, as had been used in the pilot study, were mixed on the surface with a front-end loader. A front end loader was used to transport the mulch-sand mixture from the mixing area to the trencher. The mulch wall was backfilled with the sand:mulch mixture to a level approximately even with existing grade.

Prior to excavation, the locations of a 24-inch diameter storm sewer constructed of corrugated galvanized steel and a 4-inch diameter active natural gas line were determined and clearly marked. Although preliminary plans called for the mulch wall to be continuous under the gas line, the design was modified in the interest of safety. Consequently, the mulch wall was completed in two segments that started at the closest safe distance from the gas line and moved north and south, respectively, away from the gas line (Figure 4).

As a first step, the gas line was exposed to determine its exact location, depth, and the condition of the line. To begin trenching, the cutting arm of the trencher was positioned on the ground surface a few feet from the gas line. As the cutting arm began digging, the mulch-sand mix was added and the cutting arm was lowered until it achieved full depth of 25 feet at a distance of approximately 25 feet from the gas line. The trencher then moved north as more mulch-sand mix was fed into the hopper to backfill the excavated trench.

A storm sewer line was located about 80 feet north of the gas line (Figure 4). To install the mulch wall across the storm sewer line, the line was exposed with a backhoe, a section of the line was cut and removed, and the trencher proceeded through the gap.

After the mulch wall was installed, the storm sewer was rebuilt to a serviceable condition. After crossing the storm sewer, the path of the mulch wall was directed to the east to regain the planned location parallel and east of the existing pilot mulch wall (Figure 4).

To begin installation of the south leg of the mulch wall, the trenching machine was positioned with the cutting arm parallel to the gas line. The trenching machine moved east along the gas line until full depth was achieved. Then, the path of the mulch wall was curved to the south to regain the planned location of the mulch wall (see Figure 4). This maneuver was performed so that the mulch wall would be at full 25-ft depth next to the gas line to minimize the gap created by not trenching beneath the gas line.

Soil cuttings, which accumulated on the surface next to the mulch wall, were allowed to stand for several days to dry, and then worked with earthmoving equipment to form a gently sloped cap over the top of the wall. Soil sampling performed by GSI at MW-22S, MW-23S, MW-24S, MW-25S and MW-26S in 1998 during installation of the pilot mulch wall showed all TCLP values for chlorinated solvents were below detection, indicating that spreading of the soil was acceptable (GSI, 2001).

5.4 Monitoring Well Installation

5.4.1 Groundwater Monitoring Wells. After installation of the mulch wall was completed, 13 additional monitoring wells (MW-45S through MW-57S) were installed by Geotechnical Services, Inc. of Omaha, Nebraska. A plan view of the well locations can be found in Figure 4. At monitoring well locations MW-45S, MW-47S, and MW-55S, the soil was continuously sampled to a depth of 20 feet using Shelby tube or split spoon sampling devices to confirm stratigraphy described in previous borings. The sampling tools were decontaminated between each sampling interval. Boreholes were drilled with hollow stem augers, or, if soil conditions permitted, with solid flight augers. The borehole diameters were a minimum of six inches to provide a minimum 2-inch annular space between the monitoring well casing and the borehole. Representative as-built well construction diagrams and logs are provided in Appendix A along with surveying information.

Each monitoring well was installed to a depth of approximately 20 feet and constructed with 2-inch diameter PVC. A ten-foot length of 0.01-inch slot PVC screen was installed from a depth of 10 to 20 feet below ground surface. A sand pack consisting of 20-40 grade silica sand was installed opposite the screened section. The well annulus above the sand pack was sealed with bentonite pellets and topped with cement bentonite grout to within 3 to 4 feet of the surface. Wells were completed with above-ground completions consisting of concrete pads and locking steel well covers installed to a minimum depth of 2 feet below grade in concrete. The concrete extends a minimum 3 feet below grade, to prevent frost heaving of the well and well pad. Bollards, constructed of steel pipe 4 inches in diameter and six feet in length, and set in concrete to a depth of two to three feet below grade, were placed around each well pad. Locks, keyed to Master Lock #3303, were installed on the well covers.

5.4.2 Mulch Wall Monitoring Wells. Hollow stem augers were used to install five 2-inch diameter monitoring wells in the mulch wall as shown in Figure 4. The boreholes were drilled with slow rotation and with a drilling plug in the lead auger. The boreholes were advanced one to two feet into the natural formation beneath the bottom of the mulch wall to seat the augers and prevent the flow of sand and mulch into the hollow stem augers when the drilling plug was removed. After the well was installed inside the augers, the augers were pulled and the sand-mulch wall backfill material collapsed around the well screen.

Mulch wall monitoring wells were constructed with two-inch diameter PVC with the screened section installed in the same depth interval as the groundwater monitoring wells (i.e., 10 to 20 feet below grade). Accordingly, the mulch wall wells have blank extending from 25 to 20 feet below grade, 0.02 inch slot well screen extending from 20 to 10 feet below grade, and blank extending from 10 feet below grade to the surface. The surface completions of the mulch wall wells are above grade with concrete well pads and locking steel well covers set in concrete that extends to a minimum 3 foot depth below grade. A representative as-built diagram is shown in Appendix A.

5.4.3 Monitoring Well Development: Monitoring wells were developed by extended pumping with an electric submersible pump. A minimum of ten casing volumes of groundwater was removed from each monitoring well. Development continued until the temperature, pH, and specific conductivity of the discharged fluid did not vary more than 5% between successive casing evacuations. Fluid purged from the monitoring wells during development and groundwater sampling was containerized and scanned with a PID meter for the presence of volatile organic compounds. The PID readings were less than 5 ppm; so the fluid was disposed of in a sanitary sewer at Offutt AFB.

6.0 SAMPLING PROGRAM

The performance of the mulch wall was evaluated over a 24-month period from July 2001 to July 2003 with a monitoring program that included periodic sampling of all monitoring wells associated with the pilot and full-scale mulch wall. In addition, the program included sampling of the five monitoring wells installed within the full-scale mulch wall.

6.1 Parameter List

Sampling for VOCs (TCE, cis-DCE, and VC), alternate electron acceptors/by-products (nitrate, sulfate, ferrous iron, methane, ethene, and ethane), total organic carbon, alkalinity, dissolved oxygen, pH, temperature, redox potential, and specific conductance occurred after installation and at 6 month intervals thereafter for the duration of 24 months (a total of 5 sampling events). Sampling for VOCs only was performed three months after installation of the full-scale mulch wall and every six months thereafter for a period of 18 months (a total of 4 sampling events).

VOCs were analyzed by EPA Method 8021b, nitrate and sulfate were measured using EPA Method 300, and total organic carbon was analyzed using EPA Method 9060 by

Southern Petroleum Laboratories of Houston. Hydrogen, methane, ethane, and ethene were collected using the bubble-strip method and analyzed by gas chromatography using Method AM20GAX by Microseeps, Pittsburgh, PA. Alkalinity and ferrous iron were analyzed in the field using Hach kits.

6.2 Sampling Protocols

Monitoring wells were sampled under low flow conditions (300 ml/min.) using a peristaltic pump. Each well was purged until field parameters (i.e., pH, temperature, specific conductivity, ORP, and D.O.) stabilized. A flow-through cell was used to obtain field measurements of dissolved oxygen, redox potential, temperature, pH, and specific conductance. Headspace gases (hydrogen, methane, ethene, and ethane) were collected using the bubble-strip method, following the Microseeps' procedure and using their flow-through cell. Gas samples were submitted to Microseeps, Inc., Pittsburgh, PA for gas chromatographic analysis. All other aqueous samples were submitted to Southern Petroleum Laboratories (SPL), Houston, TX for analysis using standard EPA methods.

6.3 Other Measurements

Quarterly, the static water levels in all the wells were measured. At start-up and annually, the permeability of the mulch wall was assessed by conducting rising head slug tests in the wells installed within the mulch wall.

At the end of the test, mulch samples were obtained from the mulch wall for VOC analysis, to assess the amount of sorption in the mulch wall, and for foc analysis. Mulch samples were collected by using a hand auger with a stainless steel sample bucket.

7.0 RESULTS

7.1 Direction of Groundwater Flow Through the Test Area

Static water level measurements were taken every quarter after the installation of the mulch wall. Representative potentiometric surface maps can be found in Appendix B for the following dates: October 11, 2001, July 2, 2002, and July 31, 2003. The direction of groundwater flow was generally east to west for the north part of the mulch wall, with the direction of groundwater becoming north-westerly over time. The gradient for the last two transects of wells in the south portion of the mulch wall (i.e., MW-52S, BW-4, MW-53S, and MW-54S and MW-55S, BW-5, MW-56S, and MW-57S) is very low. There also appears to be groundwater flow northward on the upgradient side of the south portion of the mulch wall. The seep to the west of the wall also contributes to the stagnant conditions to the west of the south portion of the wall.

7.2 Evaluation of Mulch Wall Permeability

Shortly after the installation of the wells within the mulch wall and then annually thereafter, the hydraulic conductivity of the mulch wall was evaluated by performing rising head slug tests. The Bouwer-Rice method was used to calculate the hydraulic conductivities of the sand:mulch fill surrounding mulch wall wells, BW-1 through BW-5. The results are shown in Table 1. By July 2002, one year after the wall was installed, the hydraulic conductivities of the fill decreased, in general, but the changes were much less than one order of magnitude. By July 2003, there were 70-80% decreases in permeability for all of the wells, a reduction in permeability of almost one order of magnitude. It is not known whether the reduction in permeability was due to settling, inorganic fouling, or organic fouling.

7.3 Geochemical Changes

7.3.1 Dissolved Oxygen. Dissolved oxygen is the most thermodynamically-favored electron acceptor used by microbes for the biodegradation of organic carbon. The presence of organic matter released from the mulch, provides a source of organic substrate for native aerobic bacteria. The intended result is the depression of the dissolved oxygen, as aerobic bacteria consume the organics and respire the dissolved oxygen. Depression of the dissolved oxygen concentrations is required to achieve a reduced groundwater environment, conducive to reductive dechlorination and other anaerobic processes.

Dissolved oxygen concentrations are presented in Figures 6, for the upgradient and mulch wall wells and for wells 15 ft and 30 ft downgradient from the wall. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

The dissolved oxygen concentration in the upgradient wells was very variable. With the exception of monitoring wells, MW-49S, MW-27S, and MW-22S, the dissolved oxygen was greater than 1 mg/L. By comparison, the dissolved oxygen concentrations in the mulch wall wells were generally less than 1 mg/L, with the exception of BW-4, which had a dissolved oxygen concentration that was frequently in the 1 to 2 mg/L range.

The dissolved oxygen concentrations in the wells 15 and 30 ft downgradient from the wall demonstrated similar trends to each other. Within 3-6 months after installation of the wall, dissolved oxygen concentrations generally became depressed (i.e., less than 1 mg/L) and remained so over the course of the two-year monitoring period due to the depletion of oxygen in the groundwater that passed through the mulch wall.

There were some exceptions to this: monitoring wells MW-53S, MW-56S, MW54-S, and MW-57S (located at the south end of the test area) had very high levels of dissolved oxygen, in the 2-7 mg/L range. Groundwater at the south end of the test area bypassed or moved north, north-west instead of passing through the wall. The result was no depression of the dissolved oxygen in this area.

7.3.2 Redox Potential. The reduction-oxidation potential is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. The redox potential, measured in mV, is presented in Figure 7 for upgradient, mulch wall, and downgradient wells. Groundwater with redox potentials lower than 50 mV are generally considered to be suitable for reductive dechlorination (USEPA, 1998). The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

With the exception of MW-49S, all the upgradient wells had positive redox potentials in July 2001 when the wall was installed. During the two year monitoring period, the redox potential was quite variable in upgradient wells.

In contrast, mulch wall wells had lower redox potentials that were generally less than zero, because of the presence of a bioavailable carbon source and bacteria that depleted the available electron acceptors. Monitoring wells BW-1 and BW-4 were exceptions, which during some monitoring events had positive redox potentials.

The wells 15 and 30 ft downgradient from the mulch wall generally showed positive redox potentials, with the exception of MW-50S and MW-51S, which are downgradient from MW-49S and BW-3. Because redox potential readings are not always reliable, measurement of electron acceptors and metabolic by-products are better indicators of whether the groundwater is sufficiently reduced to promote reductive dechlorination. Alternate electron acceptors and metabolic by-products are discussed in the following sections.

7.3.3 Nitrate. After oxygen, nitrate is the next more thermodynamically-favorable electron acceptor. Depletion of nitrate is indicative of reduced conditions, with concentrations less than 1 mg/L typically associated with conditions conducive to reductive dechlorination (USEPA, 1998).

Nitrate levels for upgradient, mulch wall, and downgradient wells are shown in Figure 8. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

With the exception of MW-49S, nitrate levels in upgradient wells were generally above 1 mg/L. By contrast nitrate levels in wells within the mulch wall were generally less than 1 mg/L, indicating active denitrification. The exceptions were monitoring wells BW-1 and BW-4, which at times had nitrate levels greater than 1 mg/L.

Six months after mulch wall installation nitrate levels were less than 1 mg/L for most of the wells 15 and 30 ft downgradient from the mulch wall. The exceptions, again, were monitoring wells MW-53S, MW-54S, MW-56S, and MW-57S in the south-west section of the test area.

7.3.4 Ferrous Iron. Ferric iron, associated with aquifer material, is another alternate electron acceptor that can be used by iron-degrading bacteria in the degradation of organic compounds and some chlorinated constituents, such as cis-DCE and vinyl chloride (Bradley and Chapelle, 1996). The ferric iron is reduced, resulting in soluble ferrous iron that can be more easily measured. Therefore, high levels of ferrous iron indicate more reduced conditions, with levels of 1 mg/L or greater indicative of conditions suitable for reductive dechlorination (USEPA, 1998). Ferrous iron can also react with sulfide, produced through sulfate reduction, generating ferrous sulfide. Ferrous sulfide precipitates out masking the total amount of ferrous iron produced through ferric iron reduction reactions.

Ferrous iron levels in upgradient, mulch wall, and downgradient wells are shown in Figure 9. Elevated ferrous iron concentrations were evident in the mulch wall itself, due to the reduced conditions and available carbon within the mulch wall, particularly for BW-5. Ferrous iron levels were generally less than 2 mg/L in wells downgradient from the mulch wall, with the exception of MW-50S, where the ferrous iron concentrations varied from 2 to 11.7 mg/L.

7.3.5 Sulfate. Sulfate is another electron acceptor that can be used for anaerobic biodegradation. It is thermodynamically less favorable than ferric iron. When sulfate is reduced, sulfide is produced. Sulfate reduction is indicative of redox conditions appropriate for reductive dechlorination (Bouwer, 1994).

Sulfate concentrations in upgradient, mulch wall, and downgradient wells were measured for the first three sampling events only and are shown in Figure 10. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

Upgradient wells generally had sulfate levels in the 30 to 45 mg/L range, which decreased over time. MW-55S had an anomalous sulfate concentration of 110 mg/L in January of 2002, for which there is no explanation.

Sulfate concentrations in mulch wall wells were generally lower than corresponding wells directly upgradient, indicating sulfate reduction was occurring and that redox conditions were conducive to reductive dechlorination.

Sulfate concentrations in wells 15 ft downgradient from the mulch wall generally decreased by more than 50%. The exceptions again were MW-53S, and MW-56S at the south end of the test area. Sulfate concentration in wells 30 ft downgradient from the mulch wall also decreased but to a lesser extent. Sulfate concentrations did not decrease in MW-54S, and MW-57S at the south end of the test area.

7.3.6 Methane. Methane is the product of methanogenesis. During methanogenesis acetate is degraded to form carbon dioxide and methane or carbon dioxide is used as an electron acceptor and is reduced to methane. Methanogenesis occurs under deeply reduced conditions, generally after oxygen, nitrate, and sulfate have been depleted in the treatment zone. The presence of methane is a better indicator of reduced conditions than redox potential or dissolved oxygen concentrations as the measurement of these parameters can sometimes be inaccurate due to entrainment of air during measurement. Methane concentrations in excess of 0.5 mg/L are generally indicative of conditions suitable for reductive dechlorination (USEPA, 1998).

Methane concentrations in all upgradient, mulch wall, and downgradient wells are shown in Figure 11. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

Methane concentrations in upgradient wells were very low, with all wells having methane concentrations less than 0.5 mg/L. In contrast, the methane levels in the mulch wall wells were much higher, ranging from 2 to 8 mg/L, representing conditions suitably reduced for reductive dechlorination.

Six months after the installation of the mulch wall, the methane concentrations 15 ft downgradient of the wall were elevated relative to upgradient wells, with concentrations in the 1 to 7 mg/L range. The exceptions again were MW-53S and MW-56S, which had very low levels of methane. Wells 30 ft downgradient from the wall generally had low methane concentrations (i.e., <0.1 mg/L) with the exception of MW-29S, which in 2002 had methane concentrations greater than 3 mg/L.

The difference in methane concentrations between wells 15 ft downgradient and those 30 ft downgradient was quite pronounced. Either the methane was removed through volatilization or through methanotrophic biodegradation. The latter reaction occurs under low dissolved oxygen conditions (i.e., 0.5 to 2 mg/L) and may be a loss mechanism for methane and possibly for TCE, cis-DCE, and vinyl chloride as they move downgradient (Wilson and Wilson, 1985; Dolan and McCarty, 1994).

7.3.7 Alkalinity*.* Alkalinity can be used as an indirect measurement of microbial activity. Increases in alkalinity result from the dissolution of aquifer material as a result of the microbial production of carbon dioxide (USEPA, 1998).

Alkalinity levels for upgradient, mulch wall, and downgradient wells are shown in Figure 12. Generally the alkalinity hovered in the 500 mg/L range in the mulch wall wells, but increased over time in upgradient and downgradient wells, indicating increased microbial activity. The highest alkalinity concentration was consistently found in BW-5 where the alkalinity ranged from over 1000 mg/L to over 2500 mg/L, more than twice the levels measured in the other wells. BW-5 also had the highest ferrous iron and TOC levels as discussed in Section 7.3.8.

7.3.8 Total Organic Carbon. To create hydrogen needed for reductive dechlorination, organic carbon from the mulch leaches into the groundwater where it is biodegraded and fermented to form hydrogen. Table 2 gives an indication of the spatial and temporal distribution of total organic carbon (TOC) in the test area. The total organic carbon in upgradient wells was generally less than 2-3 mg/L with the exception of BW-5 in July of 2002, which had a TOC value of 33 mg/L. TOC concentrations were elevated in mulch wall wells BW-2 through BW-5, a month after installation of the wall. After 6 months the TOC levels in BW-2 through BW-5 dropped off dramatically, by 57-99%.

In July 2001 (one week after wall installation), TOC levels were high 15 ft downgradient (2 months travel time) from the mulch wall, presumably due to stray mulch at the surface, which leached TOC during rainfall events, or possibly to the presence of preferential flow paths. TOC levels 30 ft downgradient were generally less than 2.5 mg/L, similar to upgradient TOC levels. The exception was high TOC levels near the south end of the mulch wall during the July 2002 sampling event. TOC levels in the two most-southerly transects had TOC levels ranging from 25-63 mg/L, probably due to the marshy nature of the aquifer in this area.

7.4 Transformation and Removal of Chlorinated Constituents

7.4.1 Trichloroethylene. Trichloroethylene is the main contaminant of concern to be treated. TCE concentration distributions for July 2001, July 2002, and July 2003 are shown in Figures 13 through 15. Upgradient TCE concentrations are generally below the MCL of 5 ug/L in the southern part of the test area over the two-year monitoring period, indicating that the southerly extent of the mulch wall was overly conservative, despite using the TCE concentration isopleth data from 2000 (Figure 2). Lack of TCE contamination in this area was fortuitous in that there appears to be no flow through the wall in the southernmost 100-150 feet of the mulch wall.

The north end of the wall generally was effective in dramatically reducing TCE concentrations 15 ft downgradient of the wall. TCE concentrations upgradient of the mulch wall were quite variable over the two year monitoring period. Nevertheless, 95% reductions in TCE concentrations were observed, on average, between July 2001 and July 2003. Good treatment effectiveness was observed in the middle of the wall, with lesser treatment efficiency noted in the northern most portion of the wall, possibly due to short-circuiting around the northern end of the wall or from groundwater with higher TCE concentrations moving in a northwest direction across the wall.

Unusually high TCE concentrations also showed up downgradient of the pilot wall in July 2003 at wells MW-33S and MW-34S. TCE concentrations in MW-33S and MW-34S before and after the full-scale wall installation in July 2001 are presented in Table 3. TCE data from MW-24S, directly upgradient from MW-33S and MW-34S, and from MW-29S, a monitoring well downgradient of the central portion of the north section of the full-scale wall are also shown in Table 3. January 1999 data represent baseline data prior to the pilot mulch wall installation. The TCE concentrations in MW-24S were quite variable until the full-scale mulch wall was installed, which acted to significantly reduce the concentrations in MW-24S. TCE concentrations in MW-33S and MW-34S were variable during the pilot test but were generally 50-60% less overall than those in MW-24S. After the installation of the full-scale wall in July 2001, concentrations in MW-33S and MW-34S decreased significantly until July 2003 when they were significantly higher than in MW-24S, suggesting the untreated TCE groundwater was short-circuiting around the north end of the treatment area. TCE concentrations in MW-29S remained low for the two-year monitoring period following the installation of the full-scale wall.

Further sampling of MW-33S, MW-34S, and MW-26S north of the treatment system should be conducted to evaluate the source of increased concentrations in that area.

7.4.2 *cis-1,2-dichloroethylene.* Cis-1,2-dichloroethene is a daughter product of the reductive dechlorination of TCE. In July 2001, cis-DCE was present at highest concentrations within the north end of the mulch wall and downgradient of the existing 100-ft pilot-scale wall, as shown in Figure 16. Concentrations were less than 100 ug/L. One year after wall installation, cis-DCE concentrations were still less than 100 ug/L, with the highest concentrations located in the north end of the mulch wall and downgradient of the pilot scale wall (Figure 17). Two years after mulch wall installation, cis-DCE concentrations increased between the pilot and full scale walls (Figure 18). More time and higher TCE concentrations resulted in increased cis-DCE concentrations.

7.4.3 *Vinyl Chloride.* Vinyl chloride is the daughter product of the reductive dechlorination of cis-DCE. It is considered a human carcinogen and has an MCL of 2 ug/L. Excessive accumulation of vinyl chloride must be avoided when reductive dechlorination is stimulated via the introduction of an electron donor.

Vinyl chloride concentrations in the test area during July 2001, July 2002, and July 2003 sampling events can be found in Figures 19 through 21. In July 2001, only MW-27S and MW-32S had vinyl chloride concentrations greater than 2 ug/L. One year after installation of the 500 ft wall, vinyl chloride concentrations in excess of 2 ug/L were observed in eight wells, but all had concentrations less than 27 ug/L (Figure 20). By July 2003, vinyl chloride concentrations had declined as shown in Figure 21. Only three wells (MW-24S, MW-23S, and MW-50S) had concentrations greater than 2 ug/L.

7.4.4 *Ethene and Ethane.* Ethene and Ethane are the products of the complete reductive dechlorination of TCE. Ethene is produced through reduction of vinyl chloride and ethane is produced through reduction of ethene. Figures 22 through 24 present the combined concentration (sum of ethene and ethane concentration) for the July 2001, July 2002, and July 2003 sampling events.

In July 2001 (Figure 22), right after wall installation, ethene and ethane concentrations were below 0.7 ug/L. Wells MW-32S and MW-31S had higher concentrations (i.e.,14 ug/L) due to their location downgradient of the pilot wall. One year after installation of the 500 ft wall, ethene/ethane concentrations increased dramatically downgradient of the north portion of the wall, with concentration ranging from 1 to 26 ug/L (Figure 23). The highest concentrations were found at the north end where TCE concentrations had been the highest. Similar results were found in July 2003 (Figure 24). Increased concentrations of ethene and ethane is evidence of enhanced reductive dechlorination.

7.4.5 *Molar cis-DCE:TCE Ratio.* The molar concentration ratio of cis-DCE to TCE gives an indication of the degree of reductive dechlorination. As the ratio increases, the amount of reductive dechlorination increases. The molar concentration ratio of cis-DCE:TCE for upgradient, mulch wall, and downgradient wells is found in Figure 25. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

Upgradient ratios are generally very low (i.e., <0.5), indicating that very little reductive dechlorination was occurring via natural attenuation in the absence of the mulch material. The exception was MW-49S where some reductive dechlorination was evident. Even within the mulch wall the cis-DCE:TCE ratios are low, with the exception of BW-3 where the ratio ranged from 1.5 to 12. BW-3 is west and downgradient of MW-49S.

Downgradient wells showed much different trends. Three months after the wall installation, the cis-DCE:TCE ratio ranged from 2 to 23. The increase in the cis-DCE:TCE ratio from less than 0.5 to 2-23 indicated that appreciable reductive dechlorination was occurring downgradient of the wall. The exception to this was the two most southerly wells (MW-53S and MW-56S), which showed very little transformation.

8.0 PERFORMANCE EVALUATION FOR NORTH SECTION OF MULCH WALL

8.1 Removal of TCE and Total Chlorinated Compounds

The evaluation of the effectiveness of mulch as a medium to remove TCE and its daughter products was determined for the north section of the full-scale mulch wall only. The south section was not included in this evaluation because groundwater appeared to not be passing through the south end and TCE concentrations in that area were very low. Short-circuiting, if any, around the north end of the wall was also not included in this evaluation because it could not be quantified.

Performance data for the north section of the mulch wall is shown in Table 4. The mean percent removal of TCE 15 ft downgradient of the wall over the two year monitoring period was 95% and the mean % removal of total chlorinated solvents was 80%. These removals are greater than those determined during the pilot test due to additional residence time in the 1.5 ft wide wall compared with the 1 ft reaction width used in the pilot test (GSI, 2001).

A molar balance of the sum of chlorinated ethenes, ethene, and ethane entering and leaving the wall was determined as shown in Table 4. The mean total ethene and ethane concentration entering the wall over the two-year monitoring period was 2.29 uM and the mean total ethene and ethane concentration leaving the wall (to the west) during the same period was 0.55 uM, for a molar balance closure of 24.2%. In other words, the removal of TCE could not be accounted for entirely by the production of reductive dechlorination daughter products such as cis-DCE, VC, ethene, and ethane.

There are several possible fates for TCE and its daughter products. First, TCE will adsorb to the mulch in the wall, given the high organic content of the mulch (see Section 8.2). In addition, there are several biological processes by which TCE's daughter products, cis-DCE and vinyl chloride, can be degraded. Vinyl chloride and cis-

DCE can be converted to carbon dioxide under methanogenic conditions, because of the presence of the mulch. Bradley et al. (1998) have shown that humic acids can act as electron acceptors for the anaerobic microbial oxidation of vinyl chloride and dichloroethene. VC anaerobic oxidation under iron reducing conditions (Bradley and Chapelle, 1996) and direct VC oxidation in aerobic microenvironments (Hartmans et. al., 1985; Hartmans and de Bont, 1992) are other possible biological loss mechanisms. In addition, ferrous sulfide precipitates in the mulch or aquifer can act to catalyze the abiotic reduction of TCE (Butler and Hayes, 2000).

8.2 Effect of Sorption

Because less than 25% of the chlorinated compound removal could be attributed to reductive dechlorination, sorption was evaluated as a possible removal mechanism because of the high carbon content of the mulch fill.

Samples of the mulch/sand fill were analyzed for organic carbon (foc) and for VOCs at the end of the test, and the results are presented in Table 5. Three samples were obtained from 5 feet below the water table, one 5 feet north, one 5 feet south, and a third 10 ft south of BW-1. TCE and trans-DCE were found at concentrations of 0.5-1 ug/Kg. cis-DCE and VC were not detected. These results indicated that sorption was not significant at these locations. Samples from deeper areas of the wall may have shown different sorbed concentrations.

Using an assumed porosity and bulk density of 0.3 and 1.3 kg/L, respectively, a measured foc of 0.018 (Table 5), and a Koc of 183, a retardation factor of 15 was calculated. Using the reported seepage velocity of 85 ft/yr (Parson’s Engineering Science, 1997), the TCE velocity through the wall was calculated to be 5.7 ft/yr or about a 3-month residence time. Modeling, using an analytical groundwater transport model, indicated that after 1 year the water leaving the wall would be within 90% of steady-state conditions, at which point sorption would not be a significant removal mechanism. Therefore, early decreases in TCE in downgradient wells may be attributable to sorption, but after the attainment of steady-state or near-steady state conditions, sorption should not have been a significant loss mechanism in TCE removal. Column studies are needed to more accurately assess the contribution of sorption for this technology.

8.3 Effectiveness in Reducing Concentrations near Base Boundary

To evaluate the effectiveness of the pilot- and full-scale mulch walls in reducing the concentrations of chlorinated constituents at the Base boundary, the concentrations of TCE, cis-DCE, and vinyl chloride in MW-9S were plotted over time (Figure 26). MW-9S is about 2 years groundwater travel time away from the mulch walls. About two years after the installation of the pilot wall in 1999, the concentrations of all the constituents began to decline. By October 2003, TCE, cis-DCE, and vinyl chloride were below their respective drinking water MCLs of 5, 70, and 2 ug/L. Therefore, the mulch walls have been effective in reducing the concentration of these constituents to levels below the MCLs, even without the installation of the upgradient zero valent iron wall.

Despite these favorable results, attention should be paid to wells MW-33S and MW-34S, which suggest that the plume may be circumventing the treatment area. Wells north of the treatment system (MW-25S and MW-26S) should be sampled to evaluate this possibility.

9.0 RECOMMENDATIONS AND LESSONS LEARNED

1. Future full-scale mulch wall installations should employ column studies to estimate the required residence times to meet remedial objectives.

2. Some engineering measure, such as lower permeability fill, should be employed at the ends of the wall to prevent transverse flow. The length of the wall should employ a safety factor to account for changes in groundwater flow direction.

3. The fill permeability should be engineered to be several orders of magnitude more permeable than the aquifer matrix to account for loss of permeability due to settling or fouling.

4. Column studies and/or microcosm studies are required to elucidate the mechanisms of TCE removal.

10.0 EXECUTIVE SUMMARY

To reduce, TCE and its daughter products to MCLs at the base boundary, a 500 ft mulch wall was installed upgradient of an existing pilot-scale mulch wall. The intent was for the mulch wall to act as a polishing step after the groundwater was treated by an upgradient zero valent iron wall. Due to the availability of funding, the mulch wall was installed before the zero valent iron wall. The focus of this report is on the effectiveness of the mulch wall alone.

The mulch wall was installed across the complete width and depth of the plume to intercept all groundwater at concentrations greater than 10 ug/L TCE. Due to the presence of an active gas line running parallel to the plume, the wall was installed in two sections. The wall was installed using a continuous trencher to a depth of 25 ft. The wall was backfilled with a 1:1 by volume mixture of sand and mulch as the wall was installed. The wall started 30 feet east of the pilot wall and was 500 ft long. Two-inch diameter monitoring wells with 10 feet of screen were installed upgradient, within, and downgradient of the wall.

Static water level measurements were conducted quarterly and slug tests were performed on the wells within the wall annually. Wells were sampled semi-annually or quarterly for volatile organic compounds, alternate electron acceptors/byproducts and water quality parameters.

Potentiometric surface maps showed the groundwater to move west, north-west through the wall. The exception was the most southerly 150 ft of the south portion of the wall. In this area the aquifer was sandier than anticipated. In addition there was a seep to the west of the south wall. The result was that groundwater appeared to flow north instead of through the wall. Fortuitously, the upgradient TCE concentrations at the south end were below the MCL.

Annual slug tests showed that the wall permeability decreased over time. After one year, there was some loss in permeability in some wells, but the losses were considerably less than one order of magnitude. By the second year, permeability losses of 70-80% were observed. It is not know whether the permeability loss is due to settling or fouling.

Dissolved oxygen, redox potential, nitrate, and sulfate concentration were generally depressed downgradient of the wall as a result of the introduction of the mulch. Ferrous iron was elevated within the wall and methane concentrations were elevated within and downgradient of the wall, indicating the attainment of conditions sufficiently reduced for reductive dechlorination. The exception was the area west of the south portion of the wall, where groundwater did not flow effectively through the wall.

The following summarizes the performance for the north section of the wall:

- 95% TCE removed
- 80% Total Chlorinated Solvents removed

The middle part of the wall was more effective than the north end. Some increases in cis-DCE, VC, ethene, and ethane were observed. The performance of the south portion of the wall was not assessed due to upgradient TCE concentrations being below the MCL and short-circuiting.

A molar balance showed that less than 25% of the chlorinated compounds entering the north section of the wall could be accounted for by a balance on chlorinated ethenes and ethanes exiting the wall. Removal mechanisms such as sorption, and other biological or abiotic processes may be at work in removing these constituents. Other biological processes can mineralize these compounds to carbon dioxide, which was not measured.

The objective of the mulch wall installation was to aid in treating the groundwater to MCLs at the Base boundary. The installation of the pilot and full-scale walls successfully decreased the concentrations of TCE, cis-DCE, and vinyl chloride to less than MCLs near the Base boundary at MW-9S as shown in Figure 26.

Reductions in permeability of the wall and possible short-circuiting around the north end of the wall, as suggested by increasing concentrations in monitoring wells MW-33S and MW-34S, should be investigated and actions taken, if necessary, to continue to achieve the remedial objectives.

11.0 REFERENCES

Bouwer, E.J. 1994. Bioremediation of Chlorinated Solvents Using Alternate Electron Acceptors. In *Handbook of Bioremediation***.** Norris, R.D., R.E. Hinchee, R.Brown, P.L. McCarty, L. Semprini, J.T. Wilson, D.H. Kampbell, M. Reinhard, E.J. Bouwer, R.C. Borden, T.M. Vogel, J.M. Thomas, and C.H. Ward (Eds), Lewis Publishers, Boca Raton, FL. p149-175.

Bradley, P.M. and F.H. Chapelle. 1996. Anaerobic Mineralization of Vinyl Chloride in Fe(III)-Reducing Aquifer Sediments. *Environ. Sci. Technol*. 30(6):2084-2086.

Bradley, P.M., F.H. Chapelle, and D.R. Lovley. 1998. Humic Acids as Electron Acceptors for Anaerobic Microbial Oxidation of Vinyl Chloride and Dichloroethene. *Appl. Environ. Microbiol*. 64: 3102-3105.

Butler, E.C. and K.F. Hayes. 2000. Kinetics of the Transformation of Halogenated Aliphatic Compounds by Iron Sulfide. *Environ. Sci. Technol*. 34(3):422-429.

Carr, C., and J.B. Hughes. 1998. High-Rate Dechlorination of PCE: Comparison of Lactate, Methanol and Hydrogen as Electron Donors. *Environmental Science and Technology*. 30(12): 1817-1824.

Dolan, M.E. And McCarty, P.L. 1994. Factors Affecting Transformation of Chlorinated Aliphatic Hydrocarbons by Methanotrophs. In *Bioremediation of Chlorinated and Polycyclic Aromatic Hydrocarbon Compounds*. Ed. R.E. Hinchee, A. Leeson, L. Semprini, and S.K. Ong. CRC Press, FL. P 303-308.

Groundwater Services, Inc. (GSI) 2001. *Mulch Biowall and Surface Amendment Pilot Test, Offutt AFB, NE*, Submitted to Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks AFB, TX. July 18, 2001.

Hartmans, S. J.A.M. de Bont, J. Tamper, and K.Ch.A.M. Luyben. 1985. Bacterial Degradation of Vinyl Chloride. *Biotechnol. Lett.* 7(6):383-388.

Hartmans, S. and J.A.M. de Bont. 1992. Aerobic Vinyl Chloride Metabolism in Mycobacterium aurum L1. *Appl. Environ. Microbiol*. 58(4)1220-1226.

He, J. Y. Sung, M.E. Dollhopf, B.A. Fathepure, J.M. Tiedje, and F.E. Loffler. 2002. Acetate versus Hydrogen as Direct Electron Donors to Stimulate the Microbial Reductive Dechlorination Process at Chloroethene-Contaminated Sites. *Environ. Sci. Technol*. 36(18): 3945-3952.

Holliger, C., G. Schraa, A.J.M. Stams, and A.J.B. Zehnder. 1993. A Highly Purified Enrichment Culture Couples the Reductive Dechlorination of Tetrachloroethene to Growth. *Applied Environ. Microbiology*. 59(9): 2991-2997

Parsons Engineering Science, Inc. 1997. *Remediation by Natural Attenuation Treatability Study for Building 301 Offutt AFB, Nebraska*. Prepared for the Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks AFB, Texas, June 1997.

USEPA, 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*. Office of Research and Development. Washington, D.C. EPA/600/R-98/128. September 1998.

Wilson, J.T. and Wilson, B.H. 1985. Biotransformation of trichloroethylene in soil. Appl. *Environ. Microbiol*. 49(1):242-243.

LIST OF TABLES

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

TABLE 1
HYDRAULIC CONDUCTIVITY CHANGES IN WELLS WITHIN THE MULCH WALL

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Well No.	Hydraulic Conductivity (cm/sec) 2001	2002	2003	K Ratio 2003/2001
B301-BW1	1.18E-03	1.03E-03	3.60E-04	0.31
B301-BW2	2.05E-03	9.03E-04	4.26E-04	0.21
B301-BW3	1.96E-03	2.04E-03	6.14E-04	0.31
B301-BW4	1.56E-03	1.37E-03	3.02E-04	0.19
B301-BW5	7.44E-04	5.40E-04	1.36E-04	0.18

NOTES

1. Bouwer-Rice method for slug test calculation.
2. Rising head tests included in analysis. If more than one rising head test was performed, the average is shown.
3. Based on URS Monitoring Reports for 2001 - 2003.

TABLE 2

TOTAL ORGANIC CARBON IN GROUNDWATER

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Date	TOC (mg/L) in Upgradient Wells							TOC (mg/L) in Mulch Wall Wells					TOC (mg/L) in Wells 15 ft Downgradient							TOC (mg/L) in Wells 30 ft Downgradient				
	B301-MW45S	B301-MW46S	B301-MW22S	B301-MW27S	B301-MW49S	B301-MW52S	B301-MW55S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5	B301-MW24S	B301-MW23S	B301-MW47S	B301-MW48S	B301-MW50S	B301-MW53S	B301-MW56S	B301-MW29S	B301-MW28S	B301-MW51S	B301-MW54S	B301-MW57S
Jul-01	<1	1.49	1.28	<1	-	1.66	1.53	2.84	6.29	37.9	266	1130	11.8	6.16	4.73	7.70	94.90	<1	1.17	<1	2.31	1.61	1.18	<1
Jan-02	1.60	2.60	2.80	1.50	1.90	<1	<1	3.30	2.70	4.50	3.80	140	2.60	1.80	1.60	1.60	3.60	<1	<1	1.80	1.90	1.80	<1	<1
Jul-02	<1	<1	<1	<1	<1	<1	33	<1	<1	2.0	63	25	<1	<1	<1	<1	<1	34	48	<1	<1	<1	39	54
Jan-03	1.58	1.71	1.15	1.17	1.72	1.21	1.54	2.00	1.36	3.15	2.91	82.75	3.11	2.28	1.29	1.22	1.71	1.03	1.18	1.38	1.08	1.50	1.05	1.06
Jul-03	1.60	1.32	1.80	1.84	1.04	1.06	2.10	1.75	3.19	2.13	2.00	67.83	2.91	2.57	2.22	1.17	1.39	1.17	1.00	2.45	1.09	1.17	1.23	1.66

Note:
Wells in each area listed from North to South. Refer to Figure 4 for exact well locations.

TABLE 3
TCE CONCENTRATIONS IN MW-24S, MW-33S, MW-34S and MW-29S

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Date	TCE Concentration (mg/L)			
	MW-24S	**MW-33S**	**MW-34S**	**MW-29S**
Jan. 1999	1.900	1.300	1.300	0.410
Jun. 1999	0.250	0.870	0.600	0.630
Feb. 2000	2.000	0.215	0.880	0.370
Aug. 2000	2.000	0.960	1.220	0.410
Jul. 2001	0.290	0.580	0.400	0.200
Jan. 2002	0.021	0.100	0.061	0.008
Jul. 2002	0.018	0.096	0.200	0.009
Jul. 2003	0.099	0.670	1.000	0.003

Notes:

Full-Scale Mulch Wall installed in July 2001.

TABLE 4
PERFORMANCE DATA FOR NORTH SECTION OF MULCH WALL

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Mean % TCE Removal[1]	95.4%
Mean % Total Chlorinated Solvent Removal[2]	80.2%
Total Ethenes and Ethane Concentration Entering Wall[3]	2.287 uM
Total Ethenes and Ethane Concentration Exiting Wall[4]	0.554 uM
Mass Balance Closure[5]	24.2%

NOTES

1. Mean % TCE Removal was calculated by subtracting the mean TCE concentrations 15 ft downgradient from the mulch wall from the mean upgradient TCE concentrations over the course of the test, dividing by the mean upgradient TCE concentration, and multiplying by 100%. Mean upgradient concentrations were calculated by taking the geometric mean of molar TCE concentrations in wells MW-45S, MW-46S, MW-22S, and MW-27S for a given sampling event, and the straight mean over the 2-year monitoring period. Mean downgradient concentrations were determined in a similar fashion for MW-24S, MW-23S, MW-47S, and MW-48S.
2. Mean % Total Chlorinated Solvent Removal was calculated in the same manner as Mean % TCE Removal, but included TCE, cis-DCE, and VC.
3. This value was calculated by first taking the geometric mean concentration of total ethenes plus ethane for each sampling event and then taking an average over the 2-year monitoring period.
4. This value is determined in a similar manner to Total Ethenes and Ethane Concentration Entering Wall but uses concentrations in downgradient monitoring wells MW-24S, MW-23S, MW-47S, and MW-48S.
5. Mass Balance closure is calculated by dividing Total Ethenes and Ethane Concentrations Exiting Wall by Total Ethenes and Ethane Concentrations Entering Wall times 100%.

TABLE 5
MULCH FILL SAMPLING RESULTS: JULY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Location ID **Field Sample ID** **Date Collected**	B301-SB1 B301-01-SB-09 7/29/2003	B301-SB2 B301-02-SB-10 7/29/2003	B301-SB3 B301-03-SB-09 7/30/2003
Volatile Organic Compounds (ug/Kg)			
1,1-Dichloroethene	< 1	< 1	< 1
Tetrachloroethene	**0.67 JB**	**0.73 JB**	**0.98 JB**
Trichloroethene	< 1	**0.45**	< 1
cis-1,2-Dichloroethene	< 1	< 1	< 1
trans-1,2-Dichloroethene	< 1	**0.31 J**	**1.3**
Vinyl chloride	< 1	< 1	< 1
Organic Carbon (Walkley-Black)			
Fraction Organic Carbon (g/g)	**0.01880**	**0.02000**	**0.0164**
Total Organic Carbon (mg/kg)	**18800**	**20000**	**16400**

Notes:
J = Estimated
B = Blank Contamination

LIST OF FIGURES

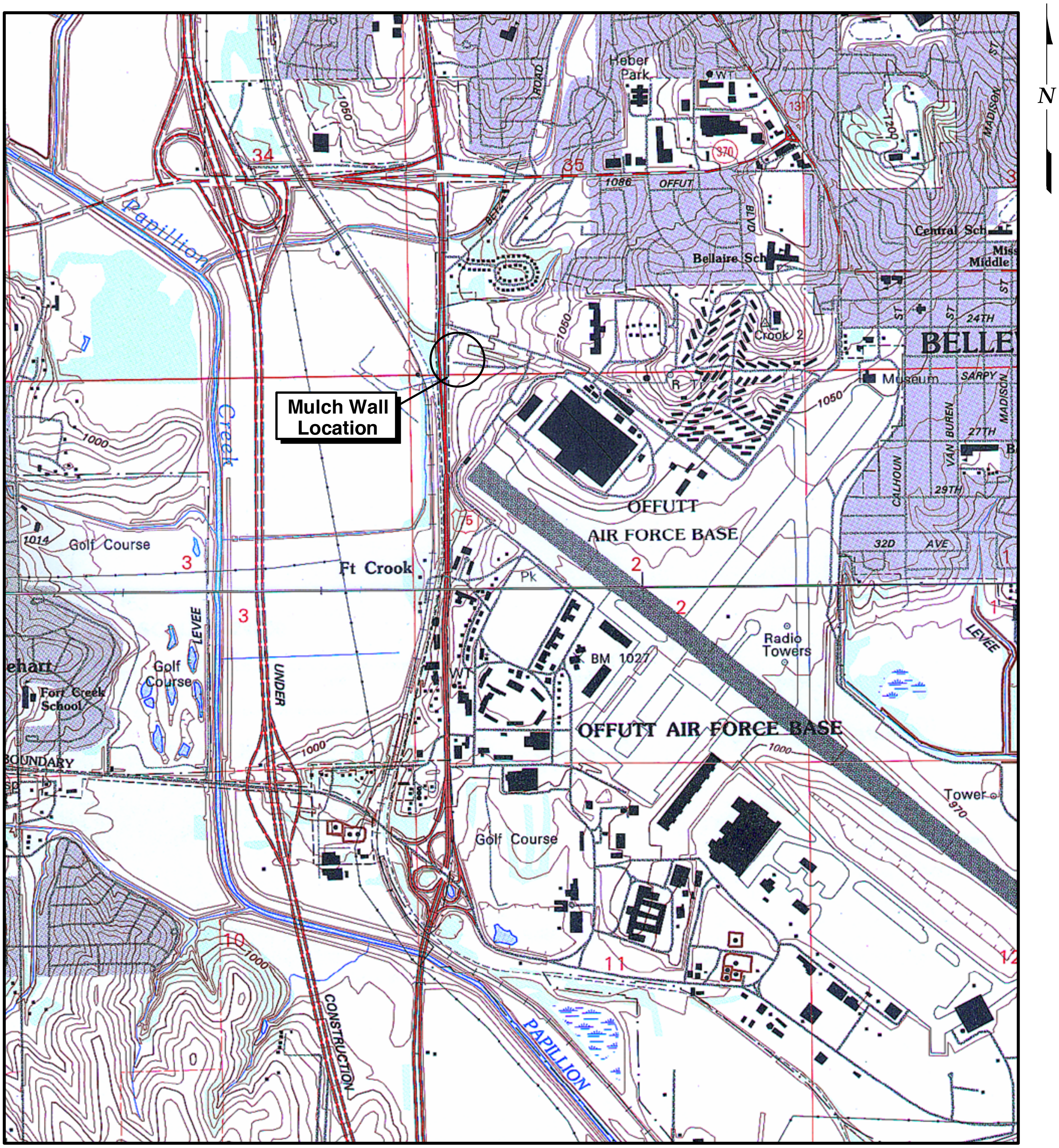
FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

LIST OF FIGURES(CONT'D)

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska



U.S. Geological Survey Map
Omaha, Nebr.-Iowa (1994)
Plattsmouth, Nebr.-Iowa (1994)
Quadrangle, 7.5 minute

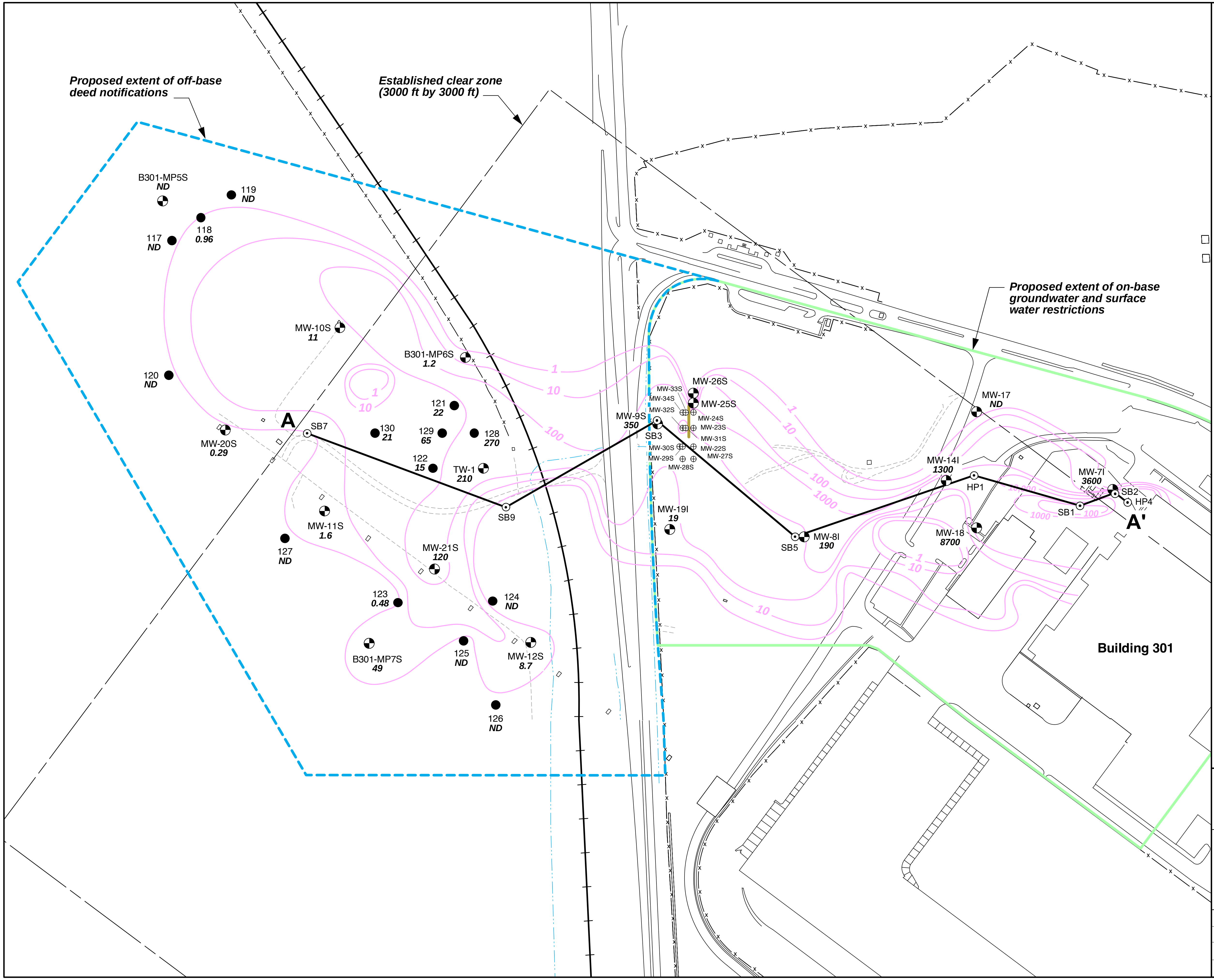
SCALE (ft.)
0 1000 2000

GROUNDWATER
SERVICES, INC.

SITE LOCATION MAP

Site B301
Offutt AFB, Nebraska

GSI Job No.:	G-2050	Scale:	As Shown	FIGURE 1
Drawn by:	CCJ	Approved by:	CEA	
Revised:	___________	Date:	4/13/04	



LEGEND

◐	Existing monitoring well location with TCE concentration (µg/L)
●	DPWS well location with TCE concentration (µg/L)
⊕	Pilot-scale mulch wall monitoring well location
⊙	Previously installed soil boring
— 10 —	Revised estimated TCE concentration contour (µg/L) based on spring 2000 LTM and historical sample results
ND	Non detect
— · —	Drainage ditch
—	Existing pilot-scale mulch wall

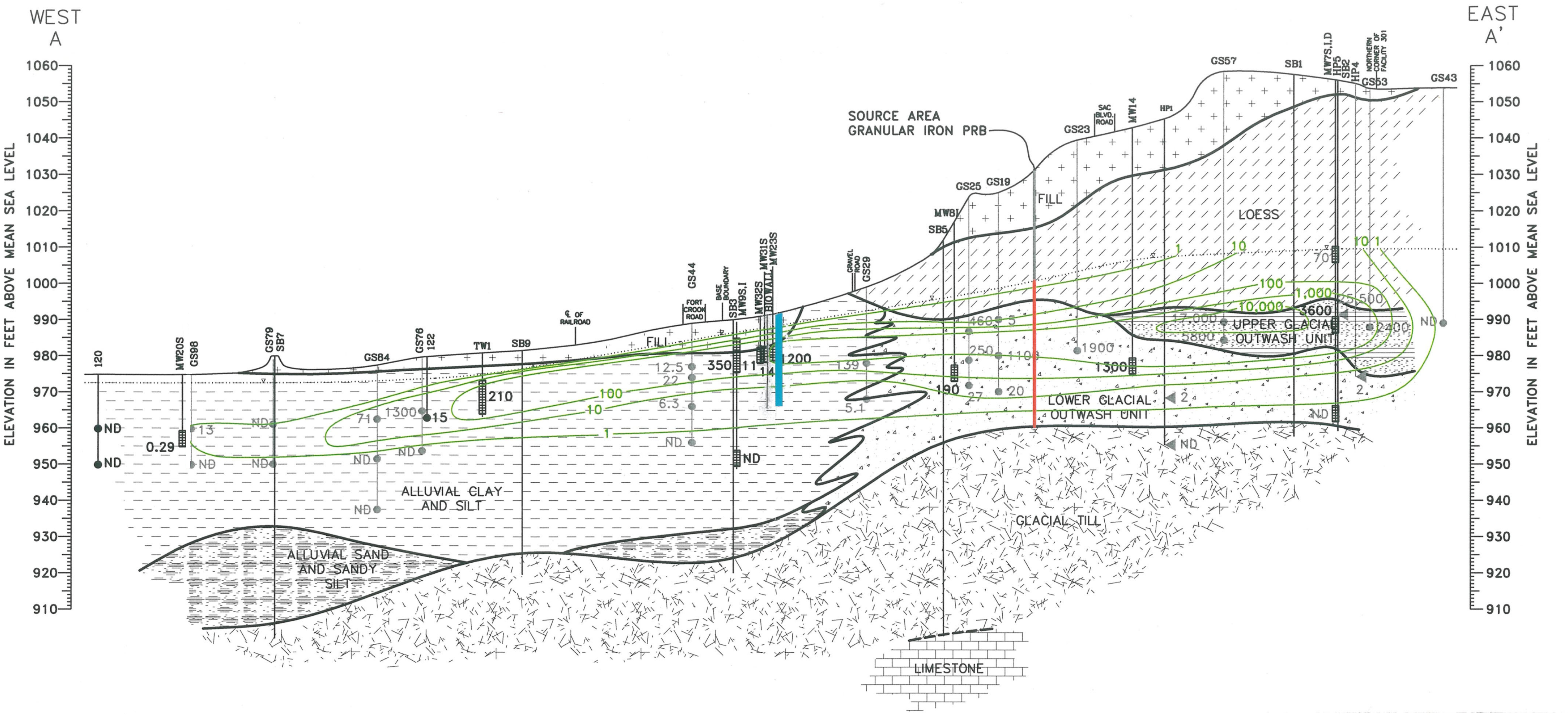
SCALE (ft.)
0 150 300

GROUNDWATER SERVICES, INC.

DISTRIBUTION OF TCE IN GROUNDWATER, SPRING 2000 LTM AND HISTORICAL SAMPLING RESULTS

Site 301B
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		FIGURE 2



GRAPHICAL HYDROSTRATIGRAPHIC UNITS SYMBOLS

⊞	FILL	▨	CLAY-RICH GLACIAL TILL
▨	LOESS	☰	ALLUVIAL CLAY AND SILT
▤	UPPER GLACIAL OUTWASH UNIT	▤	ALLUVIAL SAND AND SANDY SILT
☐	LOWER GLACIAL OUTWASH UNIT	▦	BEDROCK – WESTERN INTERIOR PLAINS CONFINING SYSTEMS

🟦	**FULL-SCALE MULCH WALL**
▽	ESTIMATED GROUNDWATER SURFACE
14 ▯	MONITORING WELL SCREEN INTERVAL WITH TCE CONCENTRATION FROM SPRING 2000 LTM
1	ESTIMATED TCE CONCENTRATION CONTOURS ($\mu g/L$) BASED ON SPRING 2000 LTM AND HISTORIC SAMPLE RESULTS
15 ●	DIRECT PUSH WATER SAMPLE LOCATION WITH TCE CONCENTRATION FROM SPRING 2000 LTM
4 ●	HISTORIC DIRECT PUSH WATER SAMPLE LOCATION WITH ADJUSTED TCE CONCENTRATION IF ABOVE 1 $\mu g/L$
◀ 2	HISTORIC HYDROPUNCH WATER SAMPLE LOCATION WITH TCE CONCENTRATION ($\mu g/L$)
ND	NON-DETECT AT SAMPLE LOCATION
🟥	**GRANULAR IRON PERMEABLE REACTIVE BARRIER**

30 15 0 30
VERTICAL SCALE IN FEET

300 150 0 300
HORIZONTAL SCALE IN FEET

VERTICAL EXAGGERATION = 10x

NOTES:

1) This figure represents a conceptual geologic model. The actual lithology between borings may vary from the shown interpretation.

2) Cross-section developed during the SFI/LTM (W-C 1998). See final SFI/LTM report for soil boring details.

GROUNDWATER SERVICES, INC.

VERTICAL DISTRIBUTION OF TCE IN GROUNDWATER ALONG HYDROGEOLOGIC PROFILE A-A'

Site B 301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	DLB
Issued:	4/13/04	Chk'd By:	MRS
Revised:	———	Appv'd By:	MRS
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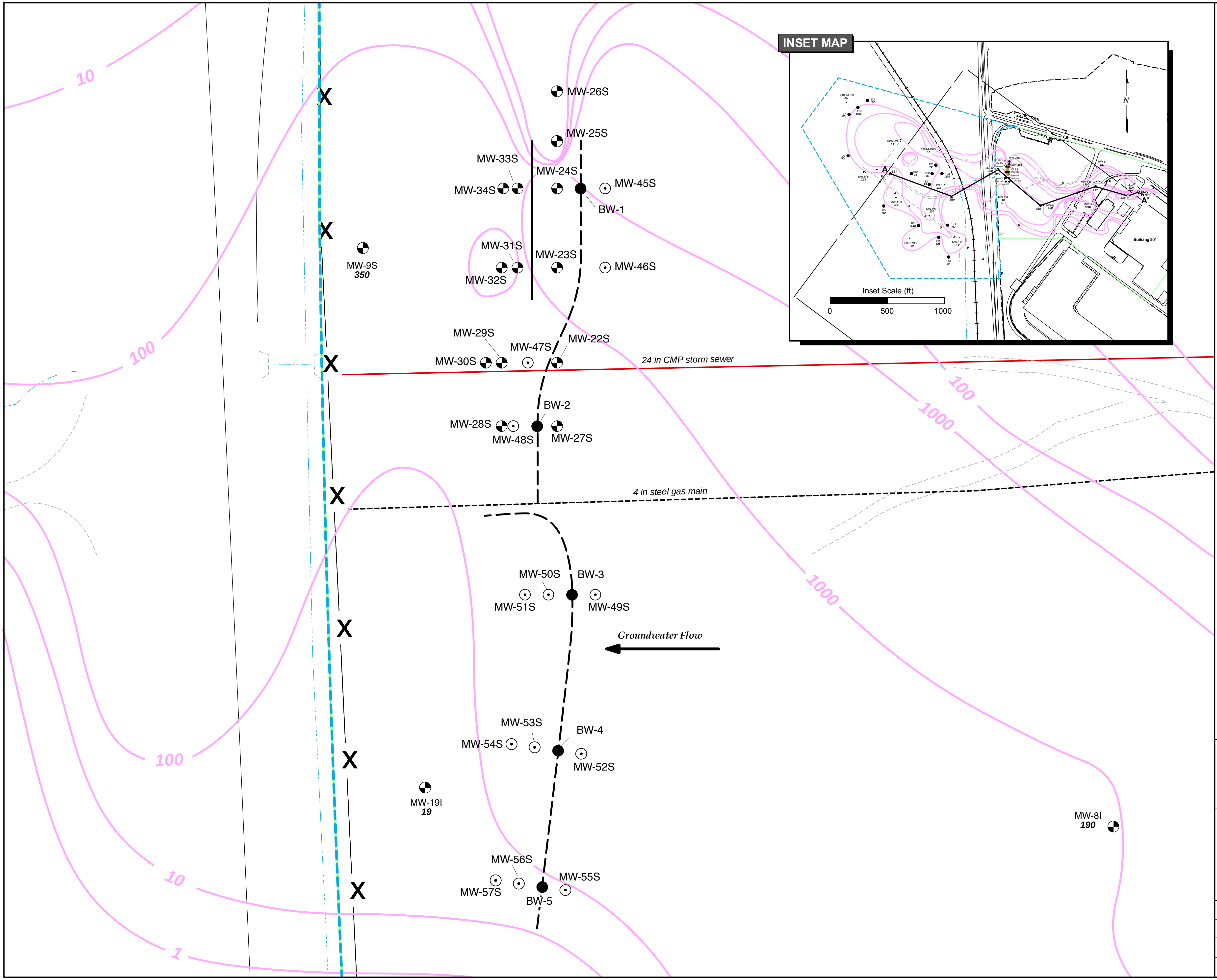


N

LEGEND

◑ Existing monitoring well location

⊙ New monitoring well location

● New monitoring well location within mulch wall

- 10 - Revised estimated TCE concentration contour (μg/L) based on spring 2000 LTM and historical sample results

— · — Drainage ditch

—— Pilot-scale mulch wall

— — Full-scale mulch wall

—— 24-in CMP storm sewer

- - - - 4-in steel gas main

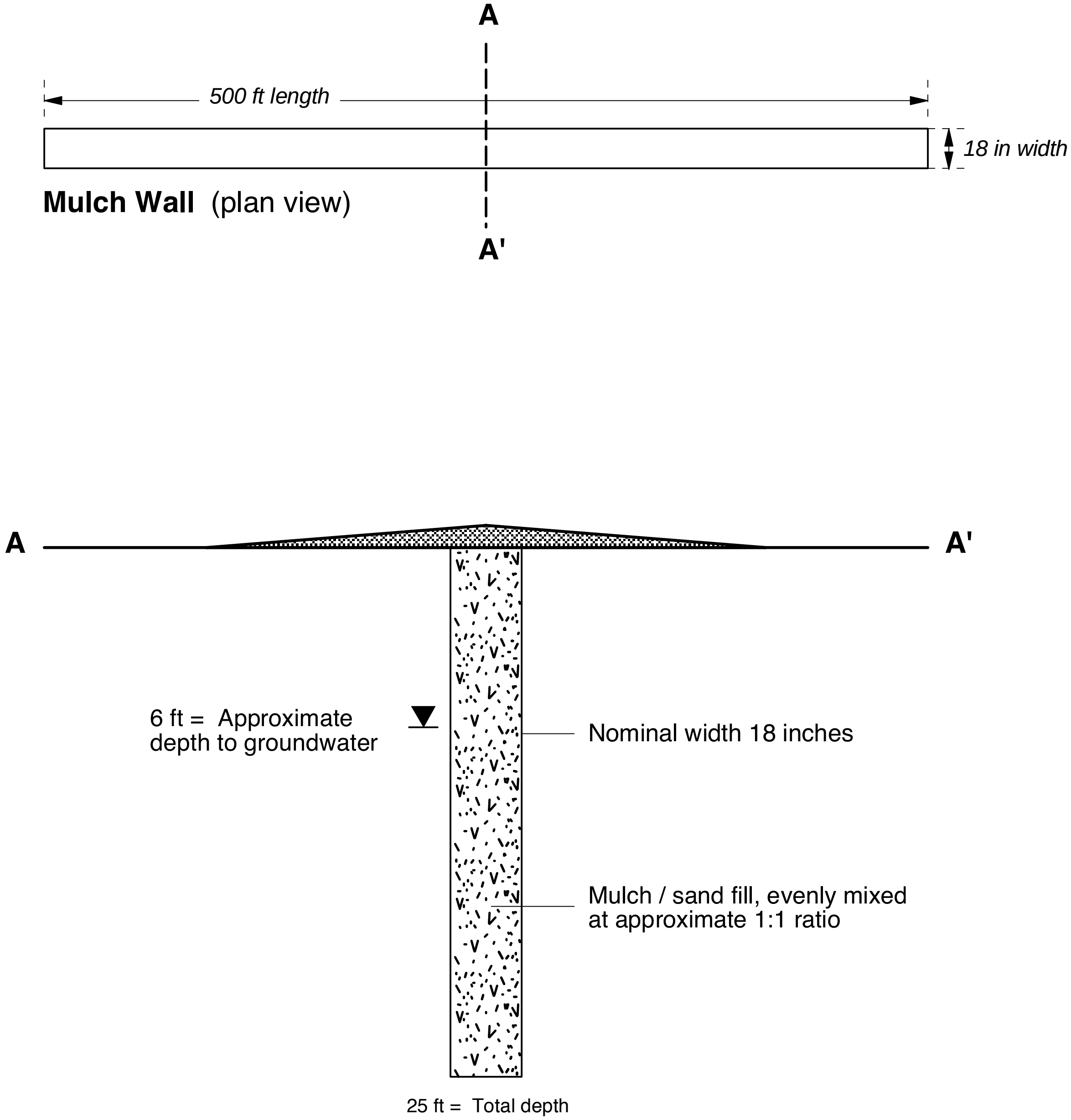
SCALE (ft.)
0 30 60

GROUNDWATER
SERVICES, INC.

LOCATION OF FULL and PILOT SCALE MULCH WALLS and MONITORING WELLS

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	______	Appv'd By:	
Scale:	As Shown	FIGURE 4	



GROUNDWATER
SERVICES, INC.

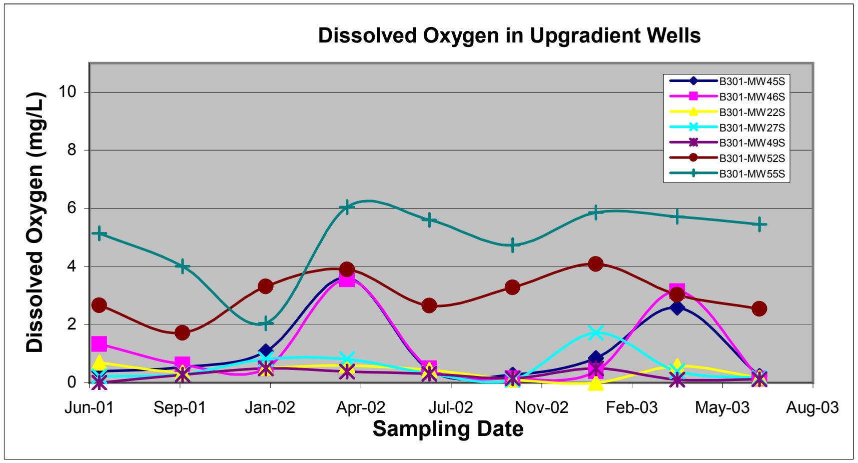
GSI Job No.	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	________	Aprv'd By:	CEA
Scale:	Not to scale		**FIGURE 5**

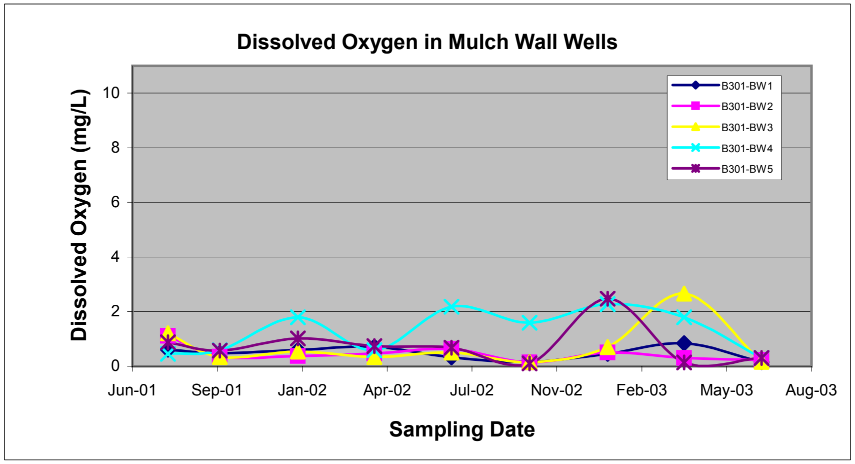
SCHEMATIC CONSTRUCTION DIAGRAM FOR FULL-SCALE MULCH WALL

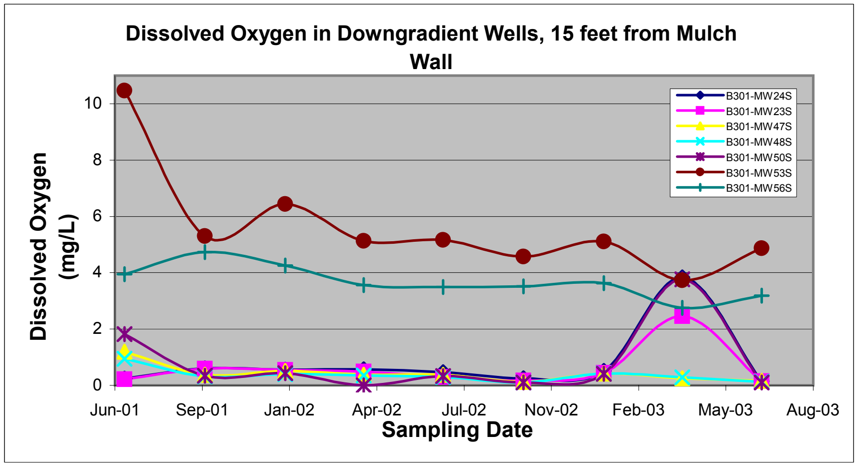
Site B301
Offutt AFB, Nebraska

FIGURE 6
DISSOLVED OXYGEN IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas


Dissolved Oxygen in Upgradient Wells


Dissolved Oxygen in Mulch Wall Wells


Dissolved Oxygen in Downgradient Wells, 15 feet from Mulch Wall

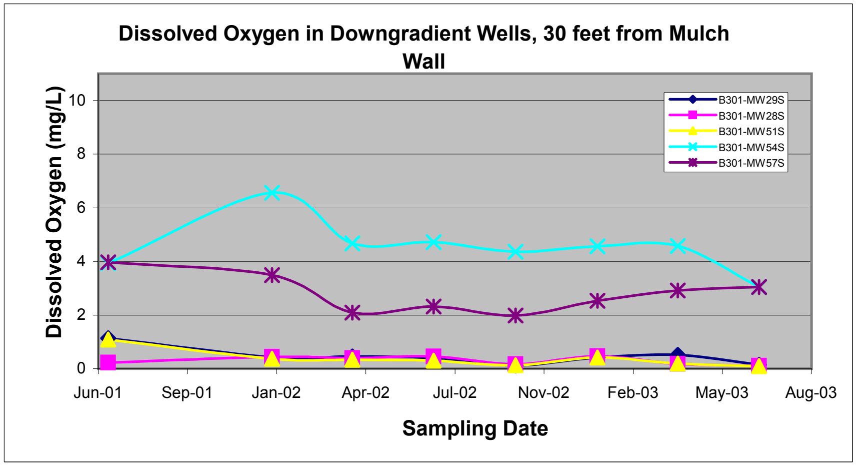
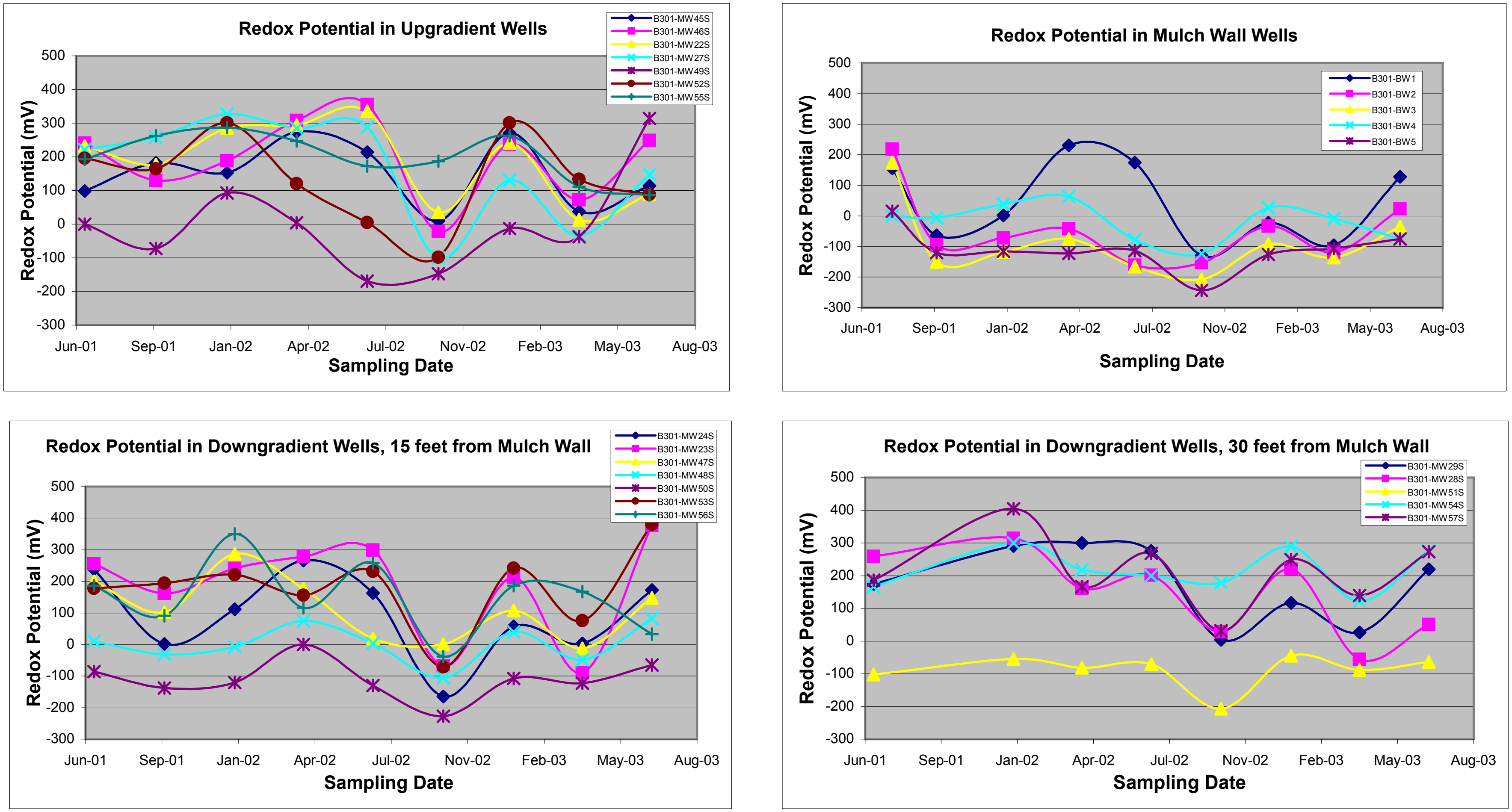

Dissolved Oxygen in Downgradient Wells, 30 feet from Mulch Wall

FIGURE 7
REDOX POTENTIAL IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas



GSI Job No. G-2050
Issued: 4/13/04
Page 1 of 1

GROUNDWATER
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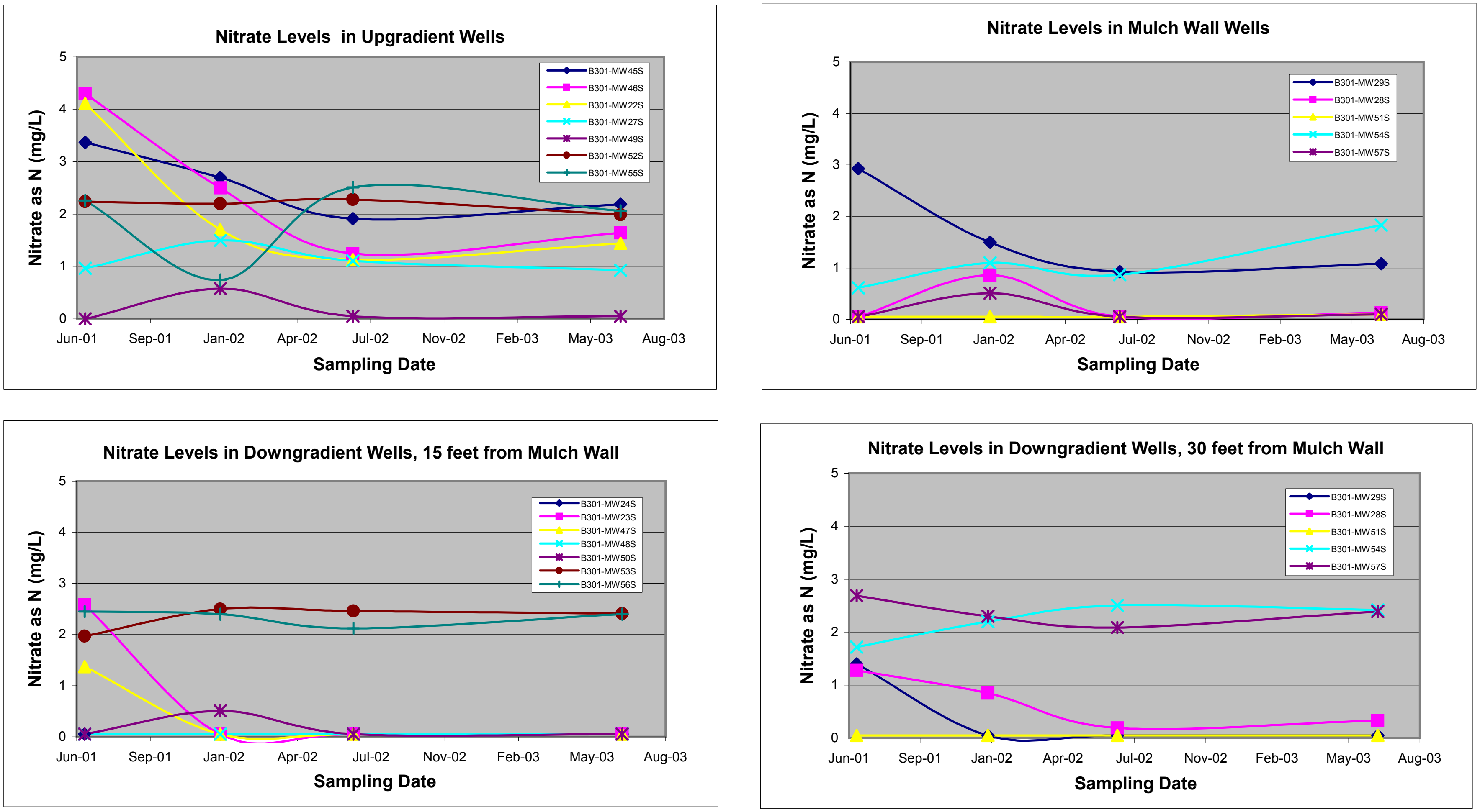
FIGURE 8
NITRATE IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

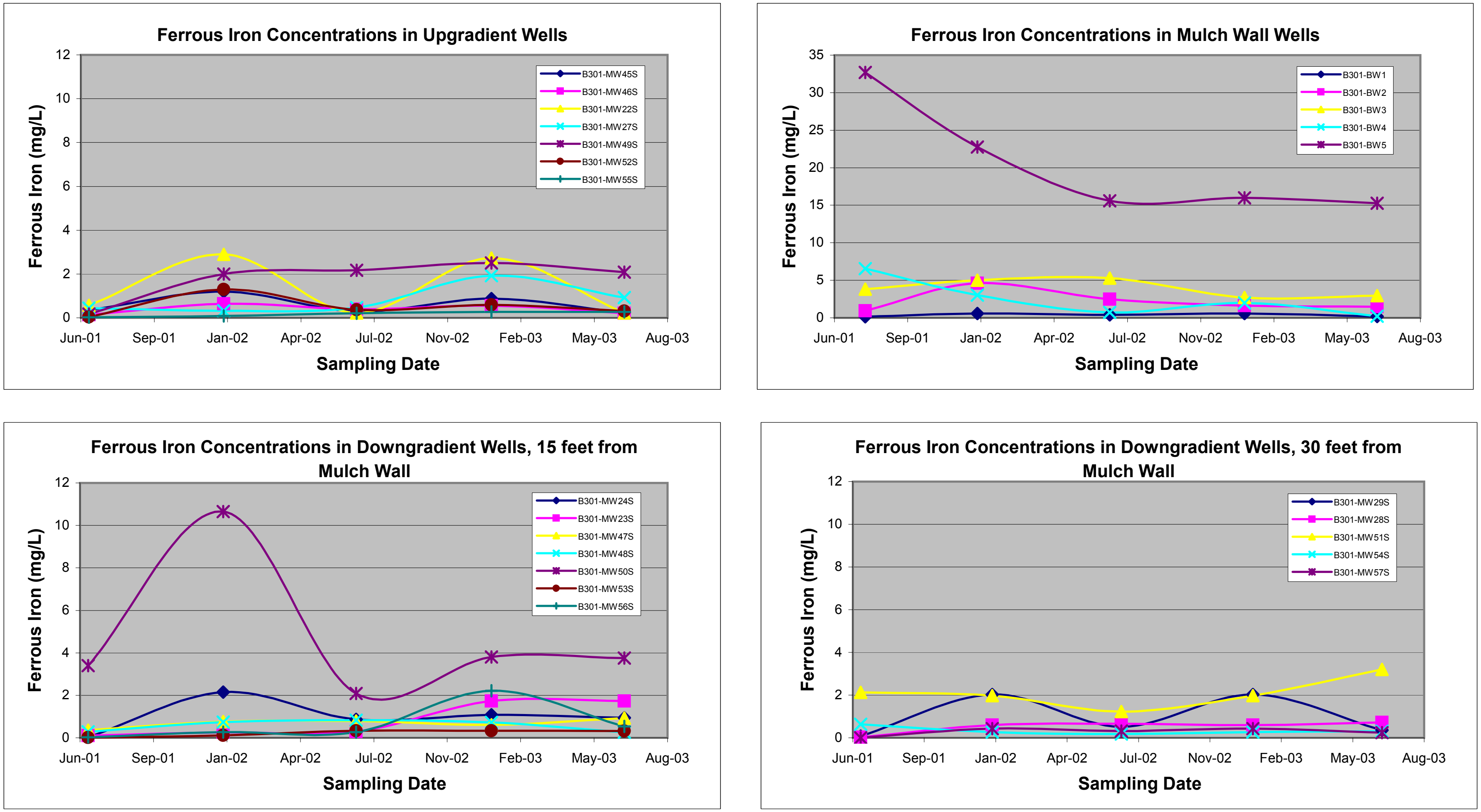
Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas



GROUNDWATER
SERVICES, INC.

FIGURE 9
FERROUS IRON IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

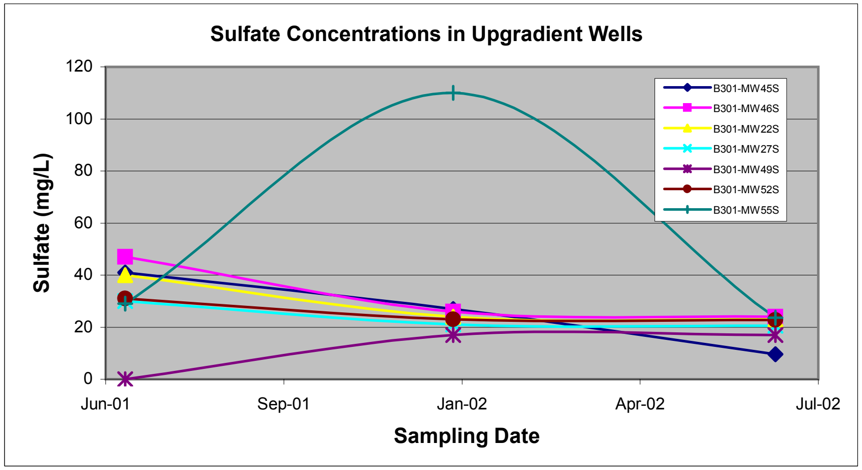


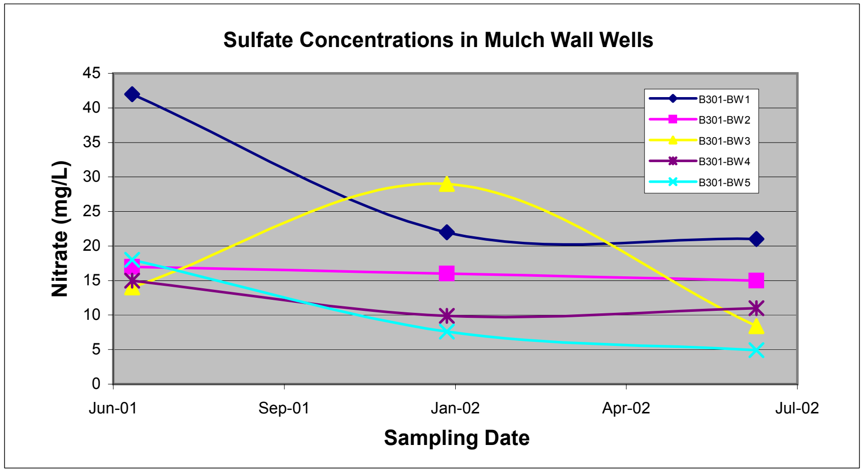
GSI Job No. G-2050
Issued: 4/13/04
Page 1 of 1

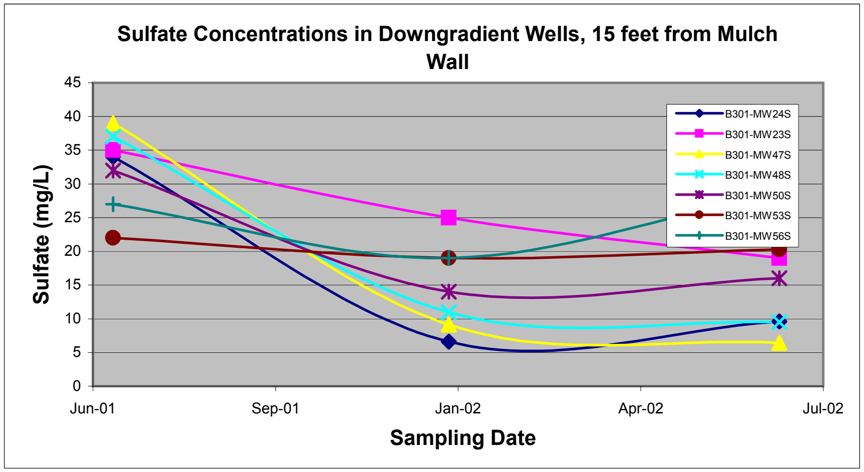
GROUNDWATER
SERVICES, INC.

FIGURE 10
SULFATE IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas


Sulfate Concentrations in Upgradient Wells


Sulfate Concentrations in Mulch Wall Wells


Sulfate Concentrations in Downgradient Wells, 15 feet from Mulch Wall

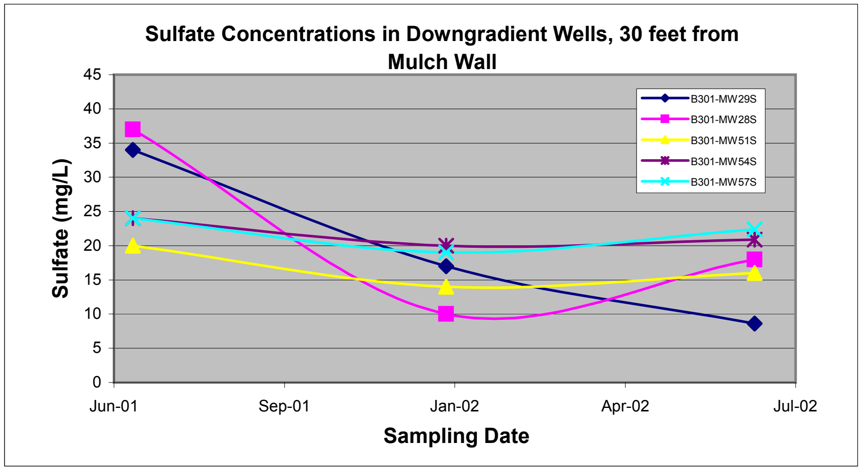
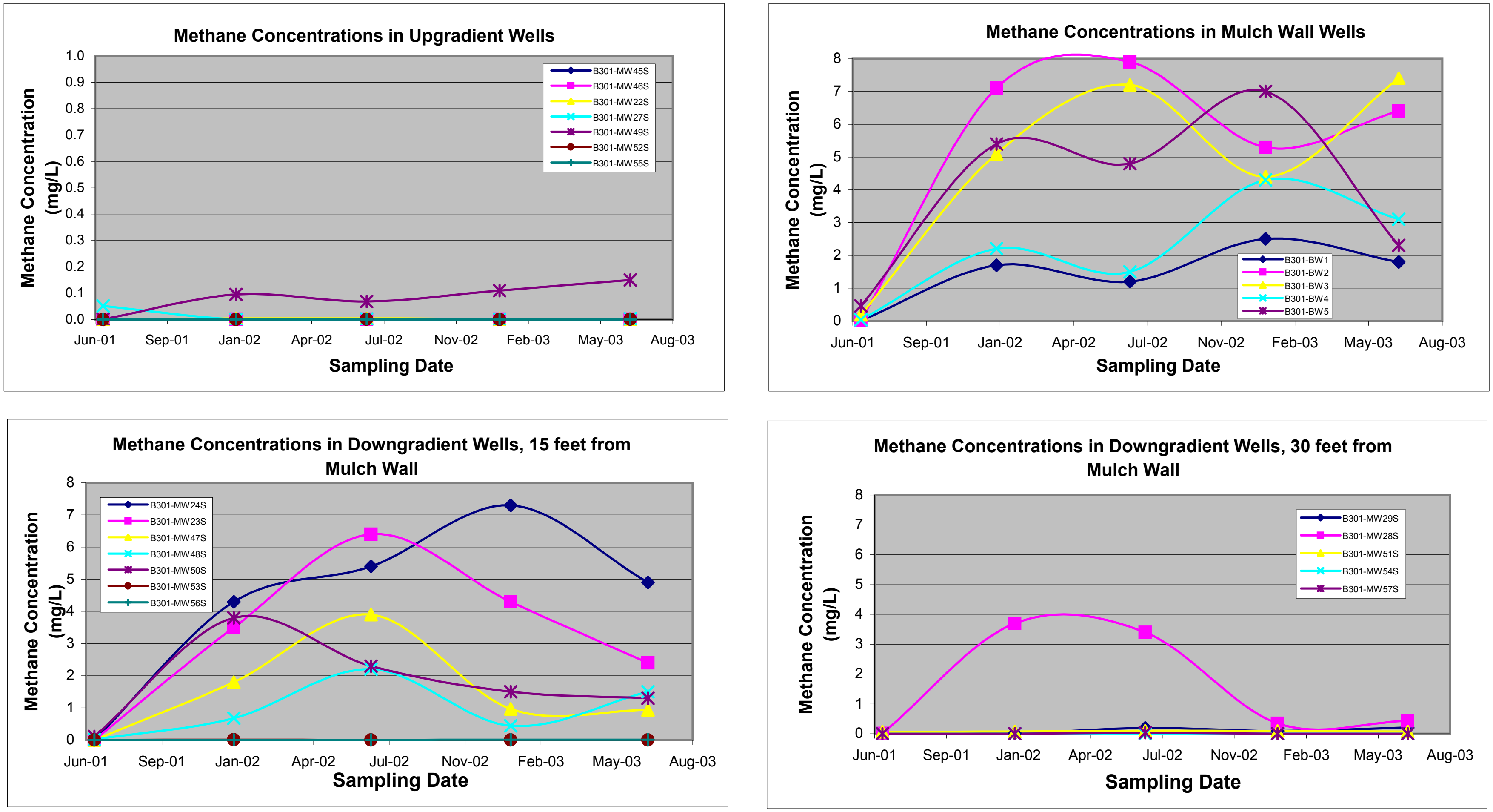

Sulfate Concentrations in Downgradient Wells, 30 feet from Mulch Wall

FIGURE 11
METHANE IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

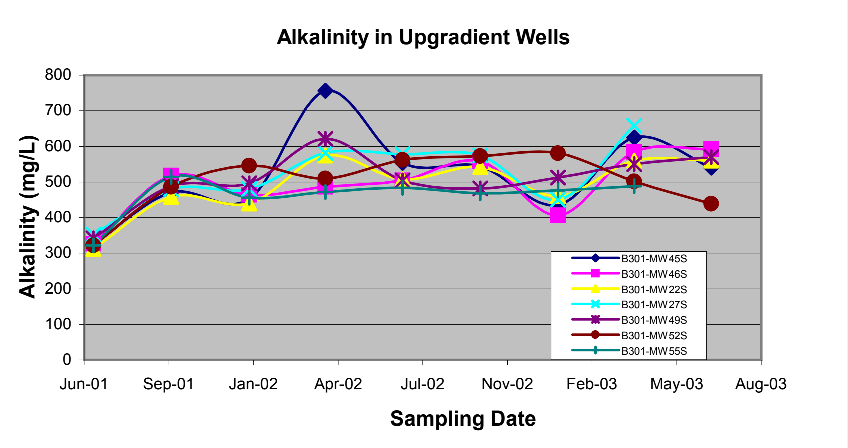
Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

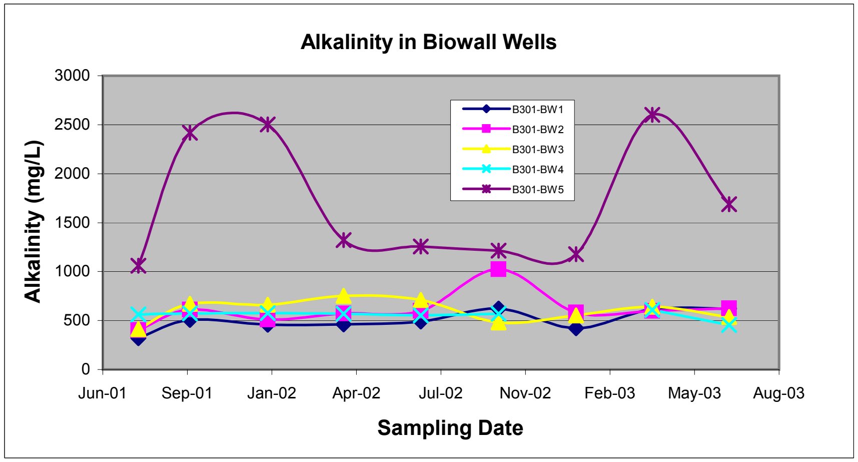


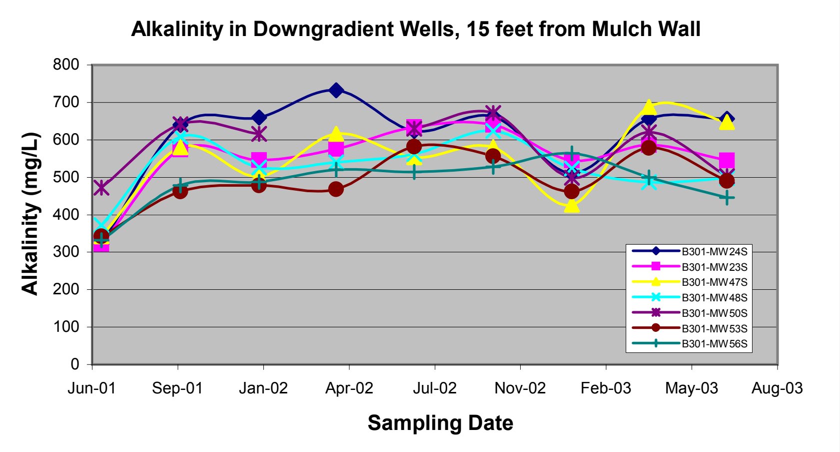
GROUNDWATER
SERVICES, INC.

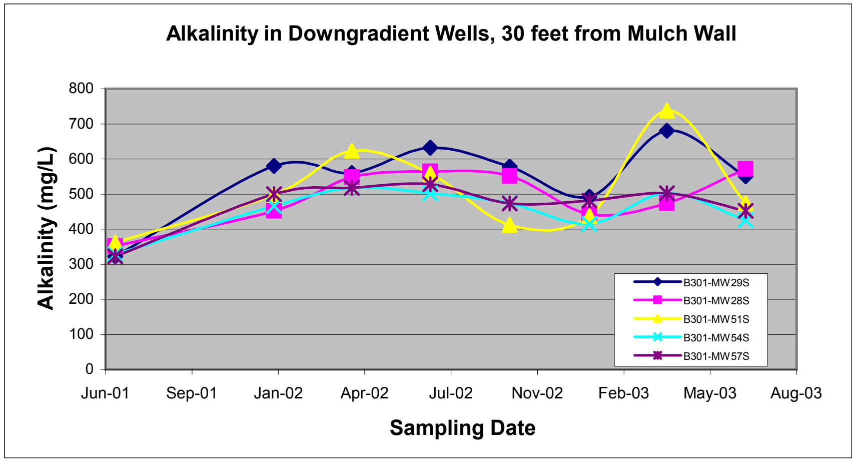
FIGURE 12
ALKALINITY IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

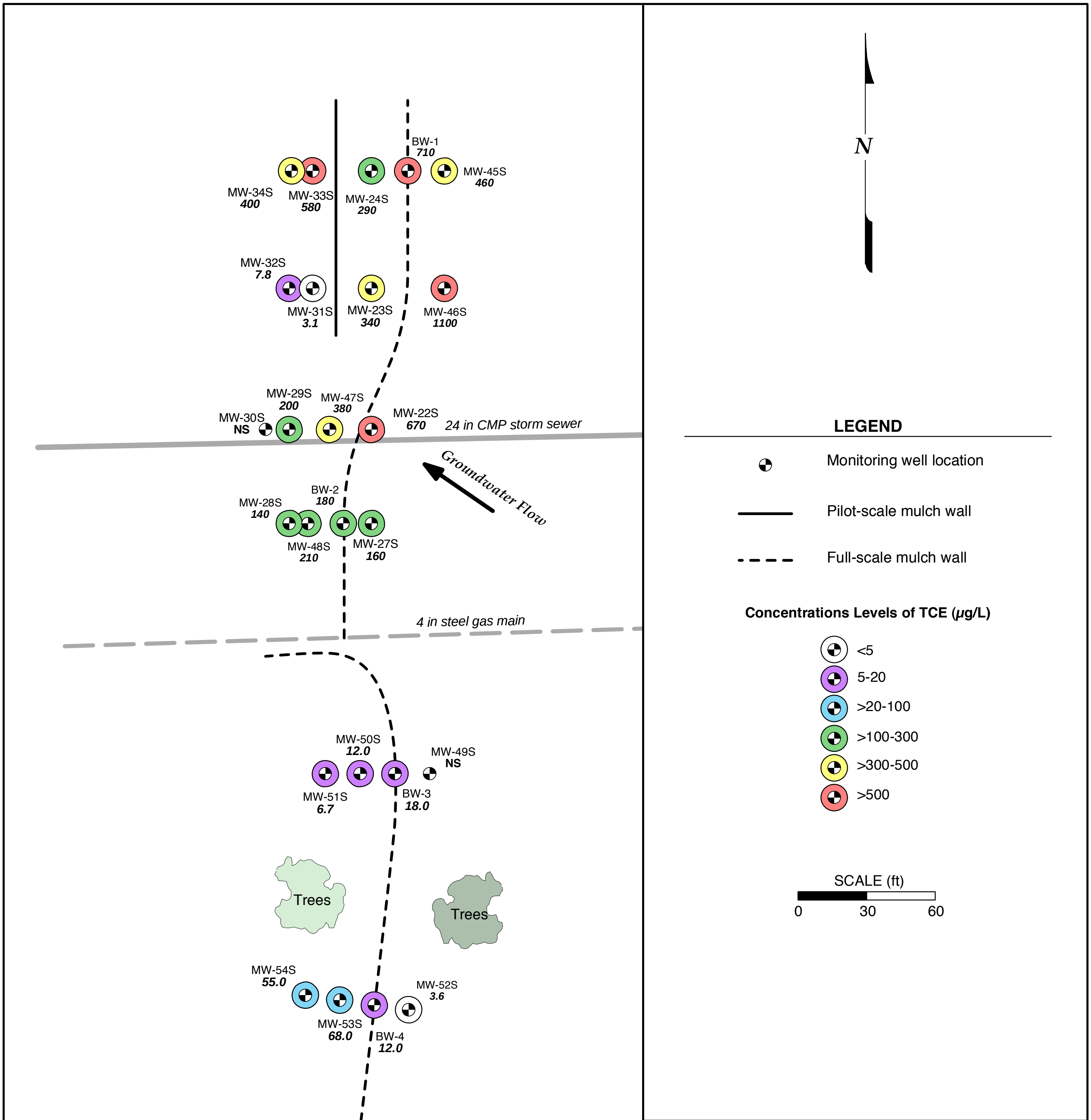
Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas


Alkalinity in Upgradient Wells


Alkalinity in Biowall Wells


Alkalinity in Downgradient Wells, 15 feet from Mulch Wall


Alkalinity in Downgradient Wells, 30 feet from Mulch Wall

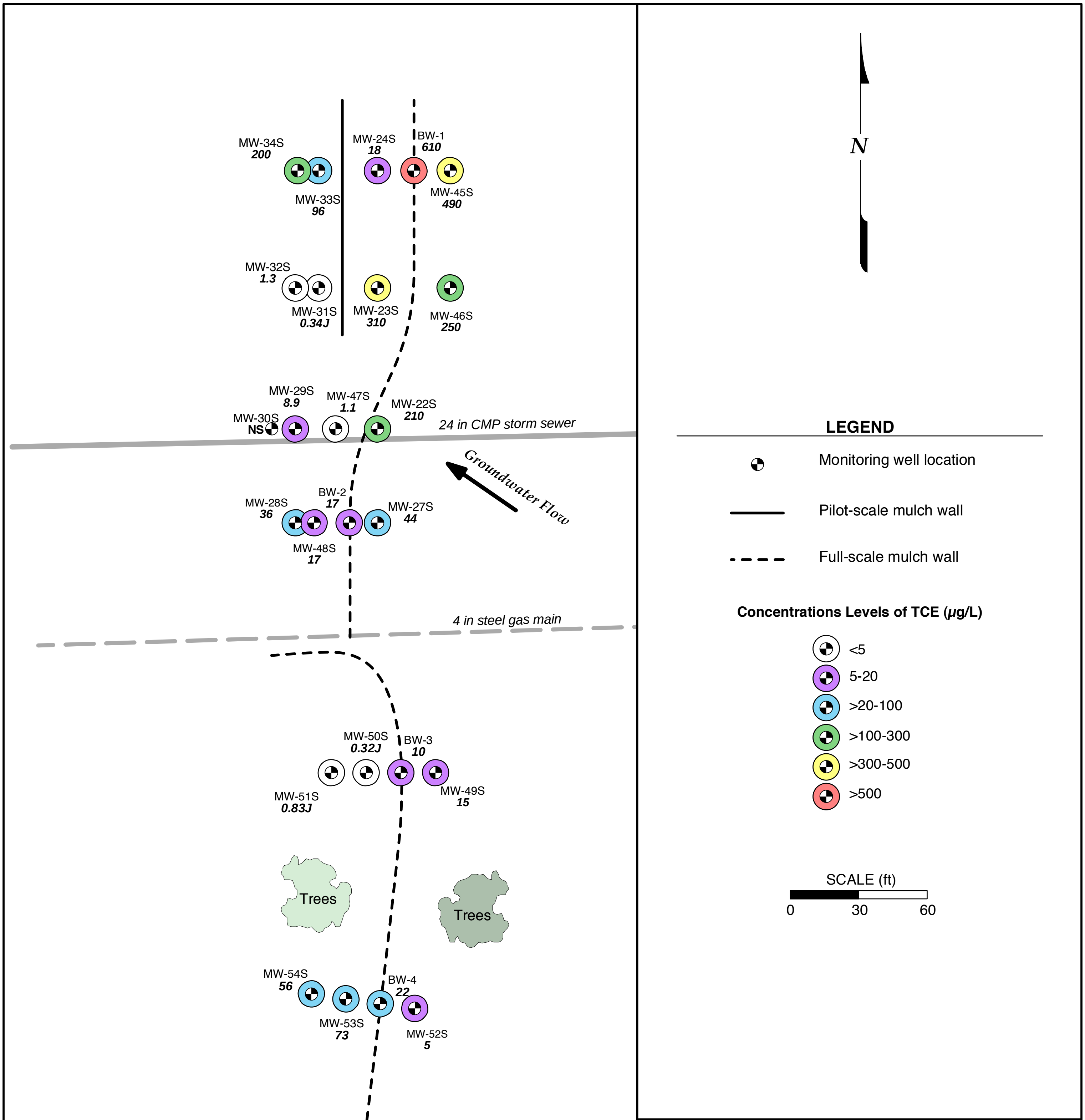


GROUNDWATER
SERVICES, INC.

TCE CONCENTRATIONS IN GROUNDWATER, JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 13**

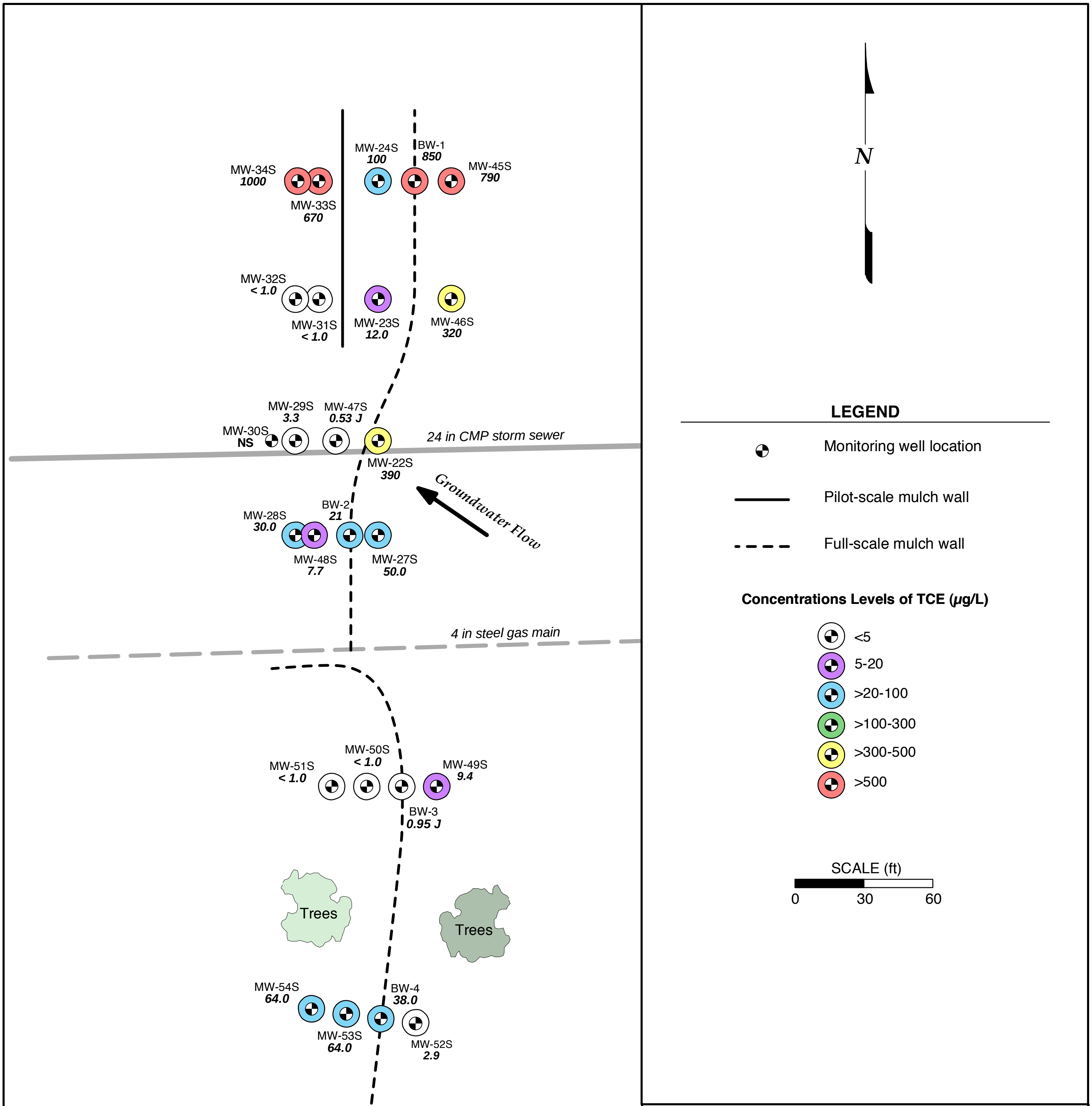


GROUNDWATER
SERVICES, INC.

TCE CONCENTRATIONS IN GROUNDWATER, JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	CCJ
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 14**

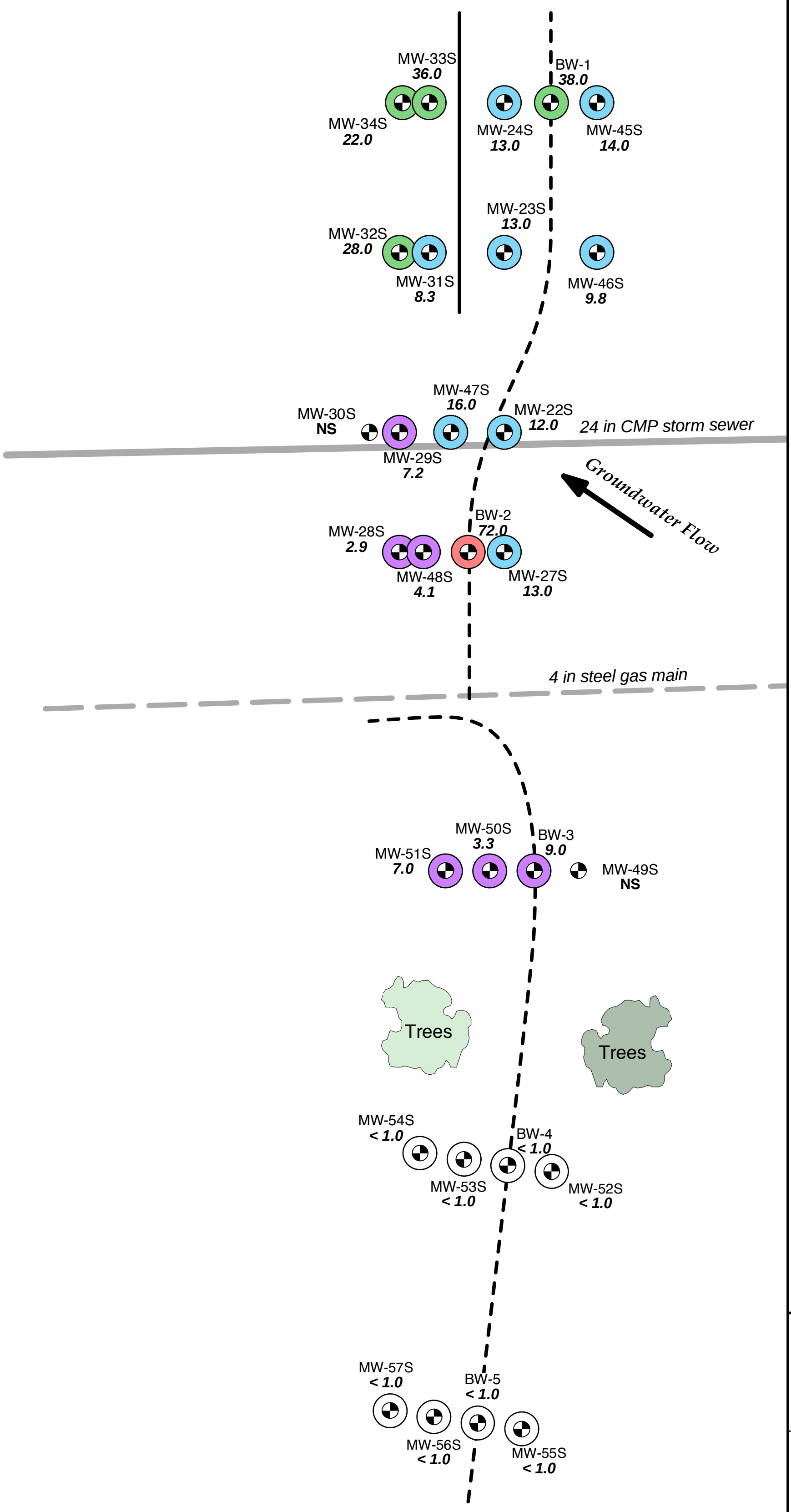


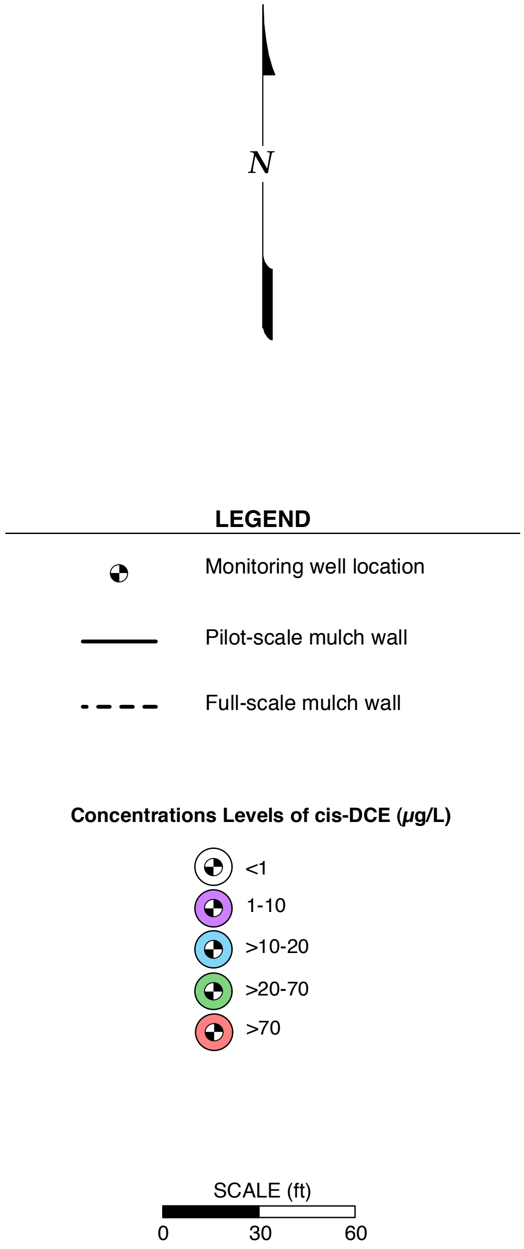
GROUNDWATER
SERVICES, INC.

TCE CONCENTRATIONS IN GROUNDWATER, JULY 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 15**



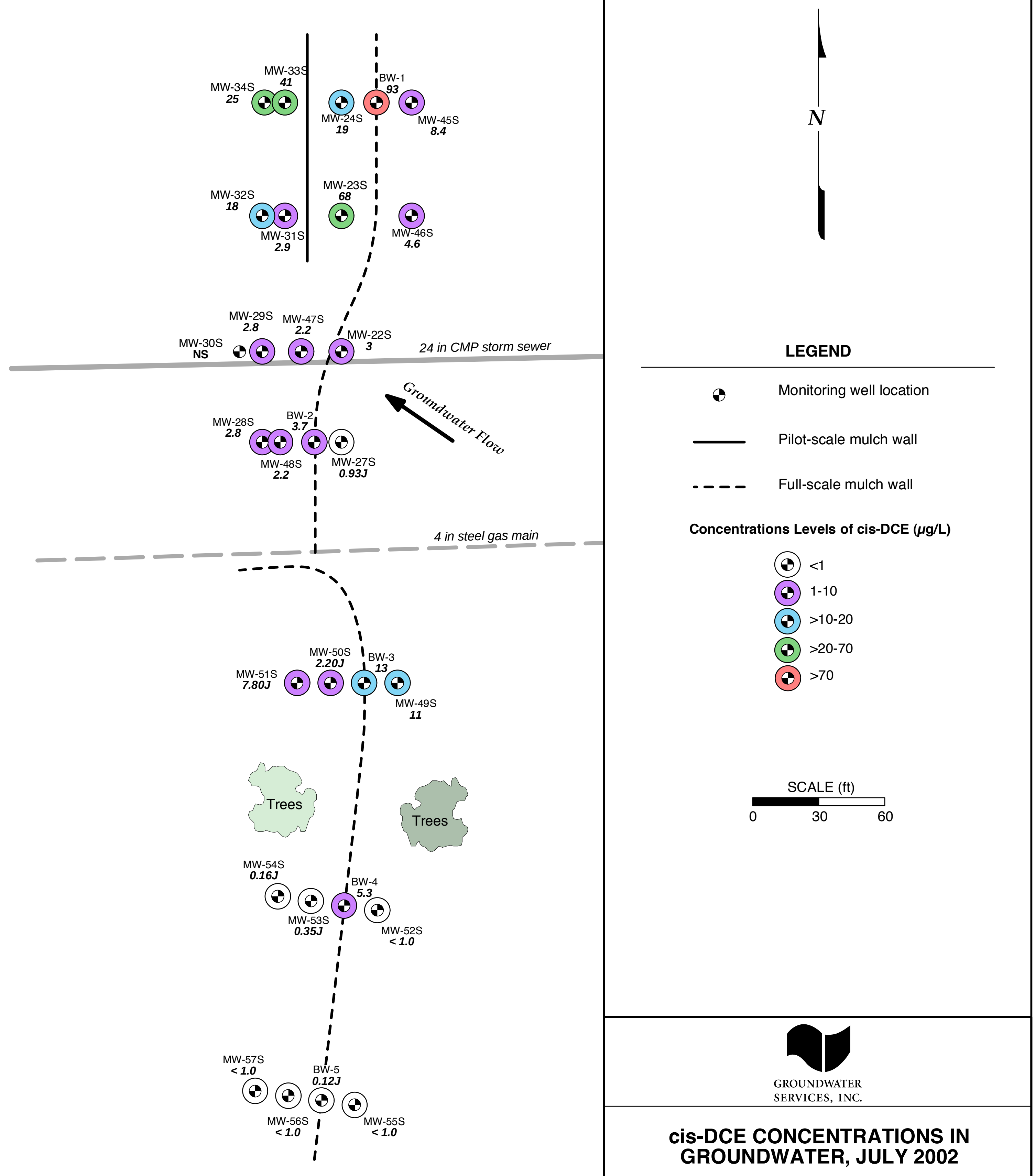


GROUNDWATER
SERVICES, INC.

cis-DCE CONCENTRATIONS IN GROUNDWATER, JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 16**

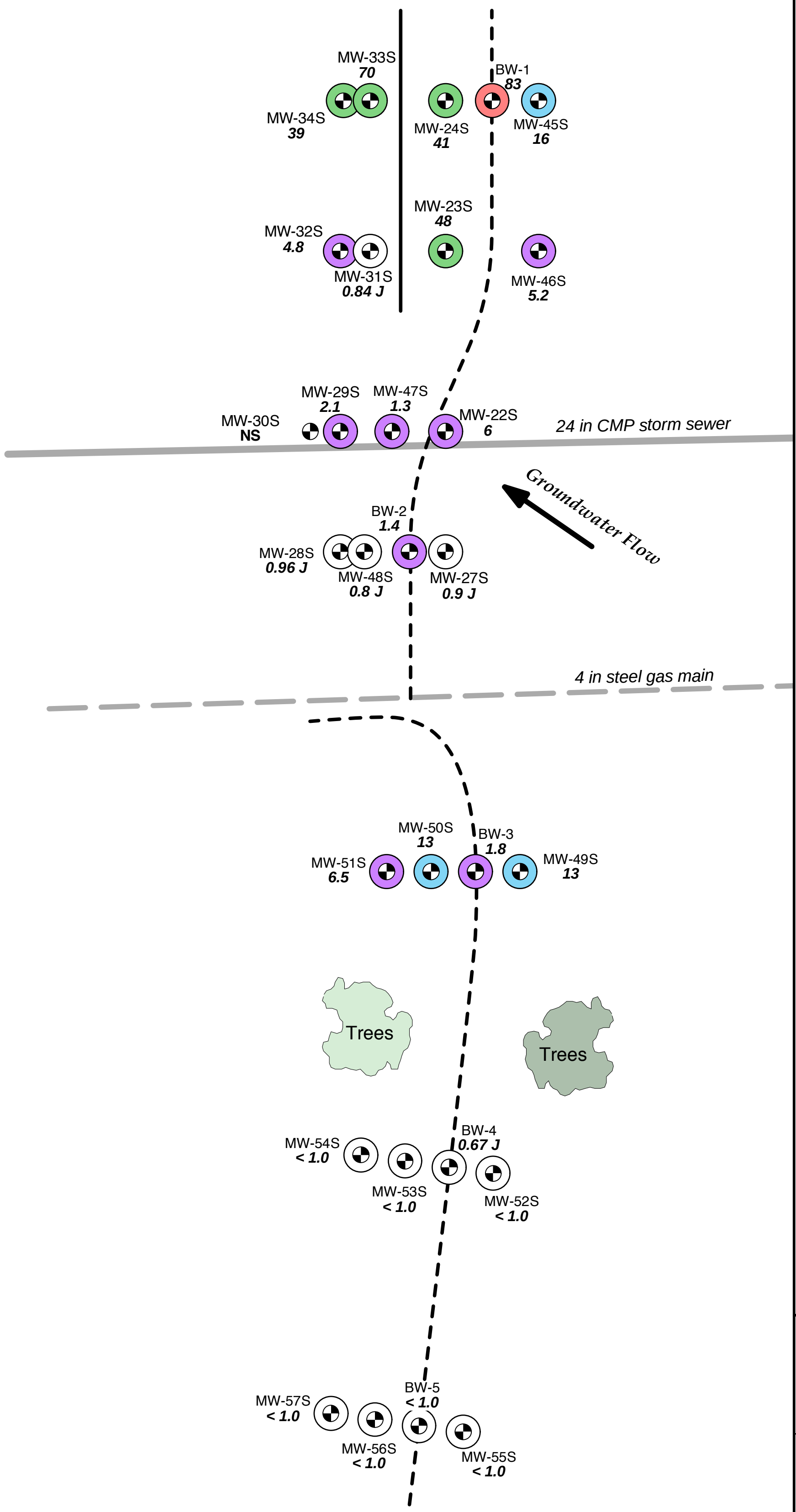


GROUNDWATER
SERVICES, INC.

cis-DCE CONCENTRATIONS IN GROUNDWATER, JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 17**



N

LEGEND

● Monitoring well location

— Pilot-scale mulch biowall

- - - Full-scale mulch biowall

Concentrations Levels of cis-DCE (μg/L)

⚪ <1

🟣 1-10

🔵 >10-20

🟢 >20-70

🔴 >70

SCALE (ft)

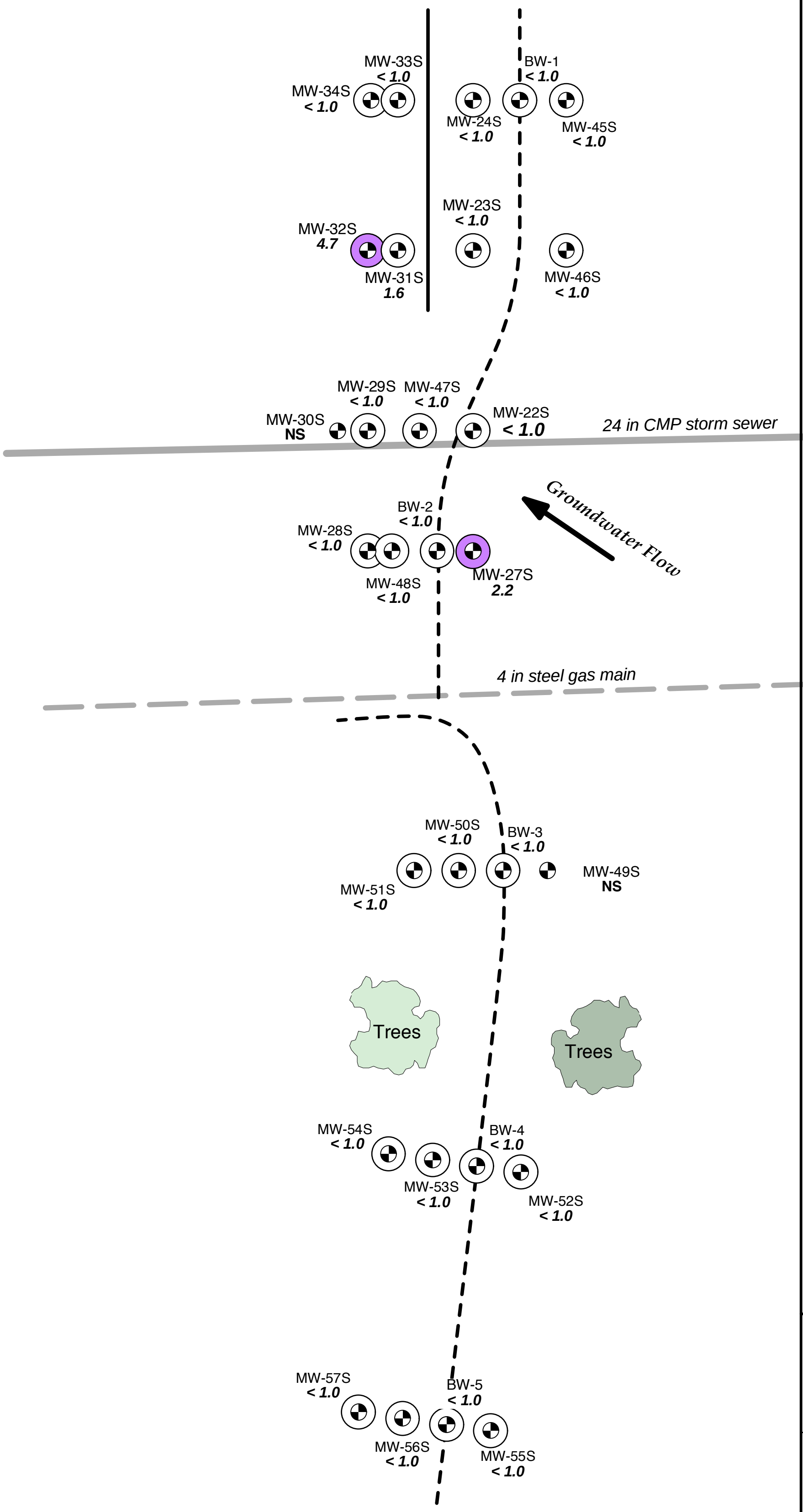
0 30 60

GROUNDWATER
SERVICES, INC.

cis-DCE CONCENTRATIONS IN GROUNDWATER, JULY 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 18**



N

LEGEND

●	Monitoring well location
▬	Pilot-scale mulch biowall
- - -	Full-scale mulch biowall

Concentrations Levels of vinyl chloride (μg/L)

○	< 2
🟣	2-10
🔵	>10-30

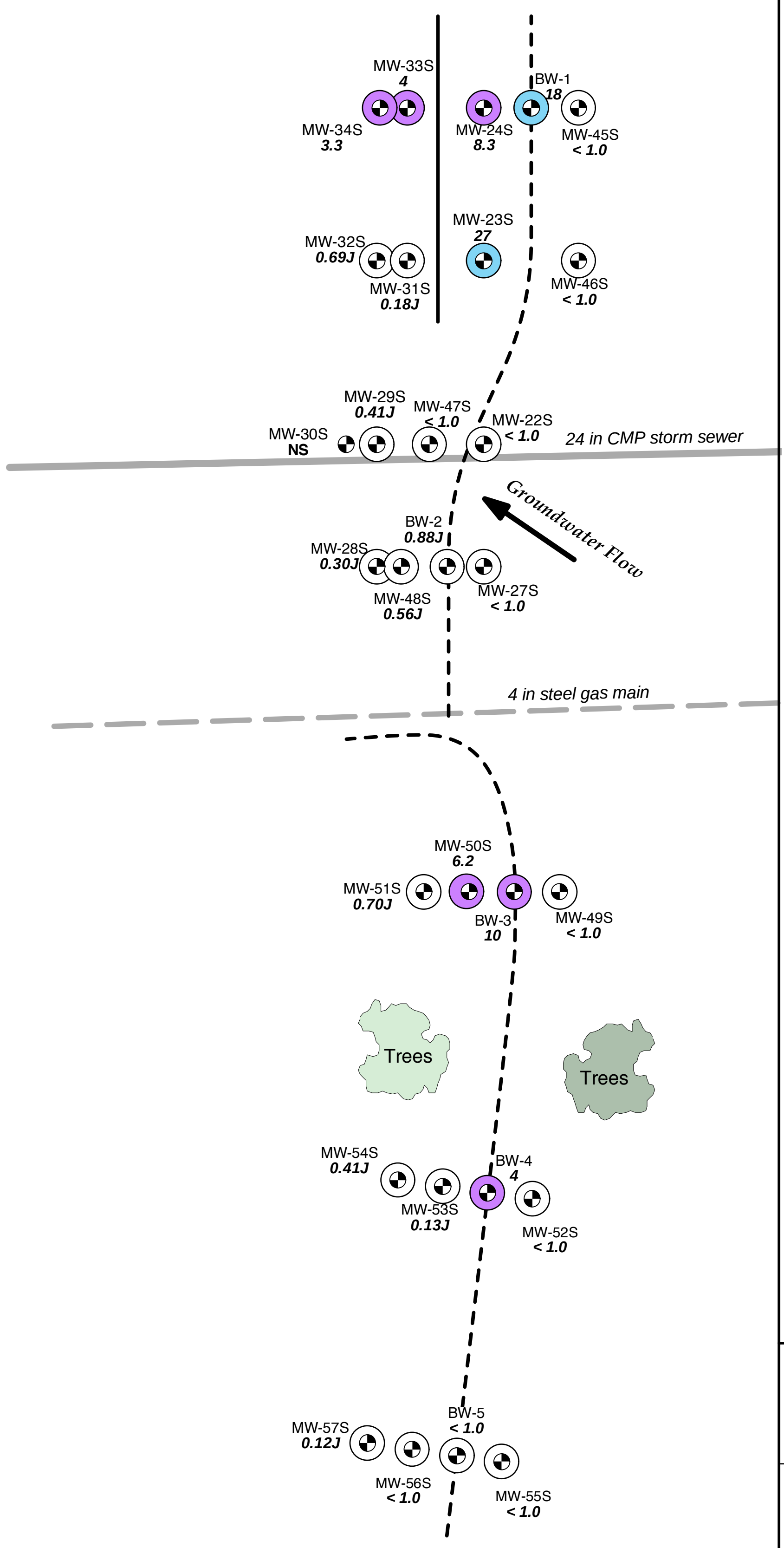
SCALE (ft)
0 30 60

GROUNDWATER
SERVICES, INC.

VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER: JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 19**

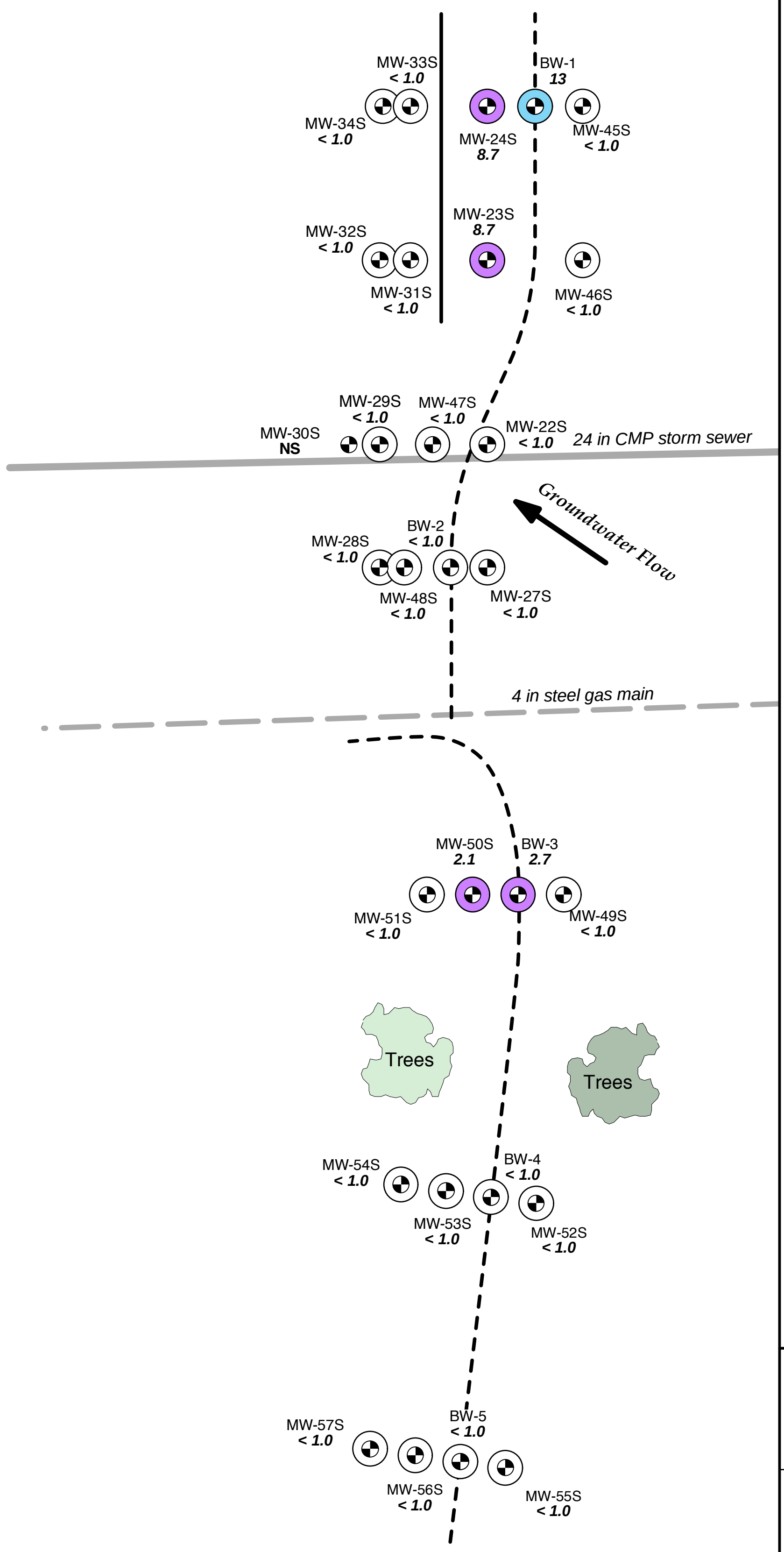


GROUNDWATER SERVICES, INC.

VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER: JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	CCJ
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		FIGURE 20



N

LEGEND

◐	Monitoring well location
—	Pilot-scale mulch biowall
- - -	Full-scale mulch biowall

Concentrations Levels of vinyl chloride (μg/L)

○	< 2
🟣	2-10
🔵	>10-30

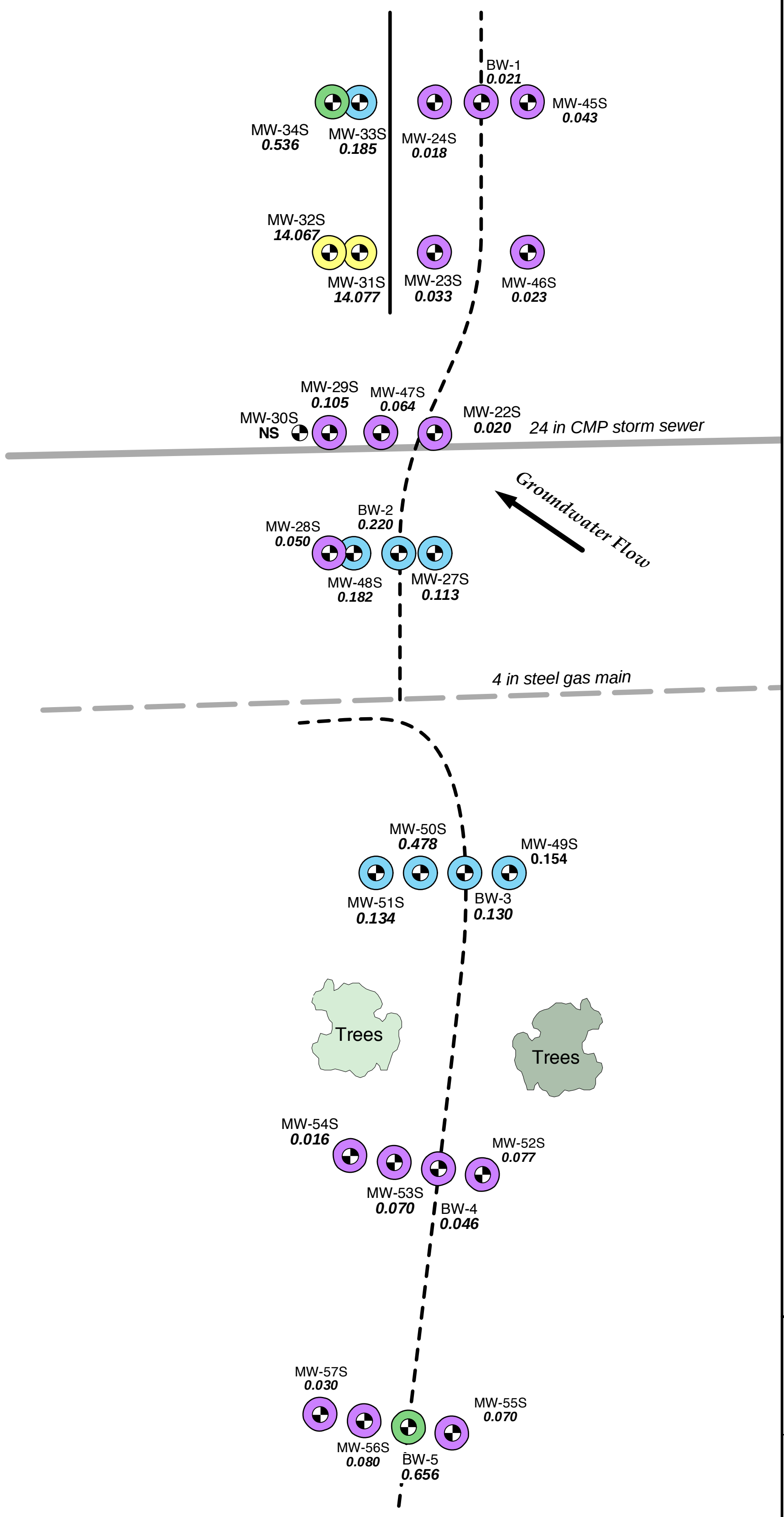
SCALE (ft)
0 30 60

GROUNDWATER
SERVICES, INC.

VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER: JULY 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 21**



LEGEND

◐ Monitoring well location

— Pilot-scale mulch wall

- - - Full-scale mulch wall

Concentrations Levels of Ethene & Ethane (μg/L)

🟣 < 0.1

🔵 0.1-0.5

🟢 >0.5-1

🟡 >1-30

SCALE (ft)

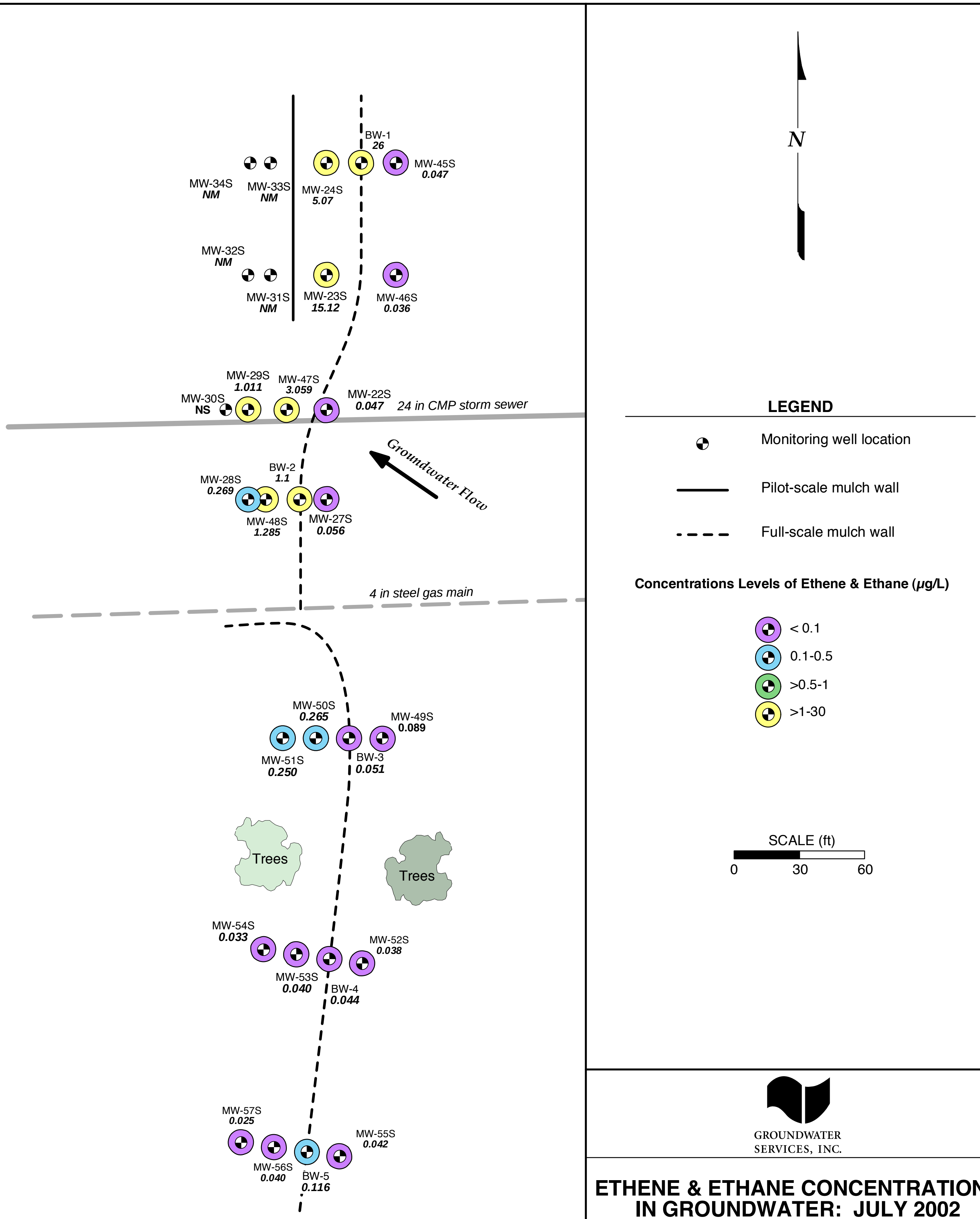
0 30 60

GROUNDWATER
SERVICES, INC.

ETHENE & ETHANE CONCENTRATIONS IN GROUNDWATER: JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 22**

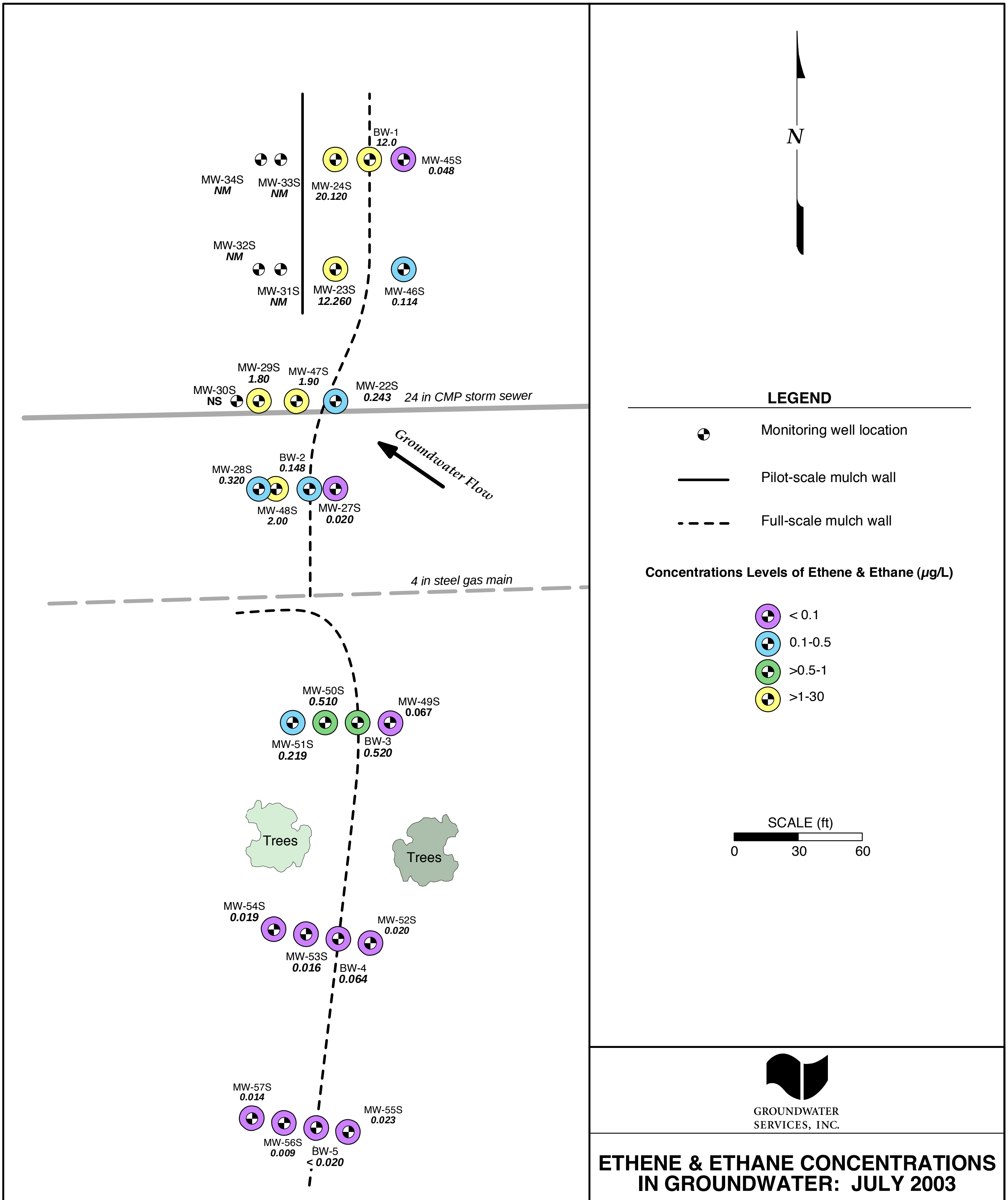


GROUNDWATER
SERVICES, INC.

ETHENE & ETHANE CONCENTRATIONS IN GROUNDWATER: JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 23**



GROUNDWATER
SERVICES, INC.

ETHENE & ETHANE CONCENTRATIONS IN GROUNDWATER: JULY 2003

Site B301
Offutt AFB, Nebraska

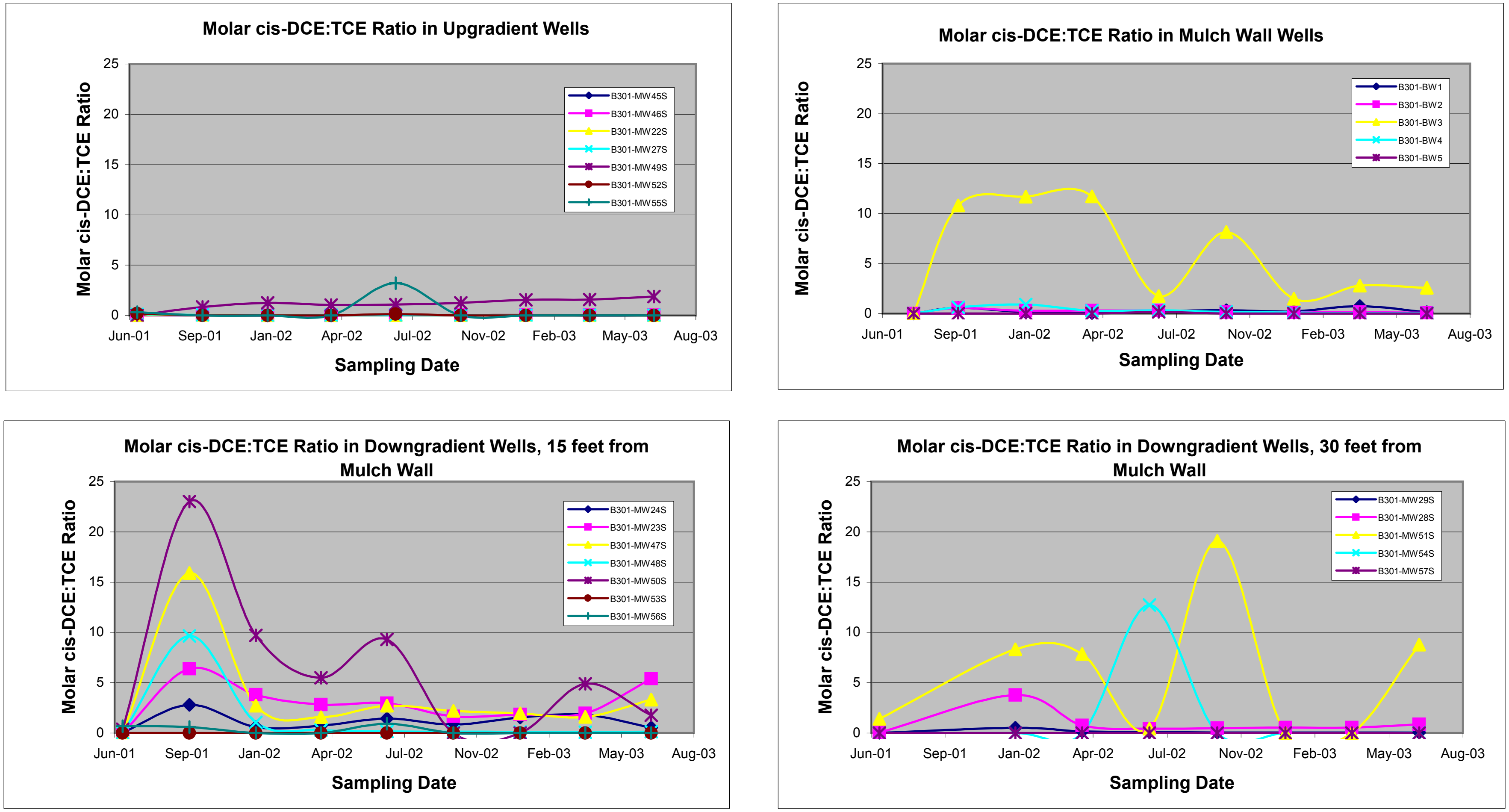
GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		FIGURE 24

GSI Job No. G-2050
Issued: 4/13/04
Page 1 of 1

GROUNDWATER
SERVICES, INC.

FIGURE 25
MOLAR cis-DCE/TCE RATIO IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

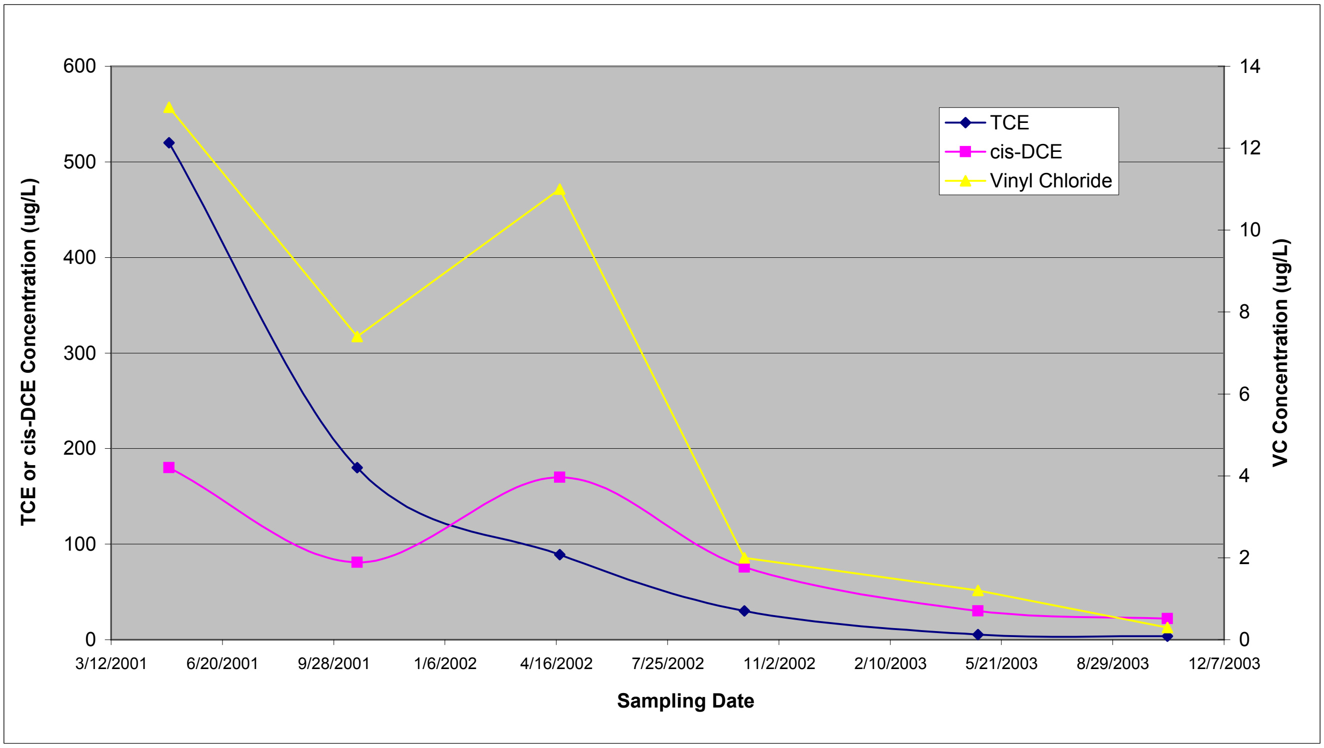


GSI Job No. G-2050
Issued: 4/13/04
Page 1 of 1

GROUNDWATER
SERVICES, INC.

FIGURE 26
CHLORINATED CONSTITUENT CONCENTRATIONS IN GROUNDWATER IN MW-9S

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas



April 13, 2004

GROUNDWATER
SERVICES, INC.

APPENDICES

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

Appendix A	Representative Monitoring Well As-Built Diagrams and Logs and Well Specifications
Appendix B	Annual Potentiometric Surface Maps
Appendix C	Monitoring Data from All Sampling Events

APPENDIX A

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

REPRESENTATIVE MONITORING WELL AS-BUILT DIAGRAMS AND LOGS AND WELL SPECIFICATIONS

TABLE A-1
MONITORING WELL SPECIFICATIONS FOR MULCH WALL WELLS
Site B301

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Air Force Center for Environmental Excellence, Brooks AFB, TX

	Well	**Well**	**Well**	**Well**	**Well**	**Well**	**Well**	**Well**	**Well**
Well Specification	**MW-45S**	**MW-46S**	**MW-47S**	**MW-48S**	**MW-49S**	**MW-50S**	**MW-51S**	**MW-52S**	**MW-53S**
Upgradient/Downgradient/Within	up	up	down	down	up	down	down	up	down
Casing Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Slot Size (in):	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Top of Casing Elev. (ft MSL):	993	993.61	993.53	993.95	994.86	993.85	993.91	998.14	996.57
Well Depth (ft BGS):	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Screen Interval (ft BGS):	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0
Northing (ft)	554411.25	554360.55	554314.6	554276.89	554176.34	554178.63	554179.3	554073.29	554073.31
Easting (ft)	2984438.43	2984439.59	2984385.21	2984378.98	2984428.65	2984398.95	2984384.13	2984422.97	2984392.8

Notes:
1) Monitoring well locations are shown on Figure 4.
2) Well casing and screen diameters given above represent nominal pipe diameter dimensions.

TABLE A-1
MONITORING WELL SPECIFICATIONS FOR MULCH WALL WELLS
Site B301

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Air Force Center for Environmental Excellence, Brooks AFB, TX

	Well	**Well**	**Well**	**Well**	**Well**	**Well**	**Well**	**Well**	**Well**
Well Specification	**MW-54S**	**MW-55S**	**MW-56S**	**MW-57S**	**BW-1**	**BW-2**	**BW-3**	**BW-4**	**BW-5**
Upgradient/Downgradient/Within	down	up	down	down	within	within	within	within	within
Casing Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Slot Size (in):	0.010	0.010	----	----	0.020	0.020	0.020	0.020	0.020
Top of Casing Elev. (ft MSL):	996.13	999.86	998.47	998.16	993.13	993.44	994.1	997.62	999.57
Well Depth (ft BGS):	20.0	20.0	20.0	20.0	22.0	22.0	22.0	22.0	22.0
Screen Interval (ft BGS):	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0
Northing (ft)	554073.54	553989.78	553993.5	553995.81	554413.11	554275.4	554176.32	554071.15	553991.1
Easting (ft)	2984379.03	2984414.89	2984384.67	2984370.34	2984423.57	2984398.41	2984416.69	2984405.1	2984397.54

Notes:
1) Monitoring well locations are shown on Figure 4.
2) Well casing and screen diameters given above represent nominal pipe diameter dimensions.

GEOLOGIST: Mark Hampton
DRILLER: Professional Service Industries
DRILLING METHOD: Flight Auger
HOLE DIAMETER: 6.0-inches

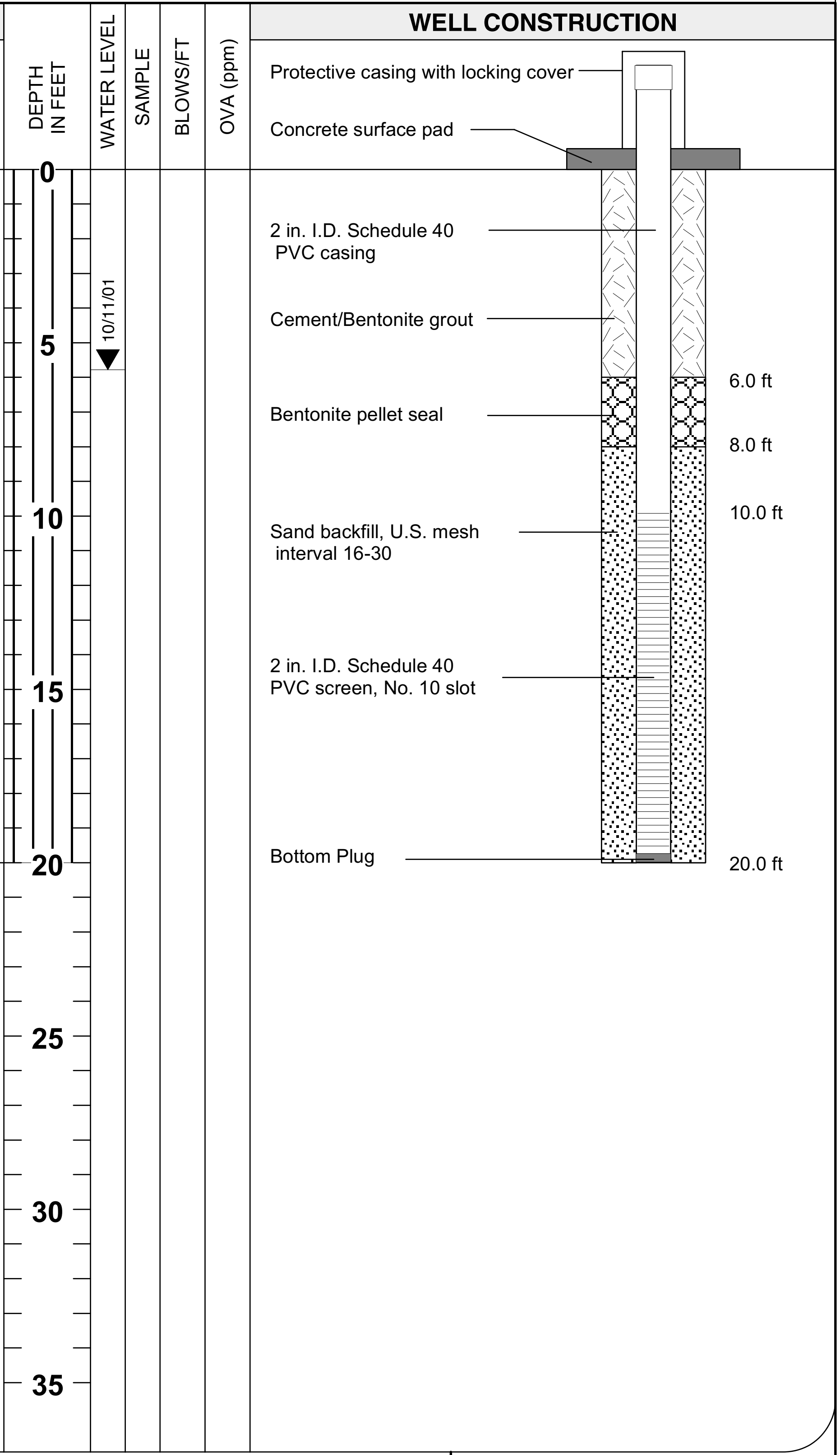
COMPLETION DATE: November 12, 1998
TOP OF CASING ELEV: 993.18 ft MSL

SOIL DESCRIPTION

GROUND SURFACE

Grayish-brown clayey SILT (ML)

Total Depth = 20.0 ft



Notes:
1. Groundwater seepage encountered at approximately 5 feet during drilling.
2. Water level elevations are approximate
3. Stratigraphy based on observation of drill cuttings

GROUNDWATER
SERVICES, INC.

LOG & AS-BUILT DIAGRAM

B301 - MW22S

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-1

GEOLOGIST: Mark Hampton
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Hollow-Stem Auger
HOLE DIAMETER: 8.25-inches

COMPLETION DATE: July 16, 2001
TOP OF CASING ELEV: 993.00 ft MSL

SOIL DESCRIPTION

GROUND SURFACE

Brown clayey, silty fine SAND (SM)

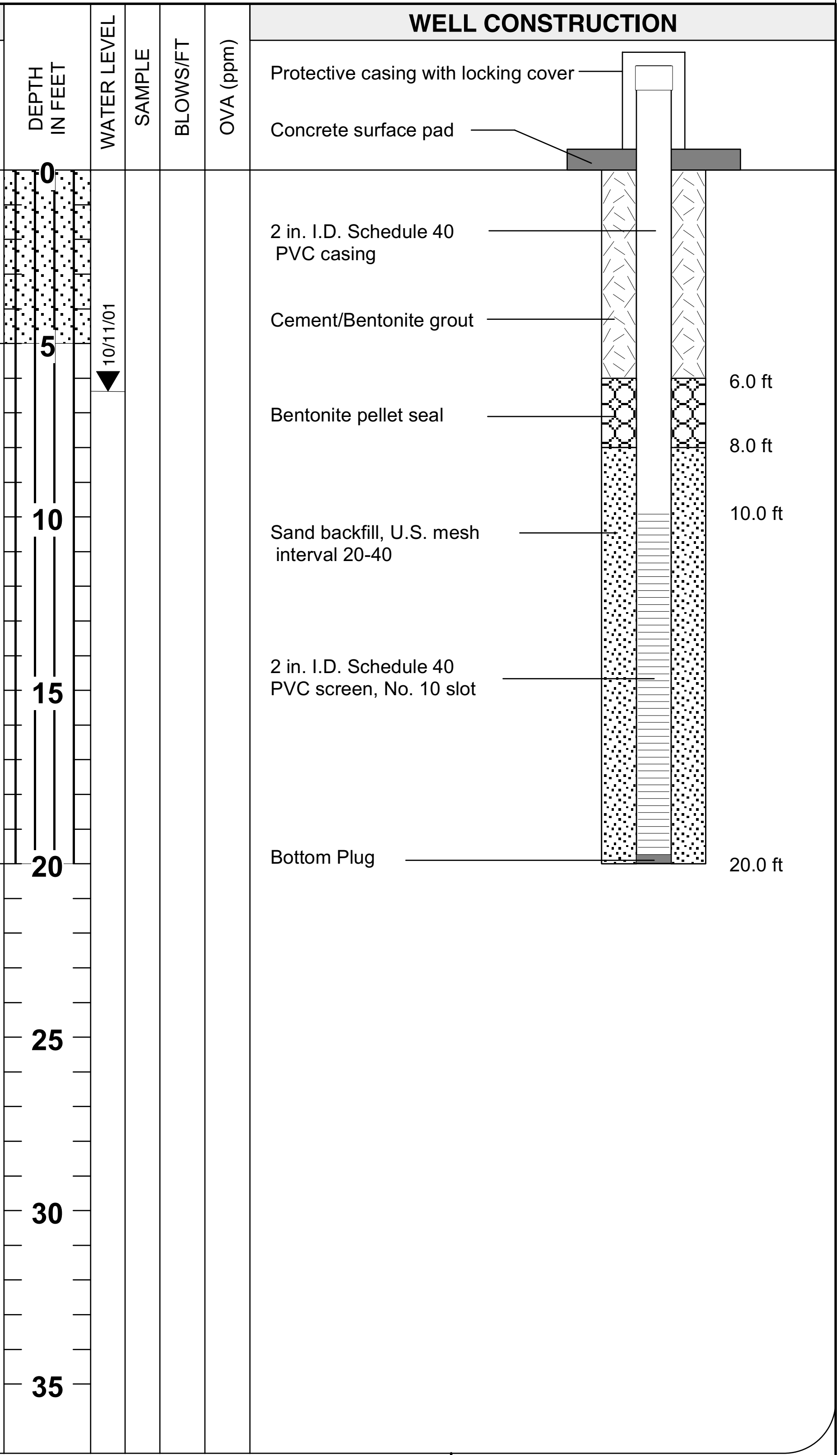
Brown clayey SILT (ML)

- becoming light brown below 9 ft.

- gray below 17 ft.

Total Depth = 20.0 ft

Note:
Groundwater seepage encountered at approximately 8 feet during drilling.



GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM

B301 - MW45S

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-2

GEOLOGIST: Mark Hampton
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Hollow-Stem Auger
HOLE DIAMETER: 8.25-inches

COMPLETION DATE: July 16, 2001
TOP OF CASING ELEV: 993.53 ft MSL

SOIL DESCRIPTION

GROUND SURFACE

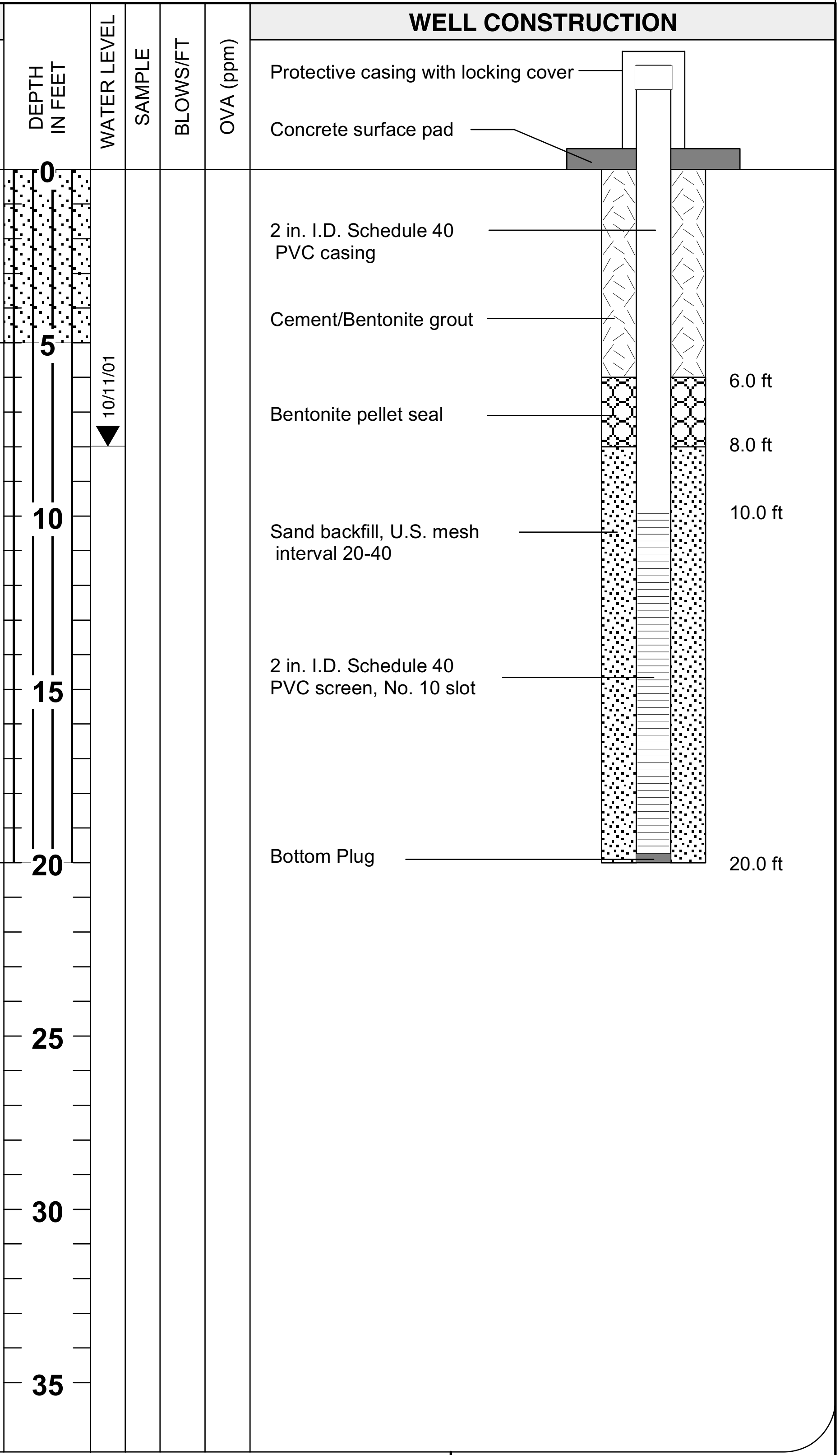
Yellowish-orange clayey, silty fine SAND (SM)

Dark gray clayey SILT (ML)

- becoming light brown below 13 ft.

Total Depth = 20.0 ft

Note:
1. Groundwater seepage encountered at approximately 6 feet during drilling.



GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM

B301 - MW47S

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-3

GEOLOGIST: Mark Hampton
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Hollow-Stem Auger
HOLE DIAMETER: 8.25-inches

COMPLETION DATE: July 17, 2001
TOP OF CASING ELEV: 999.86 ft MSL

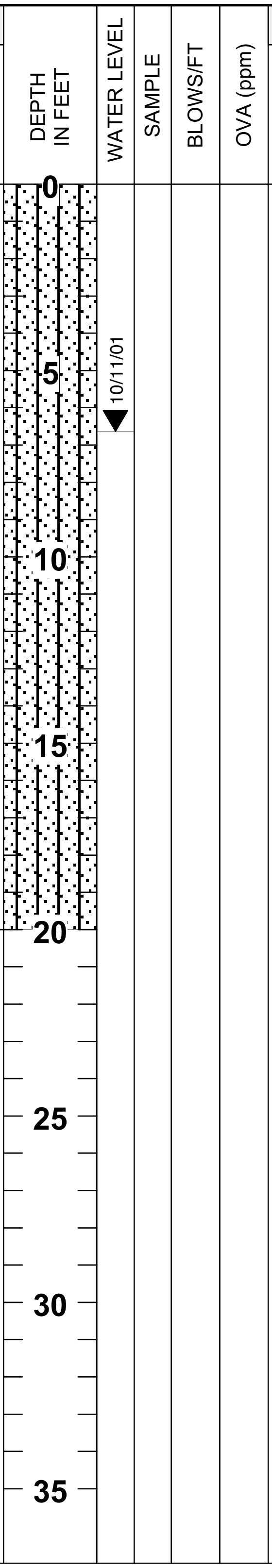
SOIL DESCRIPTION

GROUND SURFACE

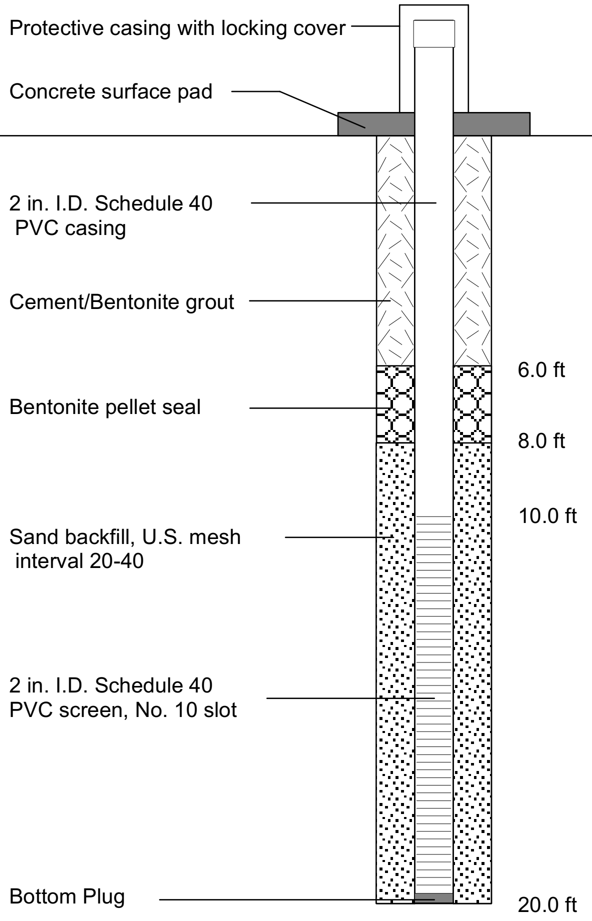
Tan clayey, silty fine SAND (SM)

- with less clay and coaser sand below 6 ft.
- with clay seam at 7 ft.

Total Depth = 20.0 ft



WELL CONSTRUCTION



Note:
Groundwater seepage encountered at approximately 6 feet during drilling.

GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM

B301 - MW55S

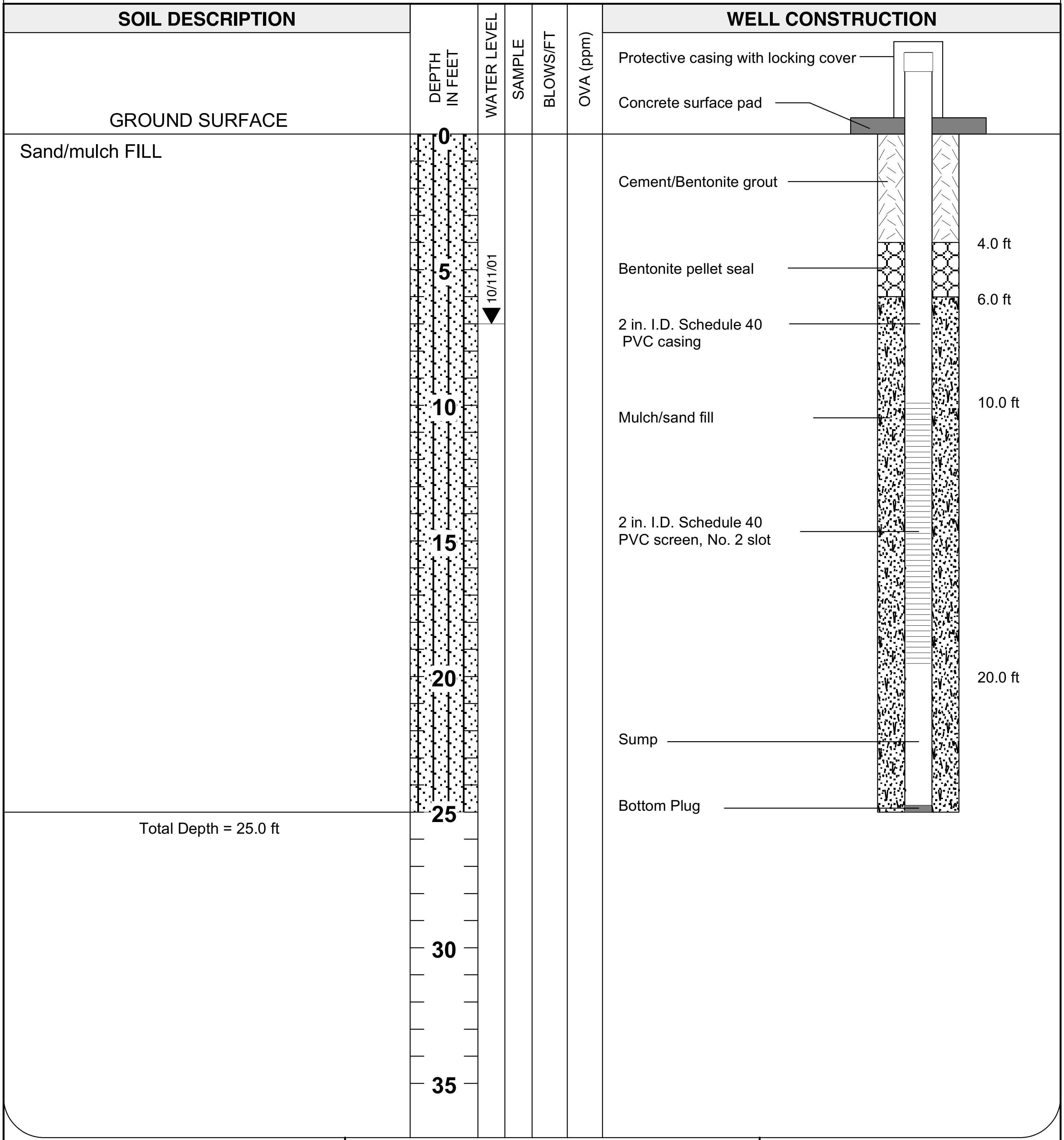
Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-4

GEOLOGIST: Mark Schipper
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Flight Auger
HOLE DIAMETER: 6.0-inches

COMPLETION DATE: August 7, 2001
TOP OF CASING ELEV: 986.61 ft MSL



GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM
MULCH WALL WELL BW-2

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

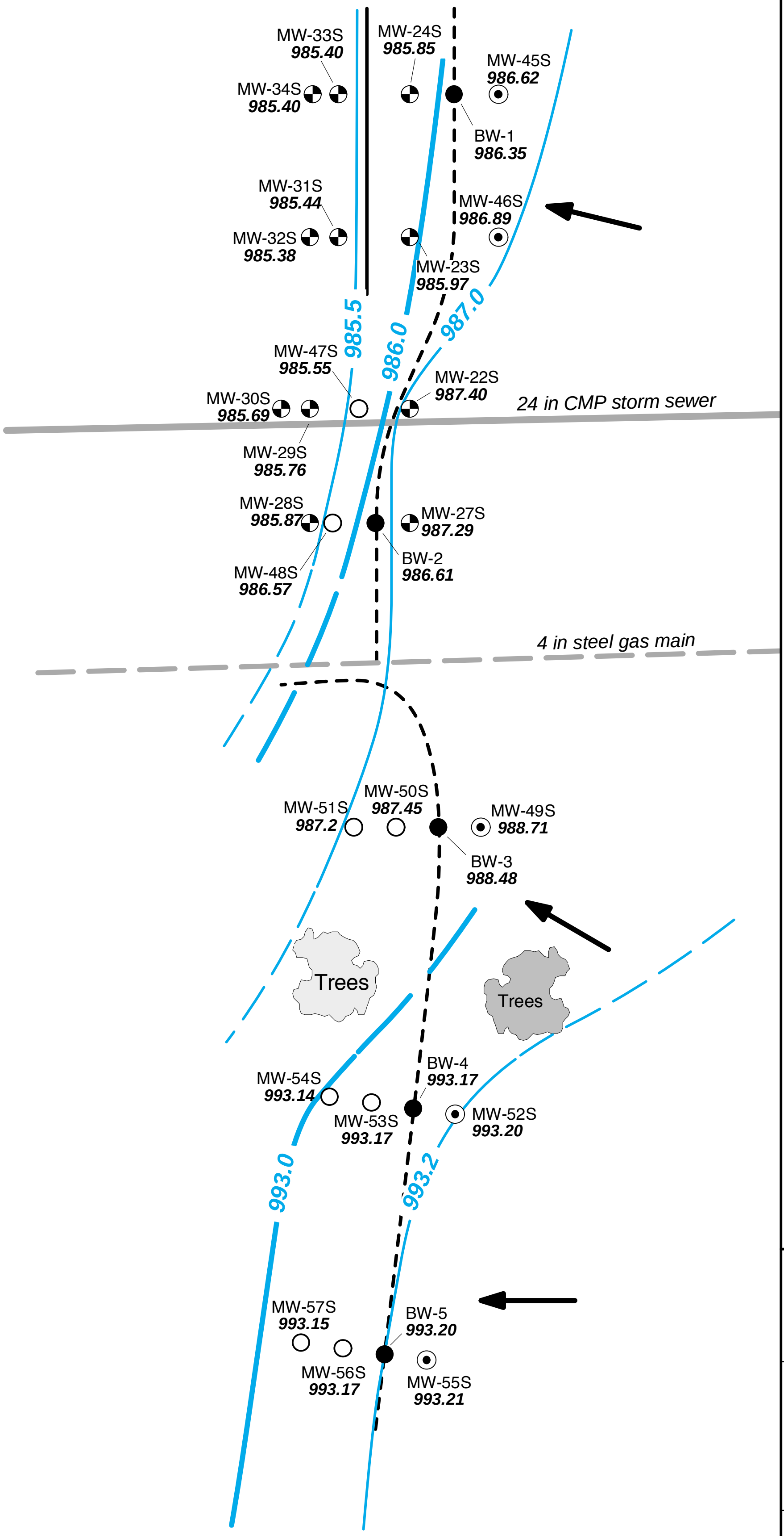
FIGURE A-5

APPENDIX B

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

ANNUAL POTENTIOMETRIC SURFACE MAPS



N

LEGEND

◕	Existing pilot scale-test monitoring well location
⊙	New upgradient background monitoring well location
○	New downgradient monitoring well location
●	New mulch wall monitoring well location
──	Existing pilot-scale mulch wall
- - -	Full-scale mulch wall
– 995.0 –	Potentiometric surface contour
←	Inferred groundwater flow direction

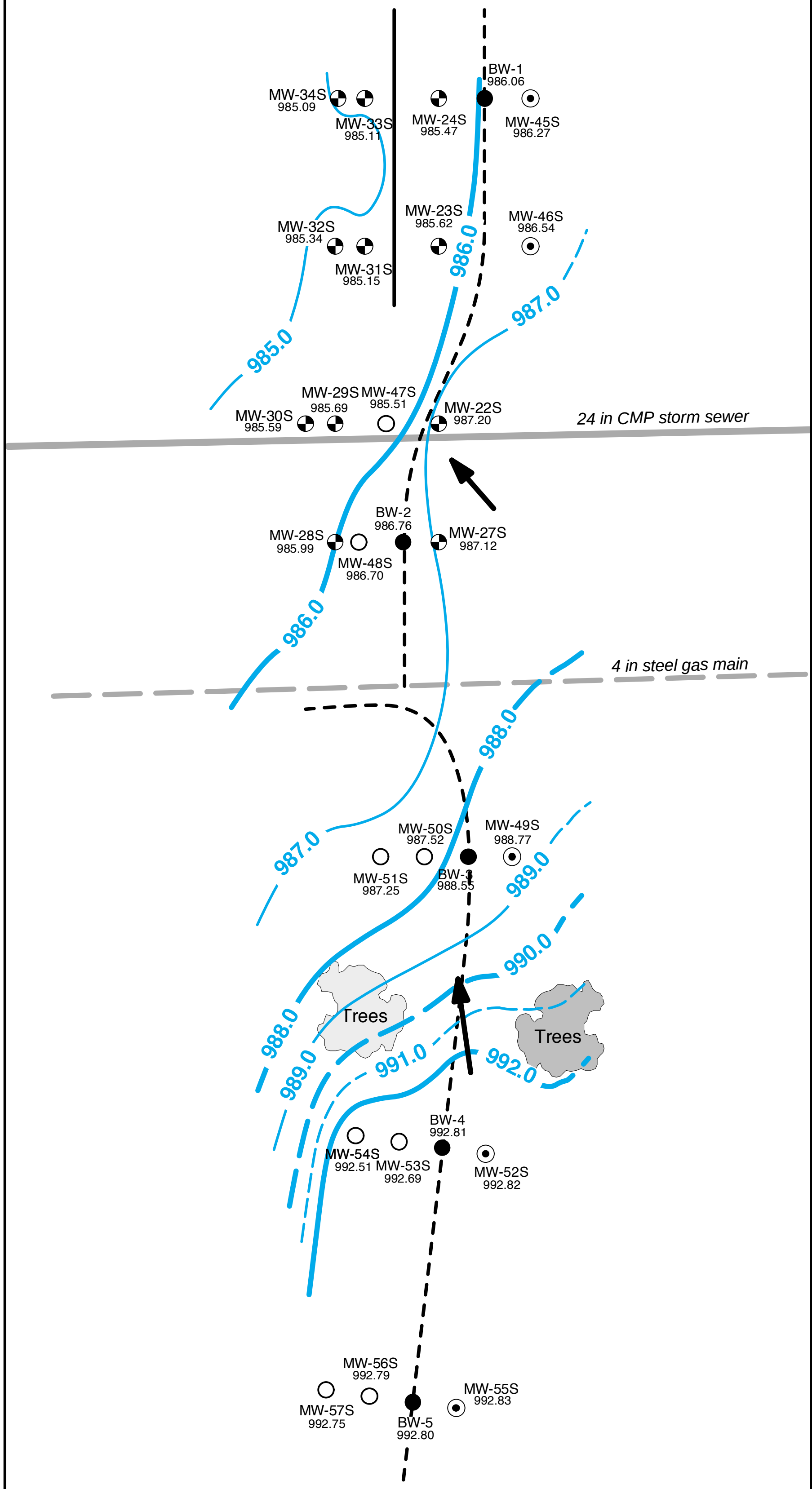
SCALE (ft.)
0 30 60

GROUNDWATER
SERVICES, INC.

POTENTIOMETRIC SURFACE MAP for MULCH WALL: OCTOBER 11, 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	DLB/CCJ
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		**FIGURE B-1**



N

LEGEND

◒	Existing pilot-scale test monitoring well location
⊙	New upgradient background monitoring well location
○	New downgradient monitoring well location
●	New mulch wall monitoring well location
———	Existing pilot-scale mulch wall
- - - -	Full-scale mulch wall
— 995.0 —	Potentiometric surface contour
◀——	Inferred groundwater flow direction

Contour Interval = 1.0 ft

SCALE (ft)

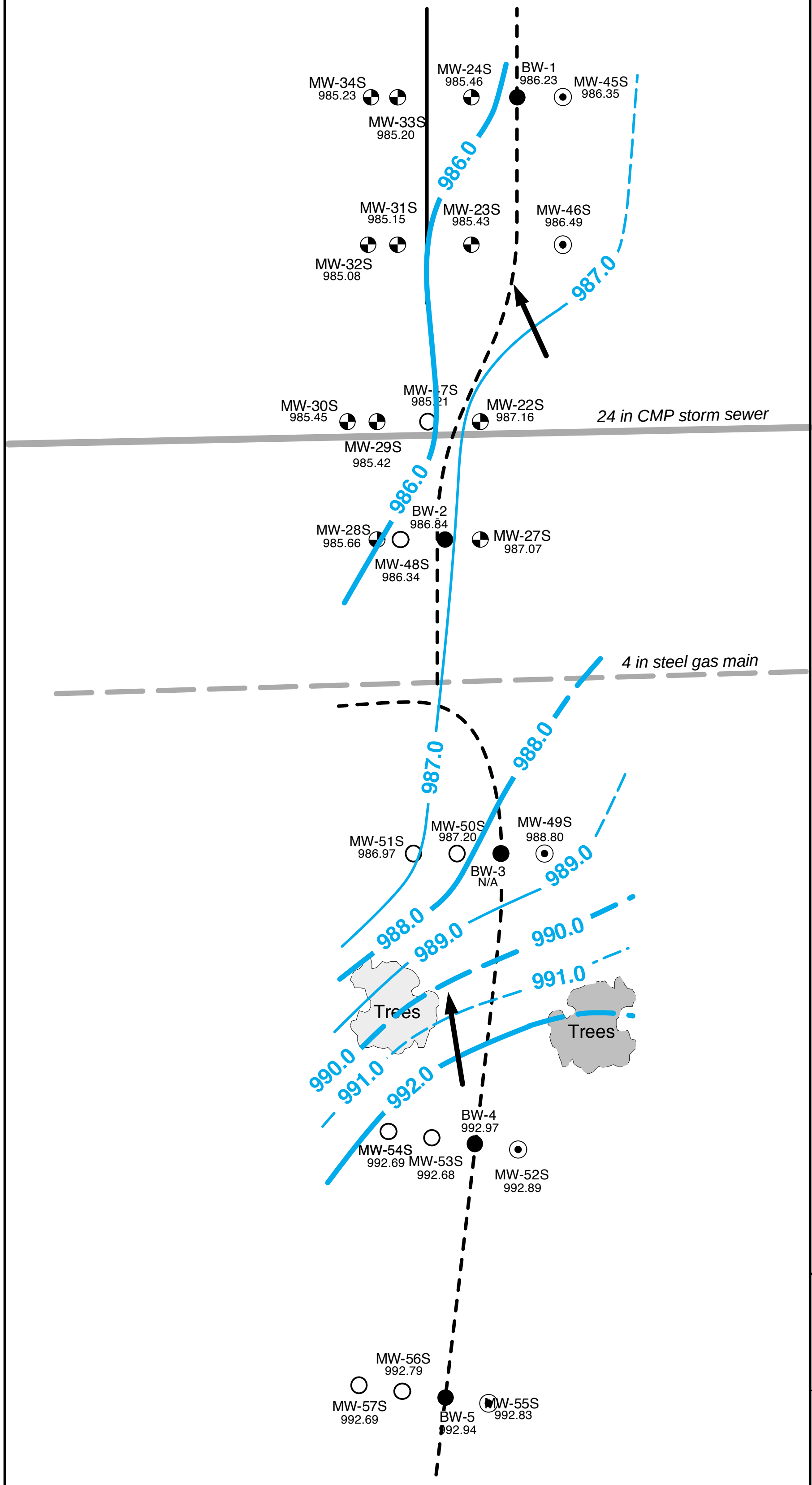
0 30 60

GROUNDWATER
SERVICES, INC.

POTENTIOMETRIC SURFACE MAP FOR MULCH WALL: JULY 2, 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS/DLB
Issued:	4/13/04	Chk'd By:	CEA
Revised:	————	Appv'd By:	CEA
Scale:	As Shown		FIGURE B-2



N

LEGEND

⊕	Existing pilot-scale test monitoring well location
⊙	New upgradient background monitoring well location
○	New downgradient monitoring well location
●	New mulch wall monitoring well location
—	Existing pilot-scale mulch wall
- - -	Full-scale mulch wall
– 995.0 –	Potentiometric surface contour
←	Inferred groundwater flow direction

Contour Interval = 1.0 ft

SCALE (ft)
0 30 60

GROUNDWATER
SERVICES, INC.

POTENTIOMETRIC SURFACE MAP FOR MULCH WALL: JULY 31, 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS/DLB
Issued:	4/13/04	Chk'd By:	CEA
Revised:	________	Appv'd By:	CEA
Scale:	As Shown		FIGURE B-3

APPENDIX C

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

MONITORING DATA FROM ALL SAMPLING EVENTS

TABLE C-1
GROUNDWATER SAMPLING RESULTS: JULY 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS												
												DUPLICATE		
		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW31S	B301-MW32S	B301-MW33S	B301-MW34S	B301-MW34SA	B301-MW45S	B301-MW46S
Date Sampled:		7/15/2001	7/15/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/15/2001	7/14/2001	7/20/2001	7/20/2001	7/19/2001
	Units													
Chlorinated Organics and Reduction By-Products														
PCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
TCE	mg/L	**0.67**	**0.34**	**0.29**	**0.16**	**0.14**	**0.2**	**0.0031**	**0.0078**	**0.58**	**0.4**	**0.4**	**0.46**	**1.1**
1,1-DCE	mg/L	**0.0025**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
cis-1,2-DCE	mg/L	**0.012**	**0.013**	**0.013**	**0.013**	**0.0029**	**0.0072**	**0.0083**	**0.028**	**0.036**	**0.023**	**0.021**	**0.014**	**0.0098**
trans-1,2-DCE	mg/L	**0.0028**	**0.0024**	**0.0019**	**0.011**	**0.0016**	**0.0021**	**0.004**	**0.0057**	**0.0019**	**0.002**	**0.0019**	<0.005	<0.005
Vinyl chloride	mg/L	<0.001	<0.001	<0.001	**0.0022**	<0.001	<0.001	**0.0016**	**0.0047**	<0.001	<0.001	<0.001	<0.005	<0.005
Ethene	ng/L	**13**	**27**	**18**	**79**	**25**	**36**	**77**	**67**	**25**	**36**	**38**	**31**	**17**
Ethane	ng/L	**7.0**	**6.0**	<5.0	**34**	**25**	**69**	**14000**	**14000**	**160**	**500**	**500**	**12**	**6.0**
cDCE/TCE ratio		**0.02**	**0.04**	**0.04**	**0.08**	**0.02**	**0.04**	**2.68**	**3.59**	**0.06**	**0.06**	**0.05**	**0.03**	**0.01**
Water Quality Parameters														
Temperature	°C	**14.3**	**14.7**	**14.7**	**14.9**	**14.8**	**14.2**	**13.6**	**14.5**	**13.8**	**13.4**	-	**15**	**15.6**
pH	pH units	**6.53**	**6.45**	**6.46**	**6.71**	**6.68**	**6.64**	**6.40**	**6.39**	**6.55**	**6.5**	**-**	**6.54**	**6.54**
Specific conductance	mS/cm	**0.599**	**0.600**	**0.603**	**0.604**	**0.598**	**0.583**	**0.022**	**0.631**	**0.584**	**0.582**	-	**0.619**	**0.616**
Total organic carbon	mg/L	**1.28**	**6.16**	**11.8**	<1	**2.31**	<1	**1.27**	<1	<1	<1	<1	<1	**1.49**
Chloride	mg/L	**14**	**19**	**20**	**7.7**	**8**	**8.3**	**22**	**22**	**21**	**20**	**21**	**17**	**13**
Natural Attenuation Parameters														
Dissolved oxygen	mg/L	**0.69**	**0.22**	**0.24**	**0.22**	**0.23**	**1.13**	**0.42**	**0.49**	**0.75**	**1.08**	-	**0.40**	**1.33**
Redox potential	mV	**232.3**	**255.3**	**238.6**	**221.9**	**259.3**	**174.5**	**84.3**	**110.8**	**266.4**	**313.8**	-	**98.5**	**240.4**
Sulfate	mg/L	**40**	**35**	**34**	**30**	**34**	**37**	**20**	**21**	**31**	**28**	**29**	**41**	**47**
Nitrate	mg/L	**4.11**	**2.58**	<0.1	**0.966**	**1.28**	**1.4**	<0.1	**1.04**	**2.35**	**1.96**	**2.07**	**3.37**	**4.3**
Ferrous Iron	mg/L	**0.573**	**0.104**	**0.0255**	**0.446**	**0.0316**	**0.0778**	**0.218**	**0.448**	<0.02	<0.02	<0.02	**0.34**	**0.133**
Methane	ug/L	**0.58**	**1.1**	**1.6**	**52**	**14**	**9.8**	**1600**	**670**	**41**	**130**	**140**	**0.48**	**0.11**
Alkalinity	mg/L	**312**	**322**	**322**	**352**	**352**	**322**	**352**	**372**	**312**	**332**	**312**	**326**	**326**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

TABLE C-1
GROUNDWATER SAMPLING RESULTS: JULY 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS											
										DUPLICATE		DUPLICATE	
		B301-MW47S	B301-MW48S	B301-MW50S	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S	B301-MW55SA	B301-MW56S	B-301-MW56SA	B301-MW57S
Date Sampled:		7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001	7/20/2001
	Units												
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	<0.005	**0.001**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TCE	mg/L	**0.38**	**0.21**	**0.012**	**0.0067**	**0.0036**	**0.068**	**0.055**	**0.0021**	**0.0027**	**0.001**	**0.0011**	**0.0017**
1,1-DCE	mg/L	<0.005	**0.007**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.016**	**0.0041**	**0.0033**	**0.007**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	<0.005	**0.0023**	**0.0067**	**0.015**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**46**	**140**	**430**	**92**	**110**	**36**	**16**	**62**	**56**	**66**	**76**	**30.0**
Ethane	ng/L	**18**	**42**	**48**	**42**	**44**	**34**	<5.0	**15**	**14**	**14**	**14**	<5.0
cDCE/TCE ratio		**0.04**	**0.02**	**0.28**	**1.04**	**0.14**	**0.01**	**0.01**	**0.24**	**0.19**	**0.50**	**0.45**	**0.29**
Water Quality Parameters													
Temperature	°C	**15.0**	**17.4**	**19.2**	**18.4**	**15.3**	**16.8**	**17.4**	**14.8**	-	**14.8**	-	**15.7**
pH	pH units	**6.66**	**6.67**	**6.51**	**6.69**	**6.78**	**6.81**	**6.83**	**6.78**	-	**6.82**	-	**6.77**
Specific conductance	mS/cm	**0.611**	**0.663**	**0.739**	**0.592**	**0.569**	**0.571**	**0.579**	**0.592**	-	**0.584**	-	**0.577**
Total organic carbon	mg/L	**4.73**	**7.7**	**94.9**	**1.61**	**1.66**	<1	**1.18**	**1.67**	**1.38**	**1.2**	**1.14**	<1
Chloride	mg/L	**16**	**10**	**12**	**7.7**	**13**	**9.3**	**10**	**23**	**22**	**15**	**15**	**13**
Natural Attenuation Parameters													
Dissolved oxygen	mg/L	**1.20**	**0.94**	**1.82**	**1.09**	**2.67**	**10.47**	**3.93**	**5.14**	-	**3.95**	-	**3.97**
Redox potential	mV	**199.9**	**10.1**	**-86.0**	**-102.2**	**195.8**	**177.8**	**166.9**	**193.0**	-	**186.5**	-	**186.2**
Sulfate	mg/L	**39**	**37**	**32**	**20**	**31**	**22**	**24**	**29**	**28**	**27**	**25**	**24**
Nitrate	mg/L	**1.37**	<0.1	<0.1	<0.1	**1.57**	**1.97**	**1.72**	**2.24**	**2.26**	**2.45**	**2.48**	**2.69**
Ferrous Iron	mg/L	**0.362**	**0.286**	**3.4**	**2.13**	**0.172**	<0.02	**0.635**	**0.0349**	**0.0226**	**0.031**	**0.036**	**0.201**
Methane	ug/L	**2.0**	**17**	**110**	**62**	**0.96**	**2.1**	**0.75**	**0.38**	**0.38**	**0.35**	**0.35**	**0.18**
Alkalinity	mg/L	**342**	**372**	**472**	**362**	**342**	**342**	**328**	**322**	**322**	**332**	**328**	**322**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

TABLE C-1
GROUNDWATER SAMPLING RESULTS: JULY 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		MULCH WALL MONITORING WELLS					
							DUPLICATE
		B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5	B301-BW5A
Date Sampled:		8/10/2001	8/10/2001	8/10/2001	8/10/2001	8/10/2001	8/10/2001
	Units						
Chlorinated Organics and Reduction By-Products							
PCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TCE	mg/L	**0.71**	**0.18**	**0.018**	**0.012**	<0.001	<0.001
1,1-DCE	mg/L	**0.0027**	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.038**	**0.072**	**0.009**	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.0031**	**0.0011**	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**21**	**220**	**130**	**46**	**630**	**460**
Ethane	ng/L	<5.0	<5.0	<5.0	<5.0	**26**	**16**
cDCE/TCE ratio		**0.001**	**0.003**	**0.03**	**0.04**	-	-
Water Quality Parameters							
Temperature	°C	**17.7**	**20.1**	**22.8**	**18.1**	**20**	-
pH	pH units	**6.18**	**6.43**	**6.4**	**5.76**	**5.34**	-
Specific conductance	mS/cm	**0.447**	**0.449**	**0.474**	**0.645**	**1.87**	-
Total organic carbon	mg/L	**2.84**	**6.29**	**37.9**	**266**	**1130**	**1130**
Chloride	mg/L	**13**	**6.3**	**6.6**	**9.8**	**35**	**34**
Natural Attenuation Parameters							
Dissolved oxygen	mg/L	**0.61**	**1.11**	**1.21**	**0.46**	**0.88**	-
Redox potential	mV	**155.4**	**218.1**	**173.8**	**0.1**	**15.4**	-
Sulfate	mg/L	**42**	**17**	**14**	**15**	**18**	**14**
Nitrate	mg/L	**2.93**	<0.1	<0.1	**0.616**	<0.1	<0.1
Ferrous Iron	mg/L	**0.133**	**0.933**	**3.82**	**6.57**	**32.7**	**29.8**
Methane	ug/L	**4.2**	**20**	**180**	**34**	**460**	**350**
Alkalinity	mg/L	**322**	**402**	**412**	**563**	**1060**	**1050**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

TABLE C-2
GROUNDWATER SAMPLING RESULTS: OCTOBER 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS												
						DUPLICATE						
		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW27S	B301-MW45S	B301-MW46S	B301-MW47S	B301-MW48S	B301-MW49S	B301-MW50S
	Date Sampled:	10/31/2001	10/30/2001	10/30/2001	10/31/2001	10/31/2001	10/30/2001	10/30/2001	10/31/2001	10/31/2001	10/31/2001	10/31/2001
	Units											
Chlorinated Organics and Reduction By-Products												
PCE	mg/L	0.011 J	0.0003 J	0.002 J	0.002 J	0.004 J	0.011 J	0.011 J	0.001 J	0.002 J	0.0003 J	<0.001
TCE	mg/L	0.58	0.074	0.058	0.12	0.12	0.77	0.79	0.017	0.014	0.021	0.001
1,1-DCE	mg/L	0.017 J	0.004 J	0.004 J	0.0006 J	0.0006 J	0.018 J	0.019 J	0.0008 J	0.0006 J	0.0003 J	<0.001
cis-1,2-DCE	mg/L	0.018 J	0.35	0.12	0.004 J	0.007 J	0.022 J	0.033 J	0.2	0.1	0.013	0.017
trans-1,2-DCE	mg/L	0.016 J	0.008	0.009	0.003 J	0.006 J	0.001	0.001	0.003 J	0.004 J	0.012	0.007
Vinyl chloride	mg/L	<0.001	0.034	0.031	0.0003 J	0.0003 J	<0.001	0.016 J	0.013	0.015	0.0003 J	0.006
cDCE/TCE ratio		0.03	4.73	2.07	0.03	0.06	0.03	0.04	11.76	7.14	0.62	17.00
Water Quality Parameters												
Temperature	°C	16.22	15.34	16.70	16.57	-	16.23	17.09	16.28	17.30	15.20	15.60
pH	pH units	6.80	6.55	6.44	6.94	-	6.67	6.73	6.82	6.88	6.95	6.85
Specific conductance	mS/cm	0.59	0.71	0.77	0.60	-	0.63	0.61	0.66	0.71	0.58	0.84
Natural Attenuation Parameters												
Alkalinity	mg/L	458	574	640	480	-	470	518	580	608	488	642
Dissolved oxygen	mg/L	0.35	0.59	0.60	0.30	-	0.54	0.63	0.37	0.32	0.27	0.34
Ferrous Iron	mg/L	0.16	0.15	0.34	0.16	-	0.11	0.09	0.08	0.42	2.41	2.55
Redox potential	mV	177	162	2	258	-	182	130	102	-31	-72	-138
Turbidity	NTU	9	4	8	10	-	9	7	10	7	4	7

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER
SERVICES, INC.

TABLE C-2
GROUNDWATER SAMPLING RESULTS: OCTOBER 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS					**MULCH WALL MONITORING WELLS**				
		DUPLICATE									
		B301-MW50S	B301-MW52S	B301-MW53S	B301-MW55S	B301-MW56S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
Date Sampled:		10/31/2001	11/1/2001	11/1/2001	11/1/2001	11/1/2001	10/30/2001	10/31/2001	10/31/2001	11/1/2001	11/1/2001
	Units										
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	<0.001	<0.001	**0.002**	<0.001	<0.001	**0.002**	**0.0004 J**	**0.0002 J**	**0.0004 J**	<0.02
TCE	mg/L	**0.001 J**	**0.002**	**0.076**	**0.0003 J**	**0.0009 J**	**0.49**	**0.085**	**0.003**	**0.019**	<0.02
1,1-DCE	mg/L	**0.0003 J**	<0.001	**0.0005 J**	<0.001	<0.001	**0.004 J**	**0.0004 J**	<0.001	**0.0004 J**	<0.02
cis-1,2-DCE	mg/L	**0.017**	<0.001	**0.0003 J**	<0.001	**0.0004 J**	**0.21**	**0.035**	**0.024**	**0.009**	<0.02
trans-1,2-DCE	mg/L	**0.006**	<0.001	<0.001	<0.001	**0.0003 J**	**0.004 J**	**0.0008 J**	**0.001**	<0.001	<0.02
Vinyl chloride	mg/L	**0.005**	<0.001	<0.001	<0.001	<0.001	**0.013**	**0.003**	**0.003**	<0.001	<0.02
cDCE/TCE ratio		**17.00**	-	-	-	**0.44**	**0.43**	**0.41**	**8.00**	**0.47**	-
Water Quality Parameters											
Temperature	°C	-	**16.40**	**15.15**	**16.24**	**15.54**	**16.05**	**18.75**	**15.25**	**16.28**	**16.73**
pH	pH units	-	**7.09**	**7.06**	**7.09**	**7.09**	**6.53**	**6.78**	**6.58**	**6.66**	**6.49**
Specific conductance	mS/cm	-	**0.60**	**0.59**	**0.72**	**0.60**	**0.65**	**0.64**	**0.95**	**0.70**	**3.01**
Natural Attenuation Parameters											
Alkalinity	mg/L	-	**486**	**462**	**514**	**478**	**506**	**612**	**672**	**574**	**2418**
Dissolved oxygen	mg/L	-	**1.72**	**5.30**	**4.01**	**4.73**	**0.48**	**0.35**	**0.34**	**0.59**	**0.57**
Ferrous Iron	mg/L	-	**0.13**	**0.13**	**0.05**	**0.10**	**0.98**	**6.15**	**5.00**	**3.18**	**30.75**
Redox potential	mV	-	**164**	**194**	**263**	**91**	**-64**	**-95**	**-151**	**-7**	**-120**
Turbidity	NTU	-	**5**	**7**	**5**	**7**	**9**	**8**	**7**	**3**	**23**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.

2) - = Not measured.

TABLE C-3
GROUNDWATER SAMPLING RESULTS: JANUARY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS											
		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW31S	B301-MW32S	B301-MW33S	B301-MW34S	B301-MW45S	B301-MW46S
Date Sampled:		1/23/2002	1/23/2002	1/23/2002	1/24/2002	1/25/2002	1/24/2002	1/29/2002	1/29/2002	1/29/2002	1/29/2002	1/23/2002	1/23/2002
	Units												
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	0.00075 J	<0.001	0.00013 J	<0.001	<0.001	<0.001	0.00036 J	0.00011 J	0.00035 J	0.00098 J	0.0015	0.0018
TCE	mg/L	0.25	0.026	0.021	0.043	0.029	0.0075	0.00027 J	0.0084	0.1	0.061	0.54	0.64
1,1-DCE	mg/L	0.00089 J	0.00036 J	<0.001	<0.001	<0.001	<0.001	<0.001	0.00045 J	0.00056 J	0.00061 J	0.0053	0.0046
cis-1,2-DCE	mg/L	0.0034	0.073	0.0094	<0.001	0.011	0.021	0.0024	0.11	0.11	0.072	0.005	0.0039
trans-1,2-DCE	mg/L	0.00073 J	0.0055	0.006	<0.001	<0.001	0.0011	0.0045	0.0036	0.0059	0.0058	0.0011	0.00098 J
Vinyl chloride	mg/L	<0.001	0.0096	0.0028	<0.001	0.0017	0.0022	0.00028 J	0.006	0.0048	0.0036	<0.001	<0.001
Ethene	ng/L	14	79	1300	6.9	120.00 J	6.9	-	-	-	-	9.5	13
Ethane	ng/L	12	2600	15000	<5	<5	400	-	-	-	-	22	9
cDCE/TCE ratio		0.01	2.81	0.45	-	0.38	2.80	8.89	13.10	1.10	1.18	0.01	0.01
Water Quality Parameters													
Temperature	°C	13.35	13.02	12.40	10.72	10.60	13.12	11.52	11.66	11.69	11.03	12.70	13.16
pH	pH units	6.53	6.33	6.27	6.66	6.63	6.53	6.32	6.38	6.35	6.31	6.49	6.5
Specific conductance	mS/cm	0.467	0.550	0.593	0.478	0.487	0.554	0.648	0.597	0.608	0.592	0.478	0.486
Total organic carbon	mg/L	2.8	1.8	2.6	1.5	1.9	1.8	-	-	-	-	1.6	2.6
Chloride	mg/L	7.3	9.6	11	6.1	6.1	6.5	-	-	-	-	9	8.9
Natural Attenuation Parameters													
Alkalinity	mg/L	440	546	660	480	452	580	746	602	660	642	452	464
Dissolved oxygen	mg/L	0.51	0.55	0.56	0.81	0.44	0.43	0.77	0.59	0.55	0.51	1.08	0.50
Ferrous Iron	mg/L	2.90	0.25	2.15	0.32	1.23	0.79	0.62	0.42	0.33	0.35	1.20	0.64
Nitrate	mg/L	1.7	<0.1	<0.1	1.5	0.85	<0.1	-	-	-	-	2.7	2.5
Sulfate	mg/L	24	25	6.6	21	17	10	-	-	-	-	27	26
Redox potential	mV	285	241	112	327	314	291	319	302	327	322	153	189
Turbidity	NTU	7	9	7	3	2	3	3	3	3	3	3	7
Hydrogen	nM	1.2	1.2	1.1	0.9	1	1.3	-	-	-	-	1.5	1.1
Methane	ug/L	3.7	3500	4300	0.46	22	3700	-	-	-	-	2.1	0.66

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

TABLE C-3
GROUNDWATER SAMPLING RESULTS: JANUARY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

					DUPLICATE		DUPLICATE						
		B301-MW47S	B301-MW48S	B301-MW49S	B301-MW49S	B301-MW50S	B301-MW50S	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S	B301-MW56S
Date Sampled:		1/24/2002	1/24/2002	1/25/2002	1/25/2002	1/25/2002	1/25/2002	1/25/2002	1/26/2002	1/26/2002	1/26/2002	1/26/2002	1/29/2002
	Units												
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	<0.001	<0.001	**0.00016 J**	**0.00037 J**	<0.001	<0.001	<0.001	<0.001	**0.0022**	**0.0015**	**0.00019 J**	**0.00028 J**
TCE	mg/L	**0.0022**	**0.014**	**0.012**	**0.017**	**0.00039 J**	**0.00054 J**	**0.0013**	**0.0057**	**0.09**	**0.081**	<0.001	**0.001**
1,1-DCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.0007 J**	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0044**	**0.011**	**0.011**	**0.011**	**0.0028**	**0.0031**	**0.008**	<0.001	<0.001	**0.00013 J**	<0.001	<0.001
trans-1,2-DCE	mg/L	<0.001	<0.001	**0.0091**	**0.0091**	**0.0063**	**0.0062**	**0.016**	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0037**	<0.001	<0.001	**0.0096**	**0.013**	**0.00092 J**	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	<5	**100**	**10**	**11**	**53**	**46**	**66**	**18**	**21**	**13**	**18**	-
Ethane	ng/L	**260**	**18**	<5	<5	<5	<5	**120**	<5	<5	<5	<5	-
cDCE/TCE ratio		**2.00**	**0.79**	**0.92**	**0.65**	**7.18**	**5.74**	**6.15**	-	-	**0.00**	-	-
Water Quality Parameters													
Temperature	°C	**12.24**	**10.24**	**11.63**	-	**11.69**	-	**11.29**	**11.93**	**13.57**	**12.97**	**13.09**	**11.27**
pH	pH units	**6.56**	**6.58**	**6.62**	-	**6.54**	-	**6.67**	**6.79**	**6.75**	**6.77**	**6.76**	**6.79**
Specific conductance	mS/cm	**0.489**	**0.499**	**0.464**	-	**0.623**	-	**0.475**	**0.495**	**0.482**	**0.476**	**0.668**	**0.493**
Total organic carbon	mg/L	**1.6**	**1.6**	**1.8**	**2**	**3.5**	**3.7**	**1.8**	<1	<1	<1	<1	<1
Chloride	mg/L	**6.3**	**6.3**	**5.8**	**5.9**	**6.7**	-	**6.9**	**8.9**	**8**	**8.8**	**32**	**13**
Natural Attenuation Parameters													
Alkalinity	mg/L	**502**	**526**	**496**	-	**616**	-	**498**	**546**	**478**	**466**	**456**	**488**
Dissolved oxygen	mg/L	**0.51**	**0.40**	**0.50**	-	**0.43**	-	**0.37**	**3.31**	**6.44**	**6.56**	**2.05**	**4.25**
Ferrous Iron	mg/L	**0.76**	**0.74**	**2.00**	-	**10.65**	-	**2.90**	**1.30**	**0.12**	**0.81**	**0.09**	**0.27**
Nitrate	mg/L	<0.1	<0.1	**0.58**	**0.57**	**0.51**	-	<0.1	**2.2**	**2.5**	**2.2**	**0.74**	**2.4**
Sulfate	mg/L	**9.1**	**11**	**17**	**17**	**14**	-	**14**	**23**	**19**	**20**	**110**	**19**
Redox potential	mV	**287**	**-8**	**93**	-	**-121**	-	**-55**	**301**	**221**	**300**	**287**	**350**
Turbidity	NTU	**3**	**3**	**3**	-	**3**	-	**3**	**3**	**3**	**4**	**4**	**3**
Hydrogen	nM	**0.92**	**0.73**	**3.5**	**2.4**	**0.86**	**0.83**	**0.75**	**0.92**	**0.98**	**1**	**1**	-
Methane	ug/L	**1800**	**680**	**95**	**99**	**3800**	**3800**	**76**	**0.07**	**12**	**0.47**	**0.17**	-

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-3
GROUNDWATER SAMPLING RESULTS: JANUARY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

			MULCH WALL MONITORING WELLS				
		B301-MW57S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
Date Sampled:		1/29/2002	1/23/2002	1/24/2002	1/25/2002	1/26/2002	1/26/2002
	Units						
Chlorinated Organics and Reduction By-Products							
PCE	mg/L	**0.0003 J**	**0.0013**	<0.001	**0.0002 J**	**0.00082 J**	<0.001
TCE	mg/L	**0.0013**	**0.48**	**0.028**	**0.0011**	**0.027**	<0.001
1,1-DCE	mg/L	<0.001	**0.0041**	<0.001	**0.0014**	**0.0026**	<0.001
cis-1,2-DCE	mg/L	<0.001	**0.051**	**0.0055**	**0.0095**	**0.018**	<0.001
trans-1,2-DCE	mg/L	<0.001	**0.0021**	<0.001	**0.00031 J**	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0079**	**0.001**	**0.0046**	**0.00047 J**	**0.00087 J**
Ethene	ng/L	-	**5200**	**890**	**53**	<5	**6.9**
Ethane	ng/L	-	**610**	**250**	<5	<5	<5
cDCE/TCE ratio		-	**0.11**	**0.20**	**8.64**	**0.67**	-
Water Quality Parameters							
Temperature	°C	**11.03**	**13.31**	**10.69**	**9.16**	**12.43**	**12.56**
pH	pH units	**6.77**	**6.38**	**6.42**	**6.24**	**6.32**	**6.33**
Specific conductance	mS/cm	**0.483**	**0.491**	**0.506**	**0.608**	**0.525**	**2.390**
Total organic carbon	mg/L	<1	**3.3**	**2.7**	**4.5**	**3.8**	**140**
Chloride	mg/L	**9.8**	**9.4**	**6.4**	**7.5**	**8.4**	**27**
Natural Attenuation Parameters							
Alkalinity	mg/L	**500**	**458**	**510**	**662**	**576**	**2502**
Dissolved oxygen	mg/L	**3.49**	**0.60**	**0.38**	**0.54**	**1.79**	**1.02**
Ferrous Iron	mg/L	**0.37**	**0.57**	**4.60**	**5.00**	**3.02**	**22.75**
Nitrate	mg/L	**2.3**	**1.5**	**0.86**	<0.1	**1.1**	**0.51**
Sulfate	mg/L	**19**	**22**	**16**	**29**	**9.9**	**7.6**
Redox potential	mV	**405**	**2**	**-72**	**-118**	**38**	**-116**
Turbidity	NTU	**3**	**3**	**10**	**3**	**3**	**21**
Hydrogen	nM	-	**0.83**	**1.3**	**1.4**	**1.2**	**1.2**
Methane	ug/L	-	**1700**	**7100**	**5100**	**2200**	**5400**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

TABLE C-4
GROUNDWATER SAMPLING RESULTS: APRIL 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS									
		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW45S	B301-MW46S	B301-MW47S	B301-MW48S
	Date Sampled:	4/22/2002	4/22/2002	4/22/2002	4/22/2002	4/22/2002	4/22/2002	4/22/2002	4/22/2002	4/22/2002	4/22/2002
	Units										
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.0012**	**0.00058 J**	< 0.001	**0.00083 J**	**0.00076 J**	**0.0002 J**	**0.0013**	**0.0016**	< 0.001	**0.00042 J**
TCE	mg/L	**0.320**	**0.045**	**0.029**	**0.044**	**0.034**	**0.009**	**1.000**	**0.530**	**0.0023**	**0.020**
1,1-DCE	mg/L	**0.0029**	**0.0011**	< 0.001	**0.00044 J**	< 0.001	< 0.001	**0.0036**	**0.0052**	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.0046**	**0.094**	**0.016**	**0.00066 J**	**0.0041**	**0.005**	**0.0087**	**0.0051**	**0.0027**	**0.0045**
trans-1,2-DCE	mg/L	**0.0013**	**0.0059**	**0.0056**	**0.00045 J**	**0.00021 J**	**0.00093 J**	**0.0027**	**0.0018**	**0.00053 J**	**0.00022 J**
Vinyl chloride	mg/L	**0.0015**	**0.025**	**0.0033**	< 0.001	**0.002**	**0.001**	< 0.001	**0.000098 J**	**0.00042 J**	**0.0023**
cDCE/TCE ratio		**0.01**	**2.09**	**0.55**	**0.02**	**0.12**	**0.56**	**0.01**	**0.01**	**1.17**	**0.23**
Water Quality Parameters											
Temperature	°C	**11.96**	**11.27**	**10.13**	**12.10**	**10.05**	**10.59**	**10.62**	**10.97**	**10.89**	**10.60**
pH	pH units	**6.87**	**6.68**	**6.63**	**6.96**	**6.86**	**6.83**	**6.81**	**6.84**	**6.85**	**6.85**
Specific conductance	mS/cm	**0.662**	**0.725**	**0.758**	**0.669**	**0.671**	**0.740**	**0.665**	**0.653**	**0.694**	**0.675**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.59**	**0.49**	**0.57**	**0.81**	**0.39**	**0.45**	**3.61**	**3.56**	**0.37**	**0.35**
Redox potential	mV	**294**	**278**	**266**	**285**	**161**	**300**	**274**	**308**	**177**	**74**
Ferrous Iron	mg/L	**0.45**	**0.56**	**0.66**	**0.49**	**0.52**	**0.94**	**0.26**	**1.12**	**1.18**	**0.97**
Turbidity	ntu	**5**	**3**	**2**	**70**	**5**	**17**	**10**	**50**	**12**	**21**
Alkalinity	mg/L	**574**	**576**	**732**	**582**	**548**	**560**	**756**	**486**	**616**	**540**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER
SERVICES, INC.

TABLE C-4
GROUNDWATER SAMPLING RESULTS: APRIL 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

		B301-MW49S	B301-MW50S	DUPLICATE B301-MW50SA	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S	B301-MW56S	B301-MW57S
Date Sampled:		4/23/2002	4/23/2002	4/23/2002	4/23/2002	4/23/2002	4/23/2002	4/23/2002	4/23/2002	4/23/2002	4/23/2002
	Units										
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00038 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.0016**	**0.0021**	< 0.001	< 0.001	< 0.001
TCE	mg/L	**0.017**	**0.00081 J**	**0.00074 J**	**0.0015**	**0.011**	**0.060**	**0.073**	**0.0001 J**	**0.0011**	**0.0013**
1,1-DCE	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.0002**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.013**	**0.004**	**0.003**	**0.0087**	< 0.001	**0.00033 J**	< 0.001	< 0.001	< 0.001	< 0.001
trans-1,2-DCE	mg/L	**0.011**	**0.0095**	**0.0093**	**0.016**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Vinyl chloride	mg/L	< 0.001	**0.0071**	**0.0075**	**0.0012**	**0.000098**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cDCE/TCE ratio		**0.76**	**4.94**	**4.05**	**5.80**	**-**	**0.01**	**-**	**-**	**-**	**-**
Water Quality Parameters											
Temperature	°C	**12.86**	**11.07**	**-**	**10.48**	**11.52**	**13.40**	**14.71**	**11.78**	**13.92**	**13.18**
pH	pH units	**6.95**	**6.90**	**-**	**6.98**	**7.02**	**7**	**6.95**	**7.01**	**6.95**	**6.79**
Specific conductance	mS/cm	**0.643**	**0.780**	**-**	**0.666**	**0.675**	**0.655**	**0.659**	**0.734**	**0.674**	**0.667**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.39**	**0.35**	**-**	**0.34**	**3.90**	**5.13**	**4.67**	**6.05**	**3.56**	**2.09**
Redox potential	mV	**4**	**-111**	-	**-82**	**120**	**156**	**218**	**247**	**116**	**166**
Ferrous Iron	mg/L	**2.41**	**3.15**	**-**	**2.17**	**0.38**	**0.55**	**0.28**	**0.57**	**0.39**	**0.46**
Turbidity	ntu	**6**	**4**	**-**	**2**	**3**	**7**	**3**	**7**	**3**	**2**
Alkalinity	mg/L	**621**	**616**	**-**	**623**	**510**	**468**	**518**	**472**	**520**	**518**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

TABLE C-4
GROUNDWATER SAMPLING RESULTS: APRIL 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

MULCH WALL MONITORING WELLS

		B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
Date Sampled:		4/22/2002	4/22/2002	4/23/2002	4/23/2002	4/23/2002
	Units					
Chlorinated Organics and Reduction By-Products						
PCE	mg/L	**0.0015**	**0.00028 J**	**0.00016 J**	**0.0008 J**	**0.00064 J**
TCE	mg/L	**0.49**	**0.017**	**0.0015**	**0.028**	**0.00011 J**
1,1-DCE	mg/L	**0.0044**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.023**	**0.0039**	**0.013**	**0.0059**	< 0.001
trans-1,2-DCE	mg/L	**0.0026**	**0.00045 J**	**0.00061 J**	< 0.001	< 0.001
Vinyl chloride	mg/L	**0.0022**	**0.0011**	**0.00085 J**	**0.001**	< 0.001
cDCE/TCE ratio		**0.047**	**0.229**	**8.67**	**0.21**	**-**
Water Quality Parameters						
Temperature	°C	**11.23**	**12.38**	**12.15**	**12.89**	**12.99**
pH	pH units	**6.74**	**6.62**	**6.51**	**6.72**	**6.48**
Specific conductance	mS/cm	**0.654**	**0.711**	**0.792**	**0.687**	**3.337**
Natural Attenuation Parameters						
Dissolved oxygen	mg/L	**0.72**	**0.47**	**0.34**	**0.59**	**0.74**
Redox potential	mV	**231**	**-42**	**-75**	**63**	**-123**
Ferrous Iron	mg/L	**0.58**	**3.17**	**4.21**	**2.8**	**20.00**
Turbidity	ntu	**3**	**50**	**10**	**7**	**40**
Alkalinity	mg/L	**462**	**572**	**752**	**568**	**1321**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.

2) - = Not measured.

TABLE C-5
GROUNDWATER SAMPLING RESULTS: JULY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

								DUPLICATE					
		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW29S	B301-MW31S	B301-MW32S	B301-MW33S	B301-MW34S	B301-MW45S
Date Sampled:		7/19/2002	7/19/2002	7/18/2002	7/22/2002	7/23/2002	7/22/2002	7/22/2002	7/25/2002	7/25/2002	7/25/2002	7/25/2002	7/18/2002
	Units												
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	0.00086 J	<0.001	<0.001	0.00097 J	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00010 J	0.00096 J
TCE	mg/L	0.21	0.031	0.018	0.044	0.036	0.0089	0.009	0.00034 J	0.0013	0.096	0.200	0.49
1,1-DCE	mg/L	0.00099 J	0.00055 J	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00027 J	0.00073 J	0.0029
cis-1,2-DCE	mg/L	0.003	0.068	0.019	0.00093 J	0.0028	0.0028	0.0027	0.0029	0.018	0.041	0.025	0.0084
trans-1,2-DCE	mg/L	0.00090 J	0.0085	0.0073	0.00039 J	0.00017 J	0.00069 J	0.00066 J	0.0058	0.0029	0.0056	0.0037	0.002
Vinyl chloride	mg/L	<0.001	0.027	0.0083	<0.001	0.00030 J	0.00041 J	0.00035 J	0.00018 J	0.00069 J	0.004	0.0033	<0.001
Ethene	ng/L	33	120	770	26	220	11	6	-	-	-	-	25
Ethane	ng/L	14	15000	43000	30	49	1000	1100	-	-	-	-	22
cDCE/TCE ratio		0.014	2.19	1.06	0.021	0.08	0.31	0.31	8.53	13.85	0.43	0.13	0.017
Water Quality Parameters													
Temperature	°C	18.23	14.16	16.06	16.90	17.07	14.52	-	14.11	14.80	13.77	14.05	14.71
pH	pH units	6.68	6.37	6.36	6.58	6.61	6.62	-	6.18	6.25	6.11	6.13	6.16
Specific conductance	mS/cm	0.620	0.690	0.660	0.630	0.620	0.710	-	0.770	0.750	0.680	0.660	0.600
Total organic carbon	mg/L	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	<1
Chloride	mg/L	5.8	8.13	9.04	5.2	5	5.3	0.6	-	-	-	-	7.19
Natural Attenuation Parameters													
Alkalinity	mg/L	508	634	624	578	564	632	-	686	682	550	534	554
Dissolved oxygen	mg/L	0.44	0.30	0.47	0.32	0.45	0.39	-	0.35	0.35	0.32	0.33	0.44
Ferrous Iron	mg/L	0.22	0.29	0.86	0.47	0.66	0.52	-	2.74	2.30	0.31	0.28	0.29
Nitrate	mg/L	1.13	<0.1	<0.1	1.11	0.192	<0.1	<0.1	-	-	-	-	1.91
Sulfate	mg/L	23	19	9.6	20.5	18	8.6	8.7	-	-	-	-	9.6
Redox potential	mV	336	299	163	288	201	276	-	17	57	145	154	214
Turbidity	NTU	2	2	3	5	8	2	-	2	12	3	7	2
Hydrogen	nM	0.84	0.73	1	1.2	1	1.1	-	-	-	-	-	1.1
Methane	ug/L	4.6	6400	5400	2	190	3400	-	-	-	-	-	0.99

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-5
GROUNDWATER SAMPLING RESULTS: JULY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

						DUPLICATE							
		B301-MW46S	B301-MW47S	B301-MW48S	B301-MW49S	B301-MW49S	B301-MW50S	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S	B301-MW56S
Date Sampled:		7/18/2002	7/22/2002	7/22/2002	7/23/2002	7/23/2002	7/23/2002	7/23/2002	7/23/2002	7/24/2002	7/24/2002	7/24/2002	7/24/2002
	Units												
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	**0.00076 J**	<0.001	**0.00011 J**	**0.00063**	**0.0006**	**0.00016**	**0.00014**	**0.00025**	**0.0013**	**0.00079 J**	<0.001	<0.001
TCE	mg/L	**0.250**	**0.0011**	**0.017**	**0.015**	**0.015**	**0.00032 J**	**0.00083 J**	**0.005**	**0.073**	**0.056**	**0.00021 J**	**0.00073 J**
1,1-DCE	mg/L	**0.0012**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0046**	**0.0022**	**0.0022**	**0.012**	**0.011**	**0.00220 J**	**0.00780 J**	<0.001	**0.00035 J**	**0.00016 J**	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.0016**	**0.00040 J**	**0.00018 J**	**0.012**	**0.012**	**0.0088**	**0.016**	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	<0.001	**0.00056 J**	<0.001	<0.001	**0.0062**	**0.00070 J**	<0.001	**0.00013 J**	**0.00041 J**	<0.001	<0.001
Ethene	ng/L	**20**	**59**	**85**	**32**	-	**240**	**120**	**29**	**22**	**20**	**27**	**18**
Ethane	ng/L	**16**	**3000**	**1200**	**57**	-	**25**	**130**	**9**	**18**	**13**	**15**	**22**
cDCE/TCE ratio		**0.018**	**2.000**	**0.129**	**0.800**	**0.733**	**6.875**	**9.398**	**0.100**	**0.005**	**0.003**	**2.380**	**0.680**
Water Quality Parameters													
Temperature	°C	**15.15**	**15.84**	**16.83**	**15.56**	-	**16.48**	**15.92**	**18.37**	**20.78**	**15.00**	**18.10**	**15.10**
pH	pH units	**5.91**	**6.6**	**6.39**	**6.67**	-	**6.60**	**6.66**	**6.71**	**6.80**	**6.66**	**6.71**	**6.78**
Specific conductance	mS/cm	**0.61**	**0.660**	**0.640**	**0.600**	-	**0.730**	**0.620**	**0.610**	**0.610**	**0.610**	**0.650**	**0.640**
Total organic carbon	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	**34**	**39**	**33**	**48**
Chloride	mg/L	**5.94**	**5.4**	**5.3**	**4.7**	-	**0.7**	**5.8**	**7**	**8**	**8.5**	**13**	**11**
Natural Attenuation Parameters													
Alkalinity	mg/L	**504**	**554**	**562**	**504**	-	**630**	**558**	**562**	**582**	**502**	**484**	**514**
Dissolved oxygen	mg/L	**0.49**	**0.37**	**0.30**	**0.31**	-	**0.33**	**0.30**	**2.65**	**5.17**	**4.72**	**5.61**	**3.49**
Ferrous Iron	mg/L	**0.39**	**0.79**	**0.83**	**2.17**	-	**2.09**	**1.23**	**0.37**	**0.33**	**0.18**	**0.21**	**0.27**
Nitrate	mg/L	**1.25**	<0.1	<0.1	<0.1	-	<0.1	<0.1	**2.28**	**2.46**	**2.51**	**2.51**	**2.12**
Sulfate	mg/L	**24**	**6.4**	**9.5**	**17**	-	**16**	**16**	**22.8**	**20.3**	**20.9**	**23.6**	**28.8**
Redox potential	mV	**355**	**19**	**3**	**-169**	-	**-130**	**-71**	**5**	**231**	**200**	**172**	**258**
Turbidity	NTU	**2**	**2**	**2**	**7**	-	**3**	**8**	**3**	**3**	**7**	**2**	**4**
Hydrogen	nM	**1.1**	**1.3**	**1.5**	**1.7**	-	**1.6**	**1.5**	**1.5**	**1.6**	**1.3**	**2**	1.4
Methane	ug/L	**0.91**	**3900**	**2200**	**68**	-	**2300**	**96**	**0.76**	**0.06**	**0.2**	**0.3**	1

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-5
GROUNDWATER SAMPLING RESULTS: JULY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

			MULCH WALL MONITORING WELLS					
							DUPLICATE	
		B301-MW57S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW4	B301-BW5
Date Sampled:		7/25/2002	7/18/2002	7/22/2002	7/23/2002	7/24/2002	7/24/2002	7/24/2002
	Units							
Chlorinated Organics and Reduction By-Products								
PCE	mg/L	<0.001	**0.001**	**0.0017**	0.0100 J	<0.001	-	**0.00057 J**
TCE	mg/L	**0.0012**	**0.61**	**0.017**	**0.010**	**0.022**	-	<0.001
1,1-DCE	mg/L	<0.001	**0.0035**	**0.00088 J**	**0.010**	**0.002**	-	**0.0039**
cis-1,2-DCE	mg/L	<0.001	**0.093**	**0.0037**	**0.013**	**0.0053**	-	**0.00012 J**
trans-1,2-DCE	mg/L	<0.001	**0.004**	**0.00019 J**	**0.00150 J**	**0.00015 J**	-	**0.00032 J**
Vinyl chloride	mg/L	**0.00012 J**	**0.018**	**0.00088 J**	**0.010**	**0.004**	-	<0.001
Ethene	ng/L	**17**	**7000**	**470**	**36**	**39**	**43**	**29**
Ethane	ng/L	**8**	**1900**	**630**	**15**	5	5	**87**
cDCE/TCE ratio		**0.42**	**0.15**	**0.22**	**1.30**	**0.24**	-	**0.12**
Water Quality Parameters								
Temperature	°C	**15.90**	**15.13**	**24.80**	**19.51**	**16.30**	-	**16.94**
pH	pH units	**6.71**	**6.18**	**6.36**	**6.32**	**6.15**	-	**5.93**
Specific conductance	mS/cm	**0.660**	**0.610**	**0.710**	**0.690**	**0.690**	-	**2.780**
Total organic carbon	mg/L	**54**	<1	<1	**2**	**63**	-	**25**
Chloride	mg/L	**9.4**	**6.98**	**0.7**	**0.9**	**0.8**	-	**20.5**
Natural Attenuation Parameters								
Alkalinity	mg/L	**528**	**492**	**600**	**710**	**552**	-	**1256**
Dissolved oxygen	mg/L	**2.32**	**0.33**	**0.63**	**0.51**	**2.18**	-	**0.68**
Ferrous Iron	mg/L	**0.32**	**0.41**	**2.47**	**5.30**	**0.72**	-	**15.6**
Nitrate	mg/L	**2.09**	**0.928**	<0.1	<0.1	**0.868**	-	<0.1
Sulfate	mg/L	**22.4**	**21**	**15**	**8.4**	**11**	-	**4.9**
Redox potential	mV	**268**	**174**	**-161**	**-166**	**-78**	-	**-114**
Turbidity	NTU	**7**	**2**	**3**	**3**	**3**	-	**9**
Hydrogen	nM	**1.8**	**1**	**1.8**	**2.4**	**1.5**	**1.9**	**2**
Methane	ug/L	**37**	**1200**	**7900**	**7200**	**1500**	**1600**	**4800**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER
SERVICES, INC.

TABLE C-6
GROUNDWATER SAMPLING RESULTS: OCTOBER 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

			DUPLICATE						DUPLICATE		
		B301-MW22S	B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW29S	B301-MW45S	B301-MW46S
Date Sampled:		10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002
	Units										
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00099 J**	**0.001**	**0.00044 J**	<0.001	**0.0011**	**0.00082 J**	**0.0005 J**	**0.00054 J**	**0.0017**	**0.00081 J**
TCE	mg/L	**0.170**	**0.200**	**0.013**	**0.012**	**0.044**	**0.037**	**0.0072**	**0.0074**	**0.480**	**0.250**
1,1-DCE	mg/L	**0.00041 J**	**0.00048 J**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.0028**	**0.00093 J**
cis-1,2-DCE	mg/L	**0.0027**	**0.0027**	**0.016**	**0.0075**	**0.00066 J**	**0.0016**	**0.0026**	**0.0026**	**0.012**	**0.0047**
trans-1,2-DCE	mg/L	**0.00049 J**	**0.00052 J**	**0.006**	**0.0053**	**0.00036 J**	<0.001	**0.00069 J**	**0.00076 J**	**0.0062**	**0.00078**
Vinyl chloride	mg/L	<0.001	<0.001	**0.0022**	**0.002**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cDCE/TCE ratio		**0.02**	**0.01**	**1.23**	**0.63**	**0.02**	**0.04**	**0.36**	**0.35**	**0.03**	**0.02**
Water Quality Parameters											
Temperature	°C	**15.82**	**-**	**16.69**	**15.39**	**15.98**	**16.95**	**16.58**	**-**	**15.70**	**16.01**
pH	pH units	**6.91**	**-**	**6.68**	**6.59**	**7.01**	**6.98**	**6.84**	**-**	**6.88**	**6.91**
Specific conductance	mS/cm	**0.73**	**-**	**0.76**	**0.81**	**0.74**	**0.73**	**0.87**	**-**	**0.74**	**0.74**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.11**	**-**	**0.17**	**0.25**	**0.10**	**0.17**	**0.12**	**-**	**0.28**	**0.15**
Redox potential	mV	**35**	**-**	**-68**	**-165**	**-100**	**28**	**4**	**-**	**10**	**-22**
Ferrous Iron	mg/L	**0.43**	**-**	**0.11**	**0.51**	**0.51**	**0.12**	**0.59**	**-**	**0.32**	**0.09**
Turbidity	ntu	**3**	**-**	**3**	**3**	**3**	**7**	**3**	**-**	**10**	**5**
Alkalinity	mg/L	**542**	**-**	**640**	**662**	**574**	**552**	**578**	**-**	**544**	**558**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

TABLE C-6
GROUNDWATER SAMPLING RESULTS: OCTOBER 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS									
		B301-MW47S	B301-MW48S	B301-MW49S	B301-MW50S	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S	B301-MW56S
Date Sampled:		10/16/2002	10/16/2002	10/17/2002	10/18/2002	10/19/2002	10/20/2002	10/21/2002	10/22/2002	10/23/2002	10/24/2002
	Units										
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00026 J**	**0.00042 J**	**0.00066 J**	<0.001	<0.001	<0.001	**0.0016**	**0.0017**	<0.001	<0.001
TCE	mg/L	**0.0016**	**0.018**	**0.013**	<0.001	**0.00056 J**	**0.012**	**0.063**	**0.063**	<0.001	**0.00068 J**
1,1-DCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0026**	**0.0019**	**0.012**	**0.0024**	**0.0079**	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.00051 J**	<0.001	**0.014**	**0.0097**	**0.014**	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	<0.001	<0.001	**0.0031**	**0.00091 J**	<0.001	<0.001	<0.001	<0.001	<0.001
cDCE/TCE ratio		**1.63**	**0.11**	**0.92**		**14.11**					
Water Quality Parameters											
Temperature	°C	**16.46**	**16.95**	**15.02**	**16.17**	**16.25**	**16.82**	**15.82**	**15.17**	**16.85**	**16.10**
pH	pH units	**6.85**	**6.91**	**6.96**	**6.95**	**7.03**	**7.09**	**7.13**	**6.94**	**7.10**	**7.13**
Specific conductance	mS/cm	**0.79**	**0.75**	**0.71**	**0.86**	**0.73**	**0.73**	**0.71**	**0.72**	**0.81**	**0.74**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.13**	**0.10**	**0.15**	**0.10**	**0.13**	**3.28**	**4.57**	**4.36**	**4.74**	**3.52**
Redox potential	mV	**1**	**-106**	**-147**	**-227**	**-207**	**-98**	**-71**	**179**	**187**	**-38**
Ferrous Iron	mg/L	**0.31**	**0.42**	**2.25**	**2.51**	**1.98**	**0.42**	**0.39**	**0.10**	**0.30**	**0.17**
Turbidity	ntu	**7**	**3**	**3**	**3**	**3**	**4**	**3**	**3**	**5**	**5**
Alkalinity	mg/L	**580**	**624**	**482**	**672**	**412**	**573**	**556**	**474**	**468**	**528**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

TABLE C-6
GROUNDWATER SAMPLING RESULTS: OCTOBER 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

			MULCH WALL MONITORING WELLS				
		B301-MW57S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
	Date Sampled:	10/25/2002	10/16/2002	10/16/2002	10/17/2002	10/17/2002	10/17/2002
	Units						
Chlorinated Organics and Reduction By-Products							
PCE	mg/L	<0.001	**0.00075 J**	**0.00058 J**	<0.001	**0.00024 J**	<0.001
TCE	mg/L	**0.0014**	**0.24**	**0.023**	**0.00098 J**	**0.017**	<0.001
1,1-DCE	mg/L	<0.001	**0.00098 J**	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	<0.001	**0.06**	**0.0021**	**0.0059**	**0.0021**	<0.001
trans-1,2-DCE	mg/L	<0.001	**0.0018**	**0.00026 J**	**0.0015**	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0098**	**0.00072 J**	**0.0034**	**0.0018**	<0.001
cDCE/TCE ratio			**0.250**	**0.09**	**6.02**	**0.12**	
Water Quality Parameters							
Temperature	°C	**16.03**	**15.88**	**17.50**	**15.51**	**16.49**	**17.16**
pH	pH units	**7.08**	**6.71**	**6.73**	**6.64**	**6.52**	**6.60**
Specific conductance	mS/cm	**0.71**	**0.74**	**0.75**	**0.82**	**0.85**	**3.31**
Natural Attenuation Parameters							
Dissolved oxygen	mg/L	**1.98**	**0.17**	**0.14**	**0.15**	**1.59**	**0.10**
Redox potential	mV	**31**	**-130**	**-153**	**-208**	**-124**	**-244**
Ferrous Iron	mg/L	**0.24**	**1.24**	**1.98**	**4.9**	**3.1**	**16.25**
Turbidity	ntu	**12**	**5**	**7**	**3**	**5**	**12**
Alkalinity	mg/L	**473**	**620**	**1024**	**481**	**569**	**1215**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.

2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-7
GROUNDWATER SAMPLING RESULTS: JANUARY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	DUPLICATE B301-MW29S	B301-MW45S	B301-MW46S	B301-MW47S	B301-MW48S
	Date Sampled:	1/28/2003	1/28/2003		1/27/2003	1/28/2003	1/28/2003	1/28/2003		1/28/2003	1/28/2003	1/27/2003
	Units											
Chlorinated Organics and Reduction By-Products												
PCE	mg/L	**0.001 J**	**<0.001**	**<0.001**	**0.00170 J**	**0.0013**	**0.00097 J**	**0.00024**	**0.00190 J**	**0.0011**	**0.00018 J**	**0.0002 J**
TCE	mg/L	**0.13**	**0.016**	**0.0075**	**0.039**	**0.029**	**0.0064**	**0.006**	**0.41**	**0.21 E**	**0.0016**	**0.01**
1,1-DCE	mg/L	**0.00036 J**	**<0.001**	<0.001	**0.00028 J**	<0.001	<0.001	<0.001	**0.0044**	**0.0024**	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0052**	**0.022**	**0.0086**	**0.00055 J**	**0.001**	**0.0026**	**0.0024**	**0.014**	**0.007**	**0.0023**	**0.00085 J**
trans-1,2-DCE	mg/L	**0.00081 J**	**0.01**	**0.0067**	**0.00041 J**	<0.001	**0.00046 J**	**0.00040 J**	**0.001**	**0.0011**	**0.00042 J**	**0.00025 J**
Vinyl chloride	mg/L	<0.001	**0.00086 J**	**0.0011**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**17**	**32**	**30**	**8**	**36**	**21**	**22**	**12**	**12.000**	**16**	**38**
Ethane	ng/L	**10**	**7000**	**13000**	**6**	**60**	**1100**	**1000**	**13**	**13**	**940**	**620**
cDCE/TCE ratio		**0.040**	**1.375**	**1.147**	**0.014**	**0.034**	**0.406**	**0.375**	**0.034**	**0.033**	**1.438**	**0.085**
Water Quality Parameters												
Temperature	°C	**13.10**	**13.04**	**11.96**	**10.54**	**10.11**	**13.06**	-	**11.87**	**11.99**	**12.39**	**10.30**
pH	pH units	**6.96**	**6.68**	**6.62**	**7.05**	**7.06**	**6.9**	-	**6.93**	**6.94**		**6.98**
Specific conductance	mS/cm	**0.670**	**0.750**	**0.810**	**0.680**	**0.680**	**72.000**	-	**0.680**	**0.69**	**0.720**	**0.670**
Total organic carbon	mg/L	**1.15**	**2.28**	**3.11**	**1.17**	**1.08**	**1.35**	**1.41**	**1.58**	**1.71**	**1.29**	**1.22**
Natural Attenuation Parameters												
Alkalinity	mg/L	**460**	**545**	**511**	**450**	**443**	**492**	-	**435**	**406**	**427**	**524**
Dissolved oxygen	mg/L	**0..46**	**0.44**	**0.51**	**1.72**	**0.47**	**0.42**	-	**0.85**	**0.4**	**0.42**	**0.42**
Ferrous Iron	mg/L	**2.73**	**1.73**	**1.08**	**1.93**	**0.60**	**2.02**	-	**0.88**	**0.56**	**0.61**	**0.73**
Redox potential	mV	**241**	**212**	**57**	**130**	**220**	**117**	-	**271**	**237**	**107**	**40**
Turbidity	NTU	**5**	**7**	**8**	**9**	**7**	**3**	-	**12**	**10**	**6**	**12**
Methane	ug/L	**2.1**	**4300**	**7300**	**1**	**88**	**350**	**360**	**1.4**	**1**	**970**	**440**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.

2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.

3) - = Not measured.

TABLE C-7
GROUNDWATER SAMPLING RESULTS: JANUARY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

		B301-MW49S	B301-MW50S	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S	B301-MW56S	B301-MW57S
	Date Sampled:		1/27/2003	1/27/2003	1/21/2003	1/21/2003	1/21/2003	1/20/2003	1/20/2003	1/20/2003
	Units									
Chlorinated Organics and Reduction By-Products										
PCE	mg/L	**0.00026 J**	<0.001	<0.001	<0.001	**0.0012**	**0.00078 J**	<0.001	<0.001	<0.001
TCE	mg/L	**0.0087**	<0.001	<0.001	**0.0081**	**0.060**	**0.050**	<0.001	<0.001	<0.001
1,1-DCE	mg/L	<0.001	<0.001	<0.001	<0.001	**0.00026 J**	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.010**	**0.0027**	**0.0058**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.01**	**0.0074**	**0.011**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0018**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**14**	**120**	**59**	**13**	**20**	**14**	**10**	**10**	**12**
Ethane	ng/L	<0.001	**16**	**140**	**9**	**10**	**10**	**<0.001**	**9**	**7**
cDCE/TCE ratio		**1.149**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Water Quality Parameters										
Temperature	°C	**12.68**	**11.25**	**10.65**	**11.97**	**13.88**	**13.30**	**12.17**	**12.56**	**11.43**
pH	pH units	**6.8**	**7.04**	**7.06**	**7.14**	**7.11**	**7.08**	**7.09**	**7.13**	**7.06**
Specific conductance	mS/cm	**0.66**	**0.740**	**0.670**	**0.680**	**0.660**	**0.670**	**0.760**	**0.670**	**0.660**
Total organic carbon	mg/L	**1.72**	**1.71**	**1.5**	**1.21**	**1.03**	**1.05**	**1.54**	**1.18**	**1.06**
Natural Attenuation Parameters										
Alkalinity	mg/L	**512**	**499**	**437**	**581**	**462**	**415**	**476**	**564**	**481**
Dissolved oxygen	mg/L	**0.49**	**0.41**	**0.42**	**4.08**	**5.11**	**4.56**	**5.86**	**3.63**	**2.53**
Ferrous Iron	mg/L	**2.5**	**3.80**	**1.97**	**0.59**	**0.33**	**0.27**	**0.27**	**2.21**	**0.43**
Redox potential	mV	**-13**	**-108**	**-45**	**301**	**242**	**288**	**263**	**186**	**249**
Turbidity	NTU	**10**	**9**	**7**	**2**	**5**	**3**	**2**	**4**	**7**
Methane	ug/L	**110**	**1500**	**88**	**0.17**	**2.9**	**0.77**	**0.04**	**9**	**0.02**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.

2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.

3) - = Not measured.

TABLE C-7
GROUNDWATER SAMPLING RESULTS: JANUARY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		MULCH WALL MONITORING WELLS				
		B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
Date Sampled:			1/27/2003	1/27/2003		1/20/2003
	Units					
Chlorinated Organics and Reduction By-Products						
PCE	mg/L	**0.0017**	**0.00034 J**	<0.001	**0.00046 J**	<0.001
TCE	mg/L	**0.2**	**0.014**	**0.002**	**0.022**	<0.001
1,1-DCE	mg/L	**0.0012**	**0.00026 J**	<0.001	**0.001**	<0.001
cis-1,2-DCE	mg/L	**0.033**	**0.0012**	**0.0026**	**0.002**	<0.001
trans-1,2-DCE	mg/L	**0.002**	**0.0003 J**	**0.0012**	**0.00025 J**	<0.001
Vinyl chloride	mg/L	**0.0065**	<0.001	**0.0018**	**0.001**	<0.001
Ethene	ng/L	**3100**	**100**	**510**	**160**	**<0.001**
Ethane	ng/L	**3300**	**280**	**10**	<0.001	**<0.001**
cDCE/TCE ratio		**0.165**	**0.086**	**1.083**	**0.091**	
Water Quality Parameters						
Temperature	°C	**12.53**	**10.45**	**11.30**	**12.79**	**12.14**
pH	pH units	**6.81**	**6.86**	**6.63**	**6.63**	**6.58**
Specific conductance	mS/cm	**0.680**	**0.690**	**0.760**	**0.720**	**2.480**
Total organic carbon	mg/L	**2**	**1.36**	**3.15**	**2.91**	**82.75**
Natural Attenuation Parameters						
Alkalinity	mg/L	**421**	**583**	**554**	**5110**	**1178**
Dissolved oxygen	mg/L	**0.46**	**0.51**	**0.7**	**2.27**	**2.48**
Ferrous Iron	mg/L	**0.56**	**1.61**	**2.71**	**1.99**	**16**
Redox potential	mV	**(23)**	**-33**	**-92**	**27**	**-126**
Turbidity	NTU	**8**	**11**	**11**	**10**	**11**
Methane	ug/L	**2500**	**5300**	**4400**	**4300**	**7000**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.

2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.

3) - = Not measured.

GROUNDWATER
SERVICES, INC.

TABLE C-8
GROUNDWATER SAMPLING RESULTS: APRIL 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS

		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW45S	B301-MW46S	B301-MW47S	B301-MW48S
Date Sampled:		4/29/2003	4/30/2003	4/30/2003	4/29/2003	4/29/2003	4/29/2003	4/30/2003	4/30/2003	4/29/2003	4/29/2003
	Units										
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00057 J**	< 0.001	< 0.001	**0.00054**	**0.00037 J**	< 0.001	**0.00076 J**	**0.00081 J**	< 0.001	< 0.001
TCE	mg/L	**0.28**	**0.033**	**0.0065**	**0.046**	**0.027**	**0.0049**	**1.5**	**0.73**	**0.0021**	**0.012**
1,1-DCE	mg/L	**0.0025**	**0.00032 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.0026**	**0.0039**	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.0066**	**0.048**	**0.0087**	< 0.001	**0.001**	**0.002**	**0.014**	**0.0098**	**0.0025**	**0.00084 J**
trans-1,2-DCE	mg/L	**0.0011**	**0.011**	**0.0051**	**0.00031**	**0.00022 J**	**0.00041 J**	**0.0027**	**0.0021**	**0.00039 J**	**0.00021 J**
Vinyl chloride	mg/L	< 0.001	**0.0047**	**0.0012**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cDCE/TCE ratio		**0.024**	**1.455**	**1.338**	**0.022**	**0.037**	**0.408**	**0.009**	**0.013**	**1.190**	**0.070**
Water Quality Parameters											
Temperature	°C	**11.64**	**12.01**	**10.08**	**11.68**	**11.01**	**11.19**	**11.85**	**11.16**	**11.46**	**11.23**
pH	pH units	**6.97**	**6.73**	**6.63**	**7.05**	**7.04**	**6.91**	**6.91**	**6.95**	**6.91**	**6.99**
Specific conductance	mS/cm	**0.553**	**0.631**	**0.714**	**0.592**	**0.627**	**0.647**	**0.601**	**0.599**	**0.66**	**0.615**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.57**	**2.46**	**3.83**	**0.4**	**0.18**	**0.51**	**2.59**	**3.15**	**0.25**	**0.29**
Redox potential	mV	**13**	**-89**	**3**	**-34**	**-56**	**26**	**37**	**72**	**-12**	**-49**
Ferrous Iron	mg/L	**0.22**	**0.29**	**0.94**	**4.75**	**0.38**	**1.24**	**2.1**	**0.45**	**1.01**	**0.31**
Turbidity	ntu	**19**	**27**	**12**	**49**	**357**	**10**	**249**	**48**	**41**	**12**
Alkalinity	mg/L	**560**	**586**	**656**	**658**	**474**	**680**	**6.25**	**584**	**688**	**487**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.

2) - = Not measured.

GROUNDWATER
SERVICES, INC.

TABLE C-8
GROUNDWATER SAMPLING RESULTS: APRIL 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS										
		B301-MW49S	B301-MW50S	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S	B301-MW56S	B301-MW57S
Date Sampled:		4/29/2003	4/28/2003	4/28/2003	4/28/2003	4/28/2003	4/28/2003	4/28/2003	4/28/2003	4/28/2003
	Units									
Chlorinated Organics and Reduction By-Products										
PCE	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	**0.00027 J**	**0.0012**	< 0.001	< 0.001	< 0.001
TCE	mg/L	**0.012**	**0.00072 J**	< 0.001	**0.0074**	**0.043**	**0.09**	< 0.001	**0.0071**	< 0.001
1,1-DCE	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.014**	**0.0026**	**0.007**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
trans-1,2-DCE	mg/L	**0.015**	**0.0091**	**0.013**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Vinyl chloride	mg/L	< 0.001	**0.0016**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cDCE/TCE ratio		**1.167**	**3.611**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Water Quality Parameters										
Temperature	°C	**12.08**	**11.76**	**11.54**	**12.59**	**13.28**	**14**	**11.28**	**12.12**	**12.06**
pH	pH units	**7.01**	**7.06**	**7.07**	**7.15**	**7.12**	**7.13**	**7.19**	**7.13**	**7.08**
Specific conductance	mS/cm	**0.576**	**0.662**	**0.608**	**0.571**	**0.572**	**0.593**	**0.646**	**0.562**	**0.586**
Natural Attenuation Parameters										
Dissolved oxygen	mg/L	**0.11**	**3.77**	**0.19**	**3.03**	**3.73**	**4.57**	**5.71**	**2.75**	**2.92**
Redox potential	mV	**-37**	**-122**	**-88**	**133**	**75**	**122**	**111**	**167**	**139**
Ferrous Iron	mg/L	**1.56**	**3.17**	**2.25**	**0.39**	**0.38**	**0.46**	**0.36**	**0.38**	**0.56**
Turbidity	ntu	**10**	**12**	**10**	**8**	**11**	**21**	**10**	**17**	**148**
Alkalinity	mg/L	**550**	**620**	**738**	**502**	**578**	**502**	**488**	**500**	**502**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

TABLE C-8
GROUNDWATER SAMPLING RESULTS: APRIL 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		MULCH WALL MONITORING WELLS				
		B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
	Date Sampled:	4/30/2003	4/29/2003	4/29/2003	4/28/2003	4/28/2003
	Units					
Chlorinated Organics and Reduction By-Products						
PCE	mg/L	< 0.001	**0.00017 J**	< 0.001	**0.00023 J**	< 0.001
TCE	mg/L	**0.085**	**0.019**	**0.0015**	**0.03**	< 0.001
1,1-DCE	mg/L	**0.00056 J**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.046**	**0.0019**	**0.0031**	**0.00071 J**	< 0.001
trans-1,2-DCE	mg/L	**0.0025**	**0.00038 J**	**0.0029**	< 0.001	< 0.001
Vinyl chloride	mg/L	**0.013**	< 0.001	**0.0026**	< 0.001	< 0.001
cDCE/TCE ratio		**0.541**	**0.100**	**2.067**	**0.024**	**-**
Water Quality Parameters						
Temperature	°C	**11.4**	**11.23**	**11.5**	**12.82**	**11.83**
pH	pH units	**6.65**	**6.87**	**6.73**	**6.84**	**6.61**
Specific conductance	mS/cm	**0.675**	**0.611**	**0.635**	**0.625**	**2.475**
Natural Attenuation Parameters						
Dissolved oxygen	mg/L	**0.84**	**0.3**	**2.66**	**1.8**	**0.14**
Redox potential	mV	**-96**	**-119**	**-136**	**-9**	**-107**
Ferrous Iron	mg/L	**1.7**	**1.5**	**2.15**	**2.1**	**16.25**
Turbidity	ntu	**31**	**21**	**41**	**18**	**53**
Alkalinity	mg/L	**614**	**600**	**640**	**610**	**2600**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.

2) - = Not measured.

TABLE C-9
GROUNDWATER SAMPLING RESULTS: JULY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

PLUME AREA MONITORING WELLS														
			DUPLICATE			DUPLICATE					DUPLICATE			
		B301-MW22S	B301-MW22S	B301-MW23S	B301-MW24S	B301-MW24S	B301-MW25S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW29S	B301-MW31S	B301-MW32S	B301-MW33S
Date Sampled:		7/29/2003	7/29/2003	7/29/2003	7/30/2003	7/30/2003	7/30/2003	7/29/2003	7/29/2003	7/29/2003	7/29/2003	7/29/2003	7/29/2003	7/30/2003
	Units													
Chlorinated Organics and Reduction By-Products														
PCE	mg/L	**0.00055 J**	**0.00053 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.00092 J**	**0.0008 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.00026 J**
TCE	mg/L	**0.39**	**0.39**	**0.012**	**0.1**	**0.097**	**0.35**	**0.05**	**0.03**	**0.0033**	**0.0036**	< 0.001	< 0.001	**0.67**
1,1-DCE	mg/L	**0.0013**	**0.0012**	< 0.001	< 0.001	< 0.001	**0.0013**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.002**
cis-1,2-DCE	mg/L	**0.006**	**0.0059**	**0.048**	**0.041**	**0.041**	**0.29**	**0.0009 J**	**0.00096 J**	**0.0021**	**0.0023**	**0.00084 J**	**0.0048**	**0.07**
trans-1,2-DCE	mg/L	**0.00098 J**	**0.00076 J**	**0.011**	**0.006**	**0.0059**	**0.013**	**0.00043 J**	**0.00015 J**	**0.00051 J**	**0.00049 J**	**0.0057**	**0.0**	**0.0067**
Vinyl chloride	mg/L	< 0.001	< 0.001	**0.0087**	**0.0087**	**0.0083**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.0012**
Ethane	ng/L	**53**	--	**12000**	**20000**	--	--	< 5	**120**	**1800**	--	--	--	--
Ethene	ng/L	**190**	--	**260**	**120**	--	--	**20**	**200**	< 5	--	--	--	--
cDCE/TCE ratio		**0.015**	**0.015**	**4.000**	**0.410**	**0.423**	**0.829**	**0.018**	**0.032**	**0.636**	**0.639**	--	--	**0.104**
Water Quality Parameters														
Temperature	°C	**14.85**	**14.85**	**15.24**	**15.04**	**15.04**	--	**17.27**	**16.94**	**14.77**	--	**15.24**	**14.11**	**14.38**
pH	pH units	**6.86**	**6.86**	**6.51**	**6.53**	**6.53**	--	**6.93**	**6.89**	**6.77**	--	**6.59**	**6.57**	**6.55**
Specific conductance	mS/cm	**0.642**	**0.642**	**0.693**	**0.678**	**0.678**	--	**0.639**	**0.61**	**0.7**	--	**0.789**	**0.8111**	**0.658**
Total Organic Carbon	mg/L	**1.80**	--	**2.57**	**2.91**	--	--	**1.84**	**1.09**	**2.45**	--	--	--	--
Natural Attenuation Parameters														
Dissolved oxygen	mg/L	**0.18**	**0.18**	**0.15**	**0.15**	**0.15**	--	**0.17**	**0.11**	**0.14**	--	**0.15**	**0.16**	**0.16**
Redox potential	mV	**89**	**89**	**377**	**172**	**172**	--	**147**	**51**	**220**	--	**54**	**14**	**122**
Ferrous Iron	mg/L	**0.22**	**0.22**	**1.73**	**0.94**	**0.94**	**0.32**	**0.93**	**0.72**	**0.36**	--	**5.00**	**0.73**	**0.28**
Turbidity	ntu	**19**	**19**	**10**	**12**	**12**	--	**27**	**17**	**17**	--	**16**	**12**	**10**
Alkalinity	mg/L	**560**	**560**	**545**	**656**	**656**	**573**	**6.48**	**572**	**551**	--	**629**	**627**	**529**
Methane	ug/L	**2.4**	--	**2400**	**4900**	--	--	**3**	**210**	**430**	--	--	--	--
Nitrate-Nitrite	mg/L	**1.44**	--	< 0.1	< 0.1	--	--	**0.93**	**0.335**	< 0.1	--	--	--	--

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.

2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.

3) - = Not measured.

TABLE C-9
GROUNDWATER SAMPLING RESULTS: JULY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS												
								DUPLICATE						
		B301-MW34S	B301-MW45S	B301-MW46S	B301-MW47S	B301-MW48S	B301-MW49S	B301-MW49S	B301-MW50S	B301-MW51S	B301-MW52S	B301-MW53S	B301-MW54S	B301-MW55S
	Date Sampled:	7/30/2003	7/30/2003	7/29/2003	7/29/2003	7/28/2003	7/28/2003	7/29/2003	7/28/2003	7/28/2003	7/28/2003	7/25/2003	7/25/2003	7/25/2003
	Units													
Chlorinated Organics and Reduction By-Products														
PCE	ug/L	**0.00071 J**	**0.00089 J**	**0.00044 J**	< 0.001	< 0.001	**0.00025 J**	**0.00025 J**	< 0.001	< 0.001	< 0.001	**0.00096 J**	**0.00084 J**	< 0.001
TCE	ug/L	**1**	**0.79**	**0.32**	**0.00053 J**	**0.0077**	**0.0094**	**0.0096**	< 0.001	< 0.001	**0.0029**	**0.064**	**0.064**	< 0.001
1,1-DCE	ug/L	**0.0026**	**0.0036**	**0.0013**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	ug/L	**0.039**	**0.016**	**0.0052**	**0.0013**	**0.0008 J**	**0.013**	**0.013**	**0.0013**	**0.0065**	< 0.001	< 0.001	< 0.001	< 0.001
trans-1,2-DCE	ug/L	**0.0033**	**0.0**	**0.00096 J**	**0.00076 J**	< 0.001	**0.014**	**0.014**	**0.008**	**0.012**	< 0.001	< 0.001	< 0.001	< 0.001
Vinyl chloride	ug/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.0**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ethane	ng/L	--	**15**	**19**	**1900**	**2000**	< 5	--	**10**	**130**	< 5	< 5	< 5	**7**
Ethene	ng/L	--	**33**	**85**	< 5	< 5	**67**	--	**500**	**89**	**20**	**16**	**19**	**16**
cDCE/TCE ratio		**0.039**	**0.020**	**0.016**	**2.453**	**0.104**	**1.383**	**1.354**	**1.300**	**6.500**	--	--	**0.016**	--
Water Quality Parameters														
Temperature	°C	**13.88**	**14.39**	**14.84**	**15.01**	**17.07**	**14.96**	--	**15.67**	**15.74**	**15.80**	**14.70**	**15.44**	**14.61**
pH	pH units	**6.62**	**6.89**	**6.78**	**6.85**	**6.84**	**6.84**	--	**6.91**	**6.90**	**7.07**	**6.84**	**6.92**	**7.12**
Specific conductance	mS/cm	**0.643**	**0.637**	**0.666**	**0.668**	**0.622**	**0.604**	--	**0.659**	**0.664**	**0.608**	**0.662**	**0.618**	**0.657**
Total Organic Carbon	mg/L	--	**1.60**	**1.32**	**2.22**	**1.17**	**1.04**	--	**1.39**	**1.17**	**1.06**	**1.17**	**1.23**	**2.10**
Natural Attenuation Parameters														
Dissolved oxygen	mg/L	**0.12**	**0.23**	**0.14**	**0.16**	**0.13**	**0.12**	--	**0.10**	**0.10**	**2.54**	**4.87**	**3.05**	**5.45**
Redox potential	mV	**254**	**114**	**249**	**147**	**82**	**314**	--	**-65**	**-64**	**88**	**380**	**276**	**86**
Ferrous Iron	mg/L	**0.28**	**0.23**	**0.21**	**0.93**	**0.25**	**2.09**	--	**3.75**	**3.20**	**0.31**	**0.32**	**0.30**	**0.27**
Turbidity	ntu	**198**	**12**	**42**	**27**	**36**	**5**	--	**12**	**15**	**51**	**7**	**21**	**10**
Alkalinity	mg/L	**548**	**540**	**592**	**648**	**498**	**570**	--	**503**	**474**	**439**	**490**	**426**	**4.8**
Methane	ug/L	--	**1**	**1**	**930**	**1500**	**150**	--	**1300**	**73**	**1.1**	**0.24**	**0.20**	**0.03**
Nitrate-Nitrite	mg/L	--	**2.19**	**1.64**	< 0.1	< 0.1	< 0.1	--	< 0.1	< 0.1	**1.99**	**2.41**	**2.42**	**2.06**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.

2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.

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Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS			**MULCH WALL MONITORING WELLS**				
			DUPLICATE						
		B301-MW56S	B301-MW56S	B301-MW57S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
Date Sampled:		7/25/2003	7/26/2003	7/25/2003	7/30/2003	7/29/2003	7/28/2003	7/28/2003	7/25/2003
	Units								
Chlorinated Organics and Reduction By-Products									
PCE	mg/L	< 0.001	< 0.001	< 0.001	**0.00079 J**	**0.00037 J**	< 0.001	**0.00047 J**	< 0.001
TCE	mg/L	< 0.001	< 0.001	< 0.001	**0.85**	**0.021**	**0.00095 J**	**0.038**	< 0.001
1,1-DCE	mg/L	< 0.001	< 0.001	< 0.001	**0.0031**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	< 0.001	< 0.001	< 0.001	**0.083**	**0.0014**	**0.0018**	**0.00067 J**	< 0.001
trans-1,2-DCE	mg/L	< 0.001	< 0.001	< 0.001	**0.004**	**0.00021**	**0.0056**	< 0.001	< 0.001
Vinyl chloride	mg/L	< 0.001	< 0.001	< 0.001	**0.013**	< 0.001	**0.0027**	< 0.001	< 0.001
Ethane	ng/L	< 5	--	< 5	**6200**	**79**	< 5	< 5	< 10
Ethene	ng/L	**9**	--	**14**	**5800**	**69**	**520**	**64**	< 10
cDCE/TCE ratio		--	--	--	**0.098**	**0.067**	**1.895**	**0.018**	**--**
Water Quality Parameters									
Temperature	°C	**15.27**	--	**15.44**	**14.58**	**18.12**	**18.05**	**16.76**	**16.76**
pH	pH units	**7.01**	--	**6.92**	**6.76**	**6.81**	**6.74**	**6.46**	**6.46**
Specific conductance	mS/cm	**0.602**	--	**0.612**	**0.65**	**0.66**	**0.66**	**2.45**	**2.45**
Total Organic Carbon	mg/L	**< 1**	--	**1.66**	**1.75**	**3.19**	**2.13**	**2.00**	**67.83**
Natural Attenuation Parameters									
Dissolved oxygen	mg/L	**3.19**	--	**3.05**	**0.15**	**0.23**	**0.16**	**0.31**	**0.31**
Redox potential	mV	**33**	--	**273**	**128**	**23**	**-35**	**-75**	**-75**
Ferrous Iron	mg/L	**0.53**	--	**0.24**	**0.18**	**1.49**	**2.95**	**0.23**	**15.25**
Turbidity	ntu	**7**	--	**12**	**37**	**21**	--	**62**	**85**
Alkalinity	mg/L	**446**	--	**452**	**620**	**625**	**537**	**456**	**1688**
Methane	ug/L	**6.2**	--	**1.1**	**1800**	**6400**	**7400**	**3100**	**2300**
Nitrate-Nitrite	mg/L	**2.40**	--	**2.39**	**1.08**	**0.13**	< 0.1	**1.83**	**0.10**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.

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