TABLES

TABLE 1-1 SUMMARY OF CONSTRUCTION DATA FOR GROUNDWATER MONITORING WELLS CONSTRUCTED PRIOR TO 2010
600 EAST GUDE DRIVE, ROCKVILLE, MARYLAND 20850

Well ID	Permit #	Date Installed	Drilling Method	Diameter (inches)	Reported Total Depth (ft bgs)	Measured Total Depth - 10/22/2009 and 10/23/2009 (ft bgs)	Casing Depth (ft bgs)	Screen Depth (ft bgs)	Historical Depth to GW (ft bgs)	Geology
OB01	MO880058	4/26/88	HSA / Mud Rotary	2	75	76.42	35	35-75	10-15	0-30 feet : unknown, 30-77 feet : rock
OB02	MO880059	5/20/88	Mud Rotary	2	121	113.25	71	no screen - open from 71-121'	10-17	0-21 feet : red clay & saprolite, 21-121 feet : rock
OB02A	MO880060	5/13/88	Mud Rotary	2	77	76.4	37	37-77	10-17	0-26.5 feet : unknown, 26.5-77 feet : rock
OB03	MO880061	6/30/88	Mud Rotary	2	154	133.13	104	104-154	16-24	0-54 feet : red clay & saprolite, 54- 154 feet : rock
OB03A	MO880062	7/8/88	Mud Rotary	2	97	94.55	50	50-97	15-25	0-47 feet : red clay & saprolite, 47-97 feet : rock
OB04	MO880063	7/22/88	Mud Rotary	2	136	131.66	86	86-136	1-3	0-30 feet : red clay & saprolite, 30-36 feet : decomposed rock, 36-136 feet : rock
OB04A	MO880064	7/29/88	Mud Rotary	2	83	81.92	33	33-83	1-4	0-3 feet : fill, 3-33 feet sandy silt with rock & quartz, 33-83 feet : rock
OB06	MO880065 *			2		66.63	Well Completion Report Missing		4-10	
OB07	MO880066 *	8/7/88	Mud Rotary	2	81	142.87	31	31-81	2-10	0-31 feet : saprolite, 31-81 feet : rock
OB07A	MO880067 *	8/30/88	Mud Rotary	2	76	97.17	26	26-76	2-8	0-26 feet : clay & saprolite, 26-76 feet : rock
OB08	MO880068 *	8/26/88	Mud Rotary	2	109	137.01	59	59-109	0-5	0-57 feet : saprolite, 57-109 feet : rock
OB08A	MO880069 *	10/5/88	Mud Rotary	2	145	79.25	95	95-145	1-6	0-40 feet : saprolite, 40-145 feet : rock
OB10	MO880070 *			2		66.82	Well Completion Report Missing		1-5	
OB11	MO880071 *	10/12/88	Mud Rotary	2	90	100.9	40	40-90	4-7	0-40 feet : saprolite, 40-90 feet : rock
OB11A	MO880072*			2		64.3	Well Completion Report Missing		3-7	
OB12	MO880073*			2		25.58	Well Completion Report Missing		12-17	
OB15	*			4	27.5	22.79	Well Completion Report Missing		16-21	
OB25	*			4	15	15.46	Well Completion Report Missing		3-7	
OB102	*			4	24.5	22.2	Well Completion Report Missing		7-11	
OB105	*			4	13	16.5	Well Completion Report Missing		0-2	

Notes:
GW=groundwater
ft=feet
HSA=hollow stem auger
bgs=below ground surface
* indicates missing well completion reports or reports that indicate conflicting well identification information and total depth measurements that do not match the total depths on the completion reports
Reported total depth data is from well completion reports. For wells OB15, OB25, OB102 and OB105 the total reported total depth data was provided by Montgomery County

TABLE 1-2 SUMMARY OF CONSTRUCTION DATA FOR GROUNDWATER MONITORING WELLS INSTALLED AS PART OF THE NATURE AND EXTENT STUDY (2010)
600 EAST GUDE DRIVE, ROCKVILLE, MARYLAND 20850

Well ID	Permit #	Date Installed	Drilling Method	Diameter (inches)	Total Depth (ft bgs)	Casing Depth (ft bgs)	Screen Depth (ft bgs)	Depth to GW - July 2010 (nearest ft bgs)	Geology
MW-1	MO951146	6/4/2010	HSA and Air Rotary	2	98	78	78-98	45	0-40 ft: brown-yellow, dry fine sand and silt, 40-98 ft: rock
MW-2A	MO951137	6/9/2010	HSA and Air Rotary	2	78	55	55-75	62	0-28 ft: brown, dry fine sand and silt, 28-75 ft: rock
MW-2B	MO951138	6/17/2010	HSA and Air Rotary	2	110	89	88-108	61	0-22 ft: brown, dry fine sand and silt, 22-108 ft: rock
MW-3A	MO951140	6/18/2010	HSA	2	25	5	5-25	10	0-25 ft: brown, moist to wet, fine to medium sand and silt
MW-3B	MO951139	6/22/2010	HSA and Air Rotary	2	96	76	76-96	11	0-35 ft: brown, moist to wet fine sand and silt; 35-96 ft: rock
MW-4	MO951151	7/6/2010	HSA	2	25	5	5-25	7	0-25 ft: brown, wet fine sand and silt
MW-6	MO951149	6/22/2010	HSA	2	25	5	5-25	16	0-10 ft: brown, dry fine sand and silt, 10-26 ft: brown and white, wet sand and clay
MW-7	MO951147	6/24/2010	HSA and Air Rotary	2	53	33	33-53	43	0-16 ft: brown and white, moist to dry fine sand and silt, 16-58 ft: rock
MW-8	MO951148	6/23/2010	HSA and Air Rotary	2	30	10	10-30	24	0-25 ft: brown fine sand and silt (moist 0-10 ft), 25-30 ft: rock
MW-9	MO951141	7/6/2010	HSA	2	25	5	5-25	19	0-1 ft: asphalt and base, 1-25 ft: brown sand and silt (moist 15-25 ft)
MW-10	MO951142	7/2/2010	HSA	2	25	5	5-25	8	0-9 ft: gray-brown, dry clay and silt, 9-25 ft: brown, moist fine sand and silt
MW-11A	MO951143	6/30/2010	HSA	2	30	10	10-30	17	0-31 ft: brown dry silt with fine sand (moist 15-31 ft)
MW-11B	MO951136	6/30/2010	HSA and Air Rotary	2	93	73	73-93	18	0-35 ft: brown fine sand and silt (some moist 15-30 ft), 35-93 ft: rock
MW-12	MO951144	7/6/2010	HSA	2	25	5	5-25	15	0-1 ft: asphalt and base, 1-25 ft: brown fine sand and silt (moist 13-25 ft)
MW-13A	MO951150	6/25/2010	HSA	2	25	5	5-25	7	0-25 ft: brown, moist to wet, fine sand and silt
MW-13B	MO951152	6/29/2010	HSA and Air Rotary	2	95	75	75-95	6	0-49 ft: brown fine sand and silt (moist to wet below 6 ft); 49-95 ft: rock

Notes:
GW = groundwater
ft = feet
HSA = hollow stem auger
bgs=below ground surface

TABLE 1-3

SUMMARY OF CONSTRUCTION DATA FOR GROUNDWATER MONITORING WELLS INSTALLED AS PART OF THE NATURE AND EXTENT STUDY, AMENDMENT NO. 1 (2011)

Well ID	Permit #	Date Installed	Drilling Method	Diameter (inches)	Total Depth (ft bgs)	Casing Depth (ft bgs)	Screen Depth (ft bgs)	Depth to GW - August 2011 (nearest ft bgs)	Geology
MW-14A	MO100151	8/1/2011	HSA and Air Hammer	2	40	30	30-40	21	0-2 ft: asphalt and fill; 2-40 ft: brown silt and fine sand
MW-14B	MO100149	8/2/2011	HSA and Air Hammer	2	98	88	88-98	23	0-2 ft: asphalt and fill; 2-40 ft: brown silt and fine sand; 40-70 ft: weathered rock; 70-100 ft: rock
MW-15	MO100150	8/3/2011	HSA	2	40	30	30-40	6	0-2 ft: asphalt and fill; 2-40 ft: brown silt and fine sand
TGW-1	NA	8/22/2011	Power Auger	1	8	3	3-8	4	Boring locations was installed using a 4" power auger. As such, soils were highly disturbed and unconsolidated. In general, soils consisted of brown clayey silt with clay content increasing with depth.
TGW-2	NA	8/23/2011	Power Auger	1	8	3	3-8	5	Boring locations was installed using a 4" power auger. As such, soils were highly disturbed and unconsolidated. In general, soils consisted of brown clayey silt with clay content increasing with depth.
TGW-3	NA	8/23/2011	Power Auger	1	8	3	3-8	5	Boring locations was installed using a 4" power auger. As such, soils were highly disturbed and unconsolidated. In general, soils consisted of brown clayey silt with clay content increasing with depth.
TGW-4	NA	8/22/2011	Power Auger	1	8	3	3-8	5	Boring locations was installed using a 4" power auger. As such, soils were highly disturbed and unconsolidated. In general, soils consisted of brown clayey silt with clay content increasing with depth.
TGW-5	NA	8/22/2011	Power Auger	1	8	3	3-8	7	Boring locations was installed using a 4" power auger. As such, soils were highly disturbed and unconsolidated. In general, soils consisted of brown clayey silt with clay content increasing with depth.
TGW-6	NA	8/8/2011	Hand and Power Augers	1	7	2	2-7	3	0-0.5 ft: topsoil; 0.5-1 ft: brown silt and clay; 1-3 ft: clay; 3-4 ft: clay and soft cobbles; 4-7 ft: cobbles
TGW-7	NA	8/8/2011	Hand and Power Augers	1	7	2	2-7	4	0-0.5 ft: topsoil; 0.5-1 ft: brown silt and clay; 1-3 ft: clay; 3-4 ft: clay and soft cobbles; 4-7 ft: cobbles
TGW-8	NA	8/8/2011	Hand and Power Augers	1	7	2	2-7	3	0-0.5 ft: topsoil; 0.5-2 ft: brown silt; 2-4 ft: clay; 4-7 ft: cobbles
TGW-9	NA	8/8/2011	Hand and Power Augers	1	6	1	1-6	2	0-0.5 ft: topsoil; 0.5-1 ft: brown silt and clay; 1-3 ft: clay; 3-6 ft: cobbles and sand
TGW-10	NA	8/5/2011	Hand Auger	1	6	2.5	2.5-6	3	0-0.5 ft: topsoil; 0.5-1 ft: brown silt and clay; 1-4 ft: clay; 4-6 ft: clay and gravel

Notes:
(1) MW-14A, MW-14B and MW-15 were installed as permanent groundwater monitoring wells in 2011.
(2) TGW-1 through TGW-10 were installed and decommissioned as temporary groundwater monitoring wells in 2011 following data collecti

Abbreviations:
GW = groundwater
ft = feet
HSA = hollow stem auger
bgs = below ground surface
NA = Not Applicable

TABLE 1-4 SUMMARY OF CONSTRUCTION DETAILS FOR LANDFILL GAS EXTRACTION WELLS AND DEWATERING SUMPS

WELL ID	NORTHING	EASTING	ELEV. (ft)	TOTAL DEPTH (ft)	SOLID PIPE LENGTH (ft)	SLOTTED PIPE LENGTH (FT)
EW-1	524685.00	1271739.00	457.2	30	NA	NA
EW-2	524876.02	1271974.08	459.2	38	NA	NA
EW-3	525075.99	1272253.00	460.2	46	NA	NA
EW-4	525283.77	1272528.88	462.2	33	NA	NA
EW-5	525493.34	1272811.88	462.3	32	NA	NA
EW-6	525701.57	1273090.18	471.5	36	NA	NA
EW-7	525846.59	1273424.41	473.9	51	NA	NA
EW-9	525547.12	1272540.42	463.3	36	NA	NA
EW-10	525795.74	1272803.67	467.5	42	NA	NA
EW-11	526021.70	1272991.79	471.4	41	NA	NA
EW-12	526216.87	1273096.54	473.7	49.5	NA	NA
EW-13	526061.43	1273237.95	475.9	50	NA	NA
EW-14	526177.00	1273268.00	475.1	41	NA	NA
EW-15	525548.12	1273428.12	466.6	35	NA	NA
EW-16	525259.00	1273410.00	458.8	46	NA	NA
EW-17	525256.92	1273728.72	467.7	49	NA	NA
EW-18	525149.25	1274038.96	462.2	38	NA	NA
EW-19	525112.14	1274359.13	465.1	30	NA	NA
EW-20	524988.08	1274602.77	461.2	30	NA	NA
EW-21	524593.90	1271512.61	457.3	32	NA	NA
EW-22	524521.95	1271711.42	460.1	NA[1]	NA	NA
EW-23	524570.40	1272053.18	455.5	NA[1]	NA	NA
EW-24	524386.03	1272325.10	462.6	52	NA	NA
EW-25	524503.28	1273291.42	446.5	28	NA	NA
EW-26	524732.78	1272290.61	456.2	31	NA	NA
EW-27	524593.89	1272608.79	462.2	31	NA	NA
EW-28	524972.00	1272609.00	462.7	30.5	NA	NA
EW-29	524439.03	1272706.65	463.5	25	NA	NA
EW-30	524454.54	1272924.70	461.8	47	NA	NA
EW-31	524286.07	1273115.03	456.2	NA[2]	NA	NA
EW-32	524277.02	1273460.89	455.7	33	NA	NA
EW-34	524765.29	1273183.56	453.1	52	NA	NA
EW-35	524679.16	1273420.41	444.3	41	NA	NA
EW-36	525153.10	1272841.37	459.0	36	NA	NA
EW-37	525060.72	1273123.93	448.3	32	NA	NA
EW-38	524957.57	1273418.77	442.2	31	NA	NA
EW-39	525372.84	1273110.22	463.5	44	NA	NA
EW-40	524912.83	1273900.40	434.4	44	NA	NA
EW-41	524914.46	1274173.29	439.8	44	NA	NA
EW-43	524687.94	1274382.92	440.8	40	NA	NA
EW-44	524718.77	1274594.03	449.9	29	NA	NA
EW-50	524691.93	1271877.94	459.9	22.5	NA	NA
EW-51	524763.79	1272055.46	456.1	25	NA	NA
EW-52	524891.63	1272170.36	462.8	28	NA	NA
EW-54	524766.93	1272474.42	461.7	35	NA	NA

Notes:

Total Depth for Wells EW-1 to EW-76 is based on well sounding data, with the exception of EW-07, EW-14, EW-19, and EW-20, for which depth was measured using a water level meter. No information regarding pipe lengths is available for these wells.

1. Field observations note that EW-22 and EW-23 make a 90-degree turn underground; therefore, total depth was undetermined.
2. Well blockage at 9 ft prevented measurement of total depth of EW-30.

EW = Extraction Well
ft = foot/feet
NA = Not Available.

TABLE 1-4 SUMMARY OF CONSTRUCTION DETAILS FOR LANDFILL GAS EXTRACTION WELLS AND DEWATERING SUMPS

WELL ID	NORTHING	EASTING	ELEV. (ft)	TOTAL DEPTH (ft)	SOLID PIPE LENGTH (ft)	SLOTTED PIPE LENGTH (FT)
EW-57	524919.03	1272744.09	458.1	20	NA	NA
EW-62	525373.34	1272925.64	463.4	37	NA	NA
EW-70	524798.39	1271853.88	457.8	44	NA	NA
EW-71	524968.25	1272111.25	460.4	54	NA	NA
EW-72	524916.85	1272370.37	462.7	58	NA	NA
EW-73	525063.91	1272423.74	467.5	60	NA	NA
EW-74	524839.17	1272607.41	462.1	35	NA	NA
EW-75	524731.77	1272784.69	463.3	26	NA	NA
EW-76	524633.45	1272904.48	461.7	86	NA	NA
EW-100	524720.11	1271278.73	424.2	31	26	9
EW-101	524811.95	1271412.16	430.4	46	26	22
EW-102	524886.23	1271542.61	436.8	39	26	15
EW-103	524988.85	1271598.64	441.5	42	26	18
EW-104	525060.49	1271733.51	447.0	47	26	23
EW-105	525164.44	1271858.58	454.1	53	26	29
EW-106	525249.97	1271981.61	457.1	52	26	28
EW-107	525336.35	1272096.28	458.7	53	26	29
EW-108	525497.90	1272169.22	441.5	27	17	12
EW-109	525603.00	1272277.00	436.6	29	17	14
EW-110	525704.87	1272360.68	431.4	37	26	13
EW-111	525817.47	1272488.84	429.0	45	26	21
EW-112	525904.52	1272583.62	430.8	46	26	24
EW-113	526003.53	1272672.42	431.0	46	26	24
EW-114	526101.61	1272780.92	438.9	39	26	15
EW-115	526192.18	1272873.96	441.4	35	26	11
EW-116	526318.49	1272986.92	445.6	35	26	11
EW-117	524967.94	1271555.75	438.8	25	17	10
EW-118	525001.19	1271605.01	440.7	25	17	10
EW-119	525066.58	1271720.89	448.0	27	17	10
EW-120	525207.25	1271930.45	456.4	20	8	15
EW-121	525323.59	1272075.20	458.6	20	8	15
EW-122	525648.32	1272307.35	432.6	20	8	15
EW-123	525383.41	1272110.40	452.9	25	13	15
EW-124	525421.31	1272125.05	448.1	25	13	15
EW-125	525359.90	1272145.69	459.2	50	20	35
EW-126	525400.00	1272123.00	452.6	35	20	20
EW-127	525429.53	1272155.44	450.5	45	20	30
EW-128	525456.40	1272230.71	459.2	40	20	25
EW-129	525521.55	1272311.17	457.9	40	20	25
EW-130	525607.48	1272377.21	455.6	45	20	30
EW-131	524778.92	1271581.48	455.5	52	20	37
EW-132	524846.00	1271685.00	456.8	52	20	37
EW-133	525261.61	1271909.81	439.5	29	14	19
EW-134	525199.19	1271828.98	439.0	29	14	19
EW-135	524680.43	1271206.29	422.0	21	11	14

Notes:

Total Depth for Wells EW-1 to EW-76 is based on well sounding data, with the exception of EW-07, EW-14, EW-19, and EW-20, for which depth was measured using a water level meter. No information regarding pipe lengths is available for these wells.

EW = Extraction Well

ft = foot/feet
NA = Not Available.

TABLE 1-4 SUMMARY OF CONSTRUCTION DETAILS FOR LANDFILL GAS EXTRACTION WELLS AND DEWATERING SUMPS

WELL ID	NORTHING	EASTING	ELEV. (ft)	TOTAL DEPTH (ft)	SOLID PIPE LENGTH (ft)	SLOTTED PIPE LENGTH (FT)
EW-136	524640.94	1271284.24	440.0	39	20	19
EW-137	524523.32	1271403.94	442.0	42	20	22
EW-138	524486.44	1271599.57	460.0	60	20	40
EW-139	524359.00	1271494.71	432.0	31	20	11
EW-140	524316.23	1271661.36	436.0	36	20	16
EW-141	524387.61	1271785.77	449.0	49	20	29
EW-142	524255.40	1271845.55	425.0	25	15	10
EW-143	524564.48	1271882.53	461.0	61	20	41
EW-144	524421.88	1271991.25	436.0	36	20	16
EW-145	524488.22	1272141.68	452.0	57	20	37
EW-146	524322.34	1272152.77	440.0	40	20	20
EW-147	524204.35	1272207.62	447.0	46	20	26
EW-148	524199.79	1272396.11	467.0	55	20	35
EW-149	524182.15	1272617.55	467.0	51	20	31
EW-150	524994.77	1271870.80	458.0	48	20	28
EW-151	525099.63	1272020.66	459.0	49	20	29
EW-152	525204.94	1272172.12	459.0	52	20	29
EW-153	525227.79	1272360.73	462.0	52	20	32
DS-0	524837.00	1271493.74	439.0	20	NA	NA
DS-1	525047.36	1271945.43	453.0	48	20	28
DS-2	525241.55	1272058.82	459.0	53	20	29
DS-3	525295.36	1272221.31	459.0	51	20	29
DS-4	525516.11	1272404.03	464.0	54	20	34
DS-5	525386.30	1272671.91	449.0	50	20	30

Notes:

EW = Extraction Well

ft = foot/feet

DS = Dewatering Sump

NA = Not Available.

TABLE 1-5
TIMELINE OF PRE-REMEDIATION SITE ACTIVITIES AT THE GUDE LANDFILL

ID	Activity	Designation	MDE Notice (County Initiation)	County Submission	MDE Approval
1	Formalize the Landfill Gas Monitoring Plan	Site Management	December 2008	April 2009	April 2009
2	Formalize the Groundwater and Surface Water Monitoring Plan	Site Management	January 2009	March 2009	May 2009
3	Remediation Approach Work Plan	Site Management	January 2009	April 2009	May 2009
4	Waste Delineation Study	Site Characterization	May 2009	January 2010	March 2012
5	Nature and Extent Study	Site Characterization	May 2009	November 2010	Comments Received (1)
6	Nature and Extent Study Amendment No.1	Site Characterization	February 2011	November 2011	March 2012
7	Assessment of Corrective Measures Work Plan	Site Management	March 2012	May 2012	June 2012
8	Consent Order	Site Management	May 2011	Multiple Submissions (2)	May 2013

ID	Activity	Designation	County Initiation	County Completion	Entity Approval
9	Remediation Feasibility Memorandum	Site Evaluation	July 2010	January 2011	---
10	Exchange of Land with M-NCPPC	Site Management	April 2010	September 2013	October 2014
11	Remediation Project Meetings with Community	Information Sharing	June 2009	On-Going	---
12	Remediation Project Webpage	Information Sharing	June 2009	On-Going	---

Notes:
1. This activity received MDE comments in February 2011 that required additional investigative field work and reporting.
2. This activity required multiple submissions and reviews by Montgomery County and MDE.

MDE = Maryland Department of the Environment
M-NCPPC = Maryland-National Capitol Park and Planning Commission

TABLE 1-6
COUNTY CONTACT AND WEBPAGE INFORMATION

Montgomery County Department of Environmental Protection, Division of Solid Waste Services
County Contact Information

Name	Title	Address	Telephone	Email
Peter R. Karasik	Central Operations Section Chief	Shady Grove Processing Facility and Transfer Station 16101 Frederick Road, Derwood, MD 20855	(240)-777-6569	Peter.Karasik@montgomerycountymd.gov
Rao Malladi	Senior Engineer	Shady Grove Processing Facility and Transfer Station 16101 Frederick Road, Derwood, MD 20855	(240)-777-6574	Rao.Malladi@montgomerycountymd.gov

Montgomery County Department of Environmental Protection, Division of Solid Waste Services
Remediation Webpage Address

http://www.montgomerycountymd.gov/sws/facilities/gude/remediation.html

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Monitored Natural Attenuation					
Onalaska Municipal Landfill Superfund Site, Onalaska, Wisconsin (EPA 2006, 2008a)	2001-present	• VOCs (including Toluene and TCE), metals, SVOCs • Contaminated groundwater area 10-70 ft bgs	• MNA study began in 2001 and P&T system shutdown • 26 monitoring points including air injection wells, piezometers, monitoring wells, and residential wells	• P&T system shutdown in 2001 for a natural attenuation study. • After 2 years of MNA, trimethylbenzenes, methylene chloride, iron and manganese remained at concentrations above cleanup goals. • Potential for reductive dechlorination observed at the site, aerobic conditions in groundwater. • 2008 MNA Study did not recommend the adoption of MNA as a remedy because data supporting MNA is not strong enough.	Not Available
Somersworth Sanitary Landfill Superfund Site, Somersworth, New Hampshire (EPA 2005a)	1996-2004	• Unconfined sand and gravel aquifer 15-75 ft thick over fractured metamorphic bedrock • Groundwater discharges to brook and wetland • Groundwater contains low concentrations of VOCs	• Preferred Source Control Remedy includes installation of a chemical treatment wall (CTW) and a permeable cover • Management of Migration Remedy includes bedrock groundwater extraction and natural attenuation occurring downgradient of the CTW • Groundwater monitoring • Landfill gas venting trench (2003)	• Groundwater monitoring network installed in 1980s. • In 1994 VOCs in groundwater appeared to have reached a steady state condition, extending to 1,700 ft downgradient. • In 4 years, the extent and overall VOC concentration had decreased even more, indicating natural attenuation is occurring. • Sampling for natural attenuation parameters supports that this is ongoing. • Thorough evaluation of lines of evidence for natural attenuation is necessary.	• $900,000 for O&M and monitoring excluding landfill gas trench

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Monitored Natural Attenuation (continued)					
Former Railroad Maintenance Facility, Sanford, Florida (Lacko et al. 2001)	1994-2000	• Industrial site • 15 ft of fine grained sand with some silt • Groundwater depth: 5 ft • VOCs including PCE; TCE; DCE, and VC • Anaerobic conditions in affected area, high alkalinity and suitable pH range for natural attenuation	• Removal of 6,700 gallons of liquid and sludge from maintenance pits and excavation of 6,000 tons of impacted soil • 15-25 wells sampled to determine groundwater quality in 1994 and 1999 • Further assessment and monitoring of VOCs continued to evaluate groundwater quality • Subsequent monitoring reduced to six wells	• VOCs appear to be naturally attenuating due to anthropogenic and biologically available native organic matter • VOCs only detected in a few wells. • Maximum concentration of VOCs is VC, indicating natural attenuation is occurring. • VC is reducing to ethane and ethane under reducing conditions.	Not Available
Enhanced Bioremediation					
Savannah River Site, Aiken South Carolina (Ross et al. 2007)	1999-2005	• PCE and TCE in groundwater • Contaminants in upper 30 ft of aquifer	• Closed with geosynthetic cap in1997 • Biosparging began 1999 • Horizontal wells 60 ft bgs • Methane and air injected to stimulate methane oxidizing organisms to mineralize TCE • Air injected for aerobic degradation of VC	• Biosparging suspended in 2005 because VOC levels dropped below alternate concentration limits. • Landfill cap and natural physical attenuation are expected to decrease chlorinated VOC concentrations to below MCL.	• $ 1 million – 2 horizontal wells • $750,000 - construction of injection pad/ piping • $225,000/yr-biosparging • $215,000/yr-monitoring
Avco Lycoming Superfund Site, Williamsport, Pennsylvania (EPA 2000a)	1995-1996 (pilot) 1997-2000 (full-scale)	• TCE, DCE, VC, • Groundwater 10-15 ft bgs • Sandy silt over fractured bedrock	• P&T in the late 1980s for onsite and offsite • Molasses injection to remediate groundwater in overburden	• Within 18 months, redox levels decreased to anaerobic conditions from aerobic environments. • Concentrations of TCE, DCE and Cr+6 have decreased to less than the cleanup goals in many of the monitoring wells.	• $145,000 for pilot • $220,000 to construct full scale injection system • $50,000/yr O&M

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Enhanced Bioremediation (continued)					
Kelly Air Force Base Demonstration, San Antonio, Texas (USDOD 2007)	1999-2001	• 20-40 ft of alluvial gravel, sand, and silt overlying impermeable clay • Groundwater 5-10 ft bgs	• Methanol and acetate (electron donors) injected continuously (2000) • Closed loop recirculation for hydraulic isolation • Bioaugmentation with *Dehalococcoides*	• 90% reduction in PCE after methanol and acetate. • DCE reduction to ethene observed only after the addition of KB-1 culture. • Site biologically limited, all dechlorinating bacteria were from the bioaugmentation culture.	• $78,000, estimated, microcosm testing • $255,936, estimated, for field testing
Case Study #7, Watertown, Massachusetts (EPA 2000b)	1996-2000	• Industrial site • Sand, gravel, silt overlying impermeable till and bedrock • Groundwater 8 ft bgs	• Pilot Study, groundwater recirculation system • Nutrients, carbon source pulsed in for 8 months, for reductive dechlorination of PCE and TCE. • Oxygen Release Compound (ORC®) then introduced, to aerobically degrade VC and DCE.	• Lag time of 4-5 months before reductive dechlorination increased. • At end of 8 months, TCE concentrations had decreased from 12 ppm to <1 ppm, with an 80% reduction in the mass of total VOCs, and VC concentrations had increased. • Lag period of 1 month after introduction of ORC®, before aerobic conditions established. • DCE and VC levels started to decrease within 3 months after ORC® introduced.	• $150,000 (1-year pilot study with 6 shallow wells)
Caldwell Trucking Superfund Site, Essex County, New Jersey (Finn et al. 2003)	2001-2002	• PCE, TCE (up to 700 ppm) in groundwater in glacial deposits and fractured bedrock • Biodegradation was substrate-limited	• Injected culture of natural microoganisms including *Dehalococcoides ethenogenes* • Injections of carbon substrates: methanol, lactate, acetate	• *Dehalococcoides* sustained in all wells. • Average reductions in PCE and TCE over 90%. • Increased concentrations of DCE, VC, and ethene.	• Not Available
Six Groundwater Sites, Aberdeen Proving Ground, Maryland (EA 2010b)	2006-2008	• PCE, TCE in groundwater • Shallow groundwater in unconsolidated sediments	• *Dehalococcoides* and carbon substrate injected • Recirculation cells, passive biobarriers, direct injection	• Reducing conditions established . • Decreased concentrations of PCE and TCE, to levels below interim remedial goals. • Production of DCE, VC, and ethane.	• Not Available

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Permeable Reactive Barrier					
Moffet Federal Airfield, Mountain View, California (EPA 1998a)	1996-1997	• Former service and support facility • VOCs including TCE, PCE, DCE • Shallow aquifer zone is 25 ft deep • Water table is 5 ft bgs • Silty sand aquifer with several sand channels	• 18-ft-deep permeable, 100% reactive iron barrier • Funnel and gate system – 2 sheet pile walls perpendicular to flow • 2 ft of pea gravel flow control zone, then 6 ft iron treatment wall, then 2 ft of pea gravel flow control • Designed to treat uppermost permeable zone of upper aquifer	• 284,000 gallons of groundwater treated. • Chlorinated VOC concentrations reduced to below detection limit within the 4th foot of iron. • Max flux data has increased, indicating an increase in influent concentration, but treatment goals continue to be met.	• $32,000 operating cost for first year ($1,400 per 1,000 gallons treated) • $373,000 capital costs
Landfill, 3Altus Air Force Base, Oklahoma (USDOD 2008)	2003-2005	• Unlined, closed landfill • Chlorinated aliphatic hydrocarbons in groundwater • High sulfate concentrations in the shallow groundwater • Limited hydraulic head to produce a significant downward gradient	• 30-ft by 30-ft by 11-ft recirculation bioreactor • Excavated, backfilled with organic material and sand • Groundwater extraction trench downgradient in shallow aquifer • Extracted groundwater distributed to bioreactor using drip irrigation • Desired remediation zone is approximately 10-20 ft below water table	• Removal efficiencies from recirculated groundwater: 97-100% for TCE, 76-96% for the sum of TCE, DCE, and VC. • Objective of reducing chlorinated VOC concentrations by 90% not achieved. • 6.5 pounds of TCE removed from 690,000 gallons of groundwater.	• $171,872 for 2-year pilot study
Offutt Air Force Base, Nebraska (AFCEE 2004)	1999-present	• VOCs including TCE • Stiff, low plastic, silty clay • Groundwater depth 3-10 ft bgs	• 100 ft pilot scale wall was successful (1999). • 500-ft-long mulch wall filled with coarse sand mixed with mulch	• Pilot scale decreased TCE by 70% with minimal VC generation. • 95% reduction of TCE observed (between 2001 and 2003). • Ethene and ethane concentrations increased dramatically. • TCE, DCE, VC below MCLs by October 2003.	Not Available

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Chemical Oxidation					
Site 11, Old Camden County Landfill, Naval Submarine Base Kings Bay, Georgia (NAVFAC 1999, Chapelle et al. 2005)	1994-1999	• PCE, TCE, DCE, VC (>4.5 ppm total) • Municipal waste disposal site • Impacted groundwater 30-40 ft bgs in sandy aquifer • Discrete PCE sources identified by direct-push sampling	• P&T at perimeter of landfill, adjacent to residential area (1994-1999) • *In situ* chemical oxidation (Fenton's) of sources near landfill edge (4 events, 1998-2001) • Injection of vegetable oil after chemical oxidant, to promote sulfate reducing conditions • MNA of concentrations <100 ppb	• Chemical oxidation of sources reduced concentrations to below cleanup levels, allowing pump and treat system to be shut off. • Oxidant caused decrease in bacterial activity, but bacteria rebounded within 6 months.	• $1,500,000 to install pump and treat system + $400,000 annual maintenance • $1,050,000 for chemical oxidation (2 events)
Unnamed Facility (Applebaum and Smith 2009)	Not Available	• TCE plume in bedrock (up to 8.4 ppm) and overburden (up to 19 ppm) aquifers • Plume extending from Facility to residential neighborhood • 15-20 ft of till overburden underlain by fractured bedrock	• Injection into overburden and bedrock of chemical oxidant (carbonate and ferrous sulfate=less exothermic than Fenton's), • Single month-long injection event • Enhanced bioremediation (lactate, soybean oil, proprietary additives)	• Effectiveness of chemical oxidant was "highly dependent upon distribution through the subsurface environment." • Injections to promote bioremediation successfully created reducing conditions and decreased TCE concentrations in the short term.	Not Available
Tenneco Automotive Site, Hartwell, Georgia (EPA 2009a)	2003-present	• TCE plume (up to 12 ppm) • Impermeable saprolite 20-50 ft bgs • Permeable weathered rock 50-60 ft contain contamination • Underlain by bedrock	Semiannual injections of chemical oxidant (permanganate) (2003-2011+)	• Plume size decreased 30% in five years (maximum TCE concentration of 120 ppb). • Effectiveness dependent on understanding of the fracture porosity of the material.	$170,000 capital + $45,000 annually

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
			Groundwater Pump and Treat		
Skinner Landfill Superfund Site, Butler County, West Chester, Ohio (EPA 2004, 2009b)	2001-present	• Dump area with buried hazardous waste lagoon • Groundwater downgradient of lagoon is VOC-contaminated • Most concentrated contamination is below former dump • Site underlain by glacial drift (0-40 ft thick) over bedrock	• Installation of multilayered cap • Groundwater Interception System including cut-off wall of soil-bentonite slurry mixture keyed into bedrock, interceptor trenches and P&T system • Groundwater discharged into sewer system • Wells to monitor the groundwater/waste contact status	• 7,654,570 gallons of groundwater pumped. • Groundwater elevations under the landfill cap indicate that groundwater levels have dropped below the buried waste. • Various inorganics detected in groundwater below trigger levels. • Target compounds have declined or remained stable below trigger levels or non-detectable.	Not Available
Onalaska Municipal Landfill Superfund Site, Onalaska, Wisconsin (EPA 2006, 2008a)	1994-2001	• Site was a sand and gravel quarry in 1960s • VOCs (including toluene and TCE), metals, SVOCs • P&T 10-70 ft bgs • Underlying sandstone bedrock about 118-140 ft bgs	• P&T system (1994-2001) to remove VOCs and iron • Air stripping used to remove VOCs • Dewatered clarifier sludge disposed in landfill	• 2.17 billion gallons of groundwater treated from 1994 through 2001. • Concentrations of organic compounds (except benzene and trimethylbenzene) decreased below cleanup goals, May 2001. • Metals continued to be detected at concentrations above cleanup goals. • P&T system shut down because of low levels of contamination and limited exposure pathways.	Not Available
Solvents Recovery Service of New England, Inc. Superfund Site, Southington, Hartford County, Connecticut (EPA 2010a)	1995-present	• VOCs, SVOCs, metals, pesticides and PCBs • Groundwater contamination in both overburden and bedrock aquifers • Overburden groundwater table 0-10 ft bgs	• Onsite interceptor system (1986-1991) • P&T system installed in 1990s • 15 groundwater extraction wells including: 12-in. overburden, 2-in.-deep overburden, and 1 in the bedrock • Treatment includes metals pretreatment, filtration, ultraviolet/oxidation, granular activated carbon, and vapor phase carbon adsorption.	• 196 million gallons treated from 1995-2010. • 16,000 pounds of VOCs removed.	• $1,625,285: O&M cost from 2005-2008 • $1,160,202: groundwater remedy, including remedial design, from 2008 to 2010

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Phytoremediation					
Edgewood Area J-Field Toxic Pits Site, Aberdeen Proving Grounds, Edgewood, Maryland (EPA 2000c, 2002a)	1996 - 1999	• TCA and TCE plume (up to 170 and 61 ppm, respectively) • Perched groundwater 2-8 ft bgs • Silty sand aquifer	• 184 hybrid poplars planted in 1996 on 1 acre, 5-6 ft bgs • Used deep rooting and plastic pipe around upper roots • Additional trees planted in 1998 • 156 viable trees remained in 2001	• Groundwater uptake: 2-10 gallons/day/tree in 1997, 1,091 gallons/day in 2001, projected 1,999 gallons/day in 2026. • Groundwater is depressed beneath trees. • Plume does not migrate offsite during growing season. • Minimal contaminant uptake after 5 years.	• $15,000 for installation of 184 trees, or $80 per tree
Former Carswell Air Force Base, Fort Worth, Texas (EPA 2000c, 2005b)	1996 - 2006	• TCE plume (<1 ppm) • Shallow aerobic silty fine sand aquifer (<12 ft bgs)	• 660 cottonwoods of different sizes planted in 1-acre area	• Average transpiration rate was 1,872 liters/day in 1997. • DO in aquifer lower beneath trees (which contribute organic carbon to aquifer) • Transpiration reduced TCE flux for first 3 years; biodegradation was dominant by 6th year.	• $8 per 5-gallon tree
Edward Sears Properties Site, New Gretna, New Jersey (EPA 2000c, 2002b)	1996	• TCE and PCE plume (up to 390 ppb and 160 ppb, respectively), and other VOCs • Contamination 5-18 ft bgs in layer of sand, silt, and clay	• 118 hybrid poplars planted on 1/3-acre • Deep rooting (9 ft bgs)	• Concentrations of non-chlorinated VOCs decreased within three growing seasons. • Evidence that anaerobic degradation of PCE, TCE is promoted in the root zone.	• $105,000 for installation, $10,000-30,000 annual maintenance
317/319 Area, Argonne National Laboratory-East, Illinois (ANL 2010, EPA 2003)	1999 (anticipated 20-year timeframe)	• VOC and tritium from a Landfill and French Drain • TCE (up to 47 ppm), PCE (up to 190 ppm) • DNAPL source of chlorinated VOCs • Glacial till aquifer • Top of contaminated unit 22-34 ft bgs	• 809 hybrid poplars and willows planted at various depths on 5-acre site • Used deep rooting (TreeMediation system), for treatment of groundwater to over 30 ft bgs • Previously installed P&T system	• Estimated transpiration of 1,440 liters/day during 2001 growing season (compared to groundwater flux of 4,860 liters/day). • No clear impact on VOC concentrations as of 2001. • Water levels depressed up to 0.5 ft as of 2001, with diurnal fluctuations.	• $1,200,000 for total project as of 2004

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Impermeable Barrier					
Western Processing Superfund Site, Kent, Washington (EPA 2008b)	1988-present	• Former waste processing facility • VOCs, metals, PCBs • Sandy and silty loam surface soil • Contaminated groundwater 5-30 ft bgs, in alluvium	• 4,400-ft-long, 40-ft-deep slurry wall around site, through aquitard (1988) • Additional slurry wall (1996) to separate clean from contaminated areas • Pump and treat system (1988) • Engineered cap (1999)	• Increased efficiency of the pump and treat remedy. • Contaminants did not spread offsite into nearby groundwater. • Original pump and treat system removed 100,000 pounds of contaminants between 1988 and 1997.	Not Available
Gilson Road Superfund Site, New Hampshire (EPA 2009c)	1981-present	• VOCs, arsenic • Unpermitted waste disposal facility • 8-53 ft of glacial outwash underlain by fractured bedrock • Overburden and bedrock aquifers contaminated	• 90-110-ft-deep slurry wall encompassing 20 acres (1982) • Engineered cap • Pump and treat (1986-1996) • MNA	• Cleanup goals within slurry wall were attained 1995. • Prevented contaminant migration in overburden, but 7,800 gallons of water per day flowed out of the containment area through bedrock fractures beneath the slurry wall.	Not Available
Site 5, Northeastern United States (EPA 1998b)	Not Available	• VOCs and metals • Municipal solid waste landfill • Interbedded sand, silt, and clay	• 7,000-ft-long, 10-ft-deep clay barrier around the landfill, keyed into clay layer • Soil/clay cap • Leachate and landfill gas collection	• Reduced landfill leachate generation and migrated lateral migration of leachate. • Met hydraulic head criteria. • Improved groundwater quality outside wall (meets required quality standards).	Not Available
Site 15, Northeastern United States (EPA 1998b)	Not Available	• VOCs, ammonia, arsenic • Sanitary landfill • Glacial lake deposits (silt, clay)	• 11,230-ft-long, 20-ft-deep soil-bentonite cutoff wall, keyed into a clay layer • Leachate collection	• Achieved inward groundwater gradient and prevented migration of site contaminants. • Improvements in groundwater quality outside the barrier.	Not Available
Site 17, Northeastern United States (EPA 1998b)	Not Available	• VOCs (including TCE), metals • Landfill • Atlantic Coastal Plain • Small zones of 2 aquifers are contaminated	• 5,965-ft-long, 15-33-ft-deep slurry wall keyed into a confining layer • Leachate and methane collection • Drain and extraction wells, and water treatment • Engineered cap	• Inward groundwater gradient established. • Leachate levels have dropped.	$55-60 million

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Landfill Gas Collection					
Somersworth Sanitary Landfill Superfund Site, Somersworth, New Hampshire (EPA 2005a)	2003-present	• Methane detected near the perimeter of the landfill during soil gas monitoring in 2001 and 2002.	• LFG venting trench installed 2003-2004. • Depth of trench extends 15 to 27 ft bgs (to seasonal low groundwater level). • 3-ft-wide trench • Gravel from bottom of trench to 3 ft bgs, geotextile fabric separator, followed by 2.5 ft of compacted clay, and 0.5 ft of topsoil. • Vertical geomembrane on outside wall of the trench. • 4-in. vent pipes embedded vertically within the gravel	• Reduced methane concentrations in soil gas outside of the landfill were observed in data collected prior to 2005. • Frequency of monitoring soil gas was reduced in 2006.	• $40,000 for O&M
Colbert Landfill Superfund Site, Spokane County, Washington (EPA 2010c)	1996-present	• Landfill (1968-1986) accepted municipal and chemical waste • Engineered cover, but no liner. • Potential for off-site gas migration, including methane	• LFG collection system part of landfill closure. • Interior and perimeter wells and trenches. • Activated carbon treatment of gas, followed by discharge to the atmosphere. • Condensate treated off-site.	• Landfill produces low volumes of methane and carbon dioxide. • Production volumes are relatively stable.	• $352,000 annual cost for operating the water treatment plant and LFG system
Coakley Landfill Superfund Site, North Hampton and Greenland, Rockingham County, New Hampshire (EPA 2011)	1996-present	• Landfill (1972-1985) accepted municipal waste and waste incinerator residue. • Waste placed in open tranches created by quarrying • Methane migration off-site	• Passive gas collection and venting system, with turbine vents on several gas vent pipes • Landfill gas monitoring occurs quarterly • Methane gas alarms installed in buildings in adjoining properties in 2007	• Remedy determined to be protective of human health and the environment • No violations reported in buildings with methane gas alarms • Sporadic violations of methane detected above the state standard in LFG monitoring probes (6.5% of readings in 5 years).	• $46,000 average annual O&M (monitoring of landfill cap, surface water drainage, ambient air, landfill gas, groundwater, and surface water)

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Cover System Improvements/Partial or Full Capping					
Mica Landfill, Spokane, Washington (Washington Ecology 2001, 2008)	1994-present	• Unlined municipal solid waste landfill • Lined leachate pond for landfill drainage • VOCs detected in wells offsite • Groundwater occurs in competent bedrock and the weathered bedrock/loess • Groundwater flows through waste	• Installation of a double-layered geosynthetic and engineered clay cap • Installation of methane and leachate collection system and stormwater control system	• Leachate quantities show a reducing trend, but groundwater still drives the leachate volumes. • Chlorinated ethene reduction. • Decreasing trend for PCE and TCE. • Increasing trend for DCE and VC. • Contamination does not migrate offsite.	Not Available
Coshocton Landfill, City of Coshocton, Ohio (EPA 2008c)	1995-present	• Approximately 30 chemicals in groundwater, surface water and sediment including VOCs • Landfill built on abandoned strip-mined land and received various industrial wastes	• Low permeability landfill cap in accordance with state requirements, runoff gradation, groundwater, surface water and landfill gas monitoring. • Ongoing O&M activities for settlement/ consolidation management, vegetation management, and cover monitoring system	• Contaminants contained in the landfill remain intact at low levels below action levels. • Settlement of the cap has not occurred. • Selected remedy successfully implemented and containment components remained satisfactory.	Not Available
Site 10, Northend Landfill, Naval Magazine Indian Island, Port Hadlock, Washington (NAVFAC 1999)	1996-present	• Unlined • Groundwater at elevations near sea level; perched water in zones • Lower portion of landfill is saturated • Groundwater flow dependent on tide • COCs include metals, pesticides and one SVOC	• Excavated material regraded over old landfill surface and compacted • Landfill cap placed over approximately 3 acres • Shoreline protection system • Three layers of vegetative geogrids along seaward side of landfill • Gas-collection system	• Groundwater monitoring indicates few significant changes in quality from historical results and chemical analysis was discontinued.	Not Available

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Site, Location, and Citation(s)	Dates Operation	Contaminants and Site Characteristics	Technological Details	Outcomes	Approximate Costs
Selective or Extensive Waste Excavation					
Clovis Landfill, Clovis, California (Serpa 2008)	1998-2008	• Landfill projected to reach capacity around 2015 • Unlined portion of landfill causing VOC contamination of groundwater	• Waste excavated and sorted • Sorted waste placed in lined portion of landfill • Sorted soil stockpiled for future use • Conveyor used to transport soil, trucks are used to transport the waste	• 2.3 million yd^3 mined. • Odors are present but they are not severe and do not migrate far. • Vectors are more attracted to active landfill area than excavation area. • Litter blown from excavation face is easily collected. • Groundwater VOC levels steadily decreased as project progressed and will continue to attenuate. • Enough soil recovered to meet facility's operational needs for 20 years. • Actual quantity of waste was more than estimated amount. • Actual daily productivity was less than estimated productivity.	• Expected cost of $3.8 million • Actual cost of $9 million
Ionia City Landfill Superfund Site, Ionia County, Michigan (EPA 2010b)	1994-1995	• 20-acre closed landfill • Former dump collected municipal and industrial wastes • Shallow aquifer	• Landfill cap (1984) • Source removal of waste and contaminated soil impacting groundwater in older fill area (1994) • Clean sand used to backfill excavated area • P&T system ('99-'03) to contain higher VOC concentrations • MNA	• 12,250 tons of waste material (drums containing solvents and paint thinners) and contaminated soil removed and disposed offsite. • Source removal eliminated need for further soil remediation. • Remaining contaminant plume is stable. • MNA is reducing the remaining concentration.	Not Available
Perdido Landfill, Cantonment, Escambia County, Florida (Florida DEP 2009)	2008	• Closed and active landfill areas • Unlined landfill cells potentially causing groundwater contamination	• 2.5 acres of an unlined cell was mined • Screened waste was disposed in a lined cell	• 54,300 yd^3 mined. • 38,00 yd^3 soil reclaimed for use as daily and intermediate cover. • Post-closure care cost avoidance.	• $8.6 per yd^3 mined

Note: Definitions for abbreviations are provided on Page 12.

TABLE 4-1: CASE STUDIES FOR REMEDIAL TECHNOLOGIES

Notes:

AFCEE – Air Force Center for Environmental Excellence
ANL – Argonne National Laboratory
bgs – below ground surface
COC – contaminant of concern
Cr+6 – chromium(VI)
CTW – chemical treatment wall
DCE – dichloroethene
DEP – Department of Environmental Protection
DNAPL – dense non-aqueous phase liquid
DO – dissolved oxygen
ft – foot/feet
EPA – U.S. Environmental Protection Agency
in. – inch(es)
LFG – landfill gas
MCL – maximum contaminant level
MNA – monitored natural attenuation
NAVFAC – Naval Facilities Engineering Command
O&M – operations and maintenance
ORC – oxygen release compound
P&T – Pump and Treat
PCB – polychlorinated biphenyl
PCE - tetrachloroethene
ppb – parts per billion
ppm – parts per million
SVOC – semivolatile organic compound
TCA – trichloroethane
TCE – trichloroethene
USDOD – United States Department of Defense
VC – vinyl chloride
VOC – volatile organic compound
yd^3 – cubic yard
yr – year

TABLE 4-2 REMEDIAL TECHNOLOGIES SCREENING SUMMARY

Remedial Technology	Effectiveness	Implementability	Cost[1]	Retained as a Corrective Measure Technology?	Additional Notes
Monitored Natural Attenuation	Moderate—natural attenuation is active at site, but COC concentrations in groundwater exceed MCLs at the point of compliance	High—relies upon sampling and analysis; detailed assessment required for regulatory approval	Low—mainly long-term monitoring and analysis	Retained	
Enhanced Bioremediation	High—could decrease COC concentrations in shallow and deep groundwater to less than MCLs	Moderate—some well installation challenges; would require periodic injections in the long term	Moderate-High—capital costs and long-term O&M	Retained	
Permeable Reactive Barrier	Low—would not address COCs in groundwater within bedrock	Moderate—would require waste relocation, long-term maintenance	High—capital costs and O&M	Not retained, due to inability to treat groundwater within bedrock	
Chemical Oxidation	Moderate—oxidant delivery to deep bedrock would likely be limited	Low—would require frequent reapplication of oxidizant; not typically used where COC source cannot be treated	Moderate-High—mostly associated with multiple annual injections for many decades	Not retained, due to need for frequent injections in the long-term	
Groundwater Pump and Treat	Moderate—would extract impacted groundwater and remove COCs, but may not completely control deep impacts	Moderate—would require careful design and significant long-term maintenance	Moderate-High—capital costs and long-term O&M	Retained	
Phytoremediation	Low—small decrease in flow of impacted groundwater across a portion of the property boundary	High—requires tree clearing prior to planting and maintenance of trees	Low—relatively low level of effort involved	Not retained, due to limited short-term effectiveness and need to remove trees	Possible enhancement to remedial alternatives
Impermeable Barrier	Low—would only marginally reduce migration of landfill gas and shallow groundwater	Moderate—would require waste relocation, trench construction	Low—cost of constructing the barrier	Not retained, due to inability to control flow of groundwater within bedrock	
Landfill Gas Collection	High—would provide direct control over landfill gas migration	High—requires drilling through waste using specialized procedures	Low—cost of gas extraction well installation	Retained	

(1) Low = <$1 million
Moderate = $1-10 million
High = >$10 million
(assuming 20 years of operations and maintenance [O&M], where applicable)

TABLE 4-2 REMEDIAL TECHNOLOGIES SCREENING SUMMARY

Remedial Technology	Effectiveness	Implementability	Cost[1]	Retained as a Corrective Measure Technology?	Additional Notes
Cover System Improvements	Moderate—could decrease occurrence of leachate seeps	High—requires minimal site disturbance	Low-Moderate—cost of additional topsoil	Retained	
Partial, Toupee, or Full Capping	Partial Capping (side-slopes): Moderate—would likely achieve RAOs for landfill gas and leachate seeps Toupee Capping (with NW and W side-slopes): Moderate—would likely achieve RAOs for landfill gas and leachate seeps Full Capping: Moderate—would likely achieve RAOs for landfill gas and leachate seeps	Partial Capping (side-slopes): High—could be implemented on side slopes after waste excavation Toupee Capping (with NW and W side-slopes): Moderate—requires extensive disturbance of the top of the landfill and accessible side-slopes, and rebuilding of landfill gas and stormwater collection systems, Full Capping: Low—requires extensive site disturbance and rebuilding of landfill gas and stormwater collection systems	Partial Capping (side-slopes): Moderate—includes site preparation and cap placement Toupee Capping (with NW and W side-slopes): High—high capital cost (less than full capping) but required relatively low O&M costs Full Capping: High—costs of cap construction and rebuilding displaced systems	Partial Capping (side-slopes): Retained as a potential contingency measure Toupee Capping (with NW and W side-slopes): Retained Full Capping: Not retained, due to extensive site disturbance and reconstruction required with minimal additional benefit compared to Toupee Capping	

(1) Low = <$1 million
Moderate = $1-10 million
High = >$10 million
(assuming 20 years of operations and maintenance [O&M], where applicable)

TABLE 4-2 REMEDIAL TECHNOLOGIES SCREENING SUMMARY

Remedial Technology	Effectiveness	Implementability	Cost[1]	Retained as a Corrective Measure Technology?	Additional Notes
Selective or Extensive Waste Excavation	Selective Excavation: Moderate—would decrease fugitive gas exceedances at the property boundary. Regrading and cap or improved cover could address leachate seeps. Extensive Excavation: High—Would remove sources of groundwater VOCs, landfill gas, and leachate. Would not address current groundwater contamination.	Selective Excavation: Moderate—land and waste disturbance, disturbance to landfill gas recovery system Extensive Excavation: Low—requires extensive site and waste disturbance, and would likely take decades to excavate entire landfill	Selective Excavation: High—includes cost of excavation and off-site disposal or on-site placement Extensive Excavation: High—may be offset to some degree by recycling of waste	Selective Excavation: Retained Extensive Excavation: Retained	
No Action	Low—would not provide monitoring and thus would not guarantee lack of unacceptable risk	Low—unlikely regulatory agency approval	Minimal—no capital or annual O&M costs	Not retained	

(1) Low = <$1 million
Moderate = $1-10 million
High = >$10 million
(assuming 20 years of operations and maintenance [O&M], where applicable)

TABLE 6-1 NUMERICAL COMPARISON OF CORRECTIVE MEASURE ALTERNATIVES

Criterion	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
ARARs and RAOs – Groundwater [a]	4	4	4	3	4	3
ARARs and RAOs – Landfill Gas [a]	4	4	5	3	3	5
ARARs and RAOs – Leachate [a]	4	4	5	4	4	5
ARARs and RAOs – Overall	**4**	**4**	**5**	**3**	**4**	**4**
Timeframe for Achieving RAOs (years) [a]	4	4	1	3	3	2
Groundwater	12 years	12 years	30+ years	16 years	11 years [b]	30+ years
Landfill Gas	9 years	9 years	10 years	4 years	4 years	3-5 years
Non-Stormwater Discharges	9 years	9 years	10 years	4 years	4 years	3-5 years
Short-Term Risks to Community [a]	2	2	1	4	4	3
Short-Term Effectiveness – Overall	**3**	**3**	**1**	**4**	**4**	**3**
Long-Term Effectiveness	**4**	**4**	**4**	**2**	**4**	**4**
Implementability	**2**	**2**	**1**	**3**	**4**	**5**
Protection of Human and Ecological Health	**3**	**3**	**4**	**5**	**5**	**5**
Source Treatment and Reduction of Toxicity, Mobility, and Volume	**4**	**4**	**5**	**3**	**3**	**4**
Cost†	**2**	**4**	**1**	**4**	**4**	**5**
Capital	$105,000,000	$52,000,000	$455,000,000	$8,000,000	$9,000,000	$26,300,000
Average Annual O&M	$2,400,000	$2,400,000	$48,000	$3,300,000	$2,400,000	$30,000
Total with 20 years O&M	**$152,000,000**	**$100,000,000**	**$456,000,000**	**$74,000,000**	**$57,000,000**	**$27,000,000**
Regulatory Acceptance	**4**	**4**	**4**	**4**	**4**	**5**
Community Acceptance	**3**	**3**	**1**	**4**	**5**	**5**
Total	**29**	**31**	**26**	**32**	**37**	**40**

5 = best; 1 = worst

[a] Rankings for these items are not included in the total; instead, the overall rankings for ARARs and RAOs and Short-Term Effectiveness are included.

[b] Timeframe for achieving RAOs in groundwater for VOCs only.

Cost Ranking*:
1 = over $200,000,000
2 = $150,000,000-$200,000,000
3 = $100,000,000-$150,000,000
4 = $50,000,000-$100,000,000
5 = under $50,000,000

Alternative Descriptions:
Alternative 1 - Selective Waste Excavation with Off-site Disposal and Enhanced Bioremediation
Alternative 2 - Selective Waste Excavation with On-site Placement and Enhanced Bioremediation
Alternative 3 - Extensive Waste Excavation with Monitored Natural Attenuation
Alternative 4 - Additional Landfill Gas Collection and Cover System Improvements with Groundwater Pump and Treat
Alternative 5 - Additional Landfill Gas Collection and Cover System Improvements with Enhanced Bioremediation
Alternative 6 - Toupee Capping and Additional Landfill Gas Collection

[*] Cost ranking based on capital cost plus 20 years of O&M.

ARAR = Applicable or Relevant and Appropriate Requirements RAO = Remedial Action Objective