

**INNOVATIVE TECHNOLOGY PILOT PROGRAM REMEDIATION
SUMMARY REPORT**

**STRICKLAND CONTRACTING COMPANY
1845 WEST JEFFERSON STREET
QUINCY, GADSDEN COUNTY, FLORIDA
FACILITY IDENTIFICATION NO. 208519720**

PREPARED FOR:

**Florida Department of Environmental Protection
Bureau of Petroleum Storage Systems
Tallahassee, Florida**

PREPARED BY:

ECT

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NOVEMBER 2007

1.0 INTRODUCTION

Environmental Consulting & Technology, Inc. (ECT) was contracted by the Florida Department of Environmental Protection (FDEP) under Contract No. GC 639 to conduct an Innovative Technology Pilot Program using ozone injection technology at the Strickland Contracting Company site located at 1845 West Jefferson Street in Quincy, Gadsden County, Florida (see Figure 1).

The contract consisted of baseline sampling; preparing an approved remedial action plan to rehabilitate the site to petroleum cleanup target levels; performing active remediation; conducting post active remediation monitoring for a minimum of 12 months; closing and restoring the site; securing the issuance of a Site Rehabilitation Order; and preparing this Special Summary Report. A quick reference summary of the general information of the project is presented in Table 1.

1.1 SITE CONDITIONS AND BACKGROUND

The site was a former construction contracting yard where large trucks, equipment, and materials were stored. The facility had underground storage tanks (USTs) containing gasoline in the southern part of the yard and a UST containing diesel fuel in the northern section of the yard (see Figure 2).

A discharge reporting form (DRF) was sent to the FDEP with a discovery date of December, 1988. The site was placed in the Early Detection Incentive (EDI) program for state funded cleanup. A phase I and II Environmental Site Assessment was conducted at the site in March 1993 where organic vapor analyzer (OVA) screening indicated petroleum impacted soil. In November 1995, a Technical Summary Report summarizing a contamination assessment reported that the soil in the northern and southern portions of the site and the groundwater in the southern portion of the site were impacted by hydrocarbons. Additional supplemental assessments conducted in November 1999, March 2000, and June 2000 further defined the extent of contamination. Finally, a Site Assessment Report was issued in February 2002 that indicated that the soil in the northern and southern portion of the site exceeded the FDEP soil cleanup target levels and the groundwater in the southern portion of the property exceeded the FDEP groundwater cleanup target levels. Pre-remediation soil conditions at the site are illustrated in Figure 3 and Table 2. Pre-remediation groundwater conditions are illustrated in Figure 4 and Table 3.

The site is underlain by a gray to orange, mottled, unconsolidated to poorly consolidated, very fine to very coarse, poorly sorted, clean to clayey sands of the Citronelle Formation. It contains significant amounts of clay, silt, and gravel which may occur as beds and lenses and may vary considerably over short distances. The formation can be a very tight to a highly permeable formation with unconfined groundwater occurring at a depth of approximately 42 to 48 feet during the course of this project. The general direction of the

groundwater flow is to the northeast. The lithologic units that were remediated during this project were dominated by clayey and silty sands of low transmissivity.

2.0 REMEDIATION SYSTEM

2.1 SYSTEM LAYOUT

The remediation system that was utilized during this Innovative Technologies Study was Blue Lightning Underground Enterprises (BLUE's) RemedO₃zone™ system which utilizes low flow-rate ozone and oxygen injection to initiate chemical oxidation of the petroleum compounds and to enhance biodegradation due to elevated dissolved oxygen concentrations in groundwater.

Two target zones were identified: the diesel impacted soil in the northern portion of the site and the gasoline impacted soil and groundwater in the southern portion of the site. Remediation of each target zone was accomplished by applying an ozone-rich, oxygen gas feed to chemically and biologically degrade petroleum compounds. A Kerfoot Technologies, Inc. patented C-Sparge® system, which provides micro-bubble delivery of gas, was deployed to provide ozone (the tri-atomic form of oxygen) and oxygen (the di-atomic form of oxygen) delivery to react with and reduce the concentrations of contaminants in the soil and groundwater. The C-Sparge® system is capable of delivering gas containing 0.3 lb/day ozone and 100 lb/day of oxygen per well point.

A small 6 x 8 foot trailer was used to contain a corona discharge ozone generator, compressor, controller, solenoid valves, and ozone sensor shut-off. The system ran off of a 120 volt electric current. For remediating the petroleum impacted soil, four gas injection spargepoints were installed to depths of 20 feet below land surface (ft bls) in the northern (diesel) area of the site while three spargepoints were installed at a depth of 17 ft bls in the southern (gasoline area) (see Figure 5). In addition, three spargepoints were installed to a depth of 50 ft bls in the southern area to remediate the petroleum impacted groundwater. The effectiveness zone for each spargepoint was estimated at 20 foot radius based on similar long term operation at other sites. Each spargepoint in the network was connected to the remediation process equipment via a 3/8-inch id HDPE tube. The layout of the remedial system is presented in Figure 5.

2.2 REMEDIAL SYSTEM DETAILS

In the aqueous phase, dissolved ozone has a half-life ranging from minutes to hours as it reacts with water to form hydroxyl-radicals or degrades back to harmless oxygen. Ozone is 12.5 times more soluble in water than oxygen which allows ozone to dissolve into water at more than 200 parts per million (ppm) and can saturate the water with dissolved oxygen following degradation. Dissolved ozone distribution in the saturated zone is typically better than gas distribution, as it is less affected by preferential flow pathways, upward migration, and has the benefit of aqueous diffusion.

Ozone gas from the corona discharge ozone generator is diluted with air in a compressor to achieve a 3 scfm, 45 psi, and 0.3 lb/day ozone production delivery condition. The process gas is directed through one of 10 Rainbird® solenoid operating valves operated by a timer, so that the gas has a rotated delivery to each of the 10 spargepoints for a 12 minute time period every 2 hours. This allows each spargepoint in the system to receive 144 minutes of processed ozone gas per day.

The expected duration of the remedial application, calculated from baseline data, was four to twelve months of continuous RemedO₃zone™ application of oxygen and ozone into the subsurface. The C-Sparge® system is designed to operate unattended with monthly equipment check site visits to insure continuing operation.

2.3 REMEDIAL SYSTEM SCHEDULE

The following is the timeline for operating the remedial system at the site:

- July 1, 2004 Collected baseline groundwater quality parameters
- March 2, 2005 Remedial system installed and began operations
- June 2, 2005 1st quarterly groundwater sampling
- September 9, 2005 Soil sampling event
- September 12, 2005 2nd quarterly groundwater sampling
- January 30, 2006 Groundwater sampling event; System shut down
- June 2, 2006 Post remedial groundwater sampling
- July 10, 2006 Post soil sampling event
- May 21, 2007 Final Post soil sampling event
- June 1, 2007 Final post groundwater sampling event

3.0 RESULTS

3.1 SOIL

Northern Area – Calculations from historic and baseline data show the initial petroleum mass adsorbed to soil has a maximum concentration of 306 milligram per kilogram (mg/kg) total petroleum hydrocarbons (TPH) by FL-PRO method at 15-17 ft bls. The mass balance calculation using historical soil data, indicate a total of about 27 lb TPH by FL-PRO method adsorbed on soils in the northern target area (see figure 3).

Table 2 shows that the northern area had levels of 1-methyl and 2-methyl naphthalene and TPH greater than the state soil cleanup target levels (SCTLs) during the remediation effort and during the post remedial monitoring period. For the post-remedial sample, a leachability alternative for TPH was calculated based on SPLP analysis to show that the sample location SB-B was below the leachability for TPH (see tables 2 and 3).

Southern Area – Petroleum mass adsorbed to soil based on historical and baseline soil sample analyses, indicate a maximum concentration of 1,450 mg/kg TPH by FL-PRO method. Mass balance calculations, indicate a total of about 19 lb TPH and 1.2 lb BTEX

(benzene, toluene, ethylbenzene and total xylenes) adsorbed on soils in the southern target area.

Table 2 shows that the southern area had elevated levels of benzene, toluene, ethylbenzene, and total xylenes during the remediation effort. Post remedial monitoring shows that the concentrations of petroleum constituents in the soil were reduced to below the cleanup target levels.

3.2 GROUNDWATER

Mass balance calculations from baseline sample data indicated a total 0.055 lb of volatile organic compounds (VOCs) in the groundwater in the southern remediation target zone. Pre-remedial concentrations of contaminants are presented in Table 4 and Figure 4. The system operated for 10 months with concentrations generally decreasing to below the state cleanup target levels for groundwater within the first seven (7) months. Post-remedial groundwater site conditions are presented in Figure 6.

During sampling of the key monitoring wells, dissolved oxygen levels were extremely high (>8 mg/l) in the area of the sparge wells, even months after the remedial system had been shut down.

4.0 CONCLUSIONS

The BLUE RemedO₃zone™ application of oxygen and ozone was successful in remediating the soil and groundwater at the site in a relatively short time period and under subsurface conditions of tight soil with low groundwater transmissivity. The system is easy to install with a drill rig and a trenching machine and is compact and simplistic in its design. The entire remediation system fit into a 6 x 8 foot trailer with plenty of extra space. To prevent overheating of the system an extra ventilation panel was cut into the floor and an electric fan was used to circulate air throughout the trailer.

During the operation of the system it was observed that during a power outage to the trailer, the entire system would restart by itself except for the compressor that required a manual restart button. Therefore, a site visit was necessary after every electrical storm to restart the compressor. A suggested design improvement for this system would be to have an automatic restart on the compressor. Because of the required manual restart of the compressor, the remedial system only operated 3,248 hours or approximately 135 days out of a possible 285.

The ozone injection system is recommended for sites under any subsurface conditions and is anticipated to be very effective for polishing difficult to remove residual contamination from soil and groundwater. Because of amount of dissolved oxygen that the system puts into the groundwater and soil vapor space, it is anticipated that this system can also greatly enhance bioremediation efforts.

FIGURES

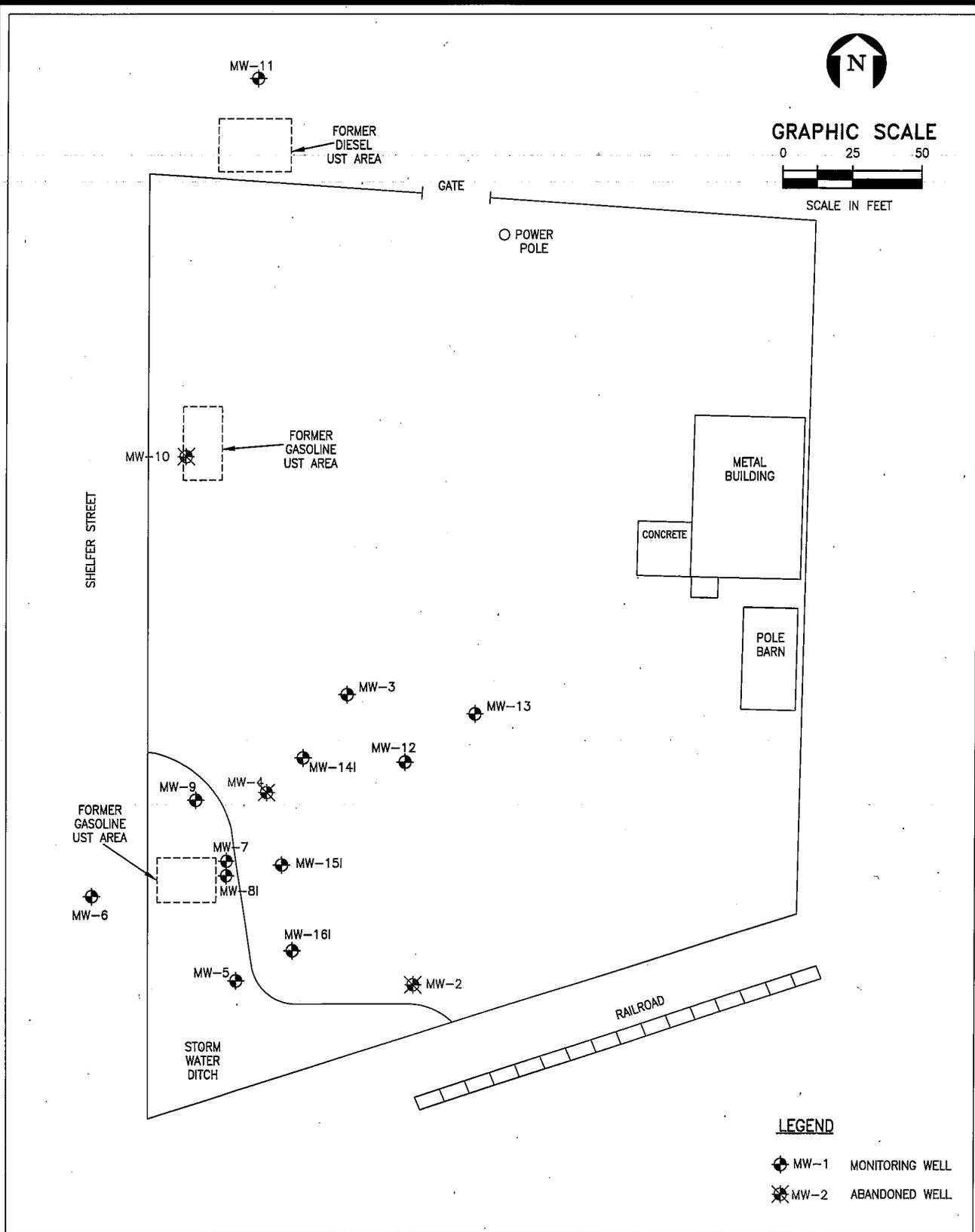


FIGURE 2.
PRE-REMEDIATION SITE CONDITIONS
STRICKLAND CONTRACTING COMPANY - QUINCY, FL.
 Source: ECT, 2007.



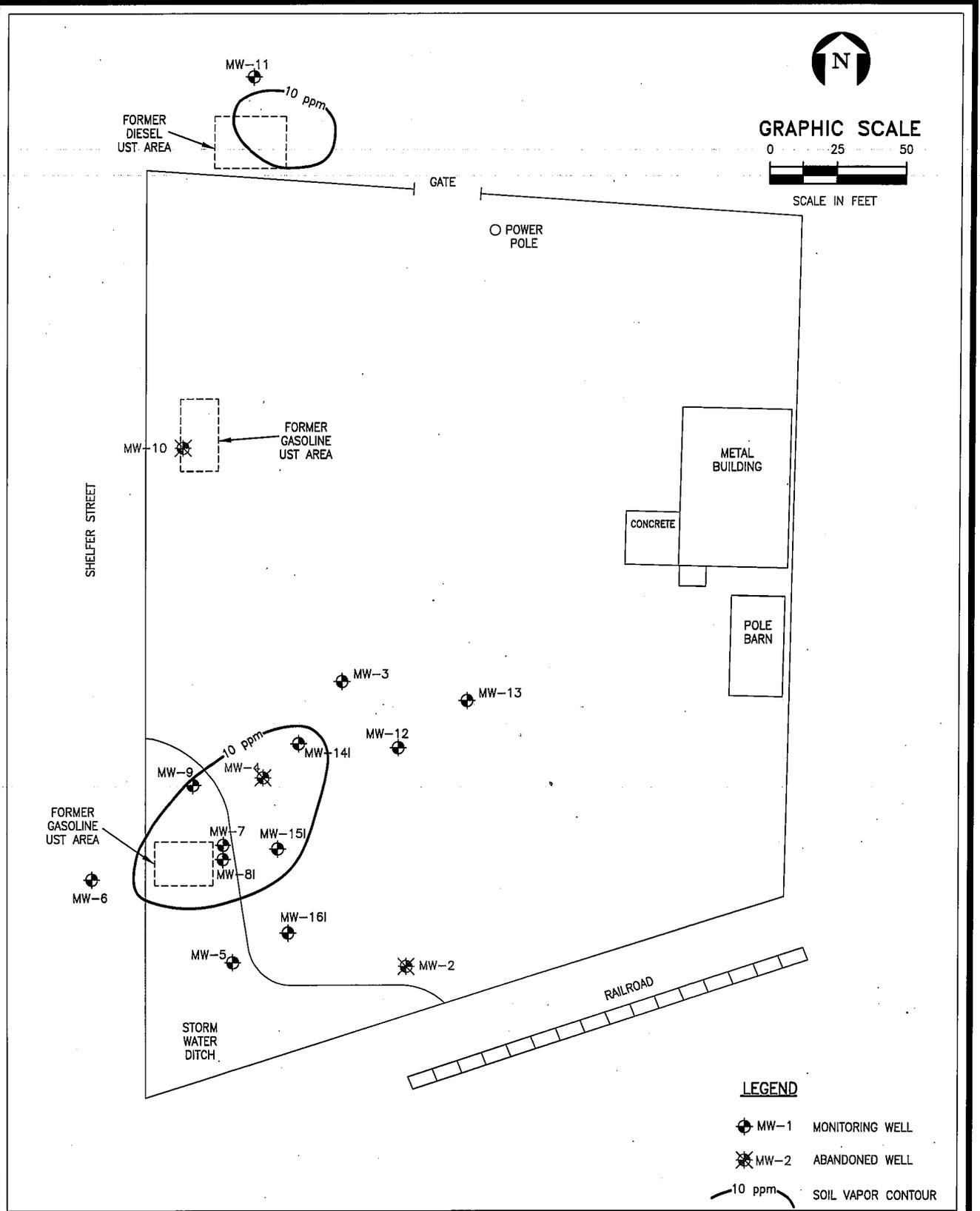


FIGURE 3.
PRE-REMEDATION SOIL CONDITIONS
STRICKLAND CONTRACTING COMPANY - QUINCY, FL.
 Source: ECT, 2007.



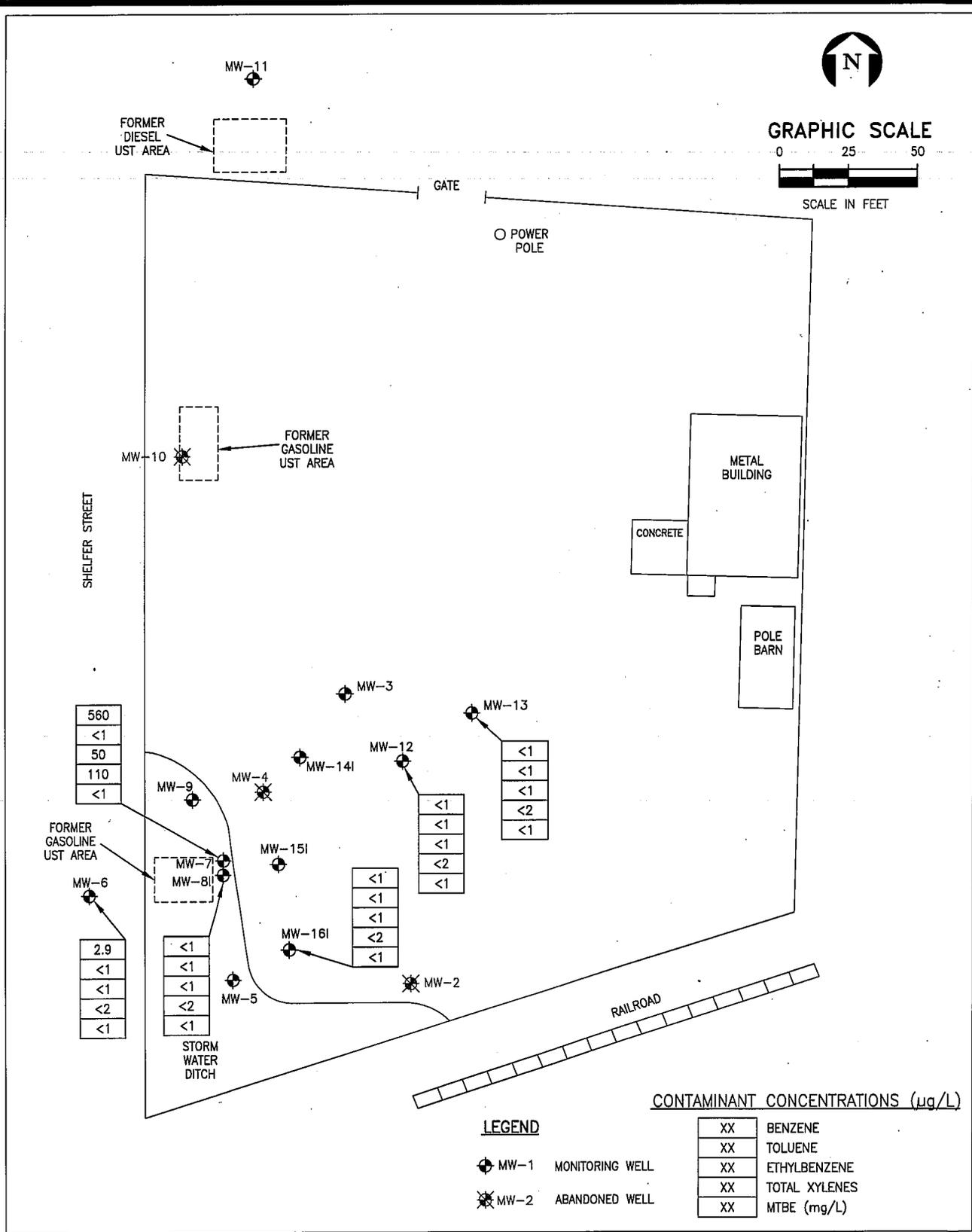


FIGURE 4.

PRE-REMEDIATION GROUND WATER CONDITIONS
 STRICKLAND CONTRACTING COMPANY - QUINCY, FL.

Source: ECT, 2007.



Environmental Consulting & Technology, Inc.

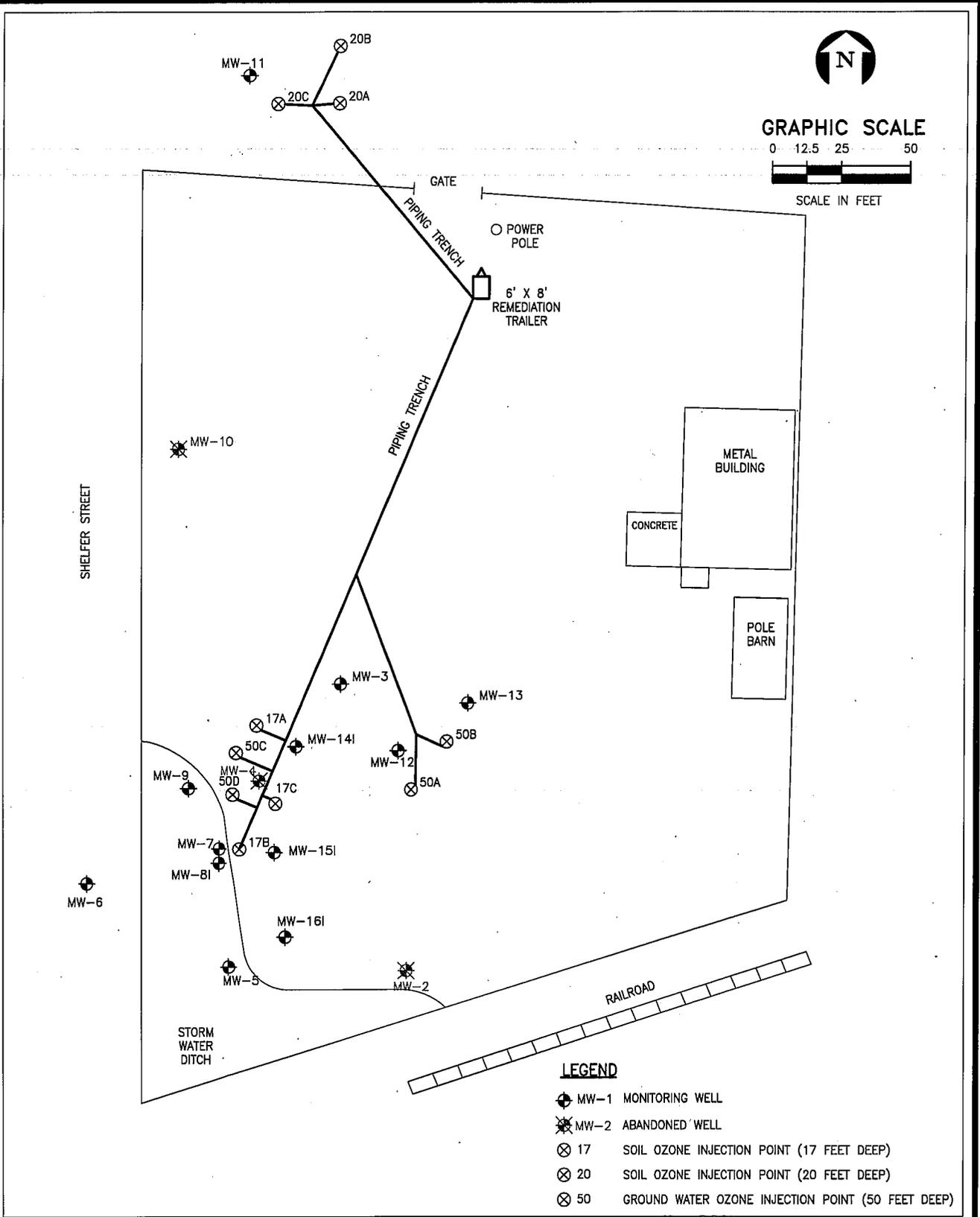


FIGURE 5.
REMEDIAL SYSTEM LAYOUT
STRICKLAND CONTRACTING COMPANY - QUINCY, FL.
 Source: ECT, 2007.



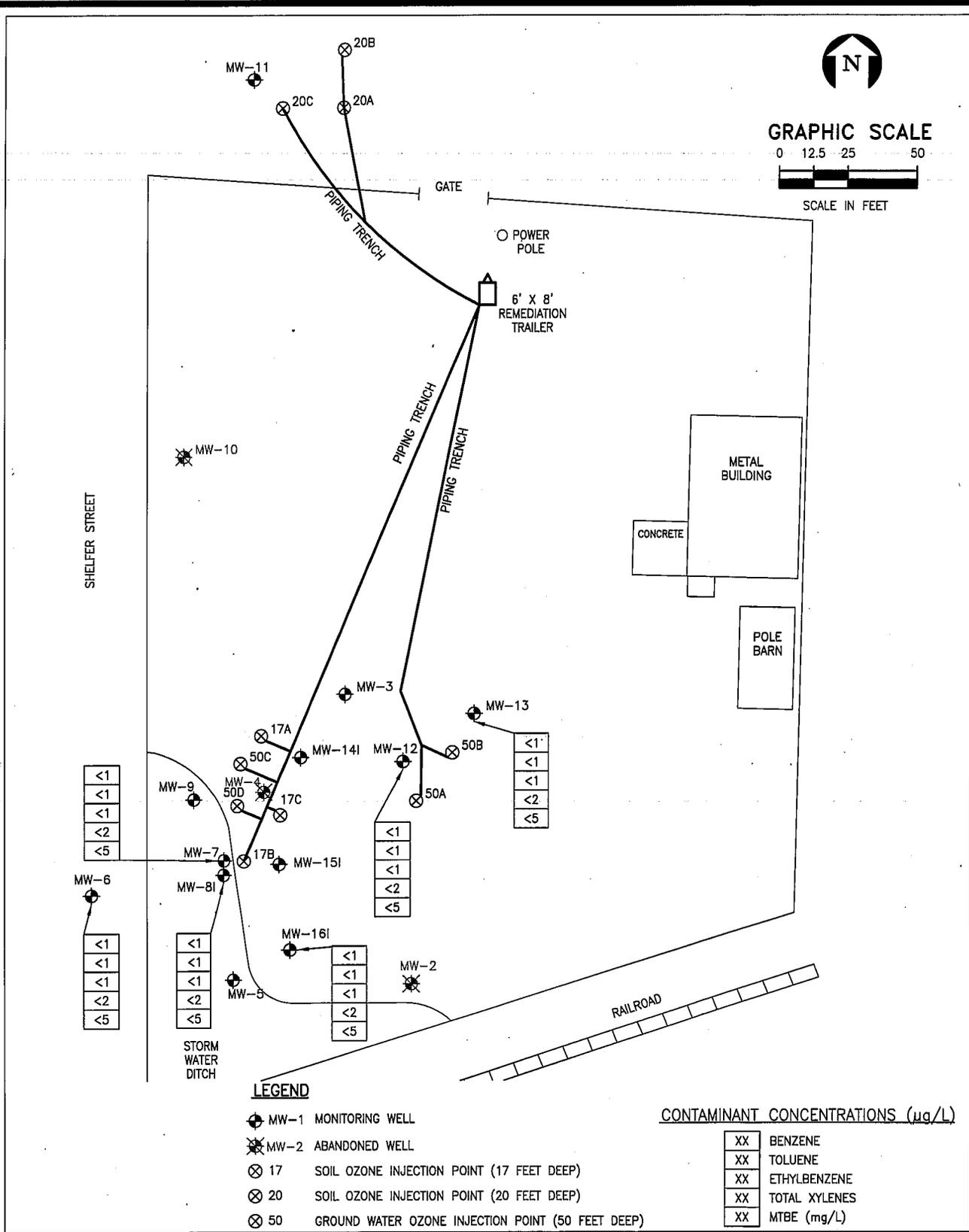


FIGURE 6.
POST-REMEDATION GROUND WATER CONDITIONS
STRICKLAND CONTRACTING COMPANY - QUINCY, FL.
 Source: ECT, 2007.



TABLES

**TABLE 1 - QUICK REFERENCE SUMMARY
OF GENERAL INFORMATION**

Dollar amount of the bid for this remediation work:		\$201,700.42
	GROUNDWATER	SOIL
Cleanup type: in situ, ex situ, combination.	in-situ	in-situ
Cleanup process: bioremediation, chemical oxidation, physical/mechanical, combination, other (indicate).	combination: chemical oxidation, bioremediation ozone injection	combination: chemical oxidation, bioremediation ozone injection
Process/product brand name	Blue Lightning Underground Enterprises (BLUE) RemedO ₃ zone™ System	Blue Lightning Underground Enterprises (BLUE) RemedO ₃ zone™ System
Major components, ingredients, or chemicals used, e.g. H ₂ O ₂ , catalyst, nutrients, bacteria, etc.	ozone	ozone
Contaminants of concern, e.g., BTEX, naphthalenes & other PAHs, TRPH, EDB, DCA, lead, etc.	BTEXM	BTEX, naphthalenes, TRPH
Cleanup time (months) to achieve groundwater criteria of Chapter 62-777, F.A.C., excluding 12 months post active remediation monitoring per 62-750, F.A.C.	10 months	10 months
Unconditional declaration of "No Further Action" for achievement of Chapter 62-777, F.A.C., cleanup goals? Yes or No.	Yes	Yes

TABLE 2: SOIL CLEANUP RESULTS

BEFORE, DURING, OR AFTER REMEDIATION	DATE	AREA WHERE BORING SAMPLED	BORING NO.	SAMPLE DEPTH (FEET)	DEPTH TO GROUNDWATER (FEET)	Benzene (ug/kg)	Toluene (ug/kg)	Ethyl Benzene (ug/kg)	Total Xylenes (ug/kg)	MTBE (ug/kg)	Naphthalene (ug/kg)	1-Methyl Naphthalene (ug/kg)	2-Methyl Naphthalene (ug/kg)	TRPH (mg/kg)
FDEP Soil Cleanup Target Levels (SCTLs)														
Before	1/17/2000	North Area	SB-C	15-17	40+	7	500	600	200	90	1,200	3,100	8,500	340
During	9/9/2005	North Area	SB-A	13-15	40+	2.34	BDL	142	67.9	BDL	BDL	1.5	2.1	5,200
	9/9/2005	North Area	SB-B	13-15	40+	<0.98	0.42 I	130	7.9	<0.27	1,100	4,200	9,100 D20	2,200
	9/9/2005	North Area	SB-C	15-17	40+	<0.88	0.67 IV	16	1.2 I	<0.24	270	1,300	1,900	500
	7/10/2006	North Area	SB-A	13-15	40+	<1.0	<0.23	21	39	<0.28	<69	<16	<190	950
	7/10/2006	North Area	SB-B	13-15	40+	4.6	27	15	36.7	<0.24	<27	<24	<27	160
	7/10/2006	North Area	SB-C	13-15	40+	2.4	12	23	20.8	<0.25	340	1,900	2,800	760
After	5/21/2007	North Area	SB-B	13-15	40+	1.3 I	8.5	5.3	13.1	<0.26	<28	<24	<28	35
						<1.0	<5.0	<1.0	<2.0	<5.0	<10	NA	12	306
Before	1/19/2000	South Area	SB-D	30	40+	1,340	37,000	9,860	42,200	BDL	3.9	3.7	5.9	1,450
During	9/9/2005	South Area	SB-D	15	40+	<1.0	0.3 I	<0.29	<0.94	<0.28	<70	<16	<190	5.0 I
	9/9/2005	South Area		30	40+	<62	1,600	3,600	16,000	<17	1,100	1,700	3,600	100
	9/9/2005	South Area		45	40+	<1.2	0.37 I	<0.34	1.1 I	<0.33	<76	<18	<210	7.5 I
	9/9/2005	South Area	SB-E	15	40+	<1.1	<0.24	<0.30	<0.95	<0.29	<71	<16	<200	6.2 I
	9/9/2005	South Area		30	40+	18	<0.29	<0.36	<1.1	<0.35	<82	<19	<230	7.7 I
	9/9/2005	South Area	SB-F	15	40+	<1.4	<0.31	<0.38	<1.2	<0.37	<78	<18	<220	4.3 I
	9/9/2005	South Area		45	40+	<1.0	<0.23	<0.29	<0.93	<0.28	<71	<16	<200	4.1 I
	9/9/2005	South Area		30	40+	<1.2	0.28 I	<0.34	<1.1	<0.33	<76	<18	<210	<3.7
	9/9/2005	South Area		45	40+	<1.4	<0.31	<0.39	<1.2	<0.37	<78	<18	<220	5.6 I
	7/10/2006	South Area	SB-D	15	40+	0.83	5.3	3.2	8.4	<4.2	<28	<24	<28	<3.4
	7/10/2006	South Area		30	40+	1.8 I	5.2 V	2.9 I	8.6 I	<0.3	<28	<25	<28	<3.4
	7/10/2006	South Area		45	40+	0.38 I	3.5 IV	1.9 I	6.0 V	<0.28	<31	<27	<31	4.1 I
	7/10/2006	South Area	SB-E	15	40+	<0.21	2.7 IV	1.6 I	4.9 V	<0.28	<28	<25	<28	<3.4
	7/10/2006	South Area		30	40+	<0.2	2.3 IV	1.2 I	4.0 V	<0.27	<28	<25	<28	<3.4
	7/10/2006	South Area		45	40+	<0.23	2.0 IV	1.0 I	3.9 V	<0.3	<31	<27	<31	<3.8
	7/10/2006	South Area	SB-F	15	40+	<0.26	2.0 IV	1.0 I	3.6 V	<0.34	<34	<30	<34	4.7
	7/10/2006	South Area		30	40+	<0.23	1.7 IV	0.78 I	3.0 V	<0.3	<30	<26	<30	<3.6
	7/10/2006	South Area		45	40+	<0.23	1.6 IV	0.73 I	2.7 V	<0.31	<32	<28	<32	<3.9

Notes:
 Values in Bold exceed state SCTLs.
 I = Result between MDL and PQL
 V = Present in blank
 D20 = Analyte result was reported from a 1:20 dilution
 TRPH for SB-B on 5/21/2007 is total of MAVPH/MADEP C5-C8 Aliphatics, MA-EPH/MADEP C9-C18 and C19-C36 Aliphatics, and C11-C22 Aromatics.

TABLE 3: SOIL SPLP ANALYTICAL SUMMARY

Facility Name: Strickland Contracting Company
 Facility ID: 208519720
 Not Analyzed = NA
 Analytical Results = µg/L unless otherwise stated
 SCTLs = Soil Cleanup Target Levels

Sample Location	Date	Sample Interval (ft)	Depth to Ground Water	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Total VOA	MTBE	Naphthalene	C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics
FDEP SCTLs													
				7	500	600	200	--	200	1,700			
MAVPH MADEP - Volatile Petroleum Hydrocarbons													
SB-B	5/2107	13-15	40+	<1	<5	<1	<2	<10	<5	<5	<26	<11	72
Compare Result to GW Standard for Leachate													
				1	40	30	20	--	20	14	--	--	--

Sample Location	Date	Sample Interval (ft)	Depth to Ground Water	Acenaphthene	Acenaphthylene	Anthracene	Benzo[a]anthracene	Benzo[a]pyrene	Benzo[b]fluoranthene	Benzo[g,h,i]perylene	Benzo[k]fluoranthene	Chrysene	Dibenz[a,h]anthracene
FDEP SCTLs													
				7	500	600	200	1,700	200	1,700			
MA-EPH MADEP - Extractable Petroleum Hydrocarbons - SPLP East													
SB-B	5/2107	13-15	40+	<10	<20	<10	<10	<10	<10	<10	<10	<10	<10
Compare Result to GW Standard for Leachate													
				20	210	2,100	0.05	0.2	0.05	210	0.5	4.8	0.005

Sample Location	Date	Sample Interval (ft)	Depth to Ground Water	Fluoranthene	Fluorene	Indeno[1,2,3-cd]pyrene	Naphthalene	Phenanthrene	Pyrene	2-Methyl Naphthalene	C9-C18 Aliphatics	C19-C36 Aliphatics	C11-C22 Aromatics
FDEP SCTLs													
MA-EPH MADEP - Extractable Petroleum Hydrocarbons - SPLP East (continued)													
SB-B	5/2107	13-15	40+	<10	<10	<10	<10	<10	<10	12	<50	<50	180
Compare Result to GW Standard for Leachate													
				280	280	0.05	14	210	210	28	--	--	--

Moisture Content = 16% by weight or 0.16
 Total Organic Carbon = 0.21% by weight or 0.0021 g/g
 Bulk density = between 112 and 117 lb/ft³ x 0.01602 = 1.86 g/cm³

Total calculated Leachability alternative for SCTLs for TRPH is 1,172 mg/kg

TABLE 4: GROUNDWATER CLEANUP RESULTS

BEFORE, DURING, OR AFTER REMEDIATION	DATE	WELL NO.	DEPTH TO GROUNDWATER (FEET)	Benzene (ug/L)	Toluene (ug/L)	Ethyl Benzene (ug/L)	Total Xylenes (ug/L)	MTBE (ug/L)	Naphthalene (ug/L)	1-Methyl Naphthalene (ug/L)	2-Methyl Naphthalene (ug/L)	TRPH (mg/L)
FDEP Groundwater Cleanup Target Levels (GWCTLs)												
				1	40	30	20	20	14	28	28	5
Before	7/1/2004	MW-6	45	2.9	<1.0	<1.0	<2.0	<1.0	NS	NS	NS	NS
During	6/2/2005		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
	9/12/2005		40	0.531	<0.13	0.341	<0.37	<0.35	0.025 I	<0.044	<0.077	0.22 I
	1/30/2006		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
After	6/2/2006		43	<0.14	<0.29	<0.10	<0.32	<0.51	<0.023	<0.044	<0.077	<0.15
Before	7/1/2004	MW-7	45	560	<1.0	50	110	<1.0	NS	NS	NS	NS
During	6/2/2005		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
	9/12/2005		40	300	4.5 I	28	78	4.8 I	0.26 I	0.19 I	<0.077	0.74
	1/30/2006		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
After	6/2/2006		43	<0.14	<0.29	<0.10	<0.32	<0.51	<0.023	<0.044	<0.077	<0.15
	6/1/2007		46	<0.40	<0.42	<0.36	<0.80	<0.92	<0.12	<0.61	<0.18	<0.052
Before	7/1/2004	MW-8i	45	<1.0	<1.0	<1.0	<2.0	<1.0	NS	NS	NS	NS
During	6/2/2005		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
	9/12/2005		40	<0.13	<0.13	<0.14	<0.37	<0.35	<0.023	<0.044	<0.077	0.16 I
	1/30/2006		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
After	6/2/2006		43	<0.14	<0.29	<0.10	<0.32	<0.51	<0.023	<0.044	<0.077	<0.15
	6/1/2007		46	<0.40	<0.42	<0.36	<0.80	<0.92	<0.12	<0.61	<0.18	<0.042
Before	7/1/2004	MW-12	46	<1.0	<1.0	<1.0	<2.0	<1.0	NS	NS	NS	NS
During	6/2/2005		43	<1.0	3.6	<1.0	4.3	<5.0	NS	NS	NS	NS
	9/12/2005		40	<0.13	<0.13	<0.14	<0.37	<0.35	<0.023	<0.044	<0.077	0.44 I
	1/30/2006		43	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
After	6/2/2006		44	<0.14	<0.29	<0.10	<0.32	<0.51	<0.023	<0.044	<0.077	<0.15
	6/1/2007		47	<0.40	<0.42	<0.36	<0.80	<0.92	<0.12	<0.61	<0.18	<0.040
Before	7/1/2004	MW-13	46	<1.0	<1.0	<1.0	<2.0	<1.0	NS	NS	NS	NS
During	6/2/2005		43	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
	9/12/2005		41	<0.13	<0.13	<0.14	<0.37	<0.35	<0.023	<0.044	<0.077	<0.15
	1/30/2006		43	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
After	6/2/2006		44	<0.14	<0.29	<0.10	<0.32	<0.51	<0.023	<0.044	<0.077	<0.15
Before	7/1/2004	MW-16i	45	<1.0	<1.0	<1.0	<2.0	<1.0	NS	NS	NS	NS
During	6/2/2005		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
	9/12/2005		40	<0.13	<0.13	<0.14	<0.37	<0.35	<0.023	<0.044	<0.077	<0.15
	1/30/2006		42	<1.0	<1.0	<1.0	<2.0	<5.0	NS	NS	NS	NS
After	6/2/2006		43	<0.14	<0.29	<0.10	<0.32	3.8 I	<0.023	<0.044	<0.077	<0.15

Notes: NS = not sampled
 Values in Bold exceed the GWCTLs.