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CORRECTIVE ACTION PLAN

at

DURHAM QUARRY
Denfield Street
Durham County
Durham, North Carolina
DEM Facility # 0-012984
Groundwater Incident # 9357

for

Teer Company
Post Office Box 13983
Research Triangle Park,
North Carolina 27709-3983

by

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Geonetics Project #10293

December 3, 1993

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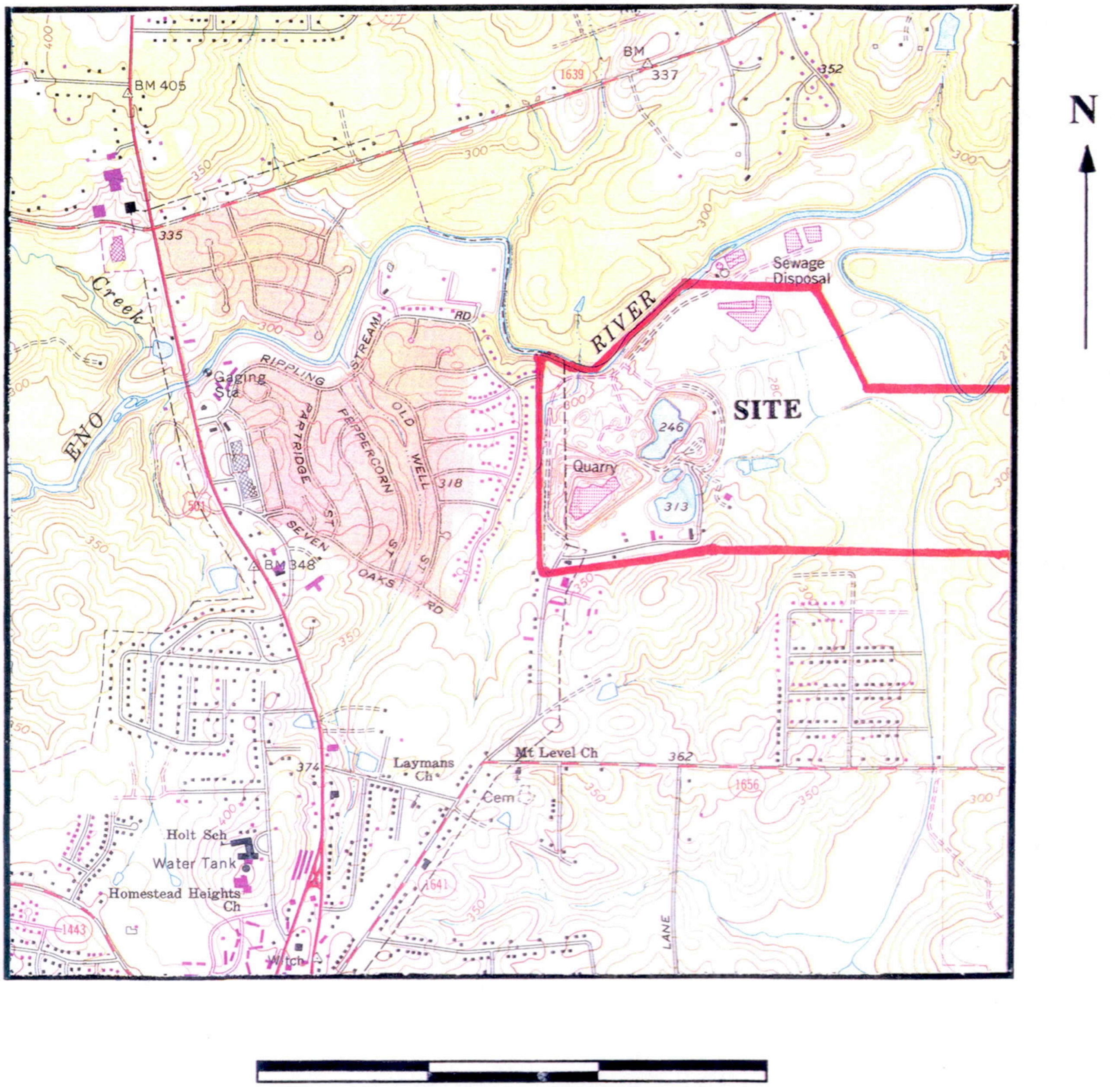
The CAP incorporates the DEM "March 1993, Groundwater Section Guidelines For The Investigation and Remediation of Soils and Groundwater" and addresses each item in the Corrective Action Plan, Section 15.3, in order.

2. Introduction

a. This Corrective Action Plan (CAP) presents a proposed plan for remediation of a petroleum contamination incident at a mining and processing site, the Durham Quarry, located at the end of Denfield Street (State Road 1641), north of Durham, in Durham County; Figures 1 and 2. Figure 1 is a portion of the U. S. Geological Survey 7 1/2 minute topographic map of the Northwest Durham Quadrangle, revised 1987. Figure 2 is the Site Map of the Durham Quarry property, drawn by Geonetics and presented in the Comprehensive Site Assessment (CSA). An unknown amount of fuel leaked into the soil and groundwater, from an area of one or more gasoline tanks, diesel tanks, and a used oil tank; and possibility the distribution lines and dispensers.

The property is presently owned and operated by the Teer Company. It has been in operation as a crushed stone quarry and processing plant since the 1940's, for use in highway and other construction materials. The North Carolina Department of Transportation originally owned and operated the site as a



Northwest Durham 7.5 min. Quad
USGS, 1987 (Revised)

Figure 1 - Location Map

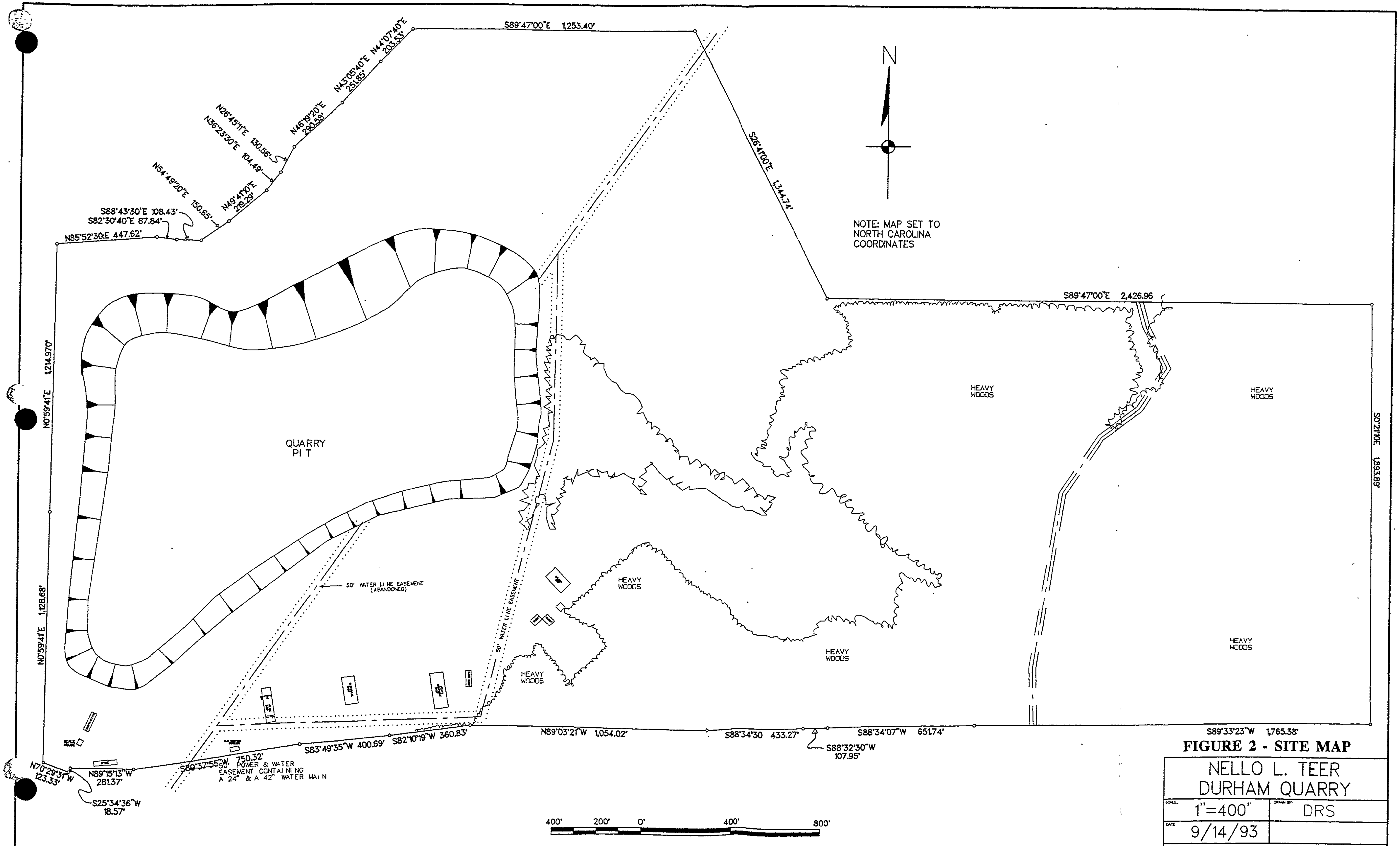


FIGURE 2 - SITE MAP

quarry and a asphalt batch plant. The property and these facilities were subsequently sold to Teer in 1951. The asphalt plant has since been relocated to another site. The North Carolina Division of Environmental Management (DEM) has assigned Groundwater Incident #9357, and the Site Facility #0-012984.

b. The purpose of this CAP, and the previously submitted CSA, is to comply with the requirements of a Notice of Violation dated January 25, 1993, to effect the remediation of both soil and groundwater at the Durham Quarry. Notification of Contamination in a site supply well (W-1) was forwarded to DEM's Raliegh Regional Office, on October 2, 1992.

The source of contamination had been from leaks in one or more of the four gasoline tanks and two diesel tanks, and possibly the piping or dispensers at a former service station on site. A used oil tank next to the truck shop had shallow soil contamination around it, due to spillage. The NOV cited violation of the current North Carolina Water Quality Standards (15A NCAC-2L .0202).

Laboratory results indicated that the highest soil contamination was TPH at 117 mg/kg (ppm) (EPA Method 5030); TPH at 2,800 mg/kg (EPA Method 3550); and TPH at 572 mg/kg (EPA Method 9071). These were located in the vicinity of the former service station and the truck shop at depths from 2 to 15 feet

BLS. Current DEM Guidelines prescribe reportable amounts of soil contamination to be those above: 10 ppm (Method 5030); 40 ppm (Method 3550); and 250 ppm (Method 9071).

The highest groundwater contamination was: benzene, 672 ug/L (ppb); and total VOA, 3,244 ug/L (ppb); in monitoring well 2 (MW-2) from a screened depth of 14 to 52 feet, BLS. One supply well (W-1) produced water containing benzene at 12 ug/L (ppb) and total VOA at 12 ug/L (ppb), from the most recent sampling (October 5, 1993). Current North Carolina Water Quality Standards (15A NCAC-2L .0202) estabilished a maximum allowable concentration of 0.001 mg/L (1 ug/L [ppb]) for benzene. The contaminant concentrations on this site have been decreasing steadily since first analyzed.

The groundwater contamination appears to have remained on the site. There is no migration toward the Eno River, north of the property. The Classification of the affected groundwater beneath the site is "GA".

c. In 1986, Teer Company registered as owner of the six active underground storage tanks (UST's) on the property. The four gasoline tanks and two diesel tanks at the former service station were emptied and removed in December 1988. They were: one 3,000 gallon gasoline, two 4,000 gallon gasoline, one 10,000 gallon gasoline, and two 10,000 gallon diesel tanks. No free product was encountered during this investigation.

The CSA lead to an estimate of the volume of contaminated soil at 91,852 cubic yards (137,778 tons). Contaminated groundwater volume was estimated to be 31,120,000 gallons (4.16 million cubic feet). The CSA showed that the concentrations of various contaminations are not very high; but, the volumes requiring treatment are considerable.

This site is eligible for the State Trust Fund reimbursement program. Following submittal of the CSA and this CAP, applications for reimbursement will be prepared for payment above the "deductable" requirement.

d. A Comprehensive Site Assessment for the Durham Quarry was submitted to the Raleigh Regional Office on October 29, 1993. It is still in the review process, and we have not heard of its approval status at this time. The extension granted by DEM for submittal of the CAP, allowed for a submittal date of December 3, 1993. To our knowledge, no other reports were required nor submitted for this site.

Soil and groundwater contamination maps and cross-sections indicating the areal and vertical extents of contamination, from the CSA, are included in the Appendix of this CAP. Water table contour maps and data tables are, likewise, contained therein. Water levels are shown on the cross-sections in the Appendix.

c. No permits or certificates of approval relating to the clean-up at this site have yet been submitted. A Soil Remediaion Permit and a Treated Groundwater Discharge Permit are now in progress, and will be submitted with or very shortly after this CAP. The NOV required that the CAP be submitted shortly after the CSA.

3. Objectives of the CAP

a. The remediation design for this site incorporates proven technology for the soil (modified in-situ bio remediation/vapor extraction) and groundwater (pump and treat with carbon polishing) remediation systems, and treated groundwater disposal. The CAP also includes aquifer pumping test results for estimating the size of the groundwater remediation system.

The goal of the proposed recovery and treatment system is to achieve hydrodynamic control of the dissolved hydrocarbon plume, and remove dissolved contaminants from the groundwater and soil to an acceptable level as opposed to complete removal. System design is based on results of the Comprehensive Site Assessment (CSA), which indicates approximately 31,120,000 gallons of groundwater and 91,852 cubic yards of soil are contaminated in excess of North Carolina environmental standards at this site. Figure 3 indicates the location and components of the proposed recovery system. Table 1 summarizes Corrective Action Plan (CAP) design parameters for this site.

b. Table 2 shows the Site Sensitivity Evaluation (SSE) prepared for the CSA. Table 2 indicates the target cleanup levels for soil to be the following: EPA Method 5030, 40 ppm; EPA Method 3550, 160 ppm; and EPA Method 9071, 550 ppm. Laboratory results indicate that the highest soil contamination is: TPH at 117 mg/kg (ppm) (EPA Method 5030); TPH at 2,800 mg/kg (ppm) (EPA Method 3550); and TPH at 572 mg/kg (ppm) (EPA Method 9071).

The target levels for groundwater cleanup are located in Subchapter 2L - Groundwater Classification and Standards, 15A NCAC 2L .0202 (g). These target levels will dictate the duration of the groundwater remediation or until it is determined by DEM and Teer that further reduction of the contaminant levels is not practical or economically feasible. The highest level of groundwater contamination is: benzene, 672 ug/L (ppb); total VOA, 3,244 ug/L (ppb). Current North Carolina Water Quality Standards 15A NCAC 2L .0202 [g] has established a maximum allowable concentration of 0.001 mg/L (1 ug/L [ppb]) for benzene.

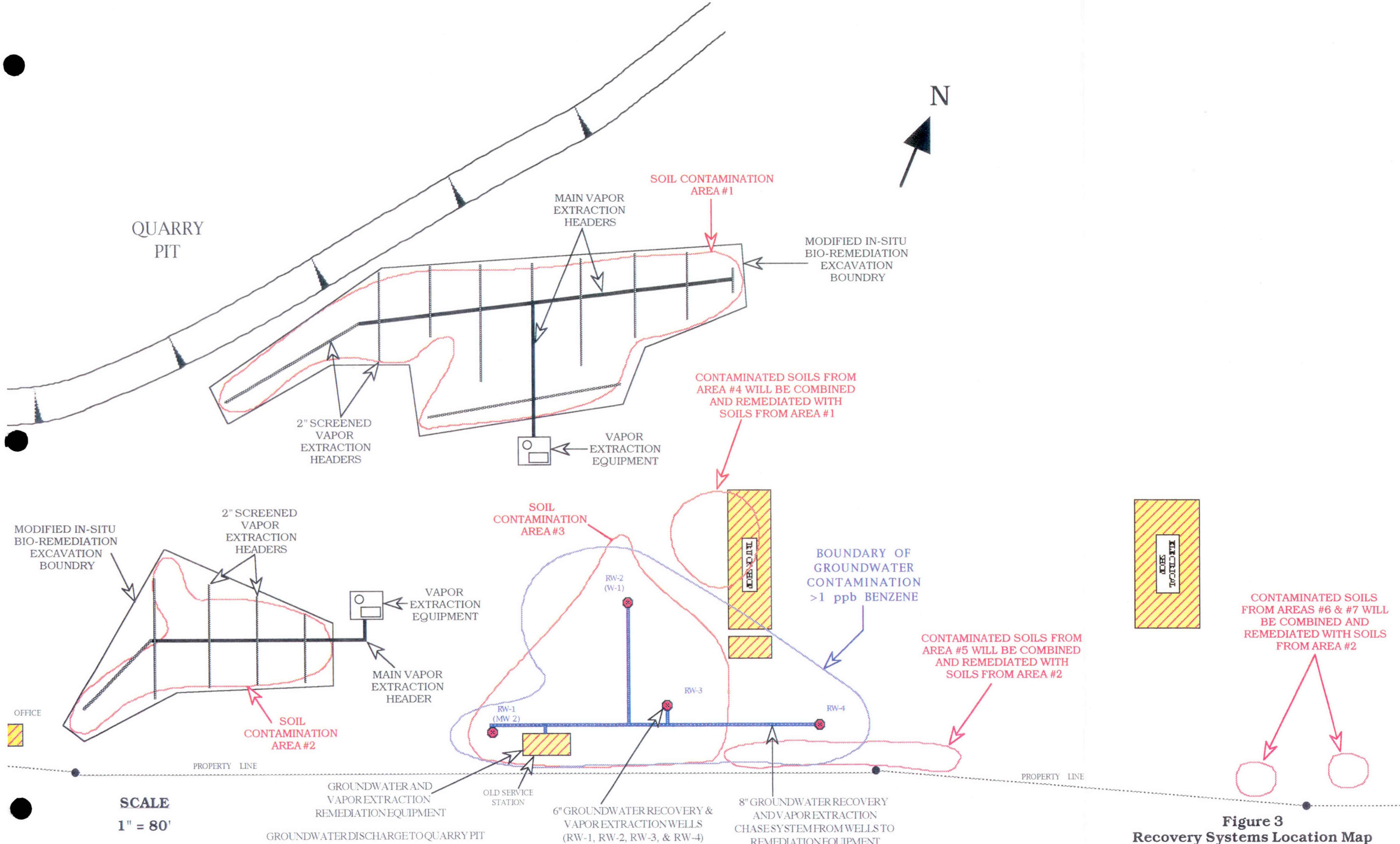


Figure 3
Recovery Systems Location Map
Teer Company - Durham Quarry
Geonetics Project #10293

TABLE 1 - CORRECTIVE ACTION PLAN DESIGN PARAMETERS
SITE: Teer Company - Durham Quarry
GEONETICS CORP. PROJECT: #10293

1) RECOVERY WELL - FOUR (4) - 6" DIAMETER
2) ESTIMATED TOTAL WELL YIELD - 20-30 GPM
3) AVERAGE WATER LEVEL - 15-25 FEET BELOW LAND SURFACE
4) CONTAMINATED AQUIFER HYDRAULIC CONDUCTIVITY - 0.38 FEET PER DAY
5) CONTAMINATED AQUIFER THICKNESS - 200 FEET
6) CONTAMINATED AQUIFER CLASSIFICATION - GA
7) CONTAMINATED AQUIFER COMPOSITION - CLAYS/SAND/ROCK
8) CONTAMINATED AQUIFER TRANSMISSIVITY - 75 SQUARE FEET PER DAY
9) CONTAMINATED AQUIFER STORAGE (SPECIFIC YIELD) - 17.5 (DIM)
10) CONTAMINATED AQUIFER POROSITY - 0.40 CUBIC FEET PER CUBIC FOOT
11) WORST CASE GROUNDWATER SYSTEM INFLUENT CONCENTRATIONS (PPB) -
    ug/L BENZENE = 353 WORST CASE FROM MW-2 5/20/93
    ug/L TOLUENE = 418
    ug/L ETHYL-BENZENE = ND
    ug/L XYLENES = 106
    ug/L TOTAL VOA = 877
    ug/L MTBE = ND
12) ESTIMATED VOLUME OF CONTAMINATED GROUNDWATER - 31,120,000 GALLONS
13) EFFLUENT DISPOSAL - ON SITE PIT DISPOSAL
14) FREE PRODUCT REMOVAL - NOT APPLICABLE
15) SOILS REMEDIATION - VAPOR EXTRACTION AND BIO-REMEDIATION
16) ESTIMATED VOLUME OF CONTAMINATED SOIL - 91,852 CUBIC YARDS
17) ESTIMATED RECOVERY WELL RADIUS OF INFLUENCE - 375 FEET
18) ESTIMATED TIME TO CLEAN UP - 4.3 YEARS

Table 2 Site Sensitivity Evaluation (SSE)

Initial Cleanup Level (Step 2) — Final Cleanup Level (Step 3)

EPA Method 5030 for Low Boiling Point Hydrocarbons such as Gasoline, Aviation Fuels, and Gasohol

Total Site Characteristics Score	**Initial** Cleanup Level TPFH (ppm)
>150	≤10
121-150	20
91-120	40
61-90	60
31-60	80
0-30	100

Select Site Category*

Category	**Final** Cleanup Level
Category A & B (Multiply initial cleanup level by 1)	1 X 40 = 40 ppm
Category C & D (Multiply initial cleanup level by 2)	2 X ____ = ______ ppm
Category E (Multiply initial cleanup level by 3)	3 X ____ = ______ ppm

EPA Method 3550 for High Boiling Point Hydrocarbons such as Kerosene, Diesel, Varsol, Mineral Spirits, Naphtha

Total Site Characteristics Score	**Initial** Cleanup Level TPFH (ppm)
>150	≤40
121-150	80
91-120	160
61-90	240
31-60	320
0-30	400

Select Site Category*

Category	**Final** Cleanup Level
Category A & B (Multiply initial cleanup level by 1)	1 X 160 = 160 ppm
Category C & D (Multiply initial cleanup level by 2)	2 X ____ = ______ ppm
Category E (Multiply initial cleanup level by 3)	3 X ____ = ______ ppm

EPA Method 9071 for Heavy Fuels - Oil & Grease (O&G) such as Fuel Oil #4, #5, #6, Motor Oil, Hydraulic Fluid

Total Site Characteristics Score	**Initial** Cleanup Level TPFH (ppm)
>150	≤250
121-150	400
91-120	550
61-90	700
31-60	850
0-30	1000

Select Site Category*

Category	**Final** Cleanup Level
Category A & B (Multiply initial cleanup level by 1)	1 X 550 = 550 ppm
Category C & D (Multiply initial cleanup level by 2)	2 X ____ = ______ ppm
Category E (Multiply initial cleanup level by 3)	3 X ____ = ______ ppm

* See Site Category Descriptions, Table 3
NCDEM Guidelines 3/10/93

c. Construction of the CA is ongoing and startup of the remediation project will proceed upon approval of the CAP and in conjunction with the necessary permits. The active source(s) of the contamination have been removed and there is no threat from free product. It is currently projected that the soils will be remediated by year end 1998 and that the groundwater, depending on recharge, could be remediated about the same time. Table 3 shows the estimated time to clean the groundwater based on the indicated parameters. Table 4 shows the expected target dates for this project.

4. Exposure Assessment

a. Soil analytical results are summarized in Table 5 and groundwater analytical results are summarized in Table 6. Violations of groundwater standards and soil clean-up levels are indicated on the previous tables.

b. The soil contamination consists of gasoline, diesel, and used oil petroleum products. The physical areas are located on Figure 4.

The contaminated groundwater consists of gasoline and diesel petroleum products. The physical area of groundwater contamination is indicated on Figure 5.

TABLE 3 - DETERMINATION; ESTIMATED TIME NEEDED TO CLEAN SITE
SITE: Teer Company - Durham Quarry
GEONETICS PROJECT: #10293

ESTIMATED SYSTEM INFLUENT - BENZENE	12.00	PPB
PUMPING RATE	30.00	GPM
VOLUME OF CONTAMINATED GW (GAL)	31,120,000.00	GALLONS
AQUIFER POROSITY	0.40	CU. FEET/CU. FOOT
SPECIFIC YIELD	0.175	CU. FEET/CU. FOOT
DILITION & SURFACE INFILTRATION	100.00%	PERCENT
GALLONS PER CUBIC FOOT	7.48	GALLONS
RECIRCULATION FROM OUTSIDE AREA	30.00	GPM
MINUTES PER DAY	1,440.00	MINUTES
CUBIC FEET OF CONTAMINATED GW	4,160,427.81	CUBIC FEET
TOTAL VOLUME OF CONTAMINATION	10,401,069.52	CUBIC FEET
SPECIFIC YIELD	1,820,187.17	CUBIC FEET
SPECIFIC YIELD IN GALLONS	13,615,000.00	GALLONS
DAYS TO PUMP THE SPECIFIC YIELD	315.16	DAYS

CONTINIOUS PUMPING WOULD DILUTE RETAINED CONTAMINATED GROUNDWATER BY A FACTOR OF:	**0.5625**	
1ST REDUCTION	6.75	
2	3.80	
3	2.14	
4	1.20	
5	0.68	**BELOW 1 PPB**
6	0.38	
7	0.21	
8	0.12	
9	0.07	
10	0.04	
11	0.02	
12	0.01	
13	0.01	
14	0.00	
15	0.00	
16	0.00	
17	0.00	
18	0.00	
19	0.00	
20	0.00	
TIME TO CLEAN-UP IN YEARS = # OF CYCLES X DAYS/CYCLE ÷ 365 =		4.32

TABLE 4 - ESTIMATED STARTUP AND COMPLETION DATES OF THE CA
SITE: Teer Company - Durham Quarry
GEONETICS PROJECT: #10293

AREA(S) OF CONCERN	ESTIMATED STARTUP DATE	ESTIMATED COMPLETION DATE
SUBMITTAL OF PILOT TEST DATA	N/A	N/A
SUBMITTAL OF NECESSARY PERMIT APPLICATIONS	1/15/94	2/15/94
COMMENCEMENT OF REMEDIAL ACTIONS	ON GOING	N/A
STAGED SYSTEMS INSTALLATION - SOIL	1/30/94	1/30/96
SYSTEM INSTALLATION - GROUNDWATER	2/30/94	3/30/94
SYSTEM ACTIVATION - SOILS	3/30/94	N/A
SYSTEM ACTIVATION - GROUNDWATER	3/30/94	N/A
SYSTEM SHUT-DOWN - SOILS	12/31/98	N/A
SYSTEM SHUT-DOWN - GROUNDWATER	12/31/98	N/A
TIME FRAME TO ACHIEVE SOIL CLEANUP GOALS	4 YEARS	N/A
TIME FRAME TO ACHIEVE GW CLEANUP GOALS	4 YEARS	N/A
PROJECT COMPLETION DATE	12/31/98	N/A

TABLE 5 - SUMMARY OF SOIL LABORATORY ANAYLSES
SITE: Teer Company - Durham Quarry
GEONETICS PROJECT: # 10293

PARAMETERS >			**8021**	**8015**	**8015**
(EPA METHOD) >			**(5030)**	**(3550)**	**(3550)**
(UNITS) >			**(ppm)**	**(ppm)**	**(ppm)**
BORING #	**DEPTH (ft.)**	**SAMPLE DATE**	**TPH**	**Kerosene Group**	**Gasoline Group**
TP-2	COMP	6/15/93	7.579	**52**	< 2
TP-3	COMP	6/15/93	0.577	< 2	< 2
TP-4	COMP	6/15/93	0.526	< 2	< 2
TP-5	COMP	6/15/93	0.849	< 2	< 2
TP-6	COMP	6/17/93	0.605	< 2	< 2
TP-7	COMP	6/17/93	0.058	< 2	< 2
TP-8	COMP	6/17/93	0.503	< 2	< 2
TP-9	COMP	6/17/93	0.742	**2000**	< 20
TP-10	COMP	6/17/93	1.603	< 2	< 2
TP-11	COMP	6/17/93	1.278	< 2	< 2
D-1	COMP	6/15/93	**24.21**	**820**	< 5
D-2	COMP	6/15/93	1.378	**22**	< 2
D-3	COMP	6/15/93	0.401	**340**	< 5
D-4	COMP	6/15/93	**116.8**	**2800**	< 25
D-5	COMP	6/15/93	0.412	< 2	< 2
D-6	COMP	6/15/93	< 0.275	< 2	< 2
D-7	COMP	6/15/93	1.055	< 2	< 2
D-8	COMP	6/15/93	0.571	< 2	< 2

Table 5 - SUMMARY OF SOIL LABORATORY ANAYLSES - CONTINUED

PARAMETERS > (EPA METHOD) > (UNITS) > BORING #	DEPTH (ft.)	SAMPLE DATE	8021 (5030) (ppm) TPH	8015 (3550) (ppm) Kerosene Group	8015 (3550) (ppm) Gasoline Group	(9071) (mg/kg) TPH
D-9	COMP	6/15/93	< 0.275	< 2	< 2	N/A
D-10	COMP	6/15/93	0.455	< 2	< 2	N/A
D-11	COMP	6/15/93	**10.717**	< 2	< 2	N/A
D-12	COMP	6/16/93	0.468	< 2	< 2	N/A
D-13	COMP	6/16/93	0.624	< 2	< 2	N/A
D-14	COMP	6/16/93	0.434	< 2	< 2	N/A
SB-1	2 to 4	7/19/93	0.903	< 2	< 2	N/A
SB-1	5 to 7	7/19/93	0.793	< 2	< 2	N/A
SB-1	10 to 12	7/19/93	0.479	< 2	< 2	N/A
SB-1	15 to 17	7/19/93	0.452	< 2	< 2	N/A
SB-1	20 to 22	7/19/93	0.479	< 2	< 2	N/A
SB-2	2 to 4	7/20/93	0.439	< 2	< 2	N/A
SB-2	5 to 7	7/20/93	0.419	< 2	< 2	N/A
SB-2	10 to 12	7/20/93	0.585	< 2	< 2	N/A
SB-2	15 to 17	7/20/93	0.446	< 2	< 2	N/A
SB-2	20 to 22	7/20/93	**63**	**31**	< 2	N/A
SB-3	2 to 4	8/4/93	< 0.275	< 2	< 2	**225**
SB-3	5 to 7	8/4/93	< 0.275	< 2	< 2	**105**
SB-3	10 to 12	8/4/93	<0.275	< 2	< 2	**132**

Table 5 - SUMMARY OF SOIL LABORATORY ANAYLSES - CONTINUED

PARAMETERS > (EPA METHOD) > (UNITS) > BORING #	DEPTH (ft.)	SAMPLE DATE	8021 (5030) (ppm) TPH	8015 (3550) (ppm) Kerosene Group	8015 (3550) (ppm) Gasoline Group	(9017) (mg/kg) TPH
SB-3	15 to 17	8/4/93	0.369	< 2	< 2	**90.3**
SB-3	20 to 22	8/4/93	0.304	< 2	< 2	**167**
SB-4	2 to 4	8/4/93	< 0.275	< 2	< 2	N/A
SB-4	5 to 7	8/4/93	0.279	< 2	< 2	N/A
SB-5	2 to 4	8/4/93	< 0.275	< 2	< 2	N/A
SB-5	5 to 7	8/4/93	< 0.275	< 2	< 2	N/A
SB-5	10 to 12	8/4/93	< 0.275	< 2	< 2	N/A
SB-5	15 to 17	8/4/93	0.323	< 2	< 2	N/A
MW-9 LOC. *	2 to 4	7/2/93	2.45	< 2	< 2	N/A
MW-9 LOC. *	5 to 7	7/2/93	9.581	**200**	< 2	N/A
MW-9 LOC. *	10 to 12	7/2/93	19.78	**775**	< 2	N/A
MW-9 LOC. *	15 to 17	7/2/93	0.888	< 2	< 2	N/A
MW-9 LOC. *	20 to 22	7/2/93	0.54	< 2	< 2	N/A
MW-9 LOC. *	25 to 27	7/2/93	1.407	< 2	< 2	N/A

NOTES:
ppm = parts per million
TP = Test Pit
D = Ditch Area Located on the South end of Property
SB = Soil Boring
* = Soil Removed During MW-9 Installation
mg/kg = milligrams per kilograms

TABLE 5 - SUMMARY OF SOIL LABORATORY ANALYSES - CONTINUED

SUMMARY OF SOIL LABORATORY ANALYSES FOR THE WASTE OIL AREA

PARAMETERS > (EPA METHOD) > (UNITS) > BORING #	DEPTH (ft.)	SAMPLE DATE	8021 (601) (ug/kg)	8021 (602) (ug/kg) TOTAL VOA	9071 (mg/L) TPH	TCLP 1311 (mg/L) As	TCLP 1311 (mg/L) Ba	TCLP 1311 (mg/L) Cd	TCLP 1311 (mg/L) Cr	TCLP 1311 (mg/L) Pb	TCLP 1311 (mg/L) Hg	TCLP 1311 (mg/L) Se	TCLP 1311 (mg/L) Ag
B-85	5	5/25/93	ND	**53.6**	**572**	ND	ND	ND	ND	ND	ND	ND	ND
B-86	10	5/25/93	ND	**82.7**	**113**	ND	1.59	ND	ND	ND	ND	ND	ND
B-86	15	5/25/93	ND	**76.6**	**172**	ND	3.04	ND	ND	ND	ND	ND	ND
B-86	20	5/25/93	ND	**92.7**	**54.5**	ND	1.22	ND	ND	ND	ND	ND	ND
Near B-86	2.5	5/25/93	ND	**73.8**	**122**	ND	1.76	ND	ND	ND	ND	ND	ND
B-87	5	5/25/93	ND	**71.8**	**183**	ND	ND	ND	ND	ND	ND	ND	ND
B-87	7	5/25/93	ND	**116.6**	**128**	ND	ND	ND	ND	ND	ND	ND	ND
TP-1	2.5	5/25/93	ND	**97.3**	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = NOT DETECTED
ug/kg = micrograms per kilograms
mg/L = milligrams per Liter
Southern Testing & Research Laboratories, Inc., Wilson, N.C.

TABLE 6 - SUMMARY OF GROUNDWATER ANALYSES
SITE: Teer Company - Durham Quarry
GEONETICS PROJECT: #10293

	PARAMETERS>	BENZENES	TOTAL VOA	MTBE	EDB	IPE	TOTAL PAH	LEAD	
	(EPA METHOD)>	(602)	(602)	(602)	(601)	(601)	(625)	(239.2)	
	(UNITS)>	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	LAB
MONITORING WELL #	**SAMPLE DATE**								
W-1	5/7/93	**16**	**22.4**	N/A	N/A	N/A	N/A	N/A	So.Testing
	5/7/93	**35.8**	**51.2**	**51.6**	N/A	N/A	N/A	N/A	PhosLab
	5/20/93	**34.4**	**53.4**	**11.8**	BDL	N/A	<MCL	<1.0	PhosLab
	5/20/93	**11.3**	**22.7**	BDL	BDL	BDL	N/A	BDL	Patterson
	5/20/93	Results suspect. To be re-sampled and re-analyzed							
W-2	5/18/93	ND	ND	ND	ND	ND	ND	<.05	So.Testing
W-3	5/19/93	ND	0.9	ND	ND	ND	ND	<.05	So.Testing
W-4	5/18/93	ND	ND	ND	ND	ND	ND	<.05	So.Testing
W-5	5/20/93	ND	0.7	ND	ND	ND	ND	<.02	So. Testing
	5/20/93	BDL	BDL	BDL	<1.0	N/A	<MCL	<1.0	PhosLab
	5/20/93	BDL	BDL	BDL	BDL	BDL	N/A	BDL	Patterson
MW-1	5/20/93	BDL	BDL	BDL	BDL	N/A	<MCL	<1.0	PhosLab
	5/20/93	BDL	BDL	BDL	BDL	BDL	N/A	BDL	Patterson
	5/20/93	ND	0.7	ND	ND	ND	ND	0.027	So.Testing
MW-2	5/7/93	**575**	**3244**	N/A	N/A	N/A	N/A	N/A	So.Testing
	5/7/93	**672**	**3110**	**23**	N/A	N/A	N/A	N/A	PhosLab
	5/20/93	**541**	**2006**	**105**	BDL	N/A	<MCL	<1.0	PhosLab
	5/20/93	**252**	**571**	BDL	BDL	BDL	N/A	BDL	Patterson
	5/20/93	**353**	**877**	ND	ND	ND	ND	<.02	So.Testing
MW-3	5/21/93	ND	ND	ND	ND	ND	ND	0.056	So.Testing
MW-4	5/18/93	ND	0.7	ND	ND	ND	ND	<.05	So.Testing

TABLE 6 - SUMMARY OF GROUNDWATER ANALYSES - CONTINUED

PARAMETERS> (EPA METHOD)> (UNITS)> MONITORING WELL #	SAMPLE DATE	BENZENES (602) (ug/L)	TOTAL VOA (602) (ug/L)	MTBE (602) (ug/L)	EDB (601) (ug/L)	IPE (601) (ug/L)	TOTAL PAH (625) (ug/L)	LEAD (239.2) (ug/L)	LAB
MW-5	5/7/93	ND	ND	N/A	N/A	N/A	N/A	N/A	So.Testing
	5/7/93	BDL	BDL	BDL	N/A	N/A	N/A	N/A	PhosLab
	5/20/93	BDL	BDL	BDL	BDL	N/A	<MCL	<1.0	PhosLab
	5/20/93	1.5	**12.4**	BDL	BDL	BDL	N/A	BDL	Patterson
	5/20/93	ND	ND	ND	ND	ND	ND	0.069	So.Testing
MW-6	5/21/93	ND	ND	ND	ND	ND	ND	0.03	So.Testing
MW-7	5/21/93	ND	ND	ND	ND	ND	ND	<.02	So.Testing
MW-8	5/19/93	ND	ND	ND	ND	ND	ND	<.05	So.Testing
MW-9	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-11	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-12S	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-13	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-14S	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-14D	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-15S	9/9/93	**10.7**	**95.9**	**8.3**	ND	ND	**13**	<0.05	So.Testing
MW-15D	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-16S	9/9/93	ND	ND	ND	ND	ND	N/A	N/A	So.Testing
MW-16D	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-17S	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-17D	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-18S	9/9/93	ND	1.3	ND	ND	ND	ND	<0.05	So.Testing

TABLE 6 - SUMMARY OF GROUNDWATER ANALYSES - CONTINUED

PARAMETERS>		BENZENES	TOTAL VOA	MTBE	EDB	IPE	TOTAL PAH	LEAD	
(EPA METHOD)>		(602)	(602)	(602)	(601)	(601)	(625)	(239.2)	
(UNITS)>		(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	LAB
MONITORING WELL #	SAMPLE DATE								
MW-19	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing
MW-20A	9/9/93	ND	1.8	**7.3**	ND	ND	ND	<0.05	So.Testing
MW-21A	9/9/93	ND	ND	ND	ND	ND	ND	<0.05	So.Testing

NOTES:
ND = NOT DETECTED
BDL = BELOW DETECTION LIMITS
ug/L = micrograms per Liter (ppb)
<MCL = LESS THAN MAXIMUM CONTAMINATION LEVELS
PhosLab, Inc. , LAKELAND, FL.
Southern Testing & Research Laboratories, Inc., WILSON, N.C.
Patterson Exploration Services, Inc., SANFORD, N.C.

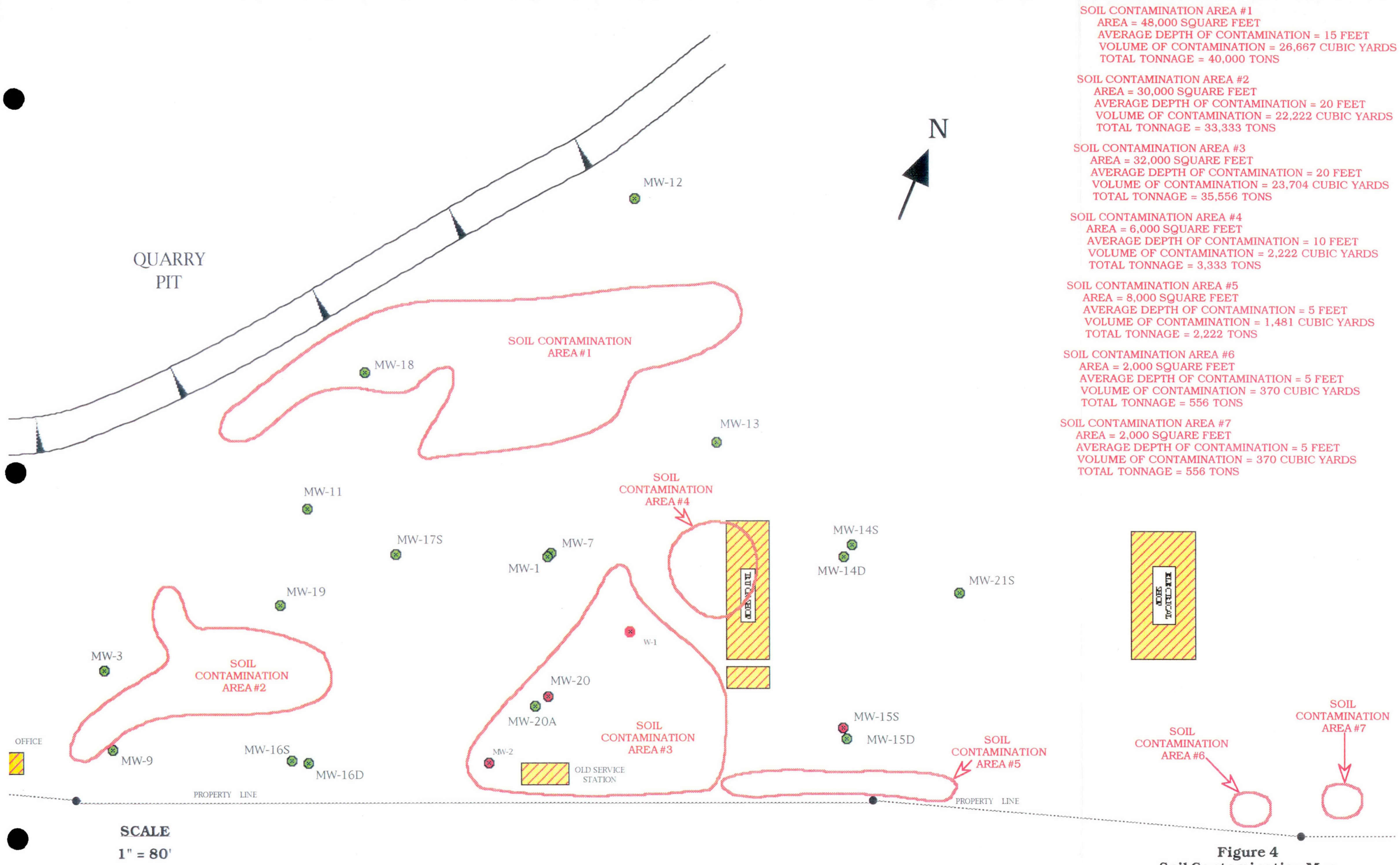


Figure 4
Soil Contamination Map
Teer Company - Durham Quarry
Geonetics Project #10293

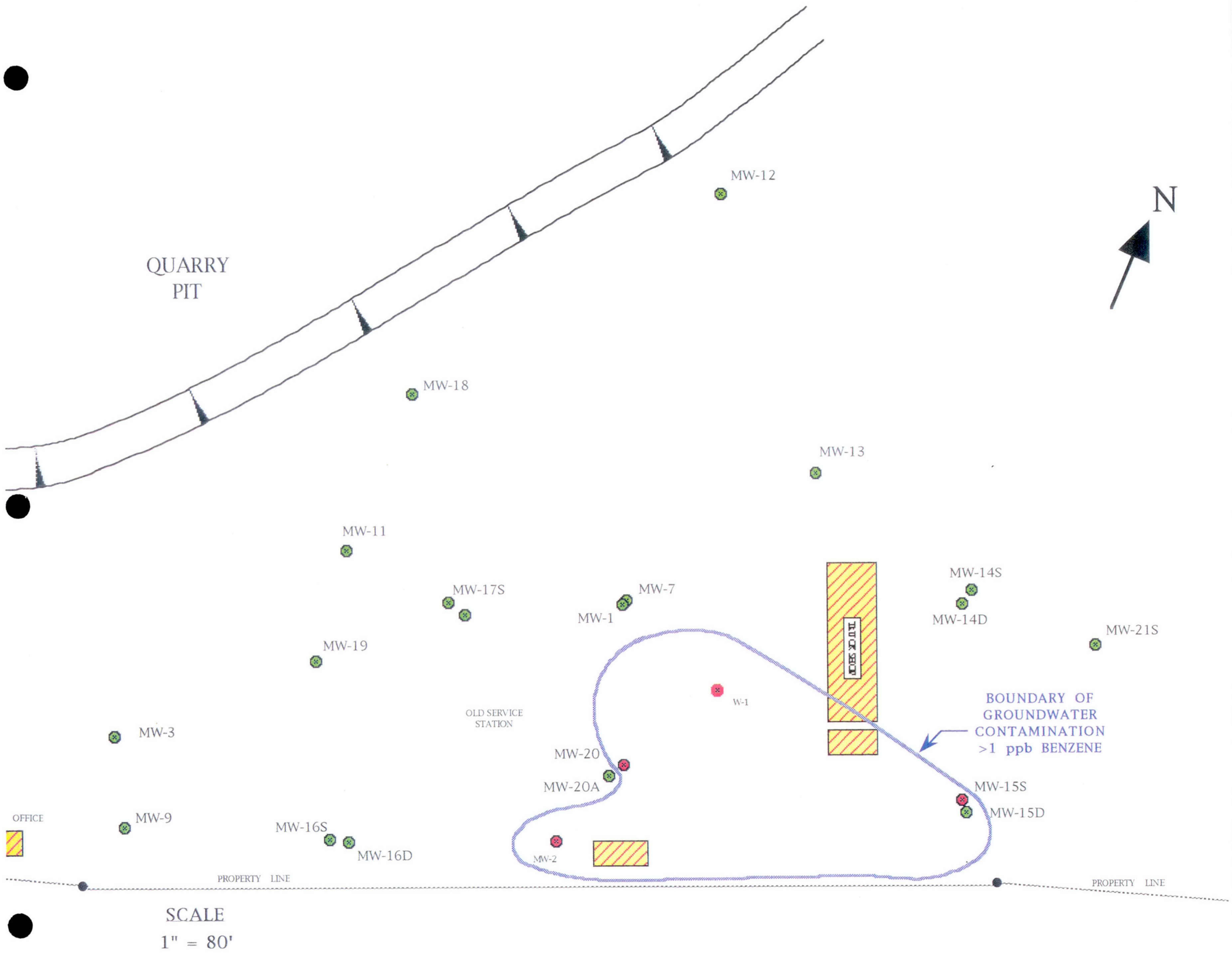


Figure 5
Groundwater Contamination Location Map

Teer Company - Durham Quarry

Geonetics Project #10293

c. The soil and groundwater contamination found at this site have limited pathways for human exposure. Both the soil and groundwater contamination are located on Teer Company property. The area is a quarry and access is limited to the employees of the Teer Company. Bottled water is provided for the employees for all aspects of consumption.

d. It is expected that after remediation of both the contaminated soil and groundwater that the residual levels of both will be low enough that there should be no effect on surface waters or groundwater in the area.

Remediated soils will remain on site and remediated groundwater will be either re-introduced in to the surficial/perched aquifer, through an infiltration gallery or discharged into the quarry pit waters via an NPDES permit.

e. Fifteen potential receptor wells, including the five supply wells on site, were found within a 1,500-foot radius of the former service station. A list of the well owners is provided below:

OWNER/RESIDENT	ADDRESS
Aron	4807 Denfield Street
Church of God	Denfield Street
Albert Lee Deer	4911 Denfield Street
Wright	4907 Denfield Street
W.T. Proctor, Inc.	4918 Denfield Street
Walters	4921 Denfield Street
Lee's Welding	1002 Communication Dr.
JoannHarris - Mobile Comm.	1003 Communication Dr.
D.W. Ward Construction Co.	Denfield Street
Mayo Farms Trucking Co.	4934 Denfield Street
Teer Company, 5 supply wells	Durham Quarry

* None of those wells located off of the Teer Property are known to be threatened from the Teer Property.

5. Evaluation of Remedial Alternatives

The majority of the contaminated soils are going to be remediated on-site in a modified in-situ bioremediation/vapor extraction process. This approach was taken due to the possible large amount of soils to be treated, about 91,000 cubic yards.

a. In evaluating soil remediation technologies it was determined that:

The cost to dig, haul, and treat the soils at a brick manufacturing facility is about $25.00 per ton. The total cost for the amount of soil at this site would be approximately $3,000,000.

The majority of the contaminated soils contain too much clay and silt to facilitate their timely cleanup using vapor extraction technology as the sole method of remediation.

To land apply the soils using Method 1 would require more than 640 acres. To land apply the soils using Method 2 would require approximately 160 acres. The Teer Company does not have enough land to apply the soils on their property and the cost to dig, haul, and spread this much soil over the necessary acreage would be prohibitive. The additional acreage would have to be leased or purchased.

Bio-remediating the soils in a wind-row type of process would require about 45,000 feet (8.5 miles) of linear distance containing wind-rows 15 feet wide at the base, by 6 feet tall with a 45° angle of repose. Again, the limitation of acreage and the cost to handle this much soil is the determinant factor.

Groundwater remediation options are limited at this site due to the volume of water to be treated (approximately 31,120,000 gallons) and to the low transmissivity of the aquifer (approximately 500 gpd/ft.). Pump and treat systems using stripping towers were eliminated due to problems of bio-fouling and freeze protection, and the costs for maintenance is higher than the proposed air sparging system. Bio-remediation in conjunction with an air sparging system might become viable after the recovery wells are installed and the proposed air sparging system is in operation. Bio-enhancing the groundwater system will be investigated on a cost-versus-time basis.

Treated effluent from the groundwater system will be discharged into the quarry pit using a NPDES permit and a backup system using an infiltration gallery will be proposed. Injection wells are also a possibility should bio-remediation be cost effective at a later date.

b. Contaminated soils located in areas 1,2,4,5,6,&7 (Figure 4) at the Durham Quarry will be remediated using a modified in-situ/vapor extraction system. The soils located in area 3 (Figure 4) will be vapor extracted at the same time that groundwater remediation is taking place.

The groundwater will be remediated using an air sparger followed with a carbon polishing system. This will ensure that the system will have a high operational time factor and that the discharge water will meet NPDES permit standards.

6. Proposed Corrective Action Plan

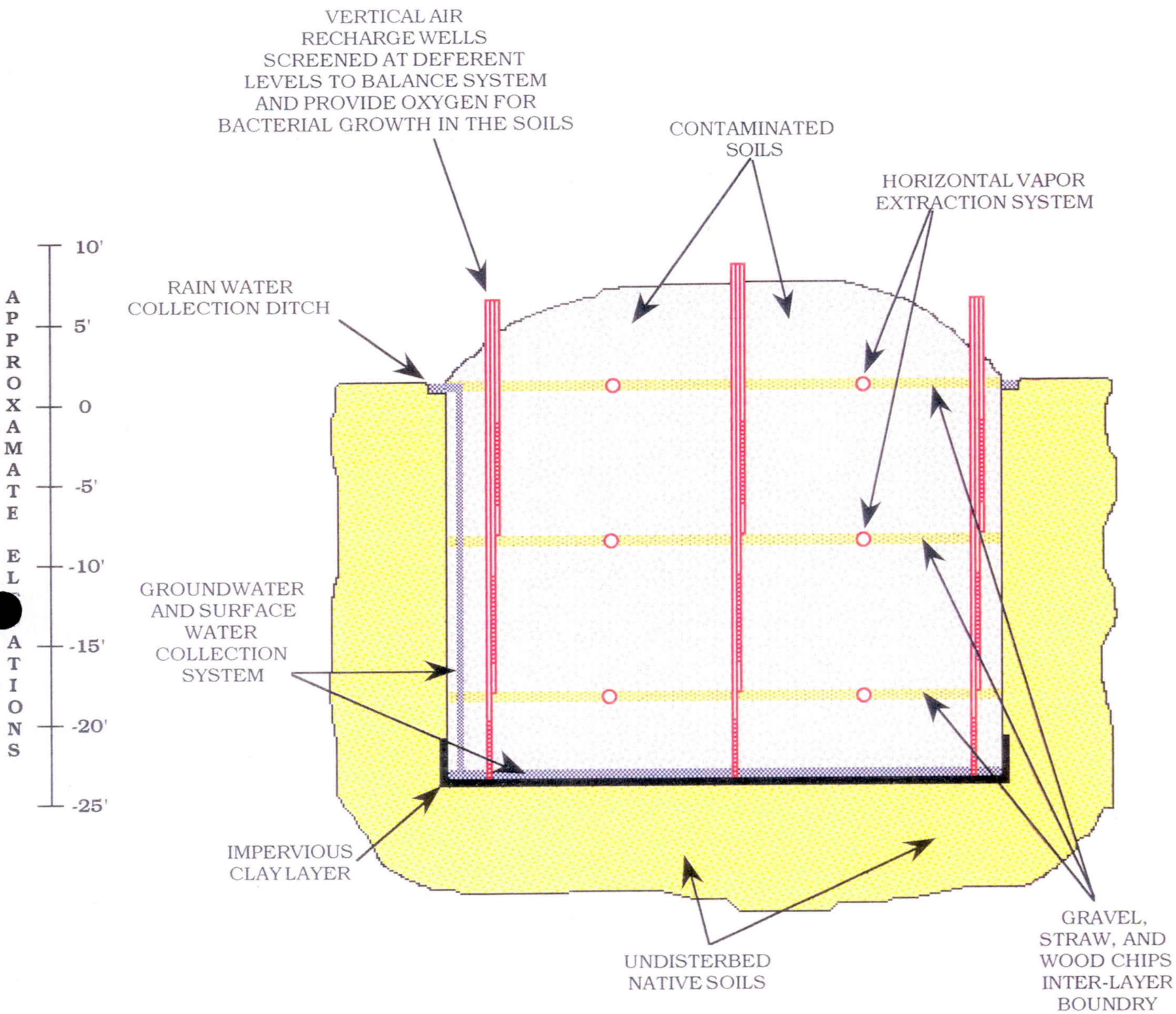
a. SOILS

There will be two different methods of soil remediation employed at this site. The first method, modified in-situ bio-remediation and vapor extraction, will be used in areas of soil contamination not underlain by contaminated groundwater and the contaminated soils do not come in contact with the groundwater. Figure 4 shows these as areas 1,2,4,5,6, & 7. These areas will be remediated in two groups. Soils from areas 1 and 5 will be remediated together while soils from areas 2,5,6, and 7 will be treated together. Soil contamination found in area 3 (underlain by contaminated groundwater) will be remediated using conventional soil vapor extraction methods.

The modified in-situ bio-remediation and vapor extraction areas will be remediated by removing the contaminated soils and placing those soils on an adjacent impervious surface for later re-introduction back into the excavation. The excavation from which the soils were removed will then have the bottom sealed with a compacted clay liner to prevent the possible downward spread of contamination. A leachate collection system will be installed atop the clay to insure that all waters coming in contact with the contaminated soils are treated.

Once the leachate collection system is in place, the contaminated soils will be blended with straw and/or wood chips to fluff the soils and allow air to circulate. Organic fertilizer will also be blended in at this time to provide nutrients for (augment) bacterial growth. The fluffed and fertilized soils will then be reintroduced into the pit in 5 foot lifts. Located between the soil lifts will be a layer of straw, gravel, and/or wood chips along with a horizontal vapor collection system. The layering will be repeated until the removed volume of treated soil is placed into and piled atop the pit. Where the soils exceed the elevation of the existing surface, the mounded soils will be sloped to maintain its shape and the perimeter of the mound will be ditched to contain, capture and treat run-off water.

The proposed location of the vapor extraction piping and the vapor extraction equipment are shown on Figure 3. Construction details of the modified in-situ bio-remediation/vapor extraction system are shown on Figure 6. The vapor collection piping, laid horizontally in the excavation, will consist of two-inch diameter slotted well screen with 0.070 slot size or equivalent. The construction will apply equal vacuum and allow adequate air flow throughout the treated soils, from the surface to the clay-sealed bottom. Vertical air recharge well clusters will be installed to ensure that sufficient oxygen levels are maintained in the treated soils for bio-remediation. There are no significant lithology changes with depth at this site which require selective treatment.



DRAWING NOT TO SCALE

Figure 6
Cross Section of Modified in-situ Bio-Remediation/Vapor Extraction System

Teer Company - Durham Quarry

Geonetics Project #10293

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Figure 7 shows the soil vapor extraction system (GeoPure Continental Model 400-600SVE, or equivalent) that will be used for the extraction of the treated soil vapors. This system, or equivalent, is rated from 400 CFM at 42" water column to 600 CFM at 43" water column. Specifications, pump curves, and pricing can be found in the Appendix. The System will be installed at the excavation site. The entire property is protected by a fence.

The soil remediation system for areas #1 and #4 will be constructed first and after the soils are remediated the equipment will be reused for areas #2, #5, #6, & #7.

Soil remediation for area #3 will use off-the-shelf vapor extraction technology. The 6-inch diameter groundwater recovery wells will double as the vapor extraction recovery wells. The wells will be screened from the surface to the sump to insure that, as the groundwater is removed for treatment, the exposed soils will be acted upon by the vacuum pump so as to not re-contaminate the groundwater. Both the groundwater and the soils will be remediated at the same time. The wells will be sealed at the top to ensure vapor removal across the entire screen surface.

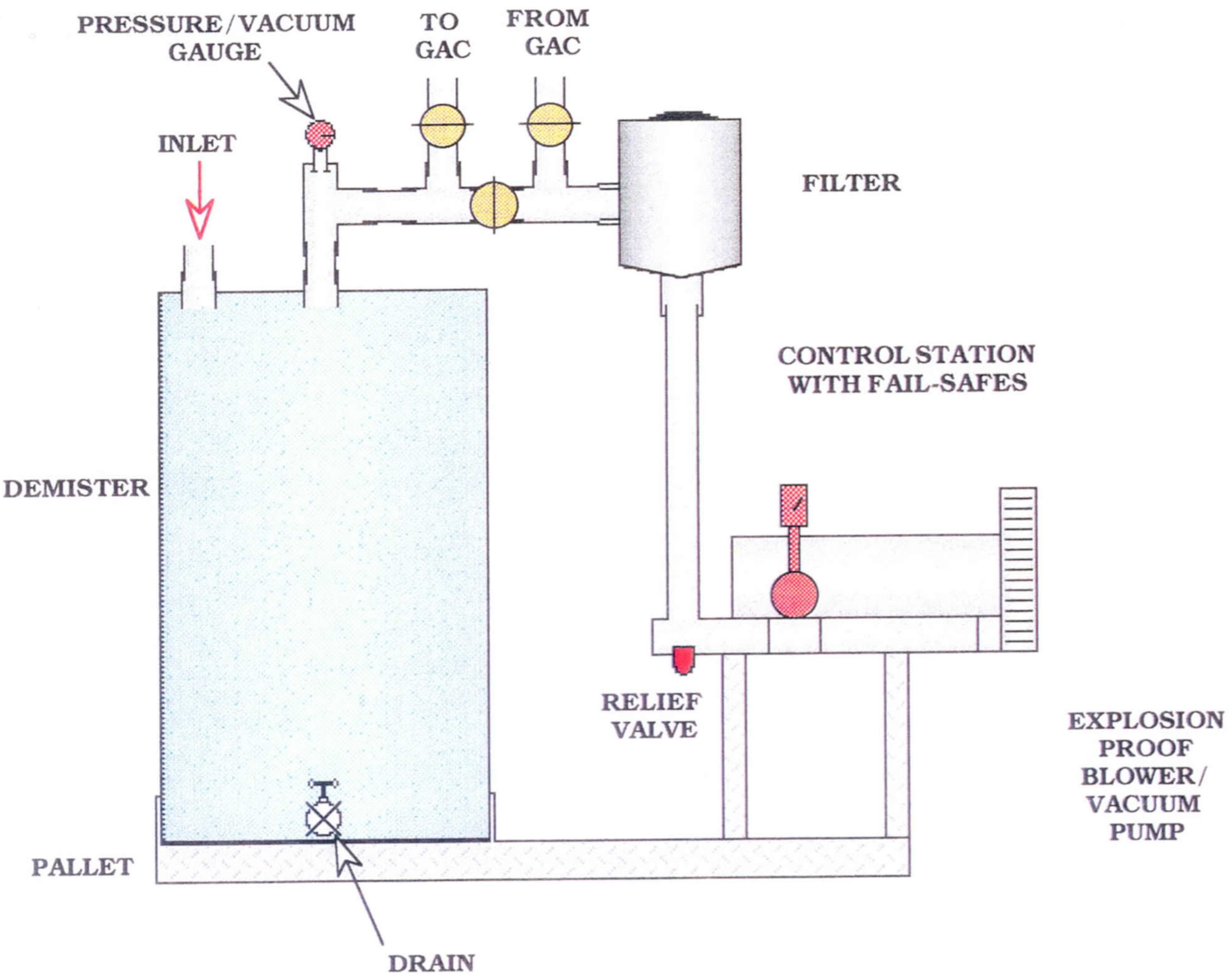


Figure 7 - Soil Vapor Extraction Equipment

Teer Company - Durham Quarry

Geonetics Project #10293

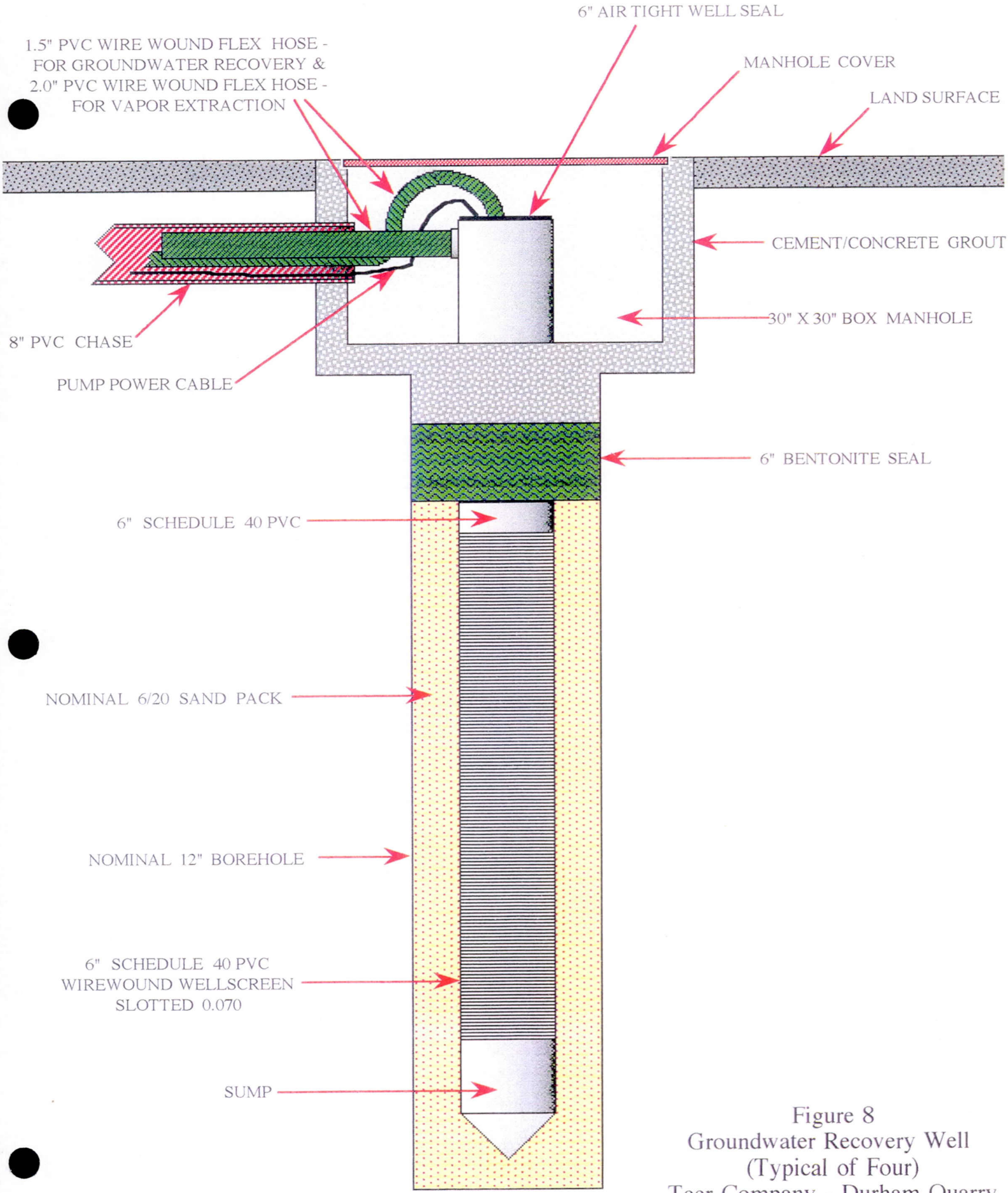
A 200 CFM Soil Vapor Extraction System (GeoPure Continental Model 200SVE or equivalent) will be used for this area. The system will use a Regenerative Blower pulling approximately 35" water column at 200 CFM. Specifications, pump curves, and pricing can be found in the Appendix.

GROUNDWATER

All recovery wells are to be of six-inch diameter. Figure 8 details the typical recovery well construction. Figure 3 shows the recovery well locations. Recovery well radius of influence is estimated on Figure 9 at 375 feet. The calculations to estimate the radius of influence are Theis equations from Lohman and are shown on Table 7. At a minimum, vertical influence should extend to the bottom of the recovery well screened interval. Developed hydraulic gradient after 45 days of continuous pumping with no recharge can be estimated from Table 7.

Predicted recovery well drawdown after 45 days of continuous pumping, with no recharge, is estimated to be 29 feet. This drawdown was observed in the pumped well, during the pumping test, at a pumping rate of 8.8 gpm. It is expected that a total of 30 gpm will be pumped from 4 wells for remediation.

Figure 10 shows the proposed piping chase construction details. Figure 11 shows the low profile diffused aerator stripper (GeoPure Continental Model 48DA1T7.5 or equivalent).



DRAWING NOT TO SCALE

Figure 8
Groundwater Recovery Well
(Typical of Four)
Teer Company - Durham Quarry
Geonetics Project #10293

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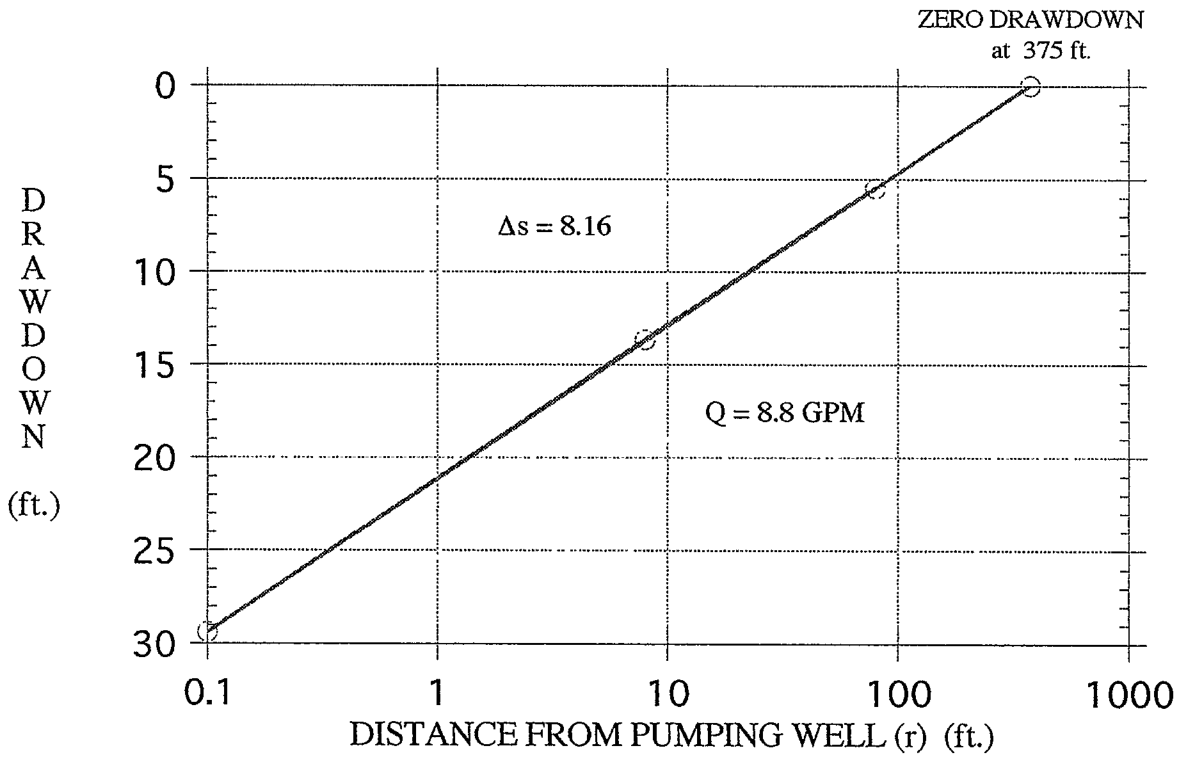
DISTANCE-DRAWDOWN PLOT



Data derived from the drawdown cycle in observation well MW-20A and pumped well MW-2, at 120 minutes of pumping, at 8.8 gallons per minute. Application of the Theis Modified Non-Equilibrium Formula, by Cooper and Jacob (1946), and Lohman (1972):

$$s = 264Q/T (\log [0.3Tt / r^2S])$$

Figure 9. - RECOVERY WELL RADIUS OF INFLUENCE

TABLE 7 - RECOVERY WELL PREDICTED RADIUS OF INFLUENCE - CALCULATIONS
SITE: Teer Company - Durham Quarry
GEONETICS PROJECT: #10293

RECOVERY DATA

TESTING VARIABLES

Actual tested Q =	**8.80**	**gpm**
Desired Q =	**8.80**	**gpm**
Δs =	**4.08**	
Radius #1 (r1) =	**0.1**	**feet**
Radius #2 (r2) =	**80.0**	**feet**
Specific Yield =	**17.5**	**percent (from EPA 625/1-81-013)**
Aquifer Thickness =	**200.0**	**feet**
t =	**45.0**	**days**

			FORMULAS
T =	569.4	gpd/ft	
T =	76.1	ft2/day	**T = 264 x Q / Δs**
Actual test Q =	8.80	gpm	
Actual test Q =	1,694.1	ft3/day	**u = r2 x S / 4 x t x T**
Expected to pump Q =	8.8	gpm	
Expected to pump Q =	1,694.1	ft3/day	**s = Q / 4 x π x T**
Δs =	4.08		
r(1) =	0.1	feet	**K = T / Aquifer Thickness**
r(2) =	80.0	feet	
S =	0.175		
t =	45.0	days	
Aquifer Thickness =	200.0	feet	
K =	0.38	ft/day	
K =	0.19	in/hr	
K =	0.00013	cm/sec	
Specific Yield =	17.5	percent	
u(1) =	1.277E-07		
u(2) =	8.174E-02		
W(u)(1) =	**15.1354**		
W(u)(2) =	**1.4645**		
s(1) =	**26.804**	**Feet of Drawdown**	
s(2) =	**2.594**	**Feet of Drawdown**	

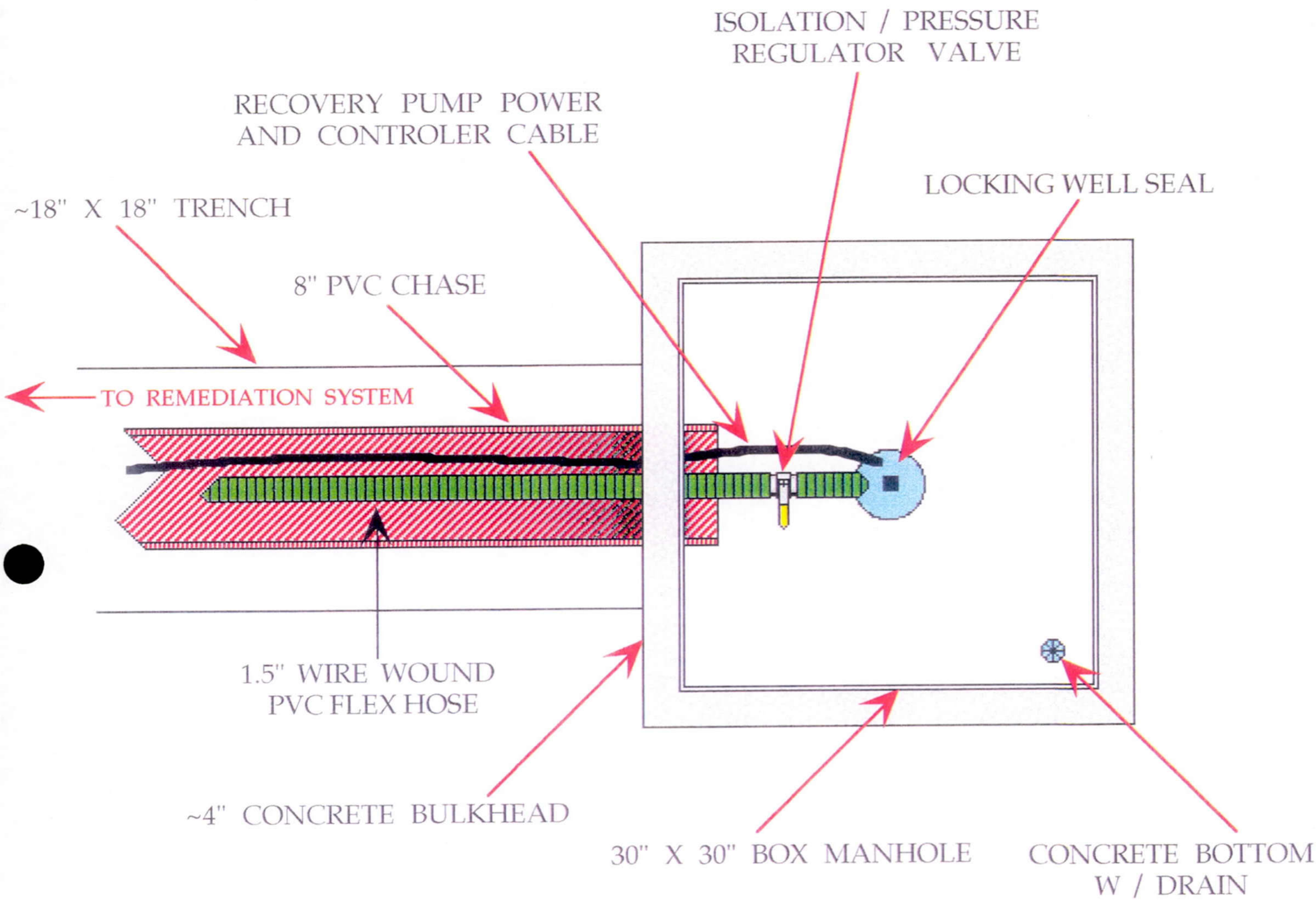
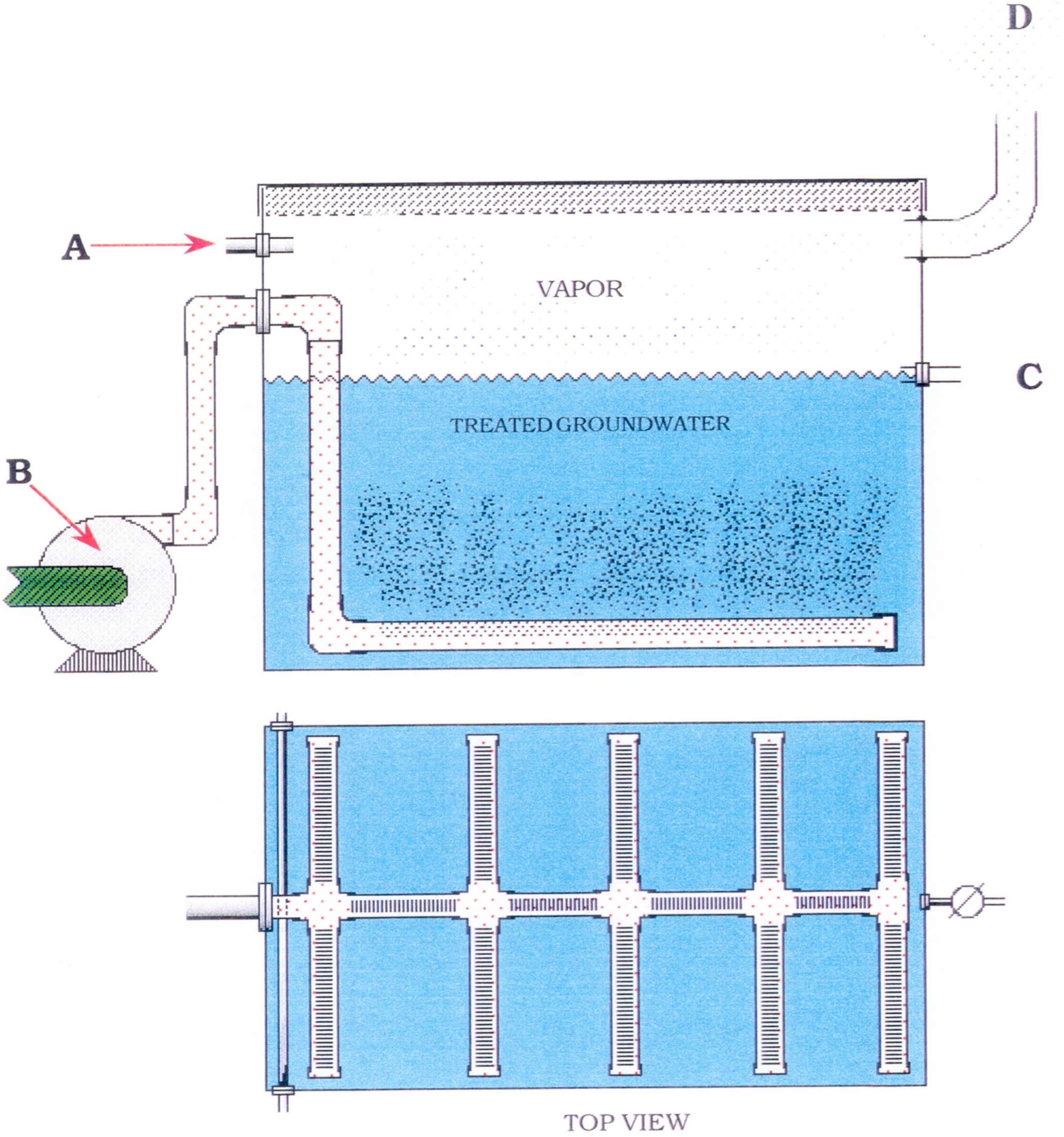


Figure 10
Recovery Well & Piping Chase Details

Teer Company - Durham Quarry

Geonetics Project #10293



LEGEND

A = CONTAMINATED WATER
B = AIR BLOWER
C = TREATED WATER
D = VAPOR STACK

Figure 11 - DIFFUSED AERATOR SYSTEM

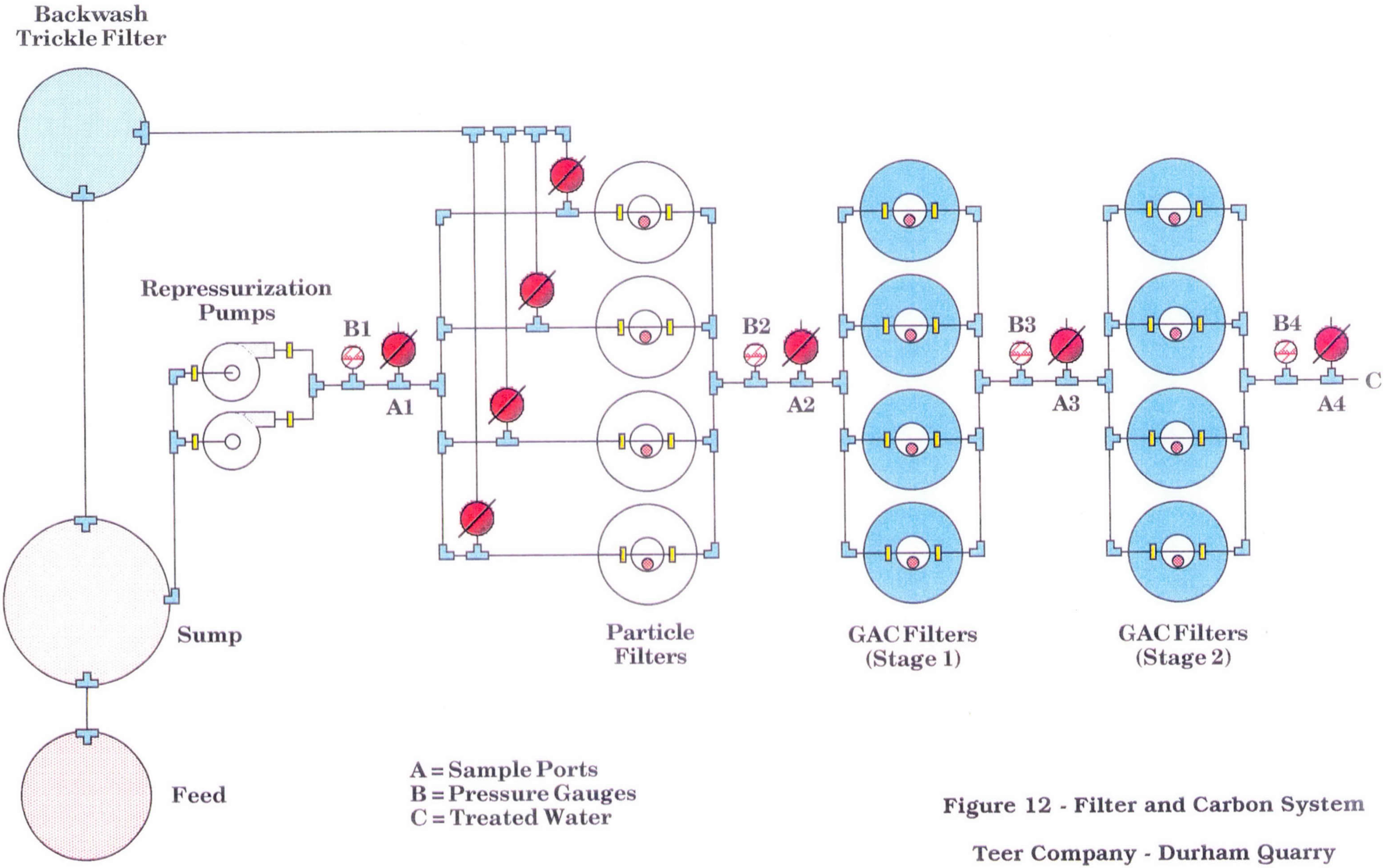
Teer Company - Durham Quarry

Geonetics Project #10293

Figure 12 shows the filter and carbon system (Continental Environmental System's Model 40FGB2L or equivalent). Both systems will be contained in a lockable building within a fenced area. The GeoPure Continental equipment specifications are included in the Appendix as provided by GeoPure Continental. GeoPure Continental design data are also included in the Appendix.

The remediation system will include four recovery wells with stainless steel Grundfos 10S05-9 pumps and pump controllers, or equivalent. The pumping test results indicate that between the four wells, the system should receive about 30 gpm. The remainder of the recovery system's capacity will be used should the soil remediation system need to process leachate from its pit collection system or run-off from its perimeter ditch system.

All recovery pump piping is 1.5 - inch diameter. Recovery pump discharge is through wire wound green PVC hose which is connected by aluminum quick connects. The connections are made by heating the hose and forcing the hose nipple side of the quick connect into the heated hose section. A stainless steel hose clamp completes the connection. Process lines are solvent welded Schedule 80 PVC or quick connected green PVC hose. Chase sections are solvent welded Schedule 40 PVC. All threaded joints are properly teflon taped.



A = Sample Ports
B = Pressure Gauges
C = Treated Water

Figure 12 - Filter and Carbon System

Teer Company - Durham Quarry

Geonetics Project #10293

The proposed treatment system includes aeration in the diffused aerator system and then three particle filters and a backwash trickle filter as pre-treatment to the GAC filters. This aeration and filtration should protect the carbon from significant quantities of precipitated iron and sediments. Should iron precipitation continue to pose a problem, corrective action will be taken using the best available technology to minimize carbon replacement costs.

b. Figure 6 shows the conceptual underground soil remediation system that will use both bio-remediation and vapor extraction technologies.

Figure 7 shows the soil vapor extraction equipment that will be used in conjunction with the groundwater remediation equipment.

Figures 8,10,11, and 12 show the components of the groundwater remediation system.

c. The basis for using the modified in-situ bio-remediation and vapor extraction system on the major amount of the contaminated soils was to:

1. Eliminate removal of soils off site.
2. Reduce handling of soils.
3. Limited area for land applying and farming.
4. Reduce soil cleanup costs.

The soils underlain by groundwater contamination will be remediated via conventional soil vapor extraction. This method was chosen to insure contaminated soils exposed, as the groundwater remediation system lowers the ambient water table, will be treated efficiently.

Time, volume of contaminated groundwater, and aquifer limitations were the variables for sizing the groundwater remediation system. Pumping test data is located in the Appendix. Equipment sizes and capacities are located in the Appendix. The recovery wells estimated radius of influence is shown in Figure 9 and the calculations are found on Table 7. By using the two stage carbon polishing system after diffused aeration, the effluent will be assured of meeting NCDEM water standards. Carbon consumption rates and system efficiencies can be found in Table 8.

d. Figure 3 shows the layout of both vapor extraction systems and the groundwater system. Also shown are the recovery wells, vapor extraction wells and piping, equipment locations, and discharge points.

e. All systems will be enclosed within a fenced area. All equipment will be equiped with explosion proof motors and automatic shutoff systems. Specifications for the systems are located in the Appendix.

TABLE 8 - GEOPURE CONTINENTAL'S CALCULATED CARBON USE RATES, USING A DIFFUSED AERATOR AND ACTUAL WORST CASE GROUNDWATER ANALYSES
SITE: Teer Company - Durham Quarry
GEONETICS PROJECT: #10293

CONTAMINATE	CONCENTRATION (ppb)	AERATOR EFFICIENCY	AFTER AERATION CONCENTRATION (ppb)	CARBON USE (lbs/day)
BENZENE	353	90.00	35.30	0.4035
TOLUENE	418	90.00	41.80	0.2090
ETHYL-BENZENE	0	90.00	0.00	0.0000
XYLENE	106	90.00	10.60	0.0312
MTBE	0	50.00	0.00	0.0000

GALLONS PER MINUTE INFLUENT	40.0
TOTAL CONTAMINATE (ppb)	87.7
TOTAL CONTAMINATE (lbs/day)	0.04210
PERCENT LOADING BY WEIGHT	6.53975
LBS OF CARBON/1000 GALLONS	0.011176
TOTAL CARBON USE (lbs/day)	**0.64375**

THE RESULTS GIVEN ARE BASED UPON HENERY'S LAW OF LINEAR ADSORPTION ISOTHERMS AND CONTINENTAL APPLICATION LABS' DATA AND ASSUME REASONABLE FLOW RATES AND CONTACT TIMES. NON REPORTED DATA SUCH AS VERY HIGH OR LOW INLET CONCENTRATIONS, pH, OR COMPETING ORGANIC MAY DRASTICALLY AFFECT OPERATING CONDITIONS.

f. Possible limitations to the modified in-situ bio-remediation/vapor extraction system are: (i) the need to increase the volume of air (CFM) or the extraction vacuum (water column inches) to ensure satisfactory removal of contaminants, and (ii) the need to increase the oxygen content, within the treated soils, to ensure bacteria growth. Should the first problem occur, additional vapor extraction equipment would be installed or sections of the treated soils would be valved in such a way as to compensate for either of those problems. Additionally the second problem could be solved by installing additional air recharge wells.

The conventional vapor extraction system, located with the groundwater system, might need additional extraction wells to insure complete remediation across the entire contaminated zone.

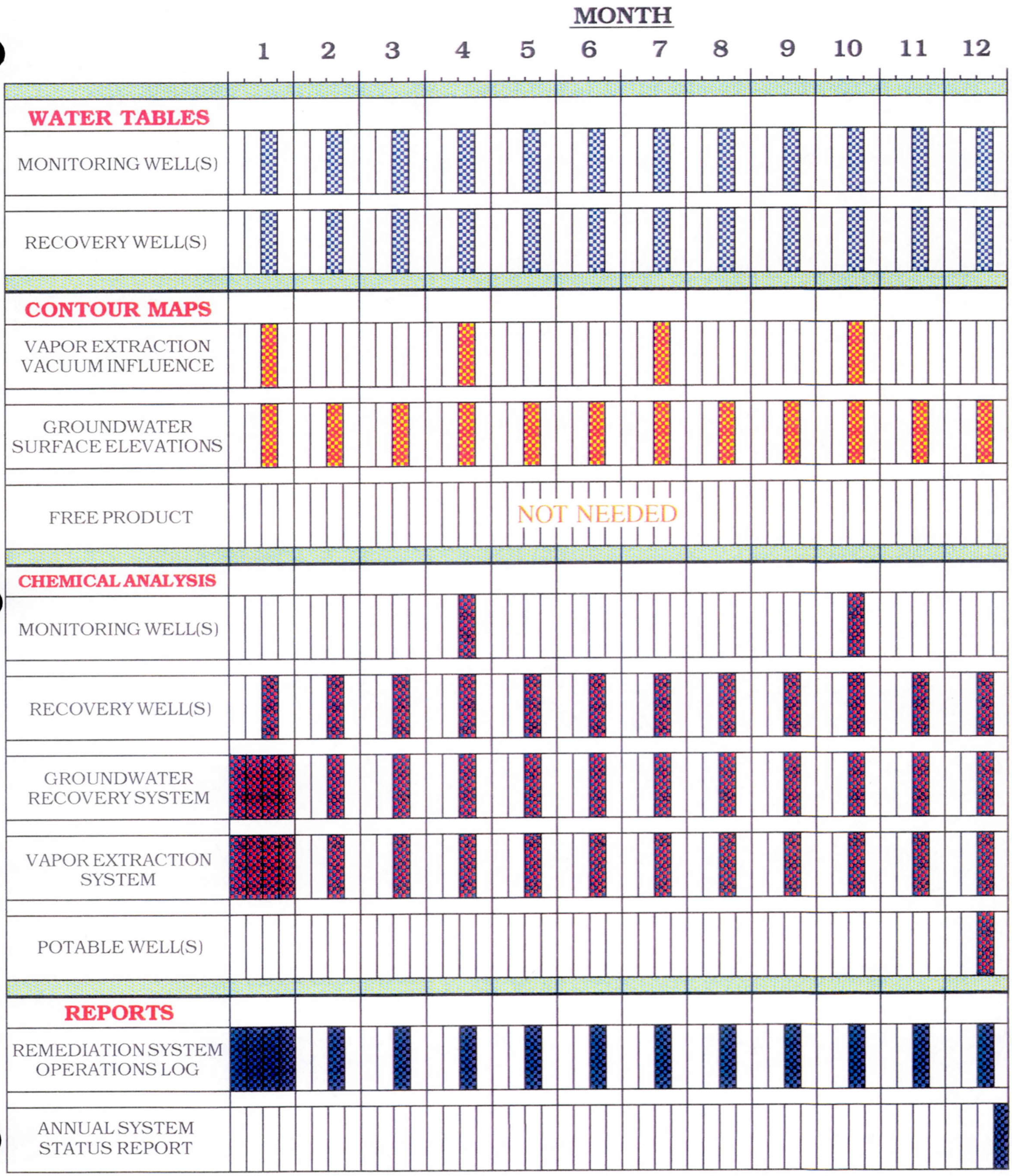
The groundwater system could be limited by the amount of groundwater available for the treatment system. Should the primary four wells not be sufficient to generate the needed flows to remediate the volume of groundwater contamination, in a reasonable time, additional recovery wells will be installed to ensure timely completion of the project.

g. On site operational logs will be maintained for all systems. The logs will record equipment operating factors such as inches of vacuum, gallons per minute (gpm) through-put, operational downtime, equipment maintenance, chemical analyses and system parameters such and vacuum and pressure readings, low and high water alarms, and high temperature alarms. The equipment installed at all locations will have the appropiate safety features to ensure that further contamination will not occur from the systems operation. Equipment fail-safes can be found in the equipment manufacturers specifications located in the Appendix. Maintenance will be performed as needed with a reserve of parts to be kept on site to minimize downtime.

h. Water phase samples from the recovery wells and vapor phase samples will be analysed and recorded, for the CSA listed and identified parameters, at least monthly for the first year. Analytical results will be used for asymptotic curve determinations. In addition, samples will be collected from monitor wells semi-annually and the results will be used to evaluate cleanup progress. Figure 13 summarizes the proposed sampling and monitoring schedule for both vapor extraction and groundwater recovery systems.

Geonetics personnel will collect and analyze treatment process samples from sampling locations at least weekly for the first month, at least monthly for the first year, and at least quarterly thereafter for analyses identified in the CSA. Treated groundwater will be discharged to the Durham Quarry pit at or below contaminant concentration limits listed in the NPDES

Figure 13 - Monitoring and Sampling Schedule



permit. Iron and TOC will be analyzed as necessary. More frequent sampling at the port between the GAC canisters will be done if breakthrough to the second canister consistently occurs between sampling episodes.

Geonetics will submit annual progress reports, including measurements of groundwater levels taken in all monitoring and recovery wells at least monthly. Monitoring data including these measurments will be reported in annual status reports to DEM. The sampling program includes analysis for the analytical groups outlined in the CSA. Periodic maintenance and site inspection will be limited to twice a month for the first quarter and monthly thereafter. The system will be modified as necessary to meet this requirement.

7. Permits

No permits or certificates of approval relating to the clean-up at this site have yet been submitted. A Soil Remediaion Permit and a Treated Groundwater Discharge Permit are now in progress, and will be submitted with or very shortly after this CAP. The NOV required that the CAP be submitted shortly after the CSA.

8. Report Certification

The planning and selection of methods relating to this Corrective Action Plan (CAP) at the Durham Quarry were performed under the supervision of two licensed Professional Geologists: Dr. Arthur W. Hayes, Geonetics' President and Senior Hydrogeologist, and Donald R. Smith, Division Manager, based in Lexington, N.C. The information contained herein, and the interpretations derived, follow accepted and approved professional practice, and are true and correct to the best of our knowledge. It is understood that interpretations and conclusions are derived from dated samples and measurements, and that conditions may change through time and in three dimensions within the earth.

GEONETICS CORPORATION

Donald R. Smith, P.G.
Date: December 3, 1993

Arthur W. Hayes, Ph.D., P.G.
Date: Dec. 2, 1993

9. References

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Model 400-600SVE Soil Vapor Extraction System;
Model 48DA1T7.5 Low Profile Diffused Aerator;
Model 40FGB2L Carbon Backwashing System;
Model 4GWRS Recovery Well Pump Controller;
Model 10S05-9 Grundfos Stainless Steel Pumps;
Filtration and Granular Activated Carbon Systems;
Model 25IAS In-Situ Air Sparging System
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N.C. ADMINISTRATIVE CODE Title 15A, Subchapter 2L; November 2, 1992, and DRAFT Guidelines Version of October 8, 1993.

N.C. DIV. OF ENVIRONMENTAL MANAGEMENT (Revised June 1993) Groundwater Section Guidelines for the Investigation and Remediation of Soils and Groundwater; internal publ., 95 p.

UNIVERSAL OIL PRODUCTS CO., Johnson Division (1972): Ground Water and Wells; St.Paul, Minn., 440 p.

Von WEDEL, Randall J. (1990): Augmented Bioremediation of Excavated Soil Contaminated with Petroleum Hydrocarbons; SUPERFUND '90 Conference, Washington, D.C. Nov. 26-28, 13 p.

APPENDIX

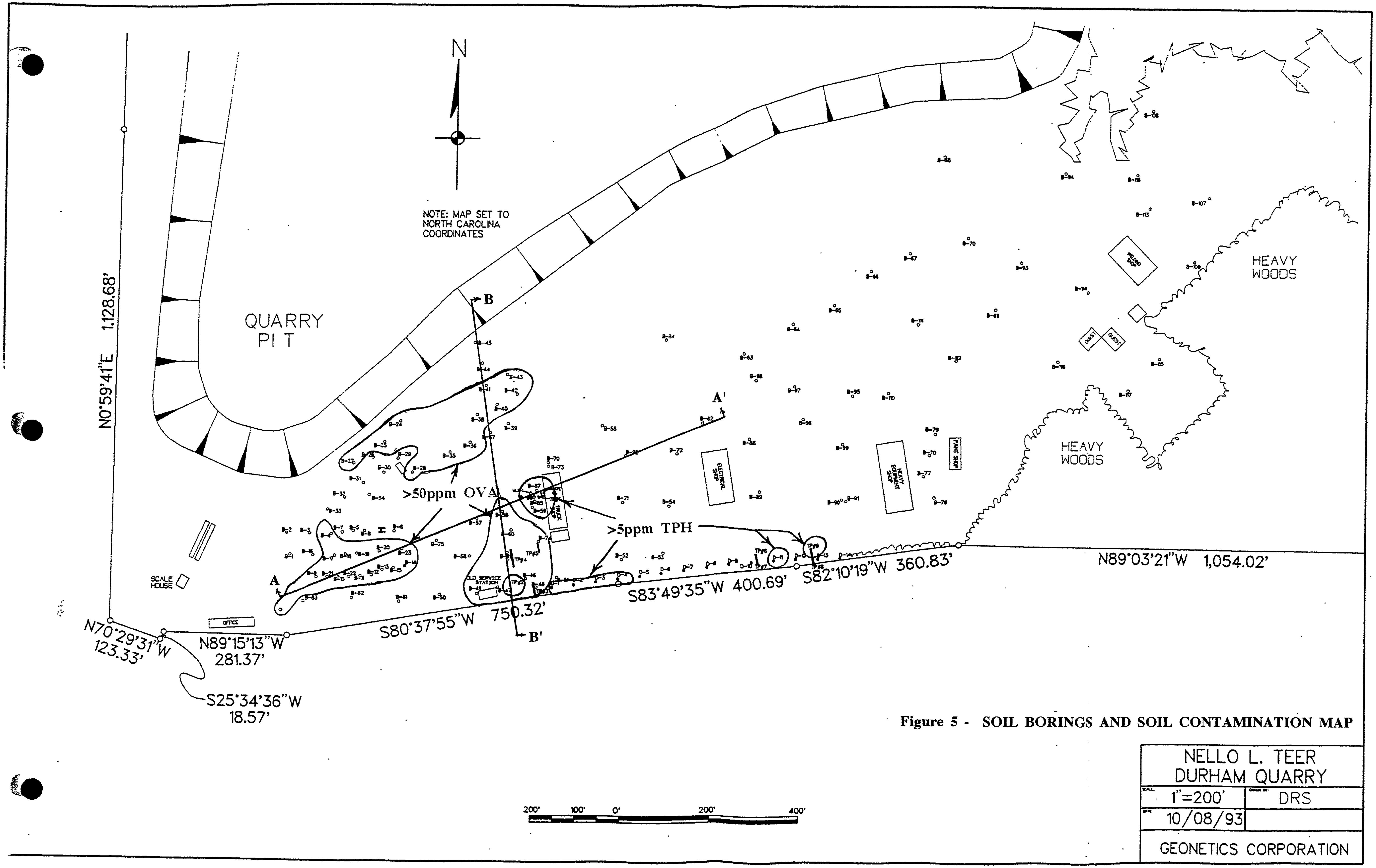
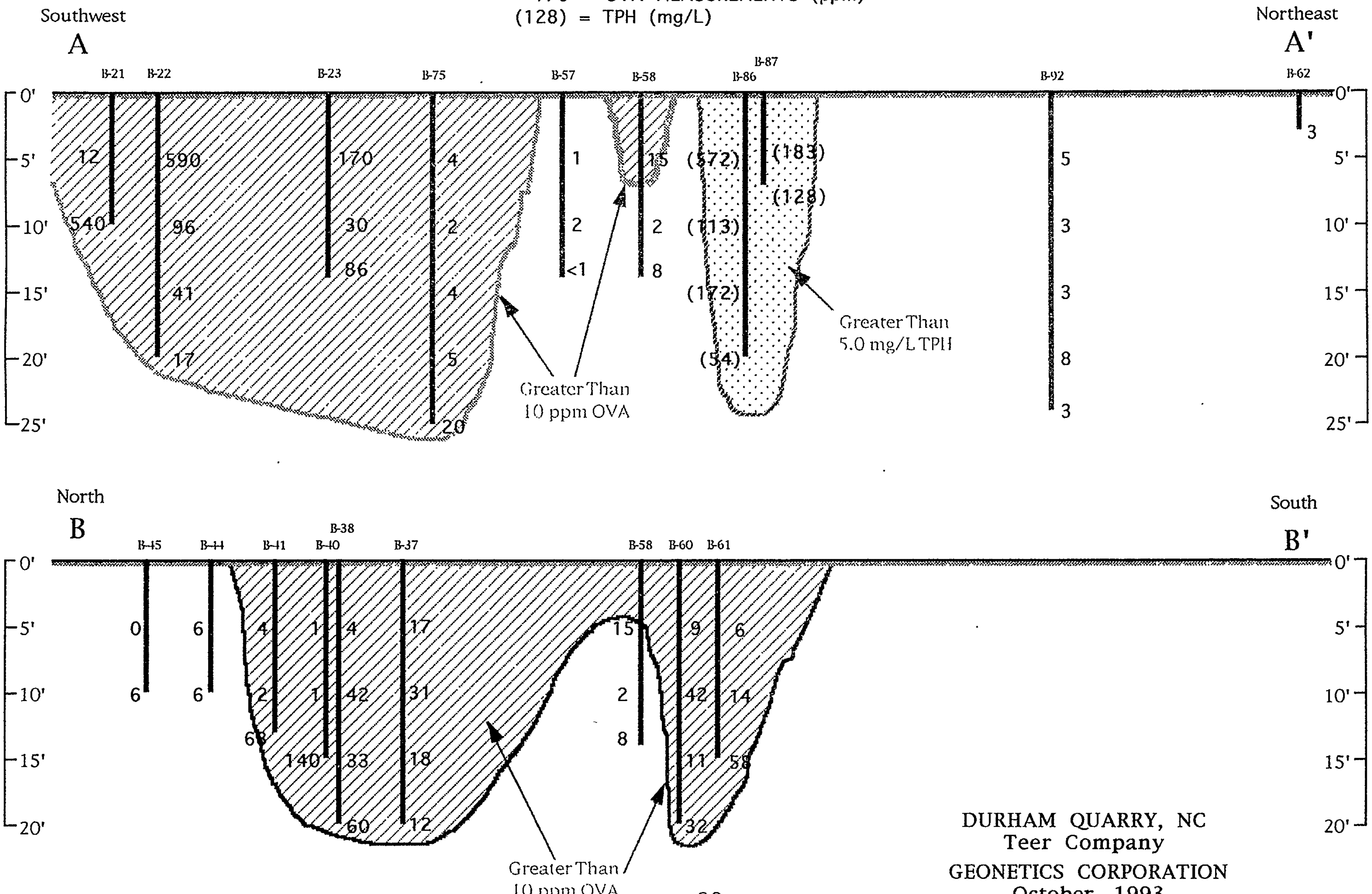


Figure 5 - SOIL BORINGS AND SOIL CONTAMINATION MAP

Figure 6 - Cross - Sections A-A' and B-B', Soil Contamination

Horizontal Scale: 1" = 100'
Vertical Scale: 1" = 10'
Vertical Exaggeration = 10 X

170 = OVA MEASUREMENTS (ppm)
(128) = TPH (mg/L)



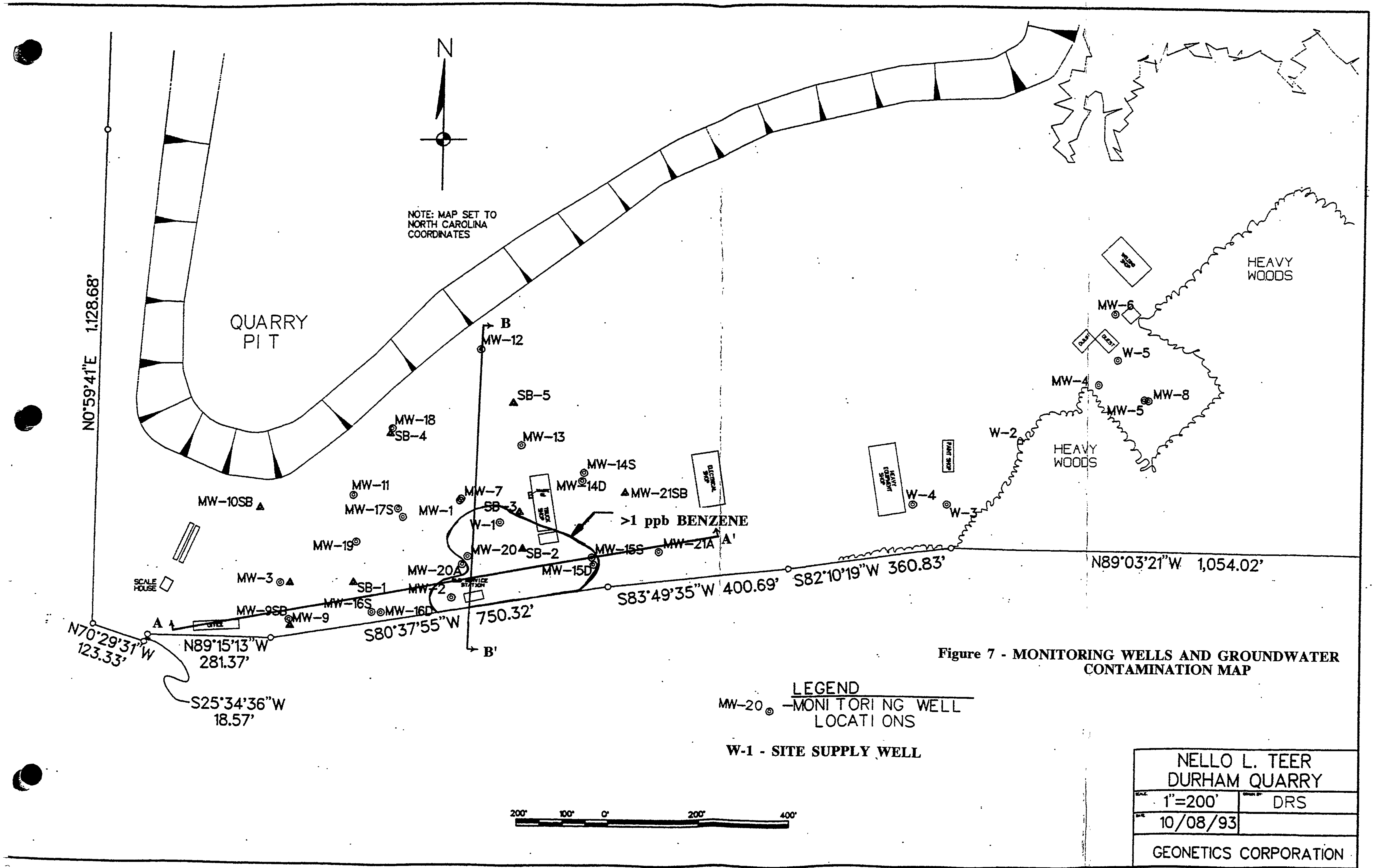
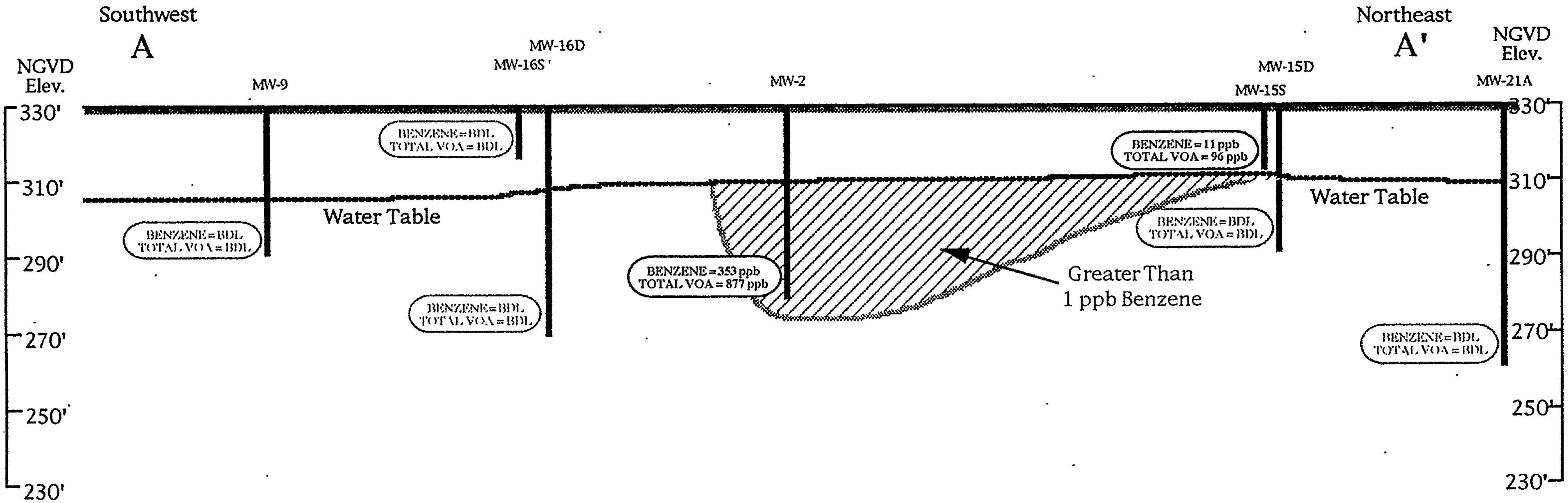


Figure 7 - MONITORING WELLS AND GROUNDWATER CONTAMINATION MAP

Figure 8 - Cross Section A-A', Groundwater Contamination

Horizontal Scale: 1" = 100'
Vertical Scale: 1" = 40'
Vertical Exaggeration = 2.5 X



DURHAM QUARRY, NC
Teer Company

GEONETICS CORPORATION
October, 1993

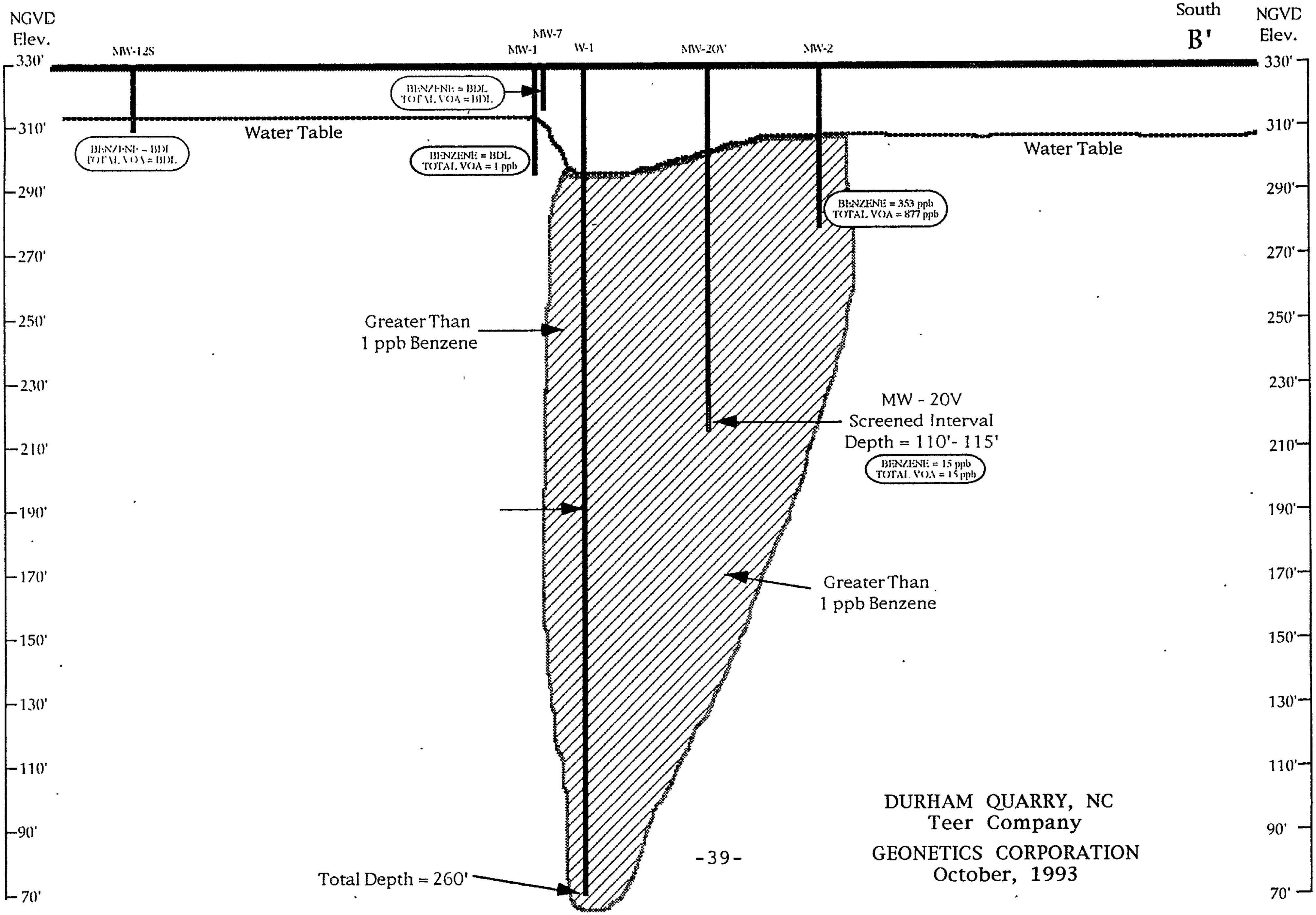
Figure 9 - Cross Section B-B', Groundwater Contamination

Horizontal Scale: 1" = 100'

Vertical Scale: 1" = 40'

Vertical Exaggration = 2.5 X

North
B



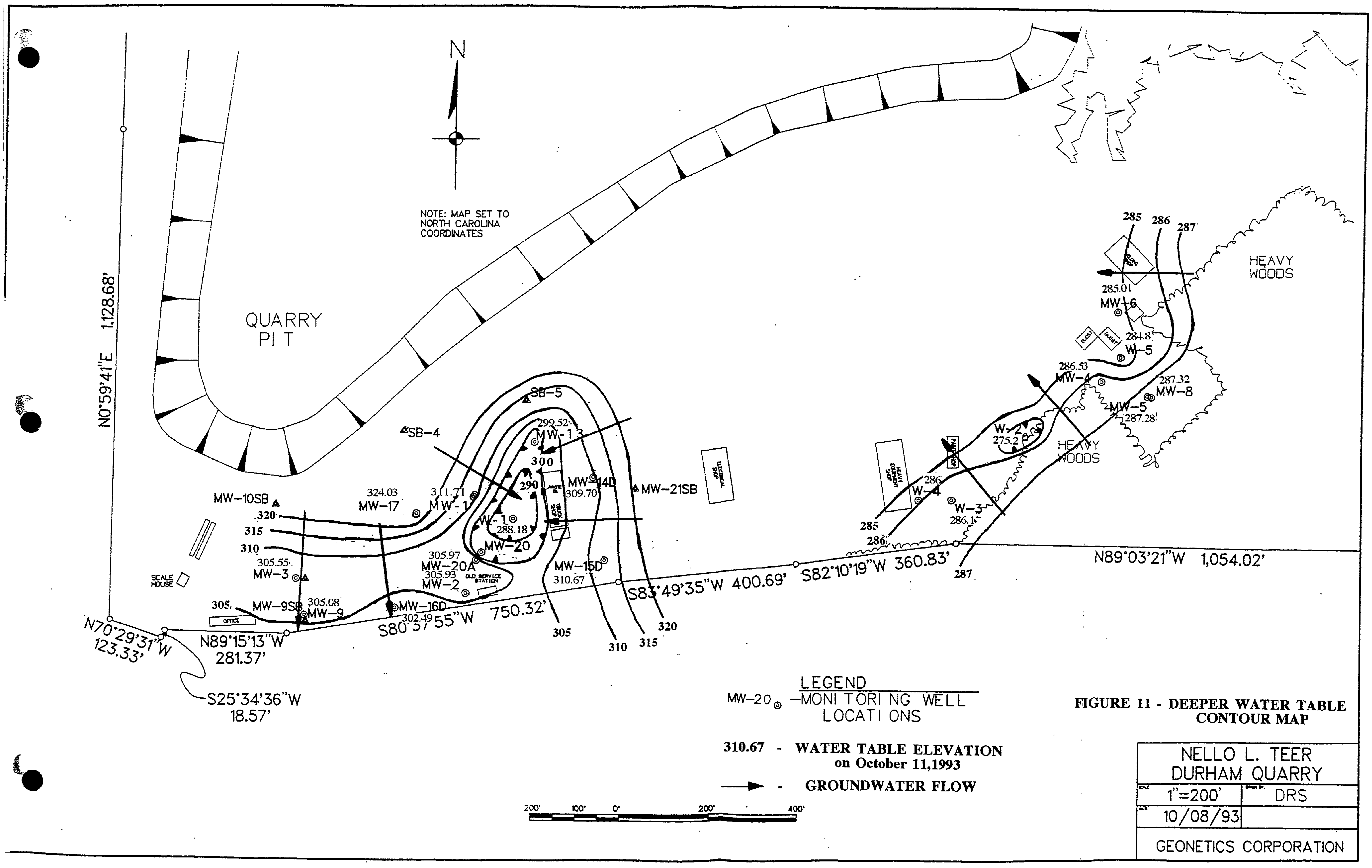


FIGURE 11 - DEEPER WATER TABLE CONTOUR MAP

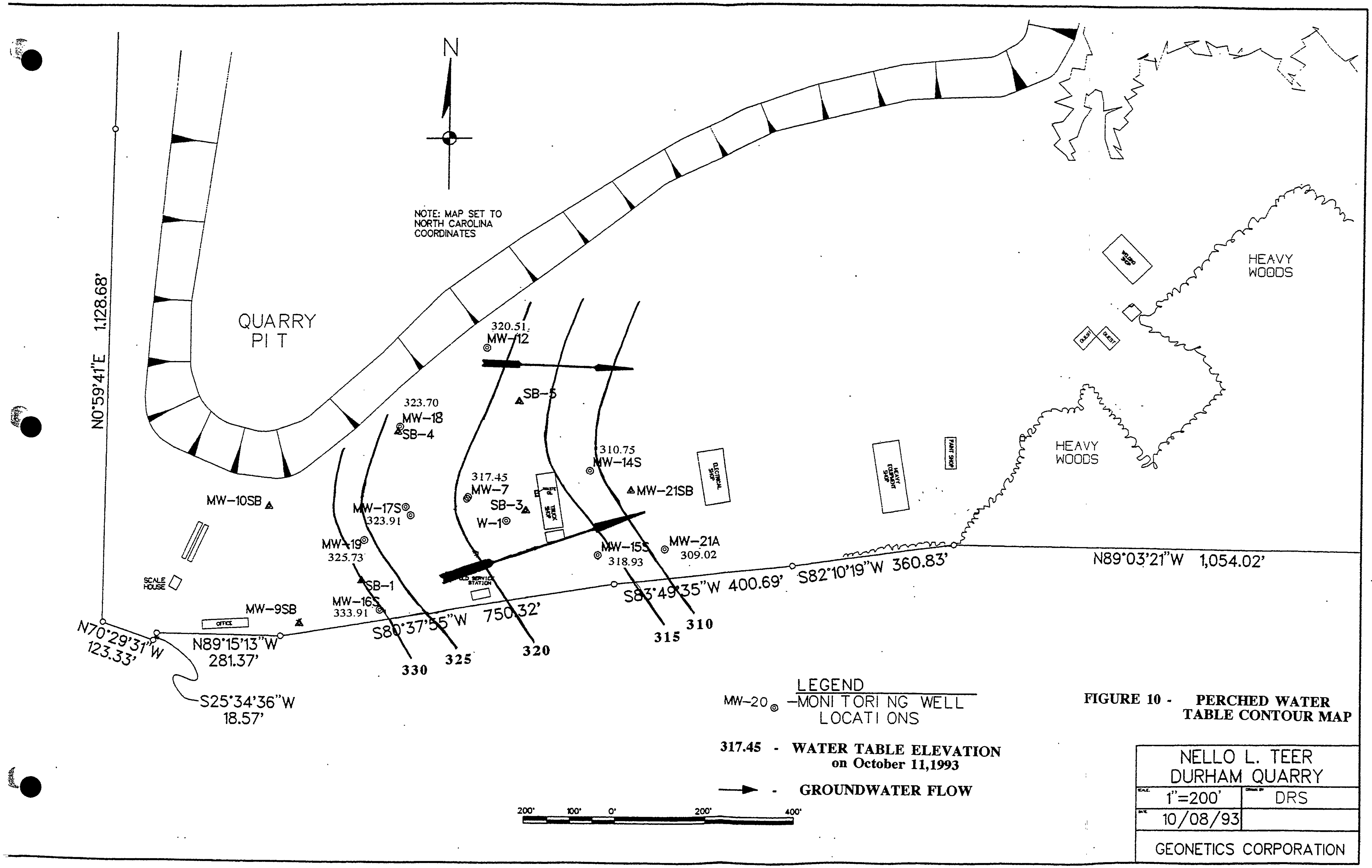


FIGURE 10 - PERCHED WATER TABLE CONTOUR MAP

Continental Environmental Services
Your Partner for a Clean Environment
SOUTHEAST OFFICE
TEL: (800) 342-1103
FAX: (904) 373-7660
2300 NW 71 PL • GAINESVILLE, FL 32606

November 18, 1993

Mike Thibodeau
Geonetics Corp
5120 S Lakeland Dr
Ste 1
Lakeland, FL 33813

QUOTE#CJ3693 PRICE FIRM FOR 60 DAYS FOB:GAINESVILLE,FL
DELIVERY: 6-8WEEKS ARO BASED ON AVAILABILITY TERMS:NET 30

We are pleased to offer the following system for the Soil Vapor Extraction System for the Durham NC - Teer Co. site:

1 Model 400-600SVE Soil Vapor Extraction System $11300.00

The system includes:
New York Blower Model 2306 Pressure Blower
7.5 HP XP motor (three phase - 460volt)
XP Motor Starter
The system is totally XP
Moisture knock out tank
(high level shutoff is a $630.00 adder and is not included in the above price)
2 Vacuum Gauges
Knockout Drain Valve
Silencers
Skid Mounted

The system is rated 400cfm @ 42" WC to 600cfm @ 43"WC.

The system, without the Moisture knock out tank, is $750.00 less.

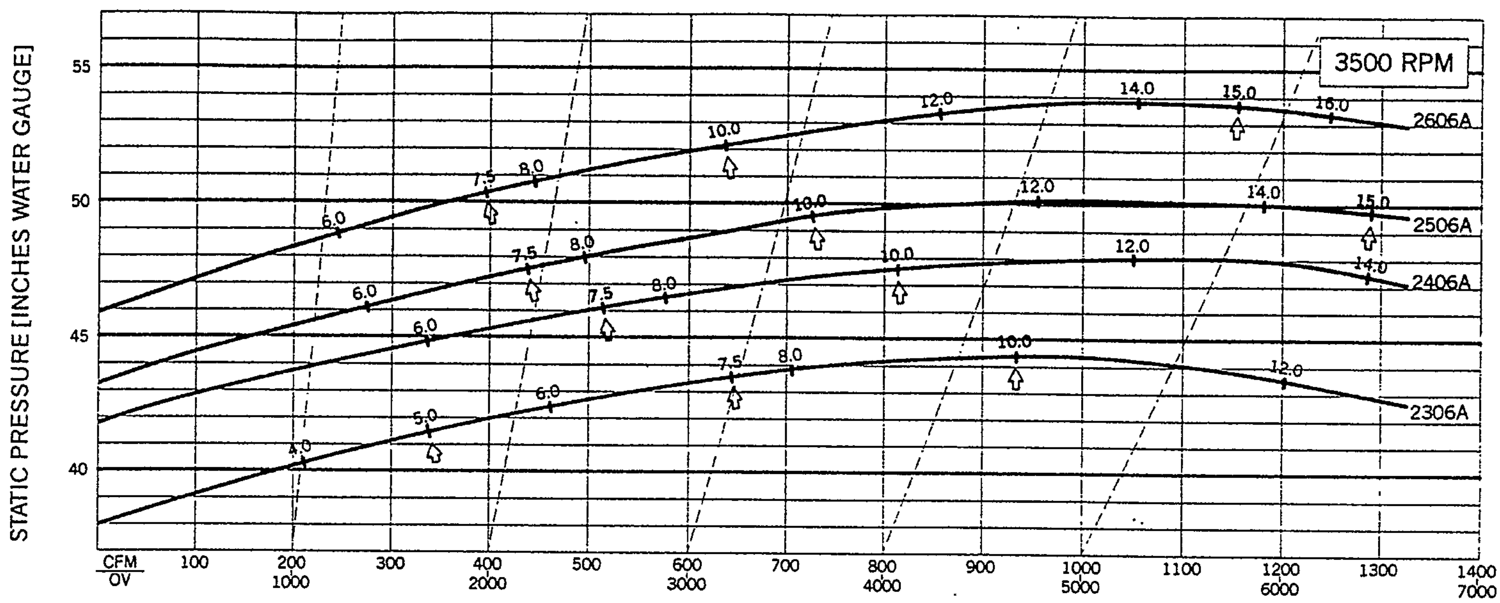
Sincerely,

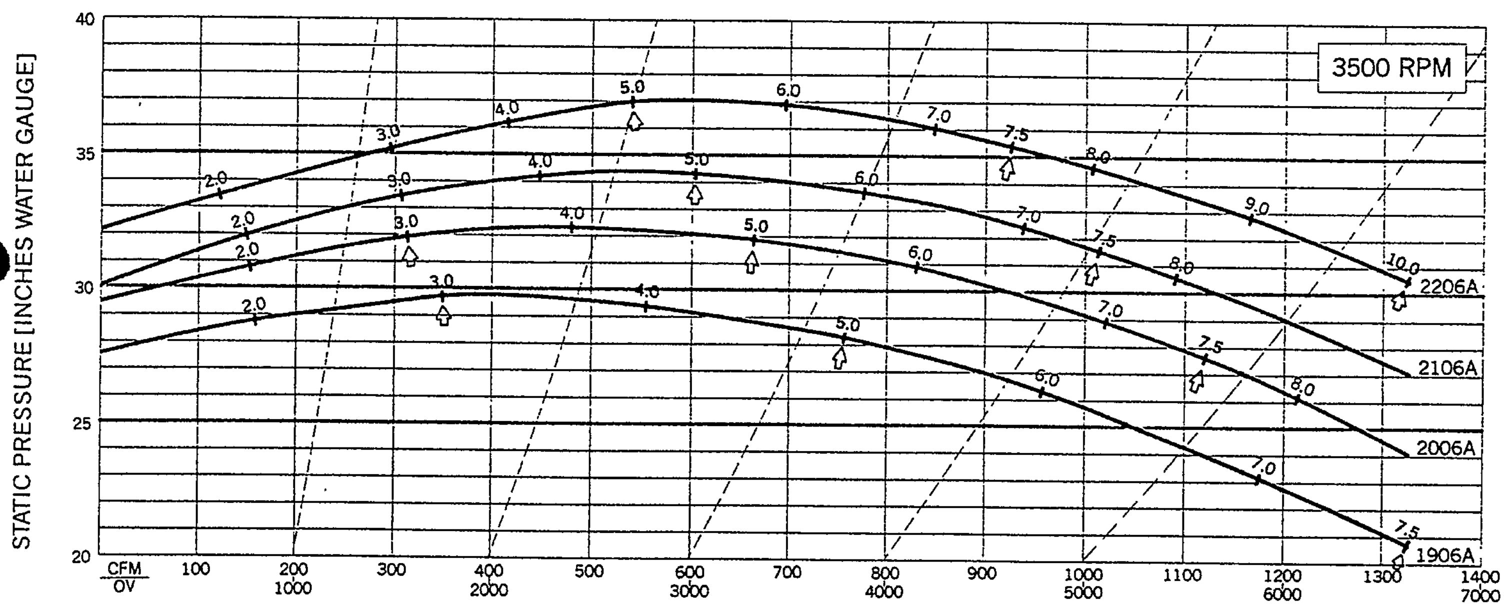
C J Saunders
Technical Rep

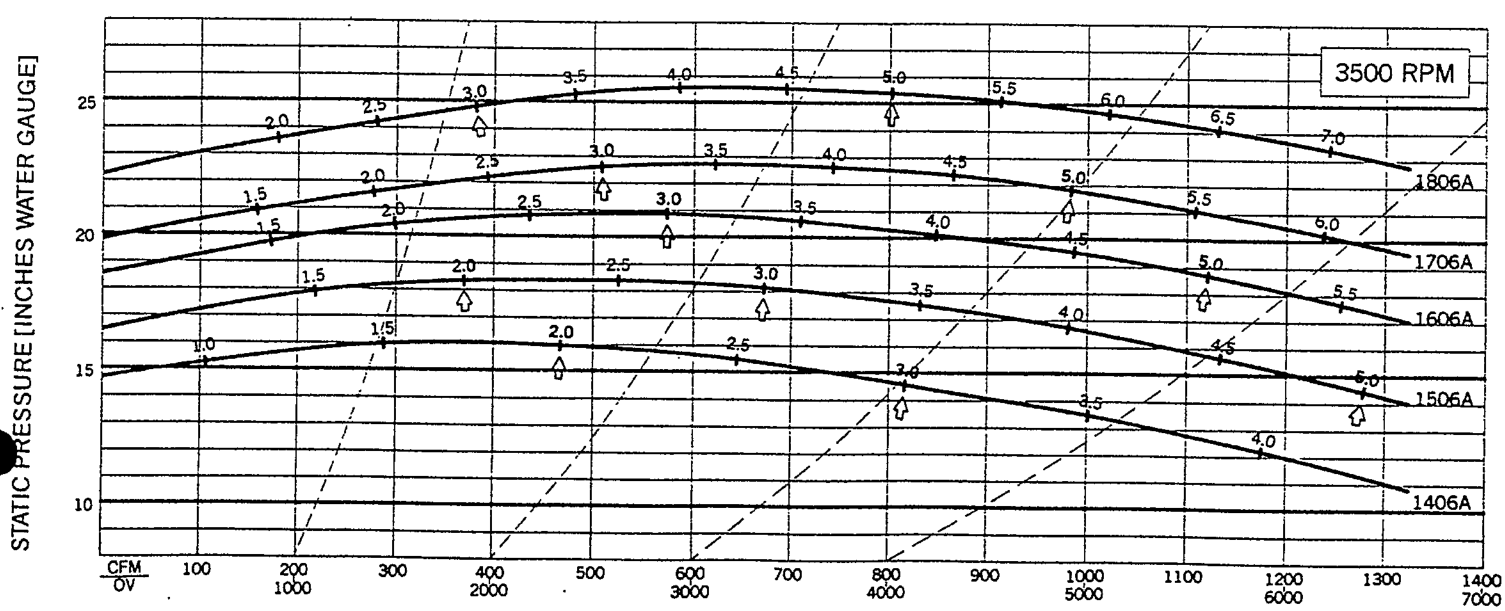
06 OUTLET SIZE

Performance shown is for Pressure Blowers with outlet duct and with or without inlet duct.

Outlet area: .20 sq. ft.







Continental Environmental Services
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SOUTHEAST OFFICE
TEL: (800) 342-1103
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2300 NW 71 PL • GAINESVILLE, FL 32606

November 18, 1993

Mike Thibodeau
Geonetics Corp
5120 S Lakeland Dr
Ste 1
Lakeland, FL 33813

QUOTE# CJ3692 DELIVERY:6-8WEEKS ARO-BASED ON AVAILABILITY
FOB:RALEIGH,NC TERMS: NET 30 FIRM FOR 60 DAYS

This proposal was prepared using the following design criteria: 40GPM flow rate - petroleum hydrocarbon contaminated water - Durham NC - Teer Co. site:

1	Model 48DA1T7.5 Low Profile Diffused Aerator Stripper & Stand(see encl)	$ 9375.00
1	Model 40FGB2L Carbon System (see enclosures)	$11550.00
16	12"x52" Carbon Vessels @ $325.00eachRENTAL = Eight to be exchanged at a time @ $325.00 each, every six months or sooner if required.	$ 5200.00
1	Main System Control Panel for all CES equipment (The main control panel can also include the recovery well pump controller)(see encl)	N/C
	Delivery & Installation parts and labor	$ 2500.00
	TOTAL :	**$28625.00**

Options for the above system are:

1	Model 4GWRS - 4 recovery well pump controller the standard price for this controller with 3 intrinsically safe level sensors per well with 25' of cable each & 25' of product hose per well is $4650.00. We will offer 10% off as an introductory offer to you.	$ 4185.00
4	Model 10S05-9 Grundfos Stainless Pumps with 25' power cable each @ $473.00 cables & hose available in longer lengths.	$ 1892.00
1	Four Well Inlet Manifold	$ 920.00

CES will combine all equipment above into a fully functional system. PLEASE SEE ENCLOSED CONDITIONS OF INSTALLATION.

Sincerely,

C J Saunders

C J Saunders
Technical Rep

Continental Groundwater Recovery System

Multi-well Controller and Groundwater Recovery Pumps
Model GWRS

one to eight pump system
Most flow rates available

The Continental Multiwell Controller allows up to eight groundwater depression pumps to be operated from one control panel. This translates to lower equipment cost as compared to multiple controllers. The controller uses an intrinsically safe conductance type probe system. The probes are adjustable to allow for changing site conditions. The controller is compatible with all two-wire submersible pumps. The controller has an internal failsafe circuit that will turn off all pumps if the treatment system fails.

POWER REQUIREMENTS:	(1) 120 v circuit, 15 amp (1-8) 220 v circuits, 20 amp (one for each pump controlled)
SENSOR TYPE:	(3) stainless steel electrodes per well connected to intrinsically safe relay; 75 feet of sensor cable per well
PUMP:	Myers Submersible Remediation Pumps OR Grundfos-Redi-Flo Submersible Pumps
MOTOR LEAD:	25 feet, 14 gauge Super Vu-Tron III chemical resistant cable
DISCHARGE LINE:	25 feet 1" Flexible Fuel Line (longer cables and lines available)

CONTINENTAL
ENVIRONMENTAL
SERVICES

SPECIFICIATIONS

4/27/93

Inlet Flow Regulating Manifold

Model:	Inlet Flow Regulating Manifold, mounted vertically
Flow Meter:	1-20 GPM Blue - White Industries F-400N Series/one per well
Throttling Valve:	1" Brass Globe/one per well
Pressure Gauge:	1-100 PSI/one per well
Sample Port:	Celon hose bibb/one per well

Specifications subject to change.

Main System Control Panel

The Continental Environmental Services' Main System Control Panel integrates all system components on a site. The control panel provides a maunal-off-automatic switch and a power on light for each pump. High level alarms are provided where required and have an indicating light on the panel door. All alarms are interfaced to turn off the recovery pumps. The control panel automatically restarts the recovery pumps when all alarms are satisfied. Custom designs are available.

Enclosure:	Nema 4 outside Nema 12 inside
Power Requirements:	120 V 15 amp
Controls:	PLC and electromechanical

Continental
Environmental
Services

CONTINENTAL ENVIRONMENTAL SERVICES

Innovators in contaminated groundwater cleanup

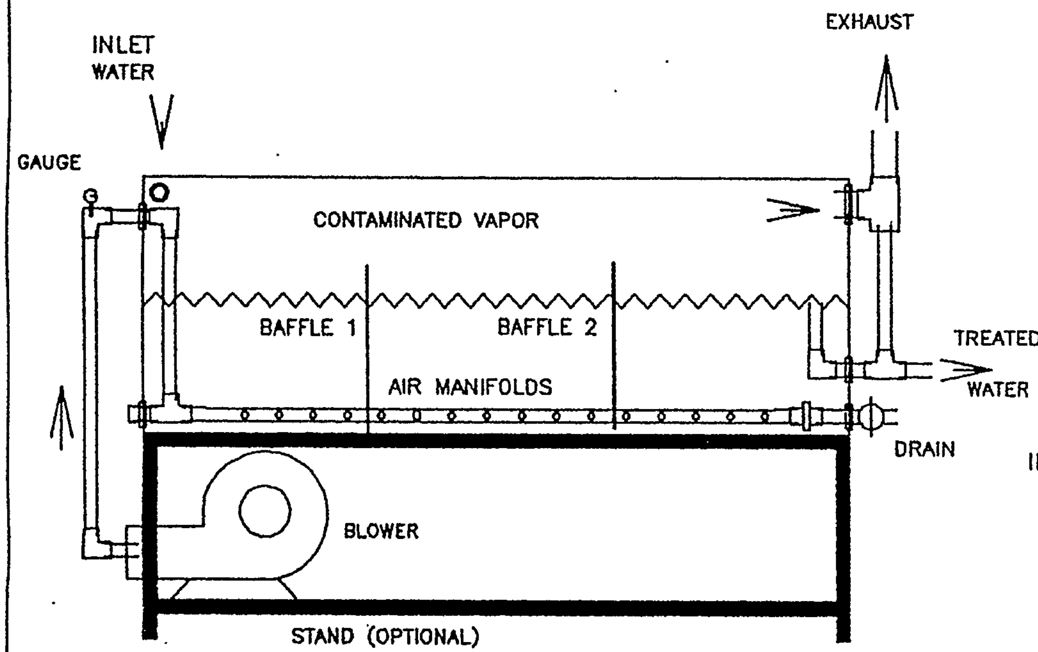
SPECIFICATIONS

3/9/93

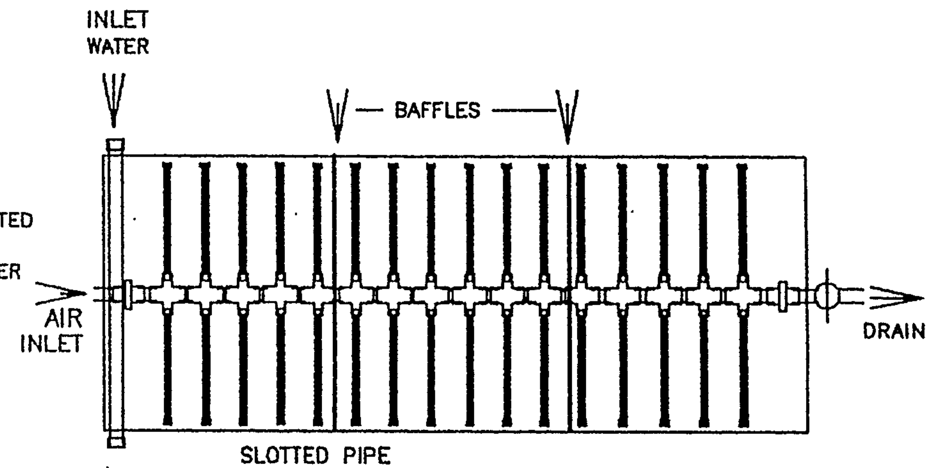
48DA1T7.5

Model:	48DA1T7.5, Multi-staged, Low Profile Diffused Aerator with minihelic gauge and pressure switch and Nema 4 motor starter
Dimensions:	8' L x 4' W x 3' H
Water Inlet:	2" MPT
Water Outlet:	4" MPT
Air Inlet:	4" MPT
Air Outet:	Two - 4" MPT
Water Volume:	360 gallons
Water Depth:	18"
Air Distributors:	Twenty-four - 1" D x 18" L - .050" slots, 3/16" apart
Air Flow Rate:	1200 CFM @ 22" H20
Air to Water Ratio:	225 to 1 @ 40 GPM, 300 to 1 @ 30 GPM, 450 to 1 @ 20 GPM, 900 to 1 @ 10 GPM
Contact Time:	9 min. @ 40 GPM, 12 min. @ 30 GPM, 18 min. @ 20 GPM, 36 min. @ 10 GPM
Blowers:	New York Blower, 1904A7.5-7.5Hp, Single Phase, TEFC (also available with XP, 3 phase)
Power Requirement:	230 volt, 30 amp

Specifications subjet to change.



SIDE VIEW



TOP VIEW

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CONTINENTAL ENVIRONMENTAL SERVICES
GAINESVILLE, FLORIDA

NORRIS ROSZEL		DALE GANN
NOT TO SCALE	2/5/93	

SPECIFICATIONS

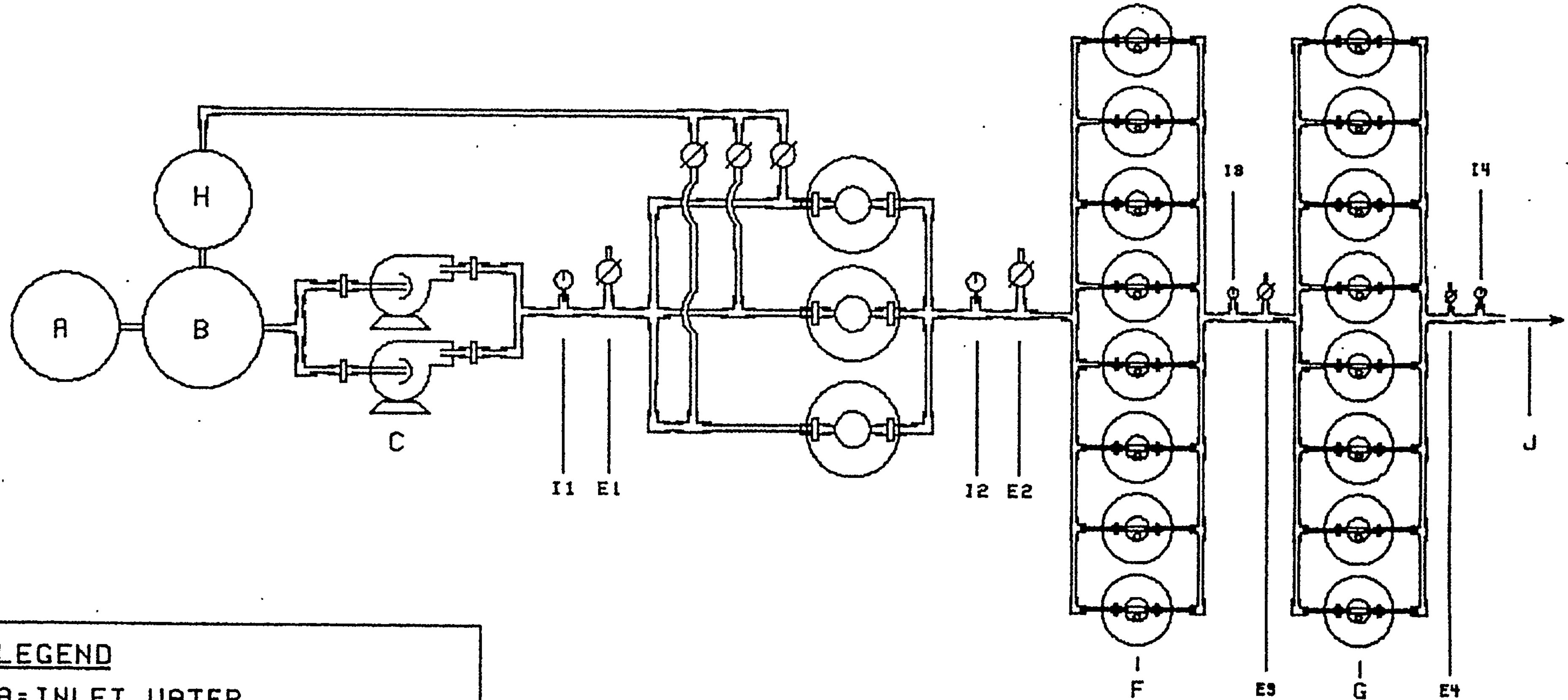
9/22/93

40FGB2L, Automatic Backwashing System

Model:	40FGB2L, 40 GPM Fiberglass tank adsorption system, automatic backwashing prefiltration, liquid phase tanks in series
Sump:	155 gallon, 36" D x 36" H Polyethylene
Pumps:	Two - 3 Hp Centrifugal
Particle Filters:	Three - 22" D x 54" H
Filtration Media:	Filter-Ag non-hydrous aluminum silicate
Carbon Filters:	Sixteen - 12" D x 52" H Fiberglass Vessels
Activated Carbon:	8 x 30 mesh iodine number 950 3.4 cubic feet (95 pounds) per vessel
Contact Time:	10.1 min. @ 40 GPM
Hydraulic Loading Rate:	6.3 GPM/Sq. Ft. @ 40 GPM
Maximum Pressure:	75 PSI
Installation Area:	12' x 13'
Power Requirements:	One - 110 V 15 amp circuit Two - 220 V 20 amp circuit

Specifications subject to change.

40 GPM HYDROCARBON REMOVAL SYSTEM



LEGEND

A=INLET WATER
B=SUMP
C=REPRESSURIZATION PUMPS
D=PARTICLE FILTERS
E=SAMPLE PORTS
F=GAC FILTERS (STAGE 1)
G=GAC FILTERS (STAGE 2)
H=BACKWASH TRICKLE FILTER
I=PRESSURE GAUGES
J=TREATED WATER

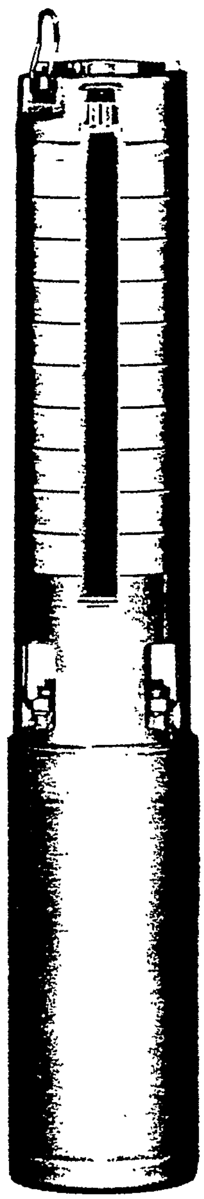
DESIGNED FOR:			
PROJECT			
DESIGNED BY: CES	DRAFTED BY: NOR	CODE 40FGB2L	CHECKED DALE GANN ENV. ENGR.
CONTINENTAL ENVIRONMENTAL SERVICES		DATE 2/2/91	

MODEL
10S

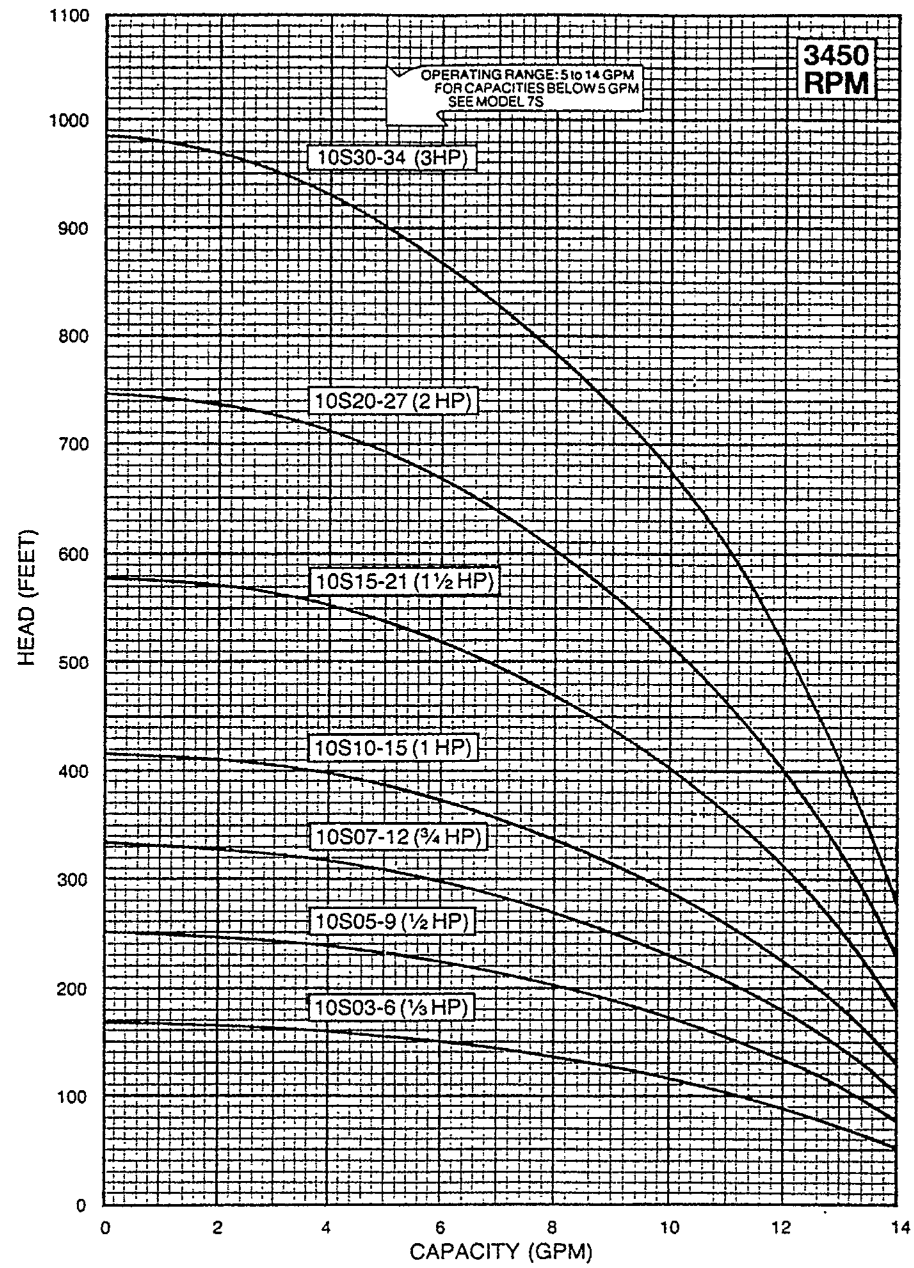
10 GPM

GRUNDFOS

FLOW RANGE
5 to 14 GPM
PUMP OUTLET
1¼" NPT



PERFORMANCE CURVES



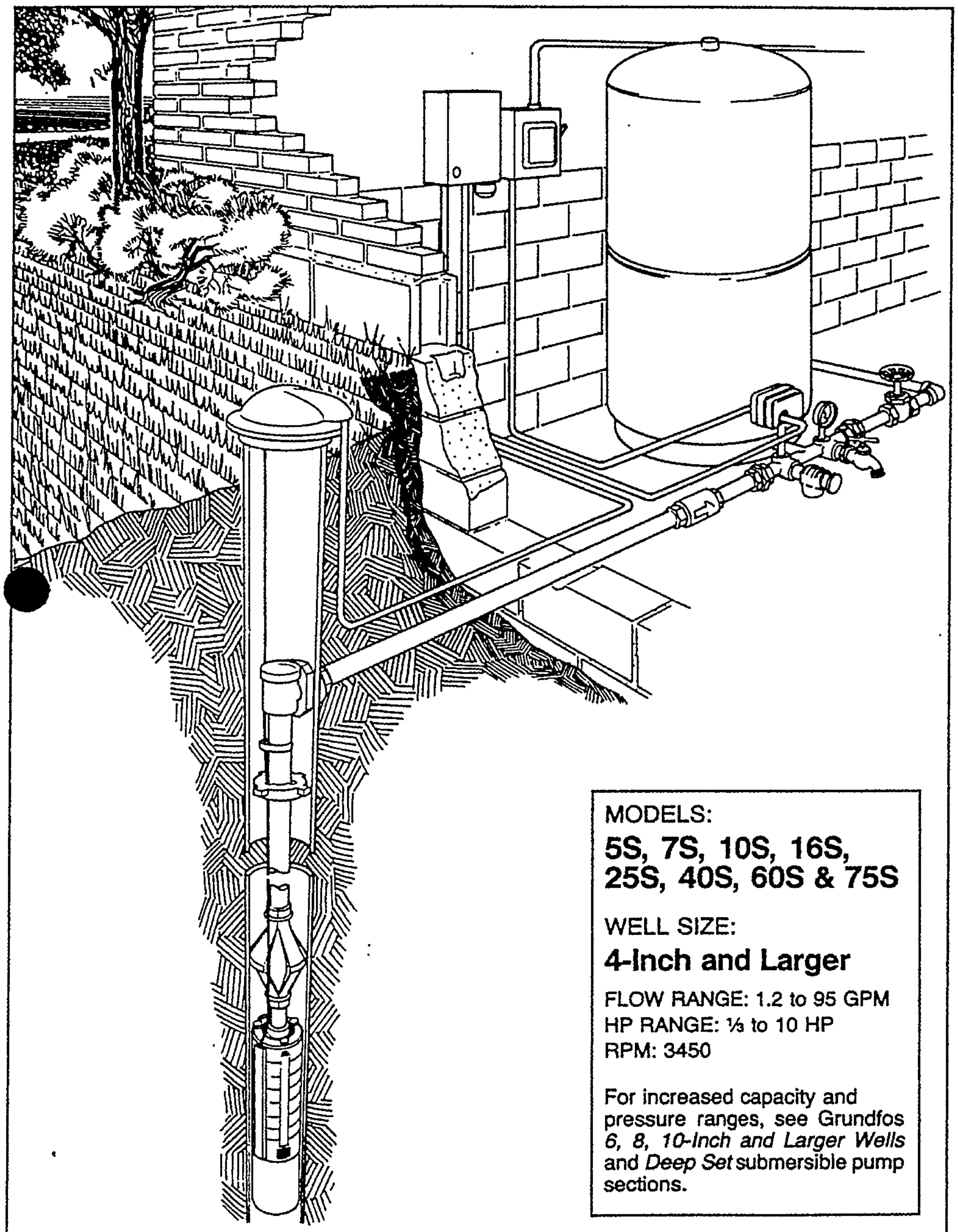
DIMENSIONS AND WEIGHTS

MODEL NO.	HP	LENGTH (INCHES)	WIDTH (INCHES)	APPROX. UNIT SHIPPING WT. (LBS.)
10S03-6	⅓	21 ⅝	3 15/16	26
10S05-9	½	24 ⅝	3 15/16	29
10S07-12	¾	27 ⅝	3 15/16	32
10S10-15	1	30 ½	3 15/16	34
10S15-21	1 ½	37 ⅞	3 15/16	44
10S20-27	2	42	3 15/16	49
10S30-34	3	54 ⅞	3 15/16	83

Specifications are subject to change without notice.

GRUNDFOS 4-inch Stainless Steel Submersible Pumps

- General
- Curves and Charts
- Materials of Construction



MODELS:

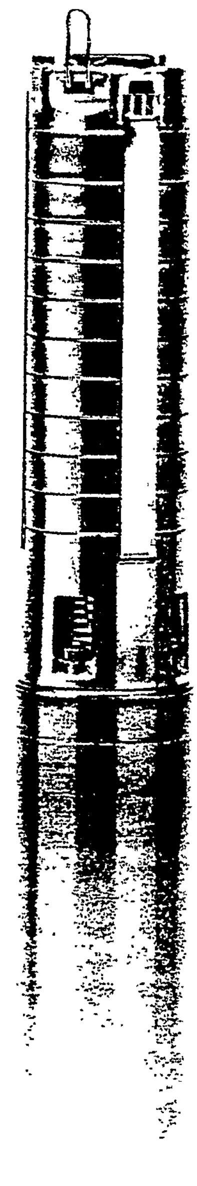
5S, 7S, 10S, 16S, 25S, 40S, 60S & 75S

WELL SIZE:

4-Inch and Larger

FLOW RANGE: 1.2 to 95 GPM
HP RANGE: ⅓ to 10 HP
RPM: 3450

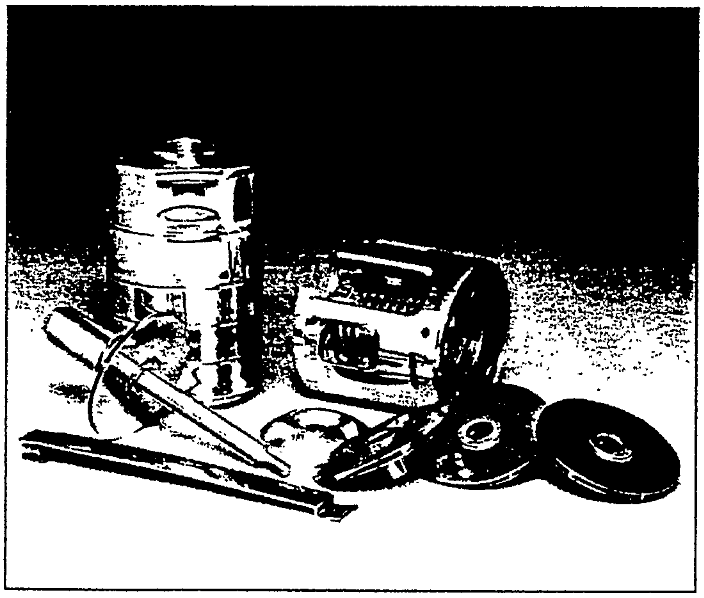
For increased capacity and pressure ranges, see Grundfos *6, 8, 10-Inch and Larger Wells* and *Deep Set* submersible pump sections.

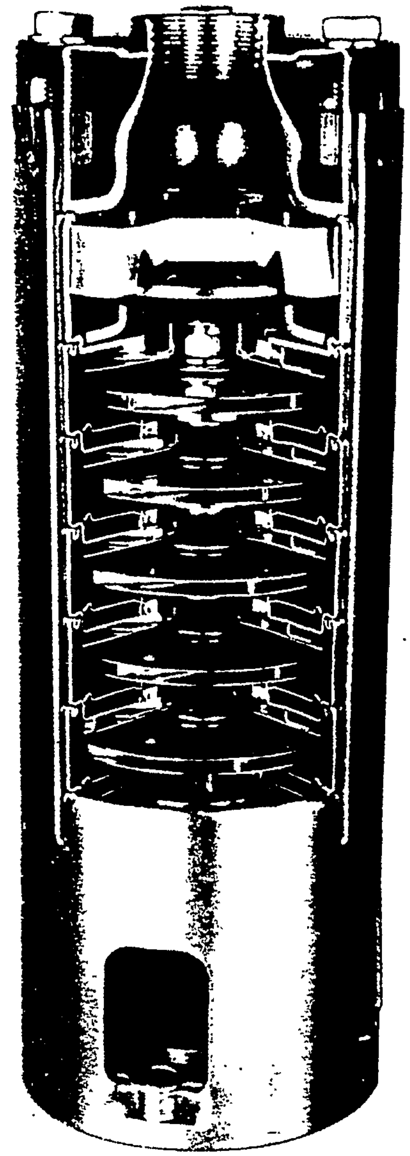


APPLICATIONS: Residential water supply for 4-inch and larger wells.

Pump Selection Guide

MODEL	MIN. WELL SIZE	FLOW RANGE (GPM)	MAX. WORKING HEAD (FEET)	MAX. WORKING HEAD (PSI)
5S	4"	1.2-7	870	377
7S	4"	3-10	680	294
10S	4"	5-14	900	390
16S	4"	10-20	980	424
25S	4"	18-32	630	273
40S	4"	24-55	755	327
60S	4"	40-75	505	219
75S	4"	45-95	460	199

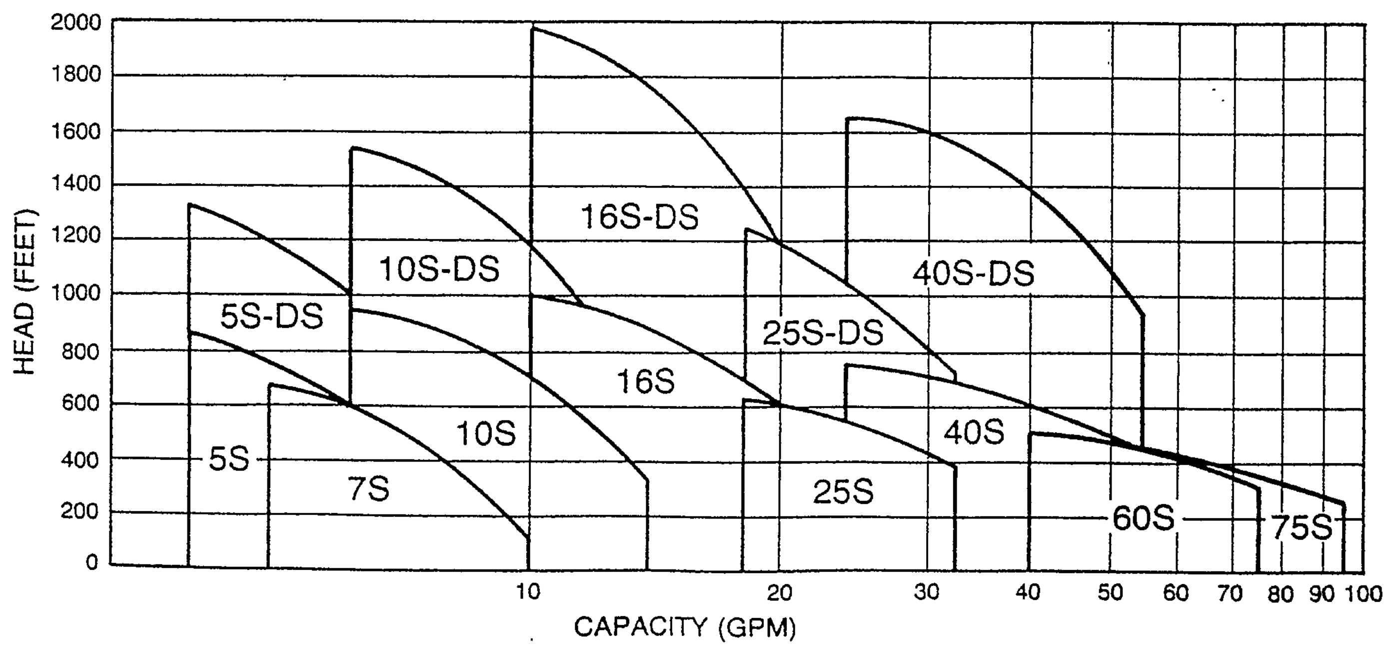




Features

- ☑ Smooth safety hook prevents frayed safety line.
- ☑ Built-in, jam-free check valve designed for failsafe operation.
- ☑ ***SnapGuard***™ cable guard is designed for easy installation and removal. Holds tight and provides maximum protection to motor leads.
- ☑ ***PrecisionForm***™ impellers are fabricated from stainless steel to provide long pump life, maximum hydraulic efficiency and top pump performance.
- ☑ Exclusive ***PrimeInducer***™ provides maximum pump protection from dry-run damage during low water situations.
- ☑ Pump inlet is totally screened to prevent damage from debris.
- ☑ All Grundfos submersibles are performance tested at the factory to verify specified performance.

4-Inch



NOTE: For Deep Set models see Section 4.

CONTINENTAL ENVIRONMENTAL SERVICES
Innovators in contaminated groundwater cleanup

CORPORATE OFFICE
TEL: (800) 342-1103
FAX: (904) 373-7660

CONDITIONS OF INSTALLATION

Continental Environmental Services will provide the following for installation:

- All equipment quoted.

- Installation
  A. Plumb from pretreatment on equipment pad to collection sump.
  B. Plumb from carbon effluent to drain line on equipment pad.
  C. Plumb all CES-owned equipment.
  D. Wire CES equipment.

- Start Up, if client's obligations are met
  A. CES equipment will be operational before the installer leaves.
  B. Adjust CES equipment so that it interacts properly with client's equipment, provided client's equipment is operational.
  C. Operator training is provided for maintenance and troubleshooting procedures.

- Activated Carbon Exchange
  A. Breakthrough will be determined by the client.
  B. Exhausted carbon will be properly disposed of.

Client will provide the following for installation:

A. Concrete pad of appropriate size with collection sump installed. Upon ordering, CES will ship appropriate sump for installation at your pad.
B. Electrical service during installation for tools and system checks.
C. Permanent electrical service to pad hard-wired into CES' control panel.
D. Plumb from recovery pumps to the pad.
In the event that CES provides depression pump equipment, client will provide plumbing, sensor wires, and power wiring from well (s) to treatment area.
CES can provide, with notice prior to site prep, installation of plumbing and wiring in client's 4" to 6" conduit.
Before installation date, client must have ready each well for the installation of the depression pump equipment, i.e. developed.
E. Water supply for start up if client's system is not operational.
F. Client will install all non-CES equipment.
G. Plumb system discharge line from pad to drain.
H. Freeze protection where required. Available from CES.
I. All permits.
J. Ready access to equipment pad.

- For faster start-ups, the above requirements need to be met before or soon after CES personnel arrive on site.

- If CES personnel complete the installation and are unable to perform start-up because of the client's unsatisfactory completion of the above requirements. CES personnel may be required to return at a later date for start-up.

- The client will be responsible and will be assessed the appropriate labor and mileage charges for the return services.

Please call your technical representative for any questions or concerns you may have about CES or your responsibilities for installation of CES systems. We look forward to serving you to the best of our abilities.

THANK YOU,
CONTINENTAL ENVIRONMENTAL SERVICES

07/02/92

FILTRATION AND GRANULAR ACTIVATED CARBON SYSTEMS

Low maintenance filtration and activated carbon systems for organic removal from groundwater are available from GeoPure . Filtration and granular activated systems feature:

Delivery of effluent at below detectable levels for most volatiles, pesticides, herbicides, and semivolatiles.

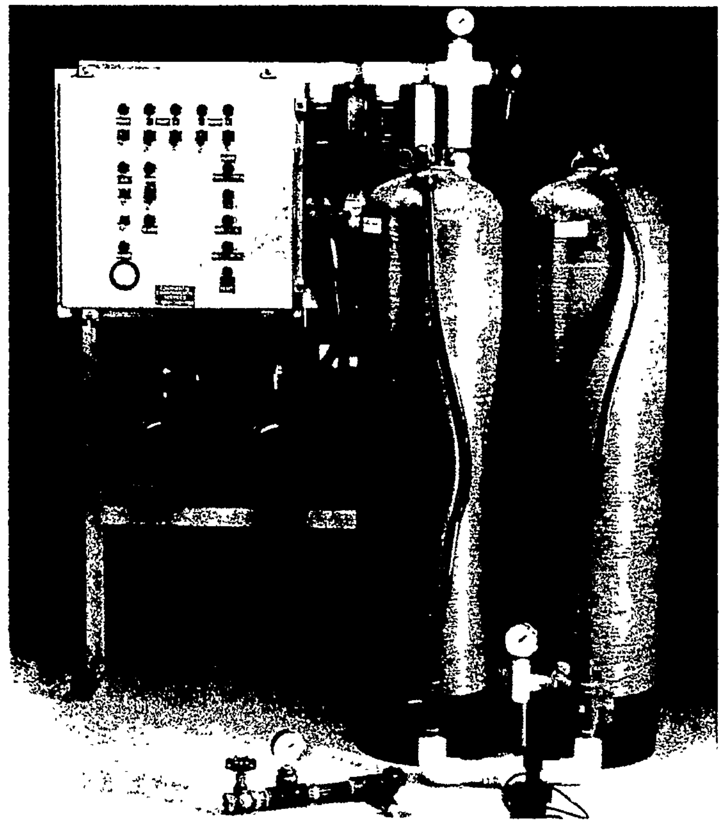
Automatic backwashing filters protect carbon from pluggage and premature exhaustion.

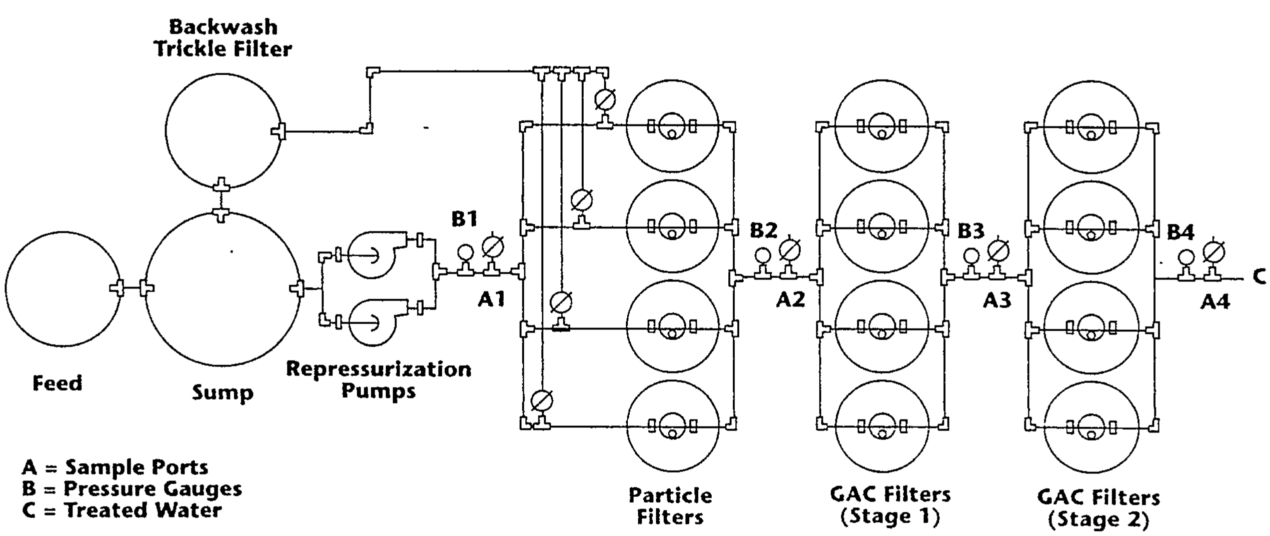
For use alone or as polisher for diffused aerator or air stripper.

Available with a variety of service contracts for routine maintenance and carbon exchanges.

Rust-proof fiberglass vessels or pressurized high flow steel vessels.

Systems available up to 250 GPM.





Drawing of Model 20FGB2L, above, shows position of GeoPure equipment following air stripping tower, oil water separator or diffused aerator. Can be used following recovery wells when carbon only is required.

GEOPURE CONTINENTAL

Your Partner for a Clean Environment

CORPORATE HEADQUARTERS: P.O. BOX 5039 GAINESVILLE, FL 32602 1-800-342-1103 FAX (904) 373-7660

SPECIFICATIONS

	MODEL			
Parameters	**10FGB2L**	**20FGB2L**	**50HPB2L**	**200HPB2L**
Flow Rate (GPM)	1-10	16-20	40-50	175-200
Pumps (type and Hp, 2 of each)	Jet 3/4 HP	Jet 1.5 HP	3 HP Centrifugal	10 HP Centrifugal
Automatic Backwashing Prefilters (Quantity/Diameter x Height)	2 12″ x 53″	4 12″ x 52″	4 22″ x 54″	2 42″ x 72″
Carbon Filters (Quantity)	4	8	2	4
Activated Carbon (in pounds)	380	760	1000	1800
Contact Time (EBCT in minutes)	10	10	10.1	9.8
Hydraulic Loading Rate (GPM/square feet)	6.3	6.3	6.3	6.3
Maximum Pressure (PSI)	75	75	75	75
Installation Area (in feet)	6 x 12	8 x 12	12 x 14	20 x 26

SPECIFICATIONS SUBJECT TO CHANGE.

GeoPure equipment and services include:

Technical assistance, installation and maintenance services.

Liquid phase activated carbon.

Vapor phase activated carbon.

Spent carbon handling for EPA-classified non-hazardous contaminants.

1 to 500 GPM pressurized remediation systems.

1 to 2500 CFM vapor phase steel drum systems.

Steel pressure vessels and carbon units up to 10 feet in diameter.

GEOPURE
CONTINENTAL

DIFFUSED AERATOR

For efficient, economical removal of organic contaminants in groundwater, the GeoPure Diffused Aerator features:

Fewer fouling problems than with packed air stripping towers.

No packing to clean or replace; easy to maintain.

Includes failsafe to integrate with other equipment.

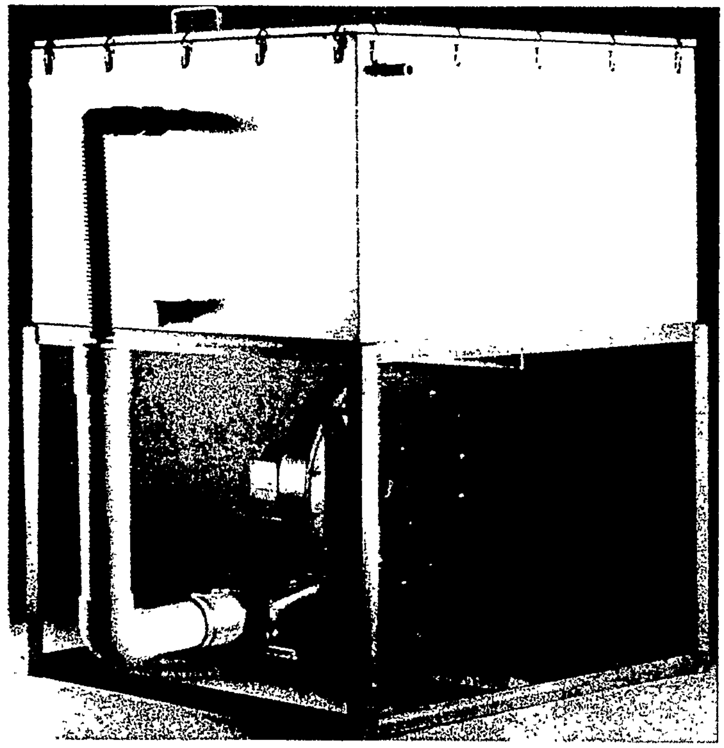
Low profile; fits easily into an equipment room or system housing.

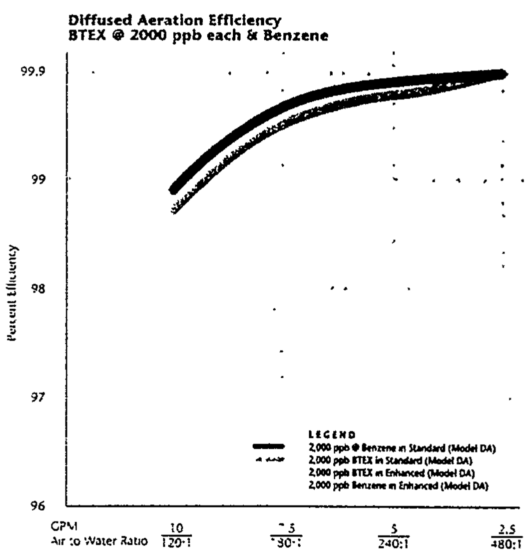
High air to water ratio: at least 95 to 1 depending on model.

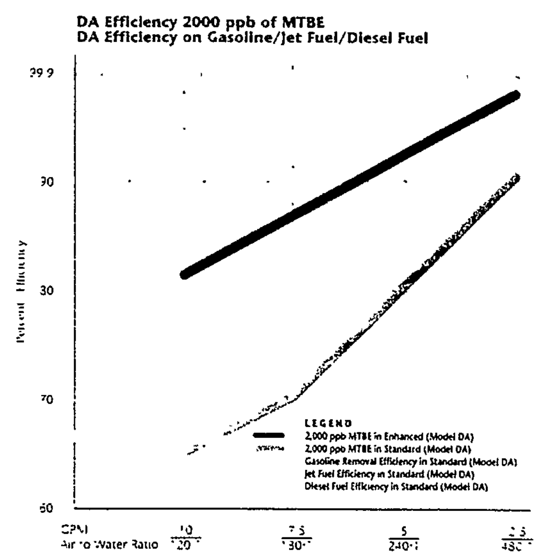
Explosion-proof available.

Air emission treatment systems and effluent carbon polishing available.

Lower cost than packed towers.







GEOPURE CONTINENTAL
SYSTEMS & SERVICES
formerly Continental Environmental Services

Your Partner for a Clean Environment

CORPORATE HEADQUARTERS: P.O. BOX 5039 GAINESVILLE, FL 32602 / 1-800-342-1103 FAX (904) 373-7660

Process Description

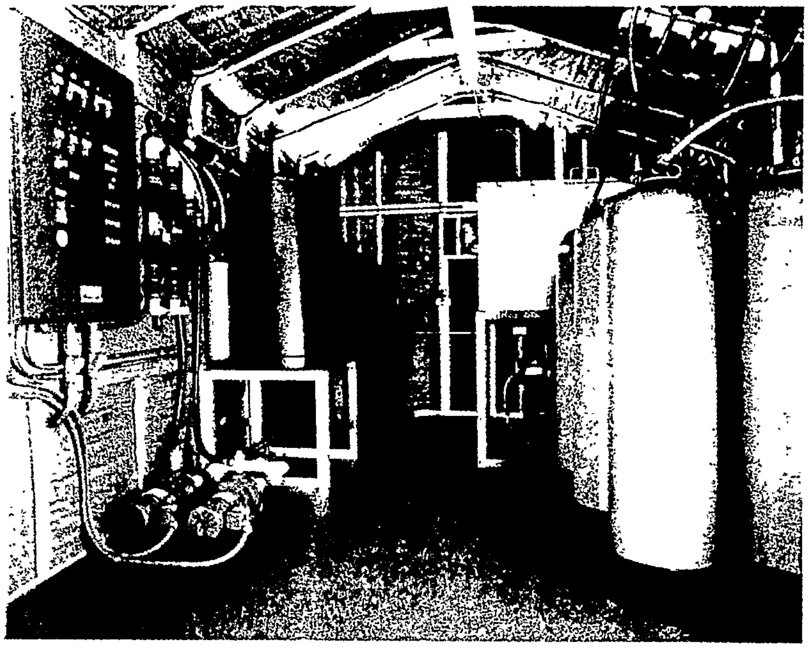
In a diffused aeration system, a blower directs air into a tank of water through diffusers that produce fine bubbles. Water enters the tank through spray nozzles at one end of the unit. This removes a measurable amount of contaminants. As the water aerates, contaminants fill the bubbles until they are saturated. Exhaust air is released into the atmosphere through an exhaust stack or is treated according to local air regulations. Treated water exits the unit for discharge or activated carbon polishing.

SPECIFICATIONS

Parameters	44DA1X2	36DA1X3	38DA1T5	48DA3T5	88DA3T7.5	88DA3T10
Dimensions	4'W x 4'L	3'W x 6'L	3'W x 8'L	4'W x 8'L	8'W x 8'L	8'W x 8'L
Contact Time	17.9 min @ 10 GPM	10.1 min @ 20 GPM	8.9 min @ 30 GPM	8.9 min @ 40 GPM	9.6 min @ 75 GPM	7.2 min @ 100 GPM
Max. Flow Rate	10 GPM	20 GPM	30 GPM	40 GPM	75 GPM	100 GPM
Air Flow Rate	220 CFM	400 CFM	700 CFM	700 CFM	1200 CFM	1400 CFM
Tank Volume	179	202	269	359	718	718
Air to Water Ratio	202 to 1 @ 10 GPM	150 to 1 @ 20 GPM	175 to 1 @ 30 GPM	131 to 1 @ 40 GPM	120 to 1 @ 75 GPM	105 to 1 @ 100 GPM
Blower	2 Hp Exp. Proof	3 Hp Exp. Proof	5 Hp 3 Phase	5 Hp 3 Phase	7.5 Hp 3 Phase	10 Hp 3 Phase

SIZES UP TO 250 GPM AVAILABLE. SPECIFICATIONS SUBJECT TO CHANGE.

INTEGRATED SYSTEM



Typical Integrated System Process Description

The fully integrated ground water remediation system from GeoPure Continental Systems & Services can include recovery pumps, oil water separator, primary collection sump, transfer pump, 44DA1X2 diffused aeration tank and 10FGB2L activated carbon system. The GeoPure controller can control from one to eight wells.

Contaminated groundwater is recovered by a pneumatic or electric system. The air supply to the pneumatic pumps is controlled by a solenoid valve that is controlled by the GeoPure controller alarm circuits. The electric pumps are controlled by intrinsically safe electrodes in the well.

Recovered groundwater is pumped into the oil water separator. Any product is skimmed off and gravity flows to the product recovery tank. When the product tank is full, an explosion-proof float switch sends a signal to the GeoPure controller which turns off the recovery pumps and turns on a high level alarm light on the controller.

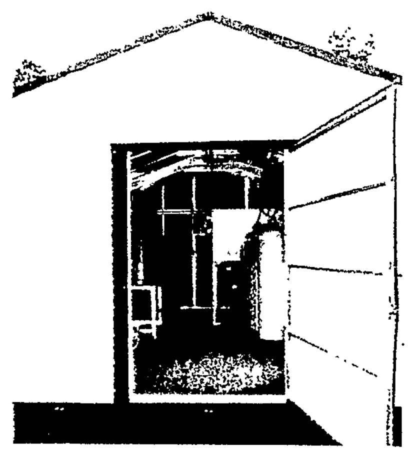
The water then gravity flows to the primary collection sump. This sump has three float switches that are connected to the controller. The lower floats control the transfer pump. There is a hand-off-auto selector switch on the controller for the transfer pump along with a green-for-on indicator light. The third float indicates high level in the sump. High level turns on a red alarm indicator on the controller and turns off the recovery pumps.

The transfer pump pumps the contaminated water to the 44DA1X2 Diffused Aeration tank. A blower blows air through diffusers in the bottom of the tank. Organics in the water are removed and exit the tank with the exhaust air.

Treated water from the 44DA1X2 gravity flows into the 10FGB2L collection sump. The sump contains five float switches that are connected to the controller. The lowest float turns the pumps off and resets the high level alarm during the backwash cycle. The second float turns the transfer pumps off and resets the high level alarm during normal operation. The third pump starts the lead pump. The fourth float starts the lag pump. The fifth float puts the system into alarm. On high-level alarm, the controller will turn off the recovery pumps and turn on an alarm indicator light on the control panel. There are two hand-off-auto selector switches and two green-for-on indicator lights on the controller for the two 10FGB2L transfer pumps.

A set of lead-lag pumps pump water through the backwash valve assembly. The valve assembly is operated by the controller. The controller sends a signal to the valves once a day to initiate the backwashing of the particle filters. The backwash water from the particle filters goes to the trickle filter where the particles settle out and the water is recycled back to the collection sump.

Water flows from the particle filters to the dual stage carbon filters. The dual stage arrangement allows for detection of breakthrough of the first stage while not discharging any contaminants through the second stage. The water is then discharged.



TOP PHOTO: The integrated system is complete with necessary instrumentation to control from one to eight wells. ABOVE: The system can be conveniently housed in a weatherproof building.

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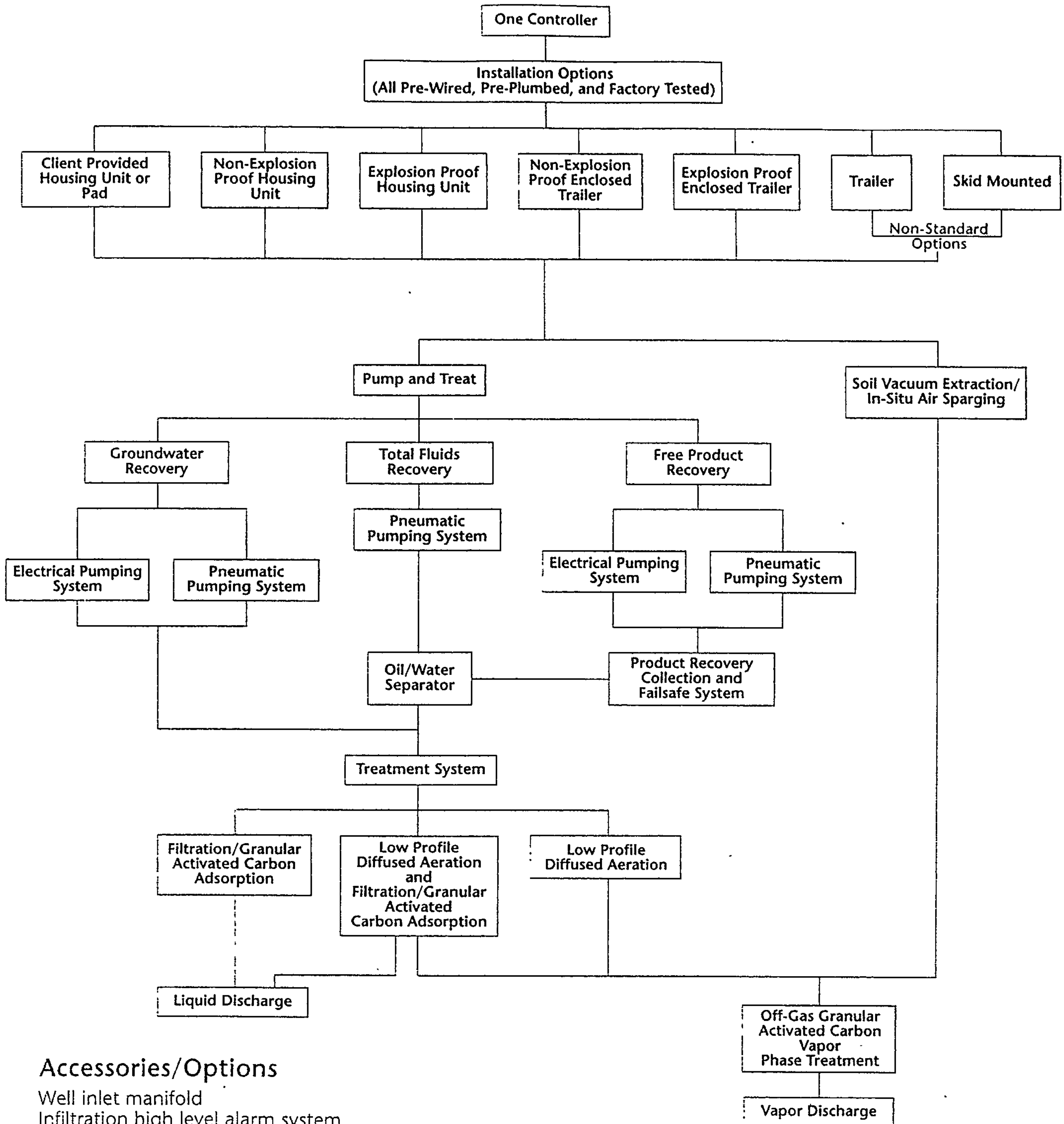


Accessories/Options

Well inlet manifold
Infiltration high level alarm system
Enhanced performance model diffused aerator
Replacement diffuser assembly
Rental manifolds to 500 GPM
Filters
Interface probes
Portable adsorption system for sampling/purge water treatment
Repressurization systems — Transfer pumps
Iron filter systems
Nutrient feed systems
Compressors with air prep packages and failsafe system
Vapor sampling collection systems
Remote telemetry
Soil vacuum extraction well manifold

Continental Environmental Services

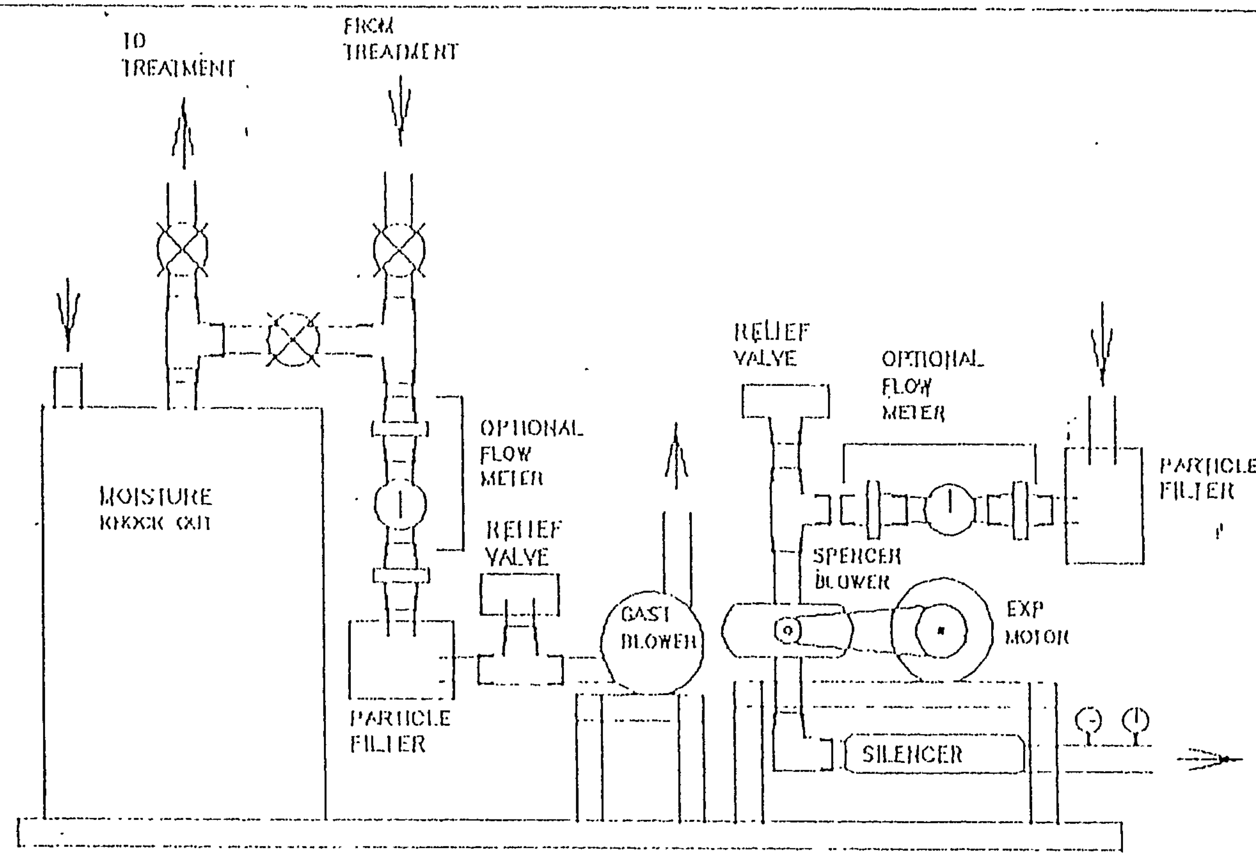
SPECIFICATIONS

8/19/93

25IAS, In-Situ Air Sparging System

Model:	25IAS, In-Situ Air Sparging System
Dimensions:	25" W x 54" L x 60" H
Outlet:	2"
Blower:	Spencer Lobe-Aire, Model RBL10, 3hp, (25 CFM at 6 PSI), motor starter with thermal overload, rugged construction, low maintenance
Inlet Filter:	Stoddard, Model F641.5
Relief Valve:	1
Flow Measurement:	Dwyer Magnehelic Differential Pressure Guage, 0 -2" Water, with pitot tube
Power Requirement:	115/230 volt, Single Phase, 30 amp, 60 Hz
Silencers:	Two - Universal, Model 1151.5
Pressure Guage:	0 - 15 PSI

Specifications subject to change.



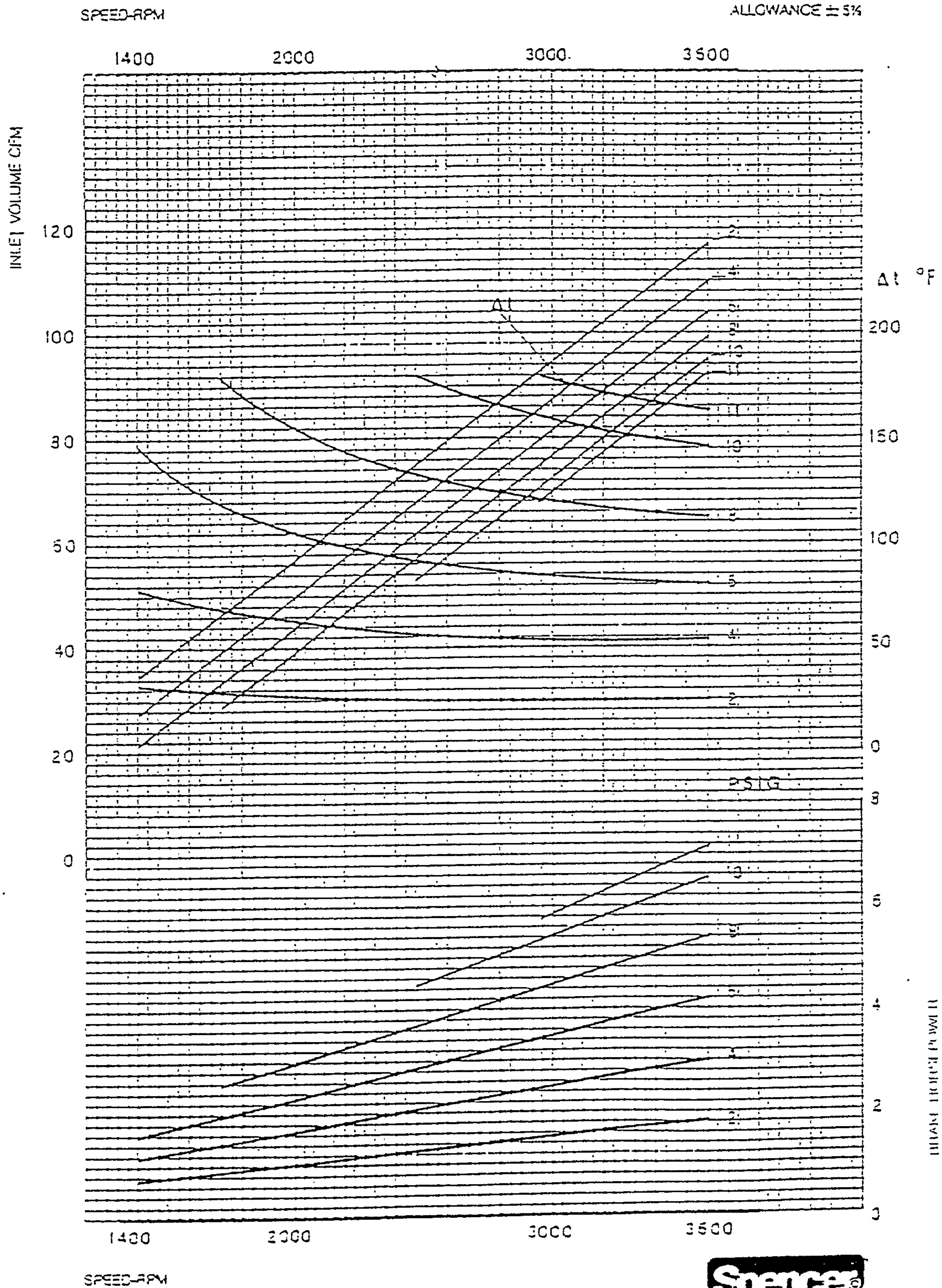
SPARGE/VENT SYSTEM		
NORRIS ROSZEL	SPARVENT	DALE GANN
NOT TO SCALE	6/9/93	

LOBE-AIRE™

SECTION—500
PAGE—501
PRESSURE PERFORMANCES
JULY 1989

CURVE DATA BASED ON INLET CONDITIONS OF 14.7 PSIA, 68°F AND 36% R.H., SUBJECT TO A ± 5% VARIANCE

See Section 300, Engineering For Information Regarding V-Belt Drive.



JOB NAME
EQUIPMENT
CUSTOMER
DATE
SPENCER
CUST. P.O.#
PER

Spencer

CONTINENTAL ENVIRONMENTAL SERVICES

Innovators in contaminated groundwater cleanup

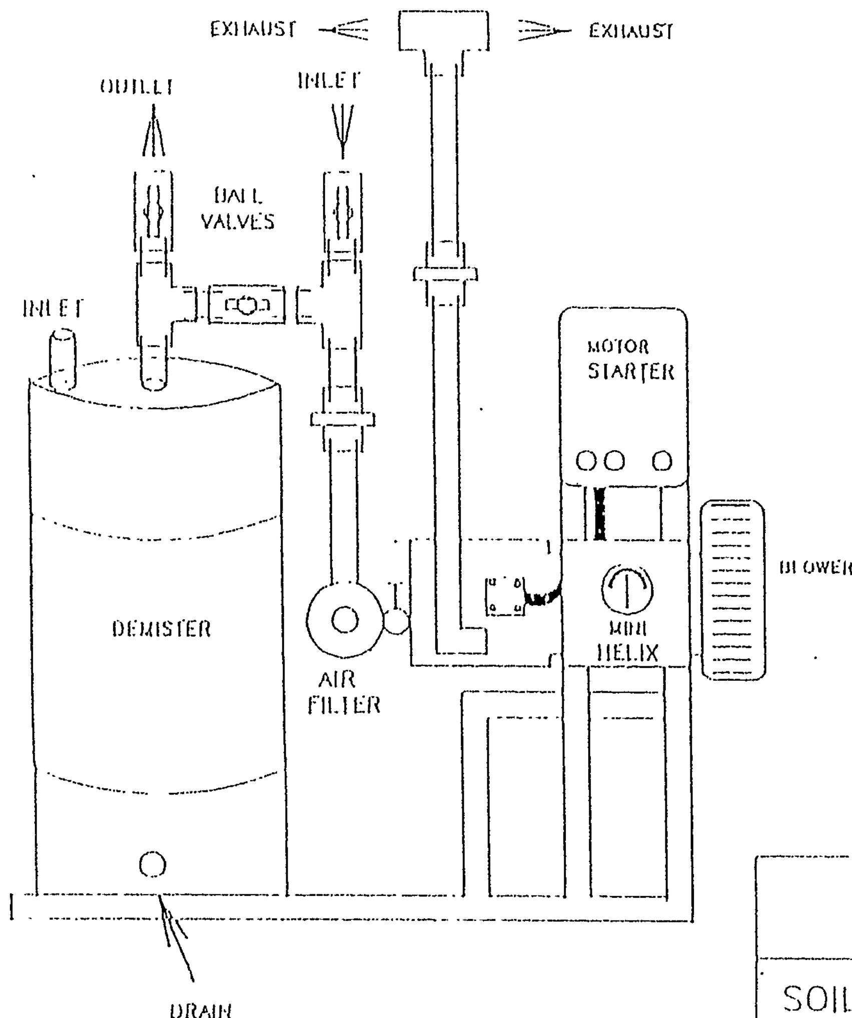
SPECIFICATIONS

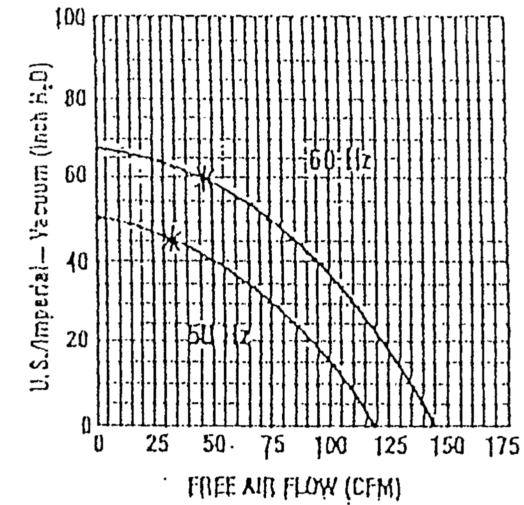
4/28/93

100SVE

Model:	100SVE, 100 cfm Soil Vapor Extraction System
Dimensions:	25" W x 54" L x 48" H
Inlet:	2"
Outlet:	2"
Blower:	Gast Regenerative Blower, Model R5125Q-50, 2.5 hp, 36" H2O vac. at 100 cfm flow, explosion-proof motor UL, XP motor starter with thermal overload, sealed air stream, rugged construction, low maintenance
Demister:	CES 55-gallon Mositure Separator, Model 55MS, 1/2" FPT drain
Inlet Filter:	Gast, Model AG337
Relief Valve:	Gast, Model AG258
Vacuum Gauge:	Dwyer International, 0" - 60" W.C.
Power Requirement:	115/230 volt, Single Phase, 20 amp, 60 Hz
Optional Equipment:	
Demister Pump Out	Explosion proof controls automatically pumps out water from the demsiter, pump 230 volt 1/3 Hp, explosion proof
Demister High Level:	Explosion proof level switch, turns off blower on high water level

Specifications subject to change.





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CONTINENTAL ENVIRONMENTAL SERVICES
GAINESVILLE, FLORIDA

100		
SOIL VENT SYSTEM (SIDE VIEW)		
NORRIS ROSZEL	SVESIDE	DALE CANN
NOT TO SCALE	1/9/93	

GUIDELINES FOR SPARGE/VENTING WELL PLACEMENT AND SIZING

A pilot study must be done on site to properly size and place a sparge/venting system. The test must have both the sparge and venting system running at the same time.

Monitor wells used to determine the effectiveness of a vapor extraction well should be placed with in 5-15' of the well.

Radius of influence on a vapor extraction well is approximately equal to the depth of the well that is above the water table.

Vacuum enhanced pumping does not increase the pumping rate over time. It causes up welling but as soon as that amount of water is pumped out the flow rate goes back to normal.

Passive air injection wells have very little effect on SVE.

Pulsing a SVE system does not increase the total mass recovered over time. It is better to run the system continuously.

Pressure measurements around a SVE well are no indication of flow rate.

Surface seals do not effect the efficiency of SVE.

Sampling of a SVE system can be done using a Tedlar bag in a vacuum chamber.

When using air sparging too much air can spread the contamination.

Screen sizes for the diffuser range from .020-.040".

Pressure range for sparging is equal to 1.5-3 times your breakout pressure.

Amount of air is usually 2-5 cfm per well.

Pulsing of the sparging system looks like it will get air into areas where steady state flow does not get to.

The radius of influence for a sparging well is usually 2-3' for each foot of well depth below the water table. This only holds true for wells with depths below water of greater than 5'.

Extraction rate should be 4-10 times the sparging rate.

DO and VOC measurements are the best way to determine the radius of influence for a sparging well.

It takes 3 lbs of oxygen to biodegrade 1 lb of hydrocarbons.

When concentrations get below 2PPM usually no biological degradation will occur.

Bacterial augmentation, adding designer bugs, does not necessarily increase long term effectiveness.

If the oxygen content in the air in the soil gets below 5% very little biodegradation will occur.

If a recovery trench is used for SVE high flows rates are needed not high vacuums.

Do not use single long runs of slotted pipe in a trench, use shorter lengths connected to a main collection header.

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QUOTATION

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ATTENTION: MIKE THIBODEAU
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CITY: LAKELAND STATE: ZIP:

DATE: 11/17/93
YOUR INQUIRY #/JOB:
PHONE:
FAX: 813-646-6375

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	PRINTED PIPE OK			
	3 ROWS OF SLOTS, 1/4" SPACING			
			$6540.00	

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Augmented Bioremediation of Excavated Soil Contaminated with Petroleum Hydrocarbons

by

Randall J. von Wedel, Ph.D.
CytoCulture Environmental Biotechnology
124 Washington Avenue
Point Richmond, CA 94801

ABSTRACT

Augmented bioremediation, using laboratory-selected cultures of aerobic bacteria, has been successfully applied to cleaning excavated soils contaminated with petroleum hydrocarbons. This paper will present results from 2 different treatment approaches: a soil washing leachbed method and a soil vacuum aeration method.

The augmented leachbed approach allows for the continuous recirculation of a soil washing leachate containing nutrients and hydrocarbon degrading bacteria. Contaminated soil is spread on, or returned to, a tank pit cavity lined with an impermeable liner and equipped with a leachate collection system. Emulsifiers in the leachate facilitate the desorption of hydrocarbon off the soil and into the aqueous phase. Dissolved phase hydrocarbon in the collected leachate is rapidly degraded to non-detectable levels in optimized bioreactors containing high density cultures of specialized bacteria. The closed system design minimizes loss of volatile organic compounds to the atmosphere. At one diesel contaminated UST site, clean-up of excavated soil lowered the average TPH levels from 2,100 ppm to 85 ppm in ten weeks. Similar leachfield systems are operating at two other underground storage tank sites and at a Superfund feasibility project.

The vacuum heap approach allows for the continuous aeration of multiple soil lifts where treatment work space is limited. A vacuum piping system is used to draw air through layers of contaminated soil inoculated with hydrocarbon degrading bacteria. The entire heap is enclosed with plastic liners and covers to control run-off, evaporation, volatilization and solar heating. Continual introduction of oxygen, nutrients and specialized bacterial cultures accelerates the biodegradation of heavier fractions of petroleum with minimal air stripping of volatiles. At a recently closed site in Oxnard, CA, a vacuum heap system decontaminated 2,400 cubic yards of soil from a pipeline spill involving diesel and crude oil. In the first month of treatment, the average TPH values were reduced from 6,700 ppm to 500 ppm. Site closure was approved after three months of operation, with average residual contamination levels of less than 10 ppm diesel.

This paper summarizes joint remediation projects performed around the country using Sybron Biochemical bacterial cultures and bioreactor designs developed by CytoCulture Environmental Biotechnology.

INTRODUCTION

The biodegradation of petroleum hydrocarbons can be accelerated in the treatment of contaminated excavated soils by optimizing culture conditions and introducing specialized strains of hydrocarbon-degrading organisms. This general approach of accelerating the natural degradation process is referred to as "augmented bioremediation" (ABR), first commercialized by Sybron Biochemical (Salem, VA). Numerous laboratory studies have reported on the success of using enrichment isolates of aerobic bacteria (usually *Pseudomonas* and *Bacillus* strains) to degrade model diesel fuels (1) and specific aromatic (2) or polynuclear aromatic fractions (3). Previous field demonstrations have supported the contention that laboratory-selected bacteria can facilitate the clean-up of gasoline-contaminated groundwater *in situ* (4). Recent data (5) have confirmed the efficacy of treating diesel contaminated groundwater in above-ground bioreactors with similar blends of Sybron bacteria. Dissolved phase hydrocarbon appeared readily degradable to non-detectable levels, but it was not clear how such an approach would work on solid-phase contaminations such as fuel spills in soil.

Soil treatment for hydrocarbon contamination poses new challenges in terms of hydrocarbon desorption (solid to dissolved phase) and availability of adequate oxygen, nutrients and bacteria biomass. Although several thermal and vapor extraction technologies are available for treating gasoline contaminated soils, the decontamination of heavier petroleum fractions adsorbed to soil presented a good opportunity for bioremediation. For over a decade, commercial biological treatments have relied on "soil farming" or "land farming" to degrade petroleum residues by enhancing the natural bacterial action in soil with nutrients, water and frequent tilling (6). Although these "enhanced" bioremediation technologies proved successful in many cases, they had serious drawbacks: poor control over the process; highly variable distribution of oxygen, nutrients, and water; long remediation times; labor intensive design; large space requirements; volatilization of lighter hydrocarbon fractions. The enhancement approach also relies entirely on the spontaneous occurrence and acclimation of indigenous hydrocarbon-degrading microorganisms.

These drawbacks of conventional "enhanced" bioremediation have been addressed in the development of augmented bioremediation techniques for treating hydrocarbon-contaminated soils. This paper reports on the results of two general soil ABR approaches to demonstrate the potential of this alternative technology for site remediation of excavated soils contaminated with fuels, solvents, lubricants and crude oils for which specific bacterial cultures have been developed.

CULTURE DEVELOPMENT

Enrichment culturing techniques were used to isolate individual strains of bacteria from petroleum contaminated soils at refinery sites. The contaminated soils provided inocula cultures in aerated shaker flasks to grow out populations which survive on minimal salts media with a particular hydrocarbon (e.g., toluene) as a sole carbon/energy source. After three days, the culture is diluted into fresh minimal salts media with the specific sole carbon source hydrocarbon, grown up for 8-13 days and transferred again. After four transfers, the flask culture is streaked onto agar plates containing the sole carbon source hydrocarbon with minimal salts. Colonies which displayed rapid growth were then tested for their sensitivity to a panel of thirteen common antibiotics as a precautionary measure, although these soil organisms are not known to be pathogenic. Organisms which exhibited resistance to antibiotics were destroyed. Several substrate concentrations were monitored for biodegradation and growth rates in batch cultures. Biokinetic studies, substrate utilization rates and bioreactor growth predictions for these strains have been previously reported (1-3).

The commercial blends of hydrocarbon-degrading strains of aerobic bacteria provide the capability of biodegrading various straight chained, branched chained, aromatic and polynuclear aromatic hydrocarbons found in diesel and other fuels. These blends include specific strains selected for the biodegradation of benzene, toluene, xylene, anthracene and naphthalene.

Substantial improvements in the rate and extent of toluene and benzene degradation using acclimated bacterial strains in model soil studies have been reported elsewhere (7, 8).

RECIRCULATING LEACHFIELD BIOREMEDIATION

Augmented Leachfield Concept

Augmented bioreclamation of hydrocarbon contaminated excavated soils has greatly improved with the introduction of soil-washing techniques. Biodegradable surfactants (emulsifiers) have proven effective in facilitating the bioremediation of gasoline contaminated aquifers *in situ* (9) and were an obvious choice for accelerating the desorption of heavy petroleum fractions in contaminated soils. Dissolved phase hydrocarbons in the leachate would be readily degraded by high density cultures of laboratory-selected bacteria maintained in efficient aerated bioreactors.

The recirculating leachfield is constructed by spreading the contaminated soil out on a gravel leachbed on top of a plastic liner. An irrigation system (sprayer or perforated leachpipe) allows for the constant flow of a treatment solution containing high density cultures of hydrocarbon-degrading bacteria, the biodegradable emulsifiers and essential nutrients from the bioreactors to the soil. As the bacteria/emulsifier/nutrient laden water penetrates the contaminated soil, the emulsifiers and the natural surfactants of the bacteria facilitate the desorption of hydrocarbons from the soil into the aqueous phase. The lined gravel bed and a sump system direct the leachate back to the bioreactors for rapid degradation of the dissolved contaminants.

Laboratory-selected bacteria, blended for the specific contaminants on site, are cultured in the bioreactors to high densities under optimal nutrient and saturated oxygen conditions. The hydraulic retention time of the bioreactors is regulated like a chemostat to control the influent hydrocarbon substrate and ensure the complete biodegradation of all petroleum fractions. While some biodegradation of hydrocarbon does occur in the soil pile itself, the design of this treatment approach favors the rapid degradation of dissolved contaminants within bioreactors.

Unlike conventional "land farming", the leachfield approach employs a controlled process of "soil washing" with emulsifiers (e.g., non-ionic detergents) to hasten the desorption of heavier petroleum fractions and facilitate the rapid biodegradation of dissolved-phase hydrocarbon under the optimized conditions afforded by a chemostat bioreactor. Soil can be treated in lifts of up to 4 feet thick depending on the composition and permeability, using less than half the space required for conventional tilling practices.

If required for air pollution abatement, the entire leachfield soil can be contained within a plastic cover and impermeable liner to minimize evaporation of volatile organics. Containment also retains moisture and increases the soil temperatures by passive solar heating. Constant monitoring of the soil leachate for pH, ammonium nitrogen and ortho phosphate levels allows for adjustments to optimize the culture conditions. Automated flow controls are used to optimize the moisture content, hydraulic retention time and leaching rate in the soil.

Augmented Leachfield Results

At an airport freight terminal in Oakland, CA, CytoCulture Environmental Biotechnology and Sybron Biochemical have closed the first augmented leachfield bioremediation project in the state. The project involved 400 cubic yards of excavated soil contaminated with diesel fuel from leaking underground storage tanks. Sybron was contracted to provide bacterial cultures, nutrients, and emulsifiers. CytoCulture provided the bioreactor system and technical field service.

Augmented Vacuum Heap Results

CytoCulture was contracted by the City of Oxnard, CA to design, build, equip and operate an excavated soil bioremediation project for the clean-up of 2,400 cubic yards of clay/silt soil contaminated with diesel and crude oil from a pipeline spill. Sybron Biochemical was subcontracted to provide site-specific bacterial cultures, laboratory support and technical field service. A local environmental engineering firm, Staal, Gardner and Dunne, Inc. (Ventura, CA) performed site characterizations, soil sample analysis, permitting, reporting and project management for the City. CytoCulture's construction phase required only eight days and within the first month of operation, the site was clean enough to apply for site closure.

At this site, the 2,400 cubic yards of contaminated excavated soil was divided into twin heaps (roughly 90 by 45 by 10 feet high) and neatly wrapped in 10 mil black Visqueen plastic. Each heap had a double plastic liner extending over a surrounding berm (built of clean fill from the site) to ensure containment of any irrigation run off. See FIGURE 1.

Permitting for this project was straight forward given the current acceptance of such biological treatment programs by the regional water quality control board and the emissions control system favored by the local air pollution control district. The vacuum system emissions were monitored with a photo-ionization detector to confirm that volatile organic emissions were below acceptable limits. The self-contained treatment system was designed to have no impact on groundwater at the site.

Although the project was contracted for a biological treatment period of 4 months, by which time the average total petroleum hydrocarbon levels in the treated soil were to be lowered to 1,000 ppm, optimal weather and soil conditions resulted in an early site closure. Soil and treatment water pH was maintained at 6.9 to 7.3 and the circulation air temperature for the heap reached 35 degrees Celsius for up to 5 hours each day.

The predominant contamination was identified as diesel fuel no. 2 ranging from 1,150 to 22,000 ppm with an average concentration of 6,700 ppm. Crude oil estimates were in the range of several thousand ppm. The remedial action program called for the reduction of TPH levels to 1,000 ppm within the four month target period. Additional contaminants included mineral spirits identified as paint thinner.

Sybron Biochemical conducted a treatability study to confirm the effectiveness of using laboratory-selected bacteria for degrading the specific hydrocarbons present in a composite soil sample.

Since there was less concern over volatile organic emissions, an open leachfield system was employed using sprayers to distribute recirculated leachate over the soil. Sybron Biochemical provided proprietary nutrients, emulsifiers and their "diesel blend" of aerobic bacteria in the form of convenient "Biosock" pre-packaged dry cultures.

A CytoCulture 1,000 gallon mobile suspension culture bioreactor system was used to maintain high density cultures of hydrocarbon degrading bacteria in circulation. Level controls were used to maintain an intermittent recirculation rate of approximately 4 gpm for the bacteria laden treated water. Nutrients (Sybron's "Accelerator II") were added periodically to maintain ammonium nitrogen and ortho phosphate concentrations at 10 ppm or greater. pH was maintained slightly alkaline, in the range of 7.5 to 8.0. Moisture content was controlled with intermittent spraying to maintain approximately 50% saturation (saturation of this particular clay and sand mixture was shown to require 37 gallons of water per cubic yard of soil). Ambient temperature ranged from 16 to 22 degrees Celsius. In less than 10 weeks of continuous operation, the average composite (4 samples) total petroleum hydrocarbon (TPH) as diesel in the soil was lowered from 2,100 ppm to 85 ppm. Site closure was approved within a month with residual hydrocarbon levels of less than 10 ppm. The treated soil was hauled to a local sanitary landfill.

In Richmond, VA, Sybron and Kemron Environmental are contracted to install and operate an *in situ* groundwater bioremediation system for a 2 acre site contaminated with No. 5 fuel oil. Approximately 300 cubic yards of heavily contaminated soil was excavated during the construction of depression trenches and reinfiltration trenches for the groundwater project. This contaminated soil is being treated as an open leachfield system integrated into the groundwater treatment process. Contaminated groundwater is pumped from two depression trenches through an oil water separator and then through a pair of 1,800 gallon air-sparged sequential batch bioreactors. A portion of the treated effluent stream is diverted from the *in situ* reinfiltration trenches to irrigate the 300 cubic yard leachfield of trench spoils. Leachate containing dissolved phase hydrocarbon is collected and pumped back to the bioreactor system. The operation was started up in the winter (December 1989) with bioreactors operating inside a warm building although the leachfield is exposed to the weather. Within the first six weeks of treatment, the leachfield soil contamination levels have dropped from an average (6 samples) fuel oil TPH value of 7,780 ppm to an average (3 samples) of 6,233 ppm in spite of the low temperatures.

In Philadelphia, Sybron and Belpar Environmental have constructed a closed leachfield system contained within an impermeable plastic liner in a former tank excavation pit. The entire leachfield system, including a leachate collection system, a soil ventilation system and a soil irrigation system is underground and capped with a layer of asphalt. The leachate will be treated in above-ground suspension culture bioreactors similar to those designed by CytoCulture for the leachfield project completed in California. The treatment program will begin with the onset of warmer temperatures in the spring.

VACUUM HEAP BIOREMEDIATION

Augmented Vacuum Heap Concept

The vacuum heap approach for augmented bioremediation provides a direct mechanism for continuously aerating excavated contaminated soil which has been inoculated with nutrients and diesel-specific bacterial cultures. The design takes maximum advantage of cost savings in large scale treatment of excavated soil (thousands of cubic yards at a time) and is particularly well suited for projects with accelerated completion deadlines, confined working space and air emission restrictions.

The process begins with the redistribution of soil into lifts (layers) with a loader. The contaminated soil is mechanically mixed and irrigated with an emulsifier, nutrients and Sybron bacteria grown up in batch cultures with CytoCulture suspension bioreactors. Perforated plastic piping is installed between soil layers of the heap and connected with manifolds to a blower system. By pulling a vacuum through the perforated pipe, outside air can be uniformly drawn through the soil to provide oxygen for the aerobic bacteria.

Since the primary contaminants are usually heavy petroleum fractions, air stripping of the hydrocarbons can be expected to be minimal and has not yet required polishing of the exhaust air (although this exhaust is defined as a point source by the local air board). As a precaution to preclude unnecessary air emissions, moisture evaporation and loss of passive solar heat, the entire soil heap is covered with a black plastic liner (there is ample air under the cover to allow for soil oxygenation). The perforated piping also allows for routine addition of nutrients and water, sufficient to moisten the soil without creating runoff. Routine maintenance includes nutrient level assays, moisture measurements, temperature monitoring, mechanical servicing and cleaning of vacuum traps. Additional technical service involves periodic infiltration of dissolved nutrients and additional batch cultures of bacteria as needed.

The study also verified that no priority pollutants were generated by the bacterial degradation process.

Bacterial plate counts indicated that the biomass (colony forming units/gm) peaked shortly after treatment was initiated and tapered off by a factor of ten over the next several weeks. Bacterial densities peaked to an average of 4.2 x 10^7 cfu/g. Phosphate and ammonia levels dropped nearly 10 fold in the course of the first 4 weeks of treatment in parallel with the bio-conversion of petroleum to biomass and carbon dioxide.

Weekly field monitoring of volatile hydrocarbon vapors from the soil heap with the photo-ionization detector (PID) indicated a rapid drop in contamination over the first 37 days of treatment. During this period, averaged hydrocarbon vapor concentration dropped from 7 ppm to less than 0.2 ppm, and remained at 0.2 ppm or less throughout the duration of the project (See FIGURE 2).

After 1 month of continuous treatment, the average TPH levels for diesel in the contaminated soil had dropped to 500 ppm. At the end of the second month, soil analysis indicated that the average (4 samples) had dropped to less than 10 ppm (see TABLE 1). At nine weeks, in preparation for site closure, additional samples taken by the Regional Water Quality Control Board (11) confirmed that the average (13 samples) TPH level had been lowered to 1.8 mg/kg (see TABLE 2), representing a 99.97% reduction in diesel contamination based on the starting average TPH of 6,700 ppm.

Toluene concentrations in the soil were reduced from 0.9 mg/kg to 0.04 mg/kg (96% reduction) and the xylenes reduced from 0.2 mg/kg to below detection. Only the heavier fractions of crude oil persisted in the soil during the nine weeks of treatment, with reductions from several thousand ppm down to an average TPH as crude oil of 460 ppm (4 samples), well within the required limits specified by the Regional Water Quality Control Board. The treated soil will be used on another city-owned site for construction or landscaping purposes.

CONCLUSION

In contrast to conventional "enhancement" approaches, the augmented bioremediation methods described above accelerate the biodegradation process by the addition of selected, acclimated bacteria, as well as nutrients, to the soil. The selected cultures are capable of achieving up to a log higher densities in hydrocarbon contaminated soil than the natural occuring populations of bacteria in laboratory studies (3) and in the field (10). Both augmented bioremediation programs for excavated soil are now becoming commercially available nationwide.

FIGURE 1

VACUUM HEAP CONSTRUCTION SCHEMATIC

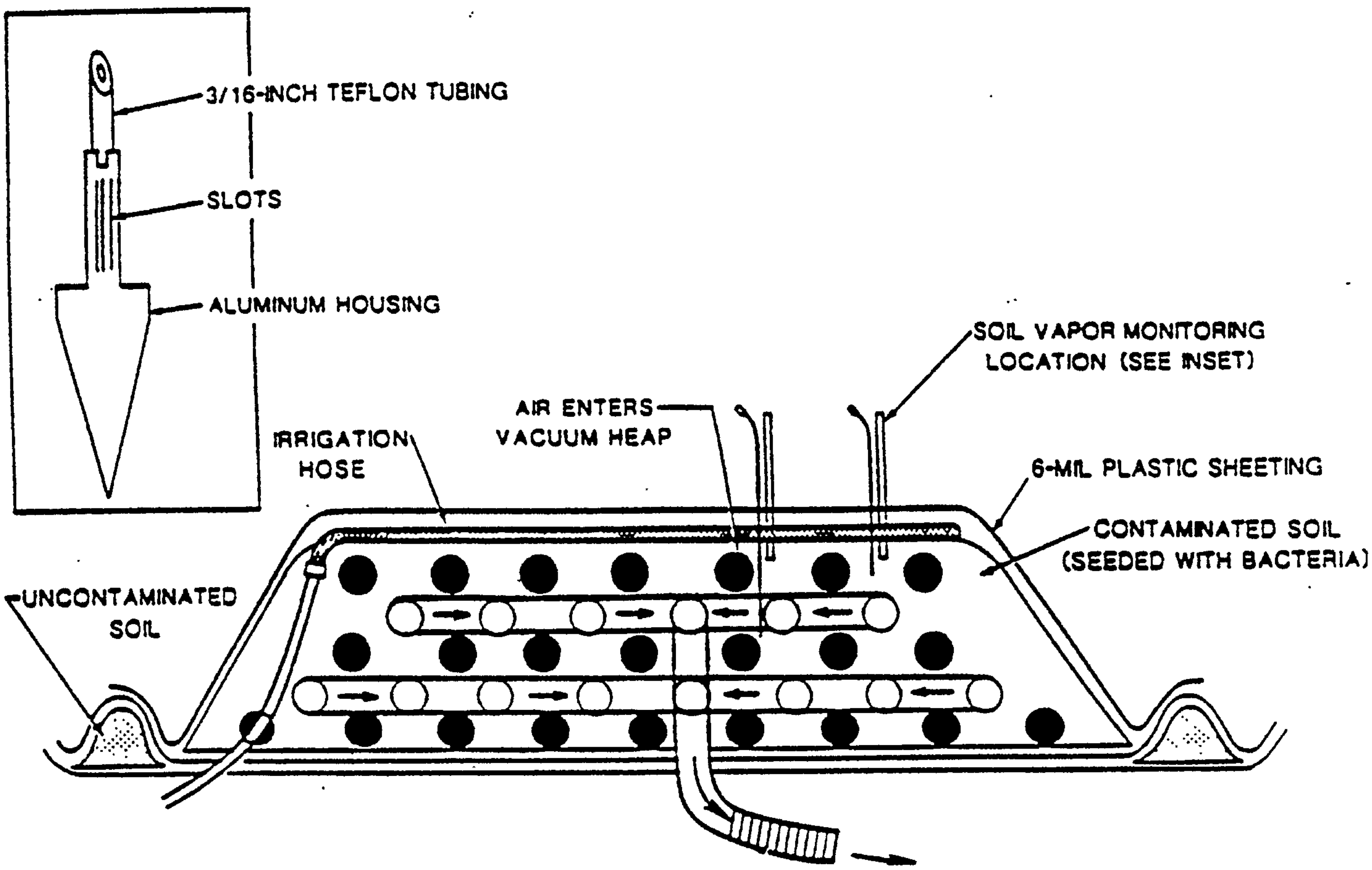

FIGURE 2

PID MONITORING OF HEAPS

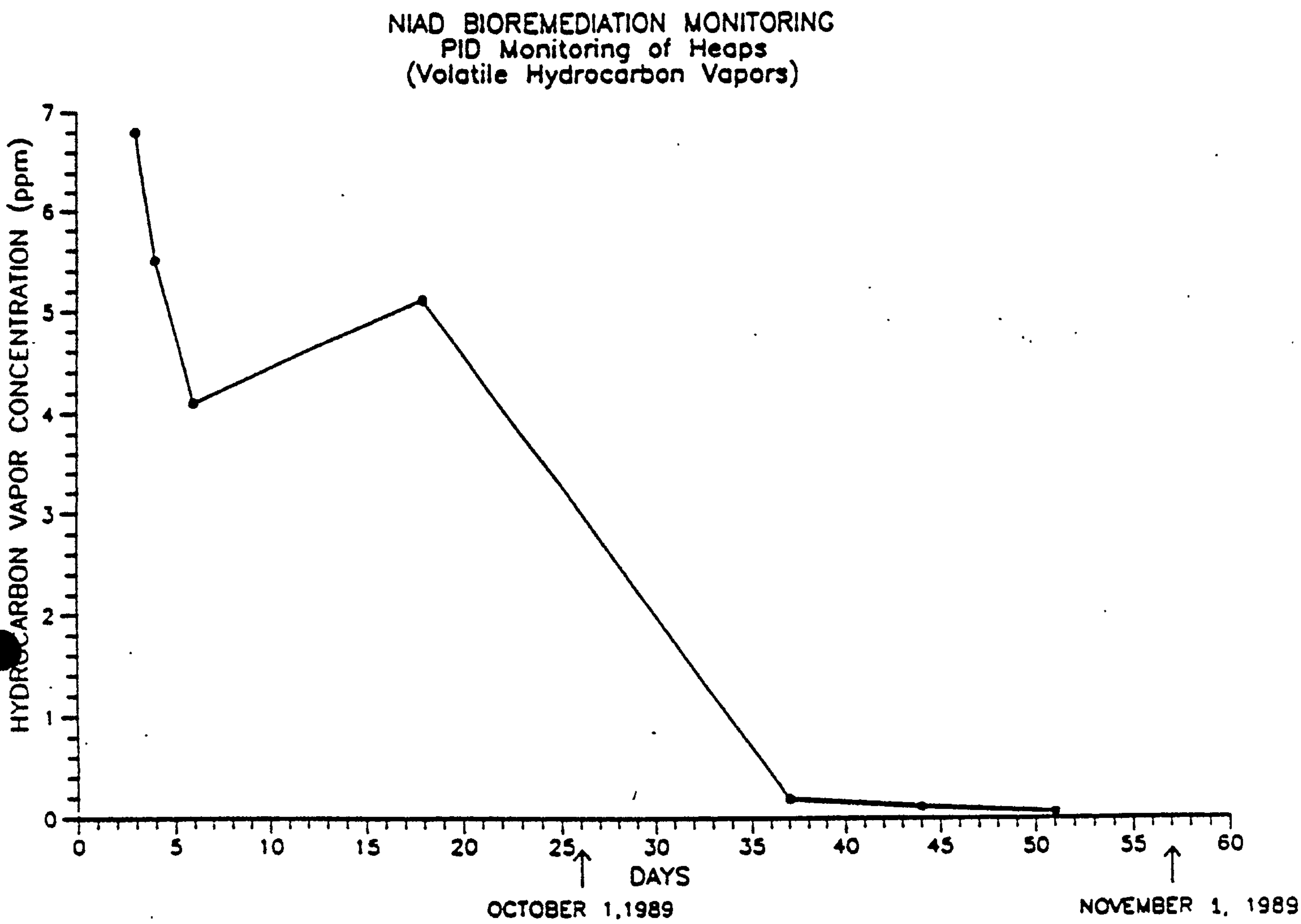

TABLE 1

MONITORING FOR TPH, BTEX, EDB, AND EDC
NIAD BIOREMEDIATION PROJECT
August/October 1989

Sample No.	Date Sampled	Benzene	Toluene	Ethyl-benzene	Xylenes	EDB	EDC	TPH (diesel fuel)
NBBS Composite 1	8/22/89	ND	0.26	0.02	0.19	ND	ND	590
NBBS Composite 2	8/22/89	ND	0.26	ND	0.02	ND	ND	340
		ND	0.26	ND	0.01	ND	ND	400
		ND	0.26	0.007	0.07	ND	ND	440
		ND	0.123	ND	0.020	ND	ND	2.2
		ND	0.02	ND	0.023	ND	ND	2.7
		ND	0.019	ND	0.021	ND	ND	1.5
		ND	0.02	ND	0.021	ND	ND	2.1

TABLE 2

ANALYTICAL RESULTS OF CONFIRMATION SOIL SAMPLING FOR SITE CLOSURE
NIAD BIOREMEDIATION PROJECT, NOVEMBER 7, 1989
(results in mg/kg)

Sample No.	Location	Benzene	Toluene	Ethyl-benzene	Xylenes	EDB	EDC	TPH (Diesel Fuel)	TPH (Crude Oil)
1	SE Corner Stockpile No. 2	ND	0.028	ND	ND	ND	ND	5.7	—
2	SE Corner Stockpile No. 2	ND	0.008	ND	0.015	ND	ND	ND	—
3	Top Stockpile No. 2	ND	0.014	ND	0.005	ND	ND	ND	230
4	NE Corner Stockpile No. 2	ND	0.016	ND	0.009	ND	ND	ND	—
5	Top Stockpile No. 2	ND	0.094	ND	ND	ND	ND	2.1	—
6	NW Corner Stockpile No. 2	ND	<u>0.21</u>	ND	ND	ND	ND	ND	770
7	SW Corner Stockpile No. 2	ND	ND	ND	ND	ND	ND	12	—
8	SE Corner Stockpile No. 1	ND	0.052	ND	ND	ND	ND	ND	—
9	SW Corner Stockpile No. 1	ND	0.051	ND	0.005	ND	ND	3.4	570
10	NE Corner Stockpile No. 1	ND	0.052	ND	ND	ND	ND	ND	—
11	NW Corner Stockpile No. 1	ND	0.014	ND	ND	ND	ND	ND	—
12	South End Stockpile No. 1	ND	0.010	ND	ND	ND	ND	ND	—
13	North End Stockpile No. 1	ND	0.015	ND	ND	ND	ND	ND	280
Average		ND	0.04	ND	ND	ND	ND	1.8	460
Action Level		0.001*	0.10*	0.68*	1 75	NA	NA	10*	1000**

* Department of Health Services (DOHS) drinking water standards.
** Regional Water Quality Control Board remedial action target level.
ND Not detected.
— Not analyzed for parameter.
___ Exceeds DOHS drinking water standards.

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In Situ *and* Ex Situ *Bioremediation of Soils Contaminated by Petroleum Distillates*

Made Available by

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Birmingham, New Jersey

In Situ and Ex Situ Bioremediation of Soils Contaminated by Petroleum Distillates

BY

Gary R. Hater, MS (Sybron Chemicals Inc.), C.D. Goldsmith, PhD (Sybron Chemicals Inc.), Randall von Wedel, PhD (Cytoculture International), James Philips (L&A Contracting), and William Hunt (Alton Geoscience)

Background

Since the early 1980s, the Biochemical Division of Sybron Chemicals Inc. (SCI) has developed several new commercial bacteria cultures for use in soil and groundwater decontamination. These cultures were grouped in a culture series designated Augmented Bioreclamation™ (ABR). The ABR series was developed for the destruction of specific organic compounds. The biological kinetics of these cultures on specific substrates such as aromatic solvents[1], diesel fuel[2], and refinery petroleum waste[3] have been documented.

ABR cultures have been used extensively for reclaiming contaminated soils and groundwater. More than 40 contaminated sites have been treated and closed in oil fields in Louisiana and several diesel fuel and gasoline remediation projects are on-going as of this writing.

In situ and *ex situ* bioremediation of soil, sludges and groundwater has been accomplished using a variety of mechanical and biological techniques with the ABR cultures.

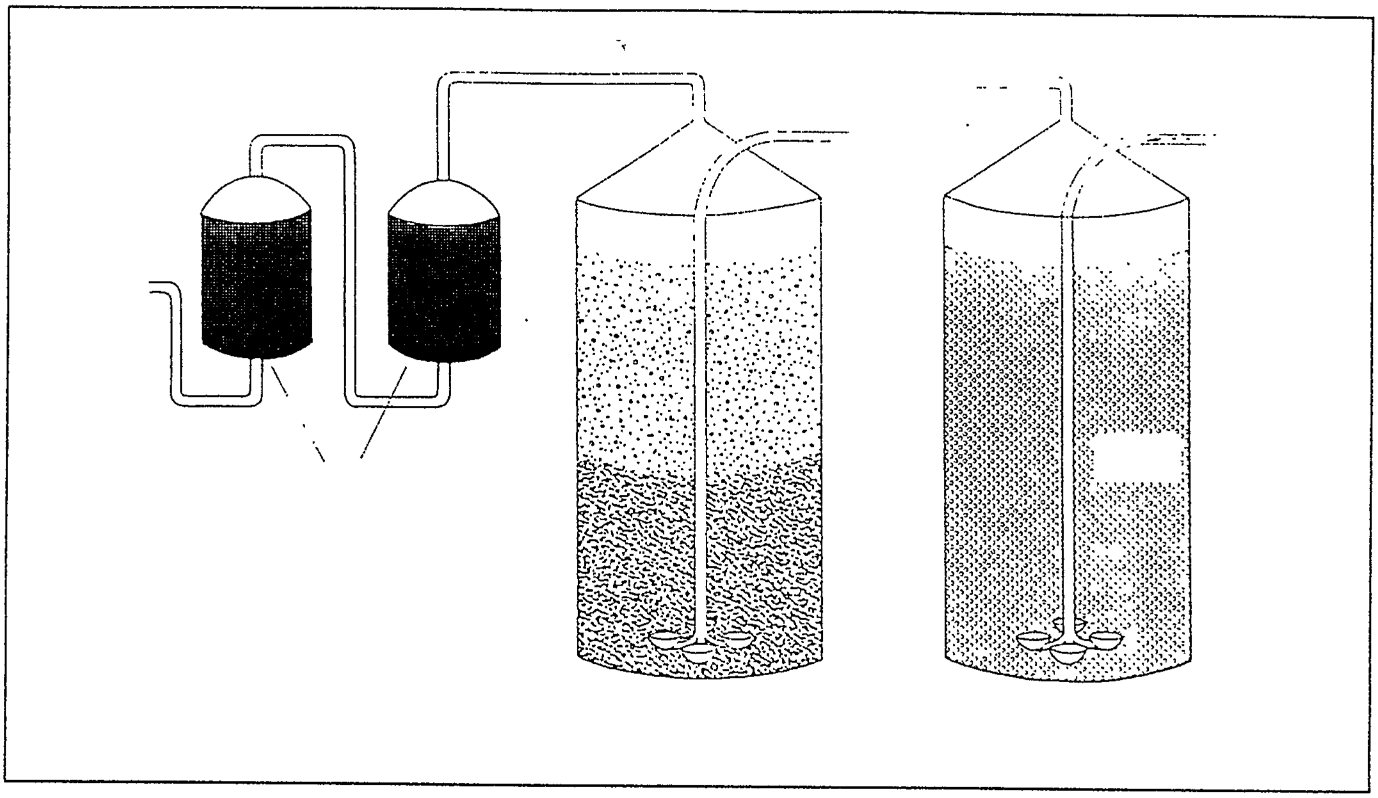
Culture Development

Cultures for the ABR series were developed in the following manner. Bacterial strains were isolated from previously contaminated areas by enrichment culturing. Specific organisms were obtained by slowly increasing the concentration of organic substrate over many culture generations. This procedure may require several months of laboratory work and eventually results in one or more strains for each contaminant or mixture of contaminants.

Strains are grown in a buffered media on the specific organic(s) during full-scale production. Subsequently, the liquid is coated onto an organic-based solid media, then dried, ground and packaged. The dry culture is supplied in a patented Biosock™ container for use as an inoculum in above ground reactors. Liquid cultures may be supplied for inoculum upon request if there is sufficient lead time. Three representative cultures of the ABR series are presented in Table 1 along with their target organics.

ABR Gasoline Blend	ABR Petroleum Blend	ABR Diesel Blend
Pseudomonas putida A	*Bacillus subtilis*	*Pseudomonas putida*
Pseudomonas putida B	*Pseudomonas aeruginosa*	*Pseudomonas alcaligenes*
Pseudomonas aeruginosa	*Pseudomonas stutzeri*	*Pseudomonas aeruginosa*
	Pseudomonas putida	*Arthr. crystallopoietes*
Target Compounds	Target Compounds	Target Compounds
Benzene	$>C_{20}$ aliphatics	Benzene
Toluene	Benzene	Toluene
Ethyl benzene	Toluene	Ethyl benzene
Xylene	Ethyl Benzene	Xylene
C_5-C[illegible] aliphatics	Xylene	Naphthalene
	Naphthalene	Methyl naphthalene
	Methyl naphthalene	Anthracene
	Anthracene	C[illegible]-C[illegible] aliphatics

TABLE 1. ABR bacterial strains.



ABR--off gas system

Notes

[1]Goldsmith, C.D., Jr. and R.K. Balderson. 1989. *Biokinetic Constants of a Mixed Microbial Culture with Model Diesel Fuel.* Hazardous Waste and Materials Journal. In press for June release.

[2]Goldsmith, C.D., Jr. and R.K. Balderson. 1988. *Biodegradation and Growth Kinetics of Enrichment Isolates on Benzene, Toluene and Xylene.* Water Science and Technology. 20:505-507.

[3]Wong, A.D. and C.D. Goldsmith, Jr., 1988. *The Impact of a Chemostat Discharge Containing Oil-degrading Bacteria on the Biological Kinetics of a Refinery Activated Sludge Process.* Water Science and Technology. 20:131-136.

[4]Hater, G.R. 1988. *Bioremediation of* In Situ *and* Ex Situ *Contaminated Soils.* Haz Mat '88, Long Beach, CA. November 8-10.

scribes the relationship between oil and grease reduction over time.

Seventeen of 26 pits that were remediated and closed in 1987 and 1988 degraded oil and grease at a rate that was expressed in tons/month. This varied from 200 to 500 tons with an average value of 213 tons/month.

Augmented landfarming of some pits is still possible where air pollution is not a major concern and land is available on site. Properly operated landfarms can reduce oil and grease content in the manipulated soil from 4% to less than 0.3% in 90 days.

[illegible]

As reported by Hater (1988) the Bacterial Contamination Interceptor™ (patent pending) has been developed as an *in situ* vadose zone technology[4]. The BCI system (Figure 5) allows for *in situ* bacterial destruction of hydrocarbon vapors using ABR cultures.

New residual hydrocarbon off-gas removal systems are under development (Figure 6). The intent of these systems is to replace and eliminate carbon usage completely.

[illegible]	[illegible] (μg/L)	[illegible] (μg/L)	[illegible] (μg/L)	[illegible] (mg/L)
Influent	450	13	4	2.9
Effluent	ND	ND	ND	ND

[illegible] Emeryville, CA project results

[illegible]	[illegible]
Temperature	2X difference in rate between 45° and 90° F
Salt Content	Salinity greater than sea water decreases rate dramatically
Residual Nutrients	Residual nitrogen and phosphorus must be above 1 ppm to maintain growth
Starting Oil Concentration	Initial concentrations below 5% FOG often indicate the pit was burned and the remaining hydrocarbons are all asphalt-like

[illegible] Factors affecting successful pit bioremediation

[illegible]	[illegible]	
Oily Solids (pit bottom)	33.500	--
Water Phase	204	--
BI-CHEM® Treated Sample with 100g sludge + 100mL supernatant	2.000	94.0
Indigenous Bacteria Sample 100g sludge + 100mL supernatant	17.700	47.2

[illegible] Oil and grease results for a batch treatment of an oil pit

DAY	Benzene (ppb)	Toluene(ppb)	Xylenes(ppb)	Ethyl Benzene (ppb)	TPM (ppm)
Effluent					
1	1.6	0.6	ND	ND	0.14
2	2.0	0.8	ND	ND	0.32
3	3.4	1.2	ND	ND	0.26
4	0.6	0.2	ND	ND	0.08
5	0.8	0.3	ND	ND	0.10
6	2.0	0.4	ND	ND	0.25
7	3.4	1.0	ND	ND	0.32
8	2.6	0.8	ND	ND	0.24
9	2.8	1.6	ND	ND	0.45
10	3.4	1.0	ND	ND	0.40
11	2.9	0.9	ND	ND	0.31
12	3.3	0.9	ND	ND	0.30
13	3.9	1.1	ND	ND	0.36
14	3.0	1.1	ND	ND	0.43
				AVERAGE	0.28
Influent					
6	2500	3000	4300	2750	149
8	2200	2360	3800	2300	97
13	1720	2160	4040	2300	103
				AVERAGE	116.3
Removal Efficiency	99.8	99.4	100	100	99.7

Buena Park, CA results

ture International, the designer, has a patent pending. Analyses for the petroleum components, TPH/TEH and benzene, xylene, and toluene were performed by EPA methods 602 and modified 8015.

It should be noted that the project is under tidal influence and brackish conditions exist periodically.

Volatilization was negligible as calculated by the bacterial biomass generated (cell yield) and is supported by data from the local air pollution board.

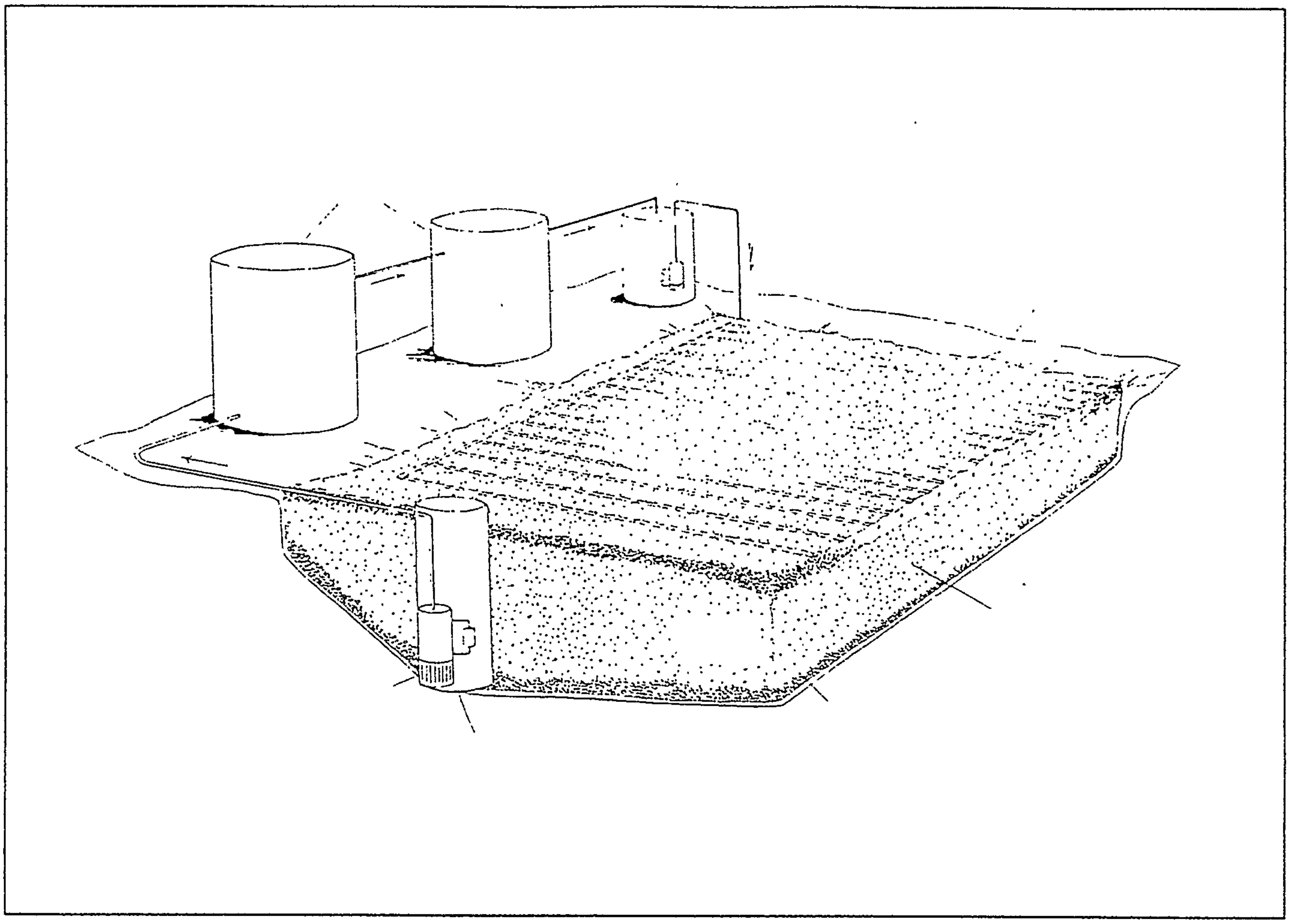
Production pits used for oil production, gas production, transmission pipelines and refinery operations vary in size from several hundred square feet to several acres. Over the last six years, Sybron Chemicals Inc. and L&A Contracting have treated and closed approximately 50 such pits using a combination of bioaugmentation and good, solid mechanical engineering. Several factors are extremely important in the feasibility of successful remediation with these techniques which are listed in Table 4.

The basis for this type of augmented remediation is briefly summarized by a respirometric and oil and grease study conducted at SCI in Salem, Virginia. Several treatments were studied including a sterile control, non-sterile control without nutrients, non-sterile control with nutrients, and ABR series culture (ABR-Petroleum Blend) with nutrients.

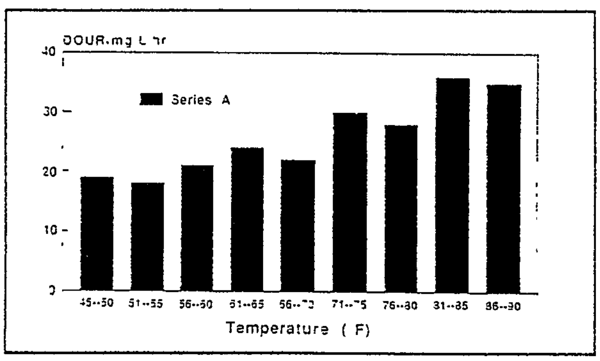
Residual oil and grease, and total oxygen consumption were measured after 20 days. The sterile and non-sterile treatment showed little oxygen consumption. The need for on-site acclimation of augmented cultures was demonstrated by superior oil and grease reduction with augmented treatments as seen in Table 5.

The relationship between oxygen consumption and temperature is presented in Figure 3. The data in Figure 3 is a compilation of data from 20 cleaned pits.

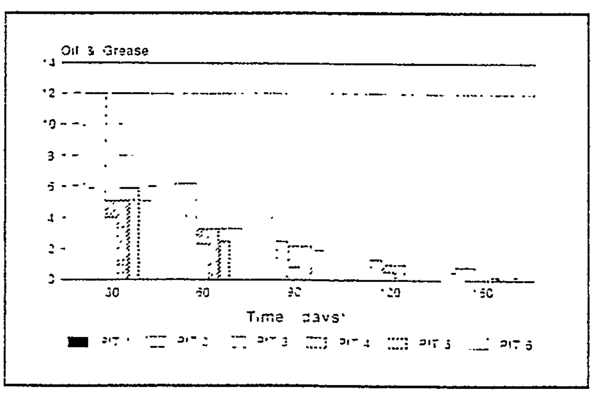
Time to complete a remediation is generally under 150 days, but is directly dependent upon the initial oil and grease concentration. Figure 4 de-



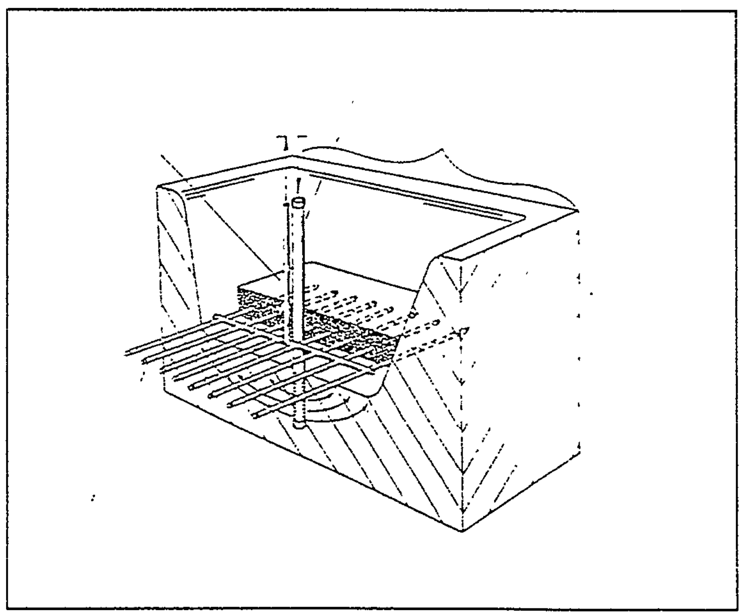
ABR-*ex situ* leachbed (cold weather and air containment conceptual).



Temperature impact on DOUR



Oil & grease reduction over time



Bacterial contaminant interceptor (BCI)

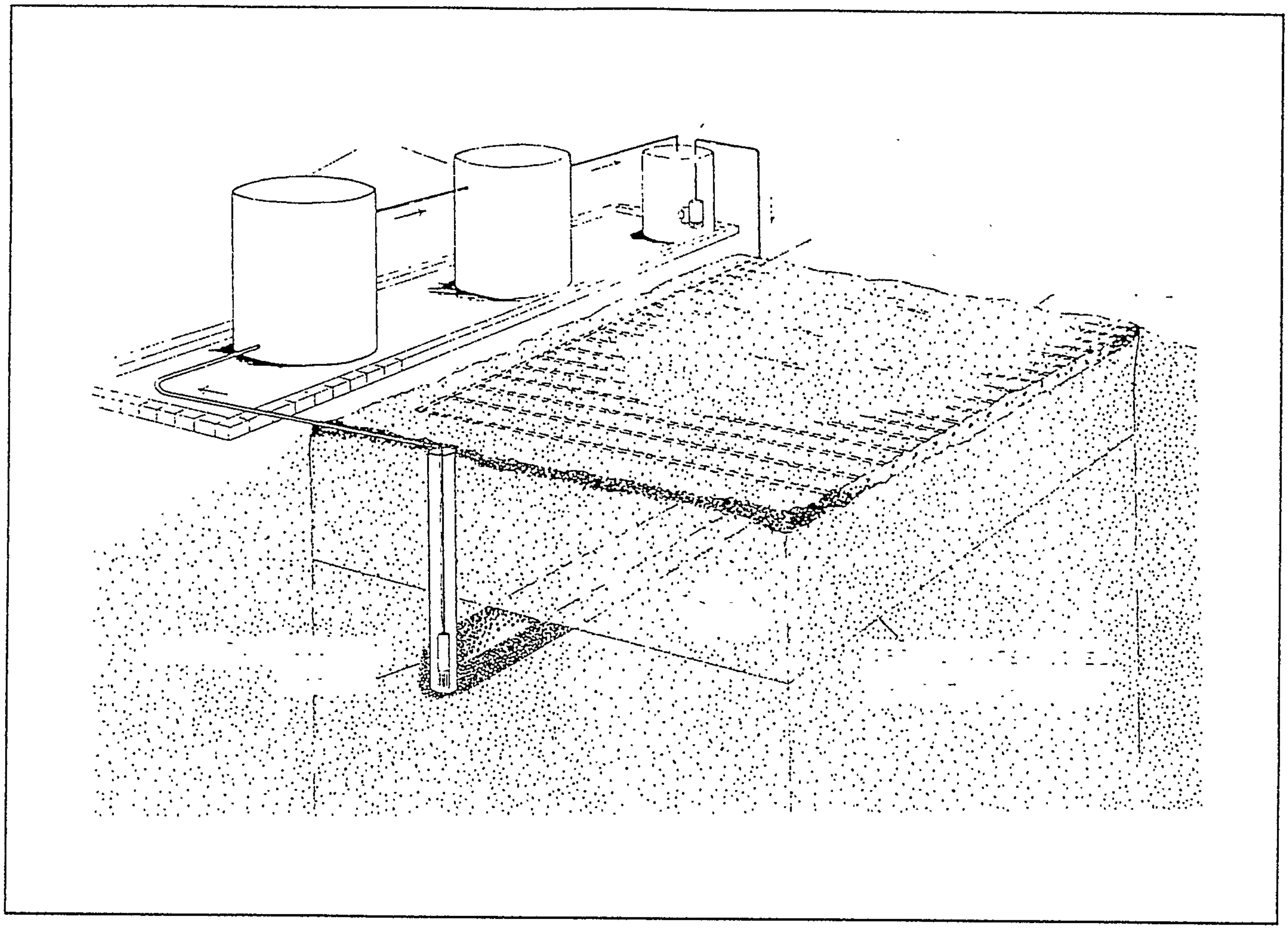


FIGURE 1 **ABR-*in situ* leachbed** (cold weather and air containment conceptual).

In Situ and Ex Situ Soil Decontamination

ABR cultures are employed at gasoline and diesel fuel contaminated sites through a treatment process using a combination of in-place and leachbed methods (see Figure 1). Typically, a leachbed is built from contaminated soil. Water is pumped through the leachate piping, trickling through the soil to begin the process. Contaminated water is drawn from an interceptor trench or well. Reactors, designed for the specific site (usually suspended culture, sequential batch or fixed film), then treat the leachate. Treatment continues until tests indicate sufficient removal of contaminants. Some systems are designed to result in zero emissions to aid in the permitting process.

A closed suspended culture reactor system with a process scheme shown in Figure 2 has yielded significant information. Removal of total petroleum hydrocarbons was in excess of 99.7%. Benzene and toluene concentrations were reduced from over 2 parts per million to less than 4 and 2 parts per billion, respectively. Removal was in excess of 99%. Xylenes and ethylbenzene were totally degraded. These results were obtained at a gasoline contaminated site located in Buena Park, California, when ambient air temperatures were at a minimum and the reactors were operating at maximum hydraulic capacity.

After eight months of treatment, six soil borings in the original tank cavity yielded five samples with less than 10 ppm TPH and one of 200 PPM. Initially, the soil ranged from 60 to 600 ppm TPH.

Similar data is being collected at a two acre diesel fuel contaminated soil and groundwater site in Emeryville, California. This system is performing both re-infiltration and pump & treat. Pump & treat effluent is being discharged to East Bay Municipal District (CA) Treatment Plant. Representative data are shown in Table 3. Removal efficiencies approximate 100%. Suspended culture reactors with diffused air draft tube aerators and a proprietary dispersion system are being used. Cytocul-

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POLLUTION ENGINEERING
CASEBOOK

NOVEMBER 1, 1992 POLLUTION ENGINEERING

by Ann Hasbach, Senior Editor

Bioremediation Cleans Soil Tainted by Pipeline Spill

Augmented bioremediation using a vacuum heap extraction system, designed by Sybron Chemicals Inc., Birmingham, N.J., was used to clean 2400 cubic yards of diesel and mineral spirits from a pipeline spill.

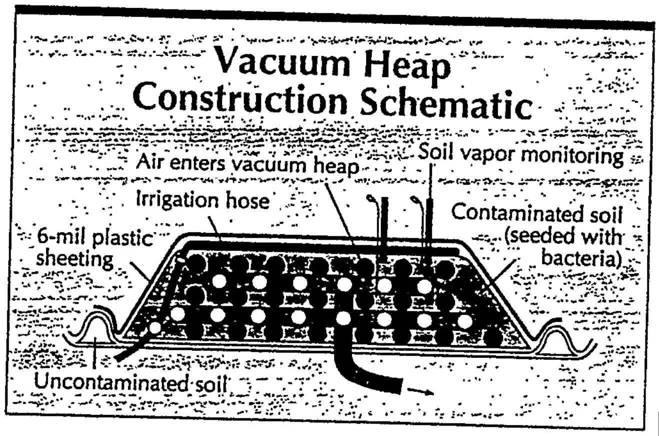
The project was expected to take six months, but site closure was granted within 70 days when soil reached less than 10 parts per million (ppm) average total petroleum hydrocarbon (TPH). The predominant contaminant, No. 2 diesel fuel, initially ranged from 1150 to 22,000 ppm with an average total petroleum hydrocarbon (TPH) concentration of 6700 ppm.

The excavated soil was placed in two piles, mechanically mixed, and irrigated with an emulsifier, nutrients and hydrocarbon-degrading bacteria. Each pile was wrapped in black plastic and fitted with a double plastic liner to control runoff, moisture evaporation, volatile air emissions, and loss of passive solar heat.

A vacuum piping system was used to draw air through the contaminated soil to provide oxygen for the aerobic bacteria. The piping system also allowed for routine addition of nutrients and water.

Routine maintenance of the vacuum heap process included nutrient level assays, moisture measurements, temperature monitoring, mechanical servicing and cleaning of vacuum traps.

Monitoring of vacuum system emissions showed volatile organic emissions were below acceptable limits.



• A petroleum hydrocarbon contaminated site was treated with an on-site vacuum heap extraction system using selectively adapted aerobic bacteria.

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