RESPONSE ACTION CONTRACT FOR
REMEDIAL, ENFORCEMENT OVERSIGHT, AND
NONTIME-CRITICAL REMOVAL ACTIVITIES IN REGION 6

TECHNICAL MEMORANDUM
APPLICATION OF MONITORED NATURAL ATTENUATION TO GROUND WATER FOR OPERABLE UNIT 1
REVISION NO. 1

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY REPORT
MANY DIVERSIFIED INTERESTS SUPERFUND SITE
HOUSTON, HARRIS COUNTY, TEXAS
EPA ID NO. TXD008083404

Prepared For:

U.S. Environmental Protection Agency
Region 6
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LIST OF ACRONYMS

B(a)P	Benzo(a)pyrene
bgs	Below ground surface
COPC	Contaminant of potential concern
CRF	Contaminant reduction factor
EPA	U.S. Environmental Protection Agency
FS	Feasibility study
K_d	Distribution coefficient
K_{ow}	Octanol-water partition coefficient
LNAPL	Light nonaqueous-phase liquid
MCL	Maximum contaminant limit
MDI	Many Diversified Interests
MNA	Monitored natural attenuation
MSSL	Medium-specific screening level
µg/L	Microgram per liter
PAH	Polycyclic aromatic hydrocarbon
R	Retardation factor
RAO	Remedial action objective
RI	Remedial investigation
SVOC	Semivolatile organic compound
Tetra Tech	Tetra Tech EM Inc
TNRCC	Texas Natural Resource Conservation Commission
TPH	Total petroleum hydrocarbons

1.0 INTRODUCTION

Tetra Tech EM Inc. (Tetra Tech) has completed the remedial investigation (RI; Tetra Tech 2003a) and feasibility study (FS; Tetra Tech 2004) for the Many Diversified Interests (MDI) Superfund site under work assignment no. 107-RICO-06CN for the U.S. Environmental Protection Agency (EPA) under Response Action Contract 68-W6-0037. With the exception of the No Action Alternative (Alternative 1), all of the remedial alternatives (Alternatives 2 through 5) included ground water remediation via source removal, monitored natural attenuation (MNA), and implementation of institutional controls. The purpose of this technical memorandum is to evaluate the potential for MNA to effectively reduce organic contaminant concentrations to acceptable levels.

MNA refers to the reliance on natural attenuation processes to achieve site-specific remedial objectives. The "natural attenuation processes" that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and ground water (EPA 1999). These natural, in situ mechanisms can include biodegradation, abiotic transformation, dispersion, dilution, sorption, or volatilization, any of which can facilitate chemical or biological stabilization, transformation, or destruction of ground water contaminants. Three lines of evidence are cited for evaluating the efficacy of MNA as an appropriate remedy for a site (EPA 1999):

- Historical ground water and soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time (EPA 1999). In the case of ground water contamination, this is generally demonstrated by point-wise declining contaminant concentration trends and stable to shrinking plume dimensions. In other words, declining trends that result solely from plume dispersion are not acceptable.
- Hydrogeologic and geochemical data that demonstrate indirectly the types of natural attenuation processes active at the site. For example, if the contaminant destruction mechanism proposed is anaerobic biological degradation, demonstrating that the plume is anaerobic and not aerobic is paramount to support the remedy.
- Field data or microcosm studies that directly demonstrate the occurrence of a particular natural attenuation process and its ability to degrade the contaminants of concern.

This memorandum details the information that has been collected to date to support an MNA remedy, identifies additional data to be collected prior to and as part of the remedial design, and briefly details how this portion of the overall remedy will be implemented at the MDI site.

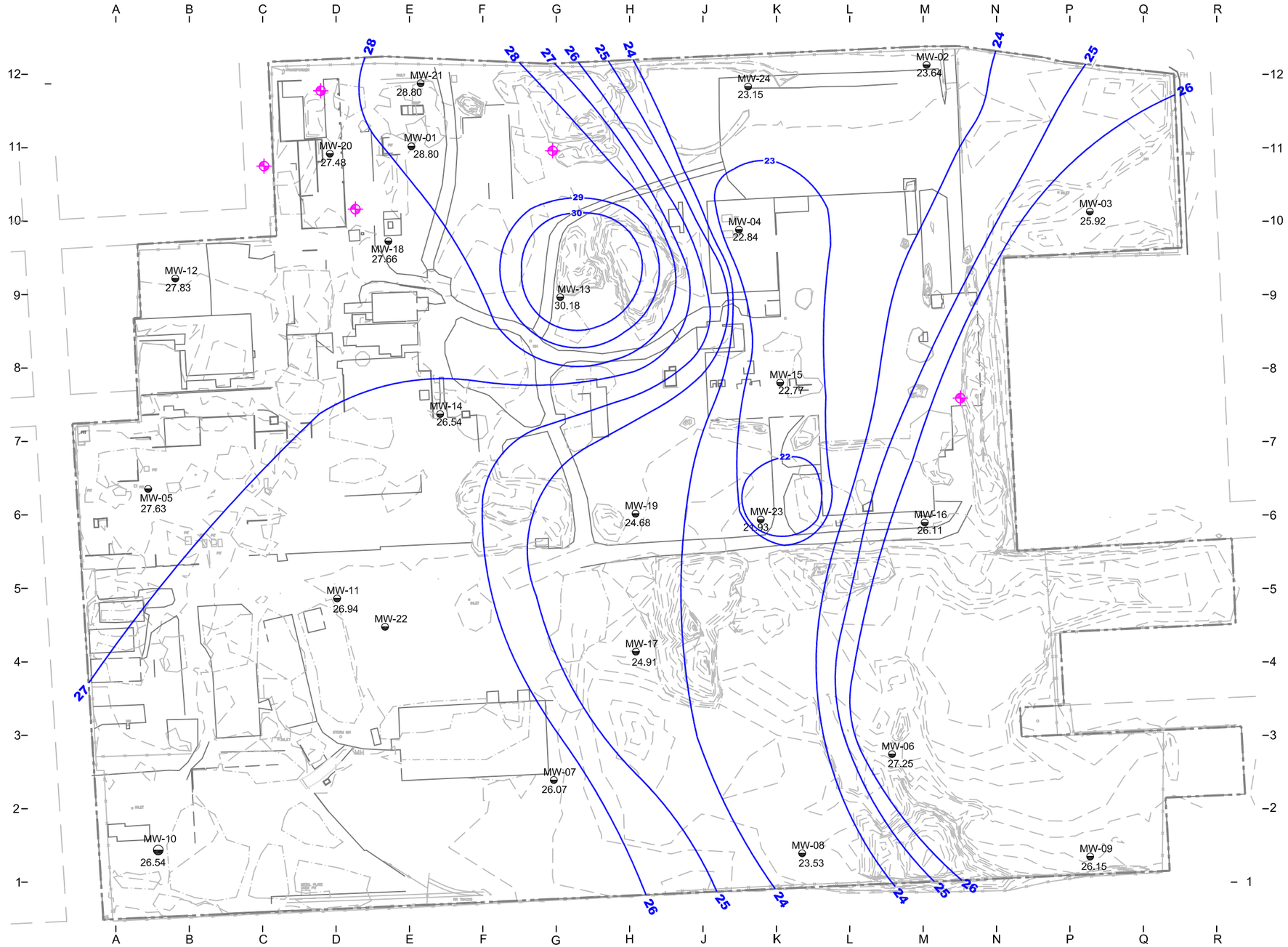
2.0 SITE CONDITIONS

During the RI, surface and subsurface soil conditions were evaluated by collecting shallow soil samples at 169 grid locations. Geoprobe® borings were advanced at 72 of these locations as well as at 56 judgmental locations. Ground water quality was evaluated by completing 35 Geoprobe® soil borings as temporary monitoring wells and installing and sampling 24 permanent monitoring wells. Aquifer conditions were assessed by performing single-well pumping tests at five locations and slug tests at six locations (Tetra Tech 2003a).

The RI revealed that soils approximately 1.5 feet below ground surface (bgs) had been impacted by lead at concentrations up to several thousand milligrams per kilogram. Soils between 1.5 feet bgs and the water table (approximately 15 feet bgs) were generally not impacted. Ground water showed some impacts from organic contamination (Tetra Tech 2003a). During the FS, several remedies were identified for contaminated soil that entailed either the excavation and removal of, or consolidation of, the lead-contaminated soils, in conjunction with treatment of ground water by source (i.e., "hot spot") removal, MNA, and implementation of institutional controls (Tetra Tech 2004). The following discussion pertains to the distribution of contaminants in ground water.

Ground water at the site has been impacted by low levels of organic and inorganic contamination. Figure 1 depicts the potentiometric surface of ground water at the MDI site and includes the location of five additional wells that are being proposed to aid in the implementation of the MNA remedy and answer some additional questions pertaining to ground water flow.

Metals detected in ground water above screening levels included manganese, molybdenum, lead, and arsenic. Molybdenum and manganese were detected in a few monitoring wells above EPA Region 6 tap water standards (EPA 2003). Lead was detected above the maximum contaminant level (MCL; EPA 2003) in two monitoring wells (MW-13 and MW-09); however, lead concentrations in nearby wells were below standards. Because MW-13 and MW-09 are surrounded by wells with low lead concentrations, these detections are thought to be associated with metallic debris within the fill, and not with an actual "release." The low concentrations and limited occurrence of the metals in ground water do not pose a risk. As such, these metals are not being addressed in the site remedy. Arsenic appears to be encroaching on site from an off-site source to the east. As such, it is not being addressed as part of the site remedy.



LEGEND:

–7 G	SITE GRID TRANSECT REFERENCE
	SITE BOUNDARY
	ELEVATION CONTOURS, CONTOUR INTERVAL = 1 FT.
	FENCE
	DEBRIS PILE
	POTENTIOMETRIC CONTOUR INTERVAL (FEET MEAN SEA LEVEL)
MW-03 25.92	MONITORING WELL LOCATION
	PROPOSED MONITORING WELLS

N

0 75 150

SCALE IN FEET

MDI SUPERFUND SITE
HOUSTON, TEXAS

FIGURE 1
POTENTIOMETRIC SURFACE MAP
MARCH 2004

PREPARED FOR: EPA

BY: Tetra Tech EM Inc.

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The organic contaminants in ground water at the site pose a potential risk to receptors and will be addressed by the ground water remedy.

Semivolatile organic compounds (SVOC) in the form of polycylic aromatic hydrocarbons (PAH) were detected at concentrations above applicable screening levels in monitoring wells MW-03, MW-07, MW-09, MW-13, and MW-16. Benzo(a)pyrene (B[a]P) was the only SVOC detected at a concentration above its MCL of 0.2 micrograms per liter (µg/L). B(a)P was detected in wells MW-03, MW-07, MW-16 at concentrations of 0.619, 0.084, and 0.063 µg/L, respectively. PAHs that exceeded EPA Region 6 medium-specific screening levels (MSSL; EPA 2003) for tap water were 3,3-dichorobenzene and atrazine (MW-13); acetophenone (MW-09 and MW-13); benzo(a)anthracene (MW-03 and MW-07); and benzo(b)fluoranthene, dibenzo(a,h)anthracene, dibenzofuran, naphthalene, and pentachlorophenol (MW-03).

Petroleum hydrocarbons as a light nonaqueous-phase liquid (LNAPL) were identified in monitoring well MW-20 (Figure 2). Because the ground water sample collected from MW-20 was analyzed for volatile organic compounds and SVOCs, as opposed to Texas Natural Resource Conservation Commission (TNRCC) Method 1005 (TNRCC 2001) for analysis for total petroleum hydrocarbons (TPH) and TNRCC Method 1006 (TNRCC 2000) for aliphatic and aromatic fractionation of TPH, these analytical procedures will be used during upcoming sampling events.

3.0 EVALUATION OF MONITORED NATURAL ATTENUATION

In order to evaluate the efficacy of MNA for the ground water plumes at the MDI site, Tetra Tech performed specific tests and collected the following data during the RI:

- Hydrogeologic data and aquifer parameters
- Geochemical parameters

The following subsections discuss the feasibility of MNA being an effective remedy within the context of these data.

3.1 DISCUSSION OF HYDROGEOLOGIC DATA

Ground water data collected during the RI were compared with a number of screening criteria, including MCLs and EPA Region 6 tap water standards (EPA 2003). As stated in Section 2.0, only B(a)P was detected above its MCL and is the contaminant of potential concern (COPC) that is the focus of this remedy. Although not detected above its MCL in well MW-20, benzene is also a COPC because benzene concentrations in ground water above the MCL have the potential to increase after source removal of LNAPL is completed. Table 1 summarizes the physical properties of benzene and B(a)P, and identifies the references used in collecting this information.

The ground water MNA remedy will be applied at two separate locations: near MW-3, where B(a)P is a concern, and near MW-20, where benzene is a potential concern. Hydrogeologic and aquifer data included physical properties of the subsurface soils, such as grain size, bulk density, effective porosity, and fraction organic carbon. Hydraulic conductivity information was collected by performing single-well pump tests and slug tests. These data are summarized in Table 2. Whereas site-specific data was collected at MW-3, site-specific information does not exist for MW-20. Because of this, data from nearby wells MW-01 and MW-18 have been tabulated, with the recognition that similar data will be collected in the LNAPL plume area during the next monitoring well installation event.

Tetra Tech was able to determine a number of variables for these contaminants, including distribution coefficients (K_d), retardation factors (R), and partition coefficients (K_{ow}) by applying site-specific data (Table 2) to the chemical properties (Table 1). These data are summarized in Table 3.

TABLE 1

SUMMARY OF PHYSICAL PROPERTIES FOR PRIMARY CONTAMINANTS OF CONCERN
MDI SUPERFUND SITE, HOUSTON, TEXAS

Compound	Physical State	Molecular Weight (gm/mole)	Density (gm/cm^3)	Solubility (mg/L)	Boiling Point ($^{\circ}C$)	Vapor Pressure (mm Hg)	Log K_{oc}	Log K_{ow}	Henry's Constant ($atm\text{-}m^3\ mol^{-1}$)
Aromatic Hydrocarbons									
Benzene	Liquid	78.11	0.8765	1,780	80.1	95	1.8 - 1.9	2.13	$5.5x10^{-3}$
Heavy Polycyclic Aromatic Hydrocarbons (HPAHs)									
Benzo(a)pyrene	Solid	252.3	1.351	0.0023	310 - 312	$5.6x10^{-9}$	6.74	6.06	$4.9x10^{-7}$

Notes:

atm Atmosphere
cm^3 Cubic centimeter
gm Gram
Hg Mercury
K_{oc} Octanol-carbon partition coefficient
K_{ow} Octanol-water partition coefficient
L Liter
m^3 Cubic meter
mg Milligram
mm Millimeter
mol Mole

All values are at 20 ^{o}C or 25 ^{o}C.
Sources: Finalized Toxicological Profiles (Agency for Toxic Substance and Disease Registry 2004)
Handbook of Environmental Data on Organic Chemicals (Vershueron 1983)

TABLE 2

HYDROGEOLOGIC PARAMETERS
MDI SUPERFUND SITE, HOUSTON, TEXAS

Parameter	Units	MW-01 3.5-4.0 feet bgs	MW-01 0.0-12.0 feet bgs	MW-01 21.0-22.0 feet bgs	MW-03 3.5-4.0 feet bgs	MW-03 12.0-14.0 feet bgs	MW-03 22.5-23.0 feet bgs	MW-18 1.0-3.0 feet bgs	MW-18 11.0-12.0 feet bgs	MW-18 14.0-16.0 feet bgs
Description	NA	Fine sand	Fine sand	Silt	Fine sand	Fine sand	Fine sand	Fine sand	Fine sand	Silt
USCS Classification	NA	SP	SP	ML	SP	SP	SP	SP	SP	ML
Liquid Limit	NA	NA	NA	34.8	27.7	30.9	24.4	NA	41.5	NA
Plastic Limit	NA	NA	NA	8.7	9.8	7.6	10.1	NA	10.2	NA
Plasticity Index	NA	NA	NA	26.1	17.9	23.3	14.3	NA	31.3	NA
Bulk Density	g/cc	1.62	1.53	1.67	1.78	1.55	1.74	1.63	1.72	1.76
Effective Porosity	% vb	25.22	35.15	7.54	12.23	19.29	17.80	30.15	3.98	16.65
Fraction Organic Content	g/g	0.0050	0.0178	0.0015	0.0111	0.0047	0.0261	0.0293	0.0014	0.00075
Grain Density	g/cc	2.65	3.57	2.65	2.62	2.69	2.69	2.84	2.65	2.67
Grain Size	mm	0.351	0.232	0.049	0.236	0.137	0.078	0.281	0.125	0.042
Hydraulic Conductivity	cm/s	2.27	1.74	1.24	1.63	2.62	3.26	3.17	8.28	2.02
Percent Moisture	% wt	15.50	27.64	18.75	13.43	23.05	18.04	13.29	22.83	18.13
Permeability	milliDarcy	241.92	18.72	0.13	0.17	2.83	34.98	322.56	8.44	2.06

TABLE 2 (Continued)

HYDROGEOLOGIC PARAMETERS
MDI SUPERFUND SITE, HOUSTON, TEXAS

Parameter	Units	MW-01 3.5-4.0 feet bgs	MW-01 0.0-12.0 feet bgs	MW-01 21.0-22.0 feet bgs	MW-03 3.5-4.0 feet bgs	MW-03 12.0-14.0 feet bgs	MW-03 22.5-23.0 feet bgs	MW-18 1.0-3.0 feet bgs	MW-18 11.0-12.0 feet bgs	MW-18 14.0-16.0 feet bgs
pH	NA	7.48	7.19	8.17	7.02	7.46	7.57	7.35	8.09	7.18
Percent Fine Sand	% wt	54.34	38.32	35.45	51.49	50.5	48.42	44.2	67.89	29.42
Percent Medium Sand	% wt	36.64	32.6	0	21.56	11.86	2.63	33.96	0	0
Percent Clay	% wt	2.88	8.62	18.94	8.59	16.7	17.47	4.8	12.61	13.57
Percent Silt	% wt	6.14	20.47	45.61	18.36	20.95	31.48	17.05	19.5	57.02
Percent Silt & Clay	% wt	9.02	29.09	64.55	26.95	37.65	48.95	21.85	32.11	70.58
Total Porosity	% vb	38.84	57.26	37.11	31.91	42.17	35.16	42.64	35.34	34.08

Notes:

bgs	Below ground surface
cm/s	Centimeter per second
g/cc	Gram per cubic centimeter
g/g	Gram per gram
mm	Millimeter
ML	Low plasticity silt
NA	Not applicable; unitless
% vb	Percent void
% wt	Percent by weight
SP	Poorly graded sand
USCS	United Soil Classification System

TABLE 3

RETARDATION FACTORS
MDI SUPERFUND SITE, HOUSTON, TEXAS

Compound	Log K_{oc}	K_{oc} (L/kg)	K_d (vadose zone)	K_d (foundry sand)	K_d (native sand)	R (foundry sand)	R (native sand)	V (foundry sand) (foot/year)	V (native sand) (foot/year)
Benzene	1.85	71	0.35	0.42	0.14	2.81	1.60	25.00	219.78
Benzo(a)pyrene	6.74	5,495,409	27,477	32,972	10,991	140,345	46,782	0.0005	0.01

Notes/Calculations:

$K_d = f_{oc} * K_{oc}$
where,
- K_d = distribution coefficient
- f_{oc} (fraction organic carbon in vadose zone) = 0.005kilogram per kilogram (kg/kg) (geometric mean of 12 vadose zone samples)
- f_{oc} (fraction organic carbon in foundry sand) = 0.006 kg/kg (geometric mean of 2 foundry sand zone samples)
- f_{oc} (fraction organic carbon in native sand) = 0.002 kg/kg (geometric mean of 4 native sand zone samples)
- K_{oc} = Octanol-carbon partition coefficient (liters per kilogram [L/kg])

$R = 1 + (P_b * K_d)/n$
where,
- R = retardation coefficient (dimensionless)
- P_b = bulk density = 1.66 kilograms per liter (kg/L) (arithmetic mean of all samples)
- K_d = distribution coefficient
- n = total porosity = 0.39 (arithmetic mean of all samples)

$V = (1/R)(K)(i)(n_e)$
where,
- V = transport velocity (dimensionless)
- R = retardation coefficient (dimensionless)
- K = hydraulic conductivity (foundry sand) = 2.5 feet/day (geometric mean of 3 values)
- K = hydraulic conductivity (native sand) = 19.3 feet/day (geometric mean of 3 values)
- i = hydraulic gradient = 0.01 (reasonable site-wide approximation)
- n_e (effective porosity of foundry sand) = 0.13 (arithmetic mean of 2 foundry sand zone samples)
- n_e (effective porosity of native sand) = 0.20 (arithmetic mean of 6 native sand zone samples)

3.2 ADDITIONAL INFORMATION REQUIRED TO SUPPORT MNA

Tetra Tech has identified additional information that will be required to support an MNA remedy at the MDI site. This includes the following:

- Information regarding the mass of the contaminants within the relatively limited confines of the ground water plumes in the subsurface
- Trend data to evaluate the stability of the contaminant plumes
- Localized geochemical data to evaluate the assimilative capacity of the aquifer

Information regarding the mass of contaminants will be collected by installing additional monitoring wells near existing well MW-20 (Figure 1). Location-specific aquifer parameters will be determined though the performance of slug tests and, if possible single well tests. At the same time, water quality samples will be collected across the site to assess plume stability. Table 4 summarizes the criteria that need to be met for an MNA remedy and identifies the way that the MDI site complies with these criteria.

3.3 IMPLEMENTATION OF MNA REMEDY

The MNA remedy will be implemented following several source removal steps:

- Existing debris and concrete overlying the source regions will be removed.
- Clean soils will be stockpiled.
- Soils with visible contamination will be excavated and stockpiled
- Verification samples will be collected from the walls and base of the excavation(s) and analyzed for VOCS and TPH near at the former LNAPL location (MW-20) and PAHs were B(a)P was detected (MW-3).
- Contaminated soils will be sampled prior to disposal at a Subtitle D landfill.
- LNAPL near MW-20 will be pumped into a storage tank, sampled, and disposed of appropriately.
- The excavations will be backfilled with clean soils.
- Replacement wells will be installed.

Once excavations have removed the source of contaminants, MNA will be relied upon to achieve the remedial action objectives (RAO) in ground water.

TABLE 4

MNA CRITERIA EVALUATION
MDI SUPERFUND SITE, HOUSTON, TEXAS

Criterion	Evaluation	Conditions Favorable?
Is the plume stable or declining in mass and area?	Insufficient trend data presently exist to verify plume stability; however, well MW-02 is downgradient from the B(a)P source at MW-03 and does not have B(a)P ground water concentrations above screening levels. This suggests the plume is not expanding at an appreciable rate. Three additional wells are scheduled to be installed cross- and downgradient from the LNAPL plume noted in MW-20 to further define the extent of the LNAPL. Plume delineation will be complete prior to the RA and an additional round of ground water sampling may provide insight into plume stability.	Direct evidence does not yet exist. Planned source removal in conjunction with the low concentrations detected suggests aquifer conditions are likely to be favorable.
Are source area MNA cleanup times comparable to aggressive source area technologies?	Source areas will be addressed during the RA. Soils will be excavated in the source areas down to the water table, with the excavations backfilled with clean soils. This portion of the ground water remedy does not rely upon MNA mechanisms to decrease the source. Source removal prior to MNA will increase effectiveness of MNA.	Yes
Is there direct evidence of contaminant destruction mechanisms?	Additional petroleum hydrocarbon data to be collected near MW-20 should provide additional information. Given the anticipated low residual concentrations post RA, contaminant destruction is not anticipated to be a concern. Sorption of B(a)P by soil organic matter and soil may limit bioavailability and therefore, biodegradation rates. Half lives for degradation of B(a)P ranges from 6 months to 1 year, and have been shown to be positively correlated with log K_{oc} and inversely correlated with solubility. Low measured concentrations do not support additional analysis of destruction mechanisms.	Direct evidence does not yet exist; aquifer conditions are likely to be favorable.

TABLE 4 (Continued)

MNA CRITERIA EVALUATION
MDI SUPERFUND SITE, HOUSTON, TEXAS

Criterion	Evaluation	Conditions Favorable?
Are there nearby water supply wells that may be impacted prior to completion of this remedy?	There are presently no downgradient water wells within the defined solute plume or within several years projected travel time. Therefore, development of a plume management zone and restriction of future ground water use within the affected area is possible with minimal or no disruption to current off-site land use.	Yes
Are transformation products benign?	Hydrocarbon transformation products are relatively benign. Transformation products of B(a)P are not well understood. Once the source has been removed, transformation to daughter products will not be as significant as dilution in removing additional site risk in the MW-03 area.	Aerobic conditions are anticipated in the shallow water-bearing zone. Given the slow rate of degradation of the heavy polycyclic aromatic hydrocarbons, this is likely not a significant concern.
Do ground water geochemical indicators support destructive mechanisms?	Additional ground water samples are being collected to complete this analysis near MW-20. Although the precise composition of the LNAPL is not known, the likely constituents can be predicted given that the LNAPL is a residual from a waste oil tank. Anticipated low concentrations of residual aliphatic and aromatic COPCs, including benzene, have been shown to be amenable to aerobic degradation at numerous sites across the country.	Yes

Notes:

B(a)P Benzo(a)pyrene
COPC Contaminant of potential concern
K_{oc} Octanol-carbon partition coefficient
LNAPL Light nonaqueous-phase liquid
MNA Monitored natural attenuation
RA Remedial action

The aliphatic and aromatic hydrocarbons in the northwest corner of the MDI site will be monitored to ensure that degradation of the remaining low levels of contamination will proceed.

In the northeast corner of the site, existing concentrations of B(a)P are already quite low. The maximum concentration detected was 0.619 µg/L, with the RAO of the MCL being 0.2 µg/L. This indicates that a contaminant reduction factor (CRF) of less than 4 (calculated by dividing the maximum detected B(a)P concentration by its MCL) will meet site RAOs, which should be achievable through MNA, given the high sorptive capacity of the subsurface soils (as evidenced by the fraction organic carbon an distribution coefficients of both the foundry sands and native sands). It is likely that those low concentrations of B(a)P remaining in the soils after the source has been removed will be sorbed onto the soils.

4.0 SUMMARY AND CONCLUSIONS

When used in conjunction with source removal, MNA is an appropriate component of the remedy for ground water at the MDI site. Based on the human health risk assessment completed for the site (Tetra Tech 2003b), B(a)P in the northeast corner of the site near MW-3 is the only COPC in ground water. To meet the MCL for this compound, a CRF of less than 4 is all that is required. Furthermore, given its sorptive capacity, it is highly unlikely that B(a)P will migrate off site. Therefore, it is likely that B(a)P will be depleted through sorption processes and dilution following source removal and will be attenuated accordingly.

LNAPL is also being addressed in the northwest corner of the facility. No priority pollutants were identified in ground water at concentrations above MCLs. However, it is possible that with complete plume delineation, benzene may be discovered above the MCL. If so, benzene and other aliphatic and aromatic compounds associated with waste oils (although not detected at the MDI site) readily degrade naturally both aerobically and anaerobically and will be very receptive to MNA.

5.0 REFERENCES

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