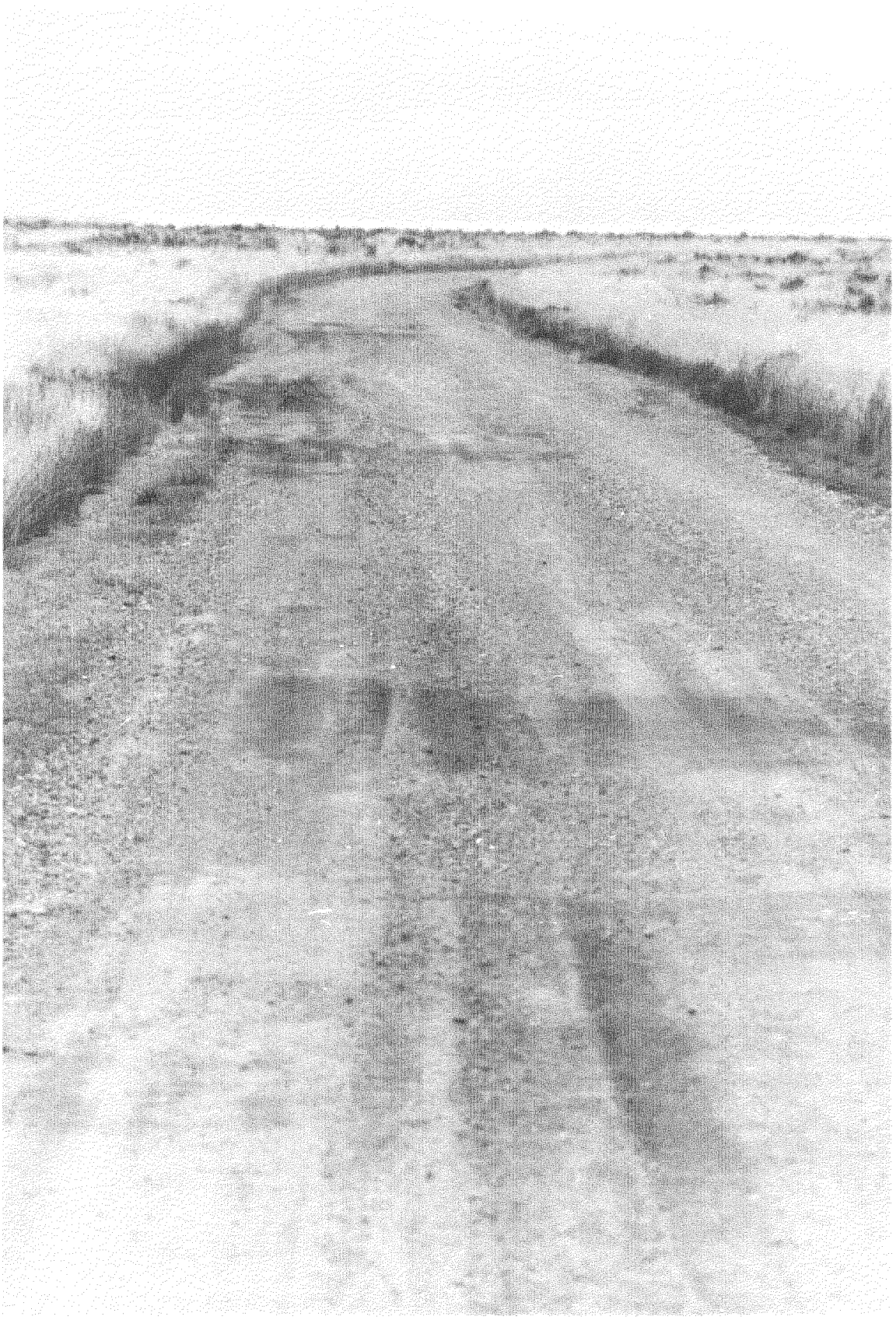
Draft

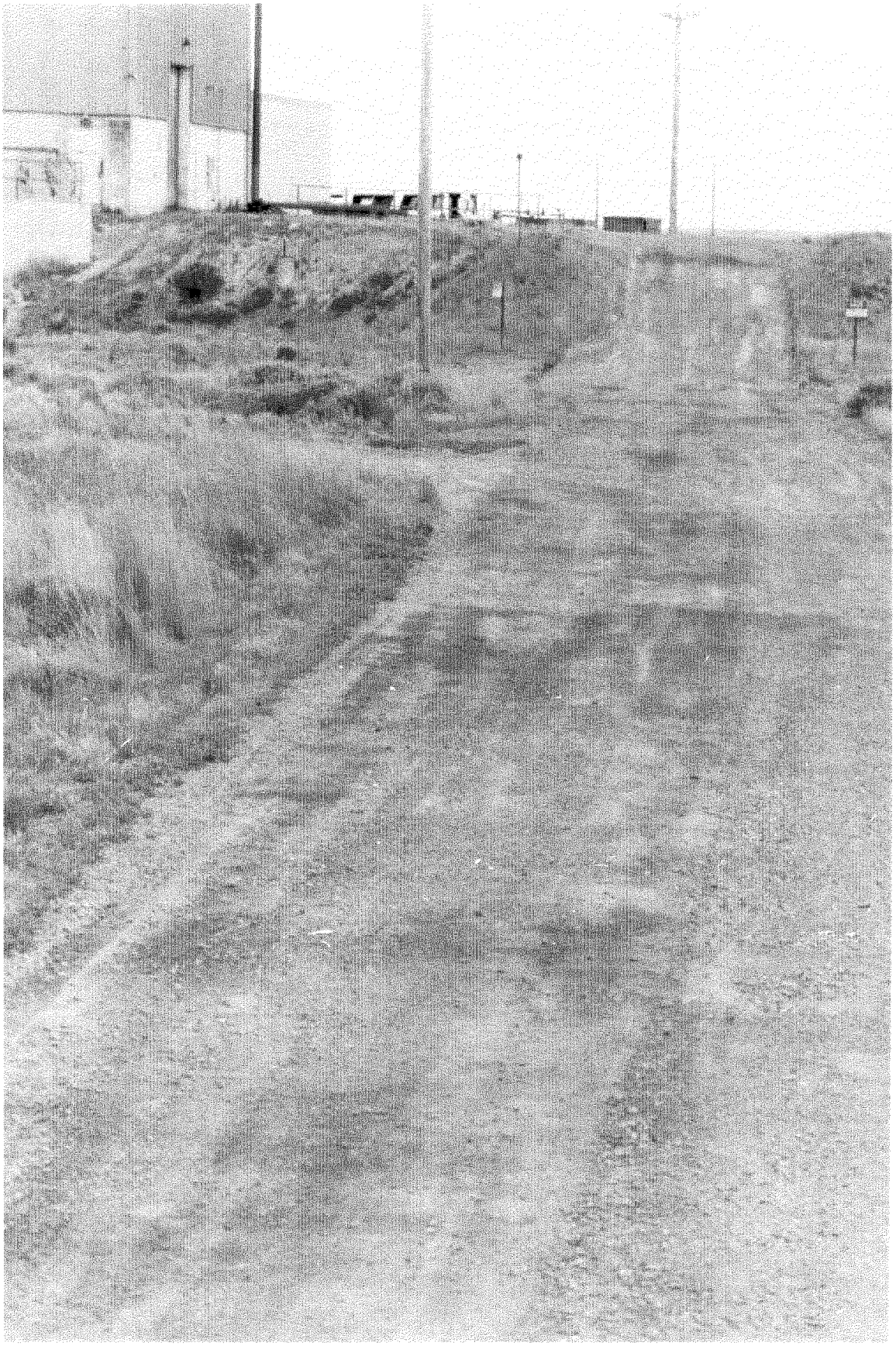
Attachment A

Photographs of Site #021

Site: 021, Stains on Road T17 Form Portland Avenue To The Backside of EOCR/STF
(PN94-0778-1-6)



Site: 021, Stains on Road T17 From Portland Avenue To The Backside of EOCR/STF
(PN94-0778-1-7)



Site: 021, Stains on Road T17 From Portland Avenue To The Backside of EOCR/STF
(PN94-0778-1-8)

Site: 021, Stains on Road T17 From Portland Avenue to the Backside of EOCR/STF
(PN99-0424-1-16)

Draft

Attachment B

Supporting Information for Site #021

(2)

DECISION DOCUMENTATION PACKAGE
COVER SHEET

prepared in accordance with

TRACK 1 SITES:
GUIDANCE FOR ASSESSING
LOW PROBABILITY HAZARD SITES
AT THE INEL

Site Description: Security Training Facility (STF) Gun Range

Site ID: STF-02 Operable Unit: 04

Waste Area Group: 10

I. SUMMARY - Physical description of the site:

The Security Training Facility (STF)-02 gun range is located approximately 2.5 mi. east of the Central Facilities Area (CFA). The access route is from U.S. Highway 20 to Jefferson Boulevard, then west to Arthur Boulevard (See Figure 1). The STF occupies facilities originally constructed to support the Experimental Organic Cooled Reactor (EOCR). STF-02 is located approximately 350 ft northeast of the STF-601 building.

The EOCR complex was converted to the STF in 1983, and served as a training center for the INEEL security helicopters and Special Response Team (SRT). This conversion included the construction of a helicopter pad, rappelling tower, physical fitness course, STF-02 gun range and surrounding soil impact berms, STF-612 shooting house, and the STF-694 gas house (see Figure 2). This site was used from 1983 until 1990 for security force practice maneuvers using small (<50 caliber) weapons. It is estimated that 4 to 5 million rounds were fired into the soil impact berms[1,2]. STF-02 was placed on inactive status following an accident at the STF-612 building on January 1, 1990. The STF-02 site was identified in the Fall of 1997 as a new CERCLA site and included in the Operable Unit (OU) 10-04 Work Plan.

Potentially contaminated areas associated with this site include: buildings STF-612 and STF-694; the inner and outer soil berms; the target range area; creosote-treated timbers used as targets and to line inner walls of STF-612; loose sand also found in the inner walls of STF-612; a rubble pile located at the northeast corner of the berms; and outlying soil areas extending a distance of 600 ft north and 50 ft on all other sides of the berms (see Figure 2).

No sample data exist for this site. Contaminants of potential concern include lead, copper, antimony, zinc, red phosphorus, mercury compounds, nitrates, and other components associated with ammunition debris. The timbers used for targets and inner walls of STF-612 were treated with coal tar creosote and may pose a potential hazard. Although the shell casings were routinely picked up and recycled after firing, recent site walk-throughs confirm that some still remain at the site. No known remedial activities have taken place to date at STF-02. Based on the estimated quantity of debris remaining in the soil, this site is potentially above the residential future land use screening level for lead in soils (400 mg/kg).[3] Preliminary surveys by a Radiological Control Technician indicate that no radiological contamination exists at the STF-02 gun range.

FIGURE 2.

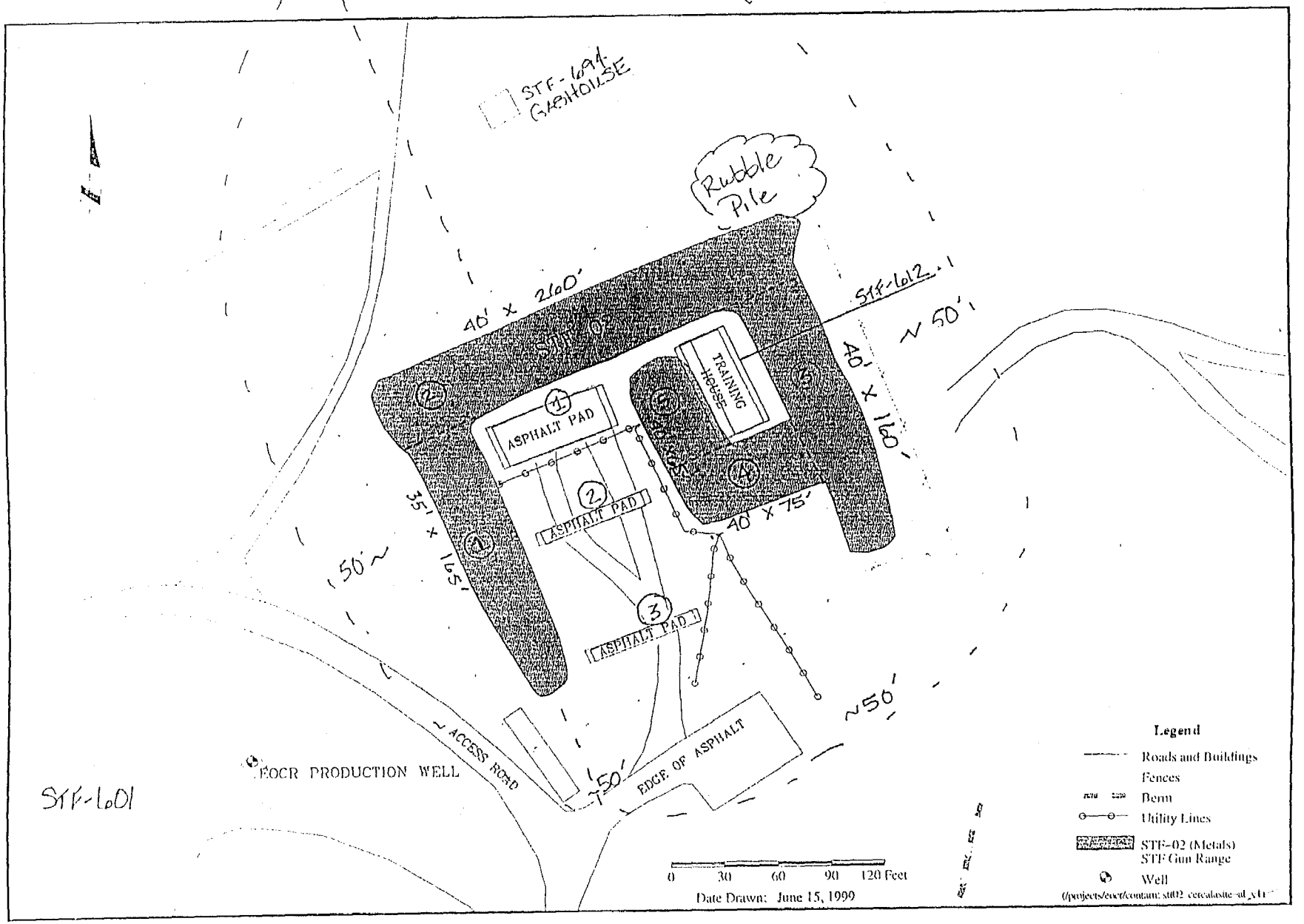
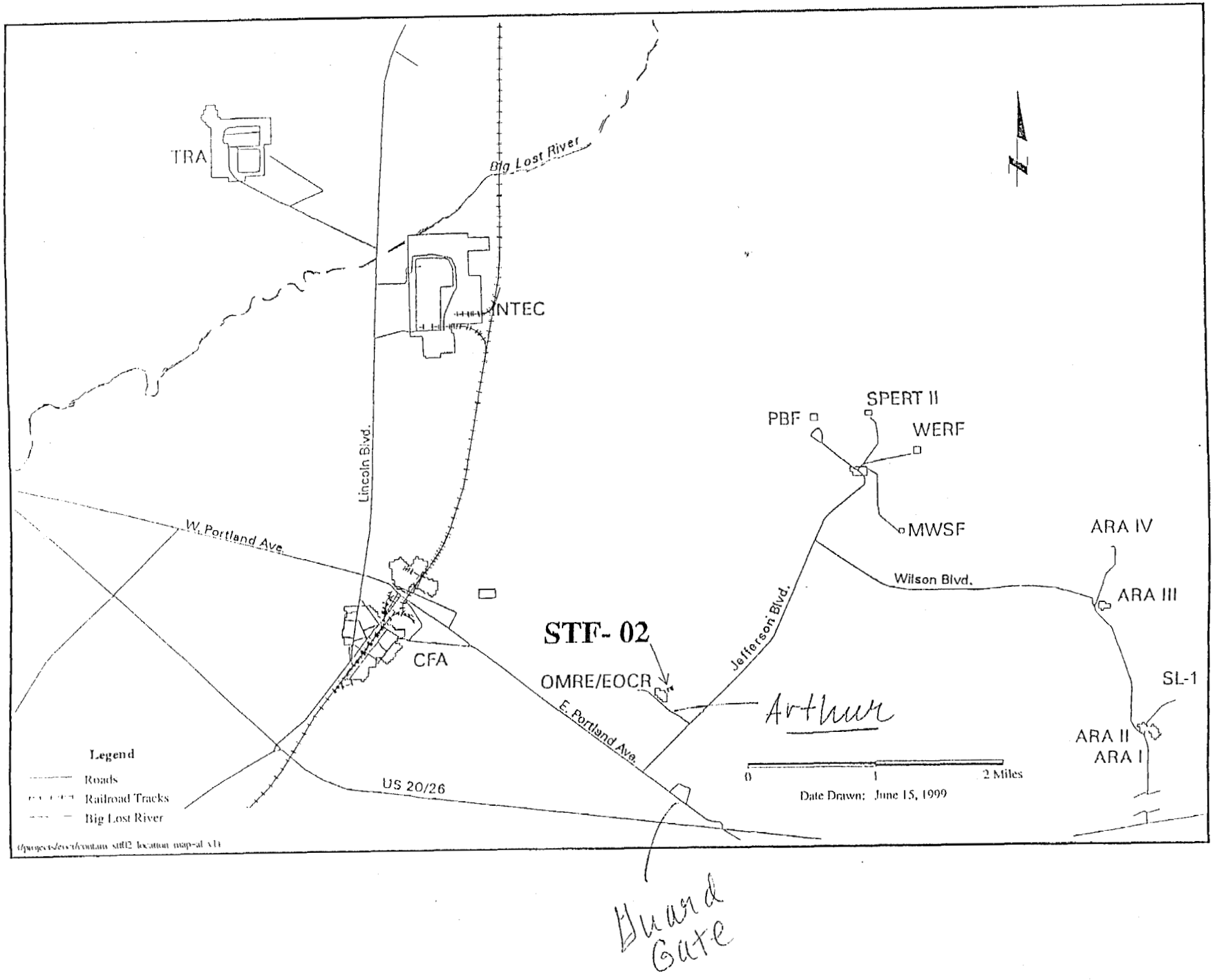

~600'
STF-694
GASHOUSE
Rubble Pile
40' x 260'
STF-02
STF-612
~50'
40' x 160'
TRAINING HOUSE
ASPHALT PAD
ASPHALT PAD
ASPHALT PAD
40' x 75'
35' x 165'
~50'
~50'
~50'
~ ACCESS ROAD
EDGE OF ASPHALT
EOCR PRODUCTION WELL
STF-601
0 30 60 90 120 Feet
Date Drawn: June 15, 1999
Legend
Roads and Buildings
Fences
Berm
Utility Lines
STF-02 (Metals)
STF Gun Range
Well

FIGURE 1.



Guard Gate

Environmental Baseline Survey Team Photos
Tied to Potential New Sites (CERCLA)

THE FOLLOWING SITES HAVE BEEN TIED TO THOSE NUMBERS USED TO MAP OUT THE POTENTIALLY NEW CERCLA SITES (PNS) IDENTIFIED BY THE ENVIRONMENTAL BASELINE SURVEY TEAM. THE NUMBER USED FOR MAPPING CAN BE SEEN IN BOLD ABOVE THE TOWNSHIP, RANGE AND SECTION.

PNS 6
T2N, R30E, Sec. 8
Proof Sheet 94-0778-1, dated 7-25-94
Photos 6 through 8
Located on approximately a 1-1/2 mile section of road T17, leading from Portland Avenue road to the back of the Security Training Facility (STF). Road is stained with what appears to be oil, possibly spread as a dust suppressant. Interviews with Company personnel indicate that this oil may be contaminated with PCBs.

PNS 9
T3N, R29E, Sec. 13
Proof Sheet 94-0546-2, dated 5-26-94
Photos 7 through 11
N. E. of TRA-732
Photos show an area identified by the EBS team as a potential CERCLA site. This site is located N. E. of TRA-732, outside the TRA facilities fence line, in an old canal that runs toward the N. E. (Note--other photos were taken of this area on a return visit. Also, reference Proof sheet number 94-948-2 for other photos of this area. Photo 7 shows a sink hole where a container (possibly a small drum or a 5 gallon bucket) can be seen buried. Photos 8 through 11 show debris in the area. Asbestos (transite) was identified in this debris as well as pipes, and a significant amount of burned wood.

PNS 9
T3N, R29E, Sec. 13
Proof Sheet 94-948-2, dated 8-12-94
Photos 6 through 12
Photos taken by EBS team of area of burned and buried debris located in the old canal just E. of TRA (outside of fence line, NE of sewage treatment plant). Photo 6 shows burned wood looking debris, Photo 7 shows pieces of suspected asbestos, photo 8 shows more debris including metal pipe, Photo 9 shows berming of more debris, and photos 10 and 11 show sink hole where concrete can see that has been buried. Photo 12 is a picture where the EBS team is attempting to show what appears to be a buried 5 gallon bucket or a small drum. (Reference Proof Sheet 94-0546, 5-26-94, Photos 6 through 10 taken of this same area)

- T2N, R29E, Sec. 35 - Potentially buried heat exchangers containing sodium located in the CFA Landfill. Interviews indicate that these heat exchangers from the Hallam Reactor. Note: The WAG 4 Manager was aware of the situation, which assured the EBS team that this had been addressed in the applicable WAG documents.

- T2N, R30E, Sec. 3 - A large circle of black, granulated, unknown substance that appears to have been dumped from a truck onto the ground, which is now devoid of vegetation. Interviews indicate that this is suspected sand blasting sand and could be radiologically contaminated. Substance is located outside the PBF/WERF fence line. Evaluations of old photos indicate this material has been there since at least 1977. (Reference photograph 50 in Appendix B)

- T2N, R30E, Sec. 6 - A stockpile area for utility line poles, treated wood, and related power management equipment at the EG&G Idaho substation in CFA. The poles stored here are treated with pentachlorophenol, which is a restricted-use pesticide. The Environmental Coordinator for this area reported that the poles were TCLP tested and found to have less than regulatory limits of RCRA hazardous substances. Therefore, this area was not found to have any significant environmental conditions.

- T2N, R30E, Sec. 8 - Staining, with what appears to be oil possibly spread as a dust suppressant, on Road T-17 from Portland Avenue to the Security Training Facility. Interviews with INEL personnel indicate that historically oil was collected from various sources in central collection areas and sprayed as a dust suppressant. Interviewees believe that there is a strong possibility that this oil may have been contaminated with PCBs. (Reference Photograph 19)

- T2N, R30E, Sec. 35 - An actively mined cinder pit approximately one mile north of Atomic City was observed by EBS assessors. This black and red cinder pit straddles the southern border of the INEL (the boundary line runs through this pit) An assessor noted that the side slopes of the pit do not appear to meet OSHA requirements; however, no potentially significant environmental conditions associated with this site were noted.

- T2N, R30E, Sec. 35 - Newly drilled well on a concrete base located approximately one-half mile north of Atomic City. Minor soil stains (possibly petroleum spills) were noted in the area of this well; however, no potentially significant environmental conditions associated with this site were noted.

- T2N, R30E, Sec. 36 - What appears to be modern trash (a big bucket) was observed located on Road T-4 near the intersection with Road T-6. Also a big vent and a large box were seen on the south end of Road T-4. No potentially significant environmental conditions associated with this site were noted.

- T2N, R32E, Sec. 1 - Stained soil (cause unknown) observed on the road to East Butte approximately 300 yards off Highway 20/26.

- T2N, R32E, Sec. 14 - Miscellaneous pieces of garbage and wood that were either blown or thrown down the north side of the East Butte peak. No potentially significant environmental conditions associated with this site were noted.

- T2N, R32E, Sec. 16 - Some garbage (modern) located in the Middle Butte Cave area. No potentially significant environmental conditions associated with this site were noted.

4

Assessors noted that the old back road (T-17) leading from Portland Avenue to the back side of STF is stained with what appears to be some type of hydrocarbon used as a dust suppressant. Interviews indicated that there is a potential that this may be PCB contaminated, because many years ago (prior to TSCA regulations addressing PCBs) oil was mixed from various sources and spread on roads as a means of disposal and dust suppressant.

STF-605 Deep Well Pumphouse

Construction: Built in 1962. Poor condition. One story. Sheet metal siding and roof. Insulated. Approximately 108 ft^2.

Use and Utilities: Vacant, one deep well pump in place but not functional. No utilities.

Pertinent environmental conditions: Assessment performed June 22, 1994. This is the old EOCR deep well pump house, and is no longer used. No significant environmental conditions identified during assessment which included walkthrough, interviews with escorts, and interviews with the WAG area Manager.

STF-607 Deluge Valvehouse

Construction: Built in 1962. Poor condition. One story. HCB walls. Metal roof. Approximately 45 ft^2.

Use and Utilities: Vacant, valves for fire protection. No utilities.

Pertinent environmental conditions: Assessment performed June 22, 1994. This is an abandoned structure that was associated with the EOCR; no longer operable. No significant environmental conditions identified during assessment which included walkthrough, interviews with escorts, and interviews with the WAG area Manager.

STF-610 Fuel Element Flow Test Facility

Construction: Built in 1962. Poor condition. One story. Steel frame with metal panel walls, corrugated sheet metal siding and roofing. Partially insulated. Approximately 976 ft^2.

Use and Utilities: Vacant, miscellaneous testing piping. No utilities.

Pertinent environmental conditions: Assessment performed June 22, 1994. This structure was associated with the old EOCR and has been abandoned; is no longer operable. No significant environmental conditions identified during the assessment which included walkthroughs, interviews with escorts, and interviews with the WAG area Manager.

STF-611 Pumphouse

Construction: Built in 1962. Poor condition. One story. Corrugated metal walls and roof. Insulated. Approximately 135 ft^2.

Use and Utilities: No longer used; was previously the drinking water supply for STF-601, one portable submersible pump, two pressure tanks, (approximately 55 gallons each). Facility no longer has potable water, on bottled water only. Power, space heater.

Pertinent environmental conditions: Assessment performed June 22, 1994. This structure was previously associated with the OMRE facility, and has now been abandoned. The area is roped off for radiological contamination. No other significant environmental conditions were identified during the assessment which included a walkthrough, interviews with escorts, and interviews with the WAG area Manager.

435.36
04/14/99
Rev. 03

NEW SITE IDENTIFICATION

021

Part A – To Be Completed By Observer

1. Person Initiating Report: Jacob Harris	Phone: 526-1877
Contractor WAG Manager: Douglas Burns	Phone: 526-4324

2. Site Title: 021, Staining on Road 17 from STF to Portland Road

3. Describe the conditions that indicate a possible inactive or unreported waste site. Include location and description of suspicious condition, amount or extent of condition and date observed. A location map and/or diagram identifying the site against controlled survey points or global positioning system descriptors shall be included to help with the site visit. Include any known common names or location descriptors for the waste site.

There is soil discoloration on the dirt road from Portland Road to the STF facility. During the July 1999 site visit, several stains were observed to a depth >2 inches, however no oil odor was detected. The GPS coordinates for this site are _____. The reference number for this site is 021 and can be found on the summary map as provided.

Part B – To Be Completed By Contractor WAG Manager

4. Recommendation:

☒ This site meets the requirements for an inactive waste site, requires investigation, and should be included in the INEEL FFA/CO Action Plan. Proposed Operable Unit assignment is recommended to be included in the FFA/CO.
WAG: Operable Unit:

☐ This site DOES NOT meet the requirements for an inactive waste site, DOES NOT require investigation and SHOULD NOT be included in the INEEL FFA/CO Action Plan.

5. Basis for the recommendation:

The conditions that exist at this site indicate the potential for an inactive waste site according to Section 2 of MCP-3448 Reporting or Disturbance of Suspected Inactive Waste Sites.

The basis for recommendation must include: (1) source description; (2) exposure pathways; (3) potential contaminants of concern; and (4) descriptions of interfaces with other programs, as applicable (e.g., D&D, Facility Operations, etc.)

6. Contractor WAG Manager Certification: I have examined the proposed site and the information submitted in this document and believe the information to be true, accurate, and complete. My recommendation is indicated in Section 4 above.

Name: _____ Signature: _____ Date: _____

7

Lockheed
Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date: May 22, 1995

To: S. M. Burns, MS 3953

From: R. S. Rice, MS 4110

Subject: CLOSURE REPORT FOR THE SAMPLING OF INEL ROADS FOR PCBS; EMS-114-94 - RSR-68-95

Attached are copies of two Reports of Analyses from Analytical Technologies, Inc. (ATI), the logbooks, and the Limitations and Validation (L&V) report for the sampling of polychlorinated biphenyls (PCBs) on Idaho National Engineering Laboratory (INEL) roads.

On April 3 and April 12, 1995, soil samples were collected from dirt roads near the East Butte, Fire Station #2, Naval Reactor Facility, and Security Training Facility. The samples were collected and analyzed according to the Abbreviated Sample and Analysis Plan for Sampling of INEL Roads for PCBs; EMS-114-94. The samples were sent to ATI under full chain of custody.

The data were validated by the Sample Management Office (SMO) at method validation level "B," as described in the SMO Standard Operation Procedure 12.1.1, "Levels of Method Validation."

A review of the data indicates that there are no PCBs present on the roadways.

If there are any questions or if you have other sampling and analysis needs, please feel free to contact me at 6-4189.

cae

Attachments

cc: (w/o Attach)
L. V. Street, MS 4110

(with Attach)
R. S. Rice File

AROCLORS
Method 8080

Sample ID

11494021PC STP

Lab Name: Analytical Technologies Inc,
Client Name: Lockheed Idaho Tech. Company
Client Project ID: EMS-114-94
Lab Sample ID: 95-04-028-01

Date Collected: 04/03/95
Date Extracted: 04/12/95
Date Analyzed: 04/14/95

Sample Matrix: Soil
Cleanup: Sulfuric Acid

Sample Weight: 30.0 g
Final Volume: 10 mL

Results are reported on a wet weight basis.

Analyte	Conc (ug/kg)	Detection Limit (ug/kg)
Aroclor 1016	ND	33
Aroclor 1221	ND	33
Aroclor 1232	ND	33
Aroclor 1242	ND	33
Aroclor 1248	ND	33
Aroclor 1254	ND	33
Aroclor 1260	ND	33

SURROGATE RECOVERY

Analyte	% Recovery	% Rec Limits
2,4,5,6-Tetrachloro-m-xylene	98	43 - 124

ND = Not Detected

AROCLORS
Method 8080

Sample ID

11494022PC

STF

Lab Name: Analytical Technologies Inc.
Client Name: Lockheed Idaho Tech. Company
Client Project ID: EMS-114-94
Lab Sample ID: 95-04-028-02

Date Collected: 04/03/95
Date Extracted: 04/12/95
Date Analyzed: 04/14/95

Sample Matrix: Soil
Cleanup: Sulfuric Acid

Sample Weight: 30.0 g
Final Volume: 10 mL

Results are reported on a wet weight basis.

Analyte	Conc (ug/kg)	Detection Limit (ug/kg)
Aroclor 1016	ND	33
Aroclor 1221	ND	33
Aroclor 1232	ND	33
Aroclor 1242	ND	33
Aroclor 1248	ND	33
Aroclor 1254	ND	33
Aroclor 1260	ND	33

SURROGATE RECOVERY

Analyte	% Recovery	% Rec Limits
2,4,5,6-Tetrachloro-m-xylene	99	43 - 124

RV

ND = Not Detected

The final two digits specifically identify the analyses requested using the codes provided by the Statistics, Reliability and Analysis Unit. See the example ID following:

Example sample number: 11494011PC

This sample ID would indicate the sample number assigned to the EMS-114-94 project. The code would indicate that the sample is for method "8080" PCBs analysis. The exact sample location will be noted in the sample log. The following samples are currently planned for this project:

Description	Sample IDs	Sample Analyses
East Butte Road	11294011PC	PCBs ✓
East Butte Road (Duplicate)	11294012PC	PCBs ✓
STF Road	11294021PC	PCBs ✓
STF Road (Duplicate)	11294022PC	PCBs ✓
NRF Road	11294031PC	PCBs ✓
NRF Road (Duplicate)	11294032PC	PCBs ✓
Fire Training Center Road	11294041PC	PCBs
Fire Training Road (Duplicate)	11294042PC	PCBs

2.10 Decontamination Procedures

To prevent cross-contamination, all reusable sampling equipment that comes in contact with the waste will be cleaned as follows:

1. Spray equipment with a nonphosphate detergent/DI water solution
2. Rinse with deionized water
3. Air dry all equipment
4. Wrap cleaned equipment in aluminum foil

MISCELLANEOUS SAMPLE LOGBOOK

PROJECT: EMS-114-94 COC#: 2024

DATE (MM/DD/YY): 04/03/95

SAMPLERS: Rice / Haney

LOCATION: Stinside Rd

REQUESTER: Sue Dunn

Charge #: 3XLA 81130

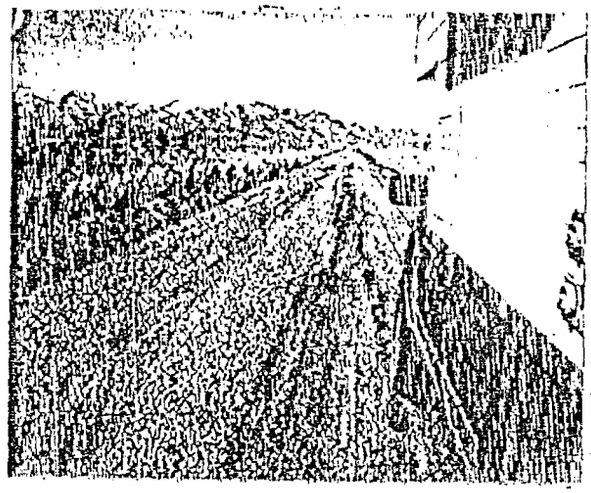
SAMPLE ID #	TIME	ANALYSIS	CONTAINER	LOT #	PRESERV.
~~114940 11PC~~		~~PCBs (8080)~~	~~250 mL WMG~~	~~DHAPEDS OH~~	~~4°C~~
~~114940 12PC~~		~~PCBs~~		~~DHAPEDS OH~~	
114940 21PC	1313	PCBs (8080)	250 mL WMG	F433 2040	4°C
114940 22PC	1313			F433 2040	
114940 31PC	1347			F433 2040	
114940 32PC	1347			F433 2040	
114940 41PC	1412			F433 2040	
114940 42PC	1412			F433 2040	

SAMPLE MATRIX

SOLID (X) LIQUID (__) SEDIMENT/SLUDGE (__)

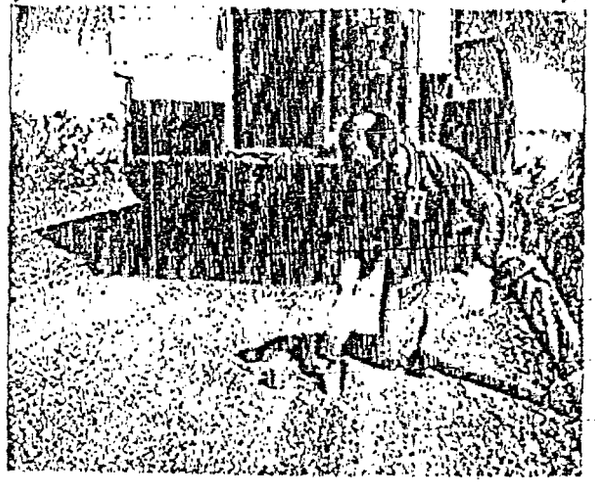
Narrative description of the sampling event including any deviations from the sampling plan:

Stained soil on ~~road~~ DHAPEDS OH several site roads was identified in 1994 during the Environmental Baseline Study. Sampling was postponed until pending weather conditions. PCB-contaminated oil may have been used as a dust suppressant. Pre-job briefing held at 1235. At the east better road, there were no visible stains. Tried to call Sue + Bill Parker - no luck. Go to STF + collect at 5 areas of most visible stains - covered a 90' area, both sides + middle of road. Sample collected 0-2", very little rock, color ranges to dark brown, silty clay. The sample location was ~4/10 th of a mile off main road + then 90' beyond. At NRF, the location is ~1/10 th mile from lincoln + stratton + collected over ~174 ft area. Same procedure. Dennis meets G. to fire station + locate stained area - not as visible here as at other sites. Take in a 37 ft radius area ~100' diameter. The last subst smelled like gear lubricant. None of the other locations had an obvious smell. Sample packaged + shipped 4/4/95. Note to customer. Notify lab.

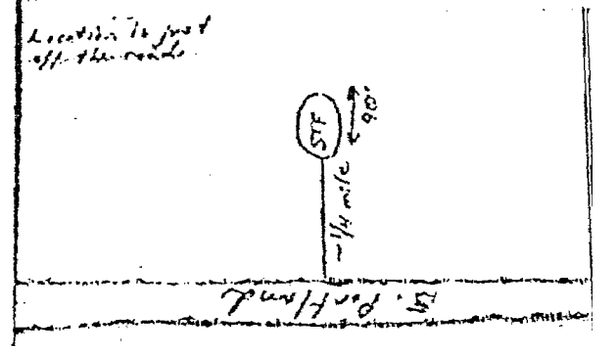


NRF

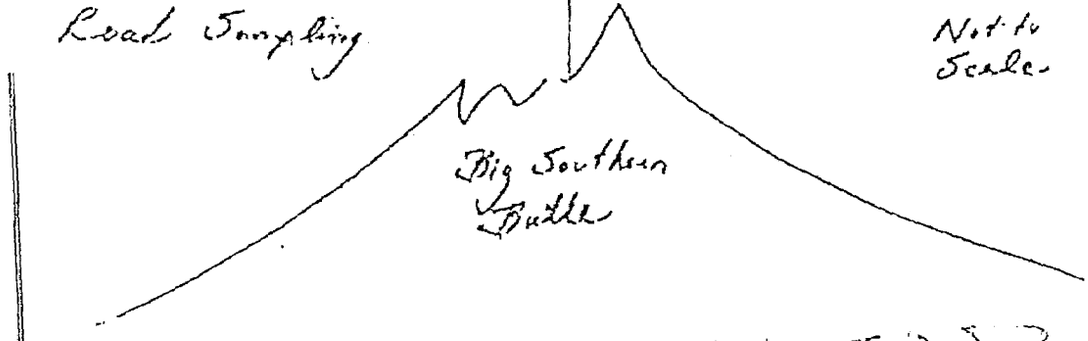
Fire Station



S-77 PCB
Road Sampling



Not to Scale



RECORDED BY: [signature] READ AND UNDERSTOOD BY: [signature]

MISCELLANEOUS SAMPLE LOGBOOK

PROJECT: ETAS-114-94 COC#: 2024

DATE (MM/DD/YY): 04/03/95

SAMPLERS: Rice / Haney

LOCATION: Sitewide Rdo

REQUESTER: Sue Burns

Charge #: 3XLA 81130

SAMPLE ID #	TIME	ANALYSIS	CONTAINER	LOT #	PRESERV.
~~114940110C~~		~~PCBs (8080)~~	~~250 ml WMG~~	~~04A2895 OH 4°C~~	
~~11494012PC~~		~~PCBs~~		~~04A2895 OH~~	
11494021PC	1313	PCBs (8080)	250 ml WMG	F4332040	4°C
11494022PC	1313			F4332040	
11494031PC	1347			F4332040	
11494032PC	1347			F4332040	
11494041PC	1412			F4332040	
11494042PC	1412			F4332040	

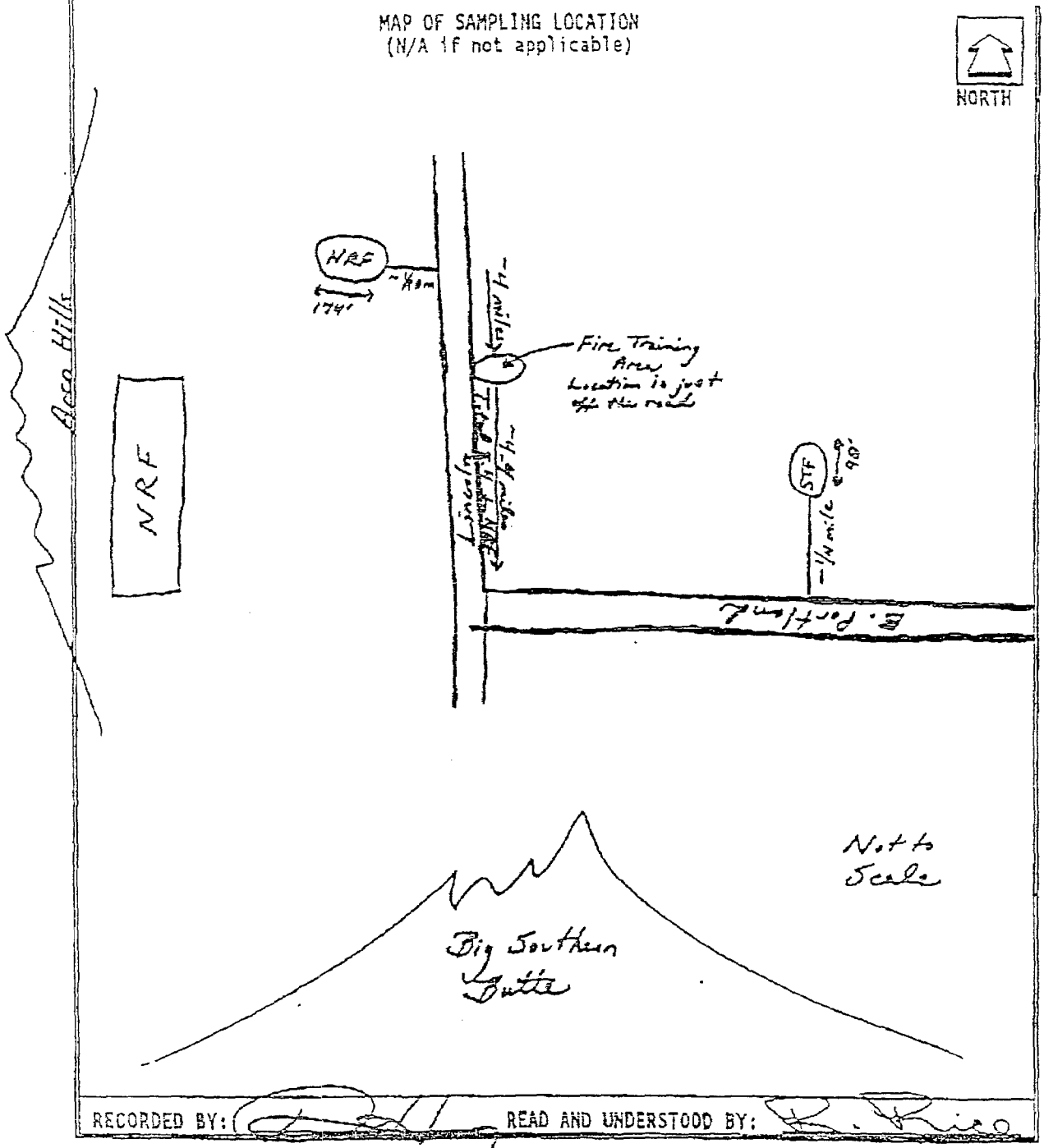
SAMPLE MATRIX

SOLID (X) LIQUID (__) SEDIMENT/SLUDGE (__)

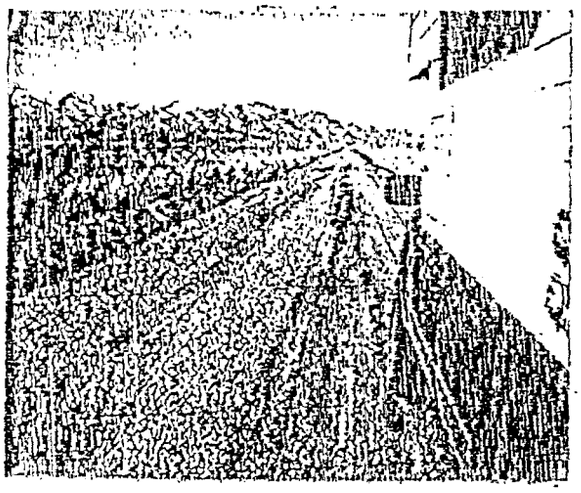
Narrative description of the sampling event including any deviations from the sampling plan:

Stained soil on ~~road~~ DIAPERS ON several sitewide roads was identified in 1994 during the Environmental Baseline Study. Sampling was postponed until pending weather conditions. PCB-contaminated oil may have been used as a dust suppressant. Pre-job briefing held at 1235. At the east better, heads, there were no visible stains. Tried to call Sue + Bill Burns - no luck. Go to STF + collect at 5 areas of most visible stains - covered a 90' area, both sides + middle of road. Samples collected 0-2", very little rock, color ranges to dark brown silty clay. The sample location was ~4/10 th of a mile off main road + then 90' beyond. At NRF, the location is ~1/10 th mile from lincoln + stretches a sample area ~194 ft across. Same procedure. Decon with G to fire station + locate stained area - not as visible here as at other sites. Take in a 3 ft radius area ~100' diameter. The last subset smelled like gear lubricant. None of the other locations had an obvious smell. Samples packaged + shipped 4/4/95. Note to customer. Notify lab.

MAP OF SAMPLING LOCATION
(N/A if not applicable)

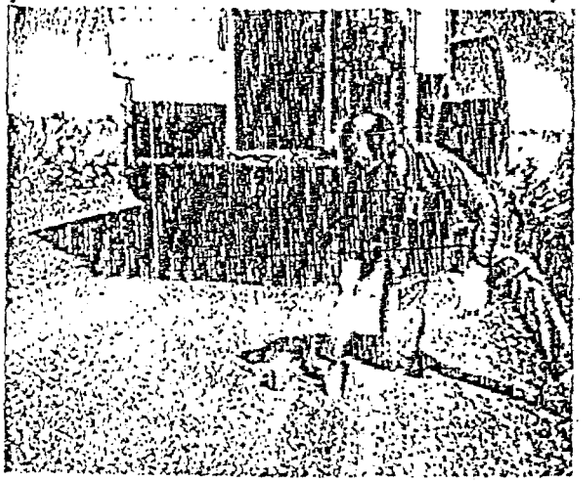


RECORDED BY: READ AND UNDERSTOOD BY:

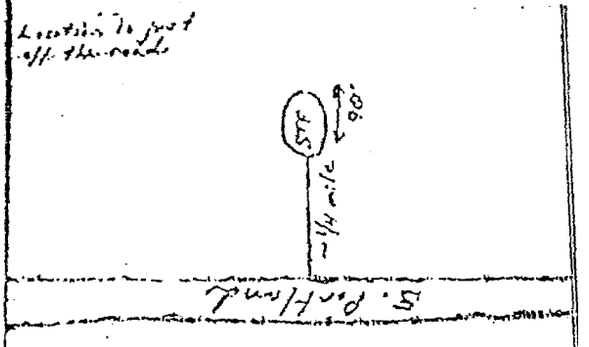


NRF

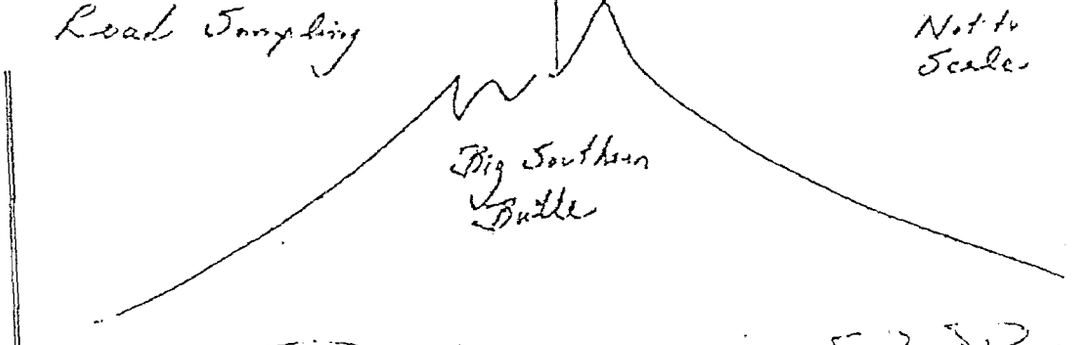
Fire Station



S-77F PCB
Road Sampling



Not to Scale



RECORDED BY: [signature] READ AND UNDERSTOOD BY: [signature]

EPA REGION III RISK-BASED CONCENTRATION TABLE: TECHNICAL BACKGROUND INFORMATION

originally developed by Roy L. Smith, Ph.D., Toxicologist
revised 4/12/99 by Jennifer Hubbard, Toxicologist

Development of Risk-Based Concentrations

General

Separate carcinogenic and non-carcinogenic risk-based concentrations were calculated for each compound for each pathway. The concentration in the table is the lower of the two, rounded to two significant figures. The following terms and values were used in the calculations:

Exposure variables	Value	Symboll
General:		
Carcinogenic potency slope oral (risk per mg/kg/d):	*	CPSo
Carcinogenic potency slope inhaled (risk per mg/kg/d):	*	CPSi
Reference dose oral (mg/kg/d):	*	RfDo
Reference dose inhaled (mg/kg/d):	*	RfDi
Target cancer risk:	1e-06	TR
Target hazard quotient:	1	THQ
Body weight, adult (kg):	70	BWa
Body weight, age 1-6 (kg):	15	BWc
Averaging time carcinogens (d):	25550	ATc
Averaging time non-carcinogens (d):	ED*365	ATn
Inhalation, adult (m3/d):	20	IRAa
Inhalation, child (m3/d):	12	IRAc
Inhalation factor, age-adjusted (m3-y/kg-d):	11.66	IFAadj
Tap water ingestion, adult (L/d):	2	IRWa
Tap water ingestion, age 1-6 (L/d):	1	IRWc
Tap water ingestion factor, age-adjusted (L-y/kg-d):	1.09	IFWadj
Fish ingestion (g/d):	54	IRF
Soil ingestion, adult (mg/d):	**100**	**IRSa**
Soil ingestion, age 1-6 (mg/d):	200	IRSc
Soil ingestion factor, age adjusted (mg-y/kg-d):	114.29	IFSadj
Residential:		
Exposure frequency (d/y):	350	EFr
Exposure duration, total (y):	30	EDtot
Exposure duration, age 1-6 (y):	6	EDc
Volatilization factor (L/m3):	0.5	K
Occupational:		
Exposure frequency (d/y):	250	EFo
Exposure duration (y):	25	EDo
Fraction of contaminated soil ingested (unitless)	0.5	FC

Sources: I = IRIS H = HEAST A = HEAST Alternate W = Withdrawn from IRIS or HEAST
E = EPA NCEA provisional value O = other

Basis: C = Carcinogenic effects N = Noncarcinogenic effects I = RBC at HI of 0.1 < RBC c

Chemical	CAS	RfDo mg/kg/d	CSFo 1/mg/kg/d	RfDi mg/kg/d	CSFi 1/mg/kg/d	VOC	Risk-based concentrations: Tap water ug/l	Ambient air ug/m3	Fish mg/kg	Soil Industrial mg/kg	Residential mg/kg
PARAQUAT DICHLORIDE	1910425	4.50E-003 I					1.6E+002 N	1.6E+001 N	6.1E+000 N	9.2E+003 N	3.5E+002 N
PARATHION	56382	6.00E-003 H					2.2E+002 N	2.2E+001 N	8.1E+000 N	1.2E+004 N	4.7E+002 N
**PENTACHLOROBENZENE	608935	8.00E-004 I					2.9E+001 N	2.9E+000 N	1.1E+000 N	1.6E+003 N	6.3E+001 N
**PENTACHLORONITROBENZENE	82688	3.00E-003 I	2.60E-001 H				2.6E-001 C	2.4E-002 C	1.2E-002 C	2.2E+001 C	2.5E+000 C
PENTACHLOROPHENOL	87865	3.00E-002 I	1.20E-001 I				5.6E-001 C	5.2E-002 C	2.6E-002 C	4.8E+001 C	5.3E+000 C
PERMETHRIN	52645531	5.00E-002 I					1.8E+003 N	1.8E+002 N	6.8E+001 N	1.0E+005 N	3.9E+003 N
PHENOL	108952	6.00E-001 I					2.2E+004 N	2.2E+003 N	8.1E+002 N	1.2E+006 N	4.7E+004 N
M-PHENYLENEDIAMINE	108452	6.00E-003 I					2.2E+002 N	2.2E+001 N	8.1E+000 N	1.2E+004 N	4.7E+002 N
O-PHENYLENEDIAMINE	95545		4.70E-002 H				1.4E+000 C	1.3E-001 C	6.7E-002 C	1.2E+002 C	1.4E+001 C
P-PHENYLENEDIAMINE	106503	1.90E-001 H					6.9E+003 N	6.9E+002 N	2.6E+002 N	3.9E+005 N	1.5E+004 N
2-PHENYLPHENOL	90437		1.90E-003 H				3.5E+001 C	3.3E+000 C	1.7E+000 C	3.0E+003 C	3.4E+002 C
PHOSPHINE	7803512	3.00E-004 I		8.60E-005 I			1.1E+001 N	3.1E-001 N	4.1E-001 N	6.1E+002 N	2.3E+001 N
PHOSPHORIC ACID	7664382			2.90E-003 I				1.1E+001 N			
PHOSPHORUS (WHITE)	7723140	2.00E-005 I					7.3E-001 N	7.3E-002 N	2.7E-002 N	4.1E+001 N	1.6E+000 N
P-PHTHALIC ACID	100210	1.00E+000 H					3.7E+004 N	3.7E+003 N	1.4E+003 N	2.0E+006 N	7.8E+004 N
PHTHALIC ANHYDRIDE	85449	2.00E+000 I		3.43E-002 H			7.3E+004 N	1.3E+002 N	2.7E+003 N	4.1E+006 N	1.6E+005 N
POLYBROMINATED BIPHENYLS		7.00E-006 H	8.90E+000 H				7.5E-003 C	7.0E-004 C	3.5E-004 C	6.4E-001 C	7.2E-002 C I
POLYCHLORINATED BIPHENYLS	1336363		2.00E+000 I		2.00E+000 I		3.3E-002 C	3.1E-003 C	1.6E-003 C	2.9E+000 C	3.2E-001 C
AROCLOR-1016	12674112	7.00E-005 I	7.00E-002 I		7.00E-002 I		9.6E-001 C I	8.9E-002 C I	4.5E-002 C I	8.2E+001 C I	5.5E+000 N
AROCLOR-1221	11104282		2.00E+000 I		2.00E+000 I		3.3E-002 C	3.1E-003 C	1.6E-003 C	2.9E+000 C	3.2E-001 C
AROCLOR-1232	11141165		2.00E+000 I		2.00E+000 I		3.3E-002 C	3.1E-003 C	1.6E-003 C	2.9E+000 C	3.2E-001 C
AROCLOR-1242	53469219		2.00E+000 I		2.00E+000 I		3.3E-002 C	3.1E-003 C	1.6E-003 C	2.9E+000 C	3.2E-001 C
AROCLOR-1248	12672296		2.00E+000 I		2.00E+000 I		3.3E-002 C	3.1E-003 C	1.6E-003 C	2.9E+000 C	3.2E-001 C
AROCLOR-1254	11097691	2.00E-005 I	2.00E+000 I		2.00E+000 I		3.3E-002 C	3.1E-003 C	1.6E-003 C	2.9E+000 C	3.2E-001 C I
AROCLOR-1260	11096825		2.00E+000 I		2.00E+000 I		3.3E-002 C	3.1E-003 C	1.6E-003 C	2.9E+000 C	3.2E-001 C
POLYCHLORINATED TERPHENYLS	61788338		4.50E+000 E				1.5E-002 C	1.4E-003 C	7.0E-004 C	1.3E+000 C	1.4E-001 C
POLYNUCLEAR AROMATIC HYDROCARBONS:											
**ACENAPHTHENE	83329	6.00E-002 I				y	3.7E+002 N	2.2E+002 N	8.1E+001 N	1.2E+005 N	4.7E+003 N
**ANTHRACENE	120127	3.00E-001 I				y	1.8E+003 N	1.1E+003 N	4.1E+002 N	6.1E+005 N	2.3E+004 N
BENZ[A]ANTHRACENE	56553		7.30E-001 E				9.2E-002 C	8.6E-003 C	4.3E-003 C	7.8E+000 C	8.7E-001 C
BENZO[B]FLUORANTHENE	205992		7.30E-001 E				9.2E-002 C	8.6E-003 C	4.3E-003 C	7.8E+000 C	8.7E-001 C
BENZO[K]FLUORANTHENE	207089		7.30E-002 E				9.2E-001 C	8.6E-002 C	4.3E-002 C	7.8E+001 C	8.7E+000 C
BENZO[A]PYRENE	50328		7.30E+000 I		3.10E+000 E		9.2E-003 C	2.0E-003 C	4.3E-004 C	7.8E-001 C	8.7E-002 C
CARBAZOLE	86748		2.00E-002 H				3.3E+000 C	3.1E-001 C	1.6E-001 C	2.9E+002 C	3.2E+001 C
CHRYSENE	218019		7.30E-003 E				9.2E+000 C	8.6E-001 C	4.3E-001 C	7.8E+002 C	8.7E+001 C
DIBENZ[A,H]ANTHRACENE	53703		7.30E+000 E				9.2E-003 C	8.6E-004 C	4.3E-004 C	7.8E-001 C	8.7E-002 C
DIBENZOFURAN	132649	4.00E-003 E				y	2.4E+001 N	1.5E+001 N	5.4E+000 N	8.2E+003 N	3.1E+002 N
FLUORANTHENE	206440	4.00E-002 I					1.5E+003 N	1.5E+002 N	5.4E+001 N	8.2E+004 N	3.1E+003 N
**FLUORENE	86737	4.00E-002 I				y	2.4E+002 N	1.5E+002 N	5.4E+001 N	8.2E+004 N	3.1E+003 N
INDENO[1,2,3-C,D]PYRENE	193395		7.30E-001 E				9.2E-002 C	8.6E-003 C	4.3E-003 C	7.8E+000 C	8.7E-001 C
2-METHYLNAPHTHALENE	91576	2.00E-002 E				y	1.2E+002 N	7.3E+001 N	2.7E+001 N	4.1E+004 N	1.6E+003 N
**NAPHTHALENE	91203	2.00E-002 I		9.00E-004 I		y	6.5E+000 N	3.3E+000 N	2.7E+001 N	4.1E+004 N	1.6E+003 N
**PYRENE	129000	3.00E-002 I				y	1.8E+002 N	1.1E+002 N	4.1E+001 N	6.1E+004 N	2.3E+003 N
PROMETON	1610180	1.50E-002 I					5.5E+002 N	5.5E+001 N	2.0E+001 N	3.1E+004 N	1.2E+003 N
PROMETRYN	7287196	4.00E-003 I					1.5E+002 N	1.5E+001 N	5.4E+000 N	8.2E+003 N	3.1E+002 N

Lockheed
Idaho Technologies Company

7

INTERDEPARTMENTAL COMMUNICATION

Date: December 20, 1994

To: R. S. Rice, MS 4110

From: C. O. Doucette, MS 3953

Subject: COMMENTS ON ABBREVIATED SAMPLING AND ANALYSIS PLAN FOR SAMPLING OF INEL ROADS FOR PCBs (EMS-114-94) - COD-06-94

Please make the following changes to the subject document. Then you can either forward the signature page for my signature or receive my approval per telecon. Thank you for your efforts.

1. In order to identify the documented source of the concern, please replace Section 2.1 with the following:

   "During the conduct of the Environmental Baseline Survey stained soil was noted on several site roads. The staining was documented on New Site Identification Forms. The roadways are being sampled to determine if any PCBs are present as interviews with site personnel indicate that PCB contaminated oil may have been used on roadways as a dust inhibitor. Samples will be collected in response to C. Doucette's request."

2. In Section 2.4, please revise the sentence to read as follows:

   "Data, acquired in accordance with the requirements specified in Section 3.1, will be used to determine if the roadways are stained with PCBs."

3. In Section 2.8, please add the following sentence at the end of the 1st paragraph:

   "The depth of the sampling will be representative of the depth of the stain, but no deeper than one foot."

4. In Section 2.8, please add the following sentence at the end of the 2nd paragraph:

   "Waste disposal is discussed in Section 6."

5. In Section 2.9, the description for Sample ID 11294032PC should be "NRF Road (Duplicate)."

6. No background samples will be required.

7. In Section 4.2, change "Cal Doucette" to "Susan Burns."

SPECIAL REQUEST INFORMATION LOG

Customer: C. O. Doucette

Customer phone: 6-8113/6-9382

Charge number: 3XLA81130

Date of request: 11-15-94

Date need completed by:

Request (describe): Take representative field screen/samples from stains on the following four dirt roads: 1) Between US RTE 20 and the East Butte; 2) Between Portland and STF; 3) Between Lincoln and NRF (North of turnoff); and 4) Fire Training Center Road.

List quality control requirements (duplicates, rinsates, etc.):

EM recommended

List analyses/methods and any special detection limits required:

EM recommended

Is special equipment needed to access sample material - keys, ladders, wrenches, etc?	No
Is the sample location in a radiation, controlled or contaminated area?	No
Is special personal protective equipment or training necessary?	No
Is a radiological work permit (RWP) or safe work permit (SWP) required?	No
Will industrial hygiene or radiological control coverage be required?	IH-Yes
If applicable, have outage requests and excavation permits been obtained?	N/A

If you need help completing this form, please contact Environmental Monitoring's Donna Haney (yhd) or Randy Rice (rr5) or call 6-4185.

Based on the priority of this job and existing identified backlog of work we estimate completion of this work/correction of this deficiency by:

b.) Other action (Please explain): Roger Cushman thought this job might be a fill-in project since it would take 4 or less hours to complete.

<<<<========== E N D O F F O R M ==========>>>>

a ICFA - MAINTENANCE WORK REQUEST - DEFICIENCY REPORT F
MSG FROM: YHO --INELVM1 TO: SOO --INELVM1 04/03/95 15:16:23
To: WJB --INELVM1 W J Becker
cc: YHO --INELVM1 D F Haney RR6 --INELVM1 R Rice
SOO --INELVM1 S M Burns

FROM: DONNA F HANEY
Subject: EMS-115-94

Bill: Randy and I collected the suspected PCB-contaminated road soils today at NRF, STF and the Fire Station. We tried to locate the East Butte road stains but didn't have any luck identifying these. Were these only identified from the air? The reason I'm asking is that there is lava material in several spots that is dark and might appear to be stains from the air. Please let us know if the East Butte road samples should be deleted or if you think we've overlooked. We'd like to ship these out tomorrow. Thanks!

P.S. When is the PCB class?

EMS-115-94
MSG FROM: SOO --INELVM1 TO: YHO --INELVM1 04/07/95 15:19:31
To: YHO --INELVM1 D F Haney

FROM: SUSAN M BURNS
WAC, MS 3953
526-9382 FAX 526-9473
Subject: EMS-115-94
Contact Gail Lewis-Kido (glk). She was on the original Environmental Baseline Survey Team. Alternate contacts are Jim Lane, Mona Dunihoo, or Scott Lebow. Let me know if you still can't find them. Good luck.

*** Forwarding note from YHO --INELVM1 04/07/95 14:28 ***
To: SOO --INELVM1 S M Burns
cc: YHO --INELVM1 D F Haney RR6 --INELVM1 R Rice

FROM: DONNA F HANEY
Subject: EMS-115-94

Bill doesn't know anything about the East Butte road - do you? Should we delete from the plan or do you know someone who could find the stains?

*** Forwarding note from YHO --INELVM1 04/03/95 15:18 ***
To: WJB --INELVM1 W J Becker
cc: YHO --INELVM1 D F Haney RR6 --INELVM1 R Rice
SOO --INELVM1 S M Burns

FROM: DONNA F HANEY
Subject: EMS-115-94

need to stabilize the poultry wastes before disposing of them on the land as crop fertilizer.

Acknowledgements

We thank Mrs. A. Ighodalo for providing poultry wastes and Dr. J. A. I. Omueti for his interest in this work.

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(9)

BIOREMEDIATION OF PETROLEUM- AND CREOSOTE-CONTAMINATED SOILS: A REVIEW OF CONSTRAINTS

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The evaluation and selection of technologies for the effective remediation of hydrocarbon-contaminated sites requires careful consideration of the waste/site/soil characteristics that determine their ultimate success. The presence of weathered hydrocarbon wastes and sub-optimal environmental conditions places technical restraints on the bioremediation of polynuclear aromatic hydrocarbon-contaminated soils. A brief overview of applicable bioremediation technologies is followed by an in-depth critical evaluation of limiting factors that can influence the efficacy of bio-treatment options, including waste composition, temperature, substrate, bioavailability, accompanying toxicants and soil structure.

Key Words—Creosote wood-preserving wastes, petroleum wastes, polynuclear aromatic hydrocarbons, bioremediation, constraints, weathered composition, bioavailability, salinity, toxic metals, soil texture, climatic conditions.

1. Introduction

Contaminated land resulting from previous industrial activity is now widely recognized as a potential threat to environmental health and its continual discovery over recent years has led to international efforts to restore contaminated soils and aquifers (Smith 1988, Hrudey & Pollard 1993). Current strategies for site clean-up emhasize on-site/*in-situ* treatment technologies that can be linked together in a process train of physico-chemical and/or biological methods capable of tackling a range of multi-media contamination (Sims 1990). This approach recognizes that application of a single technology alone is usually insufficient for effective site remediation.

Bioremediation is one component of the process train approach finding increasing application for hydrocarbon-contaminated soils. This process option has generated growing interest because of its reported cost-effectiveness. Bioremediation has been successfully applied at a number of coal-tar, petroleum and creosote hazardous waste sites in Europe (Bewley *et al.* 1990, Ellis *et al.* 1991) and North America (Piontek 1989, McGinnis *et al.* 1991, Hinchee *et al.* 1991). The presence of hydrocarbon contamination alone, however, is insufficient justification for the application of bioremediation.

Soil contamination at petroleum and wood-preserving sites has received increasing attention across Canada (CCREM 1988, CCME 1991*a,b*) because the contaminants

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frequently identified include polynuclear aromatic hydrocarbons (PAHs), BTEX compounds (benzene, toluene, ethylbenzene and xylenes), biocidal organics (pentachlorophenol, 2,4,6-trichlorophenol) and a range of toxic metals associated with refining and wood treatment operations (e.g. As, Cr, Cu, Pb and Ni). An exhaustive review of the bioremediation literature (Pollard & Hrudey 1992), coupled with an examination of waste/site/soil characteristics at several sites in Alberta (Pollard *et al.*1992, 1993) has highlighted a number of constraints that may reduce treatment efficacy at sites chronically exposed to hydrocarbon contamination. The purpose of this paper is to present a critical evaluation of the potential constraints on bioremediation technologies at petroleum and creosote wood-preserving facilities such that remediation specialists may be aware of these factors and design treatment process trains that can incorporate them accordingly.

The application and ultimate success of remedial measures is determined by a multitude of waste/site/soil characteristics and the interactions among them. These factors demand that evaluation of the potential applicability of treatment technologies is made on an individual site basis. Our discussion is largely focused on PAH bioremediation because the documented carcinogenicity of certain compounds in this group has resulted in relatively demanding clean-up criteria (Moen 1988, ATSDR 1990, CCME 1991*b*). Furthermore, the persistence of these compounds in the soil environment has been demonstrated consistently (Edwards 1983, Jones *et al.* 1989*a,b*, Wild *et al.* 1991).

2. Overview of bioremediation technologies

Biological treatment methods for the reclamation of contaminated land may be classed into four categories: *in situ* bioremediation; enhanced land treatment; slurry bioreactors; and bioventing. The first three technologies are applicable to the remediation of PAH-contaminated soils, while the last is limited to volatile organic compounds amenable to aerobic biotransformation (Long 1992). Here, we present a brief overview of these technologies, but this is a rapidly developing research field and biological soil treatment technologies are continually under refinement. For greater detail, the reader is referred to the many excellent reviews on the fundamental technical and microbiological aspects of bioremediation strategies (Lee *et al.* 1988, Morgan & Watkinson 1989*a,b*, Sims *et al.* 1990, Grady 1990, Madsen 1991, Ryan & Loehr 1991).

2.1 In situ *bioremediation*

The objective of *in situ* bioremediation is to stimulate the activity of the hydrocarbon-degrading microbial population in the subsurface vadose and saturated zones. This is achieved through the addition and management of oxygen and nutrients in a controlled, closed-loop system (Hopper 1989). Amendments (nutrients, electron acceptor and primary substrate) used to aid stimulation and maintenance of biological activity, are introduced up-gradient of the contaminated zone using wells, infiltration galleries or natural fractures in the underlying strata. Soluble transformation by-products, mobilized contaminant and unused nutrients are transported by diffusion and advection down-gradient to the recovery system. At the surface, they are treated and re-injected to recharge the contaminated zone. Site management of oxygen, nutrients and the water regime serves to contain hydraulically the contaminated zone. In this manner, off-site migration of mobile contaminants or potentially harmful metabolites is prevented.

For most circumstances, the principal factor limiting the rate of *in situ* bioremediation is the supply of amendments to the subsurface microbial population (Lee *et al.* 1988). Sites exhibiting subsurface saturated horizontal conductivities of less than 10^{-6} m s^{-1} (Thomas *et al.* 1987) are not considered amenable to this technology because of the retardation of mass transport mechanisms that are necessary for effective delivery of the amendments. Successful treatment relies on the degree of hydraulic control afforded by the delivery-recovery system. Without continual delivery of amendments and removal of metabolites, the system may become biologically inactive at one extreme or clogged with biomass because of excessive microbial activity at the other extreme. Only soluble transformation products will be recovered from the contaminated zone and poorly soluble metabolites, some of which may be toxic, may readsorb to the soil matrix. Soil washing with surfactant is therefore being used increasingly for the mobilization of trapped or adsorbed contaminants (Mahaffey *et al.* 1991).

2.2 *Enhanced land treatment*

Unfavourable environmental conditions that restrain *in situ* bioremediation, such as low operating temperatures, anoxic soil horizons and low or variable hydraulic conductivities, are often addressed in enhanced land treatment using an aerobic, on-site prepared-bed system. Enhanced land treatment methods have been used to successfully treat a wide variety of petroleum- and creosote-contaminated soils (Bartha & Bossert 1984, Bartha 1986, Visscher *et al.* 1990, Ellis *et al.* 1991).

Contaminated soil is excavated and amended with water, nutrients, electron acceptor, lime for pH adjustment and primary substrate and then returned to a lined land treatment unit fitted with a leachate collection and recirculation system (Sims 1990). Seed organisms may be used to enhance initial transformation rates. However, the ability of bacterial inocula to advance PAH degradation requires the imported organisms to compete and survive alongside the autochthonous population (Atlas 1977, Leahy & Colwell 1990). Covered treatment facilities allow the control of volatiles, temperature and the water regime within the unit. Tilling, together with the addition of straw, wood chips or similar organic matter controls soil tilth and enhances the aeration status of the soil/waste mixture. Performance monitoring should be conducted using a mass balance approach. This requires careful accounting for contaminant disappearance. Bioassay response data are necessary to demonstrate an overall change in toxicity of soil contaminants (Aprill *et al.* 1990).

2.3 *Slurry bioreactors*

Bioreactors for the controlled biotransformation of refractory pollutants are a recent development although the underlying biotechnology and process control technology is well understood (Visscher *et al.* 1990). Soil is treated as an aqueous slurry in a closed reactor using a well characterized and seeded microbial population. Process control allows reduced treatment times relative to *in situ* or enhanced land treatment methods. Consequently, slurry bioreactors are being considered for the treatment of clayey soils and for situations in which field temperatures adversely affect biotransformation rates. Reactors may be operated in the aerobic or anaerobic mode although the anaerobic microbial population is generally less flexible in adapting to changes in substrate availability and is less tolerant of inhibitory toxic metals (Kirk & Lester 1991).

(c) the presence of heterogeneous subsurface conditions, which are difficult to characterize; and

(d) sub-optimal environmental conditions for on-site and *in situ* treatment.

In addition, expensive analytical procedures are required for the reliable performance monitoring of treatment processes. Typically, hydrocarbon contamination has to be quantified by oil and grease (solvent-extractable material) or total petroleum hydrocarbon measures. The presence of solvent-extractable organic material at hydrocarbon-contaminated sites provides insufficient evidence, by itself, to justify proposing bioremediation technologies. Remedial technology selection requires a rational review of the process capabilities, limitations and site-specific constraints to insure cost-effective use of clean-up funds.

3.1 Waste composition

3.1.1 Hydrocarbon wastes

The chemical composition of hydrocarbon wastes can vary substantially depending on the nature (natural or synthetic crude, coal-tar creosote, carrier oil), composition (e.g. paraffinic, naphthenic, aromatic or intermediate crude oil), degree of processing of the source material (light naphtha, kerosene, residual fuel oil) and the extent of weathering experienced by the exposed waste product (Nyer & Skladany 1989). Petroleum hydrocarbons have historically been classified according to four generic classes; the saturates (*n*-alkanes, branched alkanes, cycloparaffins), the aromatics (mono, di and polynuclear), the resins (pyridines, quinolines, carbazoles, sulphoxides and amides) and the asphaltenes (polyhydric phenols, fatty acids, ketones, esters, metalloporphyrins, polymeric naphthenic ring compounds) (Speight 1984, Leahy & Colwell 1990). Petroleum composed of significant proportions of the latter two classes are generally characteristic of "heavy" oils (Tissot & Welte 1984).

Coal-tar creosote represents a secondary distillation product of gasified coal, in which the main chemical classes are the homocyclic polynuclear aromatics (~85% $^{w}/_{w}$), the heterocyclic polyaromatics (~3% $^{w}/_{w}$) and the phenols (~12% $^{w}/_{w}$) of various degrees of substitution (Mueller *et al.* 1989*a*). The chemical complexity of all fossil fuels, including refined products, is extreme. Process residues such as coal tar, pitch and still bottoms may typically contain several thousand individual components (Drake & Jones 1983, Enzminger & Ahlert 1987). The waste streams from auxiliary unit operations, the residues of secondary process chemicals, carrier oils associated with wood treating solutions, biotransformation products from the decomposition of hydrocarbons and wood fragments and alternative wood preservatives and process chemicals used on site will all contribute additional complexity to the residual contamination encountered in the soil.

3.1.2 Weathered wastes and recalcitrance

Hydrocarbon wastes that have been chronically exposed to soil over decades present additional difficulties for biological treatment. Weathering processes such as evaporation, photolytic loss, hydrolysis and biotransformation, selectively reduce the concentration of easily degradable substrates leaving behind refractory residues that resist further microbial attack (Bossert & Bartha 1984). Many residual compounds possess low Henry's Law constants (K_H), high octanol-water (K_{ow}) and high soil organic carbon-water (K_{oc}) partition coefficients. Such residues are usually non-volatile or semi-volatile

and they partition preferentially to the residual oil phase, to soil organic matter (SOM) and to solid surfaces. For growth on hydrocarbons, microorganisms require an aqueous phase, at least at the microscopic level, in which these substrates are dissolved. Thus, because of the unfavourable partition coefficients for many common contaminants, the bioavailability of these constituents is severely restricted (Smith *et al.* 1989, Mihelcic & Luthy 1991).

The microbial transformations of hydrocarbons in the soil environment have been thoroughly and regularly reviewed (Atlas 1981, Cerniglia 1984*a,b*, Bartha 1986, Leahy & Colwell 1990, Cerniglia 1993). Soil microorganisms display an impressive diversity in their metabolic capabilities and microbiologists continue to isolate and characterize soil microorganisms capable of utilizing petroleum and creosote waste components as carbon and/or energy sources (Mueller *et al.* 1989*b*, 1990a,b, Kelly & Cerniglia 1991). Susceptibility to biotransformation is a function of chemical structure, the degree and nature of substitution of the parent compound and, more generally, molecular weight. The following generalized sequence of decreasing susceptibility to biotransformation among chemical classes has been reported (Atlas & Bartha 1987, Leahy & Colwell 1990): *n*-alkanes > branched chain alkanes > branched alkenes > low molecular weight *n*-alkyl aromatics > monoaromatics > cyclic alkanes, polynuclear aromatics > > > asphaltenes. Compounds in petroleum or coal-tar creosote are intimately mixed and co-dissolved, a circumstance that may influence the rates of biotransformation of individual components in a positive or negative sense (Bartha 1986).

While the biotransformation of *n*-alkanes (Watkinson & Morgan 1990), aromatic hydrocarbons (Arvin *et al.* 1989, Heitkamp *et al.* 1988) and certain heterocyclic components of hydrocarbon wastes (Fedorak & Westlake 1984*a,b*) has been demonstrated, many authors have noted the refractory nature of the asphaltenes (Westlake *et al.* 1974, Bossert & Bartha 1984, Semple *et al.* 1990). Westlake *et al.* (1974) observed changes in the chemical composition of four crude oils towards the asphaltene and heterocyclic component classes following microbial utilization by a mixed culture over a 10-day period. Increases in the asphaltene content of weathered oils suggest that during biotransformation, other petroleum fractions are transformed into asphaltenes. Such changes apparently occur via free-radical initiated polymerizations to yield cross-linked, high molecular weight residues (Bossert & Bartha 1984). Huddleston & Cresswell (1977) noted for an oil initially containing 22% $^{w}/_{w}$ paraffins, 28% $^{w}/_{w}$ aromatics and 50% $^{w}/_{w}$ resin-asphaltenes, that 82% $^{w}/_{w}$ of the paraffins, 60% $^{w}/_{w}$ of aromatics but only 1% $^{w}/_{w}$ of the resin-asphaltenes fraction of the oil were lost over a 22-month period during land treatment. These observations suggest that only a small fraction of heavy asphaltic-naphthenic oils are biotreatable within a realistic time frame (Bartha 1986). These are prominent constituents of residuum pits and flash pits at many petroleum-contaminated sites and are key components in Bunker C residual fuel oil, widely used for the delivery of coal-tar creosote to untreated timber at wood-treatment facilities (Pollard & Hrudey 1992).

Investigations into the persistence of heavy oil constituents in soil microcosms including N-, S- and methyl-substituted PAH indicated that certain components (acridine, carbazole and dibenzothiophene) and their immediate biotransformation products are also among persistent components of heavy oil wastes and they could serve as indicators of residual soil contamination (Bulman *et al.* 1990, Hosler *et al.* 1991). This research has underscored the need in treatability studies to distinguish biotransformation (conversion of parent compound to another organic compound) from mineralization (conversion of the substrate to CO_2, H_2O and inorganic ions).

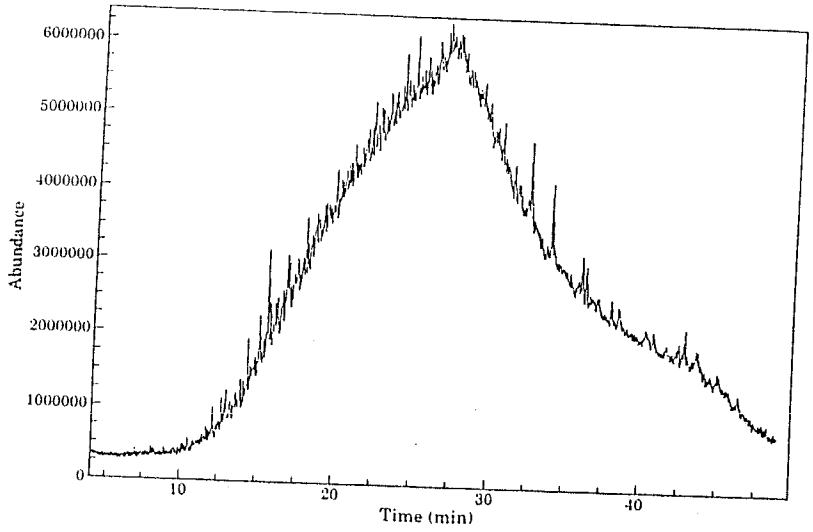

Fig. 2. Gas chromatogram of a solvent extract of weathered oil-contaminated soil.

The broad unresolved hump, characteristic to the gas chromatograms of many weathered oils (Fig. 2) has been attributed to the presence of a complex of linear long-chain alkanes (Gough & Rowland 1990) and the alicyclic alkanes including the hopanes, steranes and diasteranes. These are also proposed as indicators of residual petroleum contamination (Atlas 1981, Volkman *et al.* 1992).

Co-oxidation is frequently cited as an important mechanism for the degradation of recalcitrant substrates in the soil environment (Sims & Overcash 1983, Keck *et al.* 1989). For the high molecular weight PAH (>4 rings), co-oxidation may be a major degradation mechanism. Co-oxidation occurs when an organism growing on a particular substrate gratuitously oxidizes another substrate from which it is unable to obtain either carbon or energy (Atlas & Bartha 1987). Relationships of this kind have been used to explain discrepancies between recorded half-lives in single compound and mixed waste studies (Sims *et al.* 1987) and this phenomenon may contribute to the observed differences in apparent degradation rates between fresh and weathered wastes in soils (Gauger *et al.* 1990).

Biotransformation has been demonstrated for soil-bound components within the phenolic, heteroaromatic and polynuclear aromatic fractions of coal-tar creosote (Arvin *et al.* 1989, Mueller *et al.* 1989*a*, 1991*a,b*). A significant portion of the water-soluble fraction (BTEX, 2-3 ring PAH, phenols and low molecular weight heterocyclic compounds) is potentially degradable in contrast to the ⩾4 ring PAH, dibenzothiophenes, trimethylphenols, pyrrole and the tetra- and pentamethylcarbazoles that resist microbial attack. (Mueller *et al.* 1991*b*) have stressed that substantial biodegradation of high molecular weight PAH and other carcinogenic components in creosote-contaminated soils and sediments is integral to effective site remediations. Soil used in a solid-phase bioremediation (enhanced land treatment) study by these workers was

contaminated with a mixture of creosote/PCP to 1% by weight. Treatment was stimulated by nutrient supplementation, tilling and incubation at 23°C over a 12-week period. The differing PAH profiles of contaminated surficial soils (weathered) and contaminated (unaged) sediments were illustrative of potential biodegradation behaviour. Generalized patterns of biodegradation were consistent with the existing literature; phenols > low molecular weight heterocyclics > low molecular weight PAH > high molecular weight PAH > PCP. Microbial activity toward PAH components in the unamended unaged sediment-bound wastes began only after extensive degradation of the creosote phenols was observed. Mueller *et al.* (1991*b*) expressed doubt over the utility of land treatment for the effective remediation of weathered creosote contaminated soils at the Pensacola, Florida site.

3.2 Temperature-climatic considerations

Each microorganism possesses a growth temperature range over which it can remain active. Cessation of activity occurs at a minimum temperature because membrane gelling stops transport of nutrients and waste products across the cell membrane. At a maximum temperature, protein denaturation results in enzyme dysfunction, deterioration of the cell membrane, and ultimate thermal death (Brock & Madigan 1988). Furthermore, widely fluctuating seasonal and diurnal temperatures are generally unfavourable to the maintenance of a stable, active hydrocarbon-degrading microbial population.

Temperature has a marked influence on equilibrium (partition) and kinetic (rate) constants as described by van't Hoff isochore and Arrhenius equations respectively. Temperature also affects the viscosity and aqueous solubility of hydrocarbons. The reported optimum temperature range for the biodegradation of petroleum is 30–40°C (Bossert & Bartha 1984, Leahy & Colwell 1990) although site specific conditions may play a role in selecting a soil population with a lower optimal temperature (Morgan & Watkinson 1989*b*). Atlas (1981) reports petroleum degradation rates an order of magnitude slower at 5°C. Furthermore, at low temperatures, the volatilization of low molecular-weight hydrocarbons is significantly reduced. These solvent compounds (C_5–C_{10}) are widely held to be inhibitors of hydrocarbon degradation, at high concentration, because of their capacity to disrupt the phospholipid membrane (Atlas 1981, Pfaender & Buckley 1984, Leahy & Colwell 1990, Watkinson & Morgan 1990).

Climatic considerations are important in the design and operation of enhanced land treatment systems in that they indicate management requirements for temperature and water regimes within the treatment bed. Modifications and control of soil temperature can be achieved by irrigation to increase the soil heat capacity or the addition of mulches to reduce diurnal and seasonal temperature fluctuations (Dupont *et al.* 1988). Decreasing temperature also increases oily waste viscosity. Under low temperature conditions, wastes become increasingly viscous and extremely difficult to mix. If year-round treatment is to be provided, heating and temperature control costs could substantially increase land treatment costs.

The effect of temperature (10–30°C) on PAH persistence was studied by Coover & Sims (1987*a*) in unacclimated agricultural sandy loam soil. They found temperature was not the primary constraint for the biotransformation of high molecular weight PAHs. In their study, 50–89% by weight of these compounds remained following a 240-day study at 30°C. At 10°C, 73–93% by weight of these PAHs remained. In contrast, the lower molecular weight (<4 ring) analogues showed appreciable increases in apparent

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Agency for Toxic Substances and Disease Registry

Public Health Statement

PCBs

ATSDR Public Health Statement, June 1989

What are PCBs?

The abbreviation PCB refers to polychlorinated biphenyls. PCBs are a family of man-made chemicals that contain 209 individual compounds with varying toxicity. Commercial formulations of PCBs enter the environment as mixtures consisting of a variety of PCBs and impurities. Because of the complex nature associated with evaluating the health effects of PCBs, this document will address only seven selected classes of PCBs, which include 35% of all of the different PCBs and 98% of PCBs sold in the United States since 1970. Some commercial PCB mixtures are known in the United States by their industrial trade name, Aroclor. Because of their insulating and nonflammable properties, PCBs have been used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment. The manufacture of PCBs stopped in the United States in October 1977 because of evidence that PCBs accumulate in the environment and may cause health hazards for humans.

How might I be exposed to PCBs?

Although PCBs are no longer manufactured, human exposure still occurs. Many older transformers and capacitors still contain fluids that contain PCBs. The useful lifetime of many of these transformers can be 30 years or more.

The two main sources of human exposure to PCBs are environmental and occupational. PCBs are very persistent chemicals that are widely distributed throughout the entire environment. PCBs have been found in at least 216 of 1177 hazardous waste sites on the National Priorities List (NPL). Background levels of PCBs can be found in the outdoor air, on soil surfaces, and in water. Eating contaminated fish can be a major source of PCB exposure to humans. These PCBs originate in contaminated water, sediment, PCB-laden particulates, and in fish that have eaten PCB-contaminated prey. Although PCBs found in fish are generally concentrated in nonedible portions, the amounts in edible portions are high enough to make consumption a major source of exposure for humans. Compared with the intake of PCBs through eating contaminated fish, exposure through breathing outdoor air containing PCBs is small. Most of the PCBs in outdoor air may be present because of an environmental cycling process. PCBs in water, or on soil surfaces, evaporate and are then returned to

earth by rainfall or settling of dust particles. Reevaporation repeats the cycle. Once in the air, PCBs can be carried long distances; they have been found in snow and seawater in the Antarctic. In addition, contaminated indoor air may be a major source of human exposure to PCBs, particularly in buildings that contain PCB-containing devices.

PCBs can be released into the environment from:

- poorly maintained toxic waste sites that contain PCBs,
- illegal or improper dumping of PCB wastes, such as transformer fluids,
- leaks or fugitive emissions from electrical transformers containing PCBs, and
- disposal of PCB-containing consumer products into municipal landfills rather than into landfills designed to hold hazardous wastes.

Consumer products that may contain PCBs are:

- old fluorescent lighting fixtures and
- electrical devices or appliances containing PCB capacitors made before PCB use was stopped.

Occupational exposure to PCBs can occur during:

- repair or maintenance of PCB transformers,
- accidents or spills involving PCB transformers,
- disposal of PCB materials, and
- contact at hazardous waste sites.

How do PCBs get into my body?

PCBs enter the body through contaminated food and air and through skin contact. The most common route of exposure is by eating fish and shellfish from PCB-contaminated water. Exposure from drinking water is minimal. It is known that nearly everyone has PCBs in their bodies, including infants who drink breast milk containing PCBs.

How do PCBs affect my health?

Although PCBs have not been manufactured in the United States since October 1977, their diminishing but continued presence in certain commercial applications and trade have resulted in low-level exposure to the general population. Prior to 1977, certain occupational settings had, and may still have, higher levels of human exposure. Animal experiments have shown that some PCB mixtures produce adverse health effects that include liver damage, skin irritations, reproductive and developmental effects, and cancer. Therefore, it is prudent to consider that there may be health hazards for humans.

The U.S. Department of Health and Human Services has determined that PCBs may reasonably be anticipated to be carcinogens. Human studies to date show that irritations, such as acnelike lesions and rashes, can occur in PCB-exposed workers. Other studies of people with occupational exposure suggest that PCBs might cause liver cancer. Reproductive and developmental effects may also be related to occupational exposure and eating of contaminated fish. While the role of PCBs in producing cancer, reproductive, and developmental effects in humans cannot be clearly delineated, the suggestive evidence provides an additional basis for public health concern about humans who may be exposed to PCBs. The complexity of relating the specific mixtures for which data are available to exposures in the general population has resulted in a tendency to regard all PCBs as having a similar health hazard potential, although this assumption may not be true.

Is there a medical test to determine if I have been exposed to PCBs?

There are tests to determine PCBs in the blood, body fat, and breast milk. These tests are not routine clinical tests, but they can detect PCBs in members of the general population as well as in workers with occupational exposure to PCBs. Although these tests indicate if one has been exposed to PCBs, they do not predict potential health effects. Blood tests are the easiest, safest, and, perhaps, the best method for detecting recent large exposures. It should be recognized that nearly everyone has been exposed to PCBs because they are found throughout the environment and that nearly all persons are likely to have detectable levels of PCBs in their blood, fat, and breast milk.

What levels of exposure have resulted in harmful health effects?

Figures 1.1, 1.2, and 1.3 on the following pages show the relationship between exposure to PCBs and known health effects. Other PCBs may have different toxic properties. In the first set of graphs, labeled "Health effects from breathing PCBs," exposure is measured in milligrams of PCBs per cubic meter of air (mg/m3). In the second and third sets of graphs, the same relationship is represented for the known "Health effects from ingesting PCBs" and "Health effects from skin contact with PCBs." Exposures are measured in milligrams of PCBs per kilogram of body weight per day (mg/kg/day). It should be noted that health effects observed by one route of exposure may be relevant to other routes of exposure.

In all graphs, effects in animals are shown on the left side, effects in humans on the right. The first column on the graphs, labeled short-term, refers to known health effects from exposure to PCBs for 2 weeks or less. The columns labeled long-term refer to PCB exposures of longer than 2 weeks. The levels marked on the graphs as anticipated to be associated with minimal risk of developing health effects are based on information generated from animal studies; therefore, some uncertainty still exists. Based on evidence that PCBs cause cancer in animals, the Environmental Protection Agency (EPA) considers PCBs to be probable cancer-causing chemicals in humans and has estimated that ingestion of 1 microgram of PCB per kilogram per day for a lifetime would result in 77 additional cases of cancer in a population of 10,000 people or equivalently, 77,000 additional cases of cancer in a population of 10,000,000 people. These risk values are plausible upper-limit estimates. Actual risk levels are unlikely to be higher and may be lower.

What recommendations has the federal government made to protect human health?

For exposure via drinking water, EPA advises that the following concentrations of PCB 1016 are levels at which adverse health effects would not be expected: 0.0035 milligrams PCB 1016 per liter of water for adults and 0.001 milligrams PCB 1016 per liter of water for children.

EPA has also developed guidelines for the concentrations of PCBs in ambient water (e.g., lakes and rivers) and in drinking water that are associated with a risk of developing cancer. The guideline for ambient water is a range, 0.0079 to 0.79 nanograms of PCBs per liter of water, which reflects the increased risk of one person developing cancer in populations of 10,000,000 to 100,000 people. The guideline for drinking water is a range, 0.005 to 0.5 micrograms of PCBs per liter of water, which also reflects the risk of one person developing cancer in populations of 10,000,000 to 100,000 people.

The Food and Drug Administration (FDA) specifies PCB concentration limits of 0.2 to 3 parts per million (milligrams PCB per kilogram of food) in infant foods, eggs, milk (in milk fat), and poultry (fat).

The National Institute for Occupational Safety and Health (NIOSH) recommends an occupational exposure limit for all PCBs of 0.001 milligram of PCBs per cubic meter of air (mg/m3) for a 10-hour workday, 40-hour workweek. The Occupational Safety and Health Administration (OSHA) permissible occupational exposure limits are 0.5 and 1.0 mg/m3 for specific PCBs for an 8-hour workday.

Where can I get more information?

If you have more questions or concerns, please contact your state health or environmental department or:

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