WCH-158
Rev. 0

River Corridor
Closure Contract

100-N Area Bioremediation Engineering Study

May 2007

Washington Closure Hanford

Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Assistant Manager for River Corridor

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ACRONYMS

bgs	below ground surface
D4	Deactivation, Decontamination, Decommissioning, and Demolition
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ESB	ex situ bioremediation
ISB	in situ bioremediation
ISS	interim safe storage
MTCA	*Model Toxics Control Act*
ROD	Record of Decision
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TPH	total petroleum hydrocarbons
UPR	unplanned release
WAC	*Washington Administrative Code*
WCH	Washington Closure Hanford
WIDS	Waste Information Data System

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries

1.0 INTRODUCTION

Petroleum hydrocarbons were inadvertently introduced to the vadose zone in the 100-N Area of the Hanford Site over the operating life of the facilities located there. This unintended contamination of the vadose zone in the 100-N Area resulted primarily from leaks and spills of No. 2 (diesel) fuel oil and No. 6 (Bunker C) fuel oil from storage tanks and piping systems. In addition, other types of petroleum products (e.g., gasoline, motor oil, hydraulic oils) may also be present at these waste sites.

Petroleum hydrocarbon contamination of soils and groundwater has successfully been remediated at Superfund and other hazardous waste sites in the United States during the past 30 years through the application of bioremediation technology. As a result of these bioremediation successes, the U.S. Environmental Protection Agency (EPA), the Washington State Department of Ecology (Ecology), and the U.S. Department of Energy have selected bioremediation as the technology for remediating the petroleum-contaminated sites in the 100-N Area (EPA 1999).

Logistically, bioremediation can be classified in two primary forms: (1) in situ and (2) ex situ.

In situ bioremediation (ISB) is increasingly being used to remediate hazardous waste sites because, when compared to above-ground technologies, it is usually less expensive when contaminants are located within deeper regions of the vadose zone and therefore do not require waste extraction or excavation, and is more publicly acceptable as it relies on natural processes to effectively treat contaminants. Ex situ bioremediation (ESB) has been shown to be preferential to in situ methods when enhanced control of process variables is desired and excavation costs are minimal (i.e., for relatively shallow sites). Both of these forms of bioremediation are addressed in this report.

This report is composed of seven major sections, each with their own subsections. These sections and their descriptions are listed below.

- Section 1.0 is the introduction and includes the purpose, objective, and scope of this engineering study. The background and regulatory context of the subject 100-N Area sites are also provided in this section.
- Section 2.0 of this report provides a project description. This includes an overview of the fundamentals and field applications of bioremediation as it could be applied to the specific petroleum-contaminated sites in the 100-N Area. Site descriptions are provided and knowledge gaps are identified.
- Section 3.0 provides a proposed path forward for remediation of the 100-N Area petroleum-contaminated sites. Associated data requirements and preliminary equipment identifications are also presented.
- Section 4.0 outlines the interfaces that will need to be managed throughout the duration of the 100-N Area petroleum site remediation project. Other interfacing projects and organizations are listed, and impacts both to and from each of these interfaces are assessed.

- Section 5.0 itemizes assumptions and uncertainties relative to remediating the 100-N Area petroleum-contaminated sites.

- Section 6.0 presents a summary of the proposed path forward for remediation of the subject 100-N Area sites.

- The references used in preparing this report are listed in Section 7.0.

Rather than provide lengthy presentations on the mechanisms and technologies used to implement bioremediation, such information is incorporated by reference throughout this report. This report is therefore intended to familiarize those involved with hazardous waste site cleanups, regulatory agencies and oversight groups, with bioremediation concepts as they relate to the 100-N Area applications at the Hanford Site. This report is intended solely for use in developing a path forward for remediation of the subject sites that is in full compliance with the applicable provisions of the Interim Action Record of Decision (ROD) for the 100-N Area (EPA 1999), and applicable policy and guidance (WAC 173-340).

It should be noted that applicable regulations require that interim actions be compatible to the extent practicable with potential final remedies. Frequently, it is desired that interim actions be conducted in such a way that the interim action will constitute final remedy for the subject site, and thereby enable not only interim closure, but facilitate final closure, without further action, as well. To achieve these goals, close coordination and consultation with applicable regulatory agencies, initiated early in the interim action scoping process, is necessary.

1.1 PURPOSE OF ENGINEERING STUDY

This document provides an initial evaluation of data and information necessary to establish a remediation path forward for petroleum-contaminated sites at the 100-N Area. Assessment of available existing data relative to the data requirements for bioremediation technology is presented. Preliminary identification of information and data needed to facilitate the design of efficient bioremediation systems for the subject sites is also presented.

1.2 BACKGROUND AND REGULATORY CONTEXT

Throughout recent years, a number of decision documents have been prepared by federal and state agencies having jurisdiction and oversight at the 100-N Area of the Hanford Site, including:

- The *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-016-54 establishes the requirement to initiate remediation of 100-N Area Remaining Sites by July 31, 2008 (Ecology et al. 1989).

- Tri-Party Agreement Milestone M-016-55 requires completion of remedial actions by December 31, 2012 (Ecology et al. 1989).

- The Interim Action ROD for the 100-NR-1 and 100-NR-2 Operable Units (EPA 1999) and associated feasibility studies (DOE/RL-92-11, DOE/RL-94-61) have maintained that:

  "Petroleum sites [at 100-N]... will be remediated pursuant to Ecology's cleanup standards established... The selected remedy is to remove and ex-situ bioremediate contaminated soil and debris within the top 15 feet. This may be adjusted based on field conditions and with Ecology approval. For contamination and debris below 15 feet or the termination point of the ex-situ bioremediation point, the remedy is in-situ bioremediation..."

The regulatory endpoint for bioremediating the petroleum hydrocarbon-contaminated sites at the 100-N Area of the Hanford Site was derived from WAC 173-340, *Model Toxics Control Act* (MTCA). Specifically, the regulatory endpoint is the MTCA Method A cleanup level for total petroleum hydrocarbons (TPH) of 200 mg/kg.

Note that the 200 mg/kg cleanup level for the subject petroleum hydrocarbons was established based on the MTCA regulations in effect at the time the Interim Action ROD was developed, specifically the 1996 version of MTCA. The MTCA regulations have since been amended; the version of MTCA in effect at the time of this writing is the 2001 version. The 2001 version of MTCA provides different cleanup levels for diesel range organics and heavy oils than those presented in the 1996 version, specifically 2,000 mg/kg. However, the 2001 version also requires that the cleanup levels for selected carcinogenic (e.g., benzene) and noncarcinogenic (e.g., naphthalenes) components of these petroleum fractions be met in addition to the 2,000 mg/kg "total." This example serves to underscore the necessity of close coordination with applicable regulatory agencies to ensure that cleanup levels that facilitate final remedy and closure are identified early in the interim action scoping process.

1.3 OBJECTIVE AND SCOPE OF ENGINEERING STUDY

The scope of this study is the 100-N waste sites that have been contaminated by petroleum hydrocarbons.

The selected remedies and associated remedial action objectives and goals are established in the Interim Action ROD; therefore, this study is focused on presenting the path forward for the specified remediation and laying the design basis groundwork for a more detailed design to be completed later.

In accordance with the Interim Action ROD listed above, the work scope applicable to the remedial actions at the 100-N Area petroleum-contaminated waste sites includes the following:

- Performance of ISB of deep (i.e., contamination at depths exceeding 4.6 m [15 ft] below ground surface [bgs]) vadose zone petroleum-contaminated soils.
- Removal of shallow (i.e., contamination at depths of 4.6 m (15 ft) bgs or less) vadose zone petroleum-contaminated soils for treatment using ESB as necessary, return successfully treated soil to the excavation area, and disposal of soil not meeting cleanup standards in the Environmental Restoration Disposal Facility (ERDF).
- Establishment of necessary interfaces with existing site services (utilities and support personnel) and ERDF.

- Identification of materials that require additional treatment (e.g., macroencapsulation) to meet ERDF waste acceptance criteria (BHI 2002, *Ecological Resources Review to Activate and Expand Borrow Pits at 100-F, 100-H, and 100-N Areas*). These materials, if any, will be treated at the waste site or at ERDF to meet the criteria and disposed of at ERDF.

- Identification of material that does not meet or cannot be treated to meet ERDF waste acceptance criteria. This material will be treated/disposed of at another facility approved by the EPA.

- Sampling and analysis will be conducted to characterize waste, guide remediation, and verify that cleanup goals have been achieved.

Furthermore, all other requisite documentation and equipment necessary to plan, coordinate, and execute the subject remediation will be provided/completed in accordance with applicable requirements (DOE/RL-2005-93). These will include, but not necessarily be limited to, the following:

- Work plan

- Sampling and analysis plan including data quality objectives

- Detailed design

- Construction and associated equipment (e.g., drill rigs, injection wells, monitoring points, blower[s])

- Containers for investigation-derived waste or construction wastes

- ERDF disposal capabilities, as necessary

- Field screening Instrumentation

- Utilities (e.g., electrical, water)

- Institutional controls

- Industrial Hygiene and Radiological Control support as necessary.

Excluded from the work scope related to bioremediation, per se, of the 100-N Area petroleum hydrocarbon contaminated sites are items that include the following:

- Groundwater remediation

- Site revegetation and removal of facilities, buildings, structures, or system components that do not interfere with project work activities or that are addressed by other programs such as the Deactivation, Decontamination, Decommissioning, and Demolition (D4) Closure Project.

Soil stabilization or material macroencapsulation treatment, if required, shall be performed as a component of the remediation, but will be addressed on a case-by-case basis under a separate work scope.

Further discussion of the coordination efforts that will be required to complete this project is provided in Section 4.0.

2.0 PROJECT DESCRIPTION

This report addresses a select group of petroleum hydrocarbon sites that have impacted the vadose zone in the 100-N Area of the Hanford Site. In particular, this report focuses on ISB of "deep" sites (i.e., those with impacted soils below 4.6 m [15 ft] bgs) and ESB of "shallow" sites (i.e., those with impacted soils within 4.6 m [15 ft] bgs).

2.1 SCOPE OF PROJECT

The scope of this study is defined by applicable provisions of the Interim Action ROD. The Interim Action ROD lists 22 sites as having petroleum hydrocarbon contaminants of concern. DOE/RL-2005-93, Rev. 0, *Remedial Design Report/Remedial Action Work Plan for the 100-N Area*, documents that 6 of these 22 sites have "been excavated and closed out." Therefore, this study addresses the remediation of the remaining 16 sites in the 100-N Area with contamination of the vadose zone by petroleum hydrocarbons. These 16 sites are described in the following section. This study does not address any other sites that are characterized by other contaminants (e.g., radionuclides) or impacted matrices (e.g., groundwater).

2.2 SITE DESCRIPTIONS

The N Reactor operated between 1963 and 1987 (WHC-SD-EN-TI-251). Throughout the operational history of the N Reactor, spills, releases, and discharges were documented in unplanned release (UPR) reports. A number of these releases resulted in the petroleum hydrocarbon sites that are the subject of this study. These sites require further action in accordance with applicable provisions of the Interim Action ROD. Releases of petroleum hydrocarbons occurred through mechanisms inclusive of the following:

- Corrosion failure of piping systems used to transport diesel and fuel oils
- Overfilling of storage facilities
- Spills during fuel transfers.

Because a number of these sites have common origins, are located in close geographic proximity, etc., they have been grouped for purposes of this report into three categories. These waste sites are shown in Figures 1, 2, and 3 according to the grouping arrangements described below. Figure 1 shows the sites listed in Group 1. Figures 2 and 3 show the sites in Groups 2 and 3.

2.2.1 Sites Around the 1715-N Storage Tanks and 166-N Transfer Areas – Group 1

The Group 1 sites are those sites in close proximity to UPR-100-N-17, a "deep" site that has been selected for ISB. The "shallow" Group 1 sites substantially overlay this "deep" site and have been impacted by the same hydrocarbon contamination, specifically diesel fuel. Therefore, it is possible that an ISB system may effectively address remediation of all of the Group 1 sites and thereby minimize or eliminate the need for soil excavation and ESB at the shallow Group 1 sites.

UPR-100-N-17: 166-N Diesel Oil Supply Line Leak

In the August 1966 time frame, an estimated 302,832 L (80,000 gal) of diesel oil leaked from a failed transfer pipe system near the 166-N storage facility. Multiple references are available on this subject, but J. M. Shelby documented the potential impacts to the Columbia River on August 17, 1967. At that time, the diesel fuel was seeping from a bluff located between the leak site and the river (in direct line with known groundwater flow from the transfer line leak location). A trench was excavated between the bluff and the river to intercept the diesel and "burn" it off periodically so as to minimize impact to the Columbia River (BNWL-CC-1296, UNI-228).

UPR-100-N-18: 166-N Diesel Oil Supply Line Leak

In August 1973, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line between the 166-N and 184-N facilities (PNL-6456, UNI-228).

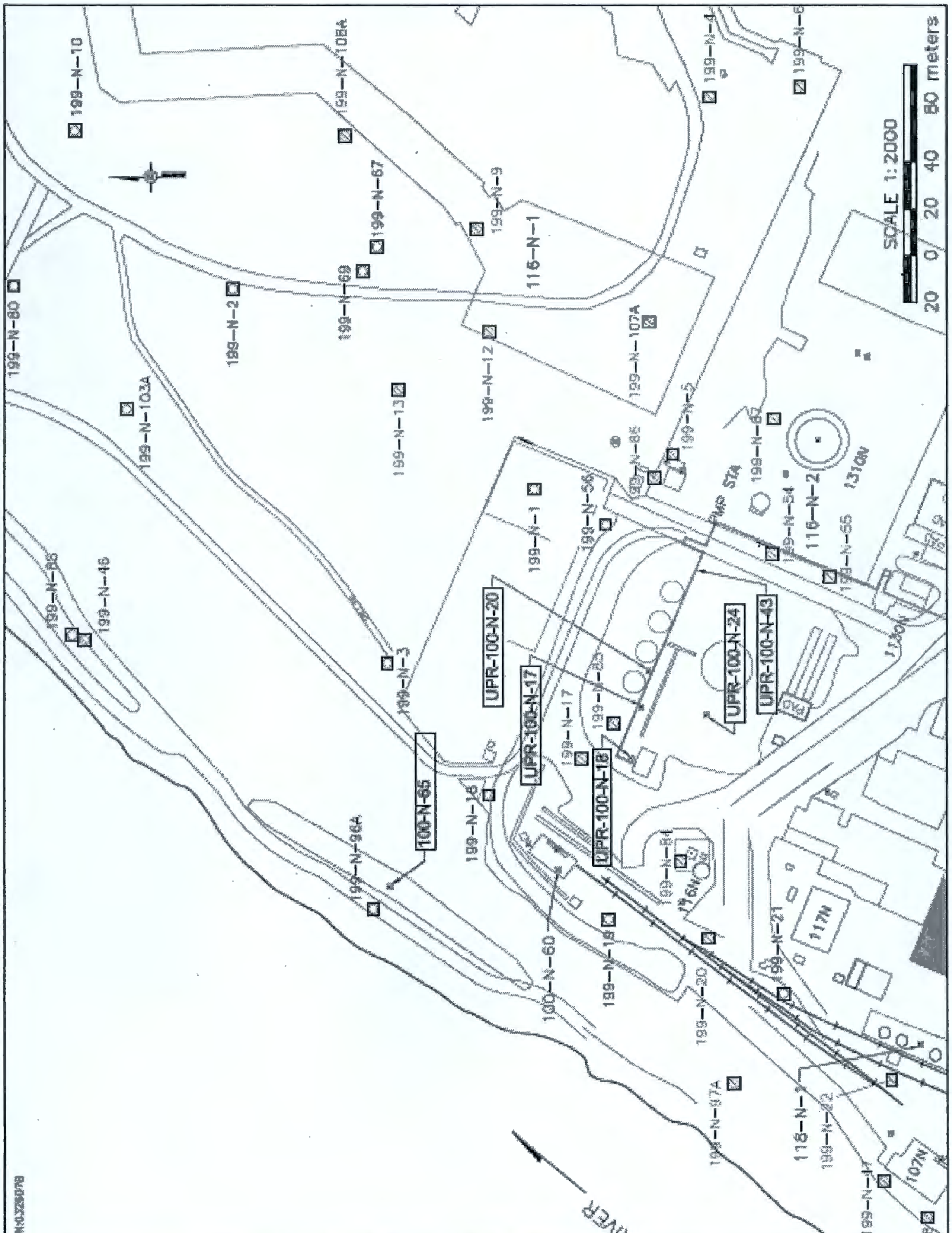
UPR-100-N-20: 166-N Diesel Oil Return Line Leak

In June 1985, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line near Tank 1 in the 166-N facility (UNI-228).

UPR-100-N-24: 166-N Fuel Oil Supply Line Leak

On February 1, 1987, a line leak was reported. Petroleum product type and quantity were not reported. No further information is available (WHC-SD-EN-TI-251).

Figure 1. Group 1 Sites.



2.2.2 Sites Around the 184-N Day Tank Storage Facility – Group 2

The Group 2 sites are those sites in close proximity to UPR-100-N-42, a "deep" site that has been selected for ISB. The "shallow" Group 2 sites substantially overlay this "deep" site and have been impacted by petroleum hydrocarbon contamination, predominantly Bunker C fuel oil. Therefore, it is possible that an ISB system may effectively address remediation of all of the Group 2 sites and thereby minimize or eliminate the need for soil excavation and ESB at the shallow Group 2 sites.

UPR-100-N-42: 184-N Day Tank Area Liquid Unplanned Release

On October 9, 1987, an unspecified quantity of petroleum material with an unspecified description was documented around the 184-N facility day tanks (Waste Information Data System [WIDS]).

UPR-100-N-19: 184-N Day Tank Fuel Oil Line Leak

In April 1984, an estimated 28,391 L (7,500 gal) of No. 6 fuel oil leaked at the 184-N Day Tank Storage Facility. It is reported that all of the fuel oil was contained within the surrounding retaining walls and did not penetrate the hard-packed sand bottom of the containment structure. The waste oil was immediately removed and disposed (UNI-228).

UPR-100-N-21: 184-N Diesel Oil Day Tank Overflow

On April 25, 1986, an estimated 3,028 L (800 gal) of diesel oil spilled into the area surrounding a day tank at the 184-N facility. Approximately 2,461 L (650 gal) were reported pumped as cleanup. No detection of this was noted in a nearby groundwater well, 199-N-16 (WIDS).

UPR-100-N-22: Diesel Oil Supply Line Leak No. 1

On June 23, 1986, an estimated 3,785 L (1,000 gal) of diesel oil leaked from a transfer line. Indication of this release was in nearby groundwater well (199-N-16). An unspecified quantity of petroleum material was subsequently pumped from well 199-N-16 (WHC-SD-EN-TI-251).

UPR-100-N-23: 184-N Diesel Oil Supply Line Leak No. 2

On January 10, 1987, an estimated 757 L (200 gal) of diesel oil leaked from a transfer line. Indication of this release was in a nearby groundwater well (199-N-16). An unspecified quantity of petroleum material was subsequently pumped from well 199-N-16 (WHC-SD-EN-TI-251).

100-N-12: 184-N Pipeline Spill

A spill inside the 184-N pipeline occurred on October 14, 1987 that leaked to the outside. "An unknown amount of fuel oil leaked from a loose pipe fitting at the 184-N Annex. Spill contained in a drain trench and cleaned up." (WIDS)

2.2.3 Other Miscellaneous Sites – Group 3

This site grouping includes sites that are not close to the Group 1 or Group 2 sites.

UPR-100-N-43: 166-N to 184-N Transfer Line Multiple Leak

A diesel oil leak occurred at three locations along the pipeline from 166-N to 184-N at three different flange joints. The exact location of these flange joints is not provided. The release was reported on April 26, 1989. A total of 46 drums and 8 dump trucks of contaminated soil were removed. Sampling was conducted in nearby wells N-16 and N-17 and oil was detected. This was reportedly cleaned up by April 26, 1989 (DOE/RL-90-22, WHC-C-89-047-100N-20).

UPR-100-N-36: 184-N Annex Diesel Generator Area Release

During excavation between 184-N and 153-N (area of approximately 40 by 18 m [130 by 60 ft], a strong smell of petroleum was noted. Neither date nor quantity of material released is reported (WIDS).

100-N-36: Oil-Stained Pad (Near 107N Building)

This was once used to support an air compressor. Neither date nor quantity of petroleum material leaked is available; however, available documentation suggests that the quantity was minimal and limited to the soil immediately beneath the pad. What little petroleum may have leaked is expected to have infiltrated through the crack between the concrete pad and the asphalt (WIDS).

100-N-35: Hanford Generating Plant/BPA Switchyard

This portion of the 100-N Area is still in use by the Bonneville Power Administration and is reported to contain spills of oil materials that could contain polychlorinated biphenyls.

100-N-65: Diesel Burn Pit Adjacent to River

This was a trench/pit excavated adjacent to river to intercept and burn diesel oil before it could significantly impact the Columbia River (refer to UPR-100-N-17). In 1994, the trench was backfilled with material to the top of the adjacent berm (WIDS) (see Figure 1).

124-N-2: 182-N Septic System

This was a septic system east of 182-N that was reported to have had petroleum introduced to it. This includes a septic tank and seepage pit and was reported pumped and isolated after the 124-N-10 Septic Treatment Facility was placed in service in February 1987 (WIDS).

Figure 2. Group 2 and 3 Sites. (1 of 2)

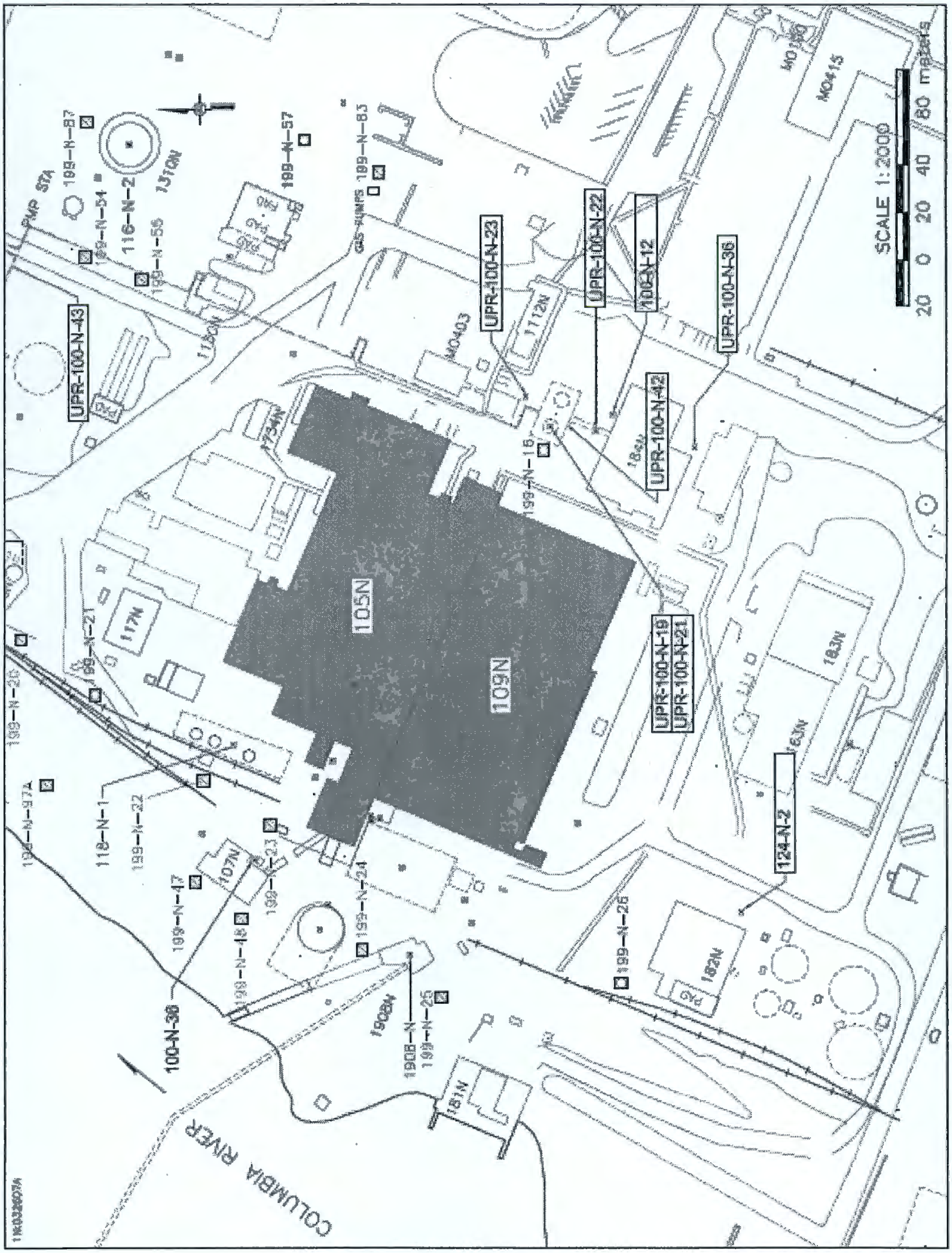
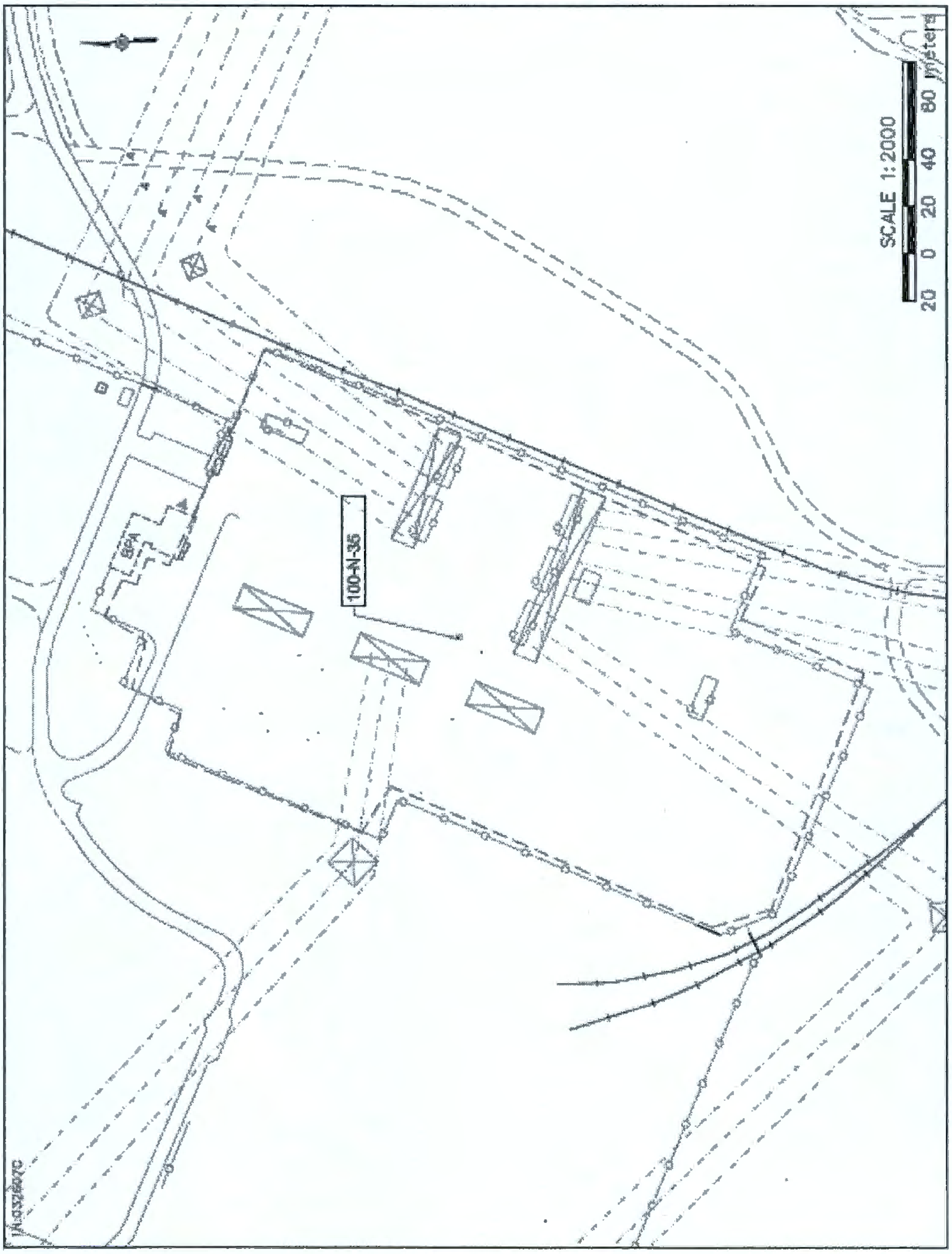


Figure 3. Group 2 and 3 Sites. (2 of 2)



2.2.4 Estimates of Impacted Soil Volumes

While the nature and extent of contamination at the subject sites has not been rigorously determined, an estimate of the areal extent, depth, and volume of impacted vadose zone soils at each of the subject sites is presented in DOE/RL-2005-93. These estimates are presented in Table 1. Groundwater depth in the 100-N Area is documented as approximately 213.3 m (70 ft) bgs (WHC-SD-EN-EV-027); therefore, for sites UPR-100-N-17 and UPR-100-N-42, the values reported in DOE/RL-2005-93 have been translated from "groundwater depth" to 21.3 m (70 ft) for the sake of completing this tabulation. Evaluating these sites in this manner suggests that a rough estimate of the total volume of soil to be remediated is approximately 127,000 m^3.

Table 1. 100-N Area Petroleum Hydrocarbon Waste Sites Status and Information.

Designation	Description	Location	Length (m)	Width (m)	Depth (m)	Volume (m^3)	Contaminants of Potential Concern
UPR-100-N-17	Pipe line leak	166-N	43.1	43.1	21.3	39,644	TPH and diesel
UPR-100-N-42	Spill	184-N	43.1	43.1	21.3	39,644	TPH
UPR-100-N-43	Pipe line leak	166-N and 184-N	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-18	Pipe line leak	166-N	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-19	Spill	184-N	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-20	Pipe line leak	166-N	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-21	Tank overfill	184-N	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-22	Pipe line leak	NA	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-23	Pipe line leak	184-N	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-24	Pipe line leak	166-N	43.1	43.1	3.0	5,573	TPH and diesel
UPR-100-N-36	Diesel generator releases	184-N Annex	39.6	18.3	3.0	2,174	TPH and diesel and motor oil
100-N-12	Pipe leak in building spilled outside	184-N	10.0	0.6	0.3	1.8	TPH
100-N-35	PCBs on concrete pad	Hanford Substation	20.0	20.0	1.0	400	TPH and PCBs
100-N-36	Oil-stained pad	107-N	20.0	20.0	1.0	400	TPH
100-N-65	Diesel burn pit	Riverbank	20.0	20.0	1.0	400	Diesel oil
100-N-2	Septic system	182-N	20.0	3.0	3.0	27	TPH
						127,274	

Source: DOE/RL-2005-93, Rev. 0.
PCB = polychlorinated biphenyl
TPH = total petroleum hydrocarbon

An alternative estimate of impacted soils volume was performed by grouping the sites as previously described and estimating the extent to which applicable shallow sites are included within the boundaries of the primary "deep" site. This alternative estimate is presented in Table 2. Such an approach indicates an estimated contaminated soil volume totaling approximately 99,000 m^3.

Table 2. Grouped 100-N Area Petroleum Hydrocarbon Waste Sites.

Group	Designation	Length (m)	Width (m)	Depth (m)	Projected Volume (m^3)	Estimated overlap with Associated Deep Site (%)	Revised Volume (m^3)
1	UPR-100-N-17	43.1	43.1	21.3	39,644	0	39,644
1	UPR-100-N-18	43.1	43.1	3.0	5,573	50	2,786
1	UPR-100-N-20	43.1	43.1	3.0	5,573	50	2,786
1	UPR-100-N-24	43.1	43.1	3.0	5,573	50	2,786
Total of Group 1							48,003
2	UPR-100-N-42	43.1	43.1	21.3	39,644	0	39,644
2	UPR-100-N-19	43.1	43.1	3.0	5,573	100	0
2	UPR-100-N-21	43.1	43.1	3.0	5,573	100	0
2	UPR-100-N-22	43.1	43.1	3.0	5,573	75	1,393
2	UPR-100-N-23	43.1	43.1	3.0	5,573	75	1,393
2	100-N-12	10.0	0.6	0.3	1.8	0	1.8
Total of Group 2							42,432
3	UPR-100-N-43	43.1	43.1	3.0	5,573	0	5,573
3	UPR-100-N-36	39.6	18.3	3.0	2,174	0	2,174
3	100-N-35	20.0	20.0	1.0	400	0	400
3	100-N-36	20.0	20.0	1.0	400	0	400
3	100-N-65	20.0	20.0	1.0	400	0	400
3	124-N-2	3.0	3.0	3.0	27.0	0	27
Total of Group 3							8,974
Total of All							99,410

2.3 BIOREMEDIATION OVERVIEW

Bioremediation is the use of microorganisms to degrade contaminants with the goal of obtaining nonhazardous end products. Bioremediation technology can be further categorized by the degree of enhancement or augmentation applied. Specifically, bioremediation technology can range from intrinsic bioremediation where naturally occurring bioactivity is allowed to proceed unaided by additional nutrients, substrates, electron donors or acceptors, or microbial amendment, to bioaugmentation where microbial amendments, nutrients, electron donors or acceptors, and/or additional substrates are introduced to facilitate higher rates of biodegradation. Between these two extremes lies enhanced bioremediation.

Enhanced bioremediation involves the introduction of nutrients and electron donors or acceptors (only) to enhance the biodegradation provided by the naturally occurring microbes indigenous to the site. Bioremediation technology can also be categorized by the type of metabolism used to degrade the subject contaminants, specifically aerobic and anaerobic. The target metabolism for a bioremediation system will depend on the contaminants of concern. Some contaminants (e.g., petroleum hydrocarbons) are degraded via an aerobic pathway, some are most effectively degraded anaerobically (e.g., carbon tetrachloride), and some contaminants can be biodegraded under either aerobic or anaerobic conditions (e.g., trichloroethene) (Norris and Kerr 1994).

Years of effective application of bioremediation technology have shown that enhanced bioremediation, utilizing aerobic metabolism, is the most effective approach to the treatment of petroleum hydrocarbons (NFESC 1996). In this case the electron acceptor is the oxygen in the air, and the typical nutrient additions are nitrogen and phosphate. Frequently, water is also introduced to the subsurface to bring soil moisture content into the optimum range for bioremediation. Upon the introduction of the air, nutrients, and, if necessary, water into the subsurface, the population of indigenous microbes thrives and utilizes the petroleum hydrocarbons as its food source. The result is that the hydrocarbons are degraded aerobically, or oxidized, to carbon dioxide and water. This approach to bioremediation of petroleum hydrocarbons has the following advantages.

- The end products of the reaction are carbon dioxide and water, two nonhazardous and innocuous substances.
- Because the reaction consumes oxygen and produces carbon dioxide, the measurement of the concentrations of these substances in the soil gas can be used to determine the "respiration rate" of the microbes. This respiration rate can be directly correlated to the rate of contaminant degradation.
- Because water is a product of the reaction, the subsurface is "self-hydrating" during the process. Frequently, this effect results in the need to adjust soil moisture content only once at the beginning of the remediation; ongoing addition of water may not be necessary.

Table 3 is a summary of optimal ranges of specific bioremediation characteristics required for successful bioremediation to occur. These characteristics, along with others identified in Figure 4, will be evaluated to determine potential effectiveness of ISB and ESB technologies.

Table 3. Optimal Ranges of Bioremediation Characteristics.

Characteristic	ISB	ESB
Intrinsic Permeability	10^{-10} cm^2	NA
Soil pH	6 - 8	6 – 8
Moisture content	40% - 85% of saturation	40% - 85% of saturation
Soil temperature	3 °C – 14 °C (37 °F – 57 °F)[a]	[b]

[a] Subgrade soil temperature in Hanford Site soils (below the freeze/thaw zone) is approximately 13 °C (55 °F) year round. It is not anticipated that measurement of soil temperature will be required during ISB.

[b] ESB biopiles operate effectively in temperate climates but can be operated in colder climates by introducing warm air through the aeration process

As previously discussed, from a logistical standpoint, bioremediation technology may be classified as in situ or ex situ. Additional information concerning ISB and ESB is provided in the following sections.

2.3.1 In Situ Bioremediation Overview

The technology was developed as a less costly, more effective alternative to above-ground treatment technologies that would require excavation of soils. Accordingly, ISB has the potential to provide advantages such as complete destruction of the contaminant(s); lower risk to site workers; less impact to local environmental, ecological, and cultural resources; and lower equipment/operating costs.

Enhanced ISB involves the injection of air, nutrients, and (if necessary) water into the subsurface to stimulate the growth of a target consortium of bacteria. For remediation of petroleum hydrocarbons, the target bacteria are indigenous, hydrocarbon-degrading heterotrophs and facultative anaerobes. The goal of enhanced ISB is to increase the indigenous biomass throughout the contaminated subsurface volume, thereby achieving effective biodegradation of the subject contaminants (EPA 2000).

As discussed above, intrinsic bioremediation is another method of ISB. Intrinsic bioremediation is one component of a natural attenuation remedy. Site characterization, reactive flow and transport modeling (if applicable), and long-term monitoring comprise the activities required to implement the natural attenuation remedy. Site characterization determines the extent of contamination and the properties of the impacted subsurface. This characterization information can then be used in a reactive transport model to predict the fate of the contaminants and whether the contaminants will affect the receptors of concern. Long-term monitoring is used to assess the fate and transport of the contaminants compared against the predictions. The reactive transport model can then be refined to obtain better predictions.

It should be noted that, given the time frame between many of the subject releases and the date of this report, it is considered probable that the components of the natural attenuation remedy, specifically intrinsic bioremediation, volatilization, adsorption, and leaching have been active to some degree at the subject sites. Accordingly, the nature and extent of contamination at the sites today may be different than it was 30 years or so ago, when many of the spills/releases occurred. Therefore, determination of the nature and extent of contamination, and the degree to which intrinsic bioremediation has occurred, or is occurring, at the sites are components of the proposed path forward.

2.3.2 Ex Situ Bioremediation Overview

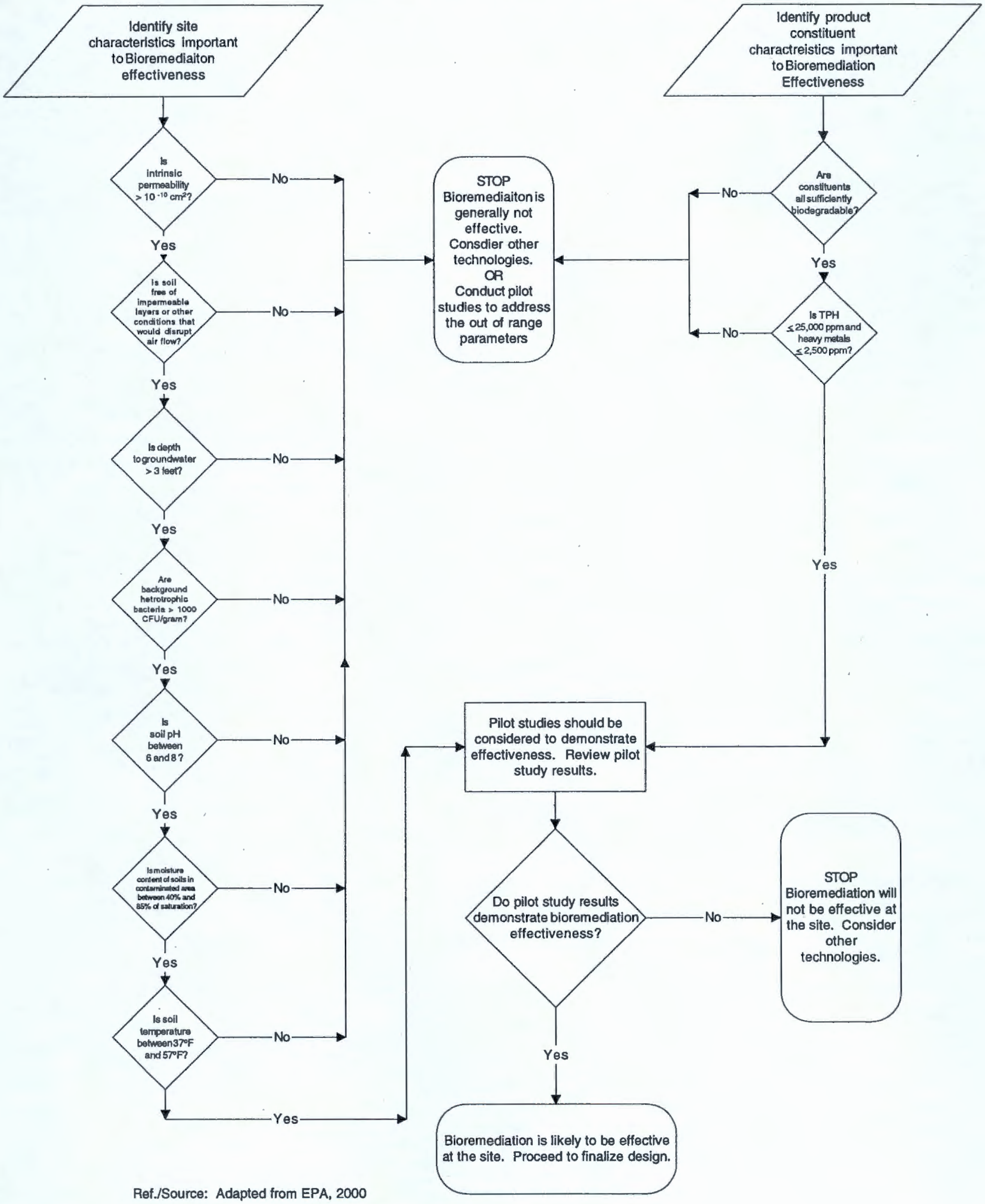
Ex situ bioremediation has many of the same advantages of ISB, but additionally has the potential to provide increased control of parameters governing destruction of the contaminant(s) (e.g., concentrations of oxygen, nutrients), and is most frequently applied when excavation costs are not significant (i.e., for shallow soils). One such method of ESB is termed the "biopile."

Biopile technology involves excavating petroleum-contaminated soils and forming them into piles or cells above ground, and stimulating aerobic microbial activity within the soils through aeration. Microbial activity can be further enhanced by adding moisture and nutrients such as nitrogen and phosphorus as necessary. The aerobic microbial activity degrades the petroleum-based constituents adsorbed to soil particles, thus reducing the concentrations of these contaminants. Biopiles typically are constructed on an impermeable base to reduce the potential migration of leachate to the subsurface environment. A perforated piping network installed above the base is connected to a blower that facilitates the aeration of the pile. In some cases, a leachate collection system is constructed, especially if a moisture addition system is being considered for the pile. The piles generally are covered with an impermeable membrane to prevent the release of contaminants and/or contaminated soil to the environment and to protect the soil from wind and precipitation. Biopiles operate effectively in temperate climates but can be operated in colder climates by introducing warm air through the aeration process (NFESC 1996).

2.4 DATA REQUIREMENTS

Although much is known about the hydrogeologic conditions of the vadose zone in the 100-N Area, many of the parameters important to successful implementation of bioremediation are not available. Specifically, data concerning the concentrations of indigenous bacteria and nutrients in the subsurface and quantitative data concerning the nature and extent of petroleum contamination do not exist. Figure 4 presents an example of an evaluation process that serves to identify applicable data needs associated with bioremediation technology.

Figure 4. Example Bioremediation Evaluation Process Flowchart.



Ref./Source: Adapted from EPA, 2000

For example, WHC-SD-EN-EV-027, *Hydrogeology of the 100-N-Area*, identifies the porosity of the 100-N soils as ranging from 14.6% to 45.1%. It has been shown that soil porosities in excess of 20% are optimal for bioremediation (NFESC 1996). Therefore, the available data suggest that soil porosities at the subject sites are suitable for effective implementation of bioremediation technology. Conversely, WHC-SD-EN-EV-027 identifies moisture content of the 100-N Area soils as ranging from 1 wt% to 3 wt%. However, the optimum soil moisture content for bioremediation is expressed as a percentage of field capacity, specifically, 60% to 85% of field capacity, and is a function of grain size, porosity, and soil type. Therefore, the data available in the referenced report do not facilitate a direct evaluation of the adequacy of the soil moisture content of the 100-N Area soils from a bioremediation technology perspective. Finally, there are no data available concerning the concentrations of indigenous hydrocarbon-degrading heterotrophs or facultative anaerobes in 100-N Area soils, nor are there data concerning background phosphate or bioavailable nitrogen concentrations. Therefore, the phased approach to remediation subsequently presented emphasizes the early collection of data concerning microbial populations and nutrient concentrations in 100-N Area vadose zone soils, as well as verification of soil pH, porosity, permeability, moisture content, and total organic carbon content.

Both diesel fuel and fuel oil have been shown to be biodegradable (NFESC 1996). However, the rates of biodegradation can be adversely affected by very high concentrations of TPH in the subsurface such that the soils' pores are saturated with TPH and the injected air cannot reach the area or, alternatively, the concentrations of the components of the TPH that are toxic to the bacteria are high enough to inhibit their growth. The physical and chemical characteristics of diesel (No. 2) fuel oil and Bunker C (No. 6) fuel oil are presented in Table 4. High concentrations of heavy metals can also inhibit microbial activity (e.g., >2,500 ppm). There are no data concerning the concentrations of TPH and heavy metals in vadose zone soils at the subject 100-N Area sites; therefore, these data will also be obtained.

The number of samples, analytes, analytical methods, and associated data precision, accuracy, representativeness, completeness and comparability parameters will be developed through application of the data quality objectives process and documented in a sampling and analysis plan.

Table 4. Physical and Chemical Characteristics of Two Refined Products. (3 Pages)

Characteristic	No. 2 Fuel Oil	No. 6 Bunker C Oil
API Gravity (20 °C)	31.6	7.3
Sulfur (wt%)	0.32	1.46
Nitrogen (wt%)	0.024	0.94
Nickel (ppm)	0.5	89
Vanadium (ppm)	1.5	73
Saturates (wt%)	61.8	21.1
n-paraffins (ppm)	8.07	1.73
C10 + C11 (ppm)	1.26	0
C12 (ppm)	0.84	0

Table 4. Physical and Chemical Characteristics of Two Refined Products. (3 Pages)

Characteristic	No. 2 Fuel Oil	No. 6 Bunker C Oil
C13 (ppm)	0.96	0.07
C14 (ppm)	1.03	0.11
C15 (ppm)	1.13	0.12
C16 (ppm)	1.05	0.14
C17 (ppm)	0.65	0.15
C18 (ppm)	0.55	0.12
C19 (ppm)	0.33	0.14
C20 (ppm)	0.18	0.12
C21 (ppm)	0.09	0.11
C22 (ppm)	0	0.1
C23 (ppm)	0	0.09
C24 (ppm)	0	0.08
C25 (ppm)	0	0.07
C26 (ppm)	0	0.05
C27 (ppm)	0	0.04
C28 (ppm)	0	0.05
C29 (ppm)	0	0.04
C30 (ppm)	0	0.04
C31 (ppm)	0	0.04
C32 plus (ppm)	0	0.05
Isoparaffins (ppm)	22.3	5
1-ring cycloparaffins (ppm)	17.5	3.9
2-ring cycloparaffins (ppm)	9.4	3.4
3-ring cycloparaffins (ppm)	4.5	2.9
4-ring cycloparaffins (ppm)	0	2.7
5-ring cycloparaffins (ppm)	0	1.9
6-ring cycloparaffins (ppm)	0	0.4
Aromatics (wt%)	38.2	34.2
Benzenes (ppm)	10.3	1.9
Indans and tetralins (ppm)	7.3	2.1
Dinaphthenobenzenes (ppm)	4.6	2
Naphthalenes (ppm)	0.2	
Methylnaphthalenes (ppm)	2.1	2.6
Dimethylnaphthalenes (ppm)	3.2	

Table 4. Physical and Chemical Characteristics of Two Refined Products. (3 Pages)

Characteristic	No. 2 Fuel Oil	No. 6 Bunker C Oil
Other naphthalenes (ppm)	0.4	
Acenaphthenes (ppm)	3.8	3.1
Acenaphthalenes (ppm)	5.4	7
Phenanthrenes (ppm)	0	11.6
Pyrenes (ppm)	0	1.7
Chrysenes (ppm)	0	0
Benzothiophenes (ppm)	0.9	1.5
Dibensothiophenes (ppm)	0	0.7
Polar materials C (wt%)	0	30.3
Insolubles (pentane) C (wt%)	0	14.4

Source: Irwin et al. 1997.

3.0 REMEDIAL DESIGN APPROACH

The following subsections present the proposed remedial design approach for the subject 100-N Area petroleum sites. The proposed approach consists of two phases and employs the observational approach whereby required site characterization and process design data are acquired in the course of, not prior to, site remediation activities. The proposed approach to the remediation of the subject sites is presented in the following sections.

3.1 SELECTION OF REMEDIATION TECHNOLOGY

The selection of the petroleum hydrocarbon remediation technology resulted from analyses performed in preceding studies and reports (e.g., the feasibility studies previously referenced herein) and is documented in the Interim Action ROD for the 100-N Area. The selected remediation technologies are ISB for sites where the depth of contamination exceeds 4.6 m (15 ft) bgs, and ESB where the depth of contamination is 4.6 m (15 ft) bgs or less (EPA 1999). It is noted that the selection of bioremediation technology was based on an assumed applicability to the 100-N waste sites, and that analytical data concerning the nature and extent of contamination at the 100-N Area petroleum sites do not yet exist.

3.2 PHASED APPROACH

The proposed path forward for remediation of the 100-N Area petroleum sites involves a phased approach that verifies the need for site remediation provides accelerated risk reduction, ensures technical effectiveness, and optimizes regulatory compliance. All these considerations are effectively addressed by integrating site characterization activities with limited remediation system installation and operations activities in Phase 1, and using the data derived from Phase 1 to design, construct, and operate full-scale remediation systems for the remaining sites in Phase 2.

The most pervasive petroleum hydrocarbon contamination in the 100-N Area occurred around the 166-N pump systems and piping (UPR-100-N-17). As previously discussed, the largest release resulted in adverse impacts to groundwater and significant contaminant migration toward the Columbia River. Because this site represents the greatest potential ongoing risk to human health and environment of the 100-N Area petroleum sites and minimal interface management is likely to be required with D4 and interim safe storage (ISS) (refer to Section 4.0), it has been selected as the focus of Phase 1.

3.2.1 Phase 1

There are three primary objectives associated with Phase 1. These are as follows:

1. Obtain data regarding the nature and extent of contamination to verify the need for site remediation (NOTE: Many of the sites have resulted from relatively small releases that occurred 20 to 30 years ago)

2. Obtain data needed to facilitate full-scale remediation system design

3. Obtain data regarding rates of biodegradation by installing and operating a pilot-scale ISB system.

These objectives would be pursued by installing a pilot-scale ISB system at UPR-100-N-17 consisting of two injection wells and a total of eight associated monitoring points. One of the injection wells would be screened at a depth near the water table, approximately 12 to 17 m (40 to 55 ft) bgs while the other would be screened in the range of 7.6 to 12.2 m (25 to 40 ft) bgs to address more shallow soils. Each injection well would have a complement of four monitoring points, installed at a depth corresponding to the injection well. These monitoring points would be installed at distances of 9 and 18 m (30 and 60 ft) from the injection well such that they form a right angle in plan view (see Figures 5 and 6). In the course of drilling the boreholes into which the injection wells and monitoring points would be installed, samples would be collected for analysis to determine the following parameters:

- Total petroleum hydrocarbons
- Total organic carbon
- Hydrocarbon-degrading bacteria (heterotrophs and facultative anaerobes)
- Phosphate
- Bioavailable nitrogen
- Porosity
- Intrinsic permeability
- Moisture content (expressed as % of field capacity and as wt%)
- pH
- Metals (*Resource Conservation and Recovery Act of 1976* metals).

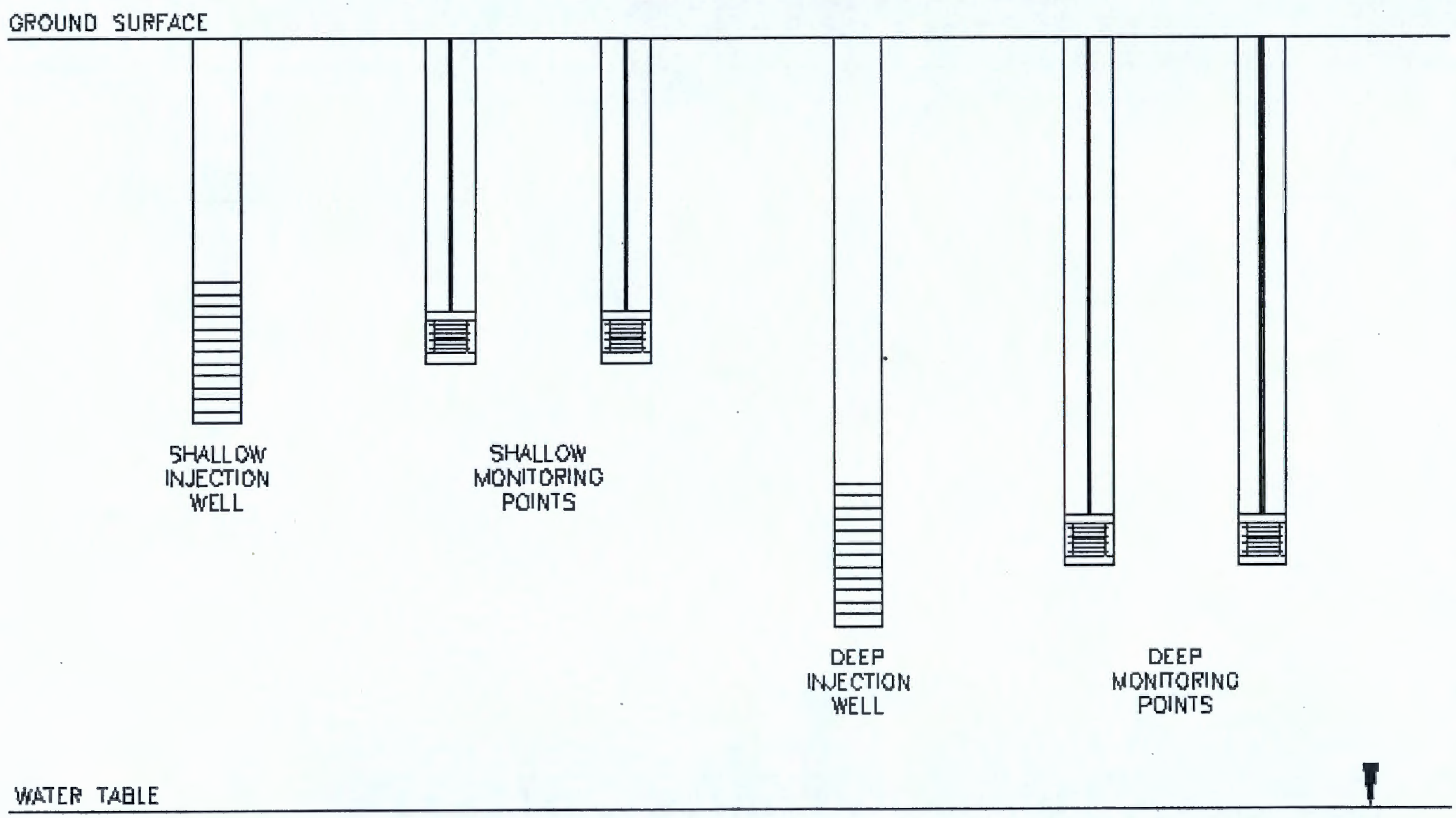
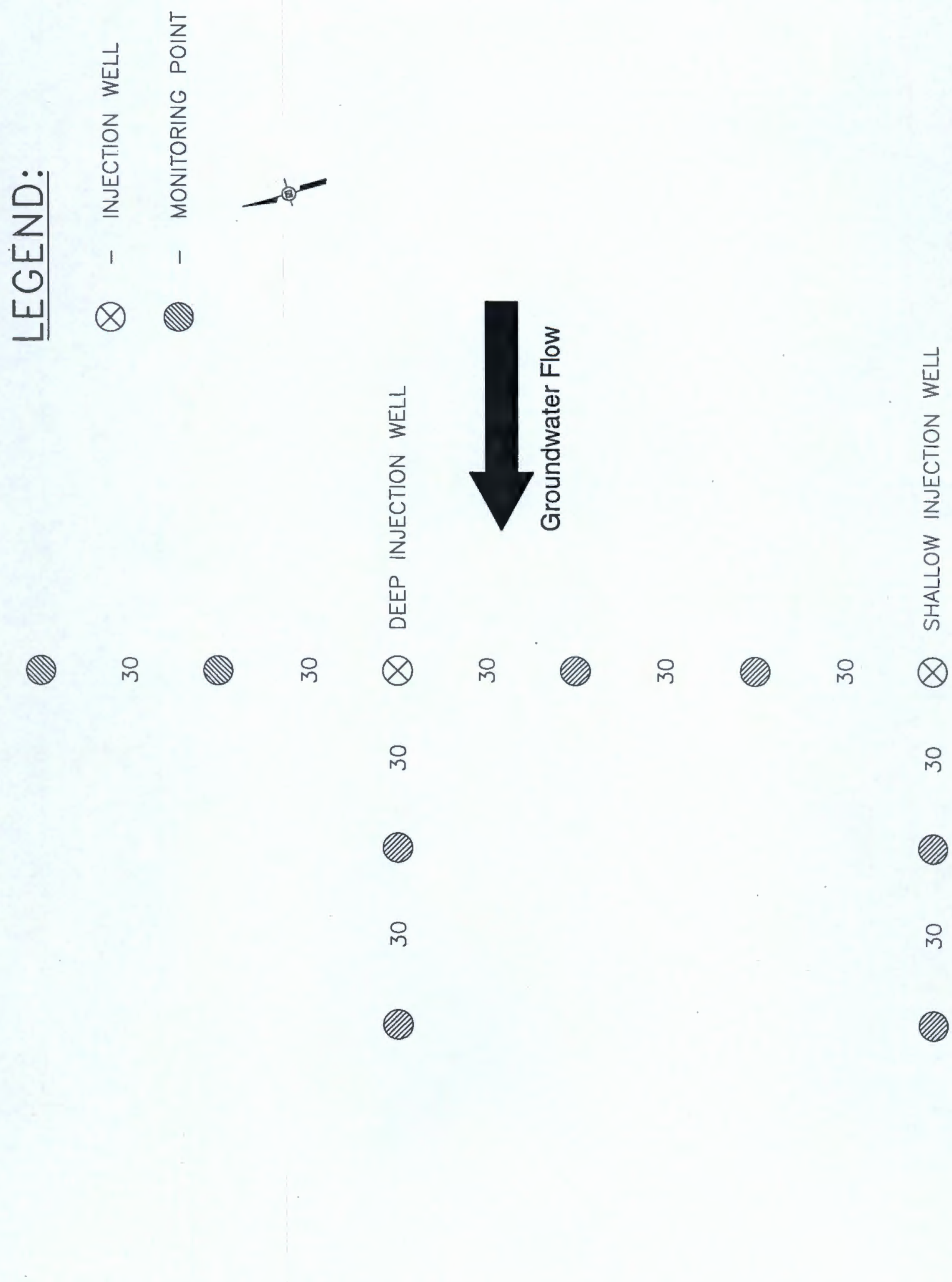


Figure 5. Proposed Pilot-Scale ISB System – Section.

Figure 6. Proposed Pilot-Scale ISB System – Plan.



Upon installation of the wells and monitoring points, the wells would be manifolded to a blower sized to provide approximately one to three air exchanges to the subsurface per hour. Upon initial start up, oxygen concentrations at the monitoring points would be monitored to provide data concerning soil gas permeability and radius of influence. Once these data are obtained, the system would then be operated such that the degree of indigenous bioactivity could be assessed. Specifically, the blower would be operated for a period of time sufficient to saturate the soil gas with oxygen. The blower would then be turned off and soil gas concentrations of oxygen and carbon dioxide would be monitored over the course of approximately 2 days to determine the respiration rate of the indigenous microbe population. This determination will not only help verify the results of the laboratory analysis concerning bacterial populations, but will also assist in determining to what degree intrinsic bioremediation is occurring, or has occurred, at the site. Finally, upon receipt of the analytical data concerning the nutrient concentrations and moisture content, any required additions of nutrients and water will be accomplished by "slugging" the injection wells with an aqueous solution of optimized nutrient concentrations. The system will then be operated as described above to obtain data regarding the improvement in respiration rate resulting from the nutrient and moisture enhancement. Upon completion of the Phase 1 testing, continued operation of the pilot-scale system will provide remediation of soils that are within its influence. It should be noted that the Phase 1 system will be designed such that all Phase 1 wells, monitoring points, and equipment can be easily integrated into the full-scale remediation system in Phase 2. It should also be noted that the data obtained as a result of Phase 1 are not only applicable to the design of ISB systems, but ESB systems as well.

3.2.2 Phase 2

The data acquired as a result of Phase 1 will facilitate the design of the of full-scale in situ and ESB systems to address the 100-N Area petroleum sites. The Phase 1 data will enable the determination of optimum injection well and monitoring point spacing, required air exchange rates, and optimum nutrient and moisture enhancements, as necessary. While it is expected that some additional site characterization will be necessary during Phase 2, such additional characterization would be focused on the nature and extent of contamination at a site (i.e., TPH concentrations and spatial distribution); additional sampling and analysis to facilitate the design of the applicable bioremediation system should not be needed.

The Phase 1 data concerning the potential for intrinsic bioremediation may also have an impact on the Phase 2 scope or, alternatively, the need for remediation at some of the subject sites. As previously noted, many of the sites that are the subject of this study resulted from relatively small (e.g., hundreds of gallons) releases that occurred 20 to 30 years ago. Furthermore, the actual concentration of TPH in the soils at the sites has never been quantified. Given that the range of hydrocarbon degradation rates for bioremediation are typically in the range of 1 ppm/day to 20 ppm/day (EPA 2000), and assuming a release occurred 20 years ago, initial concentrations of TPH in soils ranging from 7,500 ppm to an excess of 140,000 ppm could have been effectively remediated (i.e., TPH concentration of 200 ppm or less) through intrinsic bioremediation.

4.0 INTERFACES WITH OTHER PROJECTS AND OPERATING SYSTEMS

The installation and operation of 100-N petroleum hydrocarbon bioremediation system(s) will require interface between multiple organizations, operational systems, and other planned projects and activities. Within the 100-N Area, existing groups performing work include D4 closure and ISS activities, groundwater pump-and-treat system operations and maintenance, and general groundwater monitoring. Since these other actions will likely still be ongoing at the time that the petroleum hydrocarbon bioremediation system is being constructed and operated, coordination of field activities will be critical to the success of all efforts. Furthermore, multiple management and oversight groups have charters within the 100-N Area. Included in this list are Washington Closure Hanford (WCH), Fluor Hanford, Pacific Northwest National Laboratory, U.S. Department of Energy, Richland Operations Office, and Ecology.

Presently, the ongoing D4 and ISS activities are being conducted by WCH. The primary mission associated with this work scope is the D4 of many of the facilities within the 100-N Area. Secondary to the D4 activities includes provision of utility services in the 100-N Area as river corridor cleanup progresses and the surveillance and maintenance of facilities assigned to WCH. Also included in this area will be the subsequent demolition and waste disposal of portions of the 105-N Building outside the safe storage enclosure.

Presently the 100-NR-2 pump-and-treat system is being operated by Fluor Hanford to reduce the flux of strontium-90 contaminated groundwater to the Columbia River. This is accomplished through the extraction of groundwater via select wells, ion-exchange removal of strontium-90, and reinjection of "cleaned" groundwater. The objective is improvements to and maintenance of the aquifer underlying the source operable units associated with the 100-N Area. Closely related to this is the fact that the groundwater underlying the 100-N Area is monitored at this time by Pacific Northwest National Laboratory. The Groundwater Performance Assessment Project (groundwater project) defines the "interest areas" and facilitates scheduling, data review, and interpretation. Strontium-90 is the most significant groundwater contaminant beneath the 100-NR-2 Operable Unit, which this group is presently focused on (PNNL-15670, DOE/RL-2006-08). Tentative plans are being made to modify this system to improve its effectiveness.

Presently, plans to modify these existing systems, groups, etc., should have minimal impacts on the implementation of new systems and projects such as the bioremediation of petroleum hydrocarbon contaminants in the 100-N Area. However, these potential interface points should be integrated over their life cycle with the existing and planned projects and management structures involved in the 100-N Area to effectively complete all workscope.

Because of the significant accomplishments completed to date and planned within the area encompassing the Group 1 sites, no major project interface issues are expected. In fact, this should be a relatively well contoured area free of above- and below-grade structures that could impede petroleum hydrocarbon bioremediation efforts.

In the vicinity of the Group 2 sites, a major effort is planned by ISS, specifically safe storage of the N Reactor, which could be a more significant potential project interface. However, indications are that this should be very manageable, particularly as long as equipment sitings for the bioremediation are located as far away from the 109-N and 105-N structures as possible.

Sites within the Group 3 listing may not even exist after planned D4 work has been completed. These sites will be evaluated further at that time.

A potential interface may exist between any ISB efforts and the groundwater activities. These potential interfaces will be evaluated as design and operations planning mature. Other potential interfaces within the 100-N Area could occur over such items as common remedial actions between waste sites. These interfaces will be incorporated into design and operational activities, as appropriate.

5.0 ASSUMPTIONS AND UNCERTAINTIES

Key assumptions and uncertainties regarding bioremediation of the subject 100-N Area sites are listed below.

- It is assumed that adequate utilities will be available in the 100-N Area to support the bioremediation system(s). D4 activity has significantly reduced the utilities infrastructure of the 100-N Area in the area where the proposed Phase 1 remediation activities would be conducted. However, utility requirements for Phase 1 are limited to electrical power. Preliminary indications are that electrical power to the Phase 1 system may entail installation of a few hundred meters of electrical line.

- Water, air, nutrient, etc., injections into the vadose zone at 100-N will be deemed acceptable by regulatory and oversight agencies.

- It is assumed that there are suitable populations of indigenous hydrocarbon-degrading bacteria in the vadose zone at the 100-N Area. This is somewhat uncertain as no data in this regard are available. However, because it has been shown that less than 1% of potential bioremediation sites are sterile, this assumption is considered sound (Norris and Kerr 1994).

- The nature and extent of petroleum contamination at the subject sites is unknown. Therefore, the estimates of impacted soil volume presented in this report may be in error.

- Given the many years since the subject spills/releases occurred, it is probable that the components of natural attenuation, namely intrinsic bioremediation, volatilization, adsorption, and leaching, have been active to some degree. Such activity may have greatly reduced the concentration and extent of TPH contamination at the sites.

6.0 SUMMARY

The Interim Action ROD for the 100-N Area requires bioremediation to address petroleum-contaminated vadose zone soils. Sixteen specific sites were selected as the scope of this study. The selection of bioremediation was based on assumed applicability to the 100-N waste sites; actual analytical data concerning the nature and extent of petroleum contamination in the vadose zone are not available. A path forward for the required bioremediation, which employs the observational approach, is proposed to accelerate risk reduction at the subject 100-N Area site while concurrently obtaining the necessary site characterization and bioremediation process design data. Specifically, it is proposed that a pilot-scale ISB system be installed in the vicinity of the site designated UPR-100-N-17 in Phase 1.

In the course of Phase 1, the necessary characterization and process design data would be obtained, pilot testing would be performed to determine the rates of bioremediation under both intrinsic and enhanced conditions, and limited site remediation would be performed. In Phase 2, the data derived from Phase 1 would be used to design, construct, and operate full-scale bioremediation for all remaining sites that require action. It must be noted that the number of sites that require action in Phase 2, or the extent of contamination at the sites, may be different or, more specifically, less than those listed in the Interim Action ROD due to the probability that the components of natural attenuation, including intrinsic bioremediation, have been active over the 20 to 30 years since the subject petroleum releases occurred.

The proposed approach represents an aggressive bias for action toward site characterization and remediation, and accelerated risk reduction at the 100-N Area, while being fully compliant with all identified regulatory requirements. Close coordination and consultation with applicable regulatory agencies will help ensure that the interim actions are efficient and effective in achieving the goals of final remedy and closure.

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