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DEVELOPMENT OF REMEDIAL PROCESS OPTIONS PHASE II - FEASIBILITY STUDY INSTALLATION RESTORATION PROGRAM NAVAL AIR STATION FALLON, FALLON, NEVADA

T.A. Cronk
D.R. Smuin
R. M. Schlosser

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Health and Safety Research Division

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T.A. Cronk
D.R. Smuin
R. M. Schlosser*

*Oak Ridge Associated Universities

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Bethel Valley Road
Oak Ridge, Tennessee 37831-6285
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
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ABSTRACT

This technical memorandum develops process options which are appropriate for environmental restoration activities at Naval Air Station Fallon (NAS Fallon), Nevada. The document is submitted in conjunction with the feasibility study (FS) activities associated with Phase II of the Installation Restoration Program (IR Program) currently underway at the base. Contaminants at each of the twenty-one sites deemed potentially threatening in the Phase I study are addressed.

As additional site-characterization information becomes available, a second technical memorandum will be developed to screen the process options outlined herein and formulate remedial alternatives. Finally, a third technical memorandum will be developed to screen remedial alternatives and recommend the optimal remedial alternative for each site. At the completion of these activities, the resulting technical memos will be assimilated into the base-wide Feasibility Study for NAS Fallon.

Introduction of contaminants to the environment has resulted from deliberate disposal activities (both through dumping and landfilling) and accidental spills and leaks associated with normal activities at NAS Fallon over its lifetime of operation. Environmental sampling results indicate that the vast majority of contaminants of concern are petroleum hydrocarbon related. These contaminants include JP-4, JP-5, leaded and unleaded gasoline, waste oils and lubricants, hydraulic fluids, and numerous solvents and cleaners. Indeed, areas of contiguous petroleum hydrocarbon contamination can be associated with eleven of the twenty-one IR Program sites at NAS Fallon: Sites 1, 2, 3, 4, 6, 12, 13, 14, 16, 19, and 23.

The principal exposure pathways of concern associated with NAS Fallon contaminants appear to be the surface flows and shallow drainage systems to which the base contributes. Available data indicate NAS Fallon IR Program sites are not contributing excessive contamination to surface flows emanating from the base. Contaminants appear to be contained in a relatively immobile state in the shallow subsurface with little or no contaminant migration off site.

1. INTRODUCTION

1.1 BACKGROUND

This technical memorandum has been prepared as part of Phase II, Feasibility Study, of the Installation Restoration Program (IR Program) currently underway at Naval Air Station Fallon (NAS Fallon), Nevada. The IR Program is designed to ensure that Department of Defense (DOD) facilities comply with environmental legislation outlined in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of December 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) (NEESA 1984).

The IR Program is initiated through a Phase I Preliminary Assessment/Site Inspection (PA/SI). Phase I utilizes employee interviews, site inspections, record searches, and limited analytical testing to determine areas where environmental contamination may be present. Environmentally sensitive sites are recommended for inclusion in Phase II (Remedial Investigation/Feasibility Study) where additional analytical testing verifies and determines the extent and magnitude of contamination. Phase II work also includes recommending a preferred remedial alternative through a systematic evaluation of various remedial options. Finally, the preferred remedial alternative is implemented in Phase III, Remedial Design/Remedial Action.

Phase II activities commenced at Naval Air Station Fallon (NAS Fallon) in September 1988 after completion of Phase I work in April 1988. Phase I PA/SI activities concluded that twenty-one sites at NAS Fallon posed a significant threat to the environment and recommended these sites for inclusion in Phase II activities. The objective of Phase II investigations is to further assess contamination at the twenty-one sites of interest and recommend appropriate remedial measures. This objective is accomplished by: 1) confirming and quantifying contamination at the sites of concern, and 2) developing and evaluating remedial alternatives capable of providing environmental protection from any contaminants confirmed to be present.

In order to accomplish these two goals, Phase II activities consist of a

remedial investigation (RI) and a feasibility study (FS). First, the extent and magnitude of contamination at sites deemed potentially contaminated are assessed and quantified. This is accomplished through the RI portion of Phase II. If the RI confirms the presence of contaminants at a site, the development and evaluation of remedial alternatives is accomplished through the FS portion of Phase II.

In general, the RI and FS are not conducted sequentially as separate investigations. Rather, both initiatives are conducted concurrently to facilitate an exchange of information between the two activities. Information disclosed during initial stages of the RI is channeled through the FS to develop a broad range of remedial alternatives applicable to the site. As remedial alternative development and evaluation proceed in the FS, any additional data needs that become apparent are channeled back to the RI for inclusion in future site-characterization activities. In this manner, information gaps disclosed by the FS are used to guide the direction of future RI investigative efforts. The resulting iterative process is well suited for addressing the complex environments associated with most environmental restoration sites. Thus, the RI and FS collectively form the RI/FS process where subsequent activities are guided by previous investigations through a collaborative interaction between the two initiatives.

1.2 HISTORY OF NAVAL AIR STATION FALLON

The following section contains a brief history of operations at NAS Fallon. The history and nature of the environmental contaminants associated with the facility are also discussed.

NAS Fallon is located approximately six miles southeast of the town of Fallon and sixty miles east of the city of Reno, Nevada (Fig. 1.2.i). The facility lies in the central Carson Desert, commonly known as the Lahontan Valley. The climate is semiarid with an average rainfall of 12.7 cm (5 in.) per year.

Naval Air Station Fallon was originally established as a military facility in 1942 when the Civil Aviation Administration and Army Air Corps constructed four airfields in Nevada as part of the Western Defense Program.

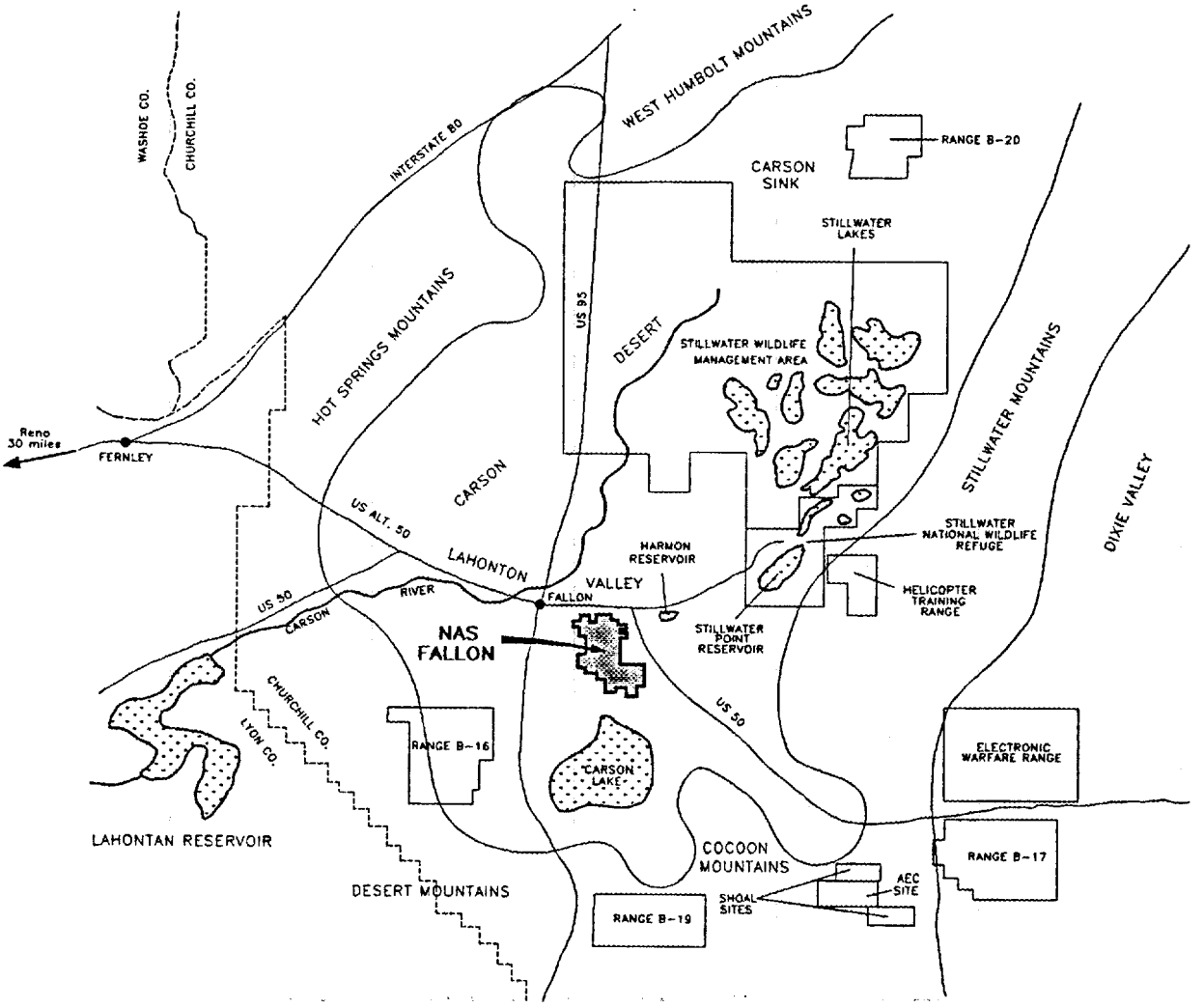


Fig. 1.2.i Regional location map of Naval Air Station Fallon.

In 1943 the Navy assumed control of the still-uncompleted facility, and on June 10, 1944, Naval Air Auxiliary Station (NAAS) Fallon was commissioned. The newly commissioned facility provided training, servicing, and support to air groups sent to the base for combat training. From 1946 to 1951, NAAS Fallon experienced varying but reduced operational status and was eventually turned over to Churchill County and the Bureau of Indian Service.

In 1951, Fallon was used as an auxiliary landing field for NAS Alameda, California, and on October 1, 1953, NAAS Fallon was re-established. On January 1, 1972, NAAS Fallon was upgraded to its current status of Naval Air Station Fallon. NAS Fallon serves primarily as an aircraft weapons delivery and tactical air combat training facility.

Since its inception in 1942, various kinds of environmentally harmful materials have been routinely used and/or disposed of at NAS Fallon. These include jet fuel (JP-4 and JP-5), oil, avgas (aviation gasoline), gasoline, antifreeze, hydraulic fluid, solvents, paint, pesticides, and industrial and municipal garbage. These substances may have been introduced into the environment during aircraft refueling, maintenance, and washing; vehicle maintenance; off-specification fuel disposal; fire training exercises; tank cleaning; sewage disposal; pest and weed control; landfilling; and accidental leaks and spills.

Environmental concerns associated with past activities at NAS Fallon have resulted in several environmental assessment initiatives. These include: 1) an investigation by ERM-West of fuel found to be floating on the water table underlying the new fuel farm facility (ERM-West 1988); 2) an investigation by the Nevada Division of Environmental Protection (NDEP) of an alleged fuel release at the new fuel farm facility (NDEP 1990); and 3) initiation of the current IR Program of which this document is a part. Portions of the IR Program initiative which have been completed to date include: the Phase I, PA/SI (Dames and Moore 1988), preliminary portions of the Phase II, RI (ORNL 1989), and the Site 2 Engineering Evaluation/Cost Analysis (EE/CA) (ORNL 1991).

Currently, the base actively implements comprehensive waste management practices to control environmental pollutants. Additionally, completion of the IR Program will assure full compliance of base activities with federal and state environmental regulations.

1.3 PURPOSE AND OUTLINE OF REPORT

1.3.1 Purpose of Report

This technical memorandum is being submitted in conjunction with the FS portion of Phase II activities currently underway at NAS Fallon, Nevada. Information concerning contaminants at NAS Fallon is taken from the Phase I study (Dames and Moore 1988), initial RI field-sampling activities (ORNL 1989), and other environmental studies (ERM-West 1988, NDEP 1990). These data are reviewed for preliminary assessment of the extent and magnitude of contaminants associated with the twenty-one sites of concern. The contaminated media of concern, exposure pathways, Applicable or Relevant and Appropriate Requirements (ARARs), and remedial action goals are defined on a site-specific basis. Finally, general response actions, technology types, and specific process options capable of satisfying the remedial action goals and providing environmental protection are formulated.

As results from additional RI site-characterization activities become available, subsequent technical memorandums will be developed to: screen the process options developed herein; develop remedial alternatives as combinations of the retained process options; and, finally, screen remedial alternatives and recommend the optimal remedial alternative for each site. At the completion of these activities, the resulting technical memorandums will be assimilated into a base-wide Feasibility Study for NAS Fallon which is consistent with Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-01, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988).

1.3.2 Outline of Report

The development of process options appropriate for remedial activities at a specific site requires an understanding of: 1) the nature, extent, and magnitude of contaminants present; 2) the mobility, transport pathways, exposure points, and affected receptors associated with contaminants; and 3) ARARs associated with contaminants. Since these points are all dependent upon past activities in and around the site, a knowledge of site history is also required.

The following format will be employed to develop process options for the sites of concern at NAS Fallon:

Site History as based on available information from previous investigations concerning environmental contaminants of concern;

Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives as determined from site history and previous environmental investigations; and,

General Response Actions, Technology Types, and Site-Specific Process Options capable of supplying environmental protectiveness in light of ARARs and remedial action objectives developed.

A flow chart showing the logic process used in the final evaluation (the development of site-specific process options from general response actions) is shown in Fig. 1.3.2.i. A general response action will include any applicable containment, treatment, removal, or institutional action capable of meeting remedial objectives. Delineation of technology types will include determining appropriate response-action technologies in light of specific circumstances associated with each site. Finally, site-specific process options appropriate for each of the technology types will be formulated.

The following section develops remedial process options appropriate for environmental restoration at each of the twenty-one potentially contaminated sites at NAS Fallon. To facilitate ease in referencing and in developing of location maps, Phase II activities to date have referenced the twenty-one areas of concern as four individual sites and four groupings encompassing the remaining seventeen sites. Grouping is based on proximity of sites to one another and/or similarity of contaminants. In order to maintain consistency throughout Phase II activities, reference to individual sites in this report

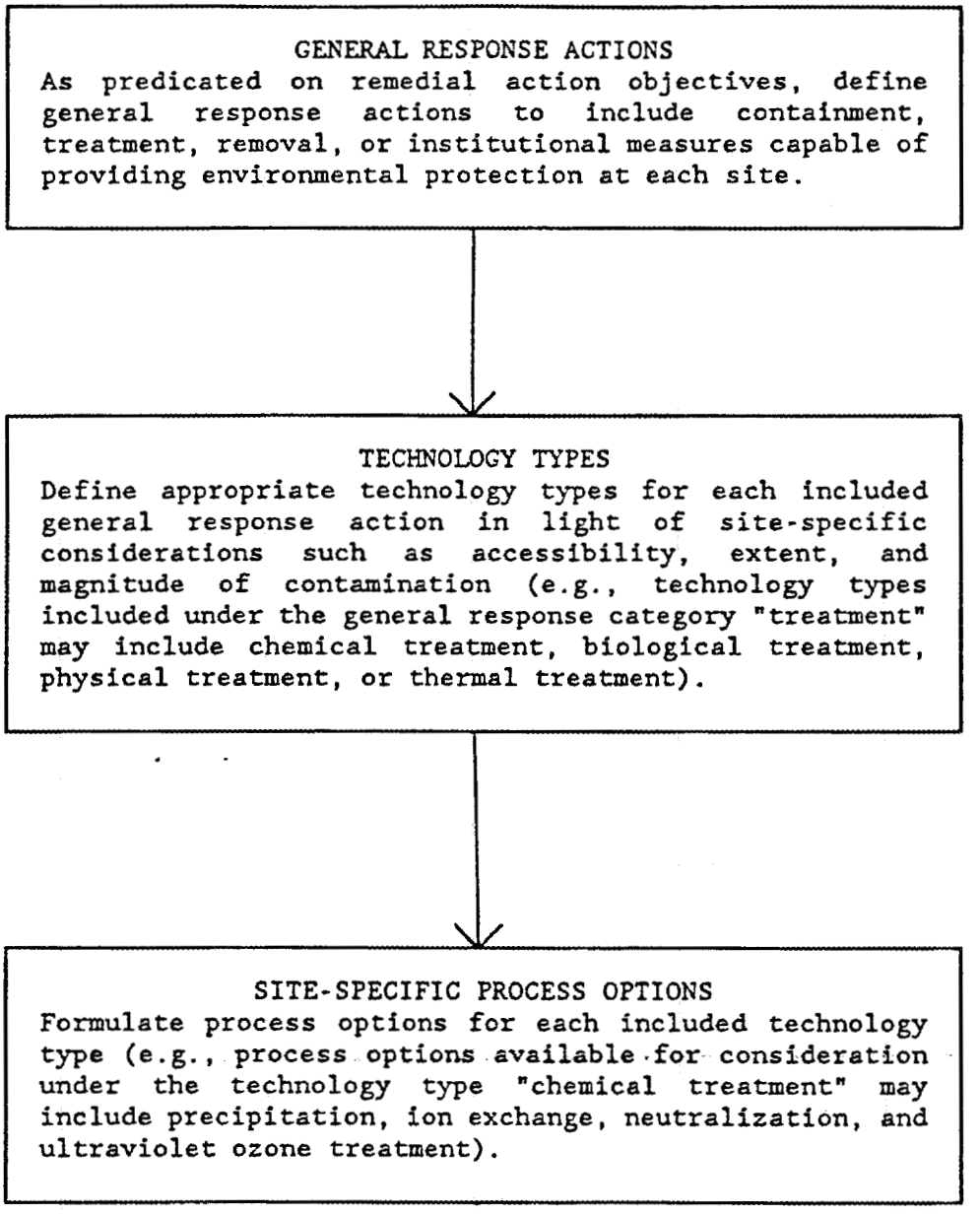


Figure 1.3.2.1 Functional relationships employed to generate process options.

will be made through the site's associated grouping. The twenty-one sites and associated groupings under investigation are shown in Fig 1.3.2.ii and include:

SITE	GROUPING
Site 1 - Crash Crew Training Area	Stand alone
Site 3 - Hangar 300 Area	Stand alone
Site 20 - Checkerboard Landfill	Stand alone
Site 24 - Road Oiling Area	Stand alone
Site 2 - New Fuel Farm	Group I
Site 4 - Transportation Yard	Group I
Site 6 - Defuel Disposal Area	Group II
Site 7 - Napalm Burn Pit	Group II
Site 21 - Receiver Site Landfill	Group II
Site 22 - Northeast Runway Landfill	Group II
Site 9 - Wastewater Treatment Plant	Group III
Site 18 - Southeast Runway Landfill	Group III
Site 10 - Ground to Air Transmitting and Receiving (GATAR) Compound	Group IV
Site 11 - Paint Shop	Group IV
Site 12 - Pest Control Shop	Group IV
Site 13 - Boiler Plant Tanks	Group IV
Site 14 - Old Vehicle Maintenance Shop	Group IV
Site 16 - Old Fuel Farm	Group IV
Site 17 - Hangar 4	Group IV
Site 19 - Post-World War II Burial Site	Group IV
Site 23 - Shipping and Receiving Disposal Site	Group IV

The memorandum concludes with a base-wide summary of contaminants of concern and recommendations concerning the direction of future Phase II activities.

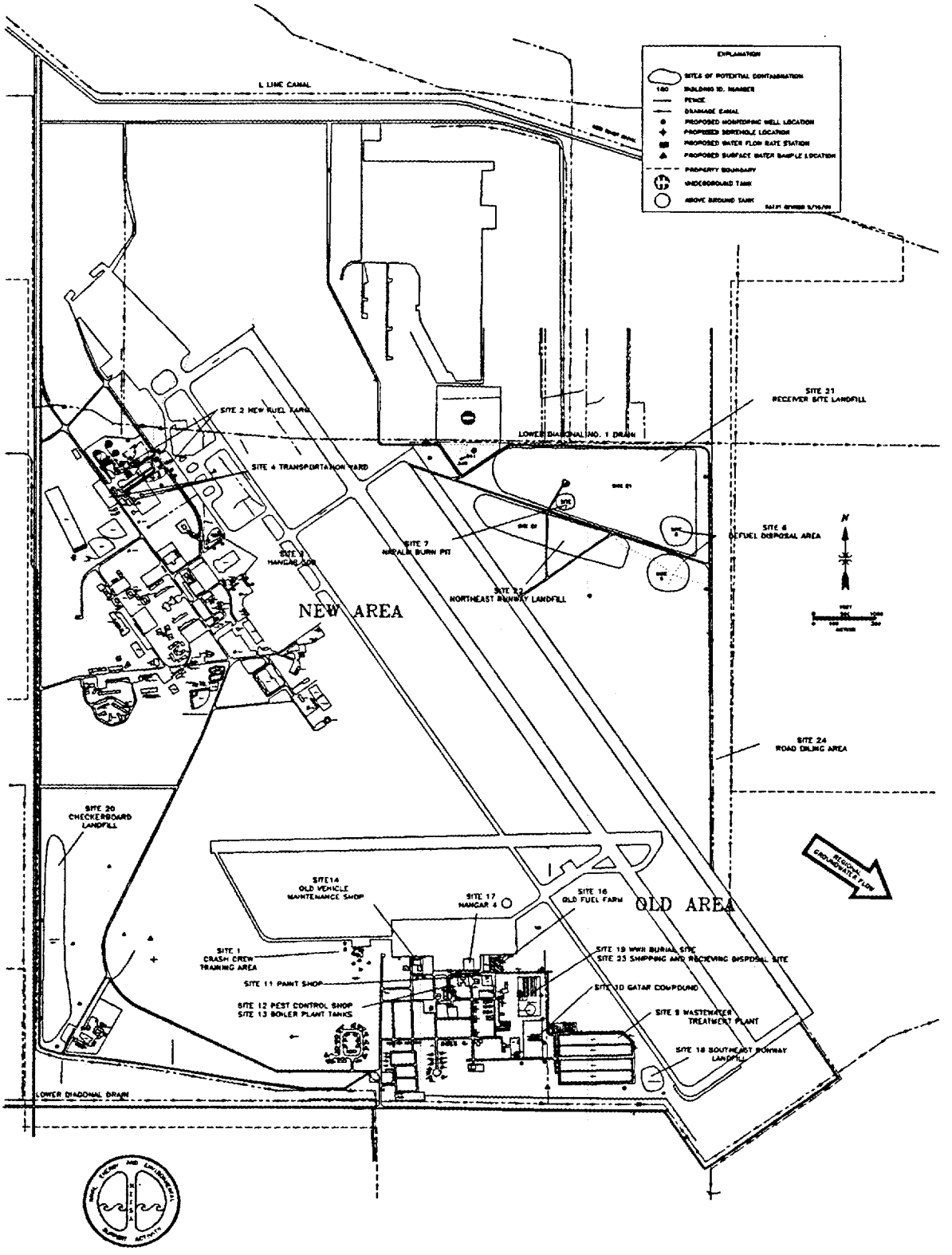


Fig. 1.3.2.ii Base-wide map of 21 contaminated sites.

2. DEVELOPMENT OF SITE-SPECIFIC PROCESS OPTIONS

2.1 SITE 1, CRASH CREW TRAINING AREA

2.1.1 Site History

As shown in Fig. 1.3.2.ii, Site 1, Crash Crew Training Area, is located in the southeastern portion of NAS Fallon in the older portion of the base. The site consists of an unlined, earth-bermed fire pit and two aboveground storage tanks (Fig 2.1.1.i). The fire pit is roughly 7.6 m (25 ft) in diameter and approximately 0.91 m (3 ft) deep. The aboveground storage tanks are located 54.5 m (180 ft) west of the fire pit and have a storage capacity of 3785 L (1,000 gal) and 18,927 L (5,000 gal).

From the mid-1950s to April 1988, the fire pit was used to conduct fire training activities for NAS Fallon personnel. Fire training activities consisted of flooding the fire pit with flammable liquids which were then ignited and extinguished. During this time period, weekly activities resulted in an estimated total of 4,731,750 L (1,250,000 gal) of petroleum hydrocarbons being burned at the site, averaging 3028 L/week (800 gal/week). The flammable liquids consisted of waste products from the old and new fuel farms, aircraft maintenance, and vehicle maintenance. Of the wastes burned, an estimated 90% was off-specification fuel, 9% oil, and 1% solvent.

Waste liquids were usually stored in the nearby storage tanks and fed to the fire pit via underground pipelines upon initiation of fire training activities. Occasionally, wastes were dumped directly into the fire pit if the storage tanks were full. From 1982 to April 1988, only off-specification JP-5 from the new fuel farm was incinerated in the fire pit. From April 1988 to the present, no petroleum hydrocarbons have been burned at the pit. Fire training activities presently consist of extinguishing wooden pallets and tires.

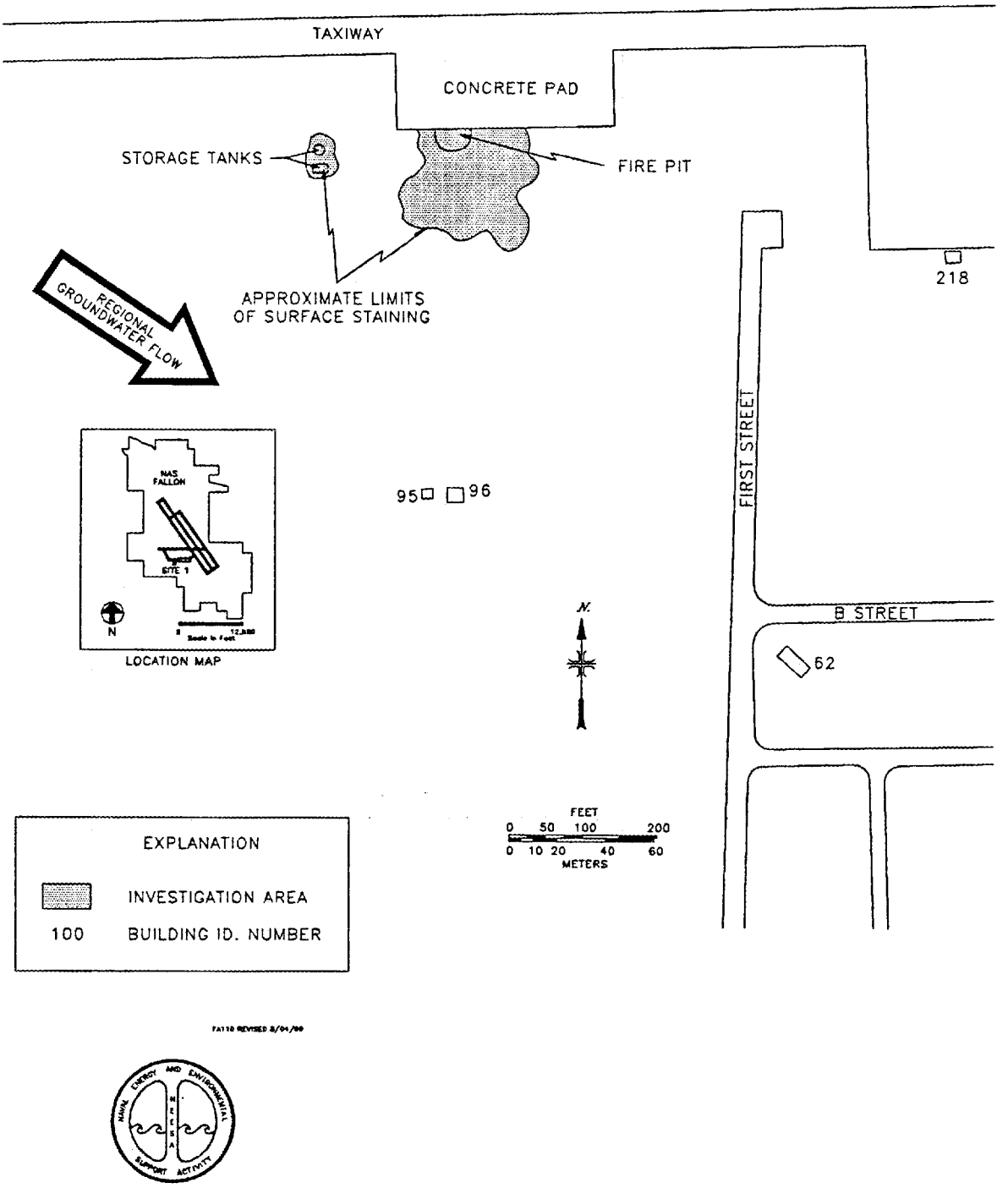


Fig. 2.1.1.i Site 1, Crash Crew Training Area.

2.1.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific, contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at Site 1.

2.1.2.1 Contaminated Media of Concern

Phase I investigations revealed soil staining in and to the south of the fire pit. Minor staining, resulting from spills during filling activities, was also observed around the two storage tanks (Fig. 2.1.1.i). Phase I activities concluded that, due to the amount of liquids disposed of at the site, subsoil and groundwater contamination is likely.

Additional contaminant assessment activities have been conducted in conjunction with the Phase II RI and include: an EM-31 geophysical survey; field screening of fifty-seven groundwater test holes; and installation of six soil borings, eight groundwater monitoring wells, and two piezometers. Results from the geophysical survey (Appendix A) confirmed the location of a former Carson River channel passing across the southwestern portion of the site (Fig. 2.1.2.i). Figure 2.1.2.ii shows the location of the groundwater test hole screening used to delineate the boundaries of a petroleum hydrocarbon plume underlying the facility. Results from the groundwater screening are given in Appendix B, Table B.1.

Also shown on Fig. 2.1.2.ii are the locations for the soil borings, the monitoring wells, and the piezometers. Laboratory results from the soil borings and initial rounds of sampling of the monitoring wells are not yet available.

Phase II site-characterization activities completed to date indicate contaminants of concern at Site I are petroleum hydrocarbons (primarily JP-5). Results also indicate the contaminated media of concern include the soils and shallow groundwater underlying the site. The atmospheric medium is not

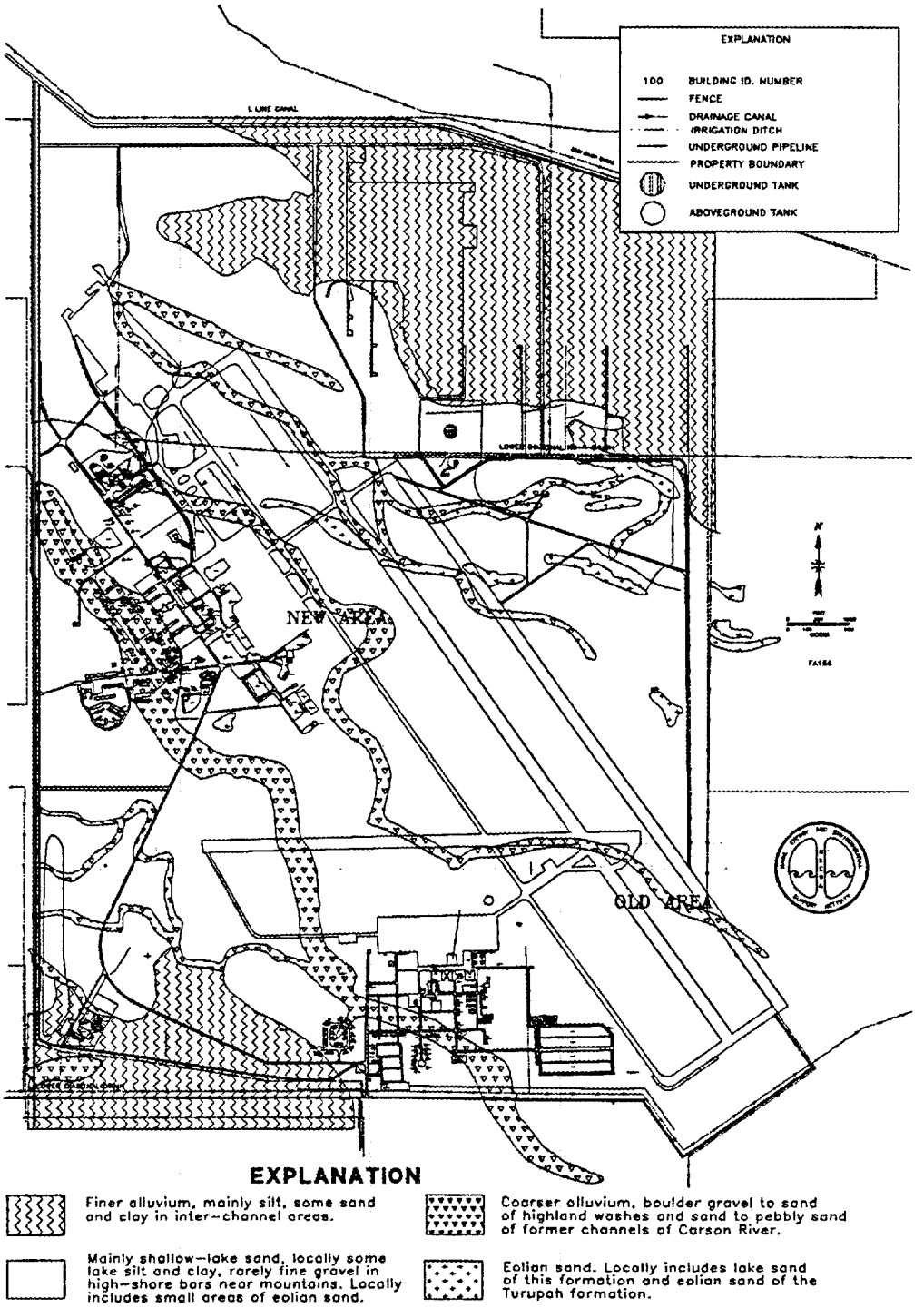


Fig. 2.1.2.i Old Carson River channels.

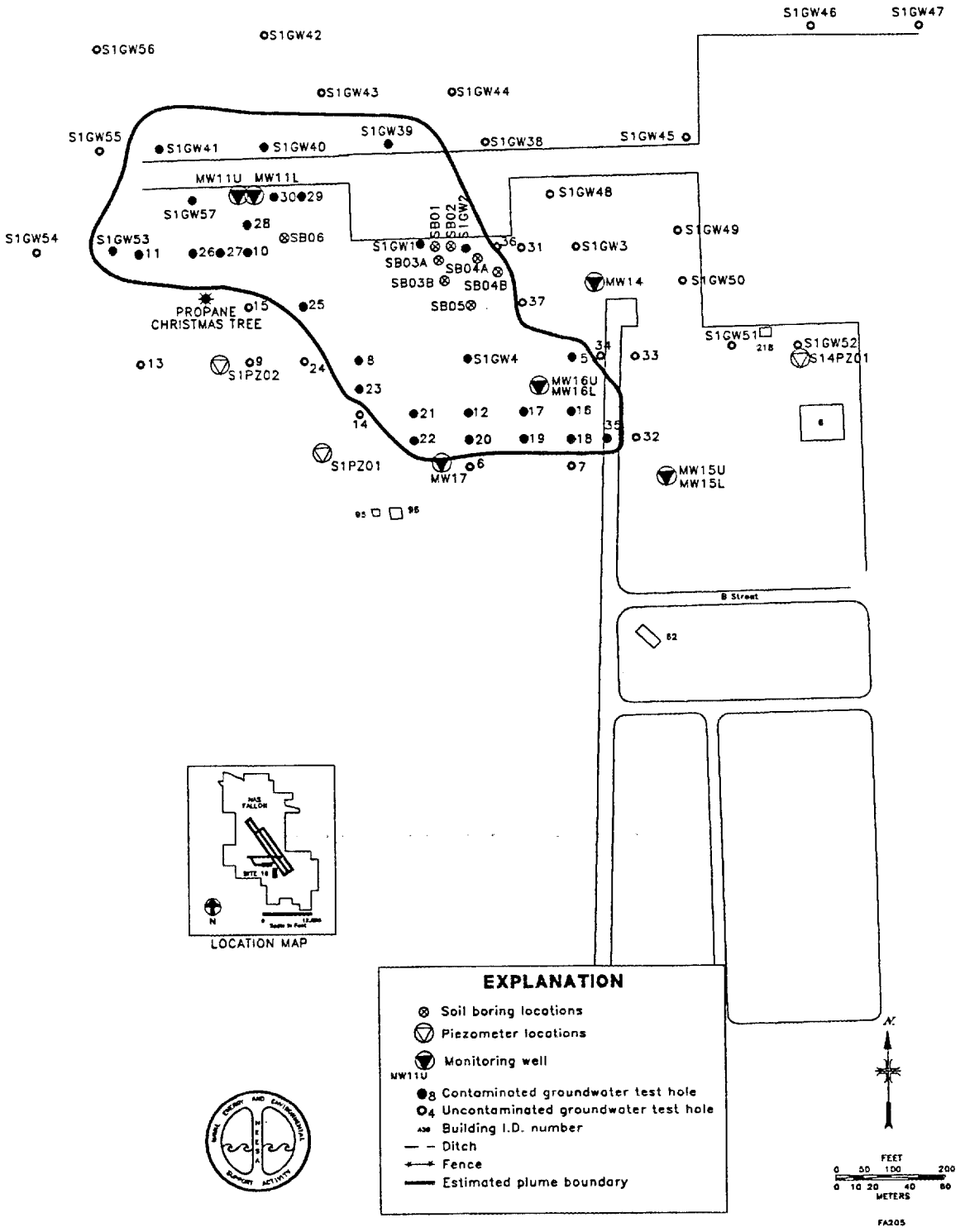


Fig. 2.1.2.ii Site 1, Crash Crew Training Area. Groundwater test hole and analytical sampling locations.

considered to be a concern because petroleum hydrocarbons have not been disposed of at the site since April 1988. Sufficient time has thus elapsed for volatile contaminants at or near the surface to have dissipated to well below levels of concern.

2.1.2.2 Exposure Pathways

Direct exposure pathways for contaminated soils at Site 1 include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants and burrowing animals as well as personnel associated with site activities such as fire training exercises and construction/maintenance. Plant and animal populations are controlled on NAS Fallon property, and exposures associated with these biota are thus minimized. Direct exposure to the human populace is also restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. Restricted access and site activities geared towards environmental safety thus prevent contaminated soils at Site 1 from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and, due to its high salinity, is not used for human consumption in the surrounding area (Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is unknown, its likely purpose in light of the poor water quality is to supply water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt aquifer which supplies drinking water for the area. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in certain portions of the base (ERM-West 1988). It is believed that these natural containment mechanisms prevent contaminants from reaching the regional domestic water source. The lack of use of shallow groundwater in the immediate vicinity and the natural containment properties associated with the regional groundwater flow system prevent the shallow groundwater from serving as a direct exposure pathway.

As with soils, contaminated groundwater associated with Site 1 does not constitute a direct exposure pathway. Soils may, however, serve as a source term for atmospheric transport of contaminated particulates, and both contaminated soils and groundwater may act as a source for contaminating surface flows. Contaminated surface flow may then serve as an exposure pathway to sensitive receptors.

Exposures to wind-blown transport of contaminated soils are minimal due to restricted access in the immediate vicinity, the natural cohesive properties of native surface soils, and dust control measures employed during construction activities. In addition, the air quality of the region is good, and airborne particulate matter is quickly dispersed. Atmospheric transport of contaminated soils is, hence, not considered a threat to the environment.

Downward transport of residual soils contamination to the underlying aquifer via surface water percolation is not considered significant because of the semiarid climate. Indeed, the alkali flats in the surrounding area indicate a negative regional water balance. It is surmised that because contaminants were originally introduced at or near the ground surface, the downward transport necessary to produce existing groundwater contamination resulted from gradients introduced from excessive spills or dumping and not from the natural percolation process.

Surface flow runoff resulting from excessive precipitation or human activities may transport contaminated surface sediments or dissolved constituents to the regional surface drainage system. In addition, contaminants presently associated with the shallow groundwater may migrate

downgradient for eventual seepage discharge into the surrounding drainage ditches. Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off site exposure points associated with surface flows include recreational exposure, direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

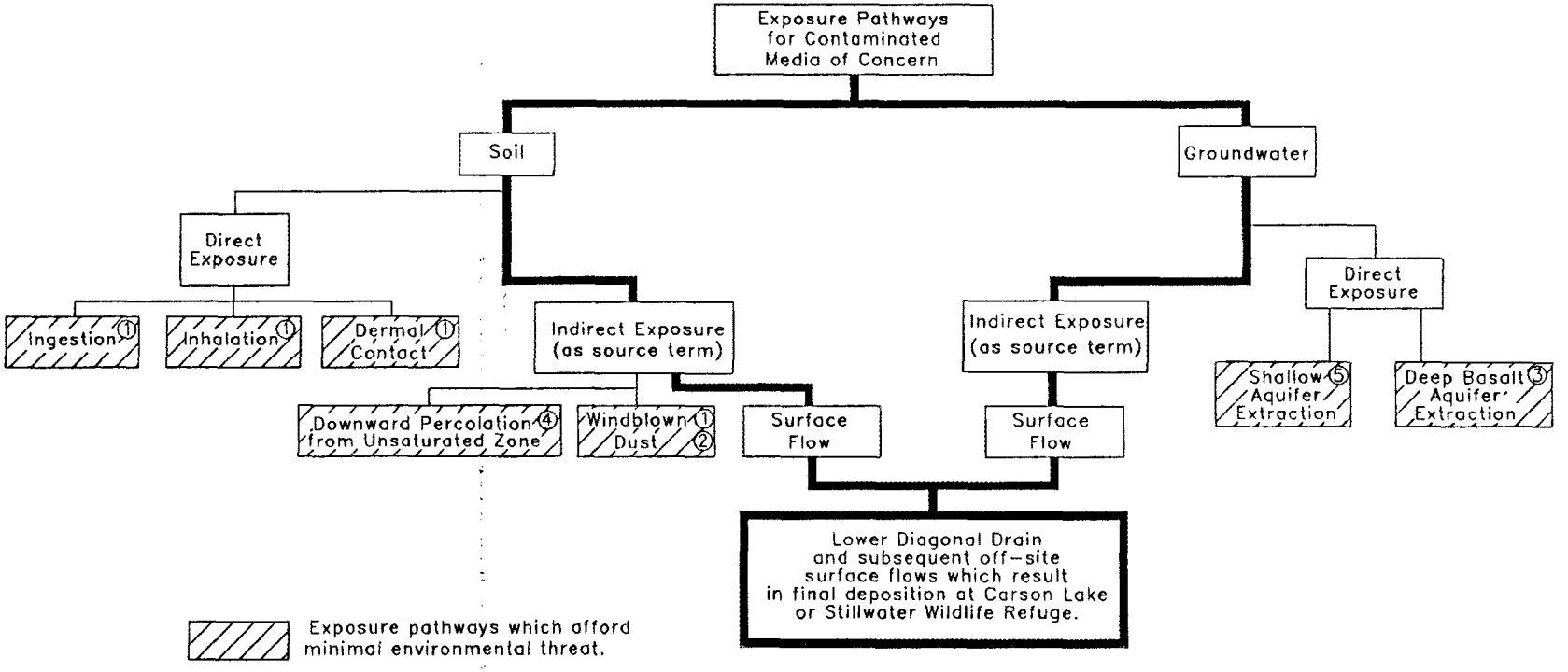
Ground- and surface-water transport to off-site receptors is thus the primary exposure pathway for contaminants of concern at Site 1. Potential off-site transport mechanisms include: 1) eventual seepage discharge of contaminated groundwater and free product to surface flows migrating off site, and 2) discharge of contaminated surface flows (from rainfall and human activity) to surface water drainage systems. The principal exposure pathway of concern is thus the regional surface flow system extending from the down-gradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. Figure 1.3.2.ii and Fig. C.3 indicate that the Lower Diagonal Drain located along the southern boundary of the base is the primary receptor point for groundwater or surface flow transport of contaminants from Site 1. Figure 2.1.2.iii is a flow chart which summarizes the above discussion and depicts the screening logic used in determining the exposure pathways of concern. As shown in the flow chart, the Lower Diagonal Drain and subsequent off-site surface flows into which it drains are the primary exposure pathways associated with contaminants at Site 1.

2.1.2.3 ARARs and Remedial Action Objectives

The State of Nevada Division of Environmental Protection (NDEP) Hydrocarbon Cleanup Policy (NDEP 1987) is given in Appendix D.

SITE 1, CRASH CREW TRAINING AREA



Exposure pathways which afford minimal environmental threat.

Primary exposure pathways of concern.

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① Exposure minimized through restricted access and inistitutional constraints.

② Exposure minimized by natural cohesive properties of native surface soils and good regional air quality.

③ Exposure minimized by natural containment properties of the regional subsurface flow system.

④ Exposure minimized by negative water balance (semi-arid climate).

⑤ Exposure minimized through restricted access, institutional constraints, and regionally poor quality of upper aquifer.

Fig. 2.1.2.iii Flow chart of exposure pathways associated with Site 1.

As stated in this NDEP Policy, remediation of petroleum-hydrocarbon-contaminated soils and groundwater may be required if action limit concentrations are exceeded. Action limit concentrations are set at 100 mg/kg total petroleum hydrocarbons (TPH) for soils and the Environmental Protection Agency (EPA) maximum contaminant levels (MCLs) or recommended maximum contaminant levels (RMCLs) for groundwater used as a drinking water (potable) source. Relevant MCLs are 5.0 μg/L for benzene (established), 700 μg/L for ethylbenzene (proposed), 10,000 μg/L for total xylene (proposed), and 2,000 μg/L for toluene (proposed). If these action limits are exceeded, the need for remedial activity is then evaluated with respect to site-specific parameters such as use of the contaminated medium; contaminant transport potential; the degree, magnitude, and toxicity of contaminants; and economic cost/benefit considerations. Although contaminants of concern may indeed exceed action limits at Site 1, the need for active remediation must still be evaluated in light of the restricted access to NAS Fallon property and the lack of use of the upper aquifer.

While the existence of soil and groundwater contaminants in excess of action limits does not in itself mandate active remediation, the existence of free-phase product on the groundwater in excess of 1.27 cm (0.5 in.) does require the implementation of an active removal action (Appendix D). Preliminary borehole screening results indicate that this action level has probably been exceeded at Site 1.

Remedial action objectives for Site 1, based on the above referenced ARARs, are formulated in Table 2.1.2.i.

2.1.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.1.3.i and 2.1.3.ii list the general response actions, technology types, and process options for Site 1 contaminated soils and groundwater respectively. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated in Table 2.1.2.i, and 2) the associated exposure pathways and affected receptors discussed in Section 2.1.2. The process options

Table 2.1.2.i. Site 1, Crash Crew Training Area. Remedial action objectives

Remedial Action Objectives - Site 1			
Contaminated Media		Applicable or Relevant and Appropriate Requirements (ARARs)	Media-Specific Remedial Action Objectives
Soil		NDEP Hydrocarbon Cleanup Policy	Prevent exposures to soils contaminated in excess of 100 mg/kg TPH
Groundwater	Dissolved Product	NDEP Hydrocarbon Cleanup Policy	Prevent exposures to groundwater used as a potable source contaminated in excess of 5.0 μg/L for benzene, 700 μg/L for ethylbenzene, 10,000 μg/L for total xylene, and 2,000 μg/L for toluene. Prevent exposures to seepage discharge of groundwater contaminants into surface waters in excess of 1.0 mg/L TPH
	v6,37 Free Product	NDEP Hydrocarbon Cleanup Policy	Initiate active free-product removal operations when free-phase product exists on the groundwater in excess of 1.27 cm (0.5 in.)

TPH: total petroleum hydrocarbons

Table 2.1.3.1. Site 1, Crash Crew Training Area. General response actions, technology types, and process options for contaminated soils

Site 1, Crash Crew Training Area. General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal)	Grout injection, In situ vitrification, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (in situ and following removal)	RF thermal stripping, Soil baking/thermal desorption, Incineration
		Chemical treatment (following removal)	Neutralization/stabilization, Precipitation, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor, Landfarming, Composting
		Physical separation/extraction (following removal)	Soil flushing, Centrifuging, Steam stripping, Soil venting, Ultrasonics
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

RF: radio frequency

Table 2.1.3.ii. Site 1, Crash Crew Training Area. General response actions, technology types, and process options for contaminated groundwater

Site 1, Crash Crew Training Area. General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Bio-clogging, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction
		Free product pumping (in situ)	Single recovery skimmer, Dual recovery system

formulated in Tables 2.1.3.i and 2.1.3.ii will serve to form the remedial action alternatives for Site 1 as Phase II work progresses.

As shown in Table 2.1.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area.

General response actions for contaminated groundwater also include institutional measures, containment, treatment, and removal (Table 2.1.3.ii). Technology type and appropriate process option listings follow for each of the general response categories. As with soils, on-site restricted pumping is included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

2.2 SITE 3, HANGAR 300 AREA

2.2.1 Site History

As shown in Fig. 1.3.2.ii, Site 3, Hangar 300 Area, is located in the west-central portion of NAS Fallon in the new area. Hanger 300 was constructed in 1960 at which time disposal of contaminants on the adjacent land areas began. Hangar 300 serves to house the Ground Support Equipment (GSE) activity which is responsible for servicing aircraft support equipment. In addition, GSE was probably involved with aircraft maintenance and the disposal of aircraft repair/maintenance waste fluids prior to the arrival of Fleet Liaison in 1976.

Environmental concerns at the site are associated with several separate areas including the north and south disposal areas, bowser disposal area, oil/water separator area, GSE area, and the wells air start building (Fig. 2.2.1.i). The wells air start building is located south of Hangar 300 (Fig. 2.2.1.i) and served to supply compressed air used to start jet engines. The wells air start facility was used from 1978 to 1987 at which time a new air start facility became operational. Contaminants at these areas are the

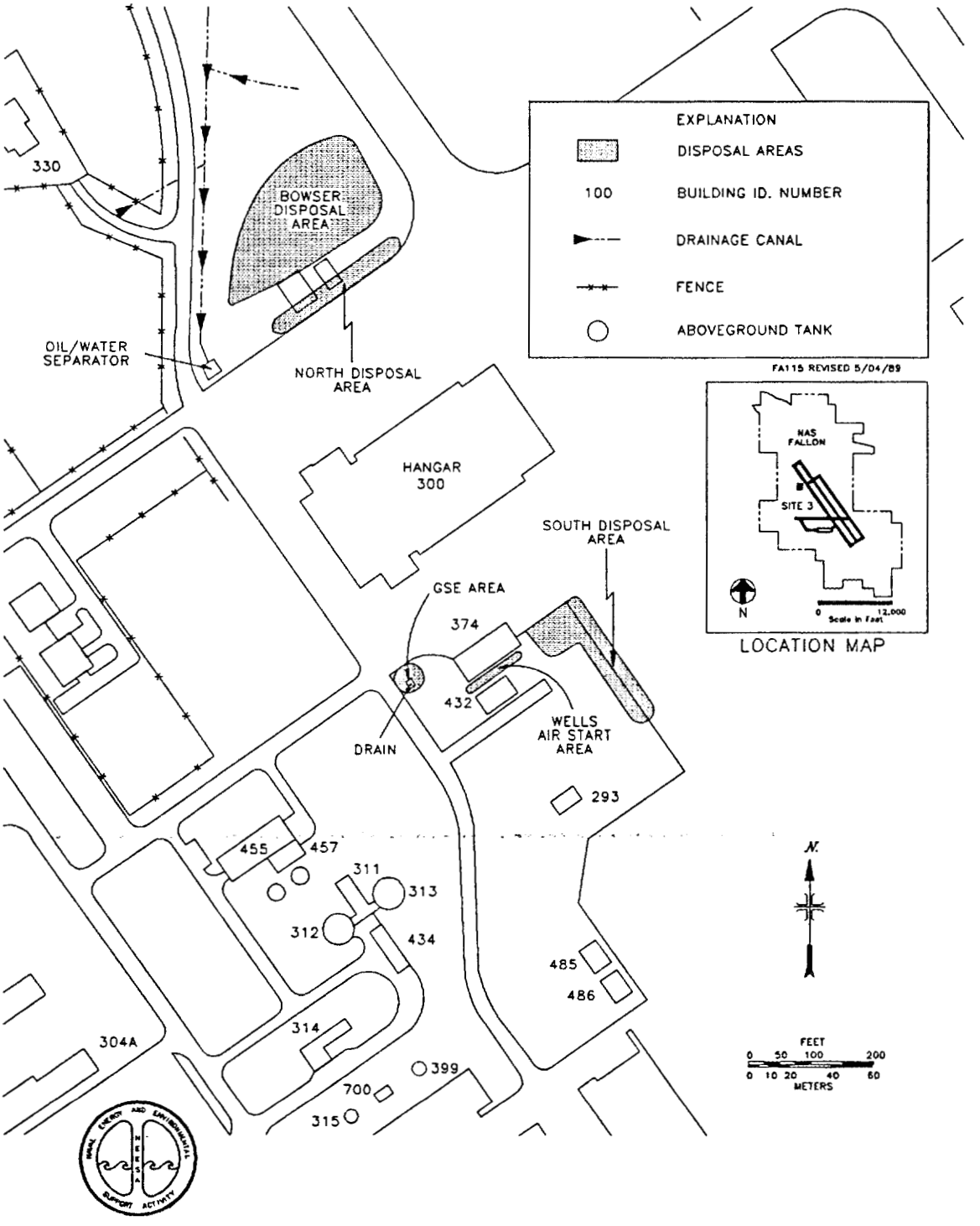


Fig. 2.2.1.i Site 3, Hangar 300 Area.

result of dumping petroleum hydrocarbon-related wastes on the open ground surfaces. Because of their close proximity, the areas are grouped into one site (Dames and Moore 1988).

The north and south disposal areas and the bowser disposal area (Fig. 2.2.1.i) all received similar contaminants derived from disposal of waste aircraft fluids. Contaminants consisted of JP-5, hydraulic fluids, lube oil, and solvents including carbon tetrachloride, trichloroethene (TCE), and PD-680 (stoddard solvent). Waste disposal at the north and south disposal areas consisted of hand-carrying fluids in small drain pans to the edge of the paved apron and dumping them on the open ground. Estimates of wastes introduced at these two areas between 1960 and 1981 total approximately 30,280 L (8,000 gal). Introduction of contaminants at the bowser disposal area differed in that contaminants were dumped in larger quantities through the periodic emptying of 946 L (250 gal) bowsers filled with waste aircraft fluids. As much as 47,318 L (12,500 gal) of liquid waste may have been disposed of at the bowser disposal area between 1960 and 1984.

The oil/water separator and associated drainage ditch are located west of the north disposal area (Fig. 2.2.1.i). The separator was designed to contain non-aqueous phase liquid (NAPL) contaminants emanating from floor drains in Hanger 300. Contaminants consisted of the waste fluids described above as well as aircraft cleaning solvent (Turco). The oil/water separator was used from 1960 to 1986 and reportedly malfunctioned on occasion allowing direct discharge of contaminants into the surface drainage ditch. It is estimated that as much as 11,356 L (3,000 gal) of wastes were discharged from the separator during this time period.

Compressor blowdown was introduced into the wells air start area between 1978 and 1987. Wastes consisted of compressor lube oil introduced into the compressed air as compressor blowby. Contaminants occasionally ponded in the unpaved area resulting in some surface drainage to the west. Approximately 2,839 L (750 gal) of waste oil may have been introduced to the ground surface during this operational time period.

The GSE area is located to the southwest of Hanger 300 (Fig. 2.2.1.i) and received fluids from spills and leaks in adjacent storage areas between 1960 and 1987. Wastes introduced include hydraulic fluid, lube oil, waste oil, and solvents (including TCE, Turco, and PD-680). As much as 5,110 L (1,350 gal) of waste liquids may have been discharged to the GSE area.

2.2.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at Site 3.

2.2.2.1 Contaminated Media of Concern

Surface soil samples (depths of 15.2-30.5 cm [6-12 in.]) were taken at the bowser disposal area and the oil/water separator drainage ditch during the Phase I PA/SI. Samples were analyzed for TPH using EPA method 418.1 and VOC using EPA method 8240, and results indicate petroleum hydrocarbon contaminants are present at both areas (Dames and Moore 1988).

Preliminary field screening and site-characterization activities conducted during the Phase II RI include: the screening of twelve groundwater test holes, eight soil borings, twelve monitoring wells, and three sediment samples. Screening, sampling and monitoring well locations are shown on Fig. 2.2.2.i. Soil, sediment, and initial groundwater samples were submitted for laboratory analysis, but results are not yet available.

Groundwater test hole screening results (Appendix B, Table B.7) did not indicate contaminants at the north disposal area or the bowser disposal area. Contaminants were, however, discovered at the wells air start area and the south disposal area (Fig. 2.2.2.i). As shown in Fig. 2.2.2.i, the contaminants extend eastward underneath the parking apron where the thick concrete of the apron prevented assessment of the eastern boundary of contaminants.

Site-characterization activities indicate the primary contaminants of concern at Site 3 are petroleum hydrocarbon-related wastes residing in the soils and shallow groundwater underneath the facility. The atmosphere is not considered to be a contaminated medium of concern because waste disposal activities at the site were terminated in the late 1980s. Sufficient time has thus elapsed for any volatile contaminants to degas and disperse into the environment.

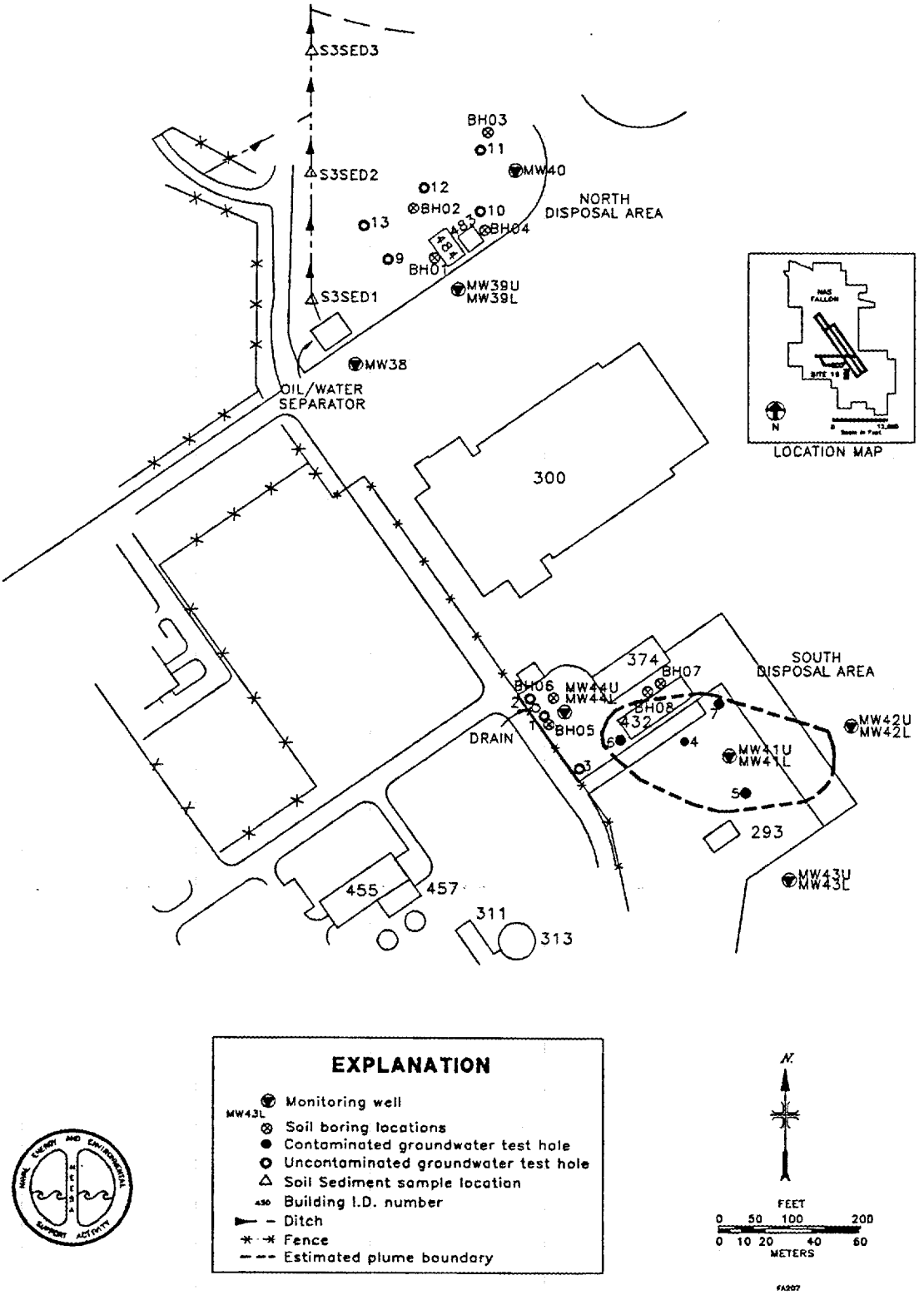


Fig. 2.2.2.i Site 3, Hangar 300 Area. Groundwater test hole and analytical sampling location.

2.2.2.2 Exposure Pathways

Direct exposure pathways for contaminated soils at Site 3 include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants and burrowing animals as well as personnel associated with site excavation activities. Plant and animal populations are controlled on NAS Fallon property, and exposures associated with these biota are thus minimized. Because NAS Fallon is a restricted area, direct exposure to the human populace is restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. Restricted access and site activities geared towards environmental safety thus prevent contaminated soils at Site 3 from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and, due to its high salinity, is not used for human consumption in the surrounding area (Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is unknown, its likely purpose in light of the poor water quality is to supply water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt drinking water aquifer. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in

certain portions of the base (ERM-West 1988). It is believed that these natural containment mechanisms prevent contaminants from reaching the regional domestic water source.

As with soils, contaminated groundwater associated with Site 3 does not constitute a substantial direct exposure pathway. Soils may, however, serve as a source term for atmospheric transport of contaminated particulates, and both contaminated soils and groundwater may act as a source for contaminating surface flows. Contaminated surface flow may then serve as an exposure pathway to sensitive receptors.

Exposures to wind-blown transport of contaminated soils are minimal due to restricted access in the immediate vicinity, the natural cohesive properties of native surface soils, and dust control measures employed during construction activities. In addition, the air quality of the region is good, and airborne particulate matter is quickly dispersed. Hence, atmospheric transport is not considered a threat to the environment.

Downward transport of residual soils contamination to the underlying aquifer via surface water percolation is not considered significant because of the semiarid climate. Indeed, the alkali flats in the surrounding area indicate a negative regional water balance. It is surmised that because contaminants were originally introduced at or near the ground surface, the downward transport necessary to produce existing groundwater contamination resulted from gradients introduced from excessive spills or dumping and not from the natural percolation process.

Surface flow runoff resulting from excessive precipitation or human activities may transport contaminated surface sediments or dissolved constituents to the regional surface drainage system. In addition, contaminants presently associated with the shallow groundwater may migrate downgradient for eventual seepage discharge into the surrounding drainage ditches. Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off-site exposure points associated with surface flows include recreational exposure, direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated

with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

Ground- and surface-water transport to off-site receptors is thus the primary exposure pathway for contaminants of concern at Site 3. Potential off-site transport mechanisms include: 1) eventual seepage discharge of groundwater contaminants to surface flows migrating off site, and 2) discharge of contaminated surface flows (from rainfall and human activity) to surface water drainage systems. The principal exposure pathway of concern is thus the regional surface flow system extending from the downgradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

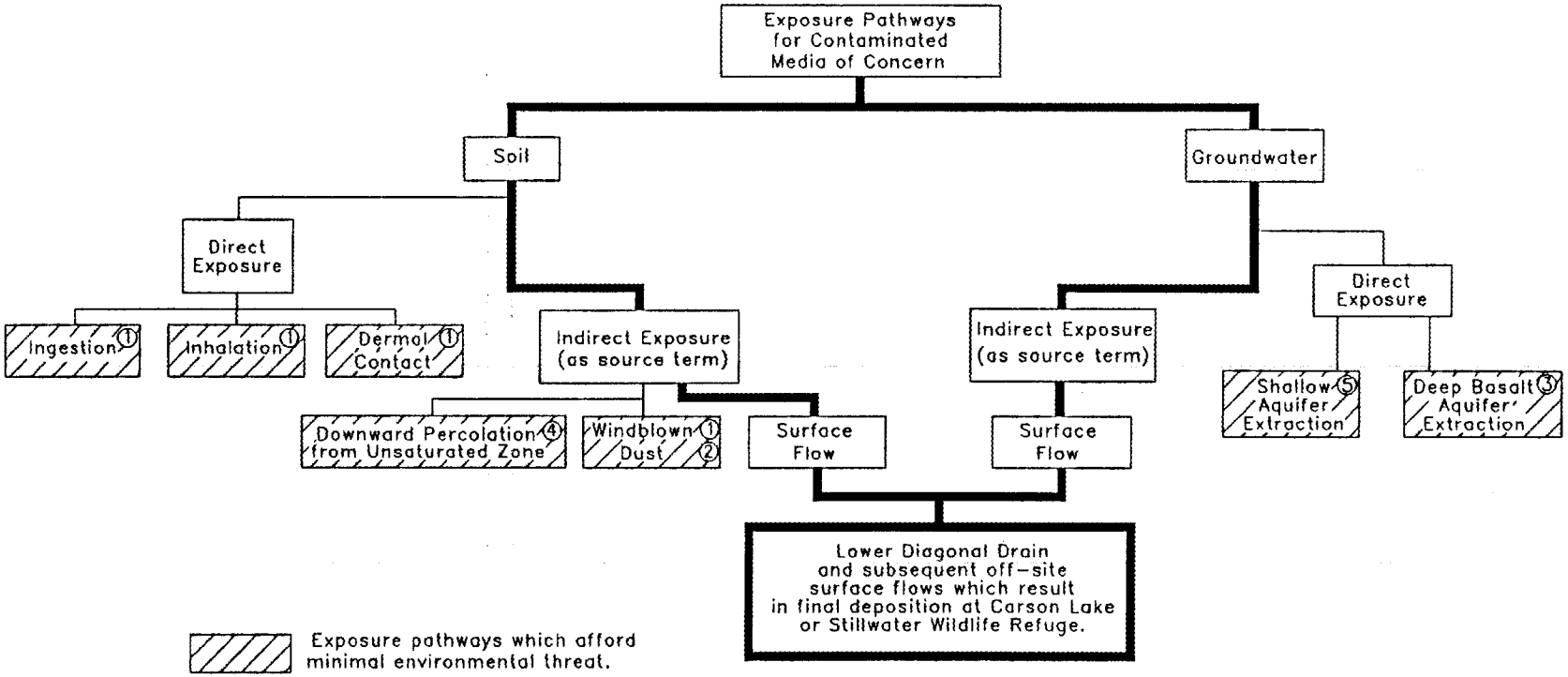
As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. As shown in Fig. 1.3.2.ii, the Lower Diagonal Drain located along the southern boundary of the base is the primary receptor point for groundwater or surface flow transport of contaminants from Site 3. Figure 2.2.2.ii is a flow chart which summarizes the above discussion and depicts the screening logic used in determining the exposure pathways of concern. As shown in the flow chart, the Lower Diagonal Drain and subsequent off-site surface flows into which it drains are the primary exposure pathways associated with contaminants at Site 3.

2.2.2.3 ARARs and Remedial Action Objectives

The State of Nevada Division of Environmental Protection Hydrocarbon Cleanup Policy (NDEP 1987) is given in Appendix D. Table 2.2.2.i lists media-specific remedial action objectives as predicated on the ARARs given in Appendix D.

As stated in this NDEP Policy, remediation of petroleum-hydrocarbon-contaminated soils and groundwater may be required if action limit concentrations are exceeded. Action limit concentrations are set at 100 mg/kg total petroleum hydrocarbons (TPH) for soils and the EPA maximum contaminant levels (MCLs) or recommended maximum contaminant levels (RMCLs) for groundwater used as a drinking water (potable) source. Relevant MCLs are 5.0 μg/L for benzene (established), 700 μg/L for ethylbenzene (proposed), 10,000 μg/L for total xylene (proposed), and 2,000 μg/L for toluene (proposed). If these action

SITE 3, HANGAR 300 AREA



Exposure pathways which afford minimal environmental threat.

Primary exposure pathways of concern.

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① Exposure minimized through restricted access and inistitutional constraints.

② Exposure minimized by natural cohesive properties of native surface soils and good regional air quality.

③ Exposure minimized by natural containment properties of the regional subsurface flow system.

④ Exposure minimized by negative water balance (semi-arid climate).

⑤ Exposure minimized through restricted access, institutional constraints, and regionally poor quality of upper aquifer.

Fig. 2.2.2.ii Flow chart of exposure pathways associated with Site 3.

Table 2.2.2.i. Site 3, Hangar 300 Area. Remedial action objectives

Remedial Action Objectives - Site 3			
Contaminated Media		Applicable or Relevant and Appropriate Requirements (ARARs)	Media-Specific Remedial Action Objectives
Soil		NDEP Hydrocarbon Cleanup Policy	Prevent exposures to soils contaminated in excess of 100 mg/kg TPH
Groundwater	Dissolved Product	NDEP Hydrocarbon Cleanup Policy	Prevent exposures to groundwater used as a potable water source contaminated in excess of 5.0 μg/L for benzene, 700 μg/L for ethylbenzene, 10,000 μg/L for total xylene, and 2,000 μg/L for toluene. Prevent exposures to seepage discharge of groundwater contaminants into surface waters in excess of 1.0 mg/L TPH.
	Free Product	NDEP Hydrocarbon Cleanup Policy	Initiate active free-product removal operations when free-phase product exists on the groundwater in excess of 1.27 cm (0.5 in.)

TPH: total petroleum hydrocarbons

limits are exceeded, the need for remedial activity is then evaluated with respect to site-specific parameters such as use of the contaminated medium; contaminant transport potential; the degree, magnitude, and toxicity of contaminants; and economic cost/benefit considerations. Although contaminants of concern may indeed exceed action limits at Site 3, the need for active remediation must still be evaluated in light of the restricted access to NAS Fallon property and the lack of use of the upper aquifer.

While the existence of soil and groundwater contaminants in excess of action limits does not in itself mandate active remediation, the existence of free-phase product on the groundwater in excess of 1.27 cm (0.5 in.) does require the implementation of an active removal action (Appendix D).

2.2.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.2.3.i and 2.2.3.ii list the general response actions, technology types, and process options for Site 3 contaminated soils and groundwater respectively. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated in Table 2.2.2.i; and 2) the associated exposure pathways and affected receptors discussed in Sect. 2.2.2. The process options formulated in Tables 2.2.3.i and 2.2.3.ii will serve to form the remedial action alternatives for Site 3 as Phase II work progresses.

As shown in Table 2.2.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area.

General response actions for contaminated groundwater also include institutional measures, containment, treatment, and removal (Table 2.2.3.ii). Technology type and appropriate process option listings follow for each of the general response categories. As with soils, on-site restricted pumping is

Table 2.2.3.1. Site 3, Hangar 300 Area. General response actions, technology types, and process options for contaminated soils

Site 3, Hangar 300 Area. General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal)	Grout injection, In situ vitrification, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (in situ and following removal)	RF thermal stripping, Soil baking/thermal desorption, Incineration
		Chemical treatment (following removal)	Neutralization/stabilization, Precipitation, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor, Landfarming, Composting
		Physical separation/extraction (following removal)	Soil flushing, Centrifuging, Steam stripping, Soil venting, Ultrasonics
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

RF: radio frequency

Table 2.2.3.ii. Site 1, Hangar 300 Area. General response actions, technology types, and process options for contaminated groundwater

Site 3 - Hangar 300 Area, General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Bio-clogging, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction
		Free product pumping (in situ)	Single recovery skimmer, Dual recovery system

included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

2.3 SITE 20, CHECKERBOARD LANDFILL

2.3.1 Site History

As shown in Fig. 1.2.i, Site 20, Checkerboard Landfill, is located in the southwestern corner of NAS Fallon near the base boundary. The site is a nearly level area of open ground near the Checkerboard Building (Fig. 2.3.1.i). Waste disposal activities at the site consisted of the burial of wet garbage, trash, and rubble between 1951 and 1965. Material scraped from the waste water treatment plant is also known to have been buried. Additionally, it is postulated that as much as 5,300 L (1,400 gal) of liquid waste originating from the old vehicle maintenance shop and aircraft maintenance were disposed of at the site. Burning of disposed liquids is also reported to have occurred.

Landfilling at the site was conducted with bulldozers which constructed trenches across the site in an east-west direction. Depth of excavation is unknown. The trenches were subsequently filled with waste and then back-filled. It is possible that excavations may have been of sufficient depth to deposit wastes below the water table. Approximately 85,000 tons of refuse were disposed of in this manner.

2.3.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at Site 20.

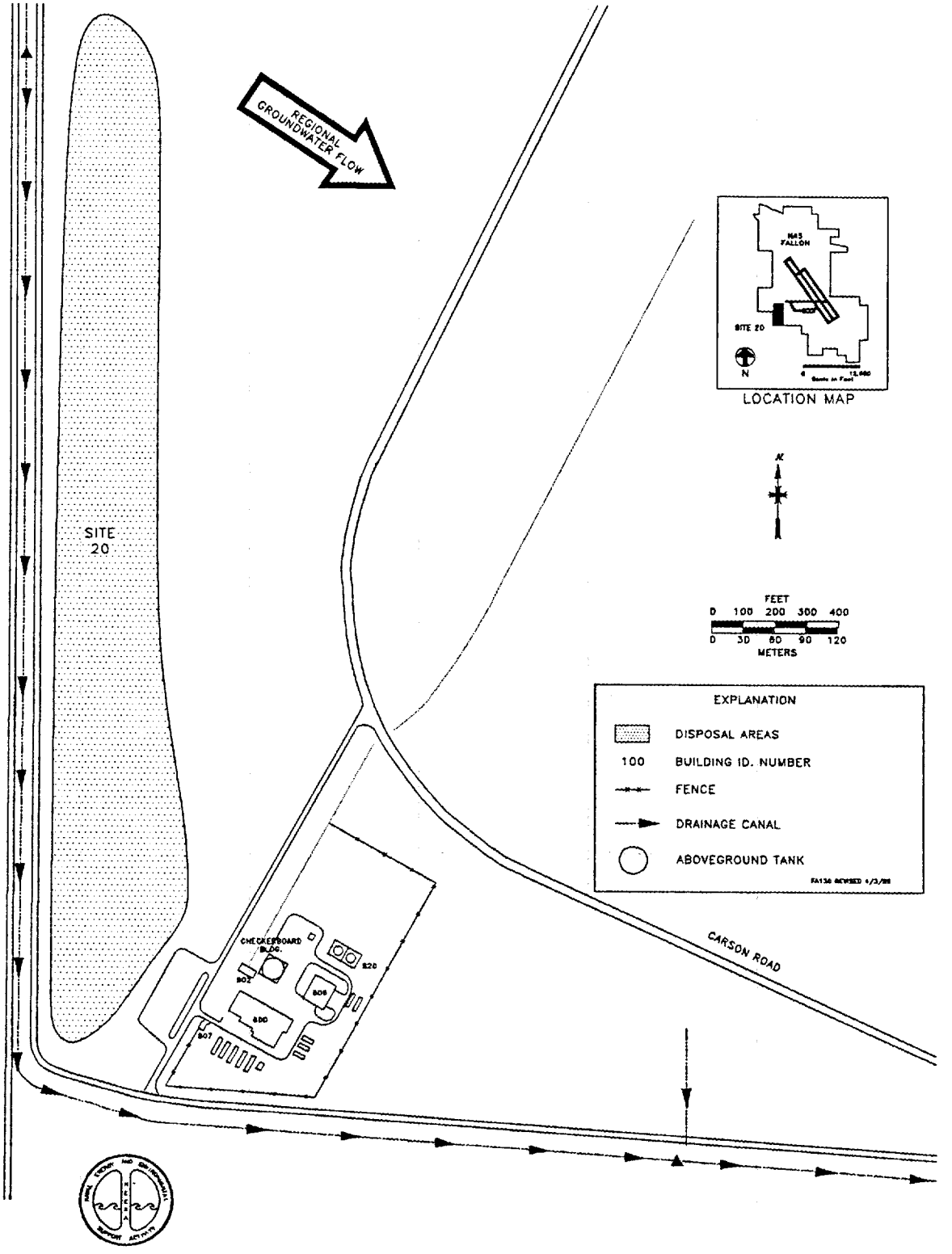


Fig. 2.3.1.i Site 20, Checkerboard Landfill.

2.3.2.1 Contaminated Media of Concern

No qualitative site-characterization analysis was conducted at Site 20 during the Phase I PA/SI investigation. Based on a visual inspection and records search, the Phase I study concluded that because disposal of liquid hydrocarbons and other hazardous materials (paint wastes and metals) was suspected (although not confirmed), soil and groundwater contamination in the area was likely (Dames and Moore 1988).

Preliminary field screening and site-characterization activities completed during the Phase II RI include the screening of thirty-six groundwater test holes and installing six monitoring wells (four single completion and one dual completion). Groundwater test hole and monitoring well locations are shown on Fig. 2.3.2.i. Initial groundwater samples have been submitted for laboratory analysis, but results are not yet available.

No contamination was detected (Appendix B, Table B.5) during screening of the groundwater test holes with the field gas chromatograph (GC). However, photoionization detector (PID) analysis of six groundwater test holes did reveal contamination of unknown type (Fig. 2.3.2.i). It is surmised that the detected contaminants must have a very short retention time in the GC column and were thus not detected during screening. The characteristics of the detected contaminant are consistent with those of methane gas which is commonly produced during the biodegradation of buried organic matter.

Site-characterization activities indicate the primary contaminants of concern at Site 20 are volatile organic compounds, possibly methane gas. Although not detected during site-characterization activities, other petroleum hydrocarbon-related wastes, metals, and paints may also be present. Contaminated media include the soils and shallow groundwater underlying the facility. The atmosphere is not considered to be a contaminated medium of concern because burial of the wastes effectively contains contaminants in the subsurface environment.

2.3.2.2 Exposure Pathways

Direct exposure to contaminated soils at Site 20 would first require removal of the overlying backfill. If contaminants are exposed through

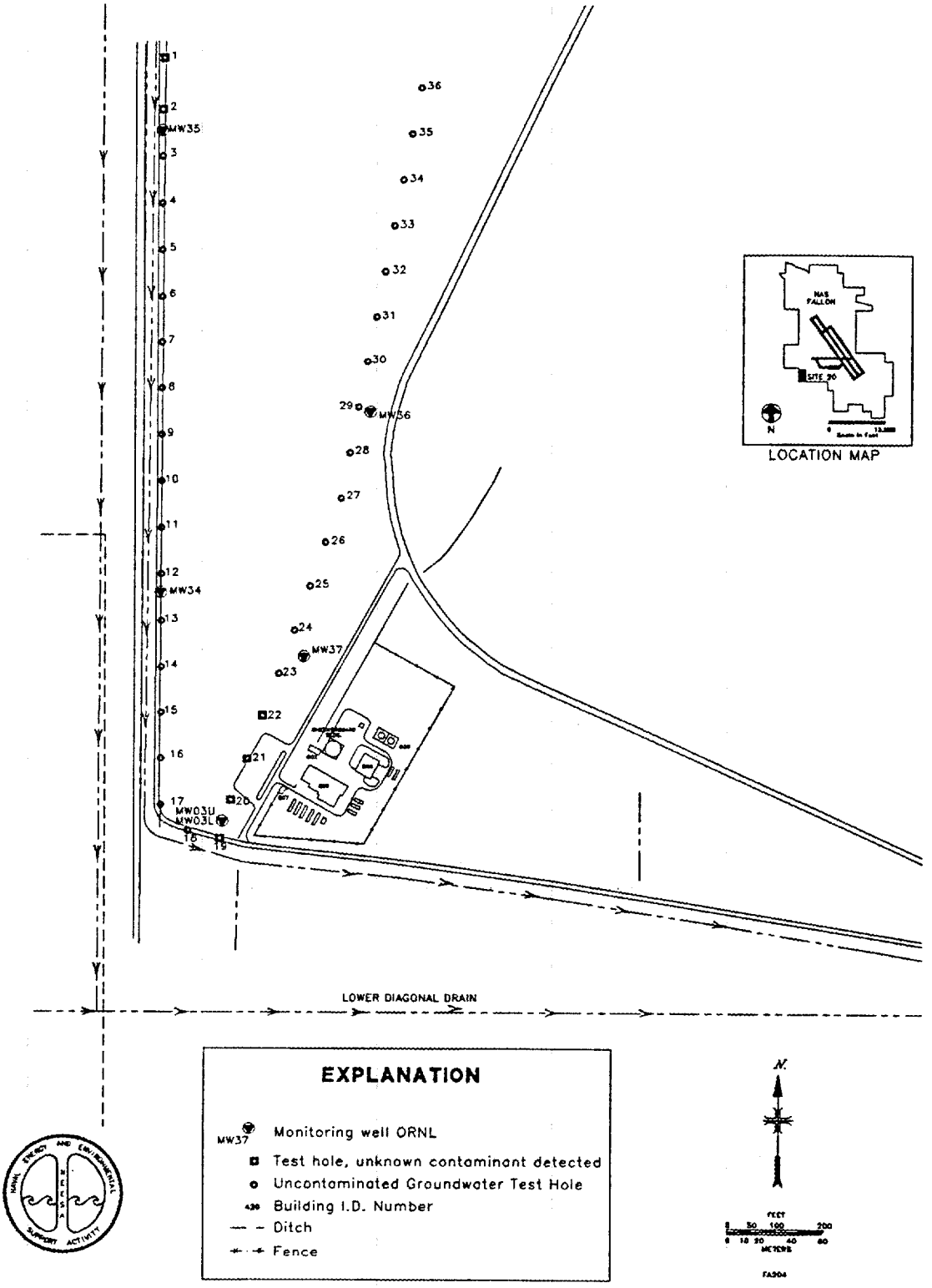


Fig. 2.3.2.i Site 20, Checkerboard Landfill. Groundwater test hole and analytical sampling locations.

excavation, exposure pathways for contaminated soils include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants (with root systems deep enough to penetrate the overlying backfill) and burrowing animals as well as personnel associated with site excavation activities. Because NAS Fallon is a restricted area, plant and animal populations at the site are controlled, and exposures associated with these biota are thus minimized. Direct exposure to the human populace is restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. Restricted access and site activities geared towards environmental safety thus prevent contaminated soils at Site 20 from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and, due to its high salinity, is not used for human consumption in the surrounding area (Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is unknown, its likely purpose in light of the poor water quality is to supply water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt drinking water aquifer. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in certain portions of the base. It is believed that these natural containment mechanisms prevent contaminants from reaching the regional domestic water source.

As with soils, contaminated groundwater associated with Site 20 does not constitute a substantial direct exposure pathway. Contaminated soils and groundwater may, however, act as a source for contaminating surface flows which could constitute an exposure pathway to sensitive receptors.

Surface flow runoff resulting from excessive precipitation or human activities offers little contaminant transport potential because contaminants are contained in a buried state. The semiarid climate of the region also minimizes the potential for percolation of residual soil contaminants into the underlying saturated zone. Indeed, the numerous alkali flats in the surrounding area indicate a negative water balance for the region which renders downward percolation unlikely.

Wastes deposited below the water table do, however, offer the potential of contributing dissolved contaminants to the surrounding groundwater. Contaminants associated with the shallow groundwater may then migrate downgradient for eventual seepage discharge into the surrounding drainage ditches.

Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off-site exposure points associated with surface flows include recreational exposure, direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

Seepage discharge of groundwater contaminants to off-site surface flow receptors is thus the primary exposure pathway for contaminants of concern at Site 20. The principal exposure pathway of concern is thus the regional surface flow system extending from the downgradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. As shown in Fig. 1.3.2.ii, the Lower Diagonal Drain located along the southern boundary of the base is the

SITE 20, CHECKERBOARD LANDFILL

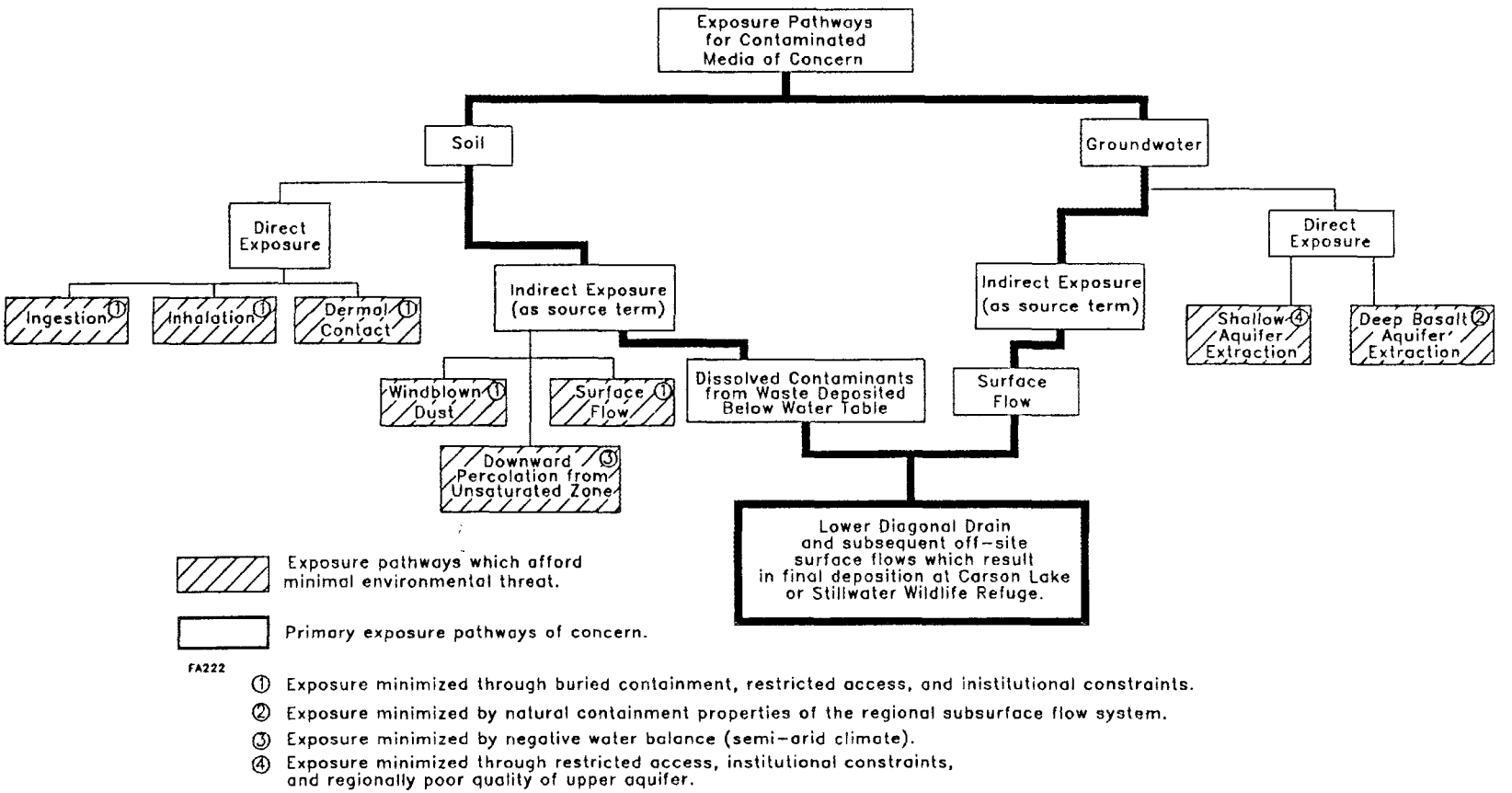


Fig. 2.3.2.ii Flow chart of exposure pathways associated with Site 20.

primary exposure pathway for seepage discharge of shallow groundwater contaminants from Site 20. Figure 2.3.2.ii is a flow chart which summarizes the above discussion and depicts the screening logic used in determining the primary exposure pathway of concern for contaminants at Site 20. As shown in the flow chart, the Lower Diagonal Drain and subsequent off-site surface flows into which it drains are the primary exposure pathways associated with contaminants at Site 20.

2.3.2.3 ARARs and Remedial Action Objectives

Site-characterization activities have not detected any significant contamination at Site 20. Six groundwater test holes in the study area indicate the presence of an unknown gaseous contaminant (possibly methane). For present purposes and until additional site characterization confirms the presence of other contaminants, ARARs will be taken as explosive limits of methane. The explosive limits for methane are (Sax and Lewis 1987),

LEL (lower explosive limit) - 5.5%,
UEL (upper explosive limit) - 15.0%.

Remedial action objectives will be to prevent generation of methane from producing an explosive hazard as determined by these limits.

2.3.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.3.3.i and 2.3.3.ii list the general response actions, technology types, and process options for Site 20 contaminated soils and groundwater respectively. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated above, and 2) the associated exposure pathways and affected receptors discussed in Sect. 2.3.2. The process options formulated in Tables 2.3.3.i and 2.3.3.ii will serve to form the remedial action alternatives for Site 20 as Phase II work progresses.

Table 2.3.3.i. Site 20, Checkerboard Landfill. General response actions, technology types, and process options for contaminated soils

Site 20, Checkerboard Landfill. General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal/grinding)	Grout injection, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (following removal/grinding)	Baking/thermal desorption, Incineration
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

Table 2.3.3.ii. Site 20, Checkerboard Landfill. General response actions, technology types, and process options for contaminated groundwater

Site 20, Checkerboard Landfill. General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to affected users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction

As shown in Table 2.3.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area. The mixed nature of the wastes deposited at the site limit the number of technology types available for containment and treatment. Bituminous concrete containment and thermal treatment will require grinding/mixing of the waste to a uniform constituency following removal. This grinding/mixing is required to assure that the containment or treatment technology is applied consistently over all the waste types in the landfill.

As shown in Table 2.3.3.ii, general response actions for contaminated groundwater also include institutional measures, containment, treatment, and removal. Listings for appropriate technology type and process options for each of the general response categories follow. As with soils, on-site restricted pumping is included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

2.4 SITE 24, ROAD OILING AREA

2.4.1 Site History

Site 24, Road Oiling Area, is shown in Fig. 2.4.1.i. Disposal activities at the site consisted of applying wastes to unpaved perimeter roads along the northern and eastern boundaries of NAS Fallon. Wastes disposed of included waste oils, hydraulic fluids, antifreeze, leaded gasoline, carbon tetrachloride, mogas, JP-4, JP-5, TCE, and TCA. These wastes were generated through general maintenance and aircraft maintenance activities where they were collected in large bowsers. Waste application consisted of dumping or spraying the accumulated wastes onto the perimeter road areas. It is estimated that as much as 140,060 L (37,000 gal) of liquid wastes were applied to the site in this manner between the years of 1946 and 1981. Since 1981, portions of the disposal area have been capped with paving.

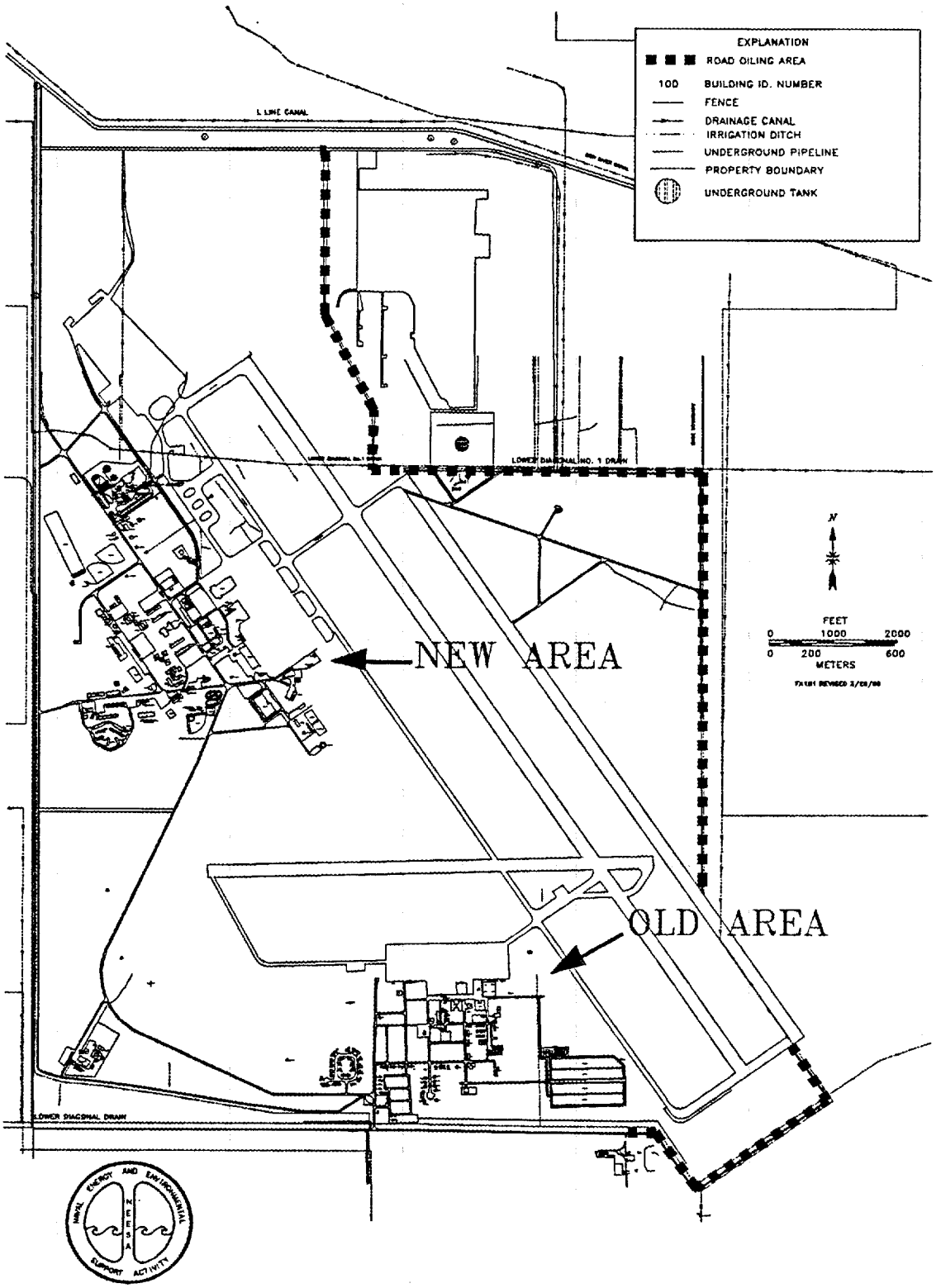


Fig. 2.4.1.i Site 24, Road Oiling Area.

2.4.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at Site 24.

2.4.2.1 Contaminated Media of Concern

No qualitative site-characterization analysis was conducted at Site 24 during the Phase I PA/SI investigation. Based on the amount of liquid wastes disposed of at the site, the Phase I study concluded that soil and groundwater contamination was likely (Dames and Moore 1988).

Phase II field screening activities at Site 24 consisted of a comprehensive groundwater test hole survey designed to encompass screening at the adjacent Group 2 Sites (Fig. 1.3.2.ii). Results of the groundwater test hole screening are given in Appendix B, Table B.8. Test hole locations are shown in Fig. 2.4.2.i which indicates that several of the seventy-nine test holes sampled were located in Site 24. No contamination associated with Site 24 was detected with the field GC during groundwater test hole screening.

Phase II site-characterization activities include five soil borings taken to the water table. Soil boring locations are shown in Fig. 2.4.2.ii. Results from laboratory analysis of soil samples so obtained are not yet available.

While site-characterization activities completed to date have not detected significant contamination at Site 24, the potential contaminants of concern include petroleum hydrocarbons, antifreeze, and solvents.

Contaminated media include the soils and shallow groundwater underlying the facility. The atmosphere is not considered to be a contaminated medium of concern because surface application of the wastes is conducive to rapid dispersal of any volatile constituents. Additionally, sufficient time has elapsed (waste disposal activities were terminated in 1981) for additional mitigation of shallow gas-phase contaminants through biodegradation.

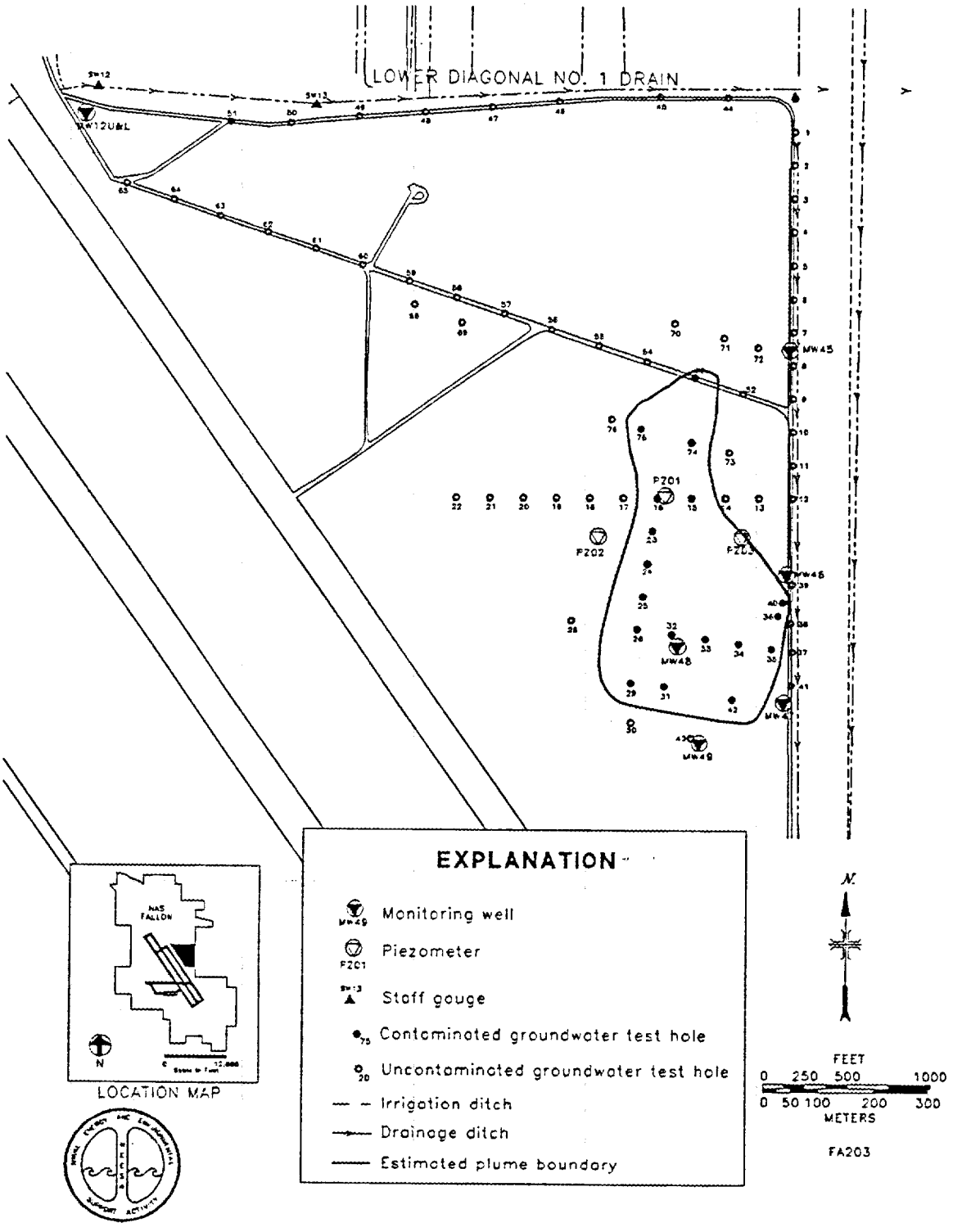


Fig. 2.4.2.i Site 24, Road Oiling Area. Groundwater test hole locations associated with Group II sites.

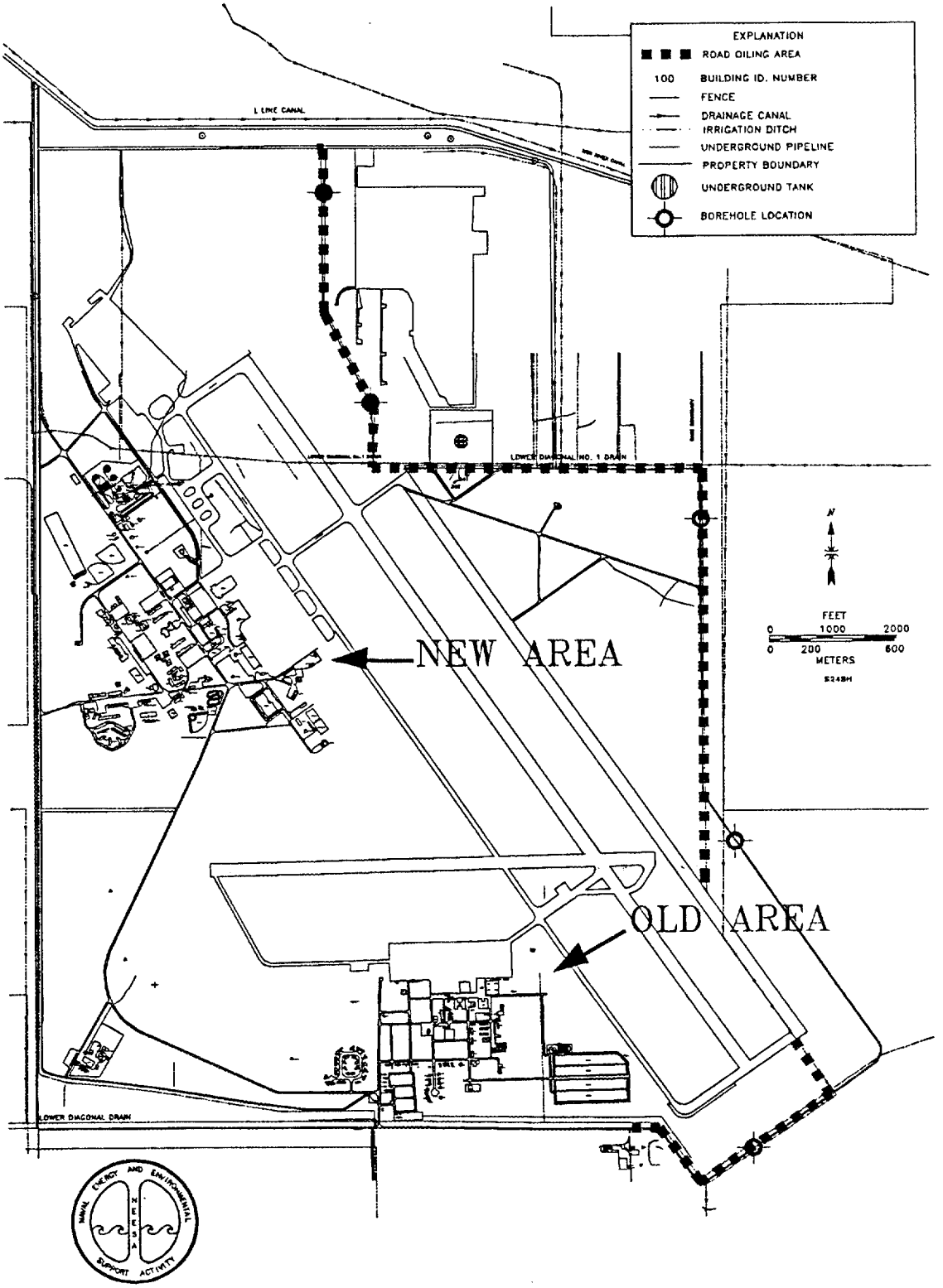


Fig. 2.4.2.ii Site 24, Road Oiling Area. Soil boring locations.

2.4.2.2 Exposure Pathways

Direct exposure pathways for contaminated soils at Site 24 include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants and burrowing animals as well as personnel associated with site excavation activities. The hardpacked, gravelly nature of the perimeter road surface is not well suited for plant or animal habitation, and exposures associated with these biota are thus minimized. Because NAS Fallon is a restricted area, direct exposure to the human populace is restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. The compacted road surface, restricted access, and site activities geared towards environmental safety thus prevent contaminated soils at Site 24 from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and, due to its high salinity, is not used for human consumption in the surrounding area (Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is unknown, its likely purpose in light of the poor water quality is to supply water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt drinking water aquifer. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in

certain portions of the base (ERM-West 1988). It is believed that these natural containment mechanisms prevent contaminants from reaching the regional domestic water source.

As with soils, contaminated groundwater associated with Site 24 does not constitute a substantial direct exposure pathway. Soils may, however, serve as a source term for atmospheric transport of contaminated particulate, and both contaminated soils and groundwater may act as a source for contaminating surface flows. Contaminated surface flow may then serve as an exposure pathway to sensitive receptors.

Exposures to wind-blown transport of contaminated soils are minimal due to restricted access in the immediate vicinity, the natural cohesive properties of native surface soils, and dust control measures employed during construction activities. In addition, the air quality of the region is good, and airborne particulate matter is quickly dispersed. Hence, atmospheric transport is not considered a threat to the environment.

Downward flushing of soils contamination to the underlying aquifer via surface water percolation is not considered significant because of the semi-arid climate. Indeed, the alkali flats in the surrounding area indicate a negative regional water balance. It is surmised that because contaminants were originally introduced at or near the ground surface, the downward transport of contaminants to the underlying groundwater would result from gradients introduced from excessive spills or dumping and not from the natural percolation process. Because wastes are no longer disposed of at the site, transport of contaminants to the upper aquifer via percolation is unlikely.

Surface flow runoff resulting from excessive precipitation or human activities may transport contaminated surface sediments or dissolved constituents to the regional surface drainage system. In addition, contaminants presently associated with the shallow groundwater (if any) may migrate downgradient for eventual seepage discharge into the surrounding drainage ditches. Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off-site exposure points associated with surface flows include recreational exposure,

direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

Ground- and surface-water transport to off-site receptors is thus the primary exposure pathway for contaminants of concern at Site 24. Potential off-site transport mechanisms include: 1) eventual seepage discharge of groundwater contaminants to surface flows migrating off site, and 2) discharge of contaminated surface flows (from rainfall and human activity) to surface water drainage systems. The principal exposure pathway of concern is thus the regional surface flow system extending from the downgradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

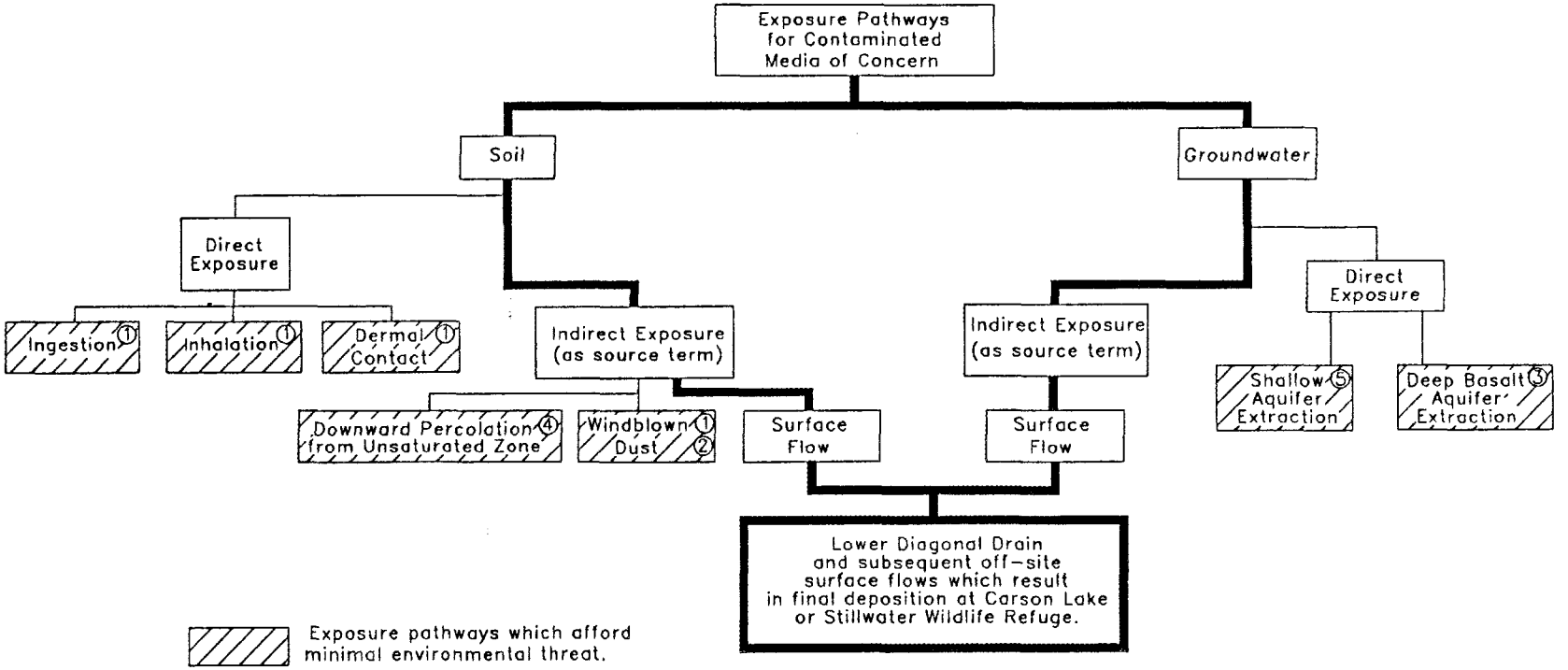
As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. As shown in Fig. 1.3.2.ii, the Lower Diagonal Drain located along the southern boundary of the base is the primary receptor point for groundwater or surface flow transport of contaminants from Site 24. Figure 2.4.2.iii is a flow chart which summarizes the above discussion and depicts the screening logic used in determining the primary exposure pathways of concern for contaminants associated with the site. As shown in the flow chart, the Lower Diagonal Drain and subsequent off-site surface flows into which it drains are the primary exposure pathways associated with contaminants at Site 24.

2.4.2.3 ARARs and Remedial Action Objectives

The State of Nevada Division of Environmental Protection Hydrocarbon Cleanup Policy (NDEP 1987) is given in Appendix D. Table 2.4.2.i lists media-specific remedial action objectives predicated on the ARARs given in Appendix D.

As stated in this NDEP Policy, remediation of petroleum-hydrocarbon-contaminated soils and groundwater may be required if action limit concentrations are exceeded. Action limit concentrations are set at 100 mg/kg total petroleum hydrocarbons (TPH) for soils and the EPA maximum contaminant levels (MCLs) or recommended maximum contaminant levels (RMCLs) for groundwater used

SITE 24, ROAD OILING AREA



Exposure pathways which afford minimal environmental threat.

Primary exposure pathways of concern.

FA228

① Exposure minimized through restricted access, compacted road surface, and institutional constraints.

② Exposure minimized by natural cohesive properties of native surface soils and good regional air quality.

③ Exposure minimized by natural containment properties of the regional subsurface flow system.

④ Exposure minimized by negative water balance (semi-arid climate).

⑤ Exposure minimized through restricted access, institutional constraints, and regionally poor quality of upper aquifer.

Fig. 2.4.2.iii Flow chart of exposure pathways associated with Site 24.

Table 2.4.2.i. Site 24, Road Oiling Area. Remedial action objectives

Remedial Action Objectives - Site 24			
Contaminated Media		Applicable or Relevant and Appropriate Requirements (ARARs)	Media-Specific Remedial Action Objectives
Soil		NDEP Hydrocarbon Cleanup Policy	Prevent exposures to soils contaminated in excess of 100 mg/kg TPH
Groundwater	Dissolved Product	NDEP Hydrocarbon Cleanup Policy	Prevent exposures to groundwater used as a potable source contaminated in excess of 5.0 μg/L for benzene, 700 μg/L for ethylbenzene, 10,000 μg/L for total xylene, and 2,000 μg/L for toluene. Prevent exposures to seepage discharge of groundwater contaminants into surface waters in excess of 1.0 mg/L TPH.
	Free Product	NDEP Hydrocarbon Cleanup Policy	Initiate active free-product removal operations when free-phase product exists on the groundwater in excess of 1.27 cm (0.5 in.)

TPH: total petroleum hydrocarbons

as a drinking water (potable) source. Relevant MCLs are 5.0 μg/L for benzene (established), 700 μg/L for ethylbenzene (proposed), 10,000 μg/L for total xylene (proposed), and 2,000 μg/L for toluene (proposed). If these action limits are exceeded, the need for remedial activity is then evaluated with respect to site-specific parameters such as use of the contaminated medium; contaminant transport potential; the degree, magnitude, and toxicity of contaminants; and economic cost/benefit considerations. Although contaminants of concern may indeed exceed action limits at Site 24, the need for active remediation must still be evaluated in light of the restricted access to NAS Fallon property and the lack of use of the upper aquifer.

While the existence of soil and groundwater contaminants in excess of action limits does not in itself mandate active remediation, the existence of free-phase product on the groundwater in excess of 1.27 cm (0.5 in.) does require the implementation of an active removal action (Appendix D).

2.4.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.4.3.i and 2.4.3.ii list the general response actions, technology types, and process options for contaminated soils and groundwater at Site 24. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated in Table 2.4.2.i, and 2) the associated exposure pathways and affected receptors discussed in Sect. 2.4.2. The process options formulated in the tables will serve to form the remedial action alternatives for Site 24 as Phase II work progresses.

As shown in Table 2.4.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area.

As shown in Table 2.4.3.ii, general response actions for contaminated groundwater also include institutional measures, containment, treatment, and

Table 2.4.3.i. Site 24, Road Oiling Area. General response actions, technology types, and process options for contaminated soils

Site 24, Road Oiling Area. General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal)	Grout injection, In situ vitrification, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (in situ and following removal)	RF thermal stripping, Soil baking/thermal desorption, Incineration
		Chemical treatment (following removal)	Neutralization/stabilization, Precipitation, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor, Landfarming, Composting
		Physical separation/extraction (following removal)	Soil flushing, Centrifuging, Steam stripping, soil venting, Ultrasonics
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

RF: radio frequency

Table 2.4.3.ii. Site 24, Road Oiling Area. General response actions, technology types, and process options for contaminated groundwater

Site 24, Road Oiling Area. General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Bio-clogging, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction
		Free product pumping (in situ)	Single recovery skimmer, Dual recovery system

removal. Technology type and appropriate process option listings follow for each of the general response categories. As with soils, on-site restricted pumping is included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

2.5 GROUP I SITES: SITE 2, NEW FUEL FARM; SITE 4, TRANSPORTATION YARD

2.5.1 Site History

The Group I Sites contain two adjacent areas of interest: Site 2, New Fuel Farm, and Site 4, Transportation Yard. As shown in Fig. 1.3.2.ii, the Group I Sites are located in the northwestern corner of NAS Fallon in the new area of the base. A discussion of the history of each site follows.

2.5.1.1 Site 2, New Fuel Farm

Site 2, New Fuel Farm, was reportedly constructed in 1957 to provide modern fuel delivery services for NAS Fallon. The New Fuel Farm was used in conjunction with the Old Fuel Farm (Site 16, Fig. 1.3.2.ii) until 1963 at which time the Old Fuel Farm was taken out of service. As shown in Fig. 2.5.1.i, Site 2 borders the Lower Diagonal No. 1 Drain to the south and lies to the northwest of Site 4, Transportation Yard. The New Fuel Farm's main operations consist of fueling and defueling aircraft and storing/dispensing other petroleum fuels routinely used on the base. Stored fuels include JP-5, avgas, diesel, and mogas. Jet fuel (JP-5) is supplied to the fuel farm via underground pipeline from Sparks, Nevada, while other stored fuels are delivered to the site by truck.

Approximately 12,113,280 L (3,200,000 gal) of JP-5 are stored in three underground (204 A, B, and C) storage tanks and two aboveground (355 and 255) storage tanks (Fig. 2.5.1.i). Two underground avgas storage tanks have a total capacity of 370,970 L (98,000 gal). Also stored at Site 2 are 60,566 L (16,000 gal) of diesel fuel and 45,425 L (12,000 gal) of mogas (ORNL 1991).

Over the lifetime of operations of the New Fuel Farm, numerous spills,

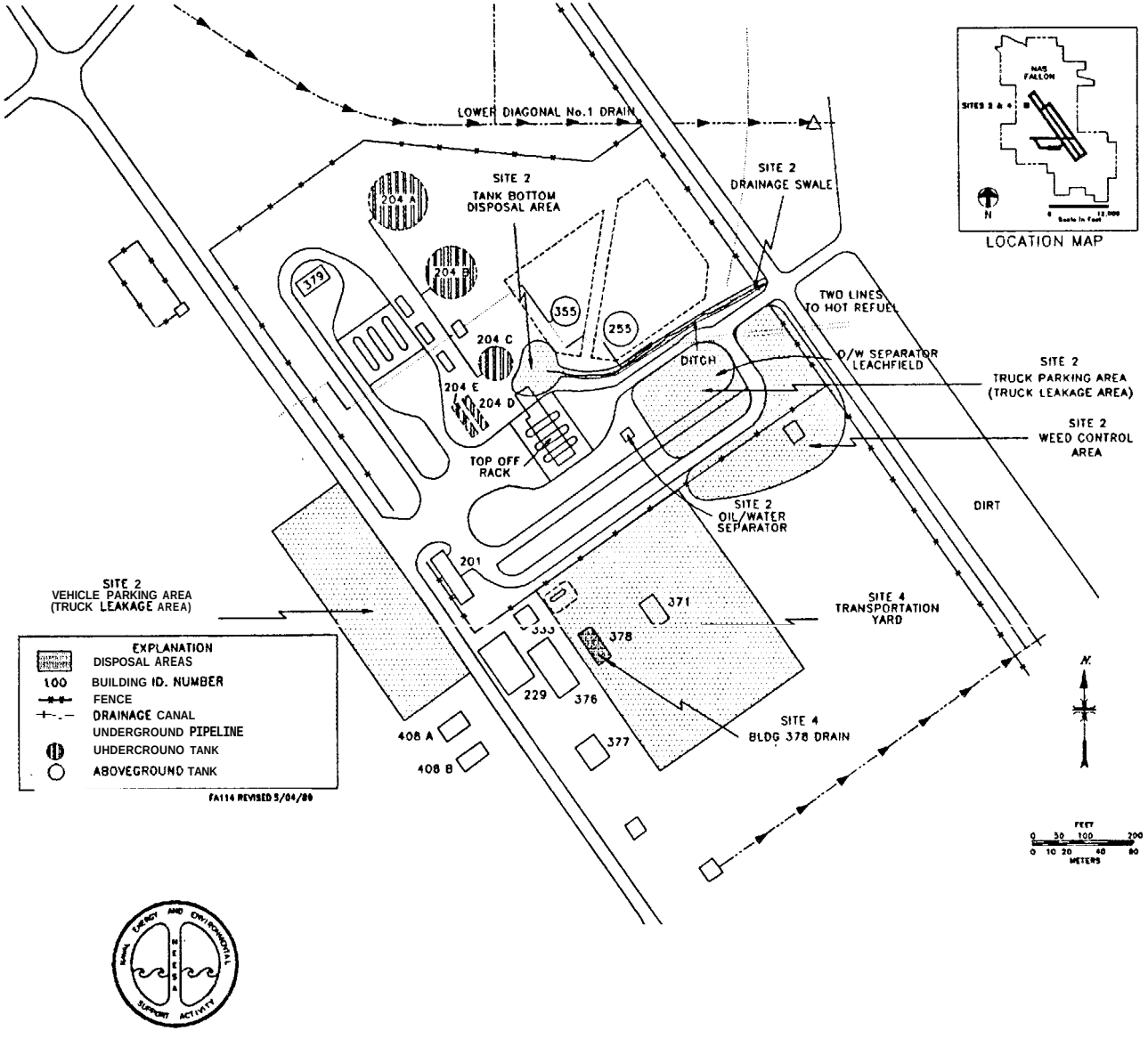


Fig. 2.5.1.i Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard.

leaks, and disposal/maintenance activities have resulted in introduction of petroleum hydrocarbons to the surface and shallow subsurface environments. Potentially contaminated areas (Fig 2.5.1.i) include the oil/water separator and associated leach field, the tank bottom disposal area, the weed control area, and the vehicle parking area (Dames and Moore 1988).

Periodic malfunctions of the oil/water separator system may have resulted in the discharge of as much as 9,464 L (2,500 gal) of petroleum hydrocarbon liquids to the oil/water separator leach field area. In addition, spills and daily draining of transport vehicles may have resulted in an additional 68,137 L (18,000 gal) of fuel being discharged to the leach field area.

The tank bottom disposal area (Fig 2.5.1.i) consists of an unpaved swale onto which tank bottom liquids (sludge consisting primarily of water periodically cleaned from the storage tanks) were applied between the years of 1957 and 1981. In 1981 the disposal practice was stopped when a filter system was installed to remove water and other impurities from the fuels. Approximately 227,124 L (60,000 gal) of waste may have been applied to the tank bottom disposal area during its lifetime of operation.

The weed control area (Fig. 2.5.1.i) is a flat, unpaved area where small amounts of waste fuels were applied to the soils for purposes of weed control. Approximately 1,893 L (500 gal) of liquid wastes may have been applied to the weed control area between the years of 1957 and 1981.

The vehicle parking area is located to the southwest of the New Fuel Farm Building (Bldg. 201, Fig. 2.5.1.i). It is reported that fuel trucks were allowed to leak fuel in this area between the years of 1957 and 1987. It is estimated that as much as 9,460 L (2,500 gal) of different fuels may have been introduced to the soils during this time period.

2.5.1.2 Site 4, Transportation Yard

Site 4, Transportation Yard, is located directly southeast of Site 2, New Fuel Farm (Fig. 2.5.1.i). The Transportation Yard is believed to have been constructed in 1971 and serves to store and maintain vehicles used by Public Works. The Building 378 floor drain and the outdoor vehicle maintenance yard (Fig. 2.5.1.i) are the contaminated areas of concern associated with Site 4.

Building 378 was used from 1976 to 1981 for painting and light overhaul

operations. The building has a cement floor and associated floor drain which reportedly was used to flush wastes into the subsoils beneath the building. It is not known if the drain system includes a grease trap and/or leach field. Wastes disposed of through the Building 378 drain include radiator coolants, vehicle fluids, and paint wastes. It is estimated that a total of 190 L (50 gal) of waste liquids may have been disposed of through the Building 378 floor drain (Dames and Moore 1988).

The outdoor vehicle maintenance yard surrounds Building 378 (Fig. 2.5.1.i). Spills or leaks of vehicle waste fluids between 1971 and 1986 may have resulted in the contamination of the area's soils. Potential contaminant waste fluids include waste oils, hydraulic fluids, transmission and gear oils, gasoline, and diesel fuel. As much as 1,514 L (400 gal) of liquid wastes could have been introduced to the outdoor vehicle maintenance yard (Dames and Moore 1988).

2.5.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at the Group I Sites.

2.5.2.1 Contaminated Media of Concern

Past activities at the Group I Sites, specifically Site 2, have resulted in public concern and several legal actions against NAS Fallon regarding environmental contamination issues. Numerous environmental investigations have been initiated to address these issues. Results from these investigations are discussed in the following paragraphs.

On August 26, 1986, the discovery of fuel floating on the water table underlying Site 2 prompted the NDEP to issue a *Finding of Alleged Violation and Order to Comply* to NAS Fallon (ORNL 1989). The order was prompted by the observation of floating product in excavations made within the fuel farm

compound. The *Order to Comply* required NAS Fallon to inform NDEP of the extent and magnitude of contamination underlying the site and implement a plan to clean up the area, subject to approval of the NDEP. ERM-West, a private consulting firm, was hired to investigate contaminants and evaluate a remedial plan (ORNL 1991). Recovery wells were installed, and in 1987 recovery of free product from these wells was initiated. By June 1987 fourteen wells were in place, and thirteen of these wells contained from 5.08 cm (2 in.) to 43.18 cm (17 in.) of free product (Dames and Moore 1988). The product recovery effort was discontinued when Phase II of the base-wide Site Program began in September 1988. The rationale for discontinuing recovery was that remediation would be implemented through the Site Program as interim protective measures (ORNL 1991).

Additional legal actions occurred in March 1989 when the NDEP notified NAS Fallon of an apparent malfunction of the oil/water separator. The notice resulted in the base discontinuing use of the oil/water separator (ORNL 1991). In February 1990 another NDEP action involved the investigation of an alleged fuel spill in January/February 1988 (ORNL 1991). The investigation concluded that a release of JP-5 jet fuel did occur on February 22, 1988, and recommended further investigation into the scope of subsurface contamination (NDEP 1990).

The Phase I PA/SI initiated shallow soil sampling efforts to address contamination of the tank bottom disposal area and the vehicle parking area (Fig. 2.5.1.i). Soil samples were submitted for laboratory analysis of TPH by EPA method 418.1. Results indicate significant petroleum hydrocarbons contamination (260 ppm and 4200 ppm) in the tank bottom disposal area and minimal contamination (< 54 ppm) in the vehicle parking area (Dames and Moore 1988).

Phase II field screening activities completed at the Group I Sites include a geophysical survey, a soil-gas survey, and field screening of ninety shallow boreholes. Field screening results were used to locate installation points for ten groundwater monitoring wells. Laboratory analysis of groundwater samples and soil samples taken from the monitoring wells have provided quantitative information concerning the magnitude and extent of contamination underlying the area. Phase II site-characterization results have facilitated preparation of a Site-Characterization Summary and Engineering Evaluation/Cost

Analysis which addresses the design of a free-product removal system for Site 2 (ORNL 1991). As Phase II work progresses, remediation achieved through interim free-product removal will be incorporated into the base-wide feasibility study. The following paragraphs discuss results from Phase II field screening and site- characterization activities at the Group I Sites.

The geophysical and soil-gas screening surveys were conducted in August and September of 1989. Soil-gas samples were taken at a depth of approximately 1.65 m (5.5 ft). A Photovac 10S50 gas chromatograph (GC) was used to screen soil-gas samples for the presence of contaminants. In general, soil-gas samples were taken on a grid system proceeding outward from areas of known contamination to areas where sample results were at the detection limits of the GC. Soil-gas sample locations and results are shown in Fig. 2.5.2.i. Results from the soil-gas survey were inconclusive. The contaminant plume was not continuous and appeared to contain sporadic areas where soil-gas samples contained no detectable contaminants. These findings may result from varying hydrogeologic conditions and relatively impermeable clay lenses compromising the efficiency of the test method. Soil-gas results were thus viewed in a qualitative sense only. These results confirmed the potential source areas of jet fuel contamination as: 1) the faulty oil/water separator, 2) runoff spills from the asphalt parking area, and 3) the tank bottom sludge disposal area east of underground tank 204C (Fig. 2.5.1.i).

The geophysical survey employed a Geonics EM-31 electromagnetometer (EM) coupled with an ultrasonic ranging and data collection system (USRADS). Results from the EM screening survey are given in Appendix A. Potential sources of fresh water recharge and/or contamination were identified as the oil/water separator leach field, a leaky water hydrant near the fuel truck topoff rack, and ponding runoff from rainfall.

During late May, June, and July 1990, a borehole screening survey was conducted at the Group I Sites. The survey consisted of screening ninety shallow boreholes ranging from 4 to 6 m (13 to 20 ft) in depth. Sample locations for groundwater screening are shown in Fig. 2.5.2.ii. Results from the borehole screening survey are given in Appendix B, Table B.10. As shown in Fig. 2.5.2.ii, four areas of contamination were delineated: 1) the area east of underground tank 204A, 2) the area between the pumping station and the

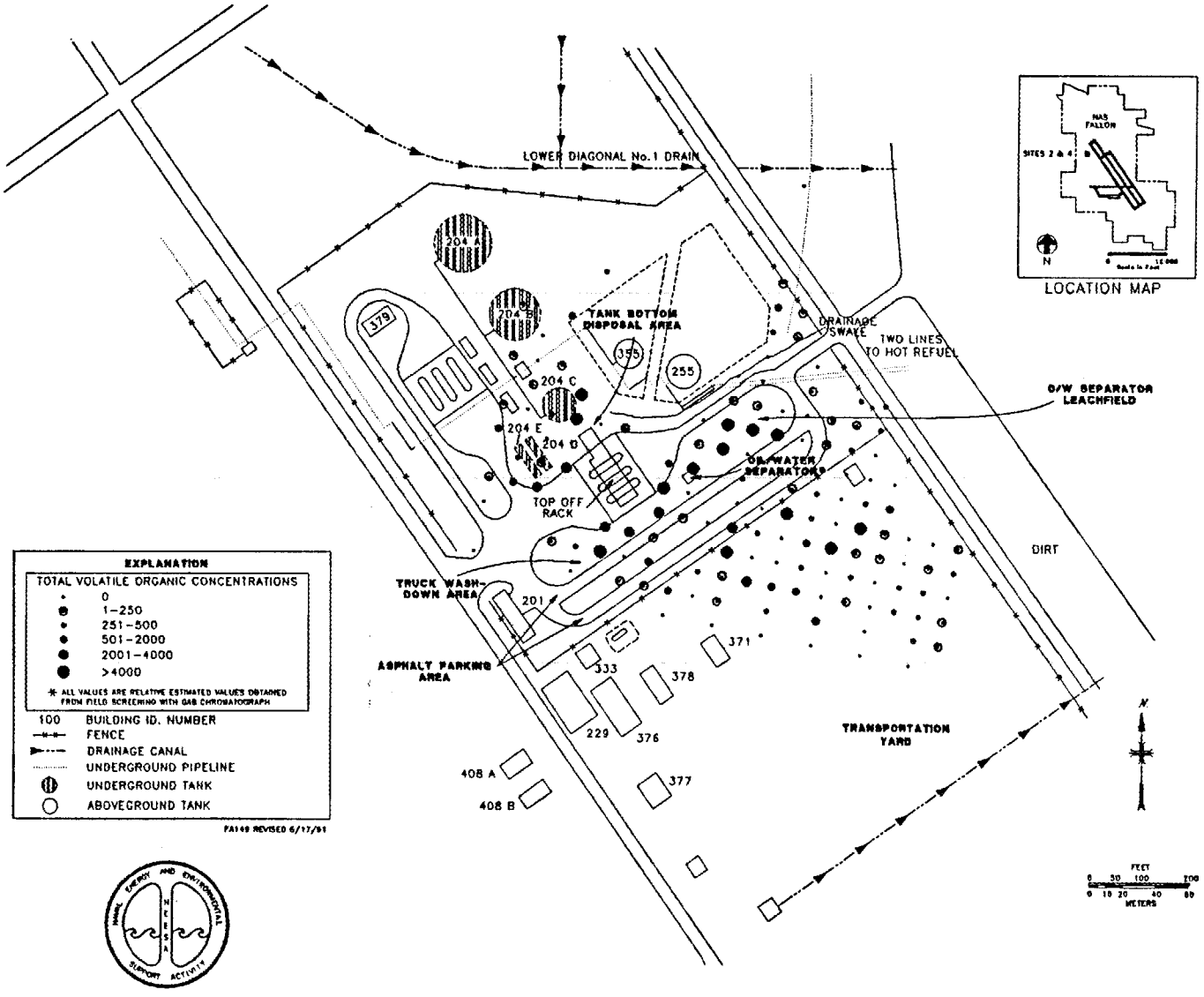


Fig. 2.5.2.i Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Soil-gas total volatile organic concentrations.

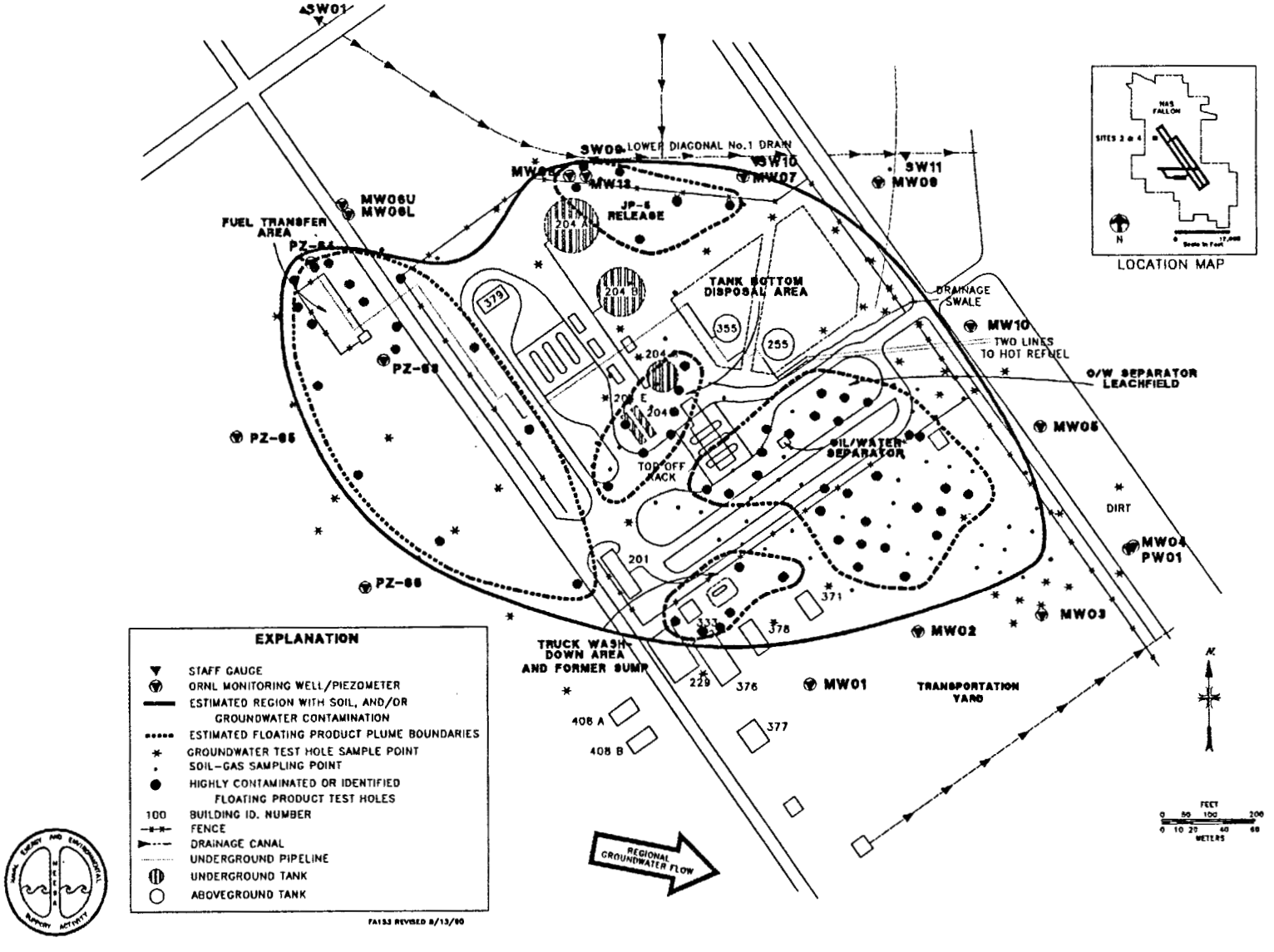


Fig. 2.5.2.ii Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Groundwater test hole locations.

fuel farm, 3) the area near a former sump used for collecting fuel from leaking tanker trucks at the fuel farm, and 4) the oil/water separator and associated leach field area.

Phase II site-characterization work also included installing ten 5 cm-(2 in.)diameter monitoring wells and one pumping well in and around the Group I Sites (Fig. 2.5.2.iii). Monitoring well MW06 was installed as a dual completion, "clean" upgradient well. Wells MW07 (single completion), MW08 (dual completion), and MW09 (single completion) were installed between the fuel facility and the Lower Diagonal No. 1 Drain. After purging, the upper completion of MW08 failed to recharge and was replaced with MW13. The remaining six wells were installed downgradient along the southern and eastern site boundaries. MW03 and MW05 are dual completions, and the other four wells are single completions. A 13 cm-(5 in.)diameter pumping well, PW01, was installed as an offset to MW04. The pumping well was used to determine hydrological parameters of the underlying aquifer.

Well placement resulted in collecting both soil samples and two rounds of groundwater samples. Soil samples were taken continuously with a split spoon or a California sampler during well installation. Sampling methodologies are described in the Phase II Remedial Investigation/Feasibility Study Work Plan (ORNL 1989). Additional sampling activities consisted of taking several surface soil samples, as well as sediment samples from the Lower Diagonal No.1 Drain (Fig. 2.5.2.iii). Groundwater samples from four existing wells installed during the ERM-West investigation (Fig. 2.5.2.iv) were also taken. Groundwater and soil sampling results are given in Tables 2.5.2.i, ii, iii, and iv.

The metals and anion analyses of groundwater samples indicate naturally high total dissolved solids (TDS) occurring in the upper aquifer of the region. These dissolved solids have rendered the groundwater in parts of the Carson Desert unfit for domestic use (Appendix C). Activities conducted at Site 2 have limited (if any) potential to introduce these contaminants into the environment, and their presence is apparently not a result of NAS Fallon activities (ORNL 1991).

The Phase II RI activities combined with results from previous investigations provide a comprehensive data base for characterization of contaminants underlying the New Fuel Farm. Table 2.5.2.v summarizes the environmental sampling completed at Site 2. The type of sample and party responsible

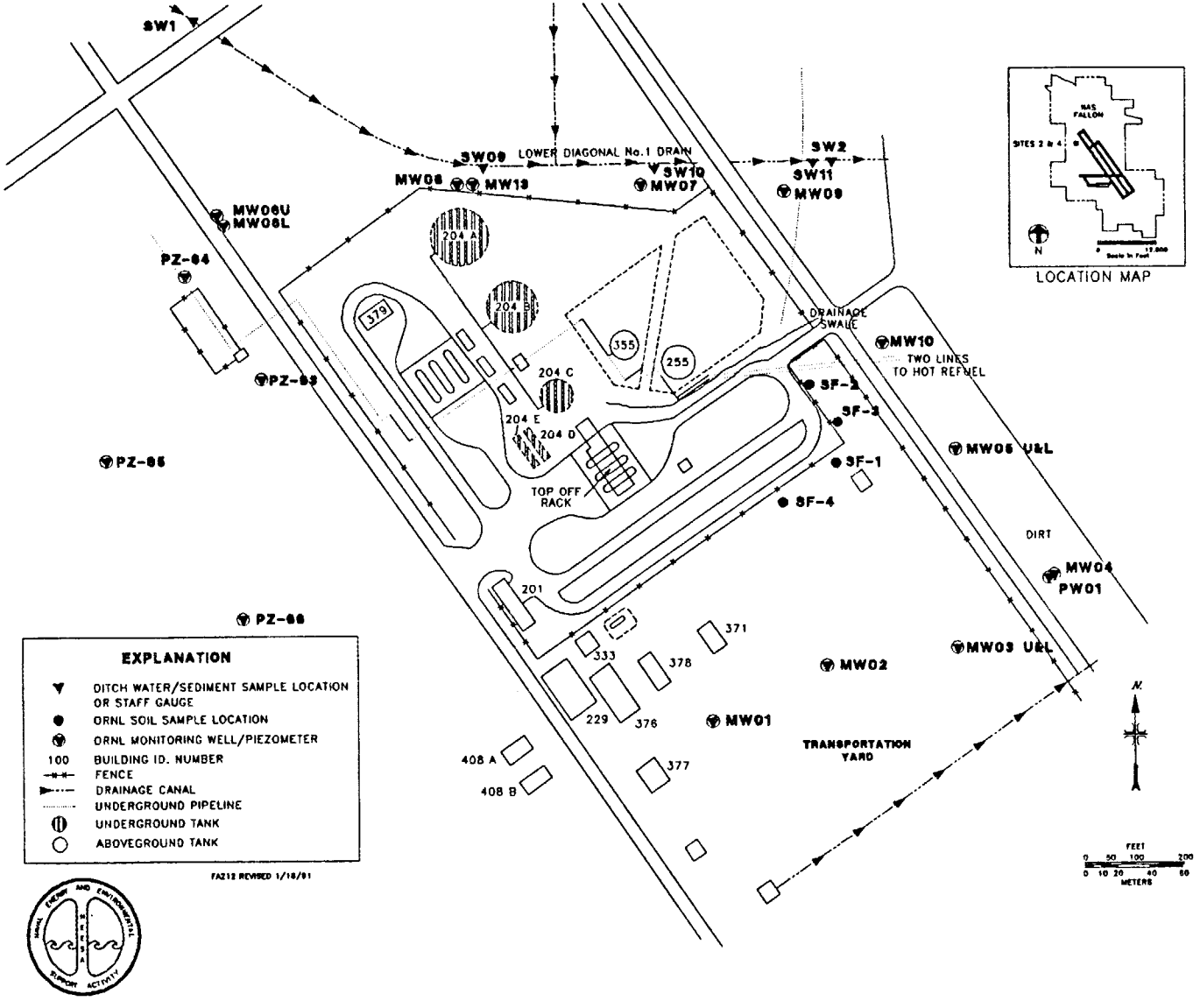


Fig. 2.5.2.iii Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. ORNL wells, piezometers, and soil sample locations.

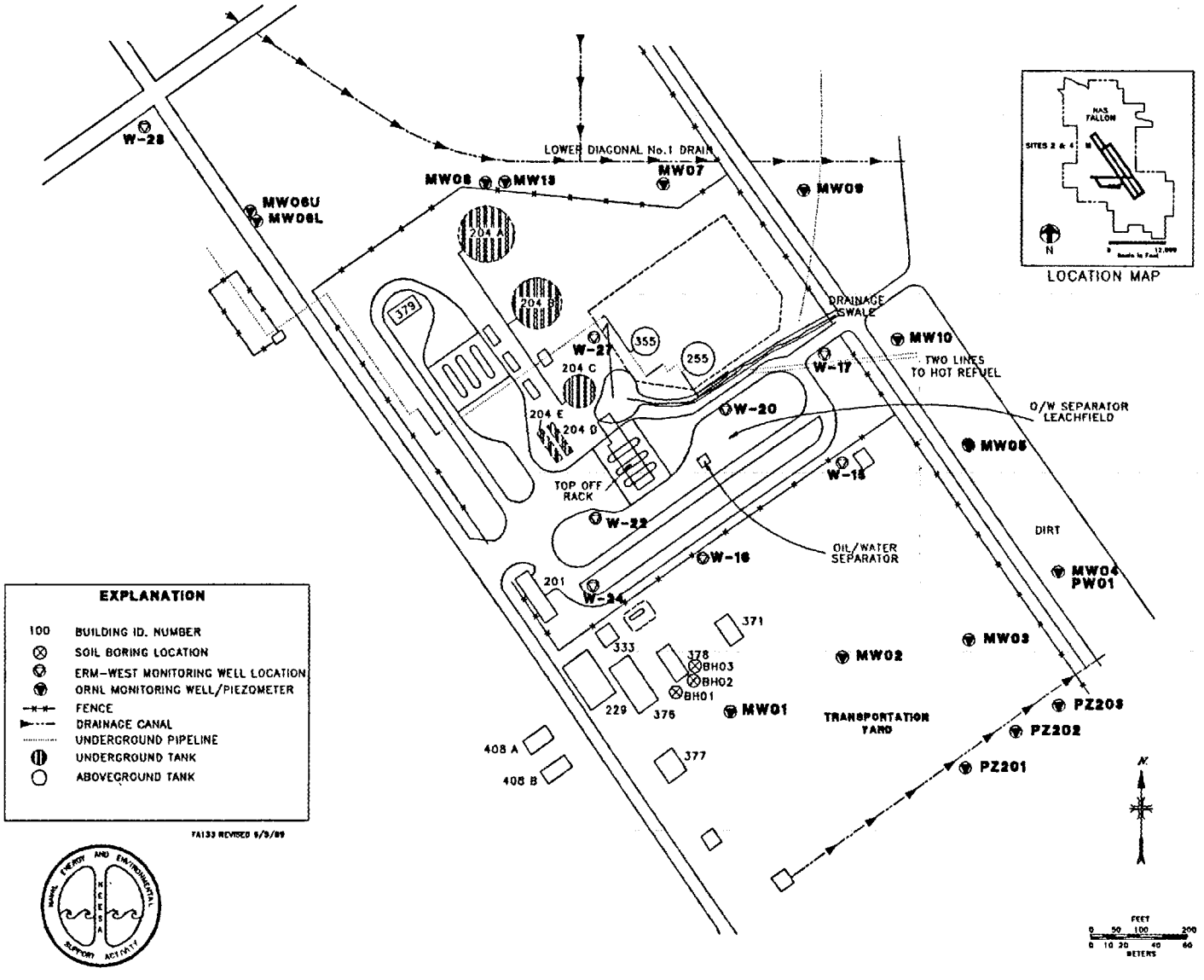


Fig. 2.5.2.iv Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. ERM-West and ORNL monitoring well location map.

Table 2.5.2.i. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Anion analysis, groundwater - ORNL/GJ investigation

SUMMARY ANION ANALYSIS	
Fluoride -	generally undetected or just above detection limit of 5 mg/L.
Chloride -	ranging from 32-2400 mg/L in the upper aquifer. Mostly over 1000 mg/L in wells not influenced by fresh water recharge.
Sulfate -	ranging from 120 to 3900 mg/L in the upper aquifer. Mostly over 1000 mg/L where no fresh water recharge is influencing water quality.
Nitrate -	generally undetected or just above detection limit of 2.5 mg/L.
Phosphate -	undetected.

Table 2.5.2.ii. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Water analysis, July 1990 - ORNL/GJ investigation

WATER ANALYSIS µg/L			
Well Number	ORNL/GJ RI/FS, Results from First Round of Sampling		
	Volatile organic compounds Method 624 det. limit 5 µg/L	Total petroleum hydrocarbons Method 418.1 det. limit 1000 µg/L	Base/neutral acid extractables Method 625 det. limit 10 µg/L
MW04	ND	ND	ND
MW05L	ND	ND	ND
MW10	ND	2000	ND
MW09	ND	ND	ND
MW05U	ND	ND	ND
MW06L	ND	ND	ND
MW01	ND	ND	ND
MW02	ND	ND	ND
MW06U	ND	ND	ND
MW03L	ND	ND	ND
MW03U	ND	ND	ND
ERM17	ND	ND	ND
ERM16	ND	ND	120*
ERM22	ND	ND	ND
ERM22	ND	ND	ND
ERM27	ND	ND	ND
ERM27	ND	ND	ND
MW07	ND	Broken	ND
MW08	ND	ND	170 diethyl-tetrahydrofuran
MW07RE	Not done	3000	Not done
MW13	7 (ethylbenzene)	ND	9 (bromocyclohexanol)
MW13	23 (xylenes)	Not done	Not done

Note: Wells listed more than once indicate the analysis of multiple samples.
ND: Not detected
* 120 µg/L bis(2-ethylhexyl) phthalate also found in blank at 10% of sample concentration.

Table 2.5.2.iii. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Water analysis, November 1990 - ORNL/GJ investigation

WATER ANALYSIS μg/L			
Well Number	ORNL/GJ RI/FS, Results from Second Round of Sampling		
	Volatile organic compounds Method 624 det. limit 5 μg/L	Low boiling point petroleum hydrocarbons Method 8015 modified det. limit 50 μg/L	High boiling point petroleum hydrocarbons Method 8015 modified det. limit 50 μg/L
MW04	ND	ND	ND
MW05L	ND	total: 84 toluene: 1 (dl:1) xylenes: 6 (dl:4)	ND
MW10	ND	ND	ND
MW09	ND	ND	ND
MW05U	ND	ND	ND
MW06L	ND	ND	ND
MW01	ND	ND	ND
MW02	ND	ND	ND
MW06U	ND	ND	ND
MW06U	ND	ND	ND
MW03L	ND	total: 140	ND
MW03U	ND	ND	ND
ERM17	ND	ND	ND
ERM16	ND	ND	ND
ERM22	ND	ND	ND
ERM27	ND	ND	ND
MW07	ND	ND	ND
MW07	ND	ND	ND
MW08	ND	ND	ND
MW13	3 TIC	total: 110 benzene: 0.9 (dl:0.5)	ND

Note: Wells listed more than once indicate the analysis of multiple samples.
ND: Not detected
dl: Detection limit
TIC: Tentatively identified compounds

Table 2.5.2.iv. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Soil analysis - ORNL/GJ investigation

SOIL ANALYSIS - ORNL/GJ RI/FS µg/kg unless noted				
Sample Location	Depth, ft	Analysis		
		VOC	TPH, mg/kg	BNA, µg/kg
MW02	6.5-7.0	ND	ND	ND
MW04	8.5-9.0	ND	17	1600 bis(2-ethylhexyl) phthalate
MW05	6.5-7.0	ND	17	3900 bis(2-ethylhexyl) phthalate
MW05	8.5-9.0	ND	16	800 bis(2-ethylhexyl) phthalate
MW06	6.5-7.0	ND	13	ND
MW08	6.5-7.0	ND	16	ND
MW09	6.5-7.0	ND	ND	ND
SF1	0.0-1.0	ND	40	ND
SF1	3.0-4.0	ND	15	ND
SF2	0.0-1.0	ND	140	ND
SF2	3.0-4.0	ND	2	ND
SF3	0.0-1.0	ND	43	ND
SF4	0.0-1.0	ND	4	ND
SW1	sediment	ND	7	ND
SW2	sediment	ND	11	ND

VOC: Volatile organic compounds (Method 624, detection limit: 10 µg/kg).
TPH: Total petroleum hydrocarbons (Method 418.1, detection limit: 10 mg/kg).
BNA: Base neutral/acid extractable semivolatile organics (Method 625, detection limit: 330 µg/kg).

Source: ORNL/GJ laboratory data from field investigation.

Table 2.5.2.v. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Summary of environmental sampling

ENVIRONMENTAL SAMPLING SUMMARY		
Responsible Party	Assessment Method	Number of Sample Locations
ORNL/GJ	Soil gas	140
	Soil borings	4
	Groundwater test holes	97
	Groundwater wells	15
	Piezometers	4
	Staff gauges	3
ERM-West	Soil gas	85
	Soil borings	5
	Groundwater wells	8

Note: Multiple samples often collected at each sample location.

for each sample are also listed.

The contaminated media of concern at the Group I Sites include the soils and shallow groundwater underlying the area. The atmosphere is not considered to be a contaminated medium of concern because volatile constituents introduced into the shallow subsurface will rapidly degas. The air quality of the surrounding region is good, and prevailing air currents will rapidly disperse any volatile contaminants rendering them innocuous to the environment.

2.5.2.2 Exposure Pathways

Direct exposure pathways for contaminated soils at Group I Sites include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants and burrowing animals as well as personnel associated with site excavation activities. Plant and animal populations are controlled on NAS Fallon property, and exposures associated with these biota are thus minimized. Because NAS Fallon is a restricted area, direct exposure to the human populace is restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. Restricted access and site activities geared towards environmental safety thus prevent contaminated soils at the Group I Sites from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and, due to its high salinity, is not used for human consumption in the surrounding area (Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is

unknown, its likely purpose in light of the poor water quality is to supply water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt drinking water aquifer. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in certain portions of the base (ERM-West 1988). It is believed that these natural containment mechanisms prevent contaminants from reaching the regional domestic water source.

As with soils, contaminated groundwater associated with Group I Sites does not constitute a substantial direct exposure pathway. Soils may, however, serve as a source term for atmospheric transport of contaminated particulate, and both contaminated soils and groundwater may act as a source for contaminating surface flows. Contaminated surface flow may then serve as an exposure pathway to sensitive receptors.

Exposures to wind-blown transport of contaminated soils are minimal due to restricted access in the immediate vicinity, the natural cohesive properties of native surface soils, and dust control measures employed during construction activities. In addition, the air quality of the region is good, and airborne particulate matter is quickly dispersed. Hence, atmospheric transport is not considered a threat to the environment.

Downward transport of residual soils contamination to the underlying aquifer via surface water percolation is not considered significant because of the semiarid climate. Indeed, the alkali flats in the surrounding area indicate a negative regional water balance. It is surmised that because contaminants were originally introduced at or near the ground surface, the downward transport necessary to produce existing groundwater contamination resulted from gradients introduced from excessive spills or dumping and not from the natural percolation process.

Surface flow runoff resulting from excessive precipitation or human activities may transport contaminated surface sediments or dissolved constituents to the regional surface drainage system. In addition,

contaminants presently associated with the shallow groundwater may migrate downgradient for eventual seepage discharge into the surrounding drainage ditches. Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off-site exposure points associated with surface flows include recreational exposure, direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

Ground- and surface-water transport to off-site receptors is thus the primary exposure pathway for contaminants of concern at the Group I Sites. Potential off-site transport mechanisms include: 1) eventual seepage discharge of groundwater contaminants to surface flows migrating off site, and 2) discharge of contaminated surface flows (from rainfall and human activity) to surface water drainage systems. The principal exposure pathway of concern is thus the regional surface flow system extending from the downgradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. As shown in Fig. 1.3.2.ii, the Lower Diagonal No. 1 Drain located along the northern boundary of the base is the primary receptor point for groundwater or surface flow transport of contaminants from the Group I Sites. Figure 2.5.2.v is a flow chart which summarizes the above discussion and depicts the screening logic used in determining the exposure pathways of concern. As shown in the flow chart, the Lower Diagonal No. 1 Drain and subsequent off-site surface flows into which it drains are the primary exposure pathways associated with contaminants at the Group I Sites.

GROUP I SITES: SITE 2, NEW FUEL FARM;
SITE 4, TRANSPORTATION YARD

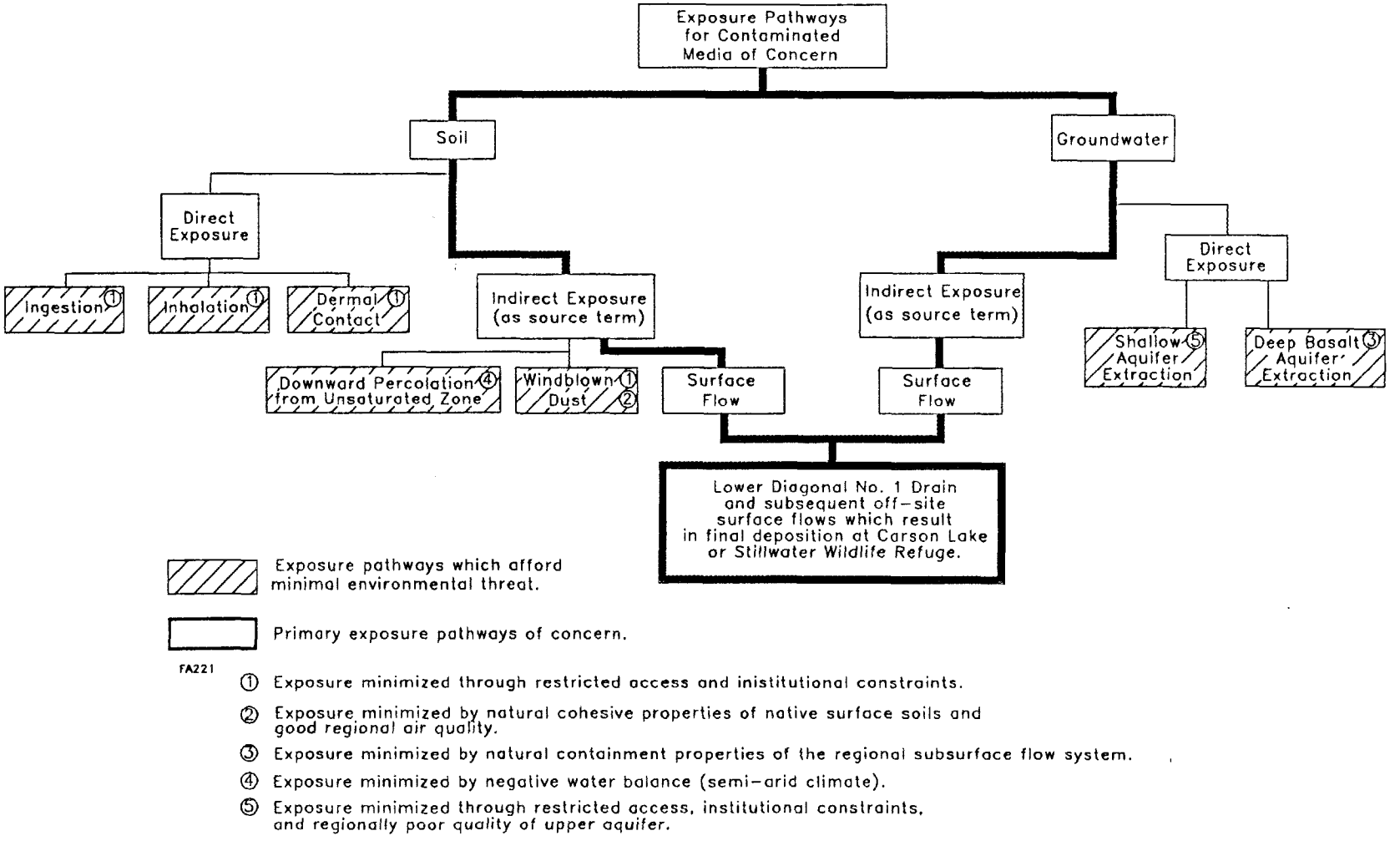


Fig. 2.5.2.v Flow chart showing exposure pathways of concern associated with Group I sites.

2.5.2.3 ARARs and Remedial Action Objectives

The State of Nevada Division of Environmental Protection Hydrocarbon Cleanup Policy (NDEP 1987) is given in Appendix D. Table 2.5.2.vi lists media-specific remedial action objectives predicated on the ARARs given in Appendix D.

As stated in this NDEP Policy, remediation of petroleum-hydrocarbon-contaminated soils and groundwater may be required if action limit concentrations are exceeded. Action limit concentrations are set at 100 mg/kg total petroleum hydrocarbons (TPH) for soils and the EPA maximum contaminant levels (MCLs) or recommended maximum contaminant levels (RMCLs) for groundwater used as a drinking water (potable) source. Relevant MCLs are 5.0 μg/L for benzene (established), 700 μg/L for ethylbenzene (proposed), 10,000 μg/L for total xylene (proposed), and 2,000 μg/L for toluene (proposed). If these action limits are exceeded, the need for remedial activity is then evaluated with respect to site-specific parameters such as use of the contaminated medium; contaminant transport potential; the degree, magnitude, and toxicity of contaminants; and economic cost/benefit considerations. Although contaminants of concern may indeed exceed action limits at the Group I Sites, the need for active remediation must still be evaluated in light of the restricted access to NAS Fallon property and the lack of use of the upper aquifer.

While the existence of soil and groundwater contaminants in excess of action limits does not in itself mandate active remediation, the existence of free-phase product on the groundwater in excess of 1.27 cm (0.5 in.) does require the implementation of an active removal action (Appendix D). Design of a free-product removal system for the Group I Sites has been initiated as an interim removal action in conjunction with Phase II activities (ORNL 1991).

2.5.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.5.3.i and 2.5.3.ii list the general response actions, technology types, and process options for contaminated soils and groundwater at the

Table 2.5.2.vi. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. Remedial action objectives

Remedial Action Objectives - Group I Sites			
Contaminated Media		Applicable or Relevant and Appropriate Requirements (ARARs)	Media-Specific Remedial Action Objectives
Soil		NDEP Hydrocarbon Cleanup Policy	Prevent exposures to soils contaminated in excess of 100 mg/kg TPH
Groundwater	Dissolved Product	NDEP Hydrocarbon Cleanup Policy	Prevent exposures to groundwater used as a potable source contaminated in excess of 5.0 μg/L for benzene, 700 μg/L for ethylbenzene, 10,000 μg/L for total xylene, and 2,000 μg/L for toluene. Prevent exposures to seepage discharge of groundwater contaminants into surface waters in excess of 1.0 mg/L TPH.
	Free Product	NDEP Hydrocarbon Cleanup Policy	Initiate active free-product removal operations when free-phase product exists on the groundwater in excess of 1.27 cm (0.5 in.)

TPH: total petroleum hydrocarbons

Table 2.5.3.i. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. General response actions, technology types, and process options for contaminated soils

Group I Sites: Site 2, New Fuel Farm; Site 4, Transportation Yard General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal)	Grout injection, In situ vitrification, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (in situ and following removal)	RF thermal stripping, Soil baking/thermal desorption, Incineration
		Chemical treatment (following removal)	Neutralization/stabilization, Precipitation, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor, Landfarming, Composting
		Physical separation/extraction (following removal)	Soil flushing, Centrifuging, Steam stripping, Soil venting, Ultrasonics
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

RF: radio frequency

Table 2.5.3.ii. Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. General response actions, technology types, and process options for contaminated groundwater

Group I Sites: Site 2, New Fuel Farm; Site 4, Transportation Yard General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Bio-clogging, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction
		Free product pumping (in situ)	Single recovery skimmer, Dual recovery system

Group I sites. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated in Table 2.5.2.vi, and 2) the associated exposure pathways and affected receptors discussed in Sect. 2.5.2. The process options formulated in the tables will serve to form the remedial action alternatives for the Group I sites as Phase II work progresses.

As shown in Table 2.5.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area.

As shown in Table 2.5.3.ii, general response actions for contaminated groundwater also include institutional measures, containment, treatment, and removal. Technology type and appropriate process option listings follow for each of the general response categories. As with soils, on-site restricted pumping is included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

2.6 GROUP II SITES: SITE 6, DEFUEL DISPOSAL AREA; SITE 7, NAPALM BURN PIT; SITE 21, RECEIVER SITE LANDFILL; SITE 22, NORTHEAST RUNWAY LANDFILL

2.6.1 Site History

The Group II Sites comprise four areas of interest: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit; Site 21, Receiver Landfill; and Site 22, Northeast Runway Landfill. As shown in Fig. 1.3.2.ii, the Group II Sites are located in the northeastern corner of NAS Fallon in the new area of the base. A discussion of the history of each of these sites follows (Dames and Moore 1988).

2.6.1.1 Site 6, Defuel Disposal Area

The Defuel Disposal Area consists of two regions of level, unpaved

surface soils. As shown in Fig. 2.6.1.i, one of the disposal areas lies within Site 21, Receiver Landfill. Disposal activities at Site 6 consisted of dumping off-specification JP-5 and JP-4 removed from aircraft fuel tanks. This fuel was contaminated with water or sediment and is commonly referred to as "defuel". Application of contaminants consisted of emptying the 18,927-L (5,000-gal) trucks used to transport defuel from aircraft to the site. It is estimated that as much as 265,000 L (70,000 gal) of contaminant were disposed of in this manner between the years of 1966 and 1972. Due to the amount of liquid waste disposed of, soils and groundwater contamination is likely.

2.6.1.2 Site 7, Napalm Burn Pit

The Napalm Burn Pit is also located within Site 21, Receiver Site Landfill (Fig. 2.6.1.i). Disposal activities consisted of burning excess napalm- generated ordnance between the early 1960s and 1983. Burning was accomplished by placing napalm canisters in the pit where they were axed open, saturated with diesel fuel, and ignited. As much as 908,500 L (240,000 gal) of napalm may have been burned in the pit.

2.6.1.3 Site 21, Receiver Site Landfill

Site 21, Receiver Site Landfill, received buried waste generated at NAS Fallon between the years of 1965 and 1980. As shown in Fig. 2.6.1.i, the site also includes two other areas of interest: the napalm burn pit and one of the defuel disposal areas. Land disposal activities consisted of burying waste in trenches excavated to an average depth of 2.4 m (8 ft) in a north-south direction. Disposal operations were conducted from east to west across the landfill.

Prior to 1975, 60 million kg (66,000 tons) of solid waste and 3,785 L (1,000 gal) of liquid hydrocarbon waste were deposited in the landfill. Solid waste included wet garbage, trash, and rubble. It is surmised that the liquid waste included JP-5, gasoline, diesel fuel, waste oils, and hydraulic fluids generated from aircraft maintenance and Public Works Transportation. Burning of liquid wastes on site is reported to have occurred. Disposal of hydrocarbon waste at the site was prohibited in 1975, and after 1979 only dry trash

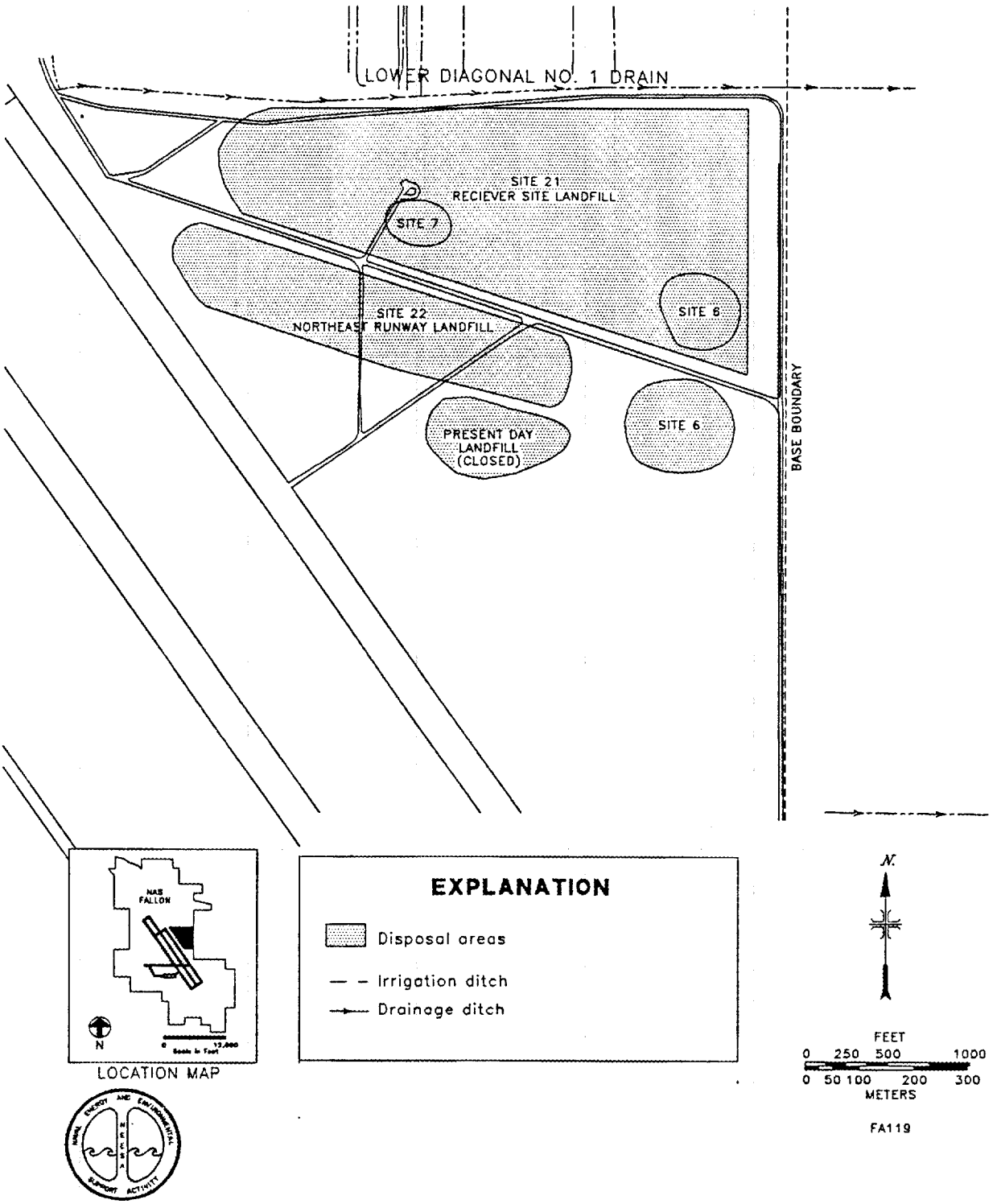


Fig. 2.6.1.i Group II sites: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit; Site 21, Receiver Landfill; and Site 22, Northeast Runway Landfill.

and rubble were allowed in the landfill. Disposal activities on the site were discontinued in 1980-81 when landfill operations were moved to the adjacent northeast runway landfill (Fig. 2.6.1.i).

2.6.1.4 Site 22, Northeast Runway Landfill

As shown in Fig. 2.6.1.i, the Northeast Runway Landfill is located south of the Receiver Site Landfill. Landfill disposal activities were transferred from the Receiver Site Landfill to Site 22 in 1980-81 and continued until 1987. The site received approximately 54.5 million kg (60,000 tons) of dry trash and rubble during its operational lifetime. Disposal consisted of burying wastes in north-south excavated trenches. Trenches were backfilled on a daily or weekly basis.

2.6.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at the Group II Sites.

2.6.2.1 Contaminated Media of Concern

No site-characterization activities were conducted at the Group II Sites during the Phase I PA/SI. Conclusions drawn from the records' searches and inspections conducted during the Phase I study are summarized as follows (Dames and Moore 1988):

Site 6, Defuel Disposal Area: due to the amount of liquid hydrocarbon waste applied to the site, soil and groundwater contamination is probable.

Site 7, Napalm Burn Pit: landfill operations in the vicinity of the site prevent location of the napalm burn pit. Contamination of soils may have resulted from incomplete incineration of napalm and diesel fuel; however, the high viscosity of napalm and small quantities of unburned waste should limit this possibility.

Site 21, Receiver Site Landfill: because liquid-hydrocarbon wastes were disposed of at the site, soil and possibly groundwater contamination may be present. In addition, it is suspected that other hazardous substances such as paint wastes and metals may have been landfilled at the site.

Site 22, Northeast Runway Landfill: although monitored, the landfill may have received minor amounts of paint wastes and metals included in accepted wastes. These hazardous substances may have resulted in the presence of soil and groundwater contaminants.

Because of the close proximity of Group II Sites, Phase II site-characterization activities assessed the four areas of interest collectively as one study area. Screening consisted of evaluating ninety-five groundwater test holes drilled in and around the area. Location points for the groundwater test holes are shown in Fig. 2.6.2.i, and results are given in Appendix B, Tables B.8 and B.11. (Note: screening activities along the Lower Diagonal No. 1 Drain [Table B.11] were conducted as a separate activity. However, due to its close proximity to the Group II Sites, results are also relevant to this narrative). As shown in Fig. 2.6.2.i, groundwater screening revealed the location of a petroleum hydrocarbon plume emanating from the southern-most disposal area of Site 6. Contaminants were not detected in any of the other test holes. An attempt to locate the napalm burn pit by drilling groundwater test holes was unsuccessful because buried trash and rubble fouled the drilling augers.

After initial screening was completed, site-characterization activities included the installation of seven monitoring wells, eight piezometers, and two staff gauges (Fig. 2.6.2.i). One upgradient well (MW12-L) was screened in the intermediate aquifer (Appendix C), and the remaining wells were completed across the water table of the shallow alluvial aquifer. Five piezometers

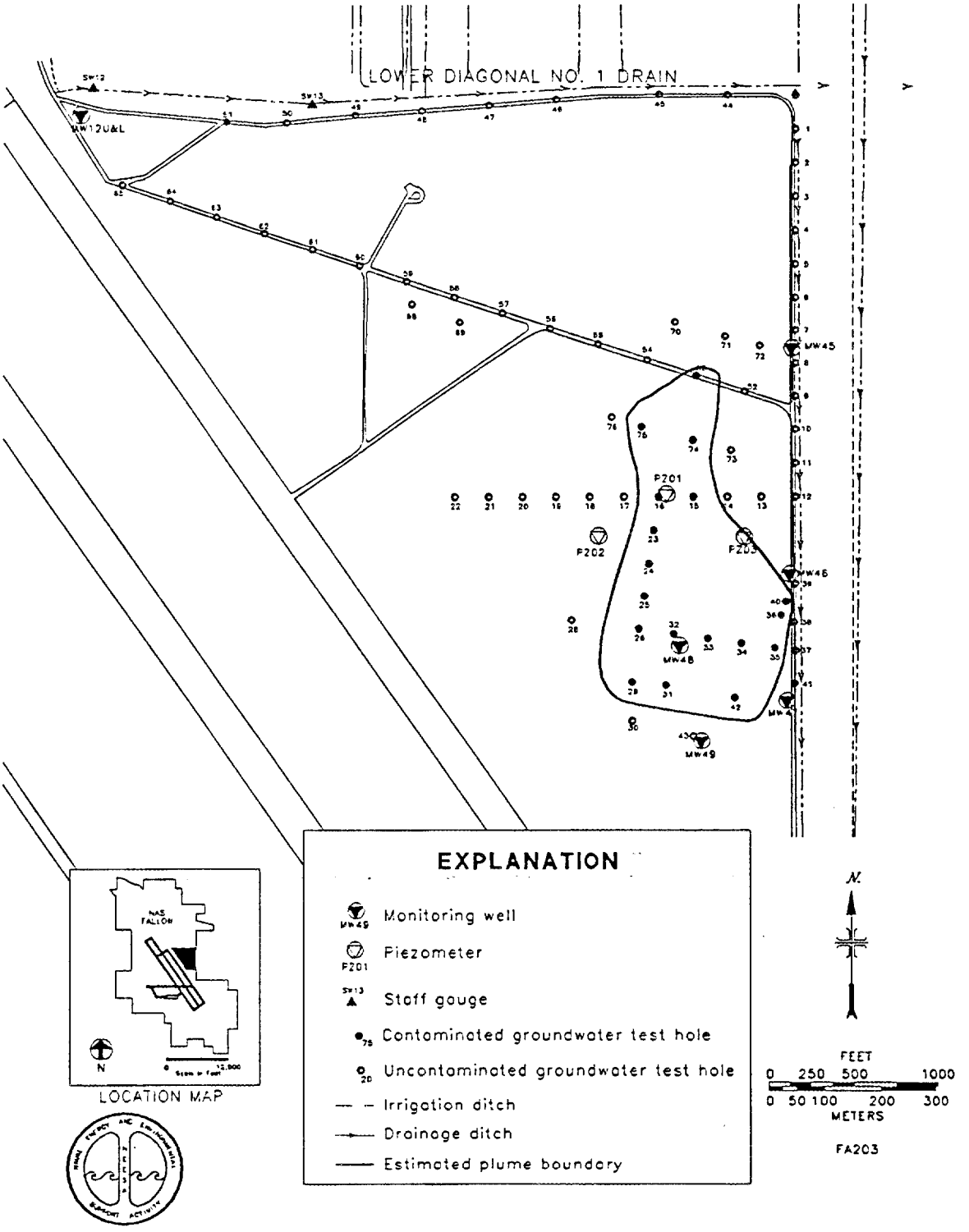


Fig. 2.6.2.i Group II sites: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit: Site 21, Receiver Landfill; and Site 22, Northeast Runway Landfill. Groundwater test hole and analytical sampling locations.

(not shown on Fig. 2.6.2.i) were installed north of the study area in conjunction with the Lower Diagonal No. 1 Drain investigation. (Note: the Lower Diagonal No. 1 Drain investigation is a separate initiative from the Site Program). Three additional piezometers were installed around the Site 6 plume. Results from laboratory analysis of monitoring well samples are not yet available.

Screening and characterization activities at the Group II Sites indicate that the primary contaminants of concern are petroleum hydrocarbon compounds, primarily JP-4 and JP-5. The contaminated media of concern include the soils and shallow groundwater underlying the southern disposal area associated with Site 6, Defuel Disposal Area. The atmosphere is not considered to be a contaminated medium of concern because volatile constituents introduced in the shallow subsurface rapidly evaporate. The air quality of the surrounding region is good, and prevailing air currents will rapidly disperse any volatile contaminants, rendering them innocuous to the environment.

2.6.2.2 Exposure Pathways

Direct exposure pathways for contaminated soils at the Group II Sites include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants and burrowing animals as well as personnel associated with site excavation activities. Plant and animal populations are controlled on NAS Fallon property, and exposures associated with these biota are thus minimized. Because NAS Fallon is a restricted area, direct exposure to the human populace is restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. Restricted access and site activities geared towards environmental safety thus prevent contaminated soils at the Group II Sites from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and due to its high salinity, is not used for human consumption in the surrounding area (Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is unknown, its likely purpose in light of the poor water quality is to supply water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt drinking water aquifer. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in certain portions of the base (ERM-West 1988). It is believed that these natural containment mechanisms prevent contaminants from reaching the regional domestic water source.

As with soils, contaminated groundwater associated with Group II Sites does not constitute a substantial direct exposure pathway. Soils may, however, serve as a source term for atmospheric transport of contaminated particulates, and both contaminated soils and groundwater may act as a source for contaminating surface flows. Contaminated surface flow may then serve as an exposure pathway to sensitive receptors.

Exposures to wind-blown transport of contaminated soils are minimal due to restricted access in the immediate vicinity, the natural cohesive properties of native surface soils, and dust control measures employed during construction activities. In addition, the air quality of the region is good, and airborne particulate matter is quickly dispersed. Hence, atmospheric transport is not considered a threat to the environment.

Downward transport of residual soils contamination to the underlying aquifer via surface water percolation is not considered significant because of the semiarid climate. Indeed, the alkali flats in the surrounding area indicate a negative regional water balance. It is surmised that because

contaminants were originally introduced at or near the ground surface, the downward transport necessary to produce existing groundwater contamination resulted from gradients introduced from excessive spills or dumping and not from the natural percolation process.

Surface flow runoff resulting from excessive precipitation or human activities may transport contaminated surface sediments or dissolved constituents to the regional surface drainage system. In addition, contaminants presently associated with the shallow groundwater may migrate downgradient for eventual seepage discharge into the surrounding drainage ditches. Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off-site exposure points associated with surface flows include recreational exposure, direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

Ground- and surface-water transport to off-site receptors is thus the primary exposure pathway for contaminants of concern at the Group II Sites. Potential off-site transport mechanisms include: 1) eventual seepage discharge of groundwater contaminants to surface flows migrating off site, and 2) discharge of contaminated surface flows (from rainfall and human activity) to surface water drainage systems. The principal exposure pathway of concern is thus the regional surface flow system extending from the downgradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. As shown in Fig. 1.3.2.ii, the Lower Diagonal No. 1 Drain located along the northern and eastern boundaries of the area of concern is the primary receptor point for groundwater or surface flow transport of contaminants from the Group II Sites. The flow chart in Fig. 2.6.2.ii summarizes the above discussion and depicts the

GROUP II SITES: SITE 6, DEFUEL DISPOSAL AREA; SITE 7, NAPALM BURN PIT
SITE 21, RECEIVER SITE LANDFILL; SITE 22, NORTHEAST RUNWAY LANDFILL

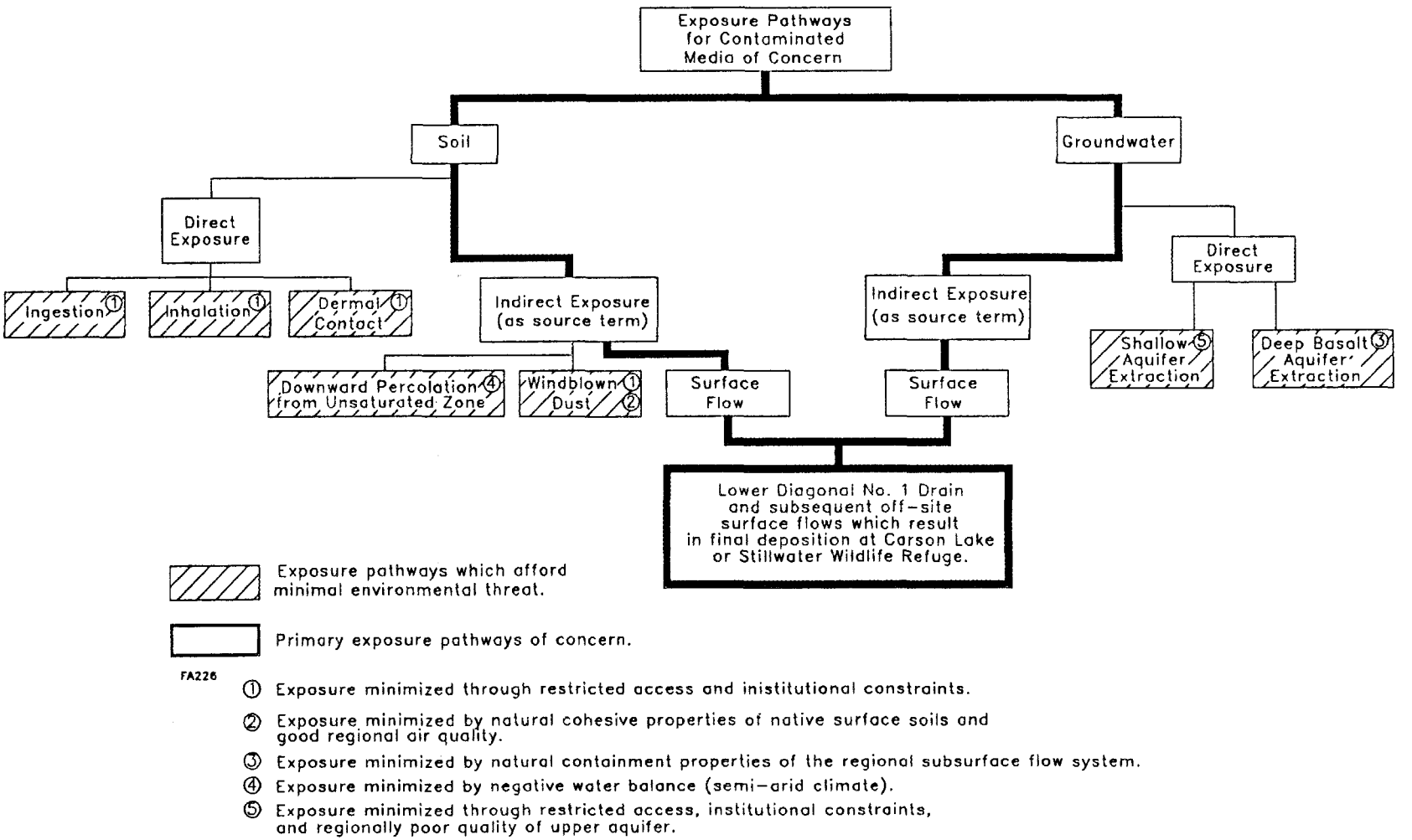


Fig. 2.6.2.ii Flow chart of exposure pathways associated with Group II sites.

screening logic used in determining the exposure pathways of concern. As shown in the flow chart, the Lower Diagonal No. 1 Drain and subsequent off-site surface flows into which it drains are the primary exposure pathways associated with contaminants at the Group II Sites.

2.6.2.3 ARARs and Remedial Action Objectives

The State of Nevada Division of Environmental Protection Hydrocarbon Cleanup Policy (NDEP 1987) is given in Appendix D. Table 2.6.2.i lists media-specific remedial action objectives predicated on the ARARs given in Appendix D.

As stated in this NDEP Policy, remediation of petroleum-hydrocarbon-contaminated soils and groundwater may be required if action limit concentrations are exceeded. Action limit concentrations are set at 100 mg/kg total petroleum hydrocarbons (TPH) for soils and the EPA maximum contaminant levels (MCLs) or recommended maximum contaminant levels (RMCLs) for groundwater used as a potable source. Relevant MCLs are 5.0 μg/L for benzene (established),700 μg/L for ethylbenzene (proposed), 10,000 μg/L for total xylene (proposed), and 2,000 μg/L for toluene (proposed). If these action limits are exceeded, the need for remedial activity is then evaluated with respect to site-specific parameters such as use of the contaminated medium; contaminant transport potential; the degree, magnitude, and toxicity of contaminants; and economic cost/benefit considerations. Although contaminants of concern may indeed exceed action limits at the Group II Sites, the need for active remediation must still be evaluated in light of the restricted access to NAS Fallon property and the lack of use of the upper aquifer.

While the existence of soil and groundwater contaminants in excess of action limits does not in itself mandate active remediation, the existence of free-phase product on the groundwater in excess of 1.27 cm (0.5 in.) does require the implementation of an active removal action (Appendix D).

2.6.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.6.3.i and 2.6.3.ii list the general response actions, technology

Table 2.6.2.i. Group II sites: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit; Site 21, Receiver Site Landfill; Site 22, Northeast Runway Landfill. Remedial action objectives

Remedial Action Objectives - Group II Sites			
Contaminated Media		Applicable or Relevant and Appropriate Requirements (ARARs)	Media-Specific Remedial Action Objectives
Soil		NDEP Hydrocarbon Cleanup Policy	Prevent exposures to soils contaminated in excess of 100 mg/kg TPH
Groundwater	Dissolved Product	NDEP Hydrocarbon Cleanup Policy	Prevent exposures to groundwater used as a drinking water source contaminants in excess of 5.0 μg/L for benzene, 700 μg/L for ethylbenzene, 10,000 μg/L for total xylene, and 2,000 μg/L for toluene. Prevent exposures to seepage discharge of groundwater contaminants into surface waters in excess of 1.0 mg/L TPH.
	Free Product	NDEP Hydrocarbon Cleanup Policy	Initiate active free-product removal operations when free-phase product exists on the groundwater in excess of 1.27 cm (0.5 in.)

TPH: total petroleum hydrocarbons

Table 2.6.3.i. Group II sites: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit; Site 21, Receiver Site Landfill; Site 22, Northeast Runway Landfill. General response actions, technology types, and process options for contaminated soils

Group II Sites: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit; Site 21, Receiver Site Landfill; Site 22, Northeast Runway Landfill General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal)	Grout injection, In situ vitrification, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (in situ and following removal)	RF thermal stripping, Soil baking/thermal desorption, Incineration
		Chemical treatment (following removal)	Neutralization/stabilization, Precipitation, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor, Landfarming, Composting
		Physical separation/extraction (following removal)	Soil flushing, Centrifuging, Steam stripping, Soil venting, Ultrasonics
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

RF: radio frequency

Table 2.6.3.ii. Group II sites: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit; Site 21, Receiver Site Landfill; Site 22, Northeast Runway Landfill. General response actions, technology types, and process options for contaminated groundwater

Group II Sites: Site 6, Defuel Disposal Area; Site 7, Napalm Burn Pit; Site 21, Receiver Site Landfill; Site 22, Northeast Runway Landfill General Response Actions, Technology Types, and Process Options			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Bio-clogging, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction
		Free product pumping (in situ)	Single recovery skimmer, Dual recovery system

types, and process options for contaminated soils and groundwater at the Group II Sites. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated in Table 2.6.2.i; and 2) the associated exposure pathways and affected receptors discussed in Sect. 2.6.2. The process options formulated in the tables will serve to form the remedial action alternatives for the Group II Sites as Phase II work progresses.

As shown in Table 2.6.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area.

General response actions for contaminated groundwater also include institutional measures, containment, treatment, and removal (Table 2.6.3.ii). Technology type and appropriate process option listings follow for each of the general response categories. As with soils, on-site restricted pumping is included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

2.7 GROUP III SITES: SITE 9, WASTEWATER TREATMENT PLANT; SITE 18, SOUTHEAST RUNWAY LANDFILL

2.7.1 Site History

The Group III Sites consist of Site 9, Wastewater Treatment Plant, and Site 18, Southeast Runway Landfill. As shown in Fig. 1.3.2.ii, the Group III Sites are located in the southeastern corner of NAS Fallon in the old section of the base. A discussion of the history of each of the sites of concern follows (Dames and Moore 1988).

2.7.1.1 Site 9, Wastewater Treatment Plant

Potential areas of contamination at Site 9, Wastewater Treatment Plant,

include: 1) the grit chamber disposal pit and Imhoff tank sludge disposal pit, 2) settling ponds used for the percolation/evaporation of treated sanitary sewer effluent, and 3) the soils and groundwater underlying a diesel underground storage tank which, upon removal in 1985, was reportedly leaking. These potentially contaminated areas are shown in Fig. 2.7.1.i.

Waste disposal activities at the grit chamber disposal pit consisted of burying as much as 20,062 L (5300 gal) per year of effluent produced in the grit chamber from the Imhoff tank. Disposal was carried out between the years of 1961 and 1985. In addition, sludge from the Imhoff tank was buried in a pit to the east of the settling ponds (Fig. 2.7.1.i) in 1980.

Contaminants may have entered soils and groundwater underlying the settling ponds through percolation of treated effluent. It is estimated that approximately 10% of the treated effluent, approximately 43,530 L/day (11,500 gal/day), may have percolated to the underlying water table between 1943 and 1987.

Additional contamination may have resulted from a 1,893-L (500-gal) diesel storage tank located north of the wastewater treatment building (Fig. 2.7.1.i) and removed in 1985. The tank was reportedly leaking, although no sampling or removal of soils was performed at the time of tank removal.

Contaminants of concern at Site 9 include diesel fuel as well as other hazardous materials removed from the sanitary sewer discharge as grit, tank sludges, or percolation of treated effluent. Suspected hazardous materials include metals, oils, paint wastes, and photographic chemicals (including silver, gold, and mercury) which may have been discharged to the sanitary sewer.

2.7.1.2 Site 18, Southeast Runway Landfill

As shown in Fig. 2.7.1.i, Site 18, Southeast Runway Landfill, is located of the southeast corner of the wastewater treatment facility. It is reported that municipal refuse and industrial trash were buried at the site during World War II (1943 to 1946). Although no details of the exact landfill location or disposal activities are available, it is expected that burial was conducted in bulldozed trenches no deeper than the area water table (average

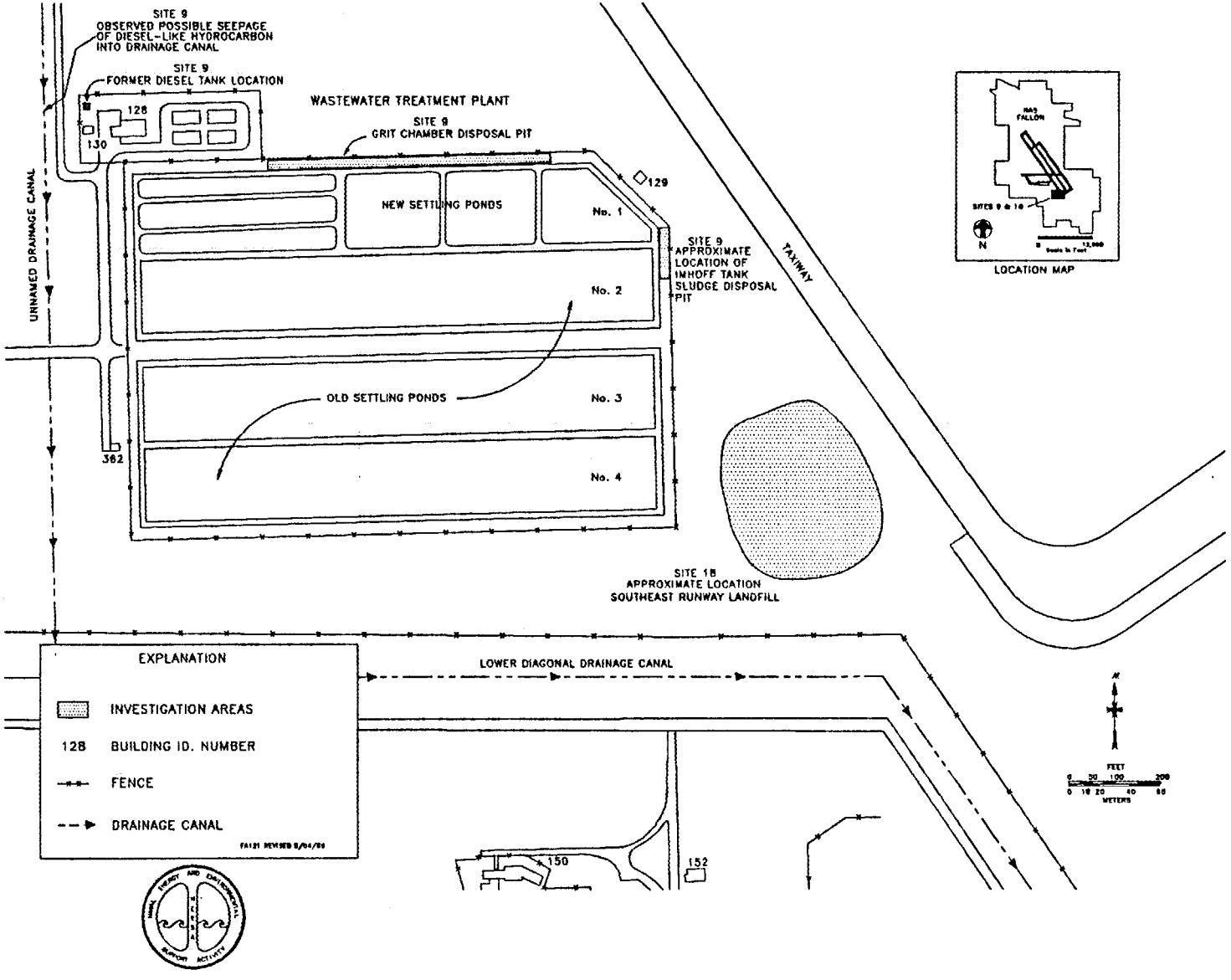


Fig. 2.7.1.i Group III sites: Site 9, Wastewater Treatment Plant; Site 18, Southeast Runway Landfill.

depth of 2.4 m [8 ft]). It is estimated that approximately 16 million kg (18,000 tons) of waste were disposed of at the site. Suspected contaminants include paints, metals, and petroleum hydrocarbons.

2.7.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at the Group III Sites.

2.7.2.1 Contaminated Media of Concern

No site-characterization activities were conducted at the Group III Sites during the Phase I PA/SI. Because of the amount and type of wastes disposed of, it is suspected that soil and groundwater contamination may be present at both areas of interest. In addition, visual inspection of the unnamed drainage ditch west of Site 9 (Fig. 2.7.1.i) located a diesel fuel-like product emanating from the subsurface. Presumably the product resulted from the underground storage tank that is reportedly leaking (Dames and Moore 1988).

Phase II site screening activities consisted of assessing ten groundwater test holes as shown in Fig. 2.7.2.i. Results of the screening are given in Appendix B, Table B.6 and indicated no contamination was detected.

Site-characterization studies completed at the Group III Sites include the installation of two monitoring wells, one piezometer, and seven soil borings (Fig. 2.7.2.i). Two of the soil borings (BH01 and BH02) were taken near the former location of the underground diesel fuel storage tank. Soil samples for these two borings were taken to the water table. The remaining soil borings were taken to a depth of 1.2 m (4 ft) near the grit chamber disposal pit and the Imhoff tank sludge disposal pit. Soil samples and groundwater samples have been submitted for laboratory analysis, but results are not yet available.

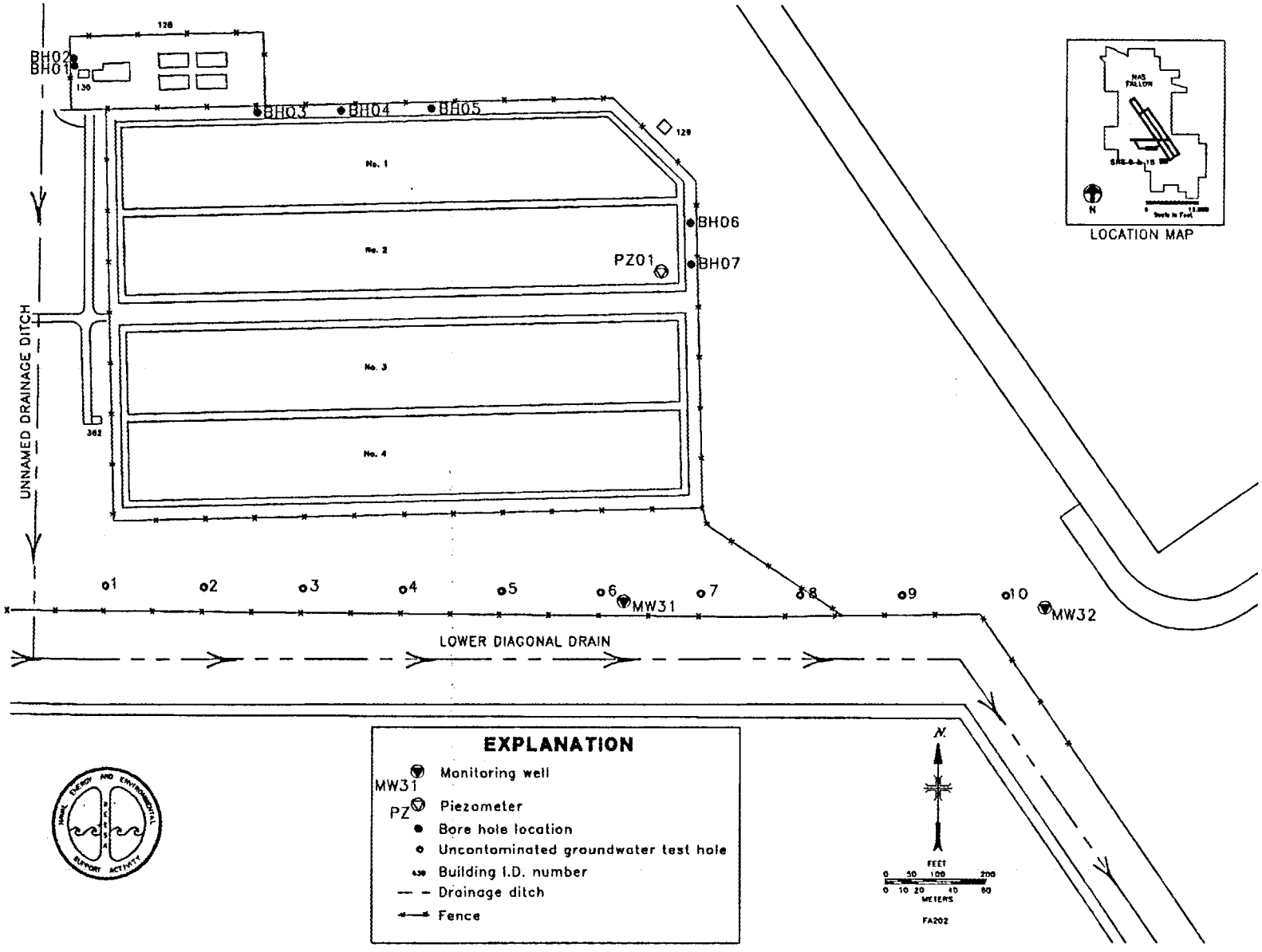


Fig. 2.7.2.i Group III sites: Site 9, Wastewater Treatment Plant; Site 18, Southeast Runway Landfill. Groundwater test hole and analytical sampling locations.

Screening and characterization activities at the Group III Sites indicate that the primary contaminants of concern are petroleum hydrocarbon compounds, primarily diesel fuel. The contaminated media of concern include the soils and shallow groundwater underlying the former location of the underground diesel storage tank (Fig. 2.7.1.i). The atmosphere is not considered to be a contaminated medium of concern because sludge and grit waste are contained in a buried state, and volatile constituents associated with treated effluents will rapidly evaporate in the settling ponds. The air quality of the surrounding region is good, and prevailing air currents will rapidly dilute and disperse any volatile contaminants once they enter the atmosphere.

2.7.2.2 Exposure Pathways

Direct exposure pathways for contaminated soils at the Group III Sites include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants and burrowing animals as well as personnel associated with site excavation activities. Plant and animal populations are controlled on NAS Fallon property, and exposures associated with these biota are thus minimized. Because NAS Fallon is a restricted area, direct exposure to the human populace is restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. Restricted access and site activities geared towards environmental safety thus prevent contaminated soils at the Group III Sites from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and, due to its high salinity, is not used for human consumption in the surrounding area

(Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is unknown, its likely purpose in light of the poor water quality is to supply water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt drinking water aquifer. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in certain portions of the base (ERM-West 1988). It is believed these natural containment mechanisms prevent contaminants from reaching the regional domestic water source.

As with soils, contaminated groundwater associated with Group III Sites does not constitute a substantial direct exposure pathway. Soils may, however, serve as a source term for atmospheric transport of contaminated particulates, and both contaminated soils and groundwater may act as a source for contaminating surface flows. Contaminated surface flow may then serve as an exposure pathway to sensitive receptors.

Exposures to wind-blown transport of contaminated soils are minimal due to restricted access in the immediate vicinity, the natural cohesive properties of native surface soils, and dust control measures employed during construction activities. In addition, the air quality of the region is good, and airborne particulate matter is quickly dispersed. Hence, atmospheric transport is not considered a threat to the environment.

Downward transport of residual soils contamination to the underlying aquifer via naturally occurring surface water percolation is not considered significant because of the semiarid climate. Indeed, the alkali flats in the surrounding area indicate a negative regional water balance. It is surmised that because contaminants were originally introduced at or near the ground surface, the downward transport necessary to produce existing groundwater contamination (i.e., diesel contamination from the formerly buried storage tank) resulted from gradients introduced from excessive spills or dumping and not from the natural percolation process.

While downward transport of contaminants via percolation of natural surface water is minimal, Site 9 does afford a substantial transport mechanism for transport of near-surface contaminants to the underlying aquifer. The settling ponds of the water treatment system afford a continuous source of potential contaminants and also produce a substantial downward flow gradient. The resulting flow system may induce downward percolation of the treated effluent into the underlying upper aquifer. As discussed in Sect. 2.7.1, the Phase I study concluded that as much as 10% of the treated effluent may percolate to the water table and, hence, contribute to groundwater contamination.

Surface flow runoff resulting from excessive precipitation or human activities may transport contaminated surface sediments or dissolved constituents to the regional surface drainage system. In addition, contaminants presently associated with the shallow groundwater (from previous spills or percolation from settling ponds) may migrate downgradient for eventual seepage discharge into the surrounding drainage ditches. Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off-site exposure points associated with surface flows include recreational exposure, direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

Ground- and surface-water transport to off-site receptors is thus the primary exposure pathway for contaminants of concern at the Group III Sites. Potential off-site transport mechanisms include: 1) eventual seepage discharge of groundwater contaminants to surface flows migrating off site, and 2) discharge of contaminated surface flows (from rainfall and human activity) to surface water drainage systems. The principal exposure pathway of concern is thus the regional surface flow system extending from the downgradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. As shown in Fig. 2.7.1.i, the unnamed drainage ditch and the Lower Diagonal Drain located along the western and southern boundaries of the area of concern are the primary receptor points for groundwater or surface flow transport of contaminants from the Group III Sites. The flow chart in Fig. 2.7.2.ii summarizes the above discussion and depicts the screening logic used in determining the exposure pathways of concern. As shown in the flow chart, the unnamed tributary to the Lower Diagonal Drain and subsequent off-site surface flows are the primary exposure pathways associated with contaminants at the Group III Sites.

2.7.2.3 ARARs and Remedial Action Objectives

Until such time as the presence of additional contaminants of concern at the Group III Sites is confirmed, ARARs and remedial action objectives will be taken as those relevant to petroleum-hydrocarbon-contaminants. The State of Nevada Division of Environmental Protection Hydrocarbon Cleanup Policy (NDEP 1987) is given in Appendix D. Table 2.7.2.i lists media-specific remedial action objectives predicated on the ARARs given in Appendix D.

As stated in this NDEP Policy, remediation of petroleum-hydrocarbon-contaminated soils and groundwater may be required if action limit concentrations are exceeded. Action limit concentrations are set at 100 mg/kg total petroleum hydrocarbons (TPH) for soils and the EPA maximum contaminant levels (MCLs) or recommended maximum contaminant levels (RMCLs) for groundwater used as a drinking water (potable) source. Relevant MCLs are 5.0 μg/L for benzene (established), 700 μg/L for ethylbenzene (proposed), 10,000 μg/L for total xylene (proposed), and 2,000 μg/L for toluene (proposed). If these action limits are exceeded, the need for remedial activity is then evaluated with respect to site-specific parameters such as use of the contaminated medium; contaminant transport potential; the degree, magnitude, and toxicity of contaminants; and economic cost/benefit considerations. Although contaminants of concern may indeed exceed action limits at the Group III Sites, the need for active remediation must still be evaluated in light of the restricted access to NAS Fallon property and the lack of use of the upper aquifer.

GROUP III SITES: SITE 9, WASTEWATER TREATMENT PLANT,
SITE 18, SOUTHEAST RUNWAY LANDFILL

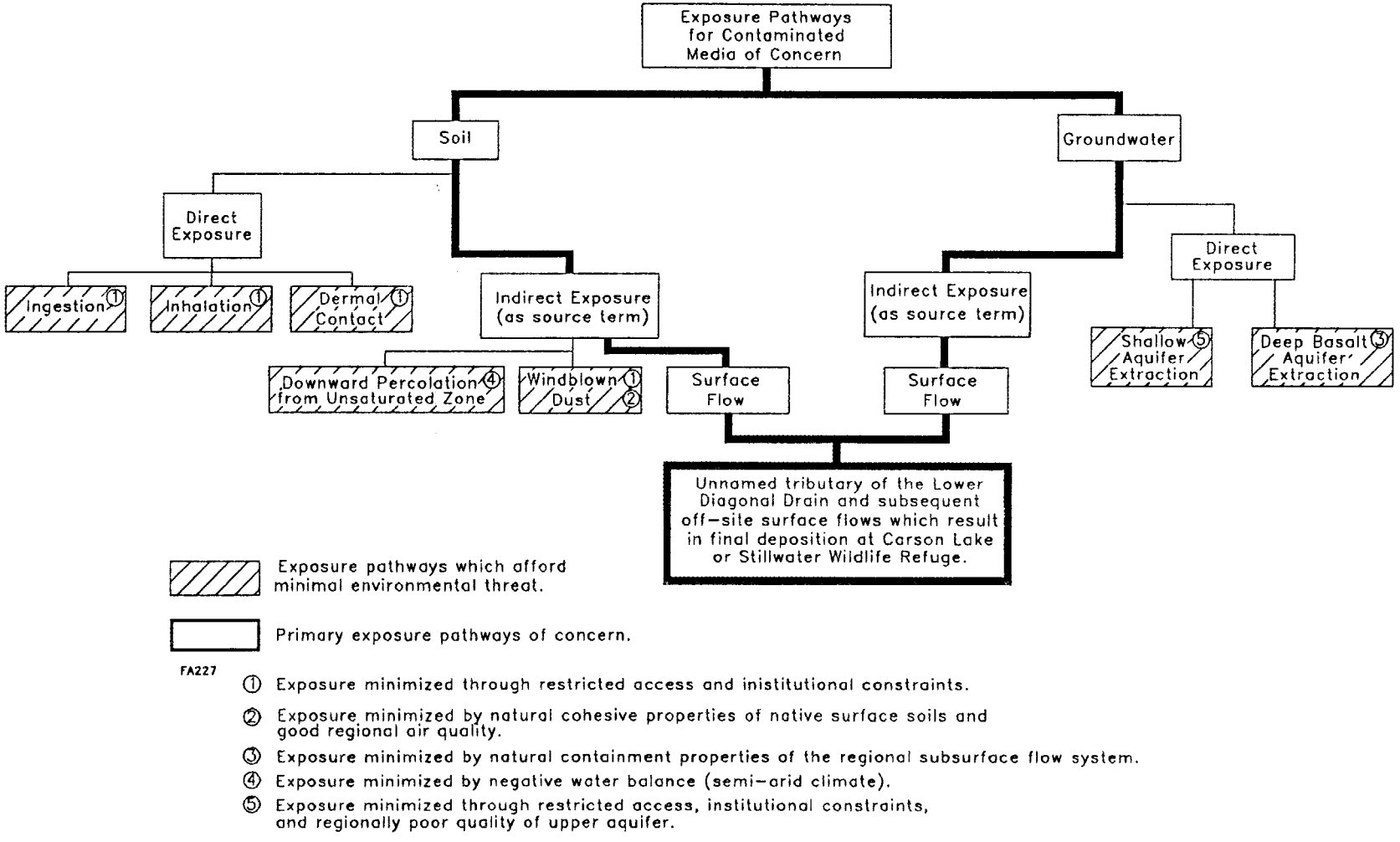


Fig. 2.7.2.ii Flow chart of exposure pathways associated with Group III sites.

Table 2.7.2.i. Group III sites: Site 9, Wastewater Treatment Plant; Site 18, Southeast Runway Landfill. Remedial action objectives

Remedial Action Objectives - Group III Sites			
Contaminated Media		Applicable or Relevant and Appropriate Requirements (ARARs)	Media-Specific Remedial Action Objectives
Soil		NDEP Hydrocarbon Cleanup Policy	Prevent exposures to soils contaminated in excess of 100 mg/kg TPH
Groundwater	Dissolved Product	NDEP Hydrocarbon Cleanup Policy	Prevent exposures to groundwater used as a potable source contaminants in excess of 5.0 μg/L for benzene, 700 μg/L for ethylbenzene, 10,000 μg/L for total xylene, and 2,000 μg/L for toluene. Prevent exposures to seepage discharge of groundwater contaminants into surface waters in excess of 1.0 mg/L TPH.
	Free Product	NDEP Hydrocarbon Cleanup Policy	Initiate active free-product removal operations when free-phase product exists on the groundwater in excess of 1.27 cm (0.5 in.)

TPH: total petroleum hydrocarbons

While the existence of soil and groundwater contaminants in excess of action limits does not in itself mandate active remediation, the existence of free-phase product on the groundwater in excess of 1.27 cm (0.5 in.) does require the implementation of an active removal action (Appendix D).

2.7.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.7.3.i and 2.7.3.ii list the general response actions, technology types, and process options for contaminated soils and groundwater at the Group III Sites. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated in Table 2.7.2.i; and 2) the associated exposure pathways and affected receptors discussed in Sect. 2.7.2. The process options formulated in the tables will serve to form the remedial action alternatives for the Group III Sites as Phase II work progresses.

As shown in Table 2.7.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area.

General response actions for contaminated groundwater also include institutional measures, containment, treatment, and removal (Table 2.7.3.ii). Technology type and appropriate process option listings follow for each of the general response categories. As with soils, on-site restricted pumping is included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

Table 2.7.3.1. Group III sites: Site 9, Wastewater Treatment Plant; Site 18, Southeast Runway Landfill. General response actions, technology types, and process options for contaminated soils

Group III Sites: Site 9, Wastewater Treatment Plant; Site 18, Southeast Runway Landfill			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal)	Grout injection, In situ vitrification, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (in situ and following removal)	RF thermal stripping, Soil baking/thermal desorption, Incineration
		Chemical treatment (following removal)	Neutralization/stabilization, Precipitation, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor, Landfarming, Composting
		Physical separation/extraction (following removal)	Soil flushing, Centrifuging, Steam stripping, Soil venting, Ultrasonics
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

RF: radio frequency

Table 2.7.3.ii. Group III sites: Site 9, Wastewater Treatment Plant; Site 18, Southeast Runway Landfill. General response actions, technology types, and process options for contaminated groundwater

Group III Sites: Site 9, Wastewater Treatment Plant; Site 18, Southeast Runway Landfill			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Bio-clogging, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction
		Free product pumping (in situ)	Single recovery skimmer, Dual recovery system

2.8 GROUP IV SITES: SITES 10, 11, 12, 13, 14, 16, 17, 19, AND 23

2.8.1 Site History

The Group IV Sites contain nine sites of interest including: Site 10, Ground to Air Transmitting and Receiving (GATAR) Compound; Site 11, Paint Shop; Site 12, Pest Control Shop; Site 13, Boiler Plant Tanks; Site 14, Old Vehicle Maintenance Shop; Site 16, Old Fuel Farm; Site 17, Hangar 4; Site 19, Post-World War II Burial Site; and Site 23, Shipping and Receiving Disposal Site. All of the sites are located in the old portion of the base (Fig. 1.3.2.ii). A discussion of the history of each site follows (Dames and Moore 1988; ORNL 1989).

2.8.1.1 Site 10, GATAR Compound

Site 10, GATAR Compound, is located in the southeastern portion of the old area of NAS Fallon (Fig. 2.8.1.i). The site originally belonged to the Air Force and came under Navy control in 1975. The area was apparently unused until 1984 when reported storage activities were initiated. Since 1986, the site has provided interim storage for Safety (Dames and Moore 1988). The site consists of a graveled area used for interim storage of hazardous materials pending removal to off-site locations. Aboveground storage practices at Site 10 have recently been discontinued, and all drums currently stored at the site are empty.

Hazardous wastes stored at Site 10 include PCBs, paints, solvents, waste oils, and hydraulic fluids. PCBs were stored primarily as transformer oil in electrical transformers. Several one-gallon containers of waste oil containing PCBs were reportedly buried on the site in 1984. The exact location of burial is unknown. Other hazardous liquids were stored in aboveground containers, primarily 208-L (55-gal) drums.

About 6.75 m^3 (9 yd^3) of asbestos materials were buried just west of the GATAR compound in about 1984. The waste was reportedly double bagged and crated prior to disposal. The area is clearly demarcated, and some subsidence of the soil overburden is apparent. Because the asbestos was apparently

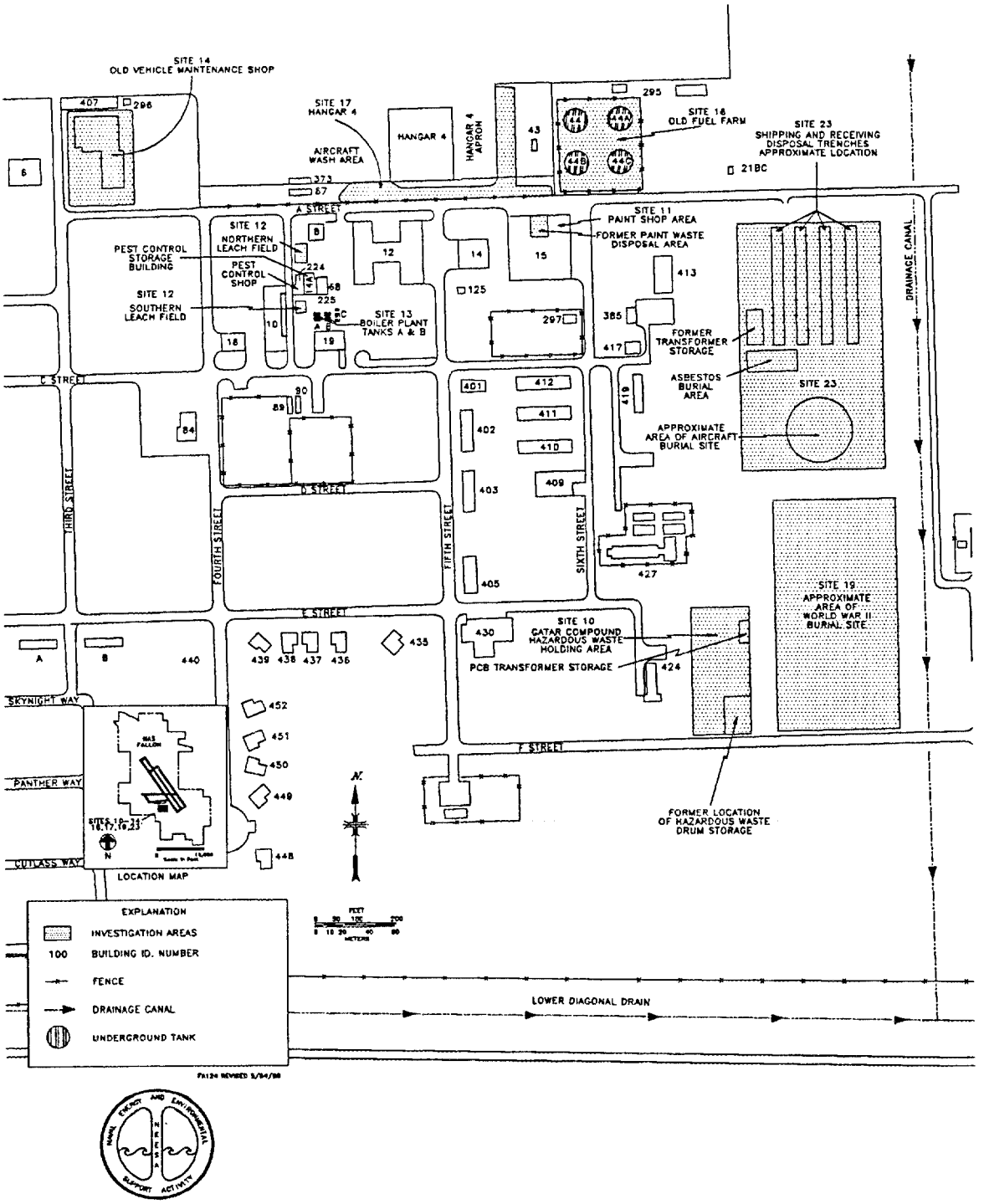


Fig. 2.8.1.i Group IV sites: Sites 10 - 14, 16, 17, 19 and 23.

properly disposed of, soil contamination is not suspected, and the area is not included in any IR Program sites.

2.8.1.2 Site 11, Paint Shop

As shown in Fig. 2.8.1.i, Site 11, Paint Shop, is located in the north-central portion of the old section of the base. Paint wastes were dumped or spilled on the unpaved ground surface to the north of the paint shop. Disposal acti- vities stopped in 1986, at which time the ground surface was paved with concrete. Although the paint shop has been in operation since the early 1960s, documented disposal activities could be obtained only for 1976 to 1986. Waste paints and thinners were introduced to soils either deliberately or from spills associated with transferal from 208-L (55-gal) drums. It is estimated that as much as 189 L (50 gal) of paint may have been applied to surface soils at this site.

2.8.1.3 Site 12, Pest Control Shop

Site 12, Pest Control Shop, has been located in the northwestern part of the old portion of NAS Fallon since the early 1960s (Fig. 2.8.1.i). Records of activities at the site are available from 1974 to present. Although the Pest Control Shop continues to be operational, the site is considered a past operation with respect to changes in the type of pesticides used.

Prior to 1974, pesticides used at the site included DDT, DDD, and DDE. Later activities included handling and storing the pesticides malathion, parathion, pyrethrin, diazinon, and 2,4-D.

Areas of contamination at the site include the north and south leach fields (Fig. 2.8.1.i). The south leach field receives runoff generated from rinsing of pest control vehicles. Rinse water from mixing pesticides and rinsing empty containers is directed to the north leach field. It is estimated that activities from 1974 to the present may have introduced about 56.8 L (15 gal) of the presently used pesticides to each leach field. It is also assumed that activities prior to 1974 introduced approximately the same volumes (i.e., 56.8 L to each leach field) of formerly used pesticides to the leach fields.

2.8.1.4 Site 13, Boiler Plant Tanks

Site 13, Boiler Plant Tanks, consists of two underground 98,420-L (26,000-gal) storage tanks formerly used to store fuel for the boiler plant. The tanks are located near the boiler house to the southeast of Site 12, Pest Control Shop (Fig. 2.8.1.i). Boiler plant fuels storage was discontinued in 1981, at which time the tanks were used for intermittent storage of other fuels and oils until about 1986. Although emptied in 1986, the tanks contained some remaining liquid as of September 1988.

Fuels were reportedly spilled on surface soils around inlets to the tank during filling operations. Spills may have consisted of No. 6 fuel oil, waste lubrication oil, hydraulic fluid, JP-5, and diesel fuel. It is estimated that up to 1,325 L (350 gal) of liquid hydrocarbons may have been spilled at each tank over its lifetime of operation.

2.8.1.5 Site 14, Old Vehicle Maintenance Shop

As shown on Fig. 2.8.1.i, Site 14 is located in the northwestern part of the old portion of NAS Fallon. The site consists of a concrete slab which served as the foundations for a mechanic bay, fueling area, and support building. The facility was used from 1943 to 1971 (exclusive of the years 1947-1950 when base operations were closed) to service and fuel Public Works Transportation and other vehicles. From 1971 to 1973 the shop reportedly served as the auto hobby shop. The shop was razed some time after 1973.

Areas of concern at the site include the former lube pits and two underground storage tanks. The lube pits apparently contained hydraulic lifts and are now filled with soil. The depth of the pits is estimated at 1.8 to 2.1 m (6 to 7 ft), and it is suspected the pits have paved floors. It is estimated that as much as 568 L (150 gal) of lubrication oil, hydraulic fluid, and radiator coolant may have leaked to each lube pit floor. The underground storage tanks were probably used to store leaded gasoline and diesel fuel. Tank conditions are unknown, although estimates of potential leakage run as high as 7,570 L (2,000 gal). The tanks were recently removed, and although no testing was done on either the removed tanks or exposed soils, unidentified petroleum hydrocarbons were observed seeping into the excavated pits.

2.8.1.6 Site 16, Old Fuel Farm

Site 16, Old Fuel Farm, served as the main fuel storage and dispersal facility for the base from 1943 to 1962 (exclusive of the years 1947-50). The site consists of four concrete underground storage tanks located in the north-central part of the old portion of the base (Fig. 2.8.1.i). In 1963, active operations at the site were transferred to the New Fuel Farm, and the storage tanks were used for dead storage of various fuels. Dead storage continued until 1985 at which time the four storage tanks were emptied. They have not been used since.

Fuels stored at the site over its lifetime of operations include avgas, JP-4, JP-5, diesel fuel, gasoline, and No. 6 fuel oil. Excavations in the area have encountered petroleum-hydrocarbon-contaminated soils which likely resulted from past leaks and spills at Site 16. It is estimated that as much as 34,070 L (9,000 gal) of liquid waste may have been introduced to the soils and groundwater underlying the site.

2.8.1.7 Site 17, Hangar 4

Potentially contaminated soils associated with Site 17, Hangar 4, are shown in Fig. 2.8.1.i. The potential areas of contamination consist of the formerly unpaved soils lying to the south and east of Hangar 4. These areas received runoff flushing from aircraft washing activities and aircraft fluids spilled on the parking apron. Contaminant introduction took place between the years of 1943 and 1987 (exclusive of the years 1947-50). Although the southern portion of the site remains open, soils to the east of Hangar 4 were capped with paving in 1985.

Estimates of liquid wastes introduced to subsoils in the area total as high as 34,070 L (9,000 gal). Potential contaminants of concern include wash solvents (Turco), lubrication oil, hydraulic fluid, grease, avgas, JP-4, JP-5, MEK (methyl ethyl ketone), isopropyl alcohol, and PD-680.

2.8.1.8 Site 19, Post-World War II Burial Site

Site 19, Post-World War II Burial Site, is located in the southeastern part of the old portion of NAS Fallon (Fig. 2.8.1.i). The site reportedly received trash and refuse generated during base-decommissioning activities between the years of 1946 to 1949. Landfilling was conducted through trench burial. The disposal trenches were probably excavated with a bulldozer to a depth of less than 2.4 m (8 ft), 2.4 m being the average depth to the water table at the site.

It is estimated that as much as 1,650 m^3 (2,200 yd^3) of waste were disposed of at Site 19. Wastes deposited included trash, vehicles, wood, paints, thinners, and approximately 3,785 L (1000 gal) of solvents.

2.8.1.9 Site 23, Shipping and Receiving Disposal Site

Site 23, Shipping and Receiving Disposal Site, is located in the northeastern part of the old portion of the base (Fig. 2.8.1.i). The site consists of the shipping and receiving disposal area, the aircraft burial area, and an area where asbestos was reportedly buried. Transformers containing PCB fluids were also allegedly stored at the site. Disposal activities at the shipping and receiving disposal area consisted of landfilling salvageable material and equipment formerly stored on the site. Although the source of this material is unknown, it is surmised that the salvage items originated through Public Works and aircraft maintenance activities. Landfilling was accomplished by burial in four bulldozed trenches. Portions of this area have subsequently been paved. An estimated 975 m^3 (1,300 yd^3) of refuse is suspected to be landfilled in the trenches. Buried wastes include junk, debris, metal, rubble, paints, thinners, petroleum liquids, oils, and lubricants.

Additional disposal activities at the site include the reported burial of a burned-out DC-3 aircraft carcass south of the landfill trenches (Fig. 2.8.1.i). It is not known if the plane contained fuel or other liquids, but it is assumed that approximately 379 L (100 gal) of liquid petroleum hydrocarbons were present at the time of burial.

As shown in Fig. 2.8.1.i, asbestos was reportedly buried at the site in

1984. Approximately 6.75 m^3 (9 yd^3) of this material were double-bagged, crated, and buried.

2.8.2 Contaminated Media of Concern, Exposure Pathways, ARARs, and Remedial Action Objectives

A synopsis of media-specific contaminant transport pathways, assimilation routes, exposure points, and affected biota for NAS Fallon is given in Appendix C. The following paragraphs expand on these initial evaluations in light of the additional characterization activities which have been completed at the Group IV Sites.

2.8.2.1 Contaminated Media of Concern

Results from soil tests, records searches, and inspections conducted during the Phase I study support the following propositions (Dames and Moore 1988):

Site 10, GATAR Compound: although no reports of PCB leakage are reported, the storage of transformer oils and reported burial of PCB containers suggest that some PCB soils contamination in the area is likely. Based on the quantities of waste routinely stored at the site, it is also probable that other hazardous materials (primarily paints, solvents, and waste oils) have been introduced to the subsurface environment. Soils contamination resulting from asbestos disposal west of Site 10 is unlikely because disposal methods appear to be appropriate.

Site 11, Paint Shop: because of the amount of wastes (primarily paints and thinners) spilled or dumped at the site, soils and shallow groundwater contamination is likely.

Site 12, Pest Control Shop: based on the amount of pesticides handled at the site over its lifetime of operation, soil and groundwater contamination near the leach fields is suspected.

Site 13, Boiler Plant Tanks: petroleum hydrocarbon contamination of soils and possibly groundwater is suspected near the fill ports of the two underground storage tanks.

Site 14, Old Vehicle Maintenance Shop: it is surmised that contaminant spills in the lube pits were contained by the paved floors. Contamination of the subsurface environment from the lube pits is thus considered unlikely. Contaminants are, however, expected to be present in the soils and possibly the groundwater near the underground storage tanks.

Site 16, Old Fuel Farm: based on the amount of petroleum product handled at the site and the contaminated soils exposed during excavation activities, soils and groundwater contamination at the site is probable.

Site 17, Hangar 4: three soil samples were taken in the runoff area south of Hangar 4. Samples were analyzed for TPH (EPA method 418.1) and VOC (EPA method 8240) to assess the potential for soils contamination from Hangar 4 activities. Results indicate TPH values range from 57 ppm to 350 ppm. Acetone was detected in two of the samples (120 ppb and 710 ppb) and trace amounts of TCE and DCA were detected in one sample. Contamination of soils and possibly the groundwater in the area is thus considered likely.

Site 19, Post-World War II Burial Site: wastes disposed of in the area (particularly suspected liquid solvents) may have contaminated soils and groundwater in the area.

Site 23, Shipping and Receiving Disposal Site: the type and quantity of waste materials buried in the four trenches have the potential to contaminate the subsurface environment of the surrounding area. Asbestos contamination of subsoils is considered minimal because the materials were properly disposed of. Leakage of liquid wastes surmised to be present in the allegedly buried aircraft may have contaminated the underlying soils and shallow groundwater.

Phase II screening activities at the Group IV sites consisted of performing two EM-31 geophysical surveys and analyzing numerous groundwater test holes installed throughout the area. The geophysical surveys were used to locate the containers of PCB fluids reportedly buried at Site 10 and to delineate the buried waste at Sites 19 and 23 inclusive (the two sites are adjacent to one another and hence one survey was used to encompass both). Results of the geophysical activities (Appendix A) were inconclusive.

Results from the groundwater test hole screening activities are given in Appendix B. Due to the close proximity of the study sites, the two contaminant plumes disclosed in the groundwater screening activity encompass several adjacent sites. In the following paragraphs, each of the contaminated areas thus disclosed are discussed in the context of their anticipated source areas (as inferred from the regional groundwater flow direction). Groundwater screening activities were not conducted at Site 17, Hangar 4, or in the area of contamination at Site 11, Paint Shop, because paving prevented installation of the necessary boreholes.

As shown in Fig. 2.8.2.i, results from screening seventeen groundwater test holes delineated a contaminant plume thought to be emanating from Site 12, Pest Control Shop, and Site 13, Boiler Plant Tanks. The north section of the plume appears to be contiguous with a plume emanating from Site 14, Old Vehicle Maintenance Shop (Fig. 2.8.2.ii). As indicated in Appendix B, Table B.3, several of the groundwater test holes contained contaminants of an unknown nature as inferred from GC and PID screening responses. It is anticipated that these anomalous screening responses are indicative of pesticide contaminants in the surrounding subsurface.

Groundwater screening activities associated with Site 14, Old Vehicle Maintenance Shop, consisted of analyzing 49 groundwater test holes (Appendix B, Table B.2). Test hole locations and the resulting plume boundary are shown in Fig. 2.8.2.ii. As mentioned above, the southeastern tail of the plume appears to merge with contaminants associated with Sites 12 and 13.

The locations of the groundwater test holes installed to assess contaminants at Sites 10, 16, 19, and 23 are shown in Fig. 2.8.2.iii. Ninety-six groundwater test holes were screened in this area, and results from screening are given in Appendix B, Table B.4. Screening results facilitated delineation of a contaminant plume underlying the area (Fig. 2.8.2.iii). It is anticipated

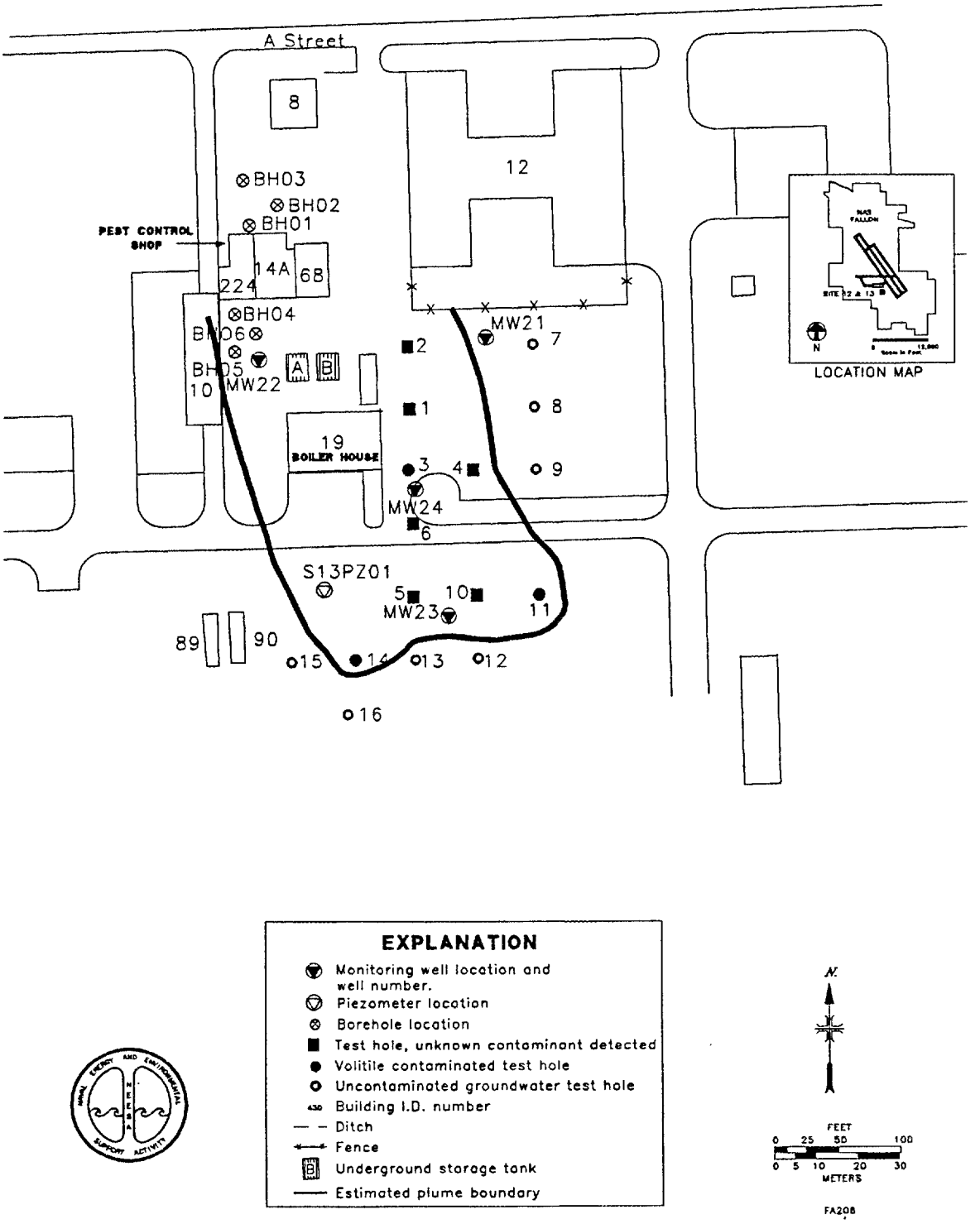


Fig. 2.8.2.i Site 12, Pest Control Shop, and Site 13 Boiler Plant Tanks. Groundwater test hole and analytical sampling locations.

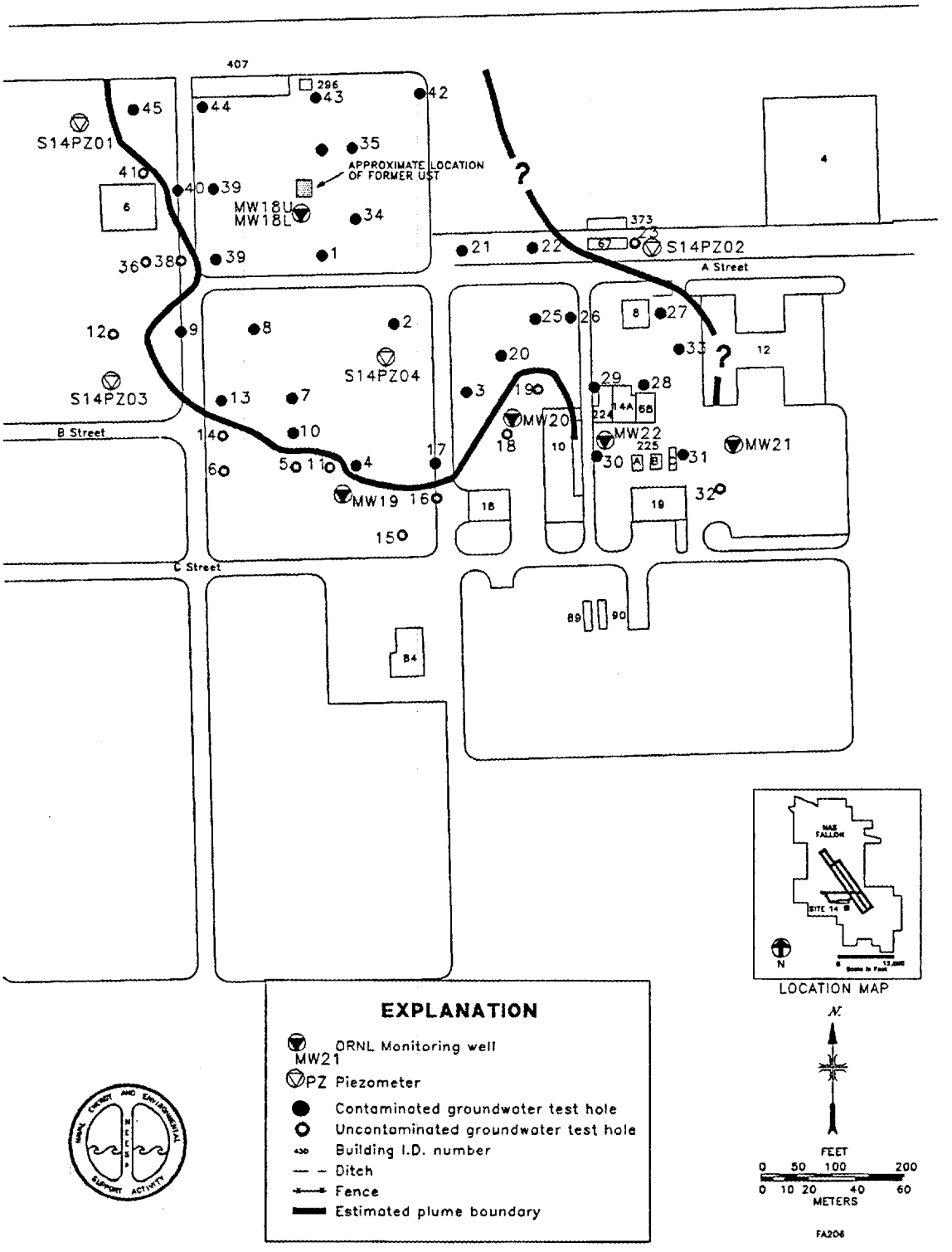


Fig. 2.8.2.ii. Site 14, Old Vehicle Maintenance Shop. Groundwater test hole and analytical sampling locations.

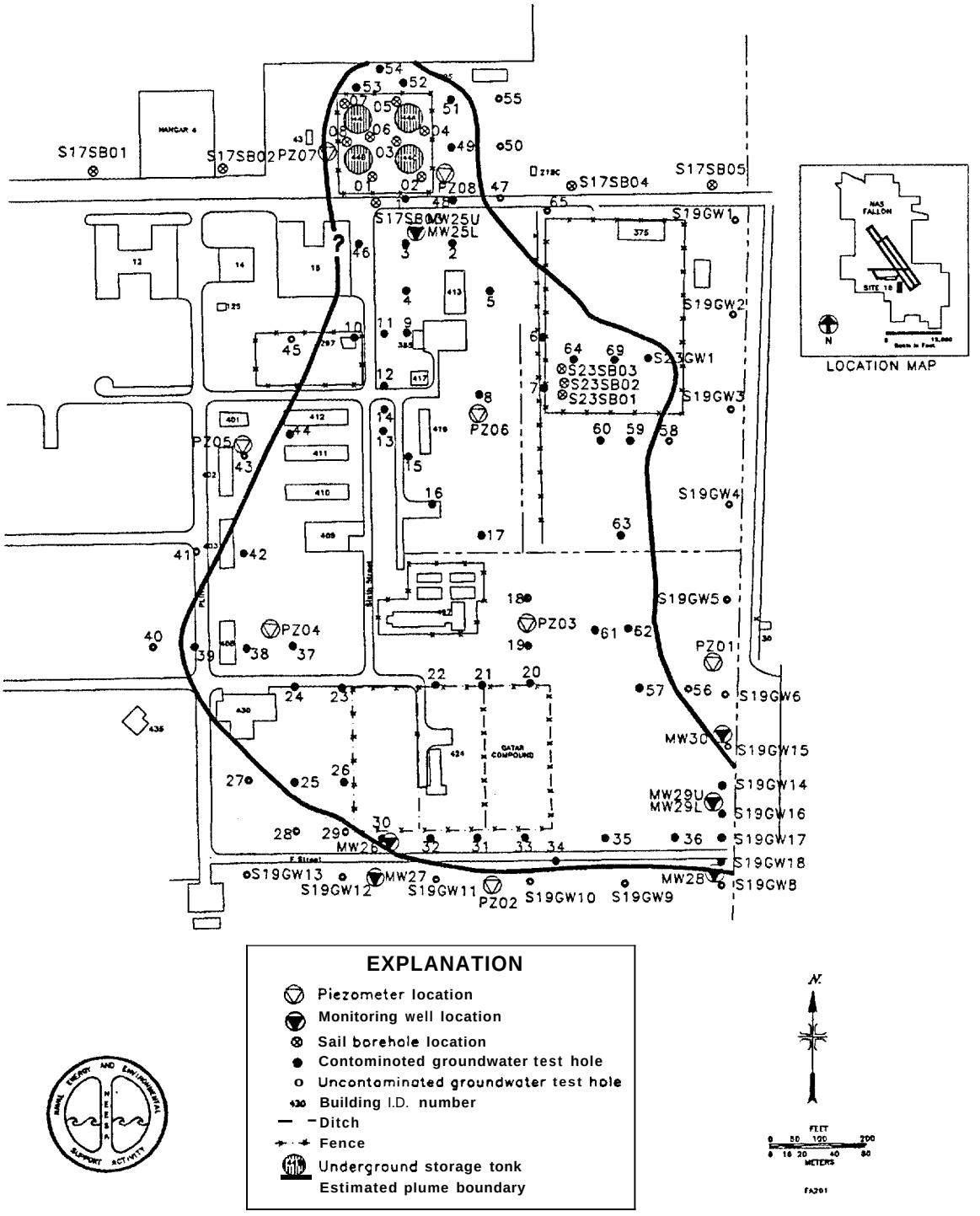


Fig. 2.8.2.iii Site 10, GATAR Compound; Site 16, Old Fuel Farm; Site 17, Hangar 4; Site 19, Post-World War II Burial Site; Site 23, Shipping and Receiving Disposal Site. Groundwater test hole and analytical sampling locations.

that the principal source area for this plume is Site 16, Old Fuel Farm. The downgradient edge of the plume (southeastern corner) affords a potential seepage discharge source into the unnamed drainage channel separating Site 9, Wastewater Treatment Plant, and the Group IV sites.

Numerous soil, sediment, and groundwater samples taken from the Group IV sites have been submitted for laboratory analysis in conjunction with Phase II RI activities. Results are not yet available. Phase II sampling locations associated with each site are:

Site 10, GATAR Compound: five soil borings taken to 1.2 m (4 ft) (Fig. 2.8.2.iv);

Site 12, Pest Control Shop: six soil borings taken to the water table and one single completion (MW22) monitoring well (Fig. 2.8.2.i);

Site 13, Boiler Plant Tanks: two single completion monitoring wells (MW23, MW24) and one piezometer (Fig. 2.8.2.i);

Site 14, Old Vehicle Maintenance Shop: one dual completion monitoring well (MW18U, MW18L), three single completion monitoring wells (MW19, MW20, MW21), and four piezometers (Fig. 2.8.2.ii);

Site 16, Old Fuel Farm: two dual completion wells (MW25U, MW25L, MW29U, MW29L), four single completion wells (MW26, MW27, MW28, MW30), eight soil borings around the underground tanks, and eight piezometers (Fig. 2.8.2.iii);

Site 17, Hangar 4: five soil borings to 1.2 m (4 ft) (Fig. 2.8.2.iii);

Site 23, Shipping and Receiving Disposal Site: three soil borings to 1.2 m (4 ft) (Fig. 2.8.2.iii).

No analytical sampling activities were conducted at Site 11, Paint Shop, because paving prevented access to the contaminated soils. The downgradient monitoring wells and piezometers associated with Site 16, Old Fuel Farm, will also be used for analytical assessment of contaminants in adjacent areas (specifically the two landfills, Sites 19 and 23). Although laboratory results are not yet available, sampling activities indicate floating hydrocarbon product is present in MW18U downgradient from Site 14 (Fig. 2.8.2.ii).

Screening and characterization activities at the Group IV sites indicate the primary contaminants of concern are petroleum hydrocarbon compounds which

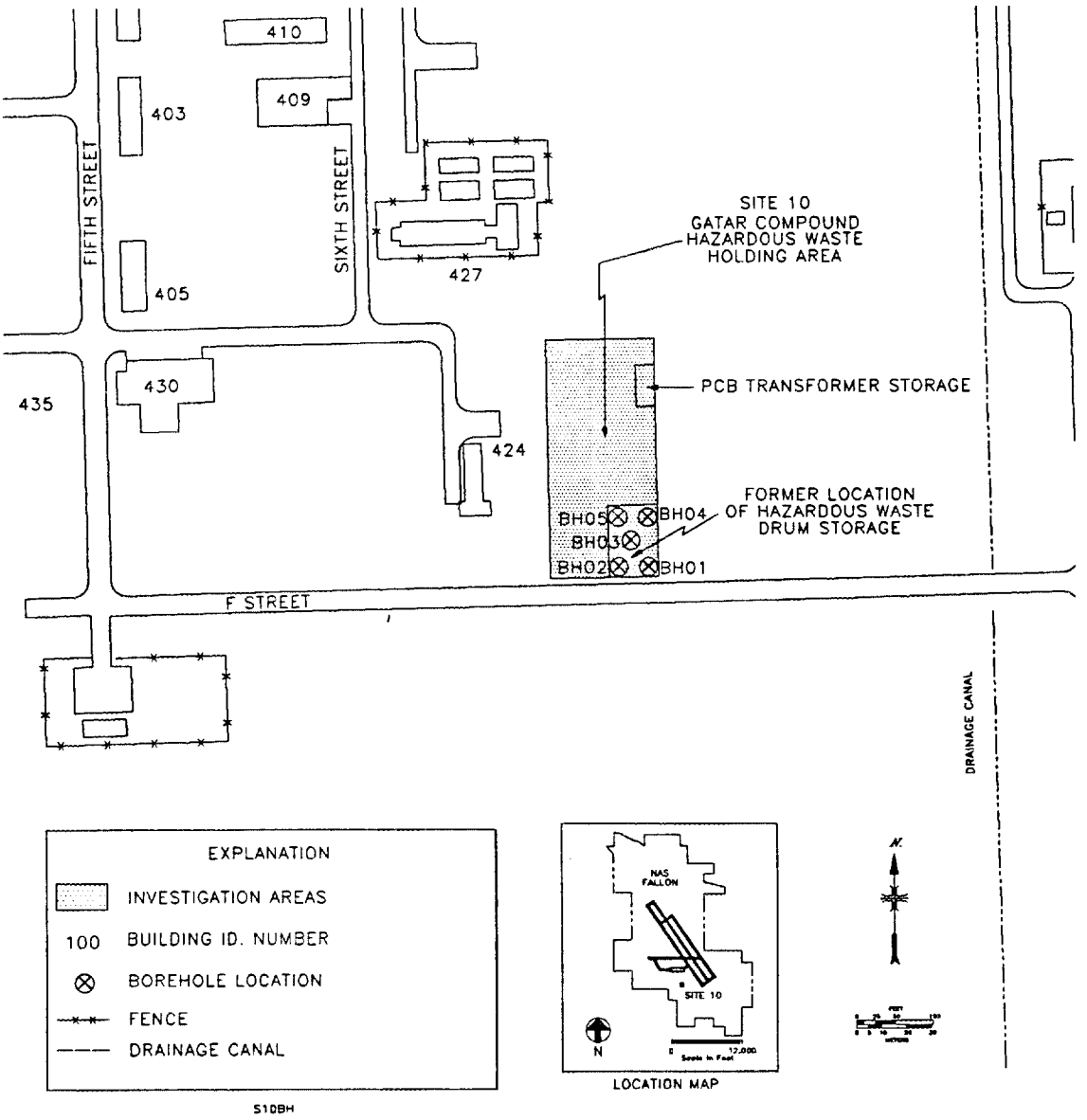


Fig. 2.8.2.iv Site 10, GATAR Compound. Analytical sampling locations.

permeate the soils and shallow groundwater of the area. Additionally, small localized areas of PCB and/or pesticide contaminants may also be present. The atmosphere is not considered to be a contaminated medium of concern because high vapor pressure contaminants will rapidly volatilize and disperse. The air quality of the surrounding region is good, and prevailing air currents will further enhance the rapid mitigation of any volatile contaminants once they enter the atmosphere.

2.8.2.2 Exposure Pathways

Direct exposure pathways for contaminated soils at the Group IV sites include dermal contact, ingestion, and inhalation of dust particles and volatile constituents. Affected biota include indigenous plants and burrowing animals as well as personnel associated with site excavation activities. Plant and animal populations are controlled on NAS Fallon property, and exposures associated with these biota are thus minimized. Because NAS Fallon is a restricted area, direct exposure to the human populace is restricted to naval personnel and subcontractors who have adequate training in handling contaminated materials. Health and safety measures requiring effective environmental monitoring, environmentally safe construction practices (i.e., dust control and explosion proof equipment), and interim protective measures (i.e., protective clothing, respirators, and appropriate decontamination procedures) further mitigate exposure to contaminated soils during on-site activities. Restricted access and site activities geared towards environmental safety thus prevent contaminated soils at the Group IV sites from constituting a primary exposure pathway.

Direct exposure pathways for groundwater include use of contaminated groundwater extracted from the shallow aquifer and percolation of contaminants into the underlying basalt aquifer. The basalt aquifer supplies domestic water to the surrounding populace and is thus considered a sensitive exposure pathway. The shallow aquifer is not pumped on NAS Fallon property and, due to its high salinity, is not used for human consumption in the surrounding area (Appendix C). One well tapping the shallow aquifer is known to exist approximately one-half mile southeast of the base. Although the use of this well is unknown, its likely purpose in light of the poor water quality is to supply

water for livestock. Direct exposures to contaminants through extraction of the shallow groundwater in the area are thus believed to be minimal.

Available site-characterization results indicate that contaminants are not migrating into the deep basalt drinking water aquifer. The PA/SI report (Dames and Moore 1988) postulates the existence of an upward flow gradient in the surrounding area. Additionally, a confining clay layer is known to exist between the contaminated shallow aquifer and the deep basalt aquifer in certain portions of the base (ERM-West 1988). It is believed that these natural containment mechanisms prevent contaminants from reaching the regional domestic water source.

As with soils, contaminated groundwater associated with Group IV sites does not constitute a substantial direct exposure pathway. Soils may, however, serve as a source term for atmospheric transport of contaminated particulates, and both contaminated soils and groundwater may act as a source for contaminating surface flows. Contaminated surface flow may then serve as an exposure pathway to sensitive receptors.

Exposures to wind-blown transport of contaminated soils are minimal due to restricted access in the immediate vicinity, the natural cohesive properties of native surface soils, and dust control measures employed during construction activities. In addition, the air quality of the region is good, and airborne particulate matter is quickly dispersed. Hence, atmospheric transport is not considered a threat to the environment.

Downward transport of residual soils contamination to the underlying aquifer via naturally occurring surface water percolation is not considered significant because of the semiarid climate. Indeed, the alkali flats in the surrounding area indicate a negative regional water balance. It is surmised that because contaminants were originally introduced at or near the ground surface, the downward transport necessary to produce existing groundwater contamination resulted from gradients introduced from excessive spills or dumping and not from the natural percolation process.

The majority of groundwater contaminants present at the Group IV sites are the result of past spills, leaks, and handling activities. Most of these activities have been discontinued, and, as such, the source areas and resulting gradients responsible for downward transport have been removed. Source termination and the negative regional water balance are thus expected to

minimize percolation of surface contamination to the underlying water table at all Group IV sites with the exception of Site 12. Site 12, Pest Control Shop, does afford a substantial transport mechanism for downward transport of near-surface contaminants. The leach field areas associated with the site create a downward flow gradient which may cause percolation of contaminants to the underlying aquifer.

Surface flow runoff resulting from excessive precipitation or human activities may transport contaminated surface sediments or dissolved constituents to the regional surface drainage system. In addition, contaminants presently associated with the shallow groundwater (from previous spills or percolation from the Site 12 leach fields) may migrate downgradient for eventual seepage discharge into the surrounding drainage ditches. Restricted access and institutional controls again minimize any sensitive surface flow exposures on NAS Fallon property. Contaminated surface flows do, however, have the potential to transport contaminants off site to sensitive exposure points. As explained in Appendix C, sensitive off-site exposure points associated with surface flows include recreational exposure, direct exposure to biota which inhabit contaminated surface flow channels and wetlands, secondary exposure to humans who consume contaminated biota, and exposures associated with the final deposition of contaminated waters into the neighboring reservoirs and wetlands (Carson Lake and Stillwater Wildlife Refuge).

Ground- and surface-water transport to off-site receptors is thus the primary exposure pathway for contaminants of concern at the Group IV sites. Potential off-site transport mechanisms include: 1) eventual seepage discharge of groundwater contaminants to surface flows migrating off site, and 2) discharge of contaminated surface flows (from rainfall and human activity) to surface water drainage systems. The principal exposure pathway of concern is thus the regional surface flow system extending from the downgradient (southeastern) edge of the base to either Carson Lake or the Stillwater Wildlife Refuge.

As explained in Appendix C, the regional drainage system was constructed to intercept and drain the shallow aquifer. As shown in Fig. 2.8.1.i, the unnamed drainage ditch and the Lower Diagonal Drain located along the eastern

and southern boundaries of the area of concern are the primary receptor points for groundwater or surface flow transport of contaminants from the Group IV sites. Figure 2.8.2.v is a flow chart which summarizes the above discussion and depicts the screening logic used in determining the exposure pathways of concern. As shown in the flow chart, the unnamed tributary to the Lower Diagonal Drain and subsequent off-site surface flows are the primary exposure pathways associated with contaminants at the Group IV Sites.

2.8.2.3 ARARs and Remedial Action Objectives

Until the presence of additional contaminants of concern (PCBs and pesticides) is confirmed, ARARs and remedial action objectives will be based on action limits for petroleum hydrocarbon contaminants. ARARs for petroleum hydrocarbon contaminants are taken from the State of Nevada Division of Environmental Protection Hydrocarbon Cleanup Policy (NDEP 1987) as given in Appendix D. Table 2.8.2.i lists media-specific remedial action objectives predicated on the petroleum hydrocarbon ARARs given in Appendix D.

As stated in this NDEP Policy, remediation of petroleum-hydrocarbon-contaminated soils and groundwater may be required if action limit concentrations are exceeded. Action limit concentrations are set at 100 mg/kg total petroleum hydrocarbons (TPH) for soils and the EPA maximum contaminant levels (MCLs) or recommended maximum contaminant levels (RMCLs) for groundwater used as a potable source. Relevant MCLs are 5.0 μg/L for benzene (established), 700 μg/L for ethylbenzene (proposed), 10,000 μg/L for total xylene (proposed), and 2,000 μg/L for toluene (proposed). If these action limits are exceeded, the need for remedial activity is then evaluated with respect to site-specific parameters such as use of the contaminated medium; contaminant transport potential; the degree, magnitude, and toxicity of contaminants; and economic cost/benefit considerations. Although contaminants of concern may indeed exceed action limits at the Group IV Sites, the need for active remediation must still be evaluated in light of the restricted access to NAS Fallon property and the lack of use of the upper aquifer.

While the existence of soil and groundwater contaminants in excess of action limits does not in itself mandate active remediation, the existence of free-phase product on the groundwater in excess of 1.27 cm (0.5 in.) does

GROUP IV SITES: SITES 10–14, 16, 17, 19, AND 23

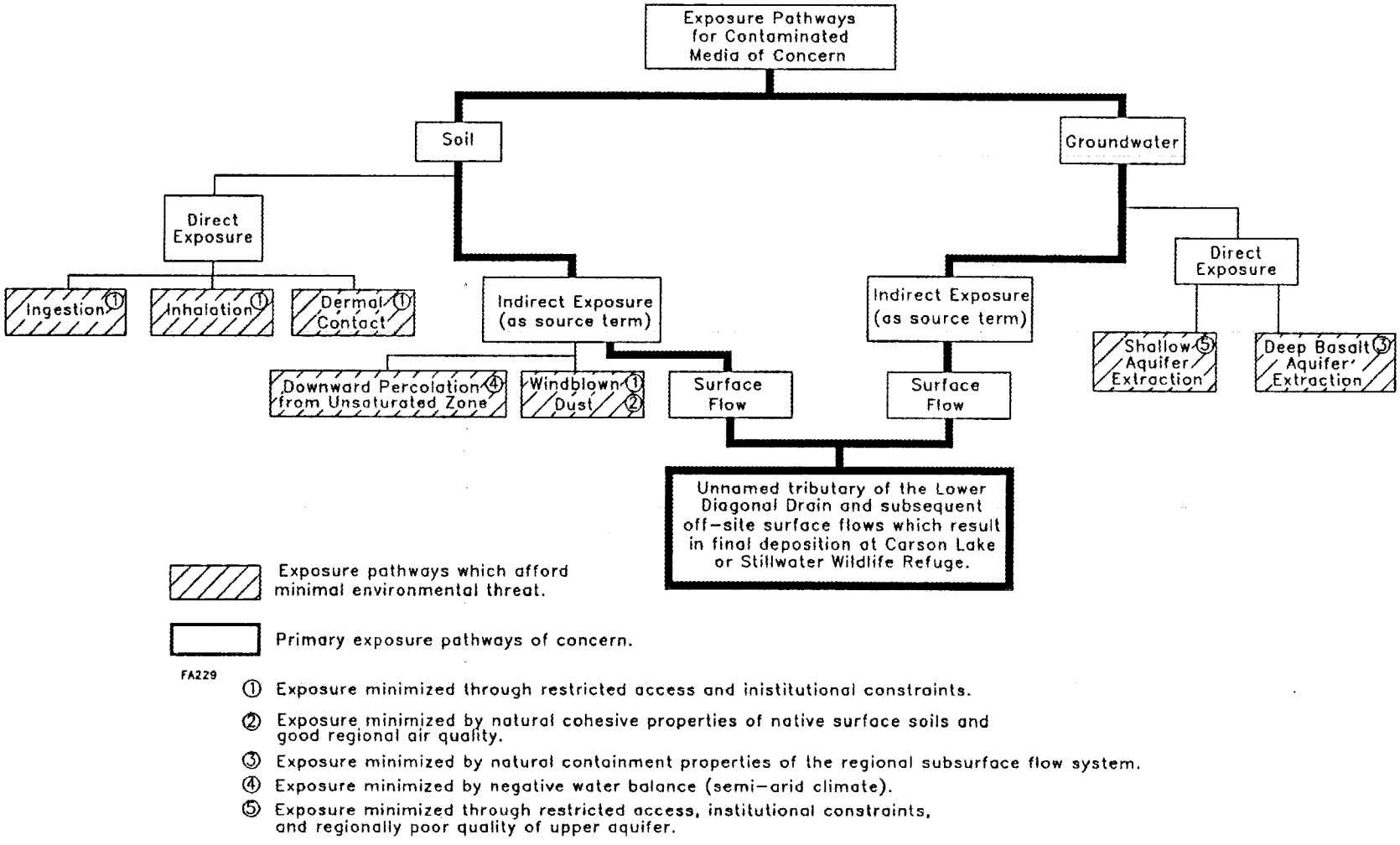


Fig. 2.8.2.v Flow chart of exposure pathways associated with Group IV Sites.

Table 2.8.2.i. Group IV sites: Sites 10 - 14, 16, 17, 19, and 23. Remedial action objectives

Remedial Action Objectives - Group III Sites			
Contaminated Media		Applicable or Relevant and Appropriate Requirements (ARARs)	Media-Specific Remedial Action Objectives
Soil		NDEP Hydrocarbon Cleanup Policy	Prevent exposures to soils contaminated in excess of 100 mg/kg TPH
Groundwater	Dissolved Product	NDEP Hydrocarbon Cleanup Policy	Prevent exposures to groundwater used as a drinking water source contaminants in excess of 5.0 μg/L for benzene, 700 μg/L for ethylbenzene, 10,000 μg/L for total xylene, and 2,000 μg/L for toluene. Prevent exposures to seepage discharge of groundwater contaminants into surface waters in excess of 1.0 mg/L TPH.
	Free Product	NDEP Hydrocarbon Cleanup Policy	Initiate active free-product removal operations when free-phase product exists on the groundwater in excess of 1.27 cm (0.5 in.)

TPH: total petroleum hydrocarbons

require the implementation of an active removal action (Appendix D).

2.8.3 General Response Actions, Technology Types, and Site-Specific Process Options

Tables 2.8.3.i and 2.8.3.ii list the general response actions, technology types, and process options for contaminated soils and groundwater at the Group IV Sites. The table listings offer varying degrees of environmental protection based on: 1) the contaminated media of concern and remedial action objectives formulated in Table 2.8.2.i; and 2) the associated exposure pathways and affected receptors discussed in Sect. 2.8.2. The process options formulated in the tables will serve to form the remedial action alternatives for the Group IV Sites as Phase II work progresses.

As shown in Table 2.8.3.i, general response actions for soils include institutional measures, containment, treatment, and removal. Applicable technology types and process options required for implementation are listed accordingly for each general response action. Restricted access is listed in conjunction with the no action technology type because NAS Fallon is already a restricted area.

General response actions for contaminated groundwater also include institutional measures, containment, treatment, and removal (Table 2.8.3.ii). Technology type and appropriate process option listings follow for each of the general response categories. As with soils, on-site restricted pumping is included with the no action technology type because the upper aquifer is not pumped on NAS Fallon property.

3. SUMMARY OF ENVIRONMENTAL CONTAMINATION AT NAS FALLON

Results from IR Program investigations completed to date indicate that the vast majority of contaminants of concern at NAS Fallon are petroleum hydrocarbon related. These contaminants include JP-4, JP-5, leaded and unleaded gasoline, waste oils and lubricants, hydraulic fluids, and numerous

Table 2.8.3.1. Group IV sites: Sites 10 - 14, 16, 17, 19, and 23. General response actions, technology types, and process options for contaminated soil

Group IV Sites: Sites 10 - 14, 16, 17, 19, 23			
Contaminated Media	General Response Actions	Technology Types	Process Options
Soil	Institutional Measures	No action/restricted access Continued monitoring Deed restrictions	(No action/restricted access) (Continued monitoring) (Deed restrictions)
	Containment	Capping (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Stabilization (in situ and following removal)	Grout injection, In situ vitrification, Bituminous concrete encapsulation
		Landfilling (following removal/treatment)	On-site landfill, Off-site landfill
	Treatment	Thermal treatment (in situ and following removal)	RF thermal stripping, Soil baking/thermal desorption, Incineration
		Chemical treatment (following removal)	Neutralization/stabilization, Precipitation, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor, Landfarming, Composting
		Physical separation/extraction (following removal)	Soil flushing, Centrifuging, Steam stripping, Soil venting, Ultrasonics
	Removal	Excavation	Backhoe, Loader, Truck or rail transport for subsequent on/off-site treatment/disposal

RF: radio frequency

Table 2.8.3.ii. Group IV sites: Sites 10 - 14, 16, 17, 19, 23.
General response actions, technology types, and
process options for contaminated groundwater

Group IV Sites: Sites 10-14, 16, 17, 19, 23			
Contaminated Media	General Response Actions	Technology Types	Process Options
Groundwater	Institutional Measures	No action/restricted pumping (on site) Restricted pumping (off site) Continued monitoring Deed restrictions	(No action/restricted pumping [on site]) Provide alternate water sources to users (Continued monitoring) (Deed restrictions)
	Containment	Vertical containment (in situ)	Clay cap, Synthetic membrane, Paving/concrete
		Horizontal containment (in situ)	Slurry wall, Sheet piling, Bio-clogging, Gradient alteration through extraction/injection
	Treatment	Thermal treatment (following removal)	Thermally enhanced volatilization, Incineration
		Chemical treatment (following removal)	Neutralization, Precipitation, Ion-exchange, Ultraviolet/ozone
		Biological treatment (both in situ and following removal)	Bionutrient injection, Surface bioreactor
		Physical separation/extraction (following removal)	Air stripping, Carbon filtration, Oil/water separation, Centrifuging
	Removal	Groundwater pumping	Well field extraction, Permeable trench extraction
		Free product pumping (in situ)	Single recovery skimmer, Dual recovery system

solvents and cleaners. Although not confirmed, other types of contaminants such as paints, thinners, metals, PCBs, and pesticides may also be present in small, localized areas. In addition, methane contamination may be present as a by-product of bioactivity in the former base landfills.

Introduction of contaminants to the environment has resulted from deliberate disposal activities (both through dumping and landfilling) and accidental spills and leaks associated with normal activities at the base. Base activities have contributed to environmental contamination since the facility was established in 1943, although problems have been greatly mitigated since the mid-1980s by environmentally sensitive management practices.

Fortunately, characteristics of the native environment such as the semiarid climate, good surrounding air quality, and naturally poor water quality of the upper aquifer have minimized contaminant exposure to surrounding receptors. Additionally, institutional restrictions, restricted access, and environmental monitoring further mitigate contaminant exposure on base property.

The principal exposure pathways of concern associated with NAS Fallon contamination appear to be the surface flows and shallow drainage systems to which the base contributes. Off-site transport of contaminants via surface flows may then provide an exposure route to sensitive receptors. The poor regional quality of surface waters in the surrounding area prevents use of these waters as a potable source. Sensitive receptors are thus limited to populace exposed to surface waters through recreational contact and flora and fauna indigenous to downstream flows and wetlands.

Phase II screening and sampling activities combined with other environmental assessments (NDEP 1990; ERM-West 1988; Dames and Moore 1988) indicate that areas of contiguous petroleum hydrocarbon contamination can be associated with eleven of the twenty-one IR Program sites at NAS Fallon. These sites include: Site 1, Crash Crew Training Area; Site 2, New Fuel Farm; Site 3, Hangar 300 Area; Site 4, Transportation Yard; Site 6, Defuel Disposal Area; Site 12, Pest Control Shop; Site 13, Boiler Plant Tanks; Site 14, Old Vehicle Maintenance Shop; Site 16, Old Fuel Farm; Site 19, Post-World War II Burial Site; and Site 23, Shipping and Receiving Disposal Site. It is surmised that

contaminants underlying Sites 4, 19, 23, and perhaps 12 may not have resulted from past activities at each site; rather, contamination is the result of subsurface migration from source areas at adjacent sites.

Records of past activities and anomalous responses from screening instruments suggest minor amounts of other contaminants may also be present in certain areas. Areas of concern and suspected contaminants include: methane gas, metals, and paint wastes at Sites 20, 21, 22, and 19, the base landfills; paint wastes at Site 11, Paint Shop; pesticides at Site 12, Pest Control Shop; and PCBs at Site 10, GATAR Compound, and Site 23, Shipping and Receiving Disposal Site. Although reported burials of asbestos have occurred at Site 23 and near Site 10, environmental contamination is not suspected because of proper disposal methods.

Current environmental assessment activities indicate NAS Fallon IR Program sites are not contributing excessive contamination to surface flows emanating from the base. Contaminants appear to be contained in the shallow subsurface underlying the facility with little or no contaminant migration off site.

4. DATA NEEDS AND RECOMMENDATIONS FOR FUTURE RI INVESTIGATIONS

Several important data needs must be addressed to effectively develop and screen remedial action alternatives. These needs include a determination of:

1. The impact of current base activities on introduction and subsequent migration of contaminants in the environment. This is especially important at sites which are currently active such as Site 2, New Fuel Farm; Site 9, Wastewater Treatment Plant; and Site 12, Pest Control Shop.

2. The current transport rate of contaminants off site via migration to surface flows. This needs to be firmly documented over time to accurately assess potential environmental impact to off-site receptors.

3. Sensitive off-site receptors who may come in contact with contaminants transported off site through either surface flows or groundwater extracted from the uppermost aquifer.

4. Additional contaminants of concern (as opposed to petroleum hydrocarbons) which may be present at NAS Fallon. This is most relevant at sites where activity records or anomalous responses from screening instruments suggest the presence of unknown contamination.

5. Additional delineation of source areas, migration rates, and the presence of free-phase petroleum hydrocarbon product in the plume areas currently known to exist. This information will be necessary to assess the effectiveness of remedial alternatives in meeting established remedial objectives.

It is suggested that future RI assessments include the following activities to address the data needs stated above.

1. Assess the possibility of leaks at Site 2, New Fuel Farm, by conducting an inventory balance and a leak-detection study. In addition, it is suggested that modeling studies be initiated at Site 12, Pest Control Shop; Site 17, Hangar 4; and Site 9, Wastewater Treatment Plant, to assess the quantities and contaminant transport potential of effluents generated at each site. The leach fields, wash activities, and settling ponds, associated with Sites 12, 17, and 9 respectively, each contribute liquids to the shallow subsurface which may enhance percolation to the shallow water table.

   Modeling will require a determination of the overall daily rate of influent water to each site. This may be determined by instrumenting the water-supply lines to each facility. Water-balance parameters of the area may then be used in conjunction with known hydrogeologic data to obtain order-of-magnitude estimates of the daily discharge rates to surrounding subsoils.

If these studies indicate the sites have a significant effect on the subsurface environment, additional studies should be initiated to assess the contaminant load in discharged effluents. This would be accomplished by implementing a time-series sampling and analysis plan for discharged effluents (e.g., sampling of the Site 9 settling ponds, the leach field supply lines at Site 12, and wash water effluent from Site 17 collected in catchment basins placed in adjacent drainage areas).

The feasibility of implementing interim protective measures at these sites should be investigated if so warranted by modeling. Protective measures may include additional treatment of effluent in the Site 9 settling ponds, collection/treatment of effluents prior to disposal at Sites 12 and 17, and collection/treatment/off-site disposal of effluents from Sites 12 and 17.

The subsurface impact of activities at Site 11, Paint Shop, should also be further investigated. This activity should include coring and sampling of expected areas of contamination underneath recently paved surfaces as well as sampling to the west and south of the building. Modeling is not suggested unless the containment afforded by recent paving appears inadequate.

2. Establish and conduct a comprehensive time-series sampling and analysis plan to document the amount of contamination being transported off site via surface water flows. This should include, at a minimum, periodic monitoring of the Lower Diagonal Drain where it exits the base. If contamination becomes evident, additional on-site tributaries should be monitored to delineate sensitive exposure points and seepage faces. The frequency of sampling activities should be sufficient to delineate seasonal fluctuations and/or trends in transport rates. Weekly sampling is suggested.

3. Implement an investigation through a records search and interview process to disclose potential off-site receptors of contaminated surface and/or groundwater flows. The investigation should not only include potential receptors (if any) but also confirm the means of exposure (e.g., ingestion of potable water or dermal contact through irrigation/stock water usage).

4. If results from initial rounds of laboratory analysis indicate the presence of additional contaminants of concern (e.g., PCBs, pesticides, paint wastes, and metals), additional sampling activities should be initiated to confirm the extent and magnitude of such contamination. This is very important for the environmentally sensitive contaminants such as pesticides and PCBs.

5. Future RI sampling activities should include a careful determination of the amount of free product (if any) in monitoring wells. In areas where plumes exist, information of past activities and inventories should be combined with current hydrogeological data to generate simulations of subsurface transport through modeling. Source areas and contaminant-transport potential may thus be further defined. Subsequent subsurface-sampling initiatives should be initiated if suggested by modeling.

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ACRONYMS AND ABBREVIATIONS

2,4-D	(2,4-dichlorophenoxy) acetic acid
ARARs	Applicable or Relevant and Appropriate Requirements
avgas	aviation gasoline
cm	centimeter
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DCA	dichloroethane
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
EE/CA	Engineering Evaluation/Cost Analysis
EPA	Environmental Protection Agency (United States)
FS	feasibility study
ft	feet
gal	gallons
GC	gas chromatograph
GSE	Ground Support Equipment
GATAR	Ground to Air Transmitting and Receiving (compound)
in.	inch
IR Program	Installation Restoration Program
kg	kilograms
L	liters
LEL	lower explosive limit
m	meters
MCLs	maximum contaminant levels
MEK	methyl ethyl ketone
μg/kg	micrograms per kilogram
μg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
ml	milliliter
mogas	motor vehicle gasoline

NAAS Fallon	Naval Air Auxiliary Station Fallon
NAS Fallon	Naval Air Station Fallon
NDEP	Nevada Division of Environmental Protection
NAPL	non-aqueous phase liquid
ORNL	Oak Ridge National Laboratory
ORNL/GJ	Oak Ridge National Laboratory/Grand Junction
OSWER	Office of Solid Waste and Emergency Response
PA/SI	preliminary assessment/site inspection
PC	personal computer
PCB	polychlorinated biphenyl
PID	photoionization detector
ppb	parts per billion
ppm	parts per million
QC	quality control
RF	radio frequency
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RMCLs	recommended maximum contaminant levels
TCA	trichloroethane
TCE	trichloroethene
TPH	total petroleum hydrocarbons
UEL	upper explosive limit
USRADS	ultrasonic ranging and data collection system
VOC	volatile organic compounds

APPENDIX A

GEOPHYSICAL SURVEY FIELD SCREENING

Field Screening Using EM-31 Geophysical Surveys And USRADS

Introduction

During August 1989 and again in November 1990, electromagnetic (EM) geophysical surveys were performed at sites at NAS Fallon. These surveys involved the use of a Geonics EM-31 electromagnetometer coupled with an ultrasonic ranging and data collection system (USRADS). Specifically, the EM was employed to map differences in the electrical conductivity of the shallow groundwater and soil profile believed to be associated with floating jet fuel (JP-5), varying degrees of groundwater salinity, and/or buried metallic debris. The surveys were performed to help guide the selection of monitoring well locations at Site 1, Site 2, Site 10, Site 19, and Site 23.

Hardware

The EM geophysical surveys were conducted using a Geonics EM-31 field-portable instrument coupled with USRADS. The EM-31 data provide a measure of the conductivity of the soil in the surveyed area. Underground conductivity contrasts often yield clues about the soil type, salinity, water content, and the location of buried metal.

USRADS is a patented, computerized data acquisition system developed by Oak Ridge National Laboratory to collect and relate data from field portable instruments to the precise physical location of the data points.

RF is used for system timing, communications, and data transfer. The propagation time of an ultrasonic signal serves as a device to measure the distance travelled while scanning. The PC is used to: calculate the surveyor position; reduce, store, and display data; prepare reports; and transfer data into electronic data bases. The hardware included in USRADS consists of a surveyor's backpack, fifteen

stationary receivers, a master receiver, a custom computer interface, and a PC.

Field Work

The field work portion of the surveys required three people for nine days. Each setup with USRADS covered a block area of 61 m × 61 m (200 ft × 200 ft). The data was collected by: one person with the instrument and the backpack who walked over the block; a second person who monitored the PC as the data was transmitted and followed the system tracking on the screen to ensure that the block was adequately covered and that the data were transmitting correctly; and a third person who helped with setup and teardown of the system. The data consisted of many thousands of individual readings taken at one-second intervals over the course of the surveys. This is far more data than acquired during the traditional survey technique of taking manual instrument readings at evenly spaced grid points. Thus, the data coverage is more thorough and the anomaly resolution more accurate.

Results

The raw field data were contoured using the Surfer program produced by Golden Software (Golden Software, Inc. 1989). The program was used to smooth the data and to remove some of the effects of cultural interferences at each site such as underground utilities, fences, above-ground tanks, etc. Smoothing can also be used to remove small-scale anomalies (e.g., manhole covers) and accent major trends. Contour maps of the data along with track maps of the survey blocks showing data collection points are included in this appendix. The maps are discussed in the individual sections for each site surveyed.

Site 1, Crash Crew Training Area

The data for the site were collected in twenty blocks covering about 61 m × 61 m (200 ft × 200 ft) each. Each block contains about 1,000 measurements, with the entire data set consisting of nearly 20,000 records. Each record has an x-y location for the measurement and the quadrature and in-phase readings from the EM-31.

After thorough examination, the data from the twenty blocks were pieced together to show the overall coverage (Fig. A.1). A number of small flaws in the data set became apparent on the plot of the tracking map. The gap in coverage between several blocks is due to a fence which prevented data collection in that area. Other data gaps were the result of brush and aboveground tanks which prevented data collection. The quadrature data collected were rated as "good quality" by the interpreting geophysicist, Jon Nyquist; however, the in-phase data showed that the threshold was set too high and repeatedly went off scale, causing the data to be clipped. Because the in-phase data are generally used only for detection of buried metal, which was not the objective at this site, the resultant loss of data was not critical. Only the quadrature data are discussed here.

Contouring the quadrature data (Fig. A.2) shows that many small 6 m to 9 m (20- to 30-ft-diameter) highs and lows exist. After buried metal, the strongest influence on terrain conductivity at the site is probably variation of water salinity and degree of soil saturation, most likely far stronger influences than the presence of jet fuel contamination. The strongest apparent trend is a high conductivity anomaly running northwest to southeast across the site. Whether this represents high salinity, increased soil moisture content, shallower depth to groundwater, or a combination of all three is impossible to say without more information. While the anomaly may be attributed to the existence of a buried river channel which trends in the same direction across the southwest corner of the site, it is difficult to

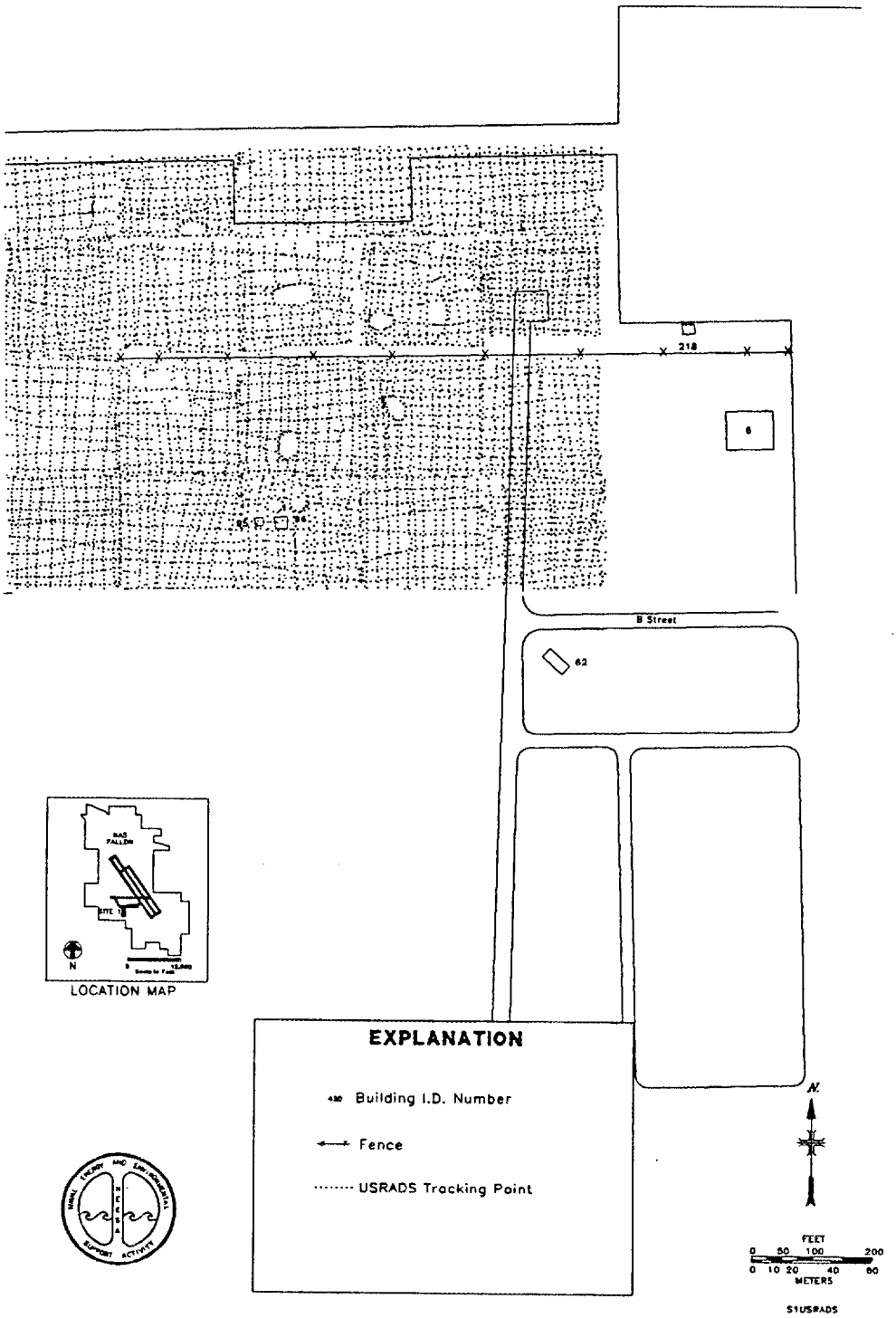

Fig. A.1 Site 1, Crash Crew Training Area. USRADS track map.

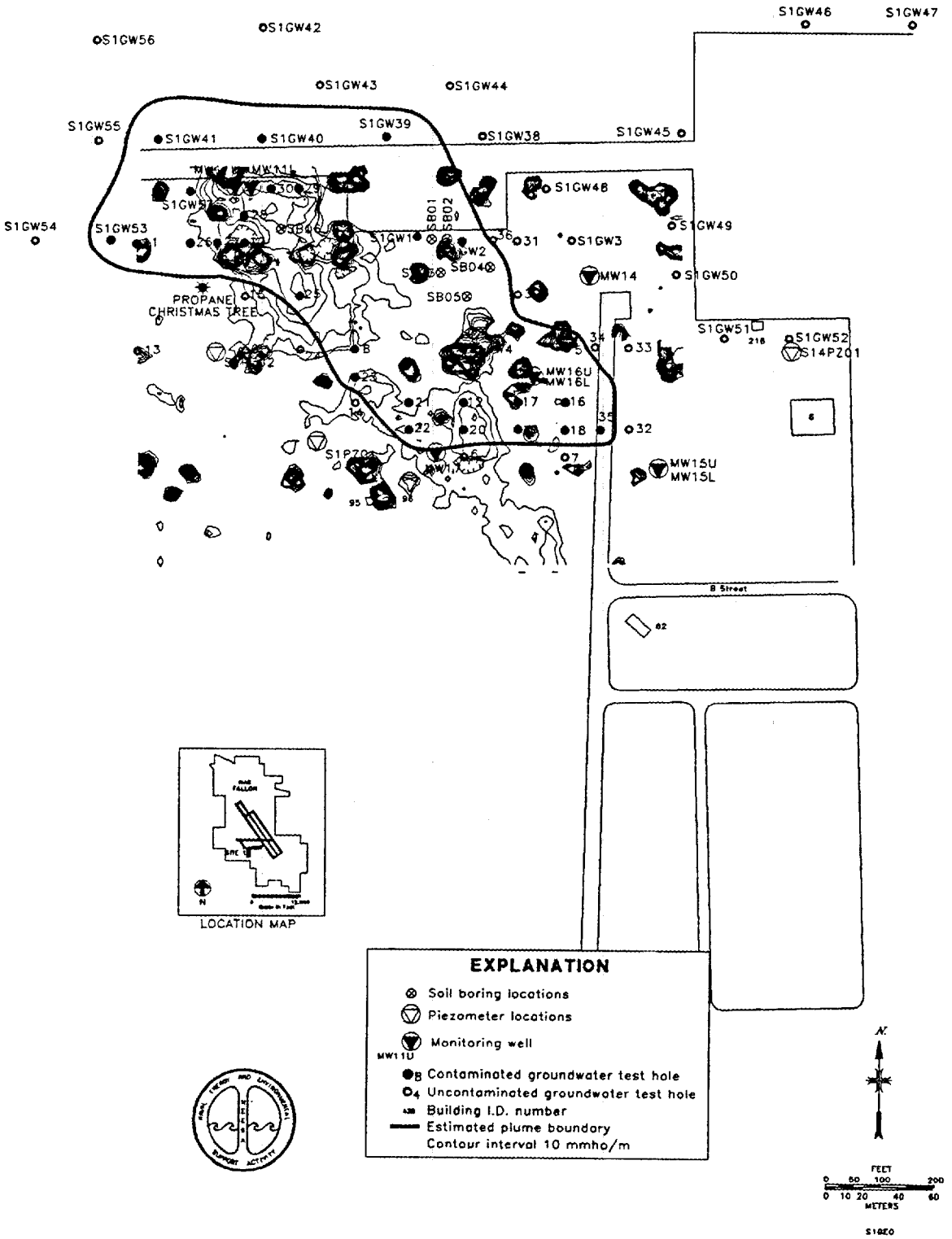

Fig. A.2 Site 1, Crash Crew Training Area. Quadrature geophysical contour map.

say without a better understanding of the precise channel configuration. Geologic cross-sections created from monitoring well logs will assist in additional interpretation. Analysis of the variation in the electrical conductivity of the water in the monitoring wells and the creation of groundwater potentiometric maps may also be revealing.

Site 2, New Fuel Farm

The results show anomalously high conductivities related to a chain link fence across the south side of the fuel farm and to two underground tanks (Fig. A.3). Two trends of low conductivity are also revealed. The two prominent, low-conductivity anomalies trend south 50 degrees east and appear to be associated with changes in the electrical conductivity of the groundwater. The conductivity of the groundwater tested in the ERM-West monitoring wells at the site ranged from less than 1,000 μmhos/cm to greater than 10,000 μmhos/cm, indicating that the water quality ranges from fresh to highly saline. The trends of low conductivity mapped by EM geophysics correlate with the wells exhibiting lower-conductivity measurements. The trends do not necessarily correlate to areas with known floating product on the groundwater but do follow the same directional trends as the former Carson River channel mapped across the site. Hence, the EM survey is probably mapping plumes of groundwater and soil with lower salinity and conductivity as opposed to mapping layers of floating hydrocarbons on the water table. Calculations performed by ORNL geophysicist Jon Nyquist support this conclusion. His evaluation concluded that the low-conductivity anomalies were too strong to be accounted for by floating hydrocarbons or by changing depth-to-water due to topography. This is not to say that the low-conductivity anomalies are not related to hydrocarbon plumes. In fact, the soil-gas survey and groundwater test hole data indicate that petroleum hydrocarbons are associated with both plumes of fresh water.

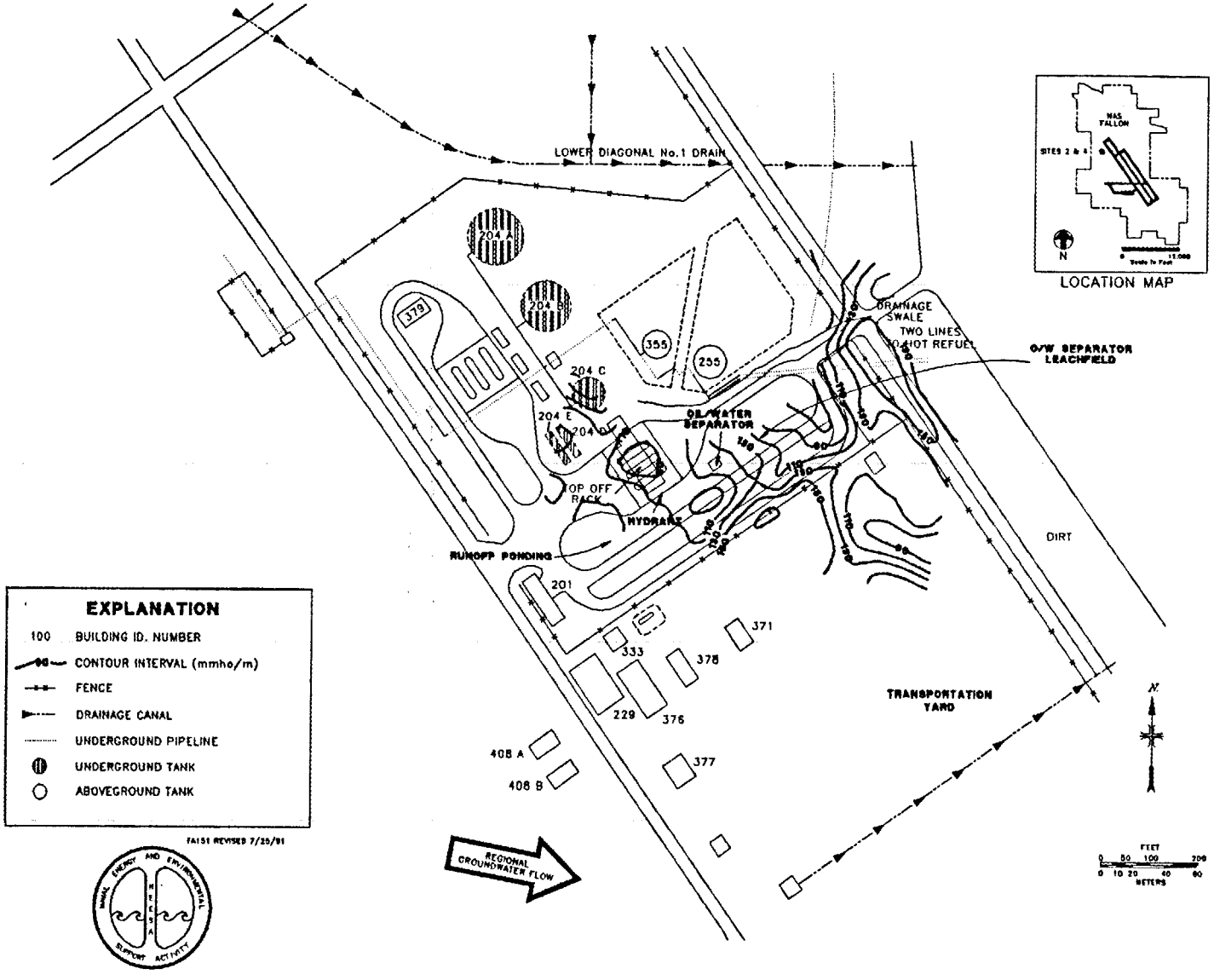

Fig. A.3 Group I sites: Site 2, New Fuel Farm; Site 4, Transportation Yard. In-phase geophysical contour map.

The largest low-conductivity anomaly is associated with the oil/water separator leach field (Fig. A.3). Historical data indicate that this area is the major source of contamination in the area. The function of the oil/water separator, which was poorly designed and maintained, was to collect fuel spills and wash water from the topoff rack. It collected both fuel and water from routine pavement washing at the topoff rack but did not effectively separate the layer of fuel from the water layer prior to discharge into the leach field. Large amounts of fresh water and fuel were discharged through the leach field into the shallow groundwater. Furthermore, the leach field is usually inundated with surface runoff from rainfall events. This water infiltrates and adds to the fresh water plume. Interpretation of the monitoring well water level data indicates that the groundwater flow gradient is approximately south 70 degrees east. Note that this is different by 20 degrees from the trend mapped by the EM geophysics. There are two possible explanations for the discrepancy: the fresh water plume may be following the trend of the buried channel (most likely) or mounding at the leach field is causing errors in the flow determination. (The surface of a mound is curved, and the calculation assumes a planar surface.)

The geophysical contour map indicates that the extent of the fresh water plume associated with the leach field has not been completely defined. The apparent end of the anomaly along the southeast boundary of the site is a distortion caused by high readings obtained along the chain link fence separating the fuel farm and the transportation yard. The anomaly resumes on the south side of the fence and appears to extend out of the surveyed area to the southeast.

A smaller, low-conductivity anomaly is located west of the oil/water separator just south of the topoff rack. A water hydrant located there was leaking fresh water at the time of the survey. It was still leaking several weeks later and probably represents a continuous source of fresh water recharge. This area also ponds water during rainfall events, and facility personnel have noted hydrocarbons

on the surface of the ponded water. The conclusion, therefore, is that the small southeasterly trending, low-conductivity anomaly in the area represents a second plume. The limits of this fresh water plume appear to be defined by the geophysical data; however, the associated soil-gas and groundwater test hole plume of petroleum hydrocarbon contamination continue to the southeast. This may be an indication that the fresh water plume is younger than part of the fuel plume.

Site 10, GATAR Compound

The coverage shown on the track map is relatively regular with no gaps in the data (Fig. A.4). The area was covered by two USRADS setups which produced approximately 2,000 data points. The area is enclosed by a chain link fence, but there were no other visible cultural interferences at the time of the survey. The purpose of the survey at this site was to locate possible cans or drums containing PCB-laden (polychlorinated biphenyl) oil which were reportedly buried in the northeast quadrant of the compound. A metal-detector survey revealed several small pieces of shallowly buried metal in the region but no other anomalies.

The quadrature data show several high and low anomalies but no apparent trends (Fig. A.5). The EM-31 quadrature data, however, show a possible concentration of more deeply buried metal about eighty feet south and twenty feet west of the northeast corner of the compound. Other anomalies appear in the region, but the large one would be the most likely place to continue the investigation for the containers of oil. Recommendations include excavating the site to determine if buried drums are present and, if so, to remove them for appropriate disposal.

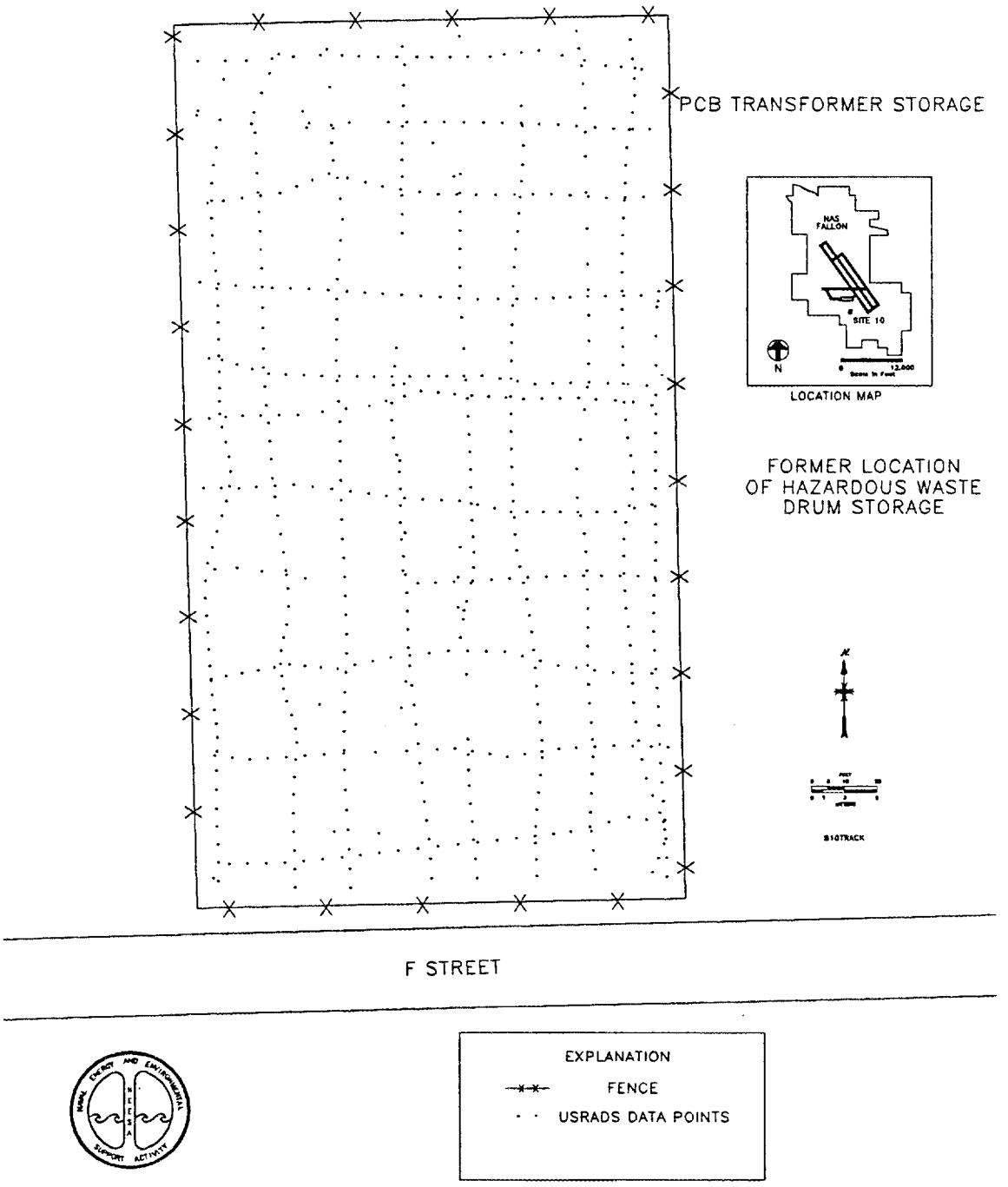

Fig. A.4 Site 10. GATAR Compound. USRADS track map.

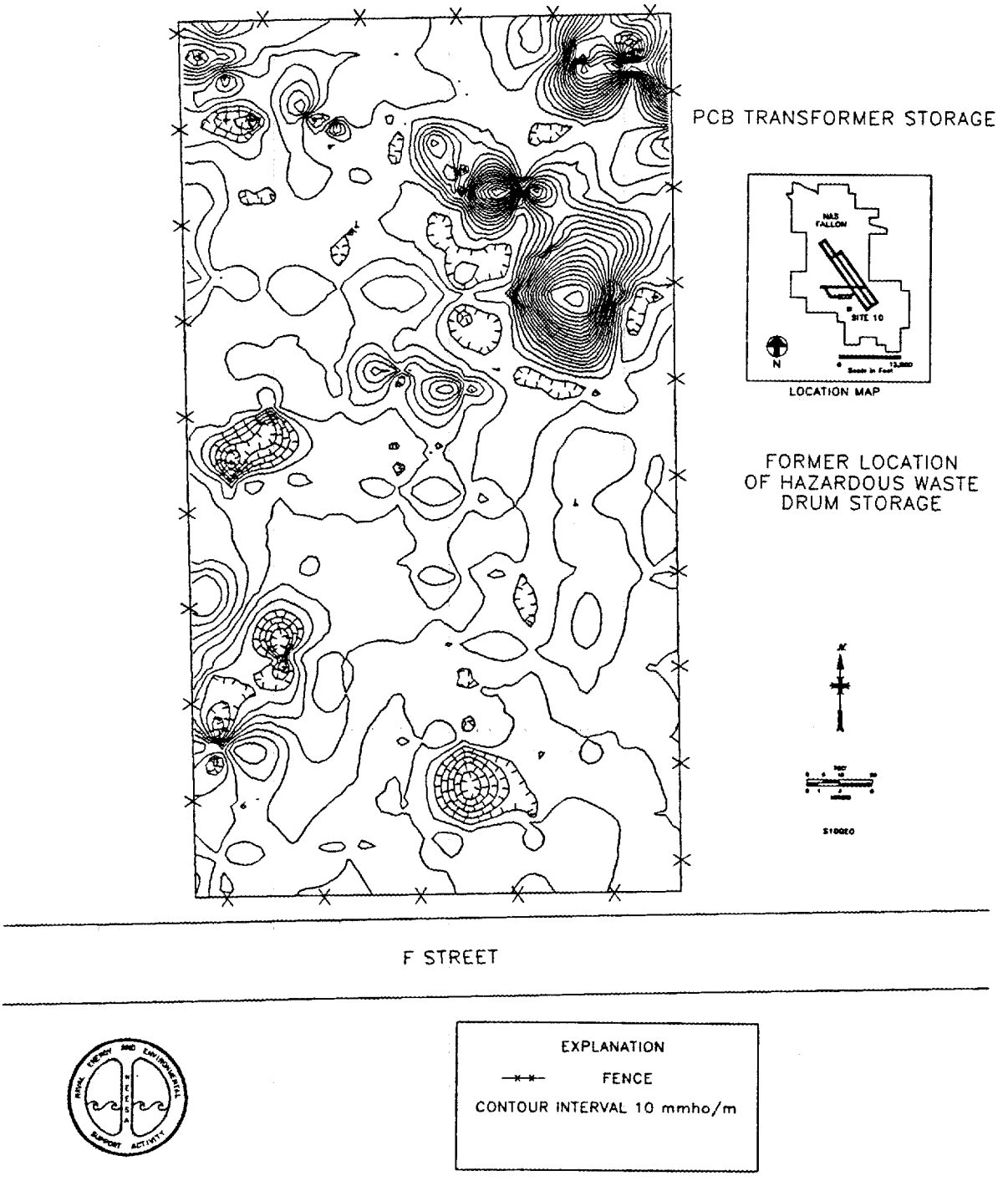

Fig. A.5 Site 10. GATAR Compound. Quadrature geophysical contour map.

Site 19, Post-World War II Burial Site and Site 23, Shipping and Receiving Disposal Site

Because these two sites are adjacent and nearly contiguous, the EM-31 survey covered the entire area. Ten USRADS setups were required to fully cover the area of 305 m × 122 m (1,000 ft × 400 ft), generating approximately 10,000 data points. Site 19 was surveyed for trends possibly related to trenches containing buried scrap metal and engine cleaning solvent. The primary purpose of surveying Site 23 was to locate the aircraft reportedly buried there in 1984. The track map (Fig. A.6) shows good coverage over the entire area with two exceptions: a rectangular segment in the southwest quarter where the fence for the GATAR compound prevented surveying and a break in the north-south tracking in the north half of the area related to an east-west trending ditch.

Review of the quadrature data revealed numerous high- and low-conductivity anomalies, many of which can be related to scattered metallic debris on the ground surface. No obvious trends are shown by the contour plot of the quadrature data (Fig. A.7). One slight low-conductivity anomaly appears to trend from northwest to southeast across the south half of the area in the vicinity of the contaminant-plume discharge area delineated by the groundwater test hole mapping. It is difficult to say if this anomaly is related to the contaminant plume.

The in-phase data similarly reflects anomalies, most of which can be related to piles of scrap metal and other debris containing metal such as rebar in concrete (Fig. A.8). The road across the southern end of the area appears to be reflected by a slight low anomaly on the in-phase data. There does not appear to be a buried aircraft in any of the surveyed area unless it is buried underneath one of the surface scrap piles. There may be trenches containing some metallic debris in the southwest quarter of the region, 30.5 m to 91.5 m (100 to 300 ft) north of the road. Otherwise, the area is devoid of in-phase anomalies.

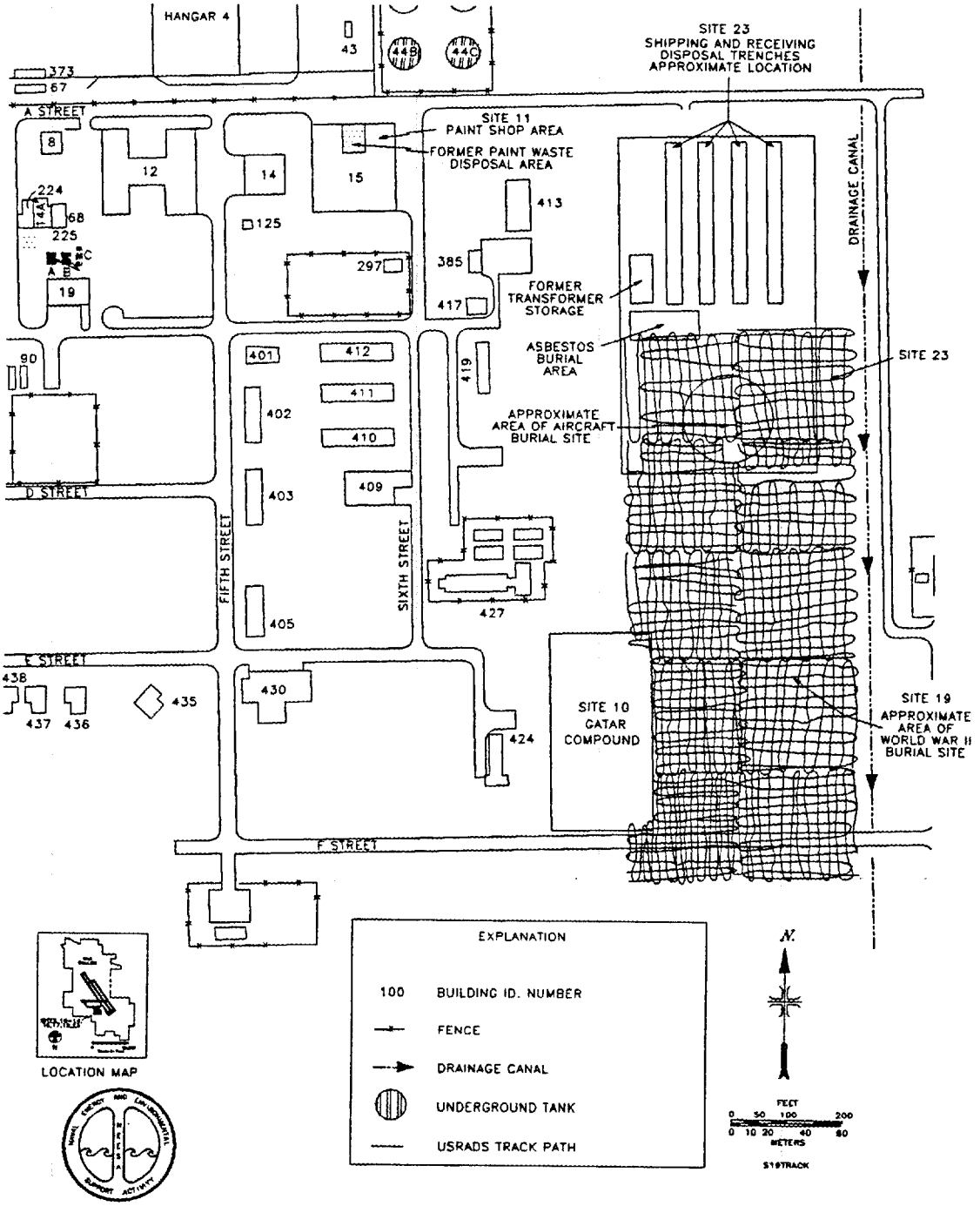

Fig. A.6 Site 19, Post-World War II Burial Site, and Site 23, Shipping and Receiving Landfill. USRADS track map.

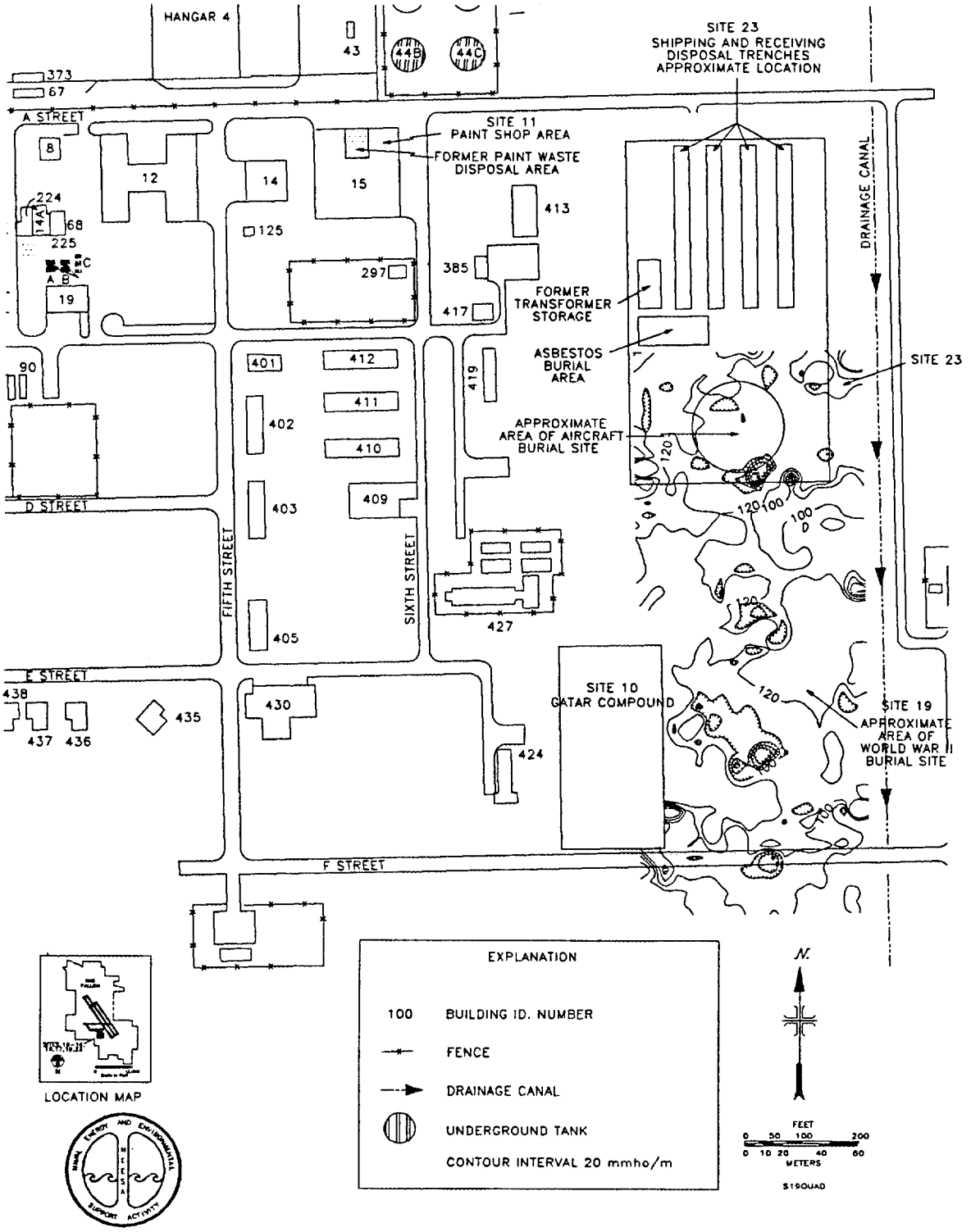

Fig. A.7 Site 19, Post-World War II Burial Site, and Site 23, Shipping and Receiving Landfill. Quadrature geophysical contour map.

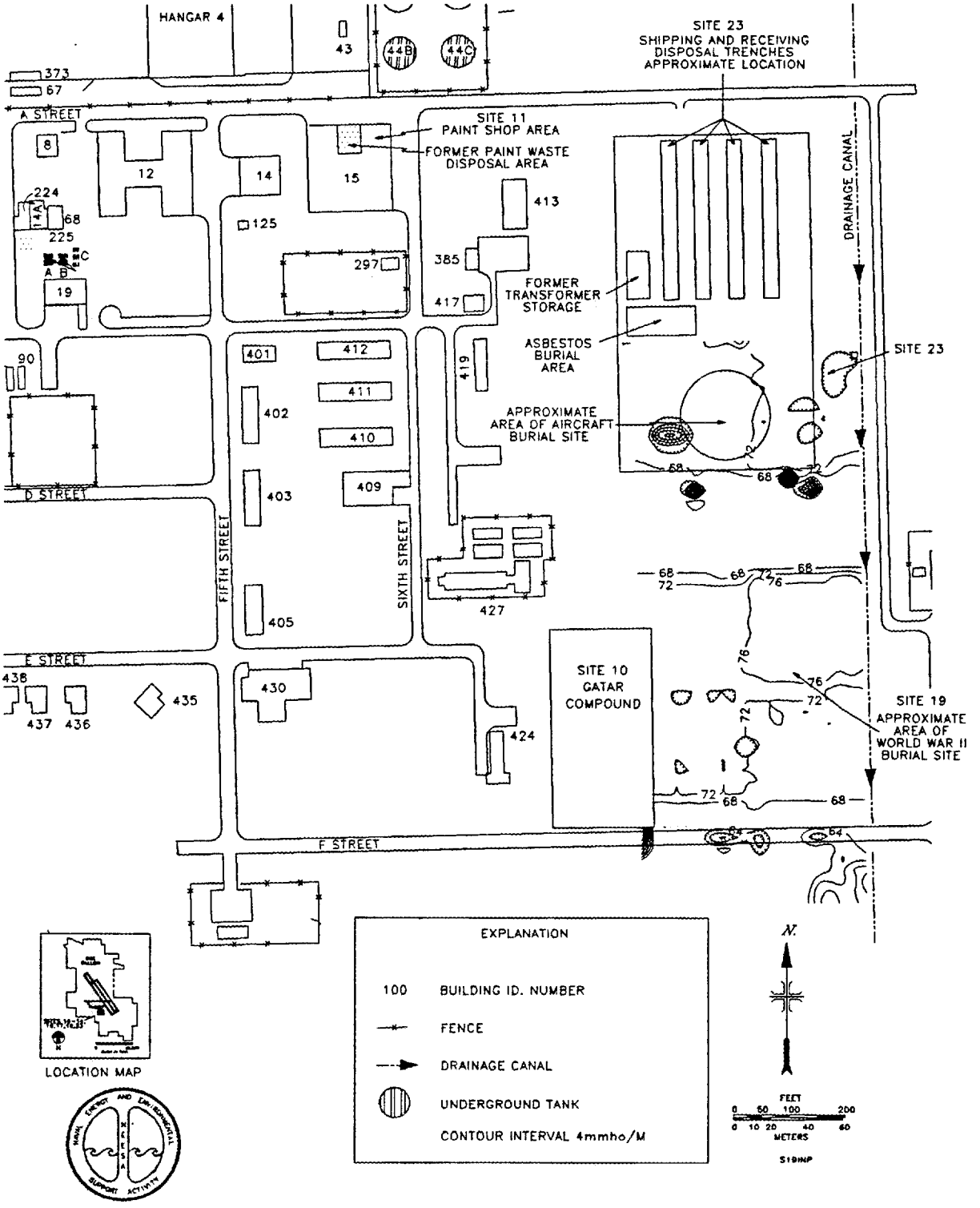

Fig. A.8 Site 19, Post-World War II Burial Site, and Site 23, Shipping and Receiving Landfill. In-phase geophysical contour map.

APPENDIX B

GROUNDWATER TEST HOLE FIELD SCREENING

GROUNDWATER TEST HOLE FIELD SCREENING

Methodology

This field-screening technique was developed by ORNL/GJ field personnel after other field-screening techniques such as soil-gas and EM-31 geophysical techniques proved inconclusive or inadequate (ORNL 1991). The technique was an outgrowth of using a hydropunch sampler, the tool of choice at the beginning of the field screening surveys. This sampler, however, was slow, inconsistent, and subject to damage when used with a hydraulic hammer. The new technique, which proved to be quicker and simpler, involved drilling a number of 4-in.-diameter auger holes into the water table with a small truck-mounted hydraulically powered auger rig. During drilling, each hole was monitored continuously for volatile organic compounds with a PID, HNU model PI-101. The PID was calibrated daily with a known gas standard. Elevated readings during drilling and in the open hole were noted in the field log book. Occasionally the PID would react to exhaust from the rig. However, this problem was eventually minimized by routing the exhaust away from and downwind of the work area with a flexible metal pipe and by checking for repeatable readings with the PID. The color and composition of the drill cuttings were also noted and recorded in the field log book.

Each hole was drilled into the shallow water table generally 1.2 m to 1.8 m (4 to 6 ft) deep. A groundwater sample was collected from the open hole with a bailer or screened auger, depending on whether or not the hole would stand open after the augers were removed. Where sandy soil was encountered, the holes tended to cave in up to the top of the water table, and a screened auger had to be drilled into the water bearing sand to obtain a sample. Otherwise, a bailer was the quickest way to obtain a sample. The water sample was poured from the bailer or screened auger into a 250-mL glass vial equipped with a teflon septum cap and certified precleaned. A new vial was used for

each sample. During the sample transfer, about 50 mL of headspace were left in the container. The sample was capped immediately and allowed to equilibrate in the container for 30 minutes to ensure that any dissolved volatile organic compounds in the water sample had sufficient time to partition into the headspace air of the vial. All augers, bailers, and other sampling tools were steam-cleaned between holes.

The capped samples were transported to the van containing the field-portable gas chromatograph (Photovac Model 10S50) where an aliquot of headspace air was removed from each vial with a syringe (usually 100 μL) and injected into the field GC. Sometimes a smaller sample aliquot was injected if there was evidence that the sample was highly contaminated. This subjective decision was made based on criteria such as: above-ambient PID readings in the open hole; visible product in the sample; noticeable hydrocarbon odor; and a gray, reduced appearance of the drill cuttings. The appearance of visible product was considered ample evidence of contamination, and generally no test was run on such samples. If a sample did not contain visible product, a test was performed.

The resultant chromatogram was inspected for anomalous peaks, and a determination of relative concentrations of volatile organic compounds was made. Thus, qualitative designations, such as "clean", "slightly contaminated", and "highly contaminated", were assigned to each groundwater test hole. The tables in this appendix designate the holes as, "pos" and "neg" indicating that the sample either tested positive or negative for volatile organic contaminants with the PID and the GC. The presence of repeatable anomalous peaks on a chromatogram was considered evidence of contaminated groundwater. In general the anomalous peaks were confirmed by PID readings in the open drill hole. In 88% of the 450 holes tested at the various sites, the field GC results were consistent with other field observations (Tables B.1 through B.10).

The field GC was regularly calibrated with benzene, toluene,

Table B.1. Groundwater test hole screening results for Site 1

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
1	1	X		ND		POS	
1	2	X		ND		POS	
1	3	X			X	POS	GC false negative
1	4	X		X		POS	
1	5		X	X		POS	PID false negative
1	6		X	X		POS	PID false negative
1	7		X		X	NEG	
1	8	X		ND		POS	
1	9		X		X	NEG	
1	10	X		X		POS	
1	11	X		X		POS	
1	12	X		X		POS	
1	13		X		X	NEG	
1	14		X		X	NEG	
1	15		X		X	NEG	
1	16		X	X		POS	PID false negative
1	17		X	X		POS	PID false negative
1	18		X	X		POS	PID false negative
1	19	X		X		POS	
1	20	X		X		POS	
1	21	X		X		POS	
1	22		X	X		POS	PID false negative
1	23	X		X		POS	
1	24		X		X	NEG	
1	25		X	X		POS	PID false negative
1	26		X	X		POS	
1	27	X		X		POS	
1	28		X	X		POS	PID false negative
1	29	X		X		POS	
1	30	X		X		POS	
1	31		X		X	NEG	
1	32		X		X	NEG	
1	33		X		X	NEG	
1	34		X		X	NEG	
1	35		X	X		POS	PID false negative
1	36		X		X	NEG	
1	37		X		X	NEG	
1	38		X		X	NEG	
1	39	X		X		POS	
1	40	X		X		POS	

Table B.1. (continued)

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
1	41		X	X		POS	PID false negative
1	42		X		X	NEG	
1	43		X		X	NEG	
1	44		X		X	NEG	
1	45		X		X	NEG	
1	46		x		x	NEG	
1	47		X		X	NEG	
1	48		X		X	NEG	
1	49		X		X	NEG	
1	50		X		X	NEG	
1	51		X		X	NEG	
1	52		X		X	NEG	
1	53	X		X		POS	
1	54		X		X	NEG	
1	55		X		X	NEG	
1	56		X		X	NEG	
1	57	X		X		POS	

Total = 57 10 holes with negative PID and positive GC
1 hole with positive PID and negative GC
19.3% disagreement between PID and GC
80.7% agreement

ND = Not Done

Table B.2. Groundwater test hole screening results for Site 14

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
14	1	X		X		POS	
14	2	X		X		POS	
14	3	X		X		POS	
14	4	X		X		POS	
14	5	X			X	NEG	PID false positive
14	6		X		X	NEG	
14	7	X		X		POS	
14	8	X		X		POS	
14	9	X		X		POS	
14	10	X		X		POS	
14	11		X		X	NEG	
14	12	X			X	NEG	PID false positive
14	13	X		X		POS	
14	14		X		X	NEG	
14	15		X		X	NEG	
14	16		X		X	NEG	
14	17	X		X		POS	
14	18	X			X	NEG	PID false positive
14	19		X		X	NEG	
14	20	X		X		POS	
14	21	X		X		POS	
14	22	X		X		POS	
14	23		X		X	NEG	
14	24		hit water line				
14	25	X		X		POS	
14	26	X		X		POS	
14	27	X		X		POS	
14	28	X		X		POS	
14	29	X		X		POS	
14	30	X		X		POS	
14	31	X		X		POS	
14	32		X		X	NEG	
14	33	X		X		POS	
14	34	X		X		POS	
14	35	X		X		POS	
14	36	X			X	NEG	PID false positive
14	37	X		X		POS	
14	38		X		X	NEG	
14	39	X		X		POS	
14	40	X		X		POS	

Table B.2. (continued)

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
14	41		X		X	NEG	
14	42	X		X		POS	
14	43	X		X		POS	
14	44	X		X		POS	
14	45	X		X		POS	
14	PZ01		X		X	NEG	
14	PZ02		X		X	NEG	
14	PZ03	X		ND		POS	
14	PZ04	X		ND		POS	

Total = 49 4 holes with negative GC and positive PID
8% disagreement between PID and GC
92% agreement

ND = Not Done

Table B.3. Groundwater test hole screening results for Site 13

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
13	1	X		X		POS	Slow PID response
13	2	X		X		POS	Slow PID response
13	3	X		X		POS	Slow PID response
13	4	X		X		POS	Slow PID response
13	5	X		X		POS	Slow PID response
13	6	X		X		POS	Slow PID response
13	7		X		X	NEG	
13	8		X		X	NEG	
13	9		X		X	NEG	
13	10	X			X	POS	False Neg GC
13	11	X			ND	POS	
13	12		X		X	NEG	
13	13		X		X	NEG	
13	14	X			X	POS	Petroleum odor
13	15		X		X	NEG	
13	16		X		X	NEG	
13	PZ01		ND	X		POS	

Total - 17 2 holes with negative GC and positive PID
Several holes had very weak GC and slow PID response
12% disagreement between PID and GC
88% agreement

ND - Not Done

Table B.4. Groundwater test hole screening results for Sites 16, 19, and 23

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
16	1	X		X		POS	
16	2	X		X		POS	
16	3	X		X		POS	
16	4	X		X		POS	
16	5	X		X		POS	
16	6	X		X		POS	
16	7	X		X		POS	
16	8	X		X		POS	
16	9	X		X		POS	
16	10	X		X		POS	
16	11	X		X		POS	
16	12	X		X		POS	
16	13		X		X	NEG	
16	14	X		X		POS	
16	15	X		X		POS	
16	16	X		X		POS	
16	17	X		X		POS	
16	18	X		X		POS	
16	19	X		X		POS	
16	20	ND		X		POS	
16	21	X		X		POS	
16	22	X		X		POS	
16	23	X		X		POS	
16	24	X		X		POS	
16	25	X		X		POS	
16	26	X		X		POS	
16	27		X		X	NEG	
16	28		X		X	NEG	
16	29		X		X	NEG	
16	30		X		X	NEG	
16	31	X		X		POS	
16	32	X		X		POS	
16	33	X		X		POS	
16	34	X		X		POS	
16	35	ND		X		POS	
16	36	X		X		POS	
16	37	X		X		POS	
16	38	X		X		POS	
16	39	X		X		POS	
16	40	X		X		POS	

Table B.4. (continued)

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
16	41		ND		X	NEG	
16	42	X		X		POS	
16	43	X		X		POS	
16	44	X		X		POS	
16	45		X		X	NEG	
16	46	X		ND		POS	
16	47		X		X	NEG	
16	48	X		X		POS	
16	49	X		X		POS	
16	50		X		X	NEG	
16	51		X	X		POS	PID false negative
16	52		X	X		POS	PID false negative
16	53	X		X		POS	
16	54		X	X		POS	PID false negative
16	55		X		X	NEG	
16	56		X		X	NEG	
16	57	X		X		POS	
16	58		X		X	NEG	
16	59		X		X	NEG	
16	60		X		X	NEG	
16	61	X		ND		POS	
16	62		X	X		POS	
16	63	X		X		POS	
16	64		X	X		POS	PID false negative
16	PZ01		X		ND	NEG	
16	PZ02		X		ND	NEG	
16	PZ03	X		ND		POS	
16	PZ04	X		ND		POS	
16	PZ05		X		ND	NEG	
16	PZ06	X		ND		POS	
16	PZ07	X		ND		POS	
16	PZ08	X		ND		POS	

Table B.4. (continued)

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
19	1		X		X	NEG	
19	2		X		X	NEG	
19	3		X		X	NEG	
19	4		X		X	NEG	
19	5		X		X	NEG	
19	6		X		X	NEG	
19	7	X		X		POS	
19	8		X		X	NEG	
19	9		X		X	NEG	
19	10	X		X		POS	
19	11		X		X	NEG	
19	12		X		X	NEG	
19	13		X		X	NEG	
19	14	X		X		POS	
19	15		X		X	NEG	
19	16	X		X		POS	
19	17		X		X	NEG	
19	18		X		X	NEG	
23	1		X		X	NEG	
23	2		X		X	NEG	
23	3		X		X	NEG	
23	4	X			X	NEG	PID false positive
23	5		X		X	NEG	
23	6		X		ND	NEG	

Total = 96 5 holes with negative PID and positive GC
1 hole with positive PID and negative GC
6% disagreement between PID and GC
94% agreement

ND = Not Done

Table B.5. Groundwater test hole screening results for Site 20

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
20	1	X			X	NEG	PID - 300 slow
20	2	X			X	NEG	PID - 60 slow
20	3		ND		X	NEG	
20	4		X		X	NEG	
20	5		X		X	NEG	
20	6		X		X	NEG	
20	7		X		X	NEG	
20	8		X		X	NEG	
20	9		X		X	NEG	
20	10		X		X	NEG	
20	11		X		X	NEG	
20	12		X		X	NEG	
20	13		X		X	NEG	
20	14		X		X	NEG	
20	15		X		X	NEG	
20	16		X		X	NEG	
20	17		X		X	NEG	
20	18		X		X	NEG	
20	19	X			X	NEG	PID - 28 ppm slow
20	20	X			X	NEG	PID - 62 ppm slow
20	21	X			X	NEG	PID - 52 ppm slow
20	22	X			X	NEG	PID - 26 ppm slow
20	23		X		X	NEG	
20	24		X		X	NEG	
20	25		X		X	NEG	
20	26		X		X	NEG	
20	27		X		X	NEG	
20	28		X		X	NEG	
20	29		X		X	NEG	
20	30		X		X	NEG	
20	31		X		X	NEG	
20	32		X		X	NEG	
20	33		X		X	NEG	
20	34		X		X	NEG	
20	35		X		X	NEG	
20	36		X		X	NEG	

Total - 36

0 holes with negative PID and positive GC
6 holes with positive PID and negative GC
16.6% disagreement between PID and GC
83.4% agreement

ND - Not Done

Table B.6. Groundwater test hole screening results for Sites 9 and 18

Site #	Hole #	PID		Field GC		Final Decision	Comments
		Pos.	Neg.	Pos.	Neg.		
9 & 18	1		X		X	NEG	
9 & 18	2		X		X	NEG	
9 & 18	3		X		X	NEG	
9 & 18	4		X		X	NEG	
9 & 18	5		X		X	NEG	
9 & 18	6		X		X	NEG	
9 & 18	7		X		X	NEG	
9 & 18	8		X		X	NEG	
9 & 18	9		X		X	NEG	
9 & 18	10		X		X	NEG	

Total - 10 0 holes with negative PID and positive GC
0 holes with positive PID and negative GC
0% disagreement between PID and GC
100% agreement

Table B.7. Groundwater test hole screening results for Site 3

Site #	Hole #	PID		Field GC		Final Decision	Comments
		Pos.	Neg.	Pos.	Neg.		
3	1		X	X		NEG	TCE?
3	2	X			X	NEG	Asphalt
3	3		X		X	NEG	
3	4		X	X		POS	TCE?
3	5		X	X		POS	TCE?
3	6		X	X		POS	TCE?
3	7	X		X		POS	TEC?
3	8		X		X	NEG	
3	9		X		X	NEG	
3	10		X		X	NEG	
3	11		X		X	NEG	
3	12		X		X	NEG	

Total = 12 4 holes with negative PID and positive GC
1 hole with positive PID and negative GC
42% disagreement between PID and GC
58% agreement

Note: TCE not detectable on PID at low concentrations

Table B.8. Groundwater test hole screening results for Sites 6, 7, 21, and 22

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
6*	1		X		X	NEG	
6*	2		X		X	NEG	
6*	3		X		X	NEG	
6*	4		X		X	NEG	
6*	5		X		X	NEG	
6*	6		X		X	NEG	
6*	7		X		X	NEG	
6*	8		X		X	NEG	
6*	9		X		X	NEG	
6*	10		X		X	NEG	
6*	11	X			X	NEG	PID slow response
6*	12	X			X	NEG	PID slow response
6*	13	X			X	NEG	PID slow response
6*	14		X		X	NEG	
6*	15	X		X		POS	PID slow response
6*	16	X		X		POS	PID slow response
6*	17	X			X	NEG	
6*	18	X			X	NEG	
6*	19		X		X	NEG	
6*	20	X			X	NEG	PID slow response
6*	21	X			X	NEG	PID slow response
6*	22	X			X	NEG	PID slow response
6*	23	X		X		POS	
6*	24	X		X		POS	
6*	25	X		X		POS	
6*	26	X		X		POS	
6*	27	X		X		POS	
6*	28		X		X	NEG	
6*	29	X			X	NEG	PID slow response
6*	30		X		X	NEG	
6*	31	X		X		POS	
6*	32	X		X		POS	
6*	33	X		X		POS	
6*	34	X		X		POS	
6*	35	X		X		POS	
6*	36	X		X		POS	
6*	37	X		X		POS	
6*	38		X		X	NEG	
6*	39		X		X	NEG	
6*	40		X		X	NEG	

Table B.8. (continued)

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
6*	41		X		X	NEG	
6*	42		X		X	NEG	
6*	43		X		X	NEG	
6*	44		X		X	NEG	
6*	45		X		X	NEG	
6*	46		X		X	NEG	
6*	47		X		X	NEG	
6*	48		X		X	NEG	
6*	49		X		X	NEG	
6*	50		X		X	NEG	
6*	51		X		X	NEG	
6*	52		X		X	NEG	
6*	53	X		X		POS	
6*	54		X		X	NEG	
6*	55		X		X	NEG	
6*	56		X		X	NEG	
6*	57		X		X	NEG	
6*	58		X		X	NEG	
6*	59		X		X	NEG	
6*	60		X		X	NEG	
6*	61		X		X	NEG	
6*	62		X		X	NEG	
6*	63		X		X	NEG	
6*	64		X		X	NEG	
6*	65		X		X	NEG	
6*	66		X		X	NEG	
6*	67	X		X		POS	
6*	68		X		X	NEG	
6*	69		X		X	NEG	
6*	70		X		X	NEG	
6*	71		X		X	NEG	
6*	72		X		X	NEG	
6*	73		X	X		POS	PID false negative
6*	74	X			X	NEG	PID slow response
6*	75	X		ND		POS	Product
6*	76		X		X	NEG	
6*	PZ01	X		X		POS	
6*	PZ02		X		X	NEG	
6*	PZ03		X		X	NEG	

* Indicates could be sites 6, 7, 21, or 22

Total - 79 — 1 hole with negative PID and positive GC
10 holes with positive PID and negative GC
14% disagreement between PID and GC
86% agreement

ND - Not Done

Table B.9. Groundwater test hole screening results for Site 4

Site #	Hole #	PID		Field GC		Final Decision	Comments
		Pos.	Neg.	Pos.	Neg.		
4	1		X		X	NEG	Within plume
4	2		X		X	NEG	Within plume
4	3		X		X	NEG	Within plume
4	4		X		X	NEG	Within plume
4	5		X		X	NEG	Within plume

Total = 5 0 holes with negative PID and positive GC
0 holes with positive PID and negative GC
0% disagreement between PID and GC
100% agreement

Table B.10. Groundwater test hole screening results for Site 2

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
2	1	X		X		POS	Next to ERM15
2	2	X		X		POS	
2	3	X		X		POS	
2	4	X		X		POS	
2	5	X		X		POS	
2	6	X		X		POS	
2	7	X		X		POS	
2	8	X		X		POS	
2	9	X		X		POS	
2	10	X		X		POS	
2	11		X		X	NEG	
2	12		X		X	NEG	
2	13	X		X		POS	
2	14		X		X	NEG	
2	15		X		X	NEG	
2	16	X			X	NEG	PID reading exhaust
2	17		X		X	NEG	
2	18		X		X	NEG	
2	19	X		X		POS	
2	20	X		ND		POS	Product
2	21		X		X	NEG	
2	22		X		X	NEG	
2	23	X		ND		POS	Product
2	24		X	X		POS	Slight GC response, Neg deflection on PID
2	25		X	X		POS	Slight GC response
2	26		X	X		POS	Slight GC response
2	27	X		X		POS	
2	28		X		X	NEG	
2	29	X		X		POS	
2	30		X		X	NEG	
2	31	X		X		POS	Product
2	32	X		X		POS	Product
2	33		X		X	NEG	
2	34		X		X	NEG	
2	35	X			X	NEG	PID reading exhaust
2	36		X		X	NEG	
2	37		X		X	NEG	
2	38	X		X		POS	Product
2	39	X		X		POS	Product
2	40	X		X		POS	Slight GC response

Table B.10. (continued)

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
2	41		X		X	NEG	
2	42	X		X		POS	
2	43		X		X	NEG	PID reading exhaust
2	44		X		X	NEG	PID reading exhaust
2	45	X			X	NEG	PID reading exhaust
2	46	X			X	NEG	PID reading exhaust
2	47		X		X	NEG	
2	48		X		X	NEG	
2	49		X		X	NEG	
2	50						No Data
2	51		X		X	NEG	
2	52		X		X	NEG	
2	53		X		X	NEG	
2	54	X		ND		POS	Product
2	55	X		ND		POS	Product
2	56	X		ND		POS	Product
2	57	X		X		POS	
2	58	X		ND		POS	Product
2	59	X		ND		POS	Product
2	60	X			X	NEG	PID reading exhaust
2	61	X		ND		POS	Product
2	62	X		ND		POS	Product
2	63	X		ND		POS	Product
2	64	X			X	NEG	PID reading exhaust
2	65	X		ND		POS	Product
2	66		X		X	NEG	
2	67		X		X	NEG	
2	68		X		X	NEG	
2	69	X		X		POS	Product
2	70		X	X		POS	PID false negative
2	71		X		ND	NEG	Site 1
2	72		X		ND	NEG	Site 6
2	73	X		ND		POS	
2	74	X		ND		POS	Product
2	75	X		ND		POS	Product
2	76		X		ND	NEG	
2	77	X		ND		POS	Product
2	78		X		ND	NEG	
2	79	X		ND		NEG	
2	80	X		ND		POS	

Table B.10. (continued)

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
2	81		X		ND	NEG	
2	82	X		ND		POS	Product
2	83		X		ND	NEG	
2	84		X		ND	NEG	
2	85	X		ND		POS	
2	86		X		ND	NEG	
2	87		X		ND	NEG	
2	88		X		ND	NEG	
2	89		X		ND	NEG	
2	90	X		ND		POS	Product

Total - 89 4 holes with negative PID and positive GC
6 holes with positive PID and negative GC
11% disagreement between PID and GC
89% agreement

ND - Not done

ethylbenzene, and xylene standards. Syringe blank samples were injected at frequent intervals as quality control (QC) samples. A continuous stream of carrier gas was run through the GC to purge the system between samples. The syringes were cleaned and baked between sample injections. If the chromatogram for the sample resembled the blank run and there were no elevated PID readings, the sample was considered "clean". Occasionally samples were tested twice to check repeatability of the results. Ten split samples were sent to a fixed-based laboratory in Reno, Nevada, for overnight analysis of volatile organic compounds by EPA Method 624. The results confirmed the field designation of "clean" for all ten samples. This field screening method has proven very effective for detecting and delineating petroleum hydrocarbon-contaminated groundwater plumes at NAS Fallon.

Rationale

The approach to field screening at different sites varied depending on what was known about contamination at each site. Some sites, such as Site 1, Crash Crew Fire Training Area, and Site 2, New Fuel Farm, were known or strongly suspected to be contaminated. In these cases the field screening started in areas of known contamination or surface staining and proceeded away from the area and downgradient in the direction of regional groundwater flow until the detectable limits of contamination were reached. The plume boundaries were then traced around the perimeter to the upgradient limits of detectable contamination. At other sites such as Site 6, Defuel Disposal Area, and Site 20, Checkerboard Landfill, where there was doubt about the potential for or location of contamination, the screening was initially conducted by drilling fence patterns of groundwater test holes across the regional groundwater flow lines downgradient from the suspected site. If contamination was detected, as at Site 6, the survey proceeded as above. However, if no contamination was detected, as at Site 20, the survey was completed around all sides of the site where it was reasonable to expect

contaminants to migrate.

Results

Maps showing the results of the groundwater screening are included in the text of the report. Tables of the results by site and by hole number are included in this appendix. A narrative summary of the results is presented below.

Site 1, Crash Crew Training Area:

Potential contaminants: jet fuel (JP-5), waste oil and other fuels, and solvents.

Screening: consisted of an EM-31 survey and fifty-seven groundwater test holes (Table B.1). A plume containing JP-5 and solvents was delineated. A former river channel was also located and partially mapped. The channel appears to trend southeast across the southwest part of the site.

Investigation: drilling and sampling six soil borings, eight monitoring wells, and two piezometers. Five wells were screened shallow to intersect the shallow alluvial water table (one of these is an upgradient well). Two wells were screened at the bottom of the shallow alluvial water table to detect any possible solvent product plume. One upgradient well was completed in the intermediate aquifer and is artesian. This precludes the migration of contaminants from the shallow alluvial aquifer through the clay- confining layer down into the other aquifers.

Group I: Sites 2 and 4, New Fuel Farm and Transportation Yard:

Potential contaminants Site 2: include JP-5, JP-4, avgas, gasoline, and diesel fuel.

Potential contaminants Site 4: could include waste oil, hydraulic fluid, radiator coolant, paint waste, and mixed fuels.

Screening: investigation results have been presented in the *Preliminary Site Characterization Summary and Engineering Evaluation/Cost Analysis for Site 2* (ORNL 1991). The groundwater test hole screening results are tabulated in Table B.10. The initial screening consisted of two types of soil-gas surveys and an electromagnetic geophysical survey. Three additional piezometers were installed in April 1991 just south of the Transportation Yard. Five groundwater test holes were drilled around Building 378
(Table B.9), and three soil borings were drilled near Building 378 (Site 4).

Site 3: Hangar 300 (renamed Hangar 1):

Potential Contaminants: include JP-5, hydraulic fluid, lube oil, and solvents.

Screening: consisted of drilling twelve groundwater test holes (Table B.7). A solvent plume was detected in the southern part of the site (GSE area and south disposal area). However, the plume appeared to go under the apron, and no boundaries were delineated due to the difficulty of drilling through the thick concrete. No contamination was detected in the north disposal area or the bowser disposal area.

Investigation: drilling eight soil borings and twelve monitoring wells and taking three sediment samples from the ditch downstream from the oil/water separator.

Group II Sites: Site 6, Site 7, Site 21, and Site 22:

Potential contaminants Site 6: JP-4 and JP-5
Potential contaminants Site 7: napalm M-2 and napalm A&B
Potential contaminants Sites 21 and 22: JP-5, gasoline, diesel fuel, waste oils, hydraulic fluid, and wet garbage leachate.

Screening: consisted of drilling ninety-five groundwater test holes around the sites and includes the Lower Diagonal No. 1 Drain investigation (Table B.8). One large fuel plume was located and delineated emanating from Site 6. No other significant contamination was detected from any other sites except along the road between Sites 21 and 22 next to the intersection of the road leading to the receiver site. Attempts to trace this contamination south yielded no other contaminated test holes. Thus, the contamination appeared to be localized and inconsistent. Attempts to locate the napalm burn pit, Site 7, by drilling groundwater test holes failed due to extensive landfill material buried in the area which prevented the drill from reaching the water table.

Lower Diagonal No.1 Drainage Ditch: Site of a recent JP-5 cleanup, this is not an IR Program site but was investigated to determine the possibility of contaminant migration from the Group II sites to the ditch. Part of this work was associated with the investigation of the fuel spill in the Lower Diagonal No. 1 Drain. No evidence of contribution to contamination in the ditch from any of the sites was found (Table B.11). The nineteen groundwater test holes, five piezometers, and two staff gauges were all considered part of the Group II investigation.

Investigation: consisted of drilling seven wells. One upgradient well, drilled to the intermediate aquifer, was artesian with respect to the shallow aquifer. All other wells were completed

Table B.11. Groundwater test hole screening results for LD#1

Site #	Hole #	PID Pos.	PID Neg.	Field GC Pos.	Field GC Neg.	Final Decision	Comments
LD#1	1		X		X	NEG	
LD#1	2		X		X	NEG	
LD#1	3		X		X	NEG	
LD#1	4		X		X	NEG	
LD#1	5		X		X	NEG	
LD#1	6		X		X	NEG	
LD#1	7		X		X	NEG	
LD#1	8		X		X	NEG	
LD#1	9		X		X	NEG	
LD#1	10		X		X	NEG	
LD#1	11		X		X	NEG	
LD#1	12		X		X	NEG	
LD#1	13		X		X	NEG	
LD#1	14		X		X	NEG	
LD#1	15		X		X	NEG	
LD#1	16		X		X	NEG	
LD#1	17		X		X	NEG	
LD#1	18		X		X	NEG	
LD#1	19		X		X	NEG	

Total = 19 0 holes with negative PID and positive GC
0 holes with positive PID and negative GC
0% disagreement between PID and GC
100% agreement

across the water table in the shallow alluvial aquifer. Five piezometers were installed along the ditch on the north side of the area, and three were installed around the Site 6 plume.

Group III Sites: Site 9 and Site 18:

Potential contaminants Site 9: oils, paint wastes, metals, and diesel fuel.
Potential contaminants Site 18: paints, metals, solvents, and hydrocarbons.

Screening: consisted of drilling ten groundwater test holes between the sites and the Lower Diagonal Drain Ditch (Table B.6). No contamination was detected.

Investigation: consisted of drilling two single completion monitoring wells, two soil borings near the former diesel tank location (to water), three soil borings in the grit disposal area (to 4 ft), two soil borings near the Imhoff tank sludge disposal pit (to 4 ft), and one piezometer.

Group IV Sites: Sites 10, Site 11, Site 12, Site 13, Site 14, Site 16, Site 17, Site 19, and Site 23:

Potential contaminants: lists can be found in the PA/SI.

Screening: consisted of drilling 162 groundwater test holes around the area and performing an EM-31 survey over Sites 19, 23, and 10 (Tables B.2, B.3, B.4). A large fuel plume was located which appeared to be emanating from the Old Fuel Farm, Site 16, and flowing toward the unnamed lateral drain north of the Lower Diagonal Drain (Table B.4). Another gasoline/diesel plume was delineated emanating from the old vehicle maintenance shop area where two leaking tanks were removed (Table B.2). This plume

appears to merge with a plume near the pesticide shop and boiler plant, Sites 12 and 13 (Table B.3).

Investigations: consisted of the following site specific tasks:

Site 10: GATAR Compound

Field personnel tried to locate and excavate the reported cans of PCB oil using EM-31 surveys and a metal detector. None were found near the surface. However, the EM survey indicates some buried metal in the northeast part of the compound which will be further investigated. Five soil borings were drilled in the former hazardous waste storage area (to 4 ft).

Site 11: Paint Shop

This area is now paved over, and the regional groundwater test hole program detected no contamination downgradient from the site.

Site 12: Pest Control Shop

Six soil borings were drilled in the vicinity of the suspected leach fields (to water). One single completion monitoring well was drilled near suspected contamination.

Site 13: Boiler Plant Tanks (tanks still in place)

Two single completion monitoring wells were drilled downgradient from the tanks in the plume delineated by groundwater test hole drilling. One piezometer was installed.

Site 14: Old Vehicle Maintenance Shop

One dual and three single completion monitoring wells were installed and sampled. Four piezometers were installed.

Site 16: Old Fuel Farm

Eight soil borings were drilled around the tanks (to water). Four single and two dual completion wells were installed and sampled mostly to assess the extent of the plume. These wells also encompass landfills, Sites 19 and 23. Eight piezometers were also installed in the area.

Site 17: Hanger 4

Five soil borings were drilled to 4 ft along the drainage swale leading to the unnamed lateral ditch.

Sites 19 and 23: Post WW II Burial Site and Shipping and Receiving

Three soil borings were drilled in the transformer storage area to a depth of 4 ft.

Site 20: Checkerboard Landfill:

Potential contaminants: JP-5, gasoline, diesel fuel, waste oils, hydraulic fluid, and wet garbage leachate.

Screening: consisted of drilling thirty-six groundwater test holes around the site (Table B.5). No contamination was detected with the field GC.

Investigation: consisted of drilling and sampling four single completion and one dual completion well.

Site 24: Road Oiling Area:

Potential contaminants: include waste oil, fuels, and solvents.

Screening: deemed unnecessary for this site since many of the groundwater test holes for the Group II sites were drilled in the road. No significant contamination was detected except that associated with the Site 6 plume.

Investigation: consisted of drilling and sampling five widely spaced soil borings to the water table along the road. Three of the wells were drilled adjacent to the road to assess the extent of the Site 6 plume and will also serve to assess the Road Oiling Area.

APPENDIX C

GENERAL CONTAMINANT TRANSPORT PATHWAYS, ASSIMILATION ROUTES, EXPOSURE POINTS, AND AFFECTED BIOTA

General Contaminant Transport Pathways, Assimilation Routes, Exposure Points, and Affected Biota

C.1 CONTAMINANT TRANSPORT PATHWAYS AND ASSIMILATION ROUTES OF CONCERN

One of the objectives of the Phase II IR Program remedial investigation is to define the potential migration pathways and exposure routes of contaminants with respect to sensitive receptors. Preliminary site-characterization results indicate the vast majority of contaminants at NAS Fallon are petroleum hydrocarbon related. Exposure by ingestion, dermal contact, or inhalation from all sites is minimal to both humans and biota because the wastes are either inaccessible (i.e., buried) or have been exposed long enough for significant near-surface volatilization to have occurred. Restricted access and institutional controls further mitigate any environmental exposure to both humans and biota from contaminants on NAS Fallon property.

Conceptual site models developed in the Phase II RI Work Plan indicate that the main environmental concern is exposure resulting from contaminated groundwater or surface water transport to sensitive off-site receptors. (ORNL 1989, Appendix A). The groundwater system underlying the base is composed of three aquifer flow systems: 1) a shallow alluvial aquifer extending from the surface to a depth of 15.2 m (50 ft), 2) an intermediate-to-deep alluvial aquifer extending from 15.2 m (50 ft) to 667 m (2200 ft) below ground surface, and 3) a basalt aquifer sandwiched in the alluvium at a depth of approximately 182 m (600 ft). The basalt aquifer serves as a domestic drinking water source for much of the surrounding area.

Due to the shallow water table, 1 to 3 m (3 to 10 ft) below ground surface, contaminants released to the soils have a high

potential for migration to the shallow groundwater. The Phase I PA/SI Report (Dames and Moore 1988) concluded that an upward flow gradient exists between the intermediate-to-deep alluvial aquifer and the shallow aquifer. The natural flow of groundwater in the area should prevent shallow contaminants from reaching the environmentally sensitive basalt aquifer at depth. Additional aquifer-characterization studies (ERM-West 1988) suggest that, at least in some portions of the Base, there is a 4.5+-m (15+ ft)-thick clay-confining layer separating the shallow aquifer and the intermediate-to-deep aquifer. These natural containment properties should thus mitigate downward migration of contaminants. Nonetheless, the lateral consistency of these flow parameters is unknown and does not preclude communication between the shallow and deep aquifers in at least some areas.

Phase II investigations must, therefore, determine if the waters are contaminated and must also identify affected receptors. Regionally, groundwater associated with the shallow aquifer is high in dissolved salt and unfit for domestic use (Glancy 1986). This lack of use greatly minimizes environmental exposure to groundwater contaminants. Exposures are facilitated primarily through natural groundwater seepage to surface media or percolation to the drinking-water source. The potential pathways of contaminant migration from the sites at NAS Fallon are, in order of importance: (1) subsurface flow in the shallow alluvial aquifer southeastward toward Carson Lake and to the drainage canals, (2) surface flow in drainage canals to the Stillwater Wildlife Refuge, (3) downward flow in shallow groundwater to the intermediate aquifer and the underlying basalt drinking-water aquifer, and (4) surface flow in irrigation ditches. These mechanisms are depicted in Fig. C.1. This figure represents a combination of the important aspects of the site-specific conceptual

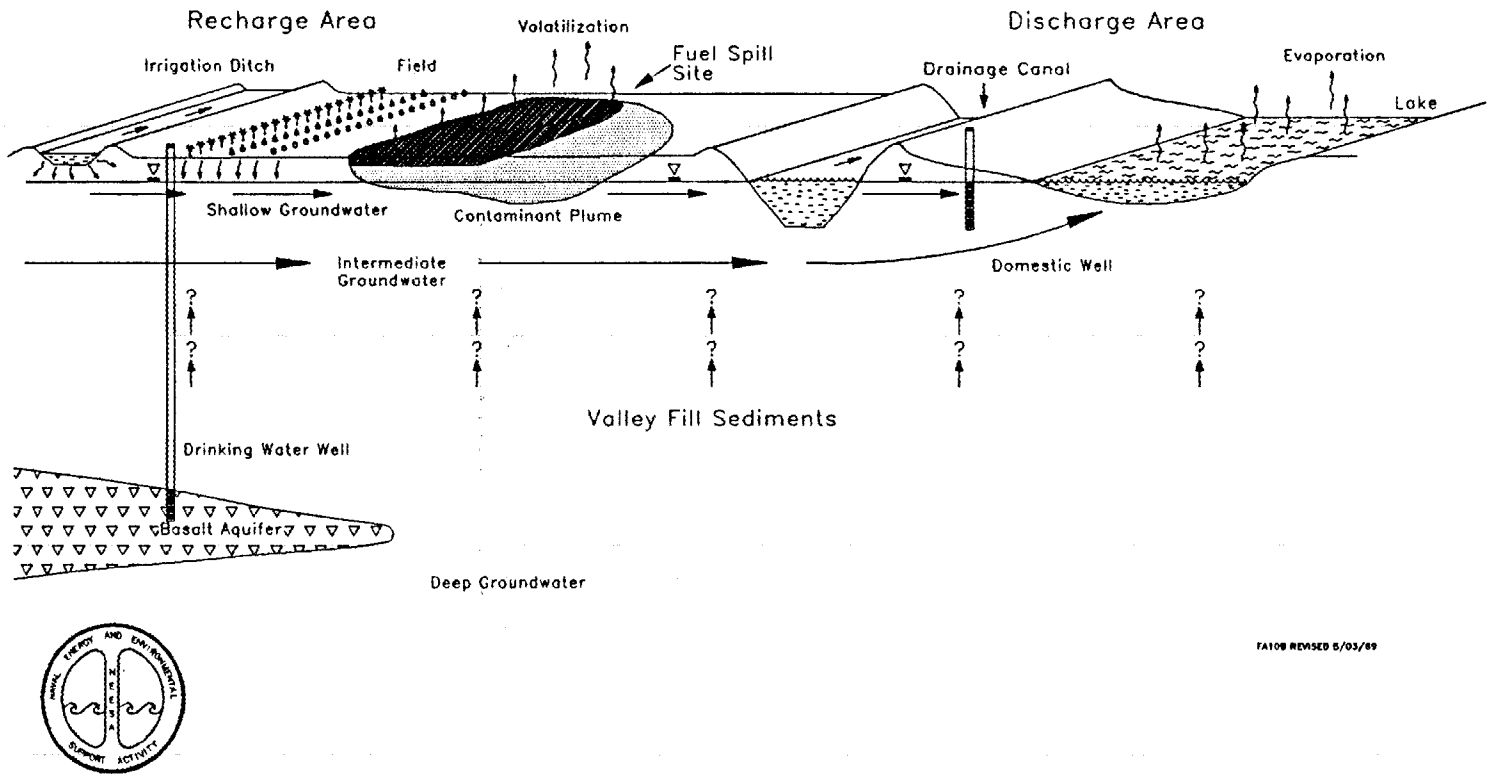

Fig. C.1 Conceptual model of potential pathways of migration at Naval Air Station Fallon.

models developed in the Phase II Work Plan (Appendix A, ORNL 1989). Note that a clear distinction is drawn between irrigation ditches and drainage canals. The irrigation ditches were constructed as a shallow system to deliver water to fields. The drainage canals were excavated deeper in order to drain excess surface runoff and shallow groundwater. The drainage canals intersect the shallow alluvial aquifer and the irrigation ditches do not; therefore, the irrigation ditches represent only a minor potential contaminant migration pathway when compared to the drainage canals. Also, flow in the drainage canals is slower than flow in the irrigation ditches.

Migration characteristics for known contaminants of concern are determined by individual contaminant characteristics such as density, viscosity, and solubility. Most of the fuels and oils would float on the water table, but small quantities will dissolve and migrate in the groundwater. Solvents, such as trichloroethene (TCE), behave differently based on the quantities available and the presence of other wastes. Some of the solvent might dissolve, some might sink as immiscible liquid, and some might float on the water table if the concentration is not high enough to break the surface tension of the water. The PA/SI report postulates that any sinking solvents would remain in the shallow aquifer due to the upward flow gradient across the boundary with the intermediate alluvial aquifer (Dames and Moore 1988). If the local groundwater flow gradient is determined to be down instead of up, there is the possibility of sinking and dissolved contaminants reaching the basalt aquifer. Since the basalt drinking-water aquifer is recharged by the intermediate and deep alluvial aquifers, this route could be a potential pathway to receptors.

Contaminants reaching the shallow aquifer may ultimately discharge into the area drainage canals. Some area drainage canals flow southeastward toward Carson Lake and others flow northeastward

toward Stillwater Point Reservoir. The regional groundwater flow direction is inferred to be southeastward toward Carson Lake. Carson Lake lies about 4.8 km (3 miles) from the base and Stillwater Point Reservoir lies approximately 16 km (10 miles) to the northeast (Fig. C.2). It is estimated that contaminants in groundwater could migrate approximately 10.6 m/yr (35 ft per year) (Glancy 1986), but if discharged into a drainage canal, the rate of migration could be several miles a day.

The drainage canals that could be affected include the Lower Diagonal Drain, the Lower Diagonal No. 1 Drain, and their tributaries on base (Fig C.3). These drainage canals discharge to the Stillwater Point Reservoir. Other drainage canals and irrigation ditches on the base are not located in proximity to the sites under investigation, and it is unlikely that they represent contaminant migration pathways for any of these sites.

Contamination of surface water could also occur during a rare rainfall or by human-induced runoff if the runoff is sufficient to carry the contaminants directly to drainage canals or irrigation ditches. It is estimated that contaminants in irrigation ditches could migrate on the order of 24 to 80 km/day (15 to 50 miles/day), while migration in the drainage canals would be considerably slower.

C.2 EXPOSURE POINTS AND AFFECTED BIOTA

Potential receptors include flora and fauna which inhabit and use downgradient and downstream surface water and persons using water from wells completed in the shallow alluvial aquifer or consuming contaminated flora or fauna. Users of the deeper groundwater are not considered likely receptors because of: 1) the significant depth to the deeper aquifer, and 2) the underlying clay layer and upward flow

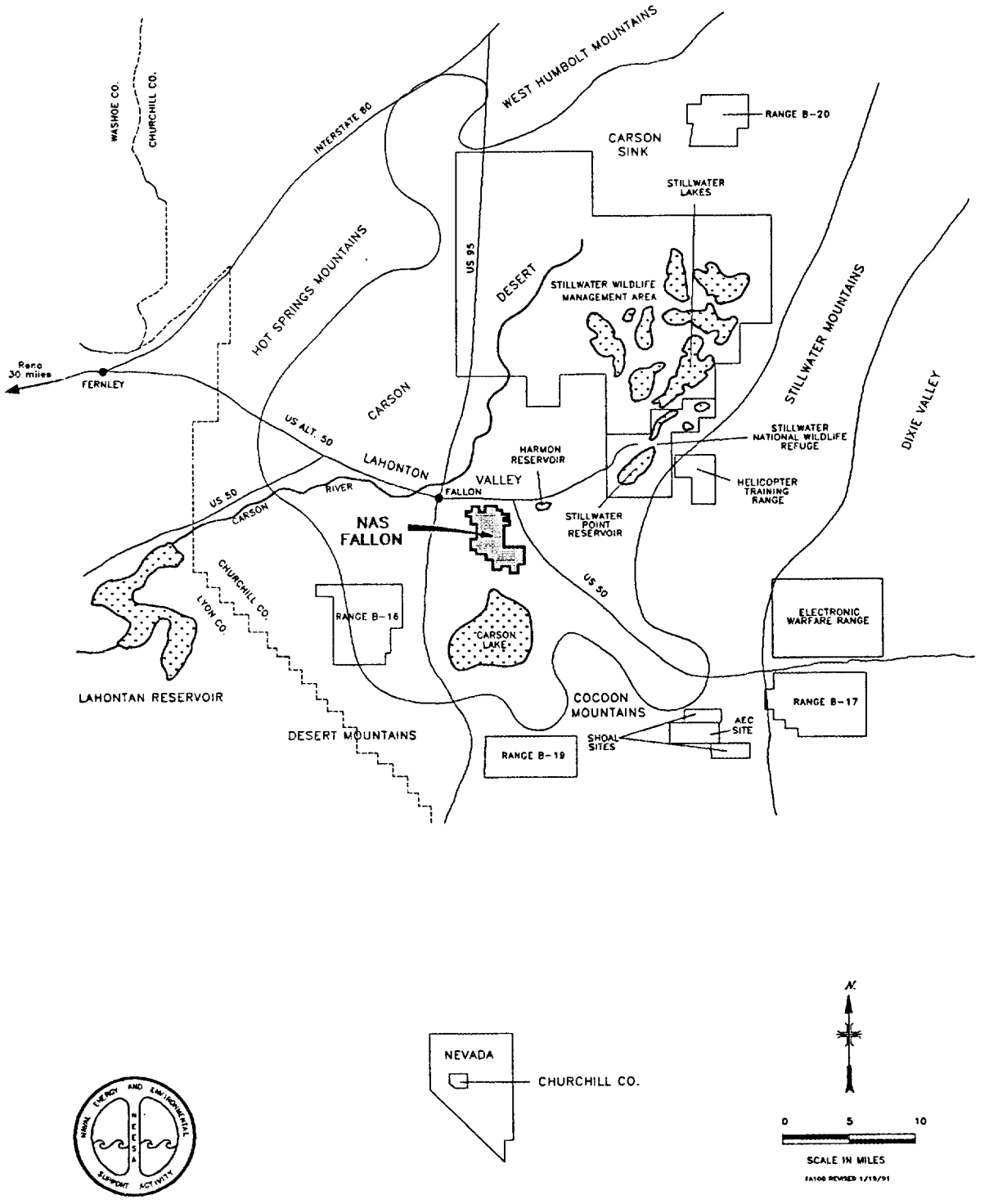

Fig. C.2 Regional location map of Naval Air Station Fallon.

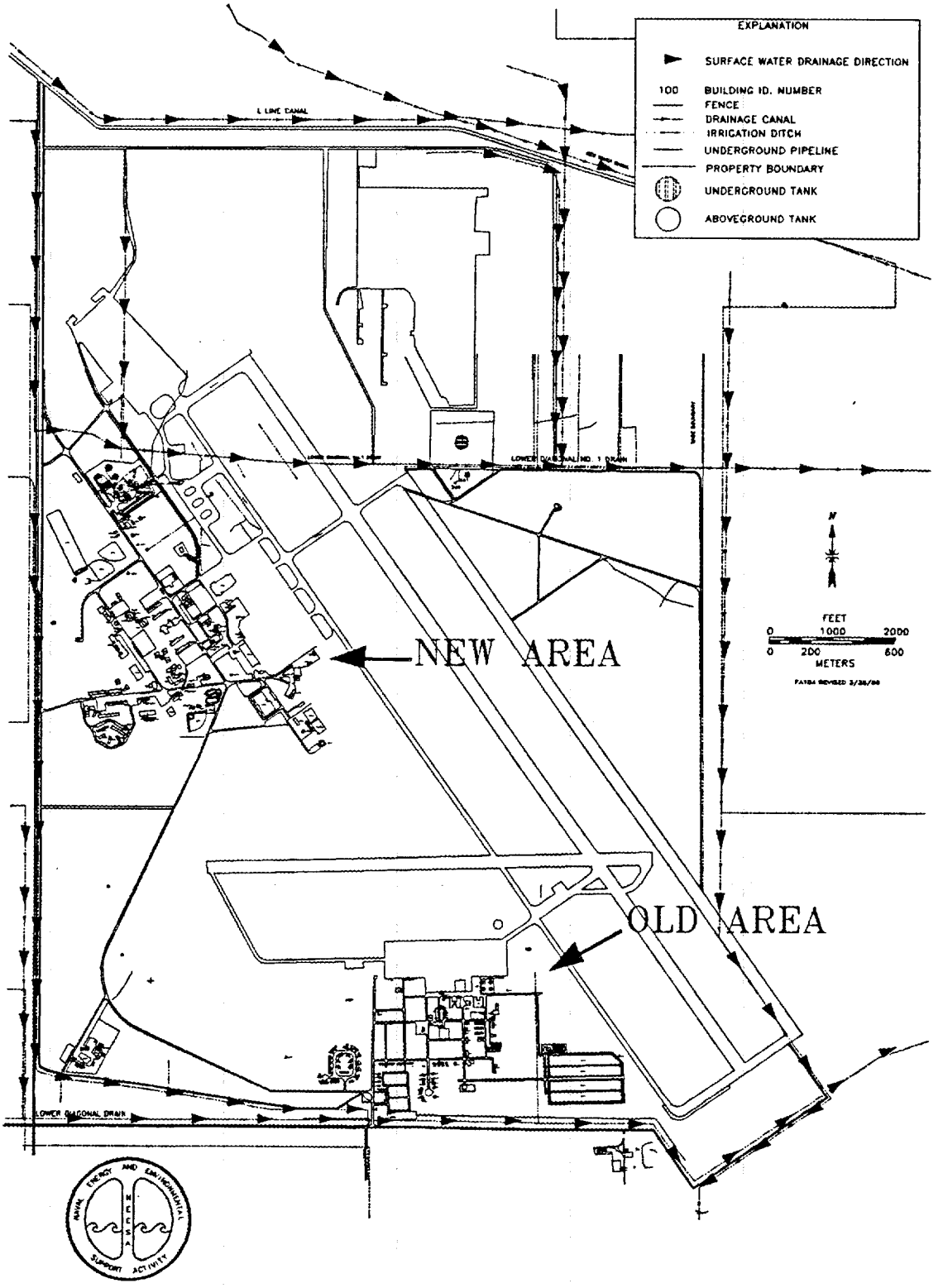

Fig. C.3 NAS Fallon. Area surface drainage system.

gradient which effectively contain contaminants in the uppermost aquifer.

Contaminants carried downstream by surface water or discharged from the shallow alluvial aquifer into drainage canals could threaten wetlands and aquatic habitat. Water from the Lower Diagonal Drain and the Lower Diagonal No. 1 Drain flows into the Stillwater Point Reservoir which is part of the Stillwater Refuge (Fig. C.2). This area is inhabited by two federally-listed endangered species: the bald eagle and the peregrine falcon. Although not federally-listed, other species of concern include the Lahontan tui chub, American white pelican, white-faced ibis, osprey, western snowy plover and long-billed curlew. Contaminant migration in surface water could also threaten the already beleaguered habitats in the Stillwater National Wildlife Management Area which includes the Stillwater National Wildlife Refuge. In recent years the refuge has been the focus of national attention due to reports of massive fish and bird die-offs. Studies are underway to identify the cause of these die-offs. The normal fluctuation of precipitation along with increased demand for available water resources have combined to create severe drought conditions in the refuge, and many marshes have dried up. This in turn has reduced the wildlife habitat in the refuge, which is considered by the Federal Fish and Wildlife agency to be critical to the migratory bird populations of the Pacific Flyway. There is also potential for exposure of humans to contaminants migrating off-site in surface water. For instance, the Lower Diagonal Drain receives minor use by area citizens for game fishing; these fish, in which contaminants may have concentrated, may be consumed by humans.

Several wells tapping the shallow aquifer may exist downgradient of NAS Fallon. In general the shallow groundwater in the surrounding area is of poor quality and unfit for domestic use (Glancy 1986). However, at least one shallow well is known to exist one-half mile

southeast of the base. Present use of this well is unknown, but it is likely that only livestock are watered from it due to the reported high mineral content of the water. Livestock, therefore, are potential receptors; humans are not believed to be directly consuming the water.

In summary, off-site transport of contaminants of concern via surface water and groundwater appear to be the major concerns at NAS Fallon. The poor quality of the shallow groundwater and the limited recreational use of surface flow in the immediate vicinity mitigate direct exposure of human receptors. Affected receptors appear to be primarily flora and fauna which inhabit the neighboring surface streams and wetlands. Human consumption of these receptors also affords a secondary exposure pathway to the local populace.

APPENDIX D

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) FOR PETROLEUM HYDROCARBONS

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) FOR PETROLEUM HYDROCARBONS

The State of Nevada Division of Environmental Protection Hydrocarbon Cleanup Policy as amended by the Proposed Regulation of the State Environmental Commission (LCB File No. R083-90, effective 10-1-90) specifies the following action levels for hydrocarbon contamination. The following statements regarding soil removal, dissolved product, and free product are direct excerpts from that document (NDEP 1987):

Soil Removal

Soil removal - The Division of Environmental Protection (DEP) may require soil removal if total petroleum hydrocarbon concentrations (TPH) in the soils are in excess of 100 mg/kg (ppm) as determined by EPA method 8015 as modified for petroleum hydrocarbons. The determination of removal shall be based upon the following site specific information:

1. Depth to groundwater: Depth to the nearest occurrence of water saturated soils. This includes perched water;

2. Quality and use of the affected groundwater: Inorganic and organic quality as well as present use and potential use of the aquifer for drinking water, irrigation, etc.;

3. Distance to the nearest drinking water well: Distance to the nearest well irregardless of gradients. Is the well presently used for drinking water purposes and what is the estimated number of users?

4. Soil type and estimated permeability: Types of soils encountered throughout the profile to groundwater in terms of it's texture, permeability, homogeneity, etc. is a major factor in migration velocity, attenuation and the potential for groundwater contamination;

5. Annual precipitation: Annual precipitation, annual evaporation, precipitation type (snow, rain), and potential for short term, high intensity events are all parameters which may influence the driving forces for contaminant migration;

6. Age and condition of the hydrocarbon contaminant: The age of the product and its amount of degradation has a direct bearing on the potential for the migration of that product as well as future negative impacts to groundwater and public health and safety;

7. Extent of the contaminated area (vertical and horizontal): A determination of the extent of contamination must include definition of both soil and groundwater contamination. This can be accomplished by the use of wells, soil gas surveys, etc.;

8. Present and future land use: Present and proposed land use is a major factor in determining the level of remediation needed for a given parcel is subject to;

9. Migration potential via preferential routes (i.e. utility lines, road base, conduits, etc.): These routes can drastically affect the movement and occurrence of

product in the subsurface environment and can have direct impacts to public health and safety;

10. Hydrocarbon product type: Product type has a direct bearing on the type of remediation proposed. Due to the volatility of some products, remediation can be accomplished via simple venting of the soils whereas other products may require removal or other methods of remediation. This also has a significant bearing on the potential for a dissolved product plume in the groundwater;

11. Vapor/explosion/safety hazard: If a safety hazard is identified the DEP will require an immediate remediation of the problem;

12. Structural impediments such as foundations, roadways, pipelines, etc. which may impede complete soil removal: In some instances structural impediments make soils removal difficult or impossible. It is the goal of the DEP to make decisions that are reasonable in regard to the cost verses benefits of soil removal in these situations.

In certain circumstances, the DEP will consider alternatives to soil removal. In situ biodegradation, soil venting and in situ chemical treatment and other methods shall be examined as viable and desirable alternatives to soil excavation and disposal.

Dissolved Product

Dissolved Product - dissolved hydrocarbon product may require remediation any time it is encountered in a potable or drinking water quality aquifer and benzene, ethylbenzene, xylene

or toluene concentrations are equal to or in excess of EPA recommended maximum contaminant levels (RMCLs) or maximum contaminant levels (MCLs). [Authors' note: The MCL for benzene is 5.0 μg/L. EPA-proposed MCLs for the remaining contaminants are: ethylbenzene - 700 μg/L; xylene (total) - 10,000 μg/L; and toluene - 2,000 μg/L (Leeden 1990)].

Discharge of affected groundwaters to surface waters shall contain no more than 1.0 mg/L TPH. Discharge to a publicly owned treatment works (POTW) shall contain no more than 10.0 mg/L TPH or the POTW discharge limit, whichever is less. Reinjection of affected waters to the groundwater shall be handled on a case by case basis by the DEP.

Free Product

Free Product - Any time free product is encountered on the groundwater in the formation in excess of one half inch (0.5 in.) (measurement accuracy of 0.01 ft), a recovery action must be undertaken. This action must include delineation of the plume boundaries, characterization of the product, and the design and implementation of an extraction/remediation system. Discharge of affected groundwater and disposal or recycling of recovered product must conform to applicable federal, state, and local requirements including fire and building codes.

Identified explosion or vapor hazards must be addressed and remediated immediately.

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