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09-05-0003

Camp Bonneville Preliminary Assessment

Vancouver, Washington

Technical Direction Document Number: 09-05-0003

February 2010

Prepared for:
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
1200 Sixth Avenue
Seattle, Washington 98101

Prepared by:

ECOLOGY AND ENVIRONMENT, INC.
720 Third Avenue, Suite 1700
Seattle, Washington 98104

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List of Abbreviations and Acronyms

Acronym	Definition
AEM	Atlanta Environmental Management, Inc.
amsl	above mean sea level
AP/PA	ammonium picrate/picric acid
AST	Aboveground Storage Tank
ATSDR	Agency for Toxic Substances and Disease Registry
Baker	Michael Baker Jr. Inc.
BCRRT	Bonneville Conservation Restoration and Renewal Team
bgs	below ground surface
BRAC	Base Realignment and Closure
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation , and Liability Information System
CERFA	Community Environmental Response Facilitation Act
cfs	cubic feet per second
COCs	Constituents of Concern
COPCs	Chemicals of Potential Concern
Corps	United States Army Corps of Engineers
CS	2-chlorobenzalmalononitrile (aka tear gas)
DA	Demolition Area
1,1-DCA	1,1-dichloroethene
DNR	Washington State Department of Natural Resources
DOC	Dissolved Organic Carbon
DOD	United States Department of Defense
E & E	Ecology and Environment, Inc.
EBS	Environmental Baseline Survey
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
ESI	expanded site inspection
ESU	Evolutionarily Significant Unit
FBI	Federal Bureau of Investigation
FS	Feasibility Study
GSA	Gary Struthers and Associates, Inc.
HC	Hart Crowser, Inc.
HE	Hand Grenade
ICs	Institutional Controls
ID	Identification
LRA	Local Redevelopment Authority
MCL	Maximum Contaminant Level

List of Abbreviations and Acronyms (Cont.)

Acronym	Definition
MEC	Munitions and Explosives of Concern
mm	millimeter
MTCA	Model Toxics Control Act
ng	Nanograms
NPL	National Priorities List
OB/OD	Open Burn/Open Detonation
OE	Ordnance and Explosive
PA	Preliminary Assessment
PAHs	Polyaromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
Parsons	Parsons Engineering Science, Inc.
Pentec	Pentec Environmental Inc.
PETN	Pentaerthritol Tetranitrate
PID	Photoionization detector
PPE	Probable point of entry
ppm	parts per million
PRG	Preliminary Remediation Goals
RAU	Remedial Action Unit
RBC	Risk-based Concentration
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RI	Remedial Investigation
ROD	Record of Decision
RPC	Reuse Planning Committee
RSF	Range Safety Fan
SSI	Supplemental Site Investigation
START	Superfund Technical Assessment and Response Team
SVOCs	Semivolatile Organic Compounds
SWI	Shannon and Wilson, Inc.
1,1,1-TCA	1,1,1-trichloroethane
TDL	Target Distance Limit
TOC	total organic carbon
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
UST	Underground storage tank
UXO	Unexploded Ordnance
VOCs	Volatile Organic Compounds
WAC	Washington Administrative Code
WC	Woodward Clyde
WMA	Wildlife Management Area

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Introduction

Pursuant to United States Environmental Protection Agency (EPA) Superfund Technical Assessment and Response Team (START)-3 Contract Number EP-S7-06-02 and Technical Direction Document (TDD) Number 09-05-003, Ecology and Environment, Inc., (E & E) conducted a Preliminary Assessment (PA) of the Camp Bonneville site, which is located near Vancouver, Washington. The PA was conducted under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA).

The PA is the first phase in the process of determining whether a site is releasing, or has the potential to release, hazardous substances, pollutants, or contaminants into the environment and whether it requires additional investigation and/or response action that is authorized by CERCLA. This process does not include extensive or complete site characterization, contaminant fate determination, or quantitative risk assessment.

The objectives of this PA are to:

- Determine whether the site is releasing, or has the potential to release hazardous constituents into the environment;
- Identify potential public health and/or environmental threats posed by the site;
- Assess the need for additional investigation and/or response action at the site; and
- Determine the potential for placement of the site on the National Priorities List (NPL).

Activities conducted as part of this PA included reviewing and evaluating available information pertaining to the site; collecting information on migration pathways and receptors; determining regional characteristics; and conducting a site visit. This document presents site background information (Section 2), a discussion of migration/exposure pathways and potential receptors (targets) (Section 3), a discussion of conclusions and recommendations (Section 4), and a list of pertinent references (Section 5).

The PA was conducted in response to a formal Preliminary Assessment Petition submitted by the Rosemere Neighborhood Association, Columbia Riverkeeper under Section 105(d) of CERCLA, 42 U.S.C. § 9605(d). A copy of the PA Petition dated February 3, 2009, is provided in Appendix A.

2 Site Background

2.1 Site Location

Site Name:	Camp Bonneville
CERCLIS ID Number:	WAN001002030
Site Address:	23201 NE Pluss Road Vancouver, Washington 98682
Latitude:	45° 41' 29.338" North (at center of site)
Longitude:	122° 24' 0.144" West (at center of site)
Legal Description:	Township 3 North, Range 3 East, Sections 34 and 35 Township 2 North, Range 3 East, Sections 1, 2, 3, and 10
County:	Clark
Congressional District:	3
Site Owner/ Representative:	Bonneville Conservation, Restoration and Renewal Team Michael J. Gage, Project Director 23201 NE Pluss Road Vancouver, Washington 98682 (360) 566-6990

2.2 Site Description

Camp Bonneville is located in Clark County, approximately 12 miles northeast of Vancouver, Washington (Figure 2-1). Generally, Lacamas Creek flows through the middle of the site with a number of tributaries that feed it. The general topography of the site is flat in the Lacamas Creek Valley, the remainder of the site consists of gently rolling hills. Camp Bonneville is a sub-installation of the Vancouver Barracks (located approximately 12 miles southwest of Camp Bonneville in Vancouver, Washington), which is a sub-installation of Fort Lewis (located approximately 100 miles north of Camp Bonneville in Tacoma, Washington). Camp Bonneville consists of approximately 3,840 acres of land that historically was used by the United States Department of Defense (DOD) to provide training for active Army, Army Reserve, National Guard, Marine Corps Reserve, Navy Reserve, Coast Guard Reserve units, and other DOD personnel. The installation consists of two cantonment areas, Bonneville cantonment and Killpack cantonment, 25 firing ranges, former sewage lagoons, and four historic landfills (Figure 2-2; WC 1997).

Camp Bonneville is located on the western slope of the Cascade Mountains in the Lacamas Creek Valley. The terrain is generally rolling. Elevations range from

289 feet above mean sea level (amsl) in Lacamas Creek at the southwest corner of the site to 1,000 feet amsl at the northwest corner, 1,350 feet amsl at the southeast corner, and 1,452 feet amsl at the south central boundary (WC 1997).

Troops from the Vancouver Barracks began to use part of the facility for a target range in 1910. The original military reservation, consisting of approximately 3,020 acres, was acquired by the federal government in 1918 (SWI 1999). In 1926, the land was officially named Camp Bonneville (Corps 1997).

The Bonneville cantonment area apparently was built in the late 1920s and was used primarily as barracks facilities. Additional uses of the buildings in the Bonneville cantonment included ammunition storage, cold storage, and a command post. The Killpack cantonment area was built and occupied by the Civilian Conservation Corps in 1935. The facilities were used for several military training programs, in addition to being used by the Vancouver Barracks. During World War II, the facility was also used to house Italian prisoners of war (SWI 1999). Figures 2-3 and 2-4 provide, respectively, illustrations of the Bonneville and Killpack cantonments.

In 1950, many of the buildings and systems at the site were rehabilitated for use in training Army Reserve units. In the early 1950s, an additional 840 acres of land were leased from the State of Washington. (SWI 1999)

In the 1980s, the facility was used by a number of civilian organizations for camping, picnics, and environmental studies. Camp Bonneville is currently used by federal, state, and local law enforcement agencies for firearms training and practice, and general training purposes. The Federal Bureau of Investigation (FBI) makes frequent use of one of the firing ranges. (SWI 1999)

In 1996, following the selection of Camp Bonneville for closure (in 1995) under the Base Realignment and Closure (BRAC) authorization, all active military training units ceased operations at the camp. All out-grants for use of the facilities were cancelled with the exception of the FBI firing range. The FBI currently plans to maintain a firing range on Camp Bonneville property after the base has been officially released by the DOD. (SWI 1999)

2.3 Ownership History

Camp Bonneville was owned and operated by the DOD from 1909 to 2006. In 1959, Vancouver Barracks, including Camp Bonneville, became a sub-installation of Fort Lewis, Washington (SWI 1999). In October 2006, the Army transferred ownership of the property to Clark County in an "early transfer," under which the DOD continued to provide funding for cleanup of the site. Clark County then transferred ownership of the land to the Bonneville Conservation Restoration & Renewal Team LLC (BCRRT), an organization managing a team of contractors in the cleanup and removal of hazardous wastes and unexploded ordnance (UXO).

2.4 Operations and Waste Characteristics

Historical operations at the site have included the storage of pesticides, maintenance of vehicles, storage of diesel fuel for building heating, sewage lagoons, at least three landfills (one additional landfill has been reported but not located), various caliber firing ranges, and troop maneuvers. All of these historical operations are discussed in detail in the "Previous Investigations" section below.

Current operations include continuing evaluation of contamination in one landfill (Landfill 4; discussed in detail below), and clearing of UXO.

2.5 Previous Investigations

This section will discuss previous investigations that concern the discovery, classification, or sampling of areas or features which may have involved the use, storage, disposal, or spilling of hazardous substances. A complete administrative record of all reports relating to the site is available at the Washington State University – Vancouver library.

2.5.1 Environmental Baseline Survey

In 1997, Woodward Clyde completed an Environmental Baseline Survey (EBS) report for the United States Army Corps of Engineers (Corps). The purpose of the report was to classify discrete areas of property associated with Camp Bonneville subject to transfer or lease into one of the standard environmental conditions types as defined in the Community Environmental Response Facilitation Act (CERFA) guidance and the DOD BRAC Cleanup Plan Guidebook. The standard environmental condition of property types are presented below (WC 1997):

- **Category 1:** Areas where no storage of hazardous substances or petroleum products has occurred for 1 year or longer and no release or disposal of hazardous substances or petroleum products has occurred (including no migration of these substances from adjacent properties). Additionally, Category 1 includes areas where no evidence exists for the release, disposal, or migration of hazardous substances or petroleum products; however, the area has been used to store less than reportable quantities of hazardous substances (40 CFR 302.4) or 600 or fewer gallons of petroleum products.
- **Category 2:** Areas where only storage of hazardous substances in amounts exceeding their reportable quantity or petroleum products exceeding 600 gallons has occurred, but no release, disposal, or migration has occurred.
- **Category 3:** Areas where storage, release, disposal, or migration of hazardous substances or petroleum products has occurred, but at concentrations that do not require a removal or remedial action.
- **Category 4:** Areas where storage, release, disposal, or migration of hazardous substances or petroleum products has occurred, and all removal or remedial actions to protect human health and the environment have been taken.
- **Category 5:** Areas where storage, release, disposal, or migration of hazardous substances or petroleum products has occurred, and removal or

remedial actions are under way, but all required actions have not yet been implemented.

- **Category 6:** Areas where storage, release, disposal, or migration of hazardous substances or petroleum products has occurred, but required removal or remedial actions have not yet been initiated.
- **Category 7:** Areas that are not evaluated or require additional evaluation.

Areas that are designated Category 1 through 4 are suitable for property transfer or lease, subject to consideration of the qualifiers. Areas that are designated Category 5 through 7 are not suitable for transfer, but may be suitable for lease (WC 1997). The designation of site areas identified under the BRAC Cleanup Plan and the basis for their designation is presented in Table 2-1. The reference map for this investigation is provided in Figure 2-5. No samples were collected as part of this investigation.

2.5.2 Base Realignment and Closure Cleanup Plan

In 1995, Woodward Clyde prepared a BRAC Cleanup Plan for the United States Army Corps of Engineers (Corps). The BRAC Cleanup Plan included a brief history of site operations and outlined the areas of concern with regard to environmental cleanup and disposal, and reuse of the site. The objectives of the cleanup plan were to: summarize the current status of Camp Bonneville environmental restoration programs; present a comprehensive strategy for implementing response actions necessary to protect human health and the environment; and present schedules for restoration and compliance activities. (WC 1995)

Twenty areas of concern for restoration or assessment were identified during the investigation; of these 20 sites, 10 consisted of known or suspected disposal areas (Figure 2-5). A summary of these areas is provided below:

- **Landfill 1:** A cultural resources survey performed in 1980 located a landfill east of the Bonneville cantonment and north of the sewage lagoon. The cultural resources survey described the disposal area as a 4-meter by 5-meter shallow depression and stated that bottle fragments contained in the landfill date its use to the early 1900s. Neither the length of use nor a comprehensive list of the quantities and types of trash disposed of in this landfill is known (WC 1995).
- **Landfill 2:** This landfill, located northeast of the Bonneville cantonment, was reported to have been partially excavated during the construction of the sewage lagoon in approximately 1978. According to an interview conducted for the EBS, fill material was unearthed at the eastern and northern borders of the sewage lagoon. Neither the type nor quantity of material disposed of in this landfill is known. The period of use is estimated at 1940-1950 (WC 1995).
- **Landfill 3:** This landfill, which is suspected to have been used as a trash burial area, is located south of Landfill 2 and the sewage lagoon. According to an interview conducted for the EBS, this area contains a refrigerator and a locker. Neither the length of use nor a comprehensive list of the quantities

and types of trash is known. The period of disposal is estimated to have been in the 1970s (WC 1995).

- **Three Grease Pits:** Two grease pits are located at the Bonneville cantonment north of Building 1828, and one is located at the Killpack cantonment east of Building 4389. The pits are composed of corrugated metal tubes, approximately 2 feet in diameter, that extend into gravel-filled pits to an unknown depth. The pits reportedly received cooking grease and oils from the mess halls. An interview conducted for the EBS indicates there was a potential for the uncontrolled disposal of potentially hazardous substances in these pits. The period of disposal is estimated to have been from 1935 to shortly before base closure (WC 1995).
- **Drum Burial Area:** A suspected drum disposal site was identified in May 1996 by an anonymous telephone caller, identifying himself as a former facility employee to the current Camp Bonneville Facility Manager. The suspected drum disposal area was located southeast of the Killpack cantonment and east of the gravel road. Metal anomalies have been confirmed at this location (WC 1995).
- **Paint/Solvent Burial Area:** A suspected paint/solvent disposal area was identified in May 1996 by an anonymous telephone caller, identifying himself as a former facility employee to the current Camp Bonneville Facility Manager. The suspected paint/solvent disposal area was located southeast of the Killpack cantonment and west of the gravel road. It was reported by the caller that paint, pesticides, and solvents were disposed of in this area (WC 1995).
- **Two Wash Racks:** The first wash rack, associated with Building 4475 at the Killpack cantonment, was identified in one of the previous environmental compliance inspections performed at Camp Bonneville. The wash rack does not have an oil/water separator. The second wash rack, associated with Building 4476, is an open gravel-covered area that gently slopes toward the road. The wash racks may have received waste oil and antifreeze during their period of use (WC 1995).
- **Maintenance Pit:** Building 4475 at the Killpack cantonment reportedly had a maintenance pit located west of the building that is now covered with concrete. The pit was an unlined excavation in the ground that potentially received vehicle fluids such as oil or antifreeze for an unknown period of time. Additionally, the ground south of the building in an area measuring approximately 4 feet by 85 feet was noted during the EBS to have stressed vegetation and red staining. This area received runoff from the galvanized steel roof of Building 4475 (WC 1995).
- **Chemical Warfare Burial Area:** The Department of the Army informed the BRAC Cleanup Team that chemical warfare burial sites had been identified at training facilities with similar utilizations and construction dates as Camp Bonneville. There had been no documentation at the time of this report that chemical warfare material was buried on the property; however, the potential was recognized and noted (WC 1995).
- **Burn Pit:** The burn pit is located north of Landfill 3. The area had been repeatedly used on an infrequent basis to burn wood and debris. Wood debris was observed to have been disposed of in this area (WC 1995).

2.5.3 Endangered Species Survey

In 1995, Pentec Environmental, Inc. conducted an endangered species survey for the Corps. The objective of the survey was to determine the presence of plant and animal species that were Federally or State-listed as endangered or threatened, or were candidates for such listing, and to estimate the relative abundance of these species within the boundaries of the site. Five target species were identified within the Camp Bonneville boundaries. None of the species were Federally listed threatened or endangered. Among the animals, two were State candidate species and one was a Federal candidate species. Among the plants, one was a State endangered species and one was a State sensitive species. The report recommended monitoring of invasive species and implementation of control measures. The hairy-stemmed checker-mallow population was deemed at risk because of its roadside location. It was recommended to install permanent markers around the plants to ensure that the area is not mowed or sprayed with herbicides. (Pentec 1995)

2.5.4 Archives Search Report

In July 1997, the Corps conducted an archives search to determine the types, quantities, and probable locations of ordnance items abandoned by DOD prior to relinquishing ownership of Camp Bonneville. Information in the report was based on a review of existing historical documents and maps, interviews, a site inspection, and descriptions of known or suspected contamination. The conclusions and recommendations from the archives search report are discussed below in the following subsections. (Corps 1997)

2.5.4.1 Ranges and Training Areas

The Army started target practice on a rifle range at Camp Bonneville in 1910. The Army placed 14 short-range and seven long-range targets in the valley, which was 350 yards wide and 2,000 yards long. In 1918, the range contained 24 targets. At some time prior to 1929, a machine gun and howitzer range was added to the training facilities. The 1959 property inventory includes the following ranges: a known distance range, a pistol range (20 targets), a submachine gun range (21 targets), a live hand grenade range, and a mortar training shell range. These targets are also depicted on a historical map dated May 28, 1943. Artillery units conducted firing exercises about twice a year from 1969 to 1985, resulting in approximately 50 rounds being fired into the impact area during each training session. Sometime in the 1970s, however, the military switched to sub-caliber rounds for training purposes. Historical maps dated between 1926 and 1994 identified many additional ranges and firing points throughout Camp Bonneville. These included the following:

- Rifle Range;
- Machine Gun Range;
- Anti-Aircraft Range – 500 inches miniature (includes overhead, parachute, climbing, and diving, and horizontal targets);
- Pistol Range;
- 1,000 inches Rifle and Light Machine Gun Range;
- Infiltration Course;

- Sub-machine Gun Range;
- Artillery Impact Area;
- Field Firing Area;
- Record Firing Range;
- 1,000 inches and Moving Target Range;
- Artillery Firing Points;
- Mortar Training Shell Course;
- Practice Grenade Range;
- Live Grenade Range;
- Rifle Grenade;
- Rocket Launcher;
- TF-1 25M;
- Free Firing .30 caliber Machine Gun Range Mortar Positions;
- Close Combat Course;
- Night Fire, KD Range;
- M60 and 25M Range;
- 14.5 Range;
- LAW, Sub-caliber, and M203 Practice Range 25-Meter Range;
- M16 Qualification Range;
- FBI Range;
- ARF Range;
- Combat Pistol Range;
- M203 Grenade Launcher (HE) Range M-31 Field Artillery Range; and
- Known Distance and Training Fire Range 25-Meter and Machine Gun Range.

Additional training in maneuvers, bivouacking, and tactics was accomplished on the many training areas at Camp Bonneville. Occasionally, vehicles would support this training, and the use of smoke or riot control agents would be authorized.

The archives search report concluded that it was possible that unserviceable munitions may have been burned in the demolition areas. A 1971 agreement between the Army and Air Force stated that all munitions had to be destroyed by burning or detonation. A 1986 amendment allowed unserviceable munitions to be destroyed by a high order detonation only, and later in 1993, the destruction of unserviceable munitions by any method was not permitted.

2.5.4.2 Ammunition and Storage Facilities

A building list from 1946 listed two ammunition magazines, buildings 2950 and 3754. The property inventory produced in 1959 when Camp Bonneville became a sub-installation of Fort Lewis shows that building 2950 was still used as a ammunition storage facility, but it does not show a building 3754. The archives search report indicated that the EBS building list noted three ammunition bunkers, and buildings 2950-52, and it listed their construction date as 1976.

2.5.4.3 Chemical Warfare Service Activities

Several documents from the 1930s discussed the expenditure of detonating gas identification (ID) sets from the Vancouver Barracks' supply. The gas ID sets consisted of a chemical agent placed in glass ampoules, vials, or bottles to train soldiers in the safe handling, identification, and decontamination of chemical warfare agents (CMA 2007). These documents all referred to the use of one set per instance, but they did not specify the location or extent of the training involved. The archives search report indicated it was known, however, that Camp Bonneville could have been the location of this activity. Camp Bonneville had two gas chambers, and it also had a 100-yard by 100-yard mustard training area. An undated map from the Real Estate Office at Fort Lewis was reviewed. It had a hand-written note in the mustard training area which read, "Gas ID." Other Chemical Warfare Service items mentioned in historical documentation included gas masks, smoke pots, demustardizing agents and apparatuses, tear gas capsules, and land mines. It was reported that the old gas chamber was burned in the 1970s. The two possible locations for the second gas chamber are Buildings 1834 and 1864, both of which are located in the Bonneville cantonment.

2.5.4.4 Potential and Confirmed Ordnance Presence

The archives search report concluded that the potential for ordnance existed throughout most of the installation. Figure 2-6 identifies the areas recommended for further action with respect to ordnance. The types of UXO determined to possibly be present at the site ranged from small arms ammunition to 155-millimeter (mm) artillery rounds, up to 4.2-inch mortars, 2.36-inch and 3.5-inch rockets, and grenades (hand and rifle). Training devices were also expected to be found throughout the post.

Ordnance confirmed to be present throughout the post included one 2.36-inch rocket, which was found near the sewage treatment facility, 3.5-inch rockets, 40-mm grenades (HE), 3-inch Trench Mortar (sandfilled), 10-mm and 155-mm phosphorous grenades, and several pieces of small arms ammunition. Based on interviews with people knowledgeable about Camp Bonneville, it was determined that ordnance items also have been found off post near the post's eastern boundary and north of the Bonneville cantonment area.

2.5.4.5 Archives Search Report Recommendations

The archives search report recommended that statistical sampling for UXO be conducted to delineate the areas containing UXO. The areas with the greatest potential for UXO were depicted on an Areas Recommended for Further Action figure (Figure 2-6).

2.5.5 Surface Water Investigation of Lacamas Creek and Tributaries

In 1998, Hart Crowser performed a limited surface water investigation of Lacamas Creek and its tributaries for the Corps. The objectives of the investigation were to determine where constituents of concern (COCs) were entering Camp Bonneville via tributaries of Lacamas Creek; and whether COCs were exiting Camp Bonneville via Lacamas Creek and potentially impacting Lacamas Lake (HC 1998). The sample locations for this investigation are provided in Figure 2-7.

A total of six surface water samples (HC-H1 through HC-H5 and HC-D1) and one blind duplicate sample (HC-D10) were collected during the investigation. Five samples were collected from near the headwaters of various tributaries to Lacamas Creek near their entry points to the post to determine concentrations upstream of the post: sample HC-H1 was collected from East Fork Lacamas Creek, sample HC-H2 was collected from an unnamed tributary to David Creek, sample HC-H3 was collected from David Creek, sample HC-H4 was collected from North Fork Lacamas Creek, and sample HC-H5 was collected from an unnamed tributary to the North Fork Lacamas Creek (Figure 2-7). Samples HC-H1 through HC-H5 were composited at the laboratory into one sample. One sample was collected from Lacamas Creek downstream of the post (HC-D1) just before the creek exits the post.

The samples were analyzed for hardness (EPA Method 6010), total suspended solids (EPA Method 160.2), cyanide (EPA Method 9012), nitrate (EPA Method 300.0), nitrate/nitrite (EPA Method 353.2), total phosphorus (EPA Method 365.4), orthophosphate (EPA Method 365.2), fecal coliform (SM 9331E), fecal streptococcus (SM 9330C), total and dissolved priority pollutant metals and barium (EPA Method 6020/7470), total petroleum hydrocarbons (TPH; Methods NWTPH-Gx and NWTPH-Dx), semivolatile organic compounds (SVOCs; EPA Method 8270C), pesticides/polychlorinated biphenyls (PCBs; EPA Method 8081A/8082), organophosphorous pesticides (EPA Method 8141A), pentaerthritol tetranitrate (PETN; EPA Method 8330), and ammonium picrate/picric acid (AP/PA, LTL 8303).

Sample results indicated that the dissolved metal barium and the total metals arsenic, barium, cadmium, chromium, copper, silver, and zinc were detected at concentrations above the composited up-post sample concentrations. No other analytes were detected at concentrations above the up-post concentrations and no SVOCs or pesticides/PCBs were detected above the instrument detection limit in any samples. (HC 1998)

The report concluded that site activities had not impacted the water quality of Lacamas Creek. (HC 1998)

2.5.6 Camp Bonneville Reuse Plan

In September 1998, a Reuse Plan was published for future possible uses of the site. The plan was prepared by the Camp Bonneville Local Redevelopment Authority (LRA) with the assistance of Otak, Inc. The plan was subsequently updated in February 20, 2003 and November 15, 2005. When the military closes a base, it asks the local community to form an LRA to prepare a reuse plan for the property. The LRA typically includes any jurisdictions, such as cities and counties, in which the military base is located. Since Camp Bonneville is in Clark County and is not within any city boundaries, Clark County formed the officially recognized Camp Bonneville LRA in November 1995. (LRA 1998)

Figure 2-8 illustrates the future possible uses of the site as outlined in the Preferred Reuse Plan.

To assist with the community-based planning effort, the Clark County Board of County Commissioners appointed a five-member Reuse Planning Committee (RPC) to oversee the reuse planning process. The RPC established six subcommittees made up of community representatives to assist in preparing planning options. The LRA RPC established seven guiding principles for planning, which required the reuse plan to be self sustaining, locally focused and directed, an open process, considerate of impacts to the surrounding neighborhoods, addressed to overall community need, based on cooperation and consensus building, and environmentally conservative (LRA 1998). The preferred reuse plan components are discussed in the following subsections.

2.5.6.1 Regional Park

A regional park was proposed that would comprise approximately 1,000 acres along the western portion of the property. The public park would provide opportunities for the local community to enjoy both active and passive recreational activities. The park would be managed and maintained by Clark County and would provide the following recreational opportunities:

- Recreation trails (for hiking, mountain biking, and equestrian use);
- Group picnic areas and picnic shelters;
- Amphitheater and stage (for outdoor school and small local events);
- Restroom facilities;
- Tent camping facilities;
- Recreational vehicle camping facilities;
- Public firing range;
- Archery practice range;
- Park watch person's residences;
- Vehicle access road;
- Designated parking area;
- Ponds for recreational use and environmental education;
- Native American cultural center in the Bonneville cantonment area;
- Environmental study area; and
- Orienteering.

2.5.6.2 Law Enforcement Training Center

A law enforcement training center was proposed to serve the regional needs of law enforcement agencies of southwest Washington. At this facility, police officers would receive basic training, learn new skills, and learn firearms techniques. The training center would be located in the Killpack cantonment. A new training building would be constructed to provide three to six classrooms for use by Clark College and county law enforcement for environmental and law enforcement training. Additionally, local law enforcement firing ranges were proposed east of Lacamas Creek in the southwest corner of the property. An equestrian riding ring was proposed in the general vicinity of the Killpack cantonment, and would be open to the general public when not being used for local law enforcement training. A physical fitness course and canine training areas were also proposed in the area. Proposed firing ranges would include a handgun range, a rifle range, and an area for the future construction of an indoor firing range.

2.5.6.3 Rustic Retreat Center/Outdoor School

A Rustic Retreat Center/Outdoor School was proposed as the primary reuse of the barracks areas. The retreat center/outdoor school would reuse many of the existing structures after upgrades were completed for compliance with applicable building codes, and structural and utility service improvements. New buildings such as a meeting hall would be located within the existing Bonneville cantonment area.

2.5.6.4 Native American Cultural Center

Rattling Thunder, a non-profit Native American cultural group representing area tribes, provides training (drums, art, Native American culture) to Native American youth in the region and assists in coordinating tribal activities such as regional powwows. Rattling Thunder requested use of a barracks building and access to kitchen and meadow areas at Camp Bonneville for a Native American Cultural Center. The center would also be open to the general public visiting the regional park and outdoor school. The Cowlitz Indian Tribe and the Confederated Tribes of Grand Ronde were also involved in the planning process and were supportive of the development of a Native American Cultural Center at Camp Bonneville.

2.5.6.5 Clark College Environmental Field Station

Approximately 50 to 60 acres were proposed to be designated for environmental studies in the southwest corner of the property. This area was selected due to the various ecosystems in this creek watershed area and its suitability for water quality research, wildlife habitat studies, and native plant community preservation and restoration programs. A new classroom building at the Killpack cantonment would also be constructed to provide three to six classrooms for use by Clark College and county law enforcement for environmental and law enforcement training.

2.5.6.6 Trails and Nature Area

Approximately 2,000 acres were proposed to be maintained for trails and nature areas in the central and eastern portions of the property. The public would access this area through hiking trails, mountain bike trails, and equestrian riding trails. Environmental learning areas would be developed for use by all age groups. Most of these recreational trails would utilize gravel and unpaved roads and cart tracks that already exist throughout the property; however, additional trails would be created as funding became available. Trails in these natural areas would also be utilized by trail maintenance staff, timber management crews, and emergency response personnel such as firefighters.

2.5.6.7 Federal Bureau of Investigation Firing Range

An area immediately adjacent to the law enforcement firing ranges was identified for lease by the FBI. Noise studies indicate that firing ranges must be located no closer than 2,000 feet from neighborhoods and public use areas. Because of this, the FBI had been asked (and had agreed) to move its range to an area that would meet this criterion. Due to safety issues, the FBI was supportive of the LRA's requirement that the relocated FBI range be baffled. The FBI estimated past usage to be 60 – 80 days per year, with usage (except for emergency training) usually able to be scheduled in advance. It was determined to be essential for the viability of the regional park that FBI use of the firing range be limited to solely meeting the FBI's needs, particularly during the peak months for park and outdoor school usage at the nearby meadow areas. The FBI was willing to share range usage with law enforcement agencies when FBI agents are available to oversee the usage.

2.5.6.8 Timber Resource Management Area

The property has significant forested areas that provide valuable wildlife habitat, stream water quality and watershed protection, and open space. Timber thinning was recommended as part of the management plan to maintain the health of this forest environment, reduce potential fire hazards, and provide a revenue product from timber sales. Forest management goals would include, but not be limited to: simulating an old growth timber stand structure by generating an older age class of Douglas fir; and optimizing growth, yield, and forest health. The county forestry staff planned to use several silvicultural techniques to accomplish this, which would be addressed in detail in a forest management plan that would span a 50-year period. The Timber Resource Management Area was divided into two phases. Phase 1 would consist of the western portion of the property, most of which is proposed as a county regional park. Phase 2 would include the balance of the property, the majority of which would be designated as open space greenway.

2.5.6.9 Wetland/Riparian Area Restoration/Enhancement and Habitat Restoration

The plan proposed the restoration and enhancement of existing wetland and riparian areas. Additionally, it was intended that the reuse development process would enhance the entire site for wildlife, fish, and native plants. Clark County would work with the Washington State Department of Fish and Wildlife and the United States Fish and Wildlife Service to explore opportunities on the site to enhance fish population and reintroduce native species.

2.5.7 Multi-Sites Investigation

In 1999, Shannon and Wilson, Inc. (SWI) conducted a Multi-Sites Investigation for the Seattle District U. S. Army Corps of Engineers. The overall objective was to identify contaminated areas and determine the next appropriate step toward restoration of those areas. The areas that were investigated included the three landfills, two suspected disposal areas, the former burn area, the former vehicle maintenance pit, the two former vehicle wash racks, and two hazardous material storage buildings. During the investigation, each of the areas was characterized and samples were collected, with the exception of Landfill 1, which could not be located. The analyses and methods applied are presented in Table 2-2.

Ground water sample results were compared to federal maximum contaminant levels (MCLs), EPA Region 3 tap water standards, and Model Toxics Control Act (MTCA) Method B standards for ground water protection. Soil sample results were compared to EPA Region 3 risk-based concentrations for residential soil exposure levels, MTCA Method A and Method B cleanup levels, and statewide background concentrations for metals. Additionally, a number of background soil samples were collected to determine background metals concentrations for the site (SWI 1999). Each of the areas assessed is discussed below in the following subsections. Figures 2-9 through 2-16 provide illustrations of the exploration plan areas. The investigation of an additional location (Landfill 4) was to be described in an addendum to the Multi-Sites Investigation report, but this addendum could not be located.

2.5.7.1 Landfill 2

This former landfill was discovered in about 1978 during excavation for construction of the sewage lagoon. According to an interview conducted during the EBS, landfill material was unearthed at the eastern and northern borders of the sewage lagoon. No description was found of the materials encountered during construction of the sewage lagoon. There is no record of the type or quantity of material that was placed in this landfill, and the dates of use are not known.

The general landfill area is bounded by the existing sewage lagoon to the northwest and wooded areas to the south and east (Figure 2-9). The landfill area slopes gently southward toward Lacamas Creek. Although most of the site area is relatively flat, portions of the area are bumpy and uneven. The area between the sewage lagoon and the gravel road to the south is covered with native grasses.

Sixty-four soil gas samples were collected in the Landfill 2 area. The soil gas sample locations were not depicted on the report map. The samples were analyzed for halogenated hydrocarbons and benzene, toluene, ethylene, and xylenes (BTEX) compounds by EPA Methods SW8010 and SW8020. These data were used as a screening tool to determine whether volatile constituents were present in and escaping from the landfill, rather than to provide a reliable quantitation of concentrations. Analytical results from this sampling event were below the method detection limits for all soil gas samples with the exception of chloroform. Trace concentrations of chloroform were detected in two samples at 4 nanograms (ng) in sample L2-SG-40 and 6 ng in sample L2-SG-58. These trace concentrations of chloroform may be due to contamination from sampling or analytical procedures.

Three soil borings (L2-SB01, L2-SB02, and L2-SB03) were drilled in the Landfill 2 area during July 1998. Monitoring wells were installed in all three borings (L2-MW01, L2-MW02, and L2-MW03). The monitoring wells were installed in locations assumed to be upgradient (one well) and downgradient (two wells) of the landfill, based on area topography and surface drainage. For safety purposes, each soil boring was initially advanced by the UXO specialists to a depth of approximately 5 to 7 feet below ground surface (bgs), which is also below the water table. The drilling rig was then moved over the hole (or immediately adjacent to it), and drilling continued by the hollow-stem auger method. One soil sample was collected for chemical analysis at or immediately above the water table in each of the downgradient soil borings. No ground water was encountered in the upgradient boring. Because the UXO specialists were required to advance the holes to depths below the water table (for safety purposes), soil samples for chemical analysis were collected from the hand auger barrel in the two downgradient borings. A soil sample was collected from the anticipated wet season water table zone at the upgradient boring (L2-SB03) using a split-spoon sampler. One soil sample was collected from each of the three soil borings.

The samples were analyzed for TPH, volatile organic compounds (VOCs), SVOCs, pesticides/PCBs, nitroaromatic and nitramine explosives, PETN, picric acid, cyanide, total organic carbon (TOC), and priority pollutant metals. In the soil samples, arsenic, barium, beryllium, chromium, copper, and thallium were detected at concentrations that exceeded one or more of the regulatory criteria. Of these, copper was detected at a concentration that exceeded the background concentration in one of the soil samples. PETN was detected above the instrument detection limit in one of the samples; however, there are no regulatory criteria for this constituent and the background sample was not analyzed for PETN.

Due to the suspect landfill material that was found to extend to and slightly within a dense stand of trees south of the gravel road, the two downgradient monitoring wells (L2-MW01 and L2-MW02) were installed to the south of the trees, as close to the landfill as possible (Figure 2-9). These two wells were installed to depths of 13.3 feet and 12.7 feet bgs, respectively. The upgradient well (L2-MW03) was installed to a depth of 10.4 feet bgs, near the northwest corner of the sewage lagoon, to allow for potential seasonal monitoring of ground water. This depth corresponded with the top of the bedrock, which is expected to perch shallow ground water during the rainy season.

Ground water samples were collected from both downgradient monitoring wells and analyzed for TPH, VOCs, SVOCs, PETN, picric acid, explosives, pesticides/PCBs, total metals, dissolved metals, and cyanide. Sample results indicate that both total and dissolved arsenic were detected at concentrations that exceeded one or more of the regulatory criteria in both ground water samples. Naphthalene was detected above the instrument detection limit but not above the regulatory criterion.

2.5.7.2 Landfill 3

This former landfill was located southeast of the existing sewage lagoon, near Lacamas Creek, and approximately 300 feet southeast of Landfill 2 (Figure 2-9). The site was described by the previous Camp Bonneville Facility Manager as having been used as a trash burial area from the mid- to late 1970s to the early mid-1980s. The landfill reportedly was approximately 40 feet long by 12 feet wide by 8 feet deep, and trended north-south. Objects such as a refrigerator, a locker, wallboard, and paint cans were reportedly buried here. Soil had been scraped from nearby and pushed onto the landfill, creating a broad mound that marked the location of the landfill in an otherwise fairly flat area on the Lacamas Creek floodplain. Lacamas Creek flows along the eastern and southern sides of the area. At its closest point, Lacamas Creek was approximately 20 feet east of the landfill area.

Eleven soil gas samples were installed in and around the perimeter of the Landfill 3 area to screen for halogenated hydrocarbons and BTEX compounds. The analyses were performed by EPA Methods SW8010 and SW8020. Analytical results for the soil gas samples were below the detection limits for all analytes in every sample.

Five soil borings (L3-SB01 through L3-SB05) were drilled in the Landfill 3 area during July 1998. The borings were drilled to characterize the shallow subsurface conditions and to evaluate potential pathways for contaminant migration from the landfill. For safety purposes, each soil boring was initially advanced by the UXO specialists to a depth of approximately 5 feet bgs. The drilling rig was then moved over the hole, and drilling continued by the hollow-stem auger method. One soil sample was collected at or immediately above the water table in each soil boring to characterize the shallow ground water pathway. Because the water table was shallow and safety provisions required the UXO specialists to advance the holes to depths of approximately 5 feet bgs using hand augers, soil samples for chemical analysis were collected from the hand auger rather than from split-spoon samplers advanced by the drilling rig. The samples were analyzed for TPH, VOCs, SVOCs, pesticides/PCBs, nitroaromatic and nitramine explosives, PETN, picric acid, cyanide, TOC, and priority pollutant metals. Sample results indicate that arsenic, barium, beryllium, chromium, copper, and thallium were detected at concentrations that exceeded at least one of the regulatory criteria.

Four ground water samples (L3-MW01 through L3-MW04) were collected from the monitoring wells installed in Landfill 3. All samples were analyzed for TPH, VOCs, SVOCs, nitroaromatic and nitramine explosives, PETN, picric acid, PCBs/pesticides, cyanide, and priority pollutant metals (total and dissolved). Sample results indicate that arsenic was detected at concentrations that exceeded at least one of the regulatory criteria and the background concentration in all of the ground water samples. Naphthalene was detected above the instrument detection limit but not above the regulatory criterion.

2.5.7.3 Burn Area

The former Burn Area was located immediately north of Landfill 3, to the southeast of the sewage lagoon (Figure 2-9). A pile of wooden debris approximately 20 feet long by 15 feet wide marked the area. The use of the area to burn wood and debris was reportedly infrequent and there is no record of the period of use or list of materials burned. This area has apparently not been used for burning material since the mid-1980s, although; according to the former Camp Bonneville Facility Manager, debris had been piled on the site for three or four years before its removal in June 1997.

Surface and near-surface soil samples were collected from five locations in and adjacent to the former Burn Area (Figure 2-9). The samples were collected to evaluate the potential for contamination resulting from past disposal and burning activities. Three sampling locations (BA-SS-03, BA-SS-04, and BA-SS-05) were within the former Burn Area. The other two locations (BA-SS-01 and BA-SS-02) were upslope (background) and downslope of the Burn Area, respectively. Two samples were collected from each location to assess the vertical extent of contamination: one from the 0 to 1-foot bgs interval, and one from the 1- to 2-foot bgs interval. Each sample was analyzed for TPH, VOCs, SVOCs, pesticides/PCBs, nitroaromatic and nitramine explosives, PETN, picric acid, and priority pollutant metals. Sample results indicate that arsenic, beryllium, chromium, copper, and thallium were detected at concentrations that exceeded at least one regulatory criterion. Of these, thallium was also detected at a concentration slightly above the background concentration. Four VOCs (acetone, toluene, m- & p-xylenes, and o-xylene) were detected above the instrument detection limit but not above the regulatory criterion. The background sample was not analyzed for VOCs.

2.5.7.4 Former Buildings 1962 and 1983

Buildings 1962 and 1983 were located near the southeastern corner of the Bonneville cantonment (Figure 2-10). They were burned in place, and the burn debris was removed to an unknown location. The report does not indicate when the buildings were burned, only that they had been burned in the past. Both buildings were constructed in the 1930s with wooden frames, walls, floors, and wooden post/concrete pillar foundations and rolled composition roofs. Based on the age and type of construction, it was assumed that lead-based paint may have been used in the buildings. Lead from the paint may have been released to soil when the buildings were burned. Additionally, asbestos and SVOCs may have been present in the composition roofing materials and, therefore, released to the soils when the buildings were burned.

Fifteen soil samples (BD-SS01-01, BD-SS02-01, BD-SS03-01, BD-SS04-03, BD-SS05-01, BD-SS06-01, BD-SS06-02, BD-SS07-01, BD-SS07-02, BD-SS08-01, BD-SS08-02, BD-SS09-01, BD-SS09-02, BD-SS10-01, and BD-SS10-02) were collected from 10 locations at the Former Buildings 1962 and 1983 areas. The samples were analyzed for SVOCs, asbestos, and lead. No SVOCs or asbestos was detected in any of the samples. Lead was not detected at concentrations that exceeded the regulatory criteria.

2.5.7.5 Drum Disposal Area

A suspected drum burial area was identified in May 1996 by an anonymous caller to the Camp Bonneville Facility Manager. The caller, who claimed to be a former employee at the camp, reported that pesticides, paints, and solvents were disposed of in this area (and in the Paint and Solvent Disposal Area, described in Section 2.5.7.6). The Drum Disposal Area reportedly was located south of the Killpack cantonment, east of the gravel road leading south from the main east-west roadway through the facility (Figure 2-11). Following the anonymous call, the

Facility Manager located suspected buried metal in this area using a metal detector.

Borings DB-SB01 and DB-SB02 were advanced immediately north and south of the disposal area, respectively (Figure 2-11). The UXO contractors advanced the borings to a total depth of 5 feet bgs. Downhole magnetometer readings were obtained every 2 feet. Refusal of the hand auger was encountered at shallow depth because cobbles were present. Therefore, a shovel was used to excavate a large hole to a depth of approximately 4 feet bgs at each location. A hand auger was then used to collect the samples from the 4- to 5-foot bgs interval (approximately 1 foot below the estimated depth of the buried drums). Soil samples from various depths were screened using a photoionization detector (PID) during excavation of the borings/holes. A wide range of analyses were performed on the soil samples from this site because of the unknown contents (if any) of the buried drums. Each soil sample was analyzed for TPH, VOCs, SVOCs, pesticides/PCBs, nitroaromatic and nitramine explosives, PETN, picric acid, and priority pollutant metals.

Sample results indicate that antimony, arsenic, beryllium, chromium, and copper were detected at concentrations that exceeded at least one of the regulatory criteria, and antimony, barium, and copper also exceeded the background concentration. An unknown hydrocarbon, and a total of 13 VOCs (acetone, 2-butanone, ethylbenzene, m- & p-xylenes, o-xylene, isopropylbenzene, n-propylbenzene, 1,3,5-trimethylbenzene, tert-butylbenzene, 1,2,4-trimethylbenzene, isopropyltoluene, naphthalene, and 2-hexanone) were detected above the instrument detection limit; however, none of the concentrations exceeded the regulatory criteria. The background sample was not analyzed for VOCs.

2.5.7.6 Paint and Solvent Disposal Area

The suspected Paint and Solvent Disposal Area was identified in May 1996 by an anonymous caller to the Camp Bonneville Facility Manager. The caller, who claimed to be a former employee at the camp, reported that pesticides, paints, and solvents were disposed of in this area and in another nearby location (the Drum Disposal Area, discussed in Section 2.5.7.5). The Paint and Solvent Disposal Area was reportedly located south of the Killpack cantonment, in an open area where a (covered) tractor shed currently exists (Figure 2-12). Following the anonymous call, the Facility Manager used a metal detector in this area to locate suspected buried metal.

Two soil borings were advanced adjacent to each of the two identified disposal locations. The UXO contractors advanced the borings to their total depths with a hand auger. Downhole magnetometer readings were obtained every 2 feet. Refusal of the hand auger was encountered at shallow depths in all boring locations because of cobbles; therefore, a shovel was used to excavate a large hole to the top of the sampling interval. A hand auger was then used to collect the samples from the desired interval. One soil sample was collected from each of the four soil borings (PD-SB01 through PD-SB04). The samples were collected from depths estimated to be just below the base of the debris. Soil samples were screened using a PID during excavation of the borings/holes. All soil samples collected at the Paint and Solvent Disposal Area were analyzed for TPH, VOCs, SVOCs, pesticides/PCBs, nitroaromatic and nitramine explosives, PETN, picric acid, and priority pollutant metals. Sample results indicate that an unknown hydrocarbon, arsenic, barium, beryllium, chromium, and copper were detected at concentrations that exceeded at least one of the regulatory criteria. None of these analytes, however, were detected at concentrations that exceeded the background concentration (the background sample was analyzed only for metals).

2.5.7.7 Maintenance Pit

The Maintenance Pit was located beneath the concrete floor slab under the west end of Building 4475, in the Killpack cantonment (Figure 2-13). Building 4475 was used as the Camp Bonneville shop office. The Maintenance Pit reportedly was an unlined excavation; the exact size, depth, and location are not known. The pit may have received vehicle fluids, such as gasoline, waste oil, lubricants, and antifreeze, as well as solvents, for an unknown period of time. In addition, pesticides may have been handled in front of the building. Building 4475 and the Maintenance Pit were bounded by Wash Rack No. 1 and a small stream to the west, a gravel drive and storage buildings to the north, and a ditch and the main road to the south. The building extends east of the Maintenance Pit area over a former underground storage tank (UST) location, which was remediated. A heating oil aboveground storage tank (AST) was located along the front (north) wall of the building. A chain link fence surrounds the entire shop office area, including the wash rack, a Hazardous Material Accumulation Point associated with the building, and a number of smaller buildings. The fence runs between Building 4475 and the ditch to the south. Numerous underground and aboveground utilities run through the area immediately west of the building. The surrounding ground surface is a mix of gravel (to the north and south) and soil (to the west). Much of this area appeared to have been filled to provide a level work area. Stressed vegetation was noted around this area. Potential causes of the vegetative stress include metals contamination from roof runoff, or other unknown factors.

Six soil samples were collected from two soil borings at the Maintenance Pit area. An attempt was made to advance soil borings at three locations in the Maintenance Pit area. One soil boring (MP-SB01) was drilled on the northeast side of the building, near the front door. Boring MP-SB01 was drilled and sampled to 11.5 feet bgs, using a hollow-stem auger drilling rig and split-spoon sampler. Three soil samples were collected from boring MP-SB01 at depths of 0, 2.5, and 10 feet bgs for laboratory analysis. Samples from boring MP-SB01 were not analyzed for pesticides/PCBs as originally planned. Therefore, a second boring (MP-SB01A) was drilled and sampled adjacent to the original boring. Boring MP-SB01A was advanced and sampled using a Geoprobe™ sampling system. Samples were collected from this boring for PCB/pesticide analyses only. Boring MP-SB02 was attempted inside of the shop office building at the Maintenance Pit location. A hole was cut in the concrete floor, and a hand auger was used to attempt to dig down to the floor of the pit. No samples were collected from boring MP-SB02 because rubble that had apparently been placed in the pit when it was abandoned prohibited drilling and sampling. Boring MP-SB03 was drilled and sampled behind (south of) the building. Because access was limited, a Geoprobe™ sampling system was used. Three soil samples were collected from this boring for laboratory analyses: at the ground surface, starting at 1.5 feet bgs, and starting at 3.5 feet bgs. All samples were analyzed for TPH, SVOCs, pesticides/PCBs, and priority pollutant metals. Subsurface samples were also analyzed for VOCs. Sample results indicate that an unknown hydrocarbon, one VOC (vinyl chloride), five pesticides (4,4,-DDE, 4,4-DDD, 4,4-DDT, alpha chlordane, and gamma chlordane), and six metals (arsenic, barium, beryllium, chromium, copper, and lead) were detected at concentrations that exceeded at least one of the regulatory criteria. Of the metals, copper and lead were detected at concentrations above the background concentration (the background sample was analyzed only for metals).

2.5.7.8 Wash Rack Number 1

The Wash Rack No. 1 area is located immediately west of the shop office building (Building 4475) in the Killpack cantonment (Figure 2-13). The wash rack was used for vehicle washing, reportedly between approximately 1978 and 1994. The wooden wash rack structure was still present during this investigation, and consisted of a two-track vehicle ramp. This area was initially identified as a concern during an environmental compliance inspection because it did not drain to an oil-water separator. Instead, wash water was discharged via uncontrolled overland flow to a nearby ditch. Potential contaminants at the Wash Rack No. 1 site include vehicle fluids, such as gasoline, waste oil, lubricants, and antifreeze; as well as solvents that may have been used during cleaning activities.

Except for a 1-inch thickness of asphalt at the extreme north end of the wash rack, the area was not paved and was covered with grass. The wash rack area is bounded by gravel (with minor asphalt) driving surfaces to the north and west. To the east of the area were a culvert and small stream, and Building 4475 (which includes the former Maintenance Pit). The wash rack structure abuts the chain-link fence that surrounds the shop office area. Most of the wash water discharge from the site would have flowed to the unnamed stream that crosses the site. The stream emerges from a culvert located below the gravel fill pad, between the shop office building and the wooden ramps of the wash rack. It flows aboveground for about 15 feet before entering another culvert running southward under the main road. A ditch that runs along the north side of the road also joins the stream and runs under the road through the same culvert. The wash rack area slopes downward to the east and south, toward the stream and ditch, respectively.

Surface soil samples (WR-SS-01-01 and WR-SS-02-01) were collected from two locations at the wash rack to evaluate potential contamination from the wash rack area. One soil boring (WR-SB01) was drilled between the two ramps of the wash rack. The boring was drilled to a depth of 11.5 feet bgs using a hollow-stem auger. Three soil samples were collected from this boring using a split-spoon sampler. All samples were analyzed for TPH, SVOCs, and priority pollutant metals. In addition, the two subsurface soil samples were analyzed for VOCs, and the two surface soil samples were analyzed for pesticides/PCBs. Sample results indicate that an unknown hydrocarbon, arsenic, barium, beryllium, cadmium, chromium, copper, and lead were detected at concentrations that exceeded at least one of the regulatory criteria. Of the metals, cadmium, copper, and lead also exceeded the background concentration. One VOC (acetone), two SVOCs [bis(2-ethylhexyl)phthalate and di-n-butylphthalate), and three pesticides (4,4-DDT, alpha chlordane, and gamma chlordane) were detected at concentrations above the instrument detection limit but not above any of the regulatory criteria (the background sample was not analyzed for these constituents).

2.5.7.9 Grease Pits

Three grease pits were identified: two located in the Bonneville cantonment north of Buildings 1828 and 1920 (Figure 2-10), and one located in the Killpack cantonment northeast of Building 4389 (Figure 2-13). Each of the grease pits consisted of a gravel-filled excavation with a corrugated metal pipe extending vertically down into the gravel. The grease pits were used for disposal of waste cooking greases and oils from nearby mess halls. Use of the pits reportedly began around 1935.

Four soil samples (GP-SB02-01, GP-SB02-02, GP-SB03-01, and GP-SB03-02) were collected from the grease pits at depths ranging from 3 to 9 feet bgs. The samples were analyzed for TPH, SVOCs, pesticides/PCBs, VOCs, and priority pollutant metals. Sample results indicate the presence of arsenic, barium, copper, and thallium in at least one of the four samples at concentrations that exceeded the regulatory cleanup criteria.

2.5.7.10 Pesticide Mixing/Storage Building

The pesticide mixing/storage building (number 1864) is located in the Bonneville cantonment (Figure 2-10). The building was reportedly built in 1955 and was used for pesticide mixing and storage from 1977 to 1980. A small unnamed creek, located approximately 130 feet east of the building, flows south towards Lacamas Creek. A sink inside the building was located during the investigation and found to discharge to a dry well along the eastern side of the building.

During the investigation, two surface soil samples (PM-SS01 and PM-SS02) were collected from the south side of the building. Additionally, four boring locations (PM-SB01 through PM-SB04) were drilled around the building. Boring PM-SB03 was advanced using a hand auger due to the presence of overhead power lines. Samples were collected from three intervals in each of the borings. Monitoring wells were installed in these borings and ground water samples were collected. Samples were analyzed for TPH, VOCs (only on subsurface samples), SVOCs, PCBs/pesticides, organophosphorus pesticides, chlorinated herbicides, and priority pollutants metals. Sample results for the soil samples indicate an unknown hydrocarbon, one SVOC (hexachlorobenzene), two pesticides (4,4-DDE and 4,4-DDT), and eight metals (arsenic, barium, beryllium, cadmium, chromium, copper, lead, and thallium) were detected at concentrations that exceeded at least one of the regulatory criteria. Of the metals, arsenic, cadmium, copper, and lead were detected at concentrations that also exceeded the background concentration.

Two VOCs (acetone and carbon disulfide), three SVOCs [di-n-butylphthalate, bis(2-ethylhexyl)phthalate, and butylbenzylphthalate), one pesticide (4,4-DDD), and two chlorinated herbicides (2,4-D and 2,4,5-T) were detected at concentrations above the instrument detection limit but not above their regulatory criteria (the background sample was not analyzed for these constituents). Sample results for the ground water samples did not indicate the presence of analytes above the regulatory criteria.

2.5.7.11 Aboveground Storage Tanks

A total of 26 ASTs were present at Camp Bonneville. Three were located in the Killpack cantonment and 23 were located in the Bonneville cantonment. During the investigation, no evidence of releases from the tanks was discovered; however, incidental spillage was reported to have occurred during tank filling. Each of the AST locations was inspected for evidence of leaks or spills. Stained soils and/or elevated PID readings were discovered at eight ASTs. One soil sample was collected from each of the eight areas and submitted for off-site fixed laboratory analysis of TPH. Sample results indicate the presence of diesel or hydrocarbons in all eight samples at concentrations that exceeded the regulatory criteria.

2.5.7.12 Former Sewage Pond

The sewage pond was located south of the Bonneville cantonment area (Figure 2-14). The exact location and dimensions of the pond were not documented. Anecdotal information indicates that the pond was an unlined lagoon that was pumped out and filled with clean soil from a local source when the lagoon was abandoned in 1978. The general area of the former sewage pond is on the Lacamas Creek floodplain and within approximately 200 feet of the creek.

During the investigation, five soil borings were advanced in the former sewage pond area. Borings SP-SB01, SP-SB02, and SP-SB03 were drilled within the apparent former pond area. Additionally, borings SP-SB04 and SP-SB05 were advanced for the installation of monitoring wells: one at an upgradient location (SP-SB04) and one at a downgradient location (SP-SB05). Ground water was encountered at a depth of 4 to 5.5 feet bgs. A total of 15 subsurface soil samples were collected from these boring locations. All samples were analyzed for TPH, SVOCs, VOCs, pesticide/PCBs, and priority pollutant metals; however, the water samples were not analyzed for pesticides/PCBs. In the soil samples, arsenic, beryllium, chromium, copper, and thallium were detected at concentrations above one or more of the regulatory criteria. Arsenic, copper, and thallium were detected at concentrations that also exceeded the background concentration. In the ground water samples, arsenic was detected at a concentration that exceeded at least one of the regulatory criteria. This detection was in the upgradient well.

2.5.7.13 Ammunition Storage Magazines

The Ammunition Storage Magazines are located east of the Bonneville cantonment and southwest of the sewage treatment lagoon (Figure 2-15). The three magazines are designated as Buildings 2950, 2951, and 2953. These small structures were constructed of concrete with heavy metal doors, and cach was covered with a mound of soil. The buildings are reported to have been constructed in 1976. The magazines were used to store munitions of various types that were brought to Camp Bonneville for training. The area was surrounded by a chain-link barbed wire-topped fence. Lacamas Creek is located immediately south of the fence.

During the investigation, 15 surface soil samples (AS-SS01 through AS-SS15) were collected from areas around the magazines. Additionally, one soil boring (AS-SB01) was advanced in the area to a total depth of 6 feet bgs. Samples were analyzed for priority pollutant metals, nitroaromatic and nitramine explosives, PETN, and picric acid. Sample results indicate that arsenic, barium, beryllium, cadmium, chromium, copper, nickel, thallium, and zinc were detected at concentrations that exceeded at least one of the regulatory criteria.

2.5.7.14 Hazardous Material Accumulation Point

The Hazardous Material Accumulation Point, Building 4476, is located in the northeast corner of the Camp Bonneville shop area, in the Killpack cantonment (Figure 2-13). The building is a three-walled structure, built in 1990, with cement masonry block walls and a concrete slab floor. The open front of the structure is secured with locking metal gates. The structure, also referred to as the Covered Vehicle Maintenance Storage, has been used for the storage of drums containing liquids such as antifreeze and waste oil. It may have been used for temporary storage of drums of other hazardous materials. The concrete floor of the building is sloped toward a sump in the middle of the floor. The sump measures approximately 2 feet square and is approximately 2 feet deep. No drains are present in the sump. No evidence or reports of spills at this location were found. The building is bounded by a gravel driving surface to the south and east, small storage buildings and equipment to the west, and woods to the north. A vehicle fuel AST, covered and within a concrete containment structure, is located immediately west of the building. The chain-link fence that surrounds the shop office area runs along the north and east sides of the building. The area is fairly flat. Drainage from the area likely flows to the ditch running parallel to the main access road, south of the fenced shop area.

Two surface soil samples (HM-SS-01 and HM-SS-02) were collected from the area. Additionally, one liquid sample (HM-SU01-01) was collected from the sump. The samples were analyzed for TPH, SVOCs, PCBs/pesticides, and priority pollutant metals. Soil sample results indicate that arsenic and beryllium were detected at concentrations above one of the regulatory criteria but not above the background concentration. Additionally, TPH and one SVOC [bis(2-ethylhexyl)phthalate] were detected at concentrations above the instrument detection limit but not above the regulatory criterion. These constituents were not analyzed in the background sample. For the liquid sample, an unknown hydrocarbon, one SVOC [bis(2-ethylhexyl)phthalate], and five metals (antimony, arsenic, beryllium, lead, and zinc) were detected at concentrations that exceeded at least one regulatory criterion and, in the case of metals, also exceeded the background concentration.

2.5.7.15 Former CS Training Building

The former CS training building was located south of the Bonneville cantonment and north of Lacamas Creek (Figure 2-16). The building burned to the ground sometime in the 1970s. CS gas (aka tear gas) is the common name for 2-chlorobenzalmalononitrile.

During the investigation, five soil borings were drilled at the CS training building area and 10 samples were collected. All samples were analyzed for tear gas and cyanide; additionally, one sample from each boring was submitted for SVOC and lead analysis. Sample results indicate that one SVOC [benzo(b)fluoranthene] and lead were detected above the regulatory criteria in at least one of the samples.

2.5.7.16 Wash Rack Number 2

The former Wash Rack Number 2 (or former maintenance rack site) is located in the Killpack cantonment at the northeast corner of the shop office area, near Building 4476 (Figure 2-13). No visible signs of contamination were noted. The wash rack was demolished in the 1980s.

During the investigation, four subsurface soil samples (W2-SB01-01, W2-SB01-02, WS-SB02-01, and W2-SB02-02) were collected from the Wash Rack Number 2 area. The samples were analyzed for TPH, SVOCs, and priority pollutant metals. Sample results indicate the presence of an unknown hydrocarbon, arsenic, barium, beryllium, chromium, and copper at concentrations that exceeded at least one of the regulatory criteria. None of the metals were detected at concentrations that exceeded the background concentrations.

2.5.7.17 Investigation Recommendations

The Multi-Sites Investigation report prepared by Shannon and Wilson, Inc. for the Seattle District U. S. Army Corps of Engineers recommended no further action for various locations because either no evidence of contamination was detected or constituents of concern were detected at concentrations below the project screening level. The locations where no further action was recommended are:

- Landfill Number 1 (existence could not be substantiated);
- Landfill Number 2;
- Landfill Number 3;
- Burn area;
- Paint and Solvent Disposal Area;
- Hazardous Materials Accumulation Point; and
- Wash Rack Number 2.

The report also recommended remedial action for those areas where soil contamination posed a potential risk to human health and the environment. Locations where remedial action was recommended are:

- Drum disposal area; and
- Wash Rack Number 1.

One area, the Maintenance Pit, was recommended for additional investigation (SWI 1999). The Multi-Sites Investigation report did not provide the recommendations for the CS building, ammunitions building, sewage pond, ASTs, pesticide mixing/storage building (1862), grease pits, and Buildings 1962 and 1983.

2.5.8 Base Realignment and Closure Hazardous, Toxic, and Radioactive Waste Site Closure Report

In September 2000, URS completed a site closure report for the Corps. The objectives of the site closure report were to document that past work at eight locations within Camp Bonneville met cleanup requirements of the Camp Bonneville BRAC cleanup team, and to prepare closeout documentation for the eight separate locations within Camp Bonneville that require no further action to meet Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements. The closure report pertained only to the hazardous, toxic, and radioactive waste components of the locations and did not include UXO (URS 2000a).

In order to achieve the objectives of the closure report, previous investigations that had been performed at the facility were reviewed, existing data was compared to cleanup levels, and potential exposure pathways and receptors were evaluated in conceptual site models.

The eight locations evaluated and recommended for closure in the report include:

- Landfill 1;
- Landfill 2;
- Landfill 3;
- Former Burn Area;
- Buildings 1962 and 1983;
- Grease Pits at the Camp Bonneville and Killpack cantonments;
- Former Sewage Pond; and
- Hazardous Materials Accumulation Point.

The site closure report prepared by URS presents the rationale for no further action at these eight locations. The rationale stated in the report is provided below.

- **Landfill Number 1:** The landfill was not located by reconnaissance and geophysical methods. Previously collected information is interpreted to be consistent with the presence of a small debris pile associated with a former residence (URS 2000a).
- **Landfill Number 2:** The soil gas survey indicated no impact to air and no evidence of volatile organics in the landfill materials. Metals were the only constituents detected in downgradient borings, and none were detected at concentrations above the screening criteria and background. Both total and dissolved arsenic were detected in both ground water wells sampled at concentrations exceeding risk-based criteria but below the MCL. Arsenic concentrations in area wells are typically slightly elevated, which may be related to background conditions (URS 2000a).

- **Landfill Number 3:** The soil gas survey indicated no impact to air and no evidence of volatile organics in the landfill materials. Metals were the only constituents detected in downgradient borings, and none were detected at concentrations above the screening criteria and background. Total and dissolved arsenic were detected in the downgradient ground water wells at concentrations exceeding risk-based criteria but below the MCL. Total and dissolved arsenic concentrations in area wells are typically slightly elevated, which may be related to background conditions (URS 2000a).
- **Burn Area:** Metals were the only constituents detected in soil in downgradient borings, and only thallium was found at a concentration above the screening criteria and background. Thallium was detected in one surface soil sample at a concentration slightly above background and the MTCA Method B ground water protection criterion, but less than two times background. Slightly elevated thallium levels, detected in one surface soil sample, may not exceed the actual natural concentration in site soils. Arsenic was detected in one nearby downgradient landfill ground water well at a concentration exceeding risk-based criteria, but below the MCL. The site does not appear to pose a threat to ground water. Arsenic concentrations in area wells are typically slightly elevated, which may be related to background conditions (URS 2000a).
- **Former Buildings 1962 and 1983:** Only lead was detected in the surface and near-surface soil samples. Concentrations detected did not exceed the screening criteria (URS 2000a).
- **Camp Bonneville Grease Pits:** No organics in soil were detected at concentrations above the screening criteria. Barium and copper were detected in soil above the MTCA Method B ground water protection level and slightly above background levels in soil, but less than two times background. Ground water was not encountered in the boring, which extends to volcanic rock (URS 2000a).
- **Camp Killpack Grease Pit:** No organics were detected at concentrations above the screening criteria in soil. Arsenic was detected in one soil sample at a concentration above the screening criteria and slightly above background, but less than two times background. Thallium was detected at a concentration above the MTCA Method B ground water criterion and slightly above background in one soil sample, but less than two times background. Ground water was not encountered in the boring (URS 2000a).
- **Former Sewage Pond:** Thallium was detected in one soil sample at a concentration above the MTCA Method B ground water protection level and slightly above background, but less than two times background. Arsenic was detected in one soil sample at a concentration above the screening levels and slightly above background, but less than two times background. Copper was detected above the MTCA Method B ground water protection criterion and slightly above background in one subsurface soil sample from the upgradient boring, but less than two times background. Arsenic, copper, and thallium, detected in only one soil sample each at concentrations only slightly above background, may be representative of natural conditions. No organic compounds were detected in ground water samples. The only metal detected in ground water above screening criteria was arsenic in the upgradient well.

The ground water arsenic concentration exceeded both MTCA and Region 3 risk-based criteria but was well below the MCL. Arsenic was not detected in the downgradient ground water well. Arsenic concentrations in ground water at Camp Bonneville typically appear to be slightly elevated and may be related to background conditions (URS 2000a).

- **Hazardous Materials Accumulation Point**: The only organics detected in surface soil samples were low concentrations of TPH and bis(2-ethylhexyl) phthalate (below screening levels). No metals were detected at concentrations above the screening levels or background (URS 2000a).

The site closure report did not address the recommendations for the pesticide mixing/storage building, ASTs, ammunitions building, or Wash Rack 2. A previous report, i.e., the Multi-Sites Investigation report recommended that the drum disposal area and Wash Rack 1 locations required remediation and the maintenance pit required further investigation.

2.5.9 Environmental Restoration – Multi-Sites

In 2000, Gary Struthers Associates, Inc. (GSA) conducted remedial environmental restoration in areas that had been recommended for remedial work during the 1991 SWI Multi-Sites Investigation and prepared the areas for closure. The scope of the work conducted included the remediation of identified hazards at each of seven designated sites to meet regulatory cleanup standards and allow for unrestricted use of the property. The closure for each location included the excavation and stockpiling of suspected contaminated soil; screening of the in-place soil for the analytes of concern, followed by additional excavation (as needed); and concluded with confirmation sampling and fixed laboratory analysis (GSA 2000). The seven areas remediated during this investigation are described below. The remedial environmental restoration report prepared by Gary Struthers Associates, Inc. does not address the recommendations/disposition of the ASTs, ammunitions building, or Wash Rack 2.

2.5.9.1 Drum Disposal Area

Initial concerns with contamination in this area were raised prior to conducting excavation activities due to the discovery of surficial drum debris not previously documented. Upon commencement of the backhoe excavation activities, numerous pieces of metallic debris were found and removed, including a locker, a large sink, an apparent bookshelf, numerous rusted-through buckets, and a bumper. These items and other debris were excavated and stockpiled. Upon further excavation, a solvent-like odor was noted. Excavation immediately ceased, and field screening was conducted with a PID on the freshly exposed soil. The PID readings from the exposed area were as high as 150 parts per million (ppm).

A total of 26 test pits were excavated from the area (Figure 2-17). The test pits were numbered 1 to 26 in the approximate sequence in which they were dug. Each of these test pits had an approximate footprint of 4 feet by 6 feet and was advanced to approximately 4 feet deep. Water was observed in several of the test pits. While digging in Test Pit #25, the backhoe bucket pulled up a relatively intact bucket (approximately 5-gallon size) containing fresh paint. The paint bucket was damaged by the time it was brought to the surface, and paint was dripping from it. The bucket of paint was placed upon a separate visqueen staging area. Another item of concern, which was discovered during the test pit activities, was an apparent clay tile drain line running through the area from the general direction of the Killpack cantonment. Two soil samples and three ground water samples were collected from the 26 test pits. The samples were submitted for off-site fixed laboratory analysis of VOCs, SVOCs, pesticides/ PCBs, herbicides, and metals (not all samples were analyzed for all constituents). Sample results indicated that concentrations for all analytes detected were below the site-specific cleanup criteria. Restoration at this site included placement of plastic sheeting into each of the exposed test pits prior to backfilling the test pits with the excavated soil.

2.5.9.2 Paint and Solvent Disposal Areas

The remediation activities for this area began with a geophysical survey to attempt to identify and delineate the extent of buried drums or metal debris. The geophysical survey uncovered two disposal areas each to a limited extent. Based on the survey, two soil borings were drilled at each location (Figure 2-12). Samples were analyzed for TPH, VOCs, SVOCS, pesticides/PCBs, nitroaromatic and nitramine explosives, PETN, picric acid, and priority pollutant metals. Sample results indicated the presence of arsenic, barium, beryllium, chromium, and copper at concentrations that exceeded the regulatory criteria; however, all results were below the background concentrations. Restoration of this area consisted of returning the excavated soil, less the debris, to the excavations and regrading of the area.

2.5.9.3 Wash Rack Number 1

The remediation activities for this area began with the dismantling of the timbers that formed the wash rack. Once the wash rack was removed, a backhoe was used to excavate the footprint of the area (Figure 2-18). The area was excavated to a depth of 3 feet bgs. At a depth of 3.0 feet bgs, a soil sample (H1) was collected from the floor of the excavation for Hanby field analysis. An additional field sample (H2) was collected from the 3.6-foot bgs depth of the excavation floor. A third field sample (H3) was collected from the 3.5-foot depth interval of the west sidewall of the excavation. These three field Hanby analyses revealed screening level concentrations of 0 ppm, 10 ppm, and 0 ppm, respectively.

Confirmation samples were collected and analyzed for diesel- and heavy oil-range TPH, cadmium, and lead. The results from the initial confirmation samples indicated that additional excavation of the northern and western sidewalls was needed due to the presence of elevated levels of diesel-range TPH. Additional excavation of 3 feet was conducted in the area. A total of eight soil samples (including one duplicate sample) were collected and submitted for off-site fixed laboratory analysis of TPH, VOCs, SVOCs, pesticides/PCBs, and metals (not all samples were submitted for all analyses). Sample results indicated that concentrations for all analytes detected were below the screening criteria.

Restoration of this area included hauling in imported backfill material to match the native material, and regrading of the area.

2.5.9.4 Maintenance Pit

Remediation of the area included excavation of the footprint of the maintenance pit to a depth of 0.8 feet bgs and collection of soil samples H4 and H5 from the eastern portion of the excavation floor, and sample H6 from the western portion of the floor (Figure 2-18). The samples were submitted for laboratory analysis for diesel- and heavy oil-range TPH, vinyl chloride, PCBs, DDD, DDE, DDT, and lead. Sample results indicated that additional excavation was required due to the presence of TPH and lead. The excavation was advanced to approximately 2.7 feet bgs and expanded in the northern, eastern, southern, and western sidewalls by approximately 2, 4.3, 0.5, and 5.6 feet, respectively. A total of 12 soil samples were collected and submitted for off-site fixed laboratory analysis of TPH, VOCs, SVOCs, pesticides/PCBs, and metals (not all samples were submitted for all analyses). Sample results indicated that concentrations for all analytes detected were below the established cleanup levels. Restoration of this area included hauling in imported backfill material to match the native material, and regrading the area.

2.5.9.5 Former CS Training Building

During the investigation, five soil samples were collected from the former CS training building area (Figure 2-19). Samples were analyzed for VOCs, SVOCs, and metals. Sample results indicated that lead was detected at concentrations that exceeded the regulatory criteria in two of the samples. Restoration of this area included hauling in imported backfill material to match the native material, and regrading the area.

2.5.9.6 Pesticide Mixing/Storage Building

Excavation was conducted south of the entry of the building (number 1864) and continued to a depth of 2.5 feet bgs (Figure 2-20). A total of eight soil samples (including one duplicate) were collected and submitted for off-site fixed laboratory analysis of TPH, VOCs, SVOCs, pesticides/PCBs, chlorinated herbicides, and metals (not all samples were submitted for all analyses). Sample results indicated that concentrations for all analytes detected were below the established cleanup levels. No remediation was conducted at this location.

2.5.9.7 Selected Above-ground Storage Tank Locations

A total of eight AST locations were selected for remedial action. Samples collected from the AST locations were submitted for off-site fixed laboratory analysis of TPH using method NWTPH-Gx and Dx. These locations are discussed below.

- **AST #1 – Building T-1833:** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The excavation in this area reached approximately 2 feet bgs. The confirmation sample from this area indicated additional contamination. Based on these results, further excavation was conducted to 4 feet bgs. Again, confirmation samples were collected and submitted for analysis. Sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading the area. The AST support blocks were reset at the original location and the AST was placed on them.

- **AST #2 – Building T-1837:** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The excavation in this area reached approximately 5 feet bgs. Confirmation sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading the area. The AST support blocks were reset at the original location and the AST was placed on them.
- **AST #3 – Building T-1828:** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The excavation in this area reached approximately 5 feet bgs. Confirmation sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading of the area. The AST support blocks were reset at the original location and the AST was placed on them.
- **AST #4 – Building T-1940 (Day Room):** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The excavation in this area reached approximately 2.5 feet bgs. Confirmation sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading of the area. The AST support blocks were reset at the original location and the AST was placed on them.
- **AST #5 – Building T-1922:** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The excavation in this area reached approximately 2.3 feet bgs. Confirmation sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading of the area. The AST support blocks were reset at the original location and the AST was placed on them.
- **AST #6 – Building T-1922:** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The excavation in this area reached approximately 4.5 feet bgs. Confirmation sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading of the area. The AST support blocks were reset at the original location and the AST was placed on them.
- **AST #7 – Building T-1942:** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The

excavation in this area reached approximately 4.5 feet bgs. Confirmation sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading of the area. The AST support blocks were reset at the original location and the AST was placed on them.

- **AST #8 – Building T-1980:** Soil around the AST was excavated until visual observation and field screening by Hanby analysis indicated that residual contamination above regulatory criteria had likely been removed. The excavation in this area reached approximately 2.5 feet bgs. The confirmation sample from this area indicated additional contamination. Based on these results; further excavation was conducted to 5 feet bgs. Again, confirmation samples were collected and submitted for analysis. Sample results indicated no TPH above regulatory criteria. Restoration of this area included hauling in imported backfill material to match the native material, and regrading of the area. The AST support blocks were reset at the original location and the AST was placed on them.

2.5.9.8 Site Summary and Recommendations

The GSA study results from the confirmation sampling data indicated that the paint and solvent disposal area, Wash Rack Number 1 area, the maintenance pit area, the former CS training building, the pesticide mixing/storage building, and the eight AST locations were in compliance with the site clean-closure levels. Additionally, results of this remedial activity indicated that further investigation of the drum disposal area and surrounding fields was necessary prior to continuing remedial actions in that area.

2.5.10 Supplemental Site Investigation

In 2000, URS completed a supplemental site investigation (SSI) for the Corps at two locations near the Killpack cantonment. The objectives of the SSI were to: evaluate chemicals of potential concern (COPCs) in surface soil and in flooring material of Building 4126 at the Pesticide Storage Area that had not previously been investigated; evaluate COPCs in surface and subsurface soil and ground water at the largest Ammunition Storage Magazine (Building 2953); and evaluate potential exposure to human and ecological receptors based on a conceptual site model (URS 2000b).

Sample results were compared to MTCA Method A and B cleanup levels, natural background soil metals concentrations in Washington State, and the background soil metals concentrations that were calculated in the 1999 SWI investigation. The following subsections provide a discussion of the specific areas included in the supplemental site investigation performed by URS.

2.5.10.1 Pesticide Storage Area

The Pesticide Storage Area (Building 4126) is located on the edge of a small, flat, grassy field approximately 75 feet south of the gravel road in front of the Killpack cantonment (Figure 2-21). Overall, the ground surface in this area slopes very gently to the south, away from the road. The building is approximately 4 feet west of an approximately 8-foot by 8-foot concrete pad. A surface soil sample

(SS04) was collected from an exposed strip of soil between the building entrance and the building, and a surface soil sample (SS05) was collected from the south side of the building. Additionally, a flooring material sample (FS01) was collected.

The soil samples were submitted to an off-site fixed laboratory for analysis of petroleum hydrocarbons, organochlorine pesticides/PCBs, metals, and herbicides. Sample results indicated that 4,4-DDT and 2,4,5-T were detected at concentrations that exceeded the screening criteria. Based on these results, it was recommended that the building be demolished and that surface soil to approximately 1 foot bgs beneath the footprint of the building and to a distance of approximately 4 feet outside the footprint of the building be excavated and disposed of.

2.5.10.2 Ammunition Storage Magazines

The Ammunition Storage Magazines (Buildings 2950, 2951, and 2953 as previously discussed in section 2.5.7.13) are located approximately 2,000 feet northeast of the Pesticide Storage Area on the south side of the road leading into the facility from the Killpack cantonment (Figure 2-15). They are positioned on a flat, graded terrace approximately 10 feet below the elevation of the road. The SSI investigated soil near the largest magazine, Building 2953 (Figure 2-22). An approximately 10-foot-wide by 50-foot-long access road descends from the main gravel road on the west side of Building 2953 and ends in front of the magazine entrance on the south side. Overall, the ground surface in this area slopes away from the road and continues to descend toward the south away from the terrace.

Three surface soil samples (SS01, SS02, and SS03) were collected in three locations in front of the magazine door. Subsurface soil samples were collected from soil boring SB-01 approximately 15 feet south of the bunker. Ground water was not encountered in the boring location. The samples were submitted to an off-site fixed laboratory for analysis of priority pollutant metals, SVOCs, ordnance, and propellants. Sample results indicated that antimony, cadmium, lead, and 2,4-dinitrotoluene were detected at concentrations that exceeded the screening criteria.

Based on these sample results, it was recommended to dispose of soil (0 to 1-foot bgs) along the short footpath leading to the door of Building 2953. This included an approximately 4-foot-wide area along the approximately 6-foot-long path. In addition, it was recommended that soil (0 to 1-foot bgs) at Buildings 2950 and 2951 be excavated and disposed of in areas where metals concentrations exceeded screening values during the 1999 SWI investigation.

2.5.11 Geophysical Survey

In October 2000, Parsons Engineering Science, Inc. (Parsons) conducted a geophysical survey of a suspected drum burial area. The survey was conducted using a G-858 portable cesium magnetometer/gradiometer. Eleven anomalies were encountered during the investigation that indicated the possibility of buried drums. These anomalies were mostly encountered in the suspect drum burial area, which was estimated to be approximately 10 to 15 feet across. The total depth was not determined. (Parsons 2001)

2.5.12 Environmental Restoration – Pesticide Storage Area and Ammunition Storage Magazines

Based on the results and recommendations of the SSI in 2001 (discussed in Subsection 2.5.10), GSA performed a remediation environmental restoration for the Pesticide Storage Area (Building 4126) and the Ammunition Storage Magazines (Buildings 2950, 2951, and 2953; GSA 2001).

2.5.12.1 Pesticide Storage Area

Work on the Pesticide Storage Area (Building 4126) began with characterization and sampling of the physical structure. Following sampling, the structure was dismantled. After demolition was completed, a backhoe was used to excavate the footprint of the building and its drip-line to a depth of 1 foot bgs. Samples were collected from each side wall of the excavation as well as the floor. The results from the samples indicated that no additional excavation was required. Clean backfill was imported and the excavation area filled and graded.

2.5.12.2 Ammunition Storage Magazines

A backhoe was used to excavate the footprint of three magazines (2950, 2951, 2953) to a depth of 1 foot bgs. Confirmation samples were collected from the four side walls as well as the floor in each of the magazines. Results from the samples indicated that no additional excavation was required. Clean fill material was imported and the areas were filled and graded.

2.5.13 Environmental Restoration – Drum Burial Area

Based on information contained in previous reports, an environmental restoration was performed at the drum burial area in 2002, by GSA for the Corps. During the investigation, soil from the drum burial area (as discussed in Subsections 2.5.9.1 and 2.5.11) was excavated and stockpiled. Confirmation soil samples were collected for fixed laboratory analysis of Resource Conservation and Recovery Act (RCRA) metals plus copper, VOCs, SVOCs, polyaromatic hydrocarbons (PAHs), pesticides/PCBs, and TPH. Following receipt of sample results that were below the cleanup criteria established under previous investigations, the area was backfilled and was no longer considered an environmental concern. The environmental restoration report does not indicate the depth of the excavation (GSA 2002).

2.5.14 Record of Decision – Multiple Sites

In August 2002, URS completed a Record of Decision (ROD) for multiple sites for the Corps. The sites included in the ROD were Landfill 1, 2, and 3; the former Burn Area; Buildings 1962 and 1983; the Grease Pits; the former Sewage Pond; the Hazardous Materials Accumulation Point; the Drum Disposal Area; the Paint and Solvent Disposal Area; Wash Rack 1; the Maintenance Pit, Wash Rack 2; the Pesticide Mixing/Storage Building 1864; the ASTs; the CS Gas Training Building; the Pesticide Storage Area Building 4126; and the Ammunition Storage Magazines 2950, 2951, and 2953. Based on analysis from previous investigations, COPCs either were not detected or were detected below the regulatory cleanup levels at some of the areas. The remaining areas contained contaminants above regulatory cleanup levels. At these areas, remediation had been conducted and contaminants had been removed. Subsequent confirmation sampling at these areas determined that contaminants were below established cleanup levels. Because contaminants were either not present or had been removed, it was determined that no risk to human health or the environment was posed at these areas. The EPA, Ecology, and the Army determined that no further action would be required at these locations (URS 2002).

2.5.15 Ecology Enforcement Order

On February 4, 2003, an Enforcement Order 03TCPHQ-5286 was issued for Camp Bonneville. The enforcement order divided the site into three remedial action units (RAUs). The RAUs and their status are described below (Ecology 2003).

- **RAU 1:** This RAU consists of the 20 acres where hazardous substances other than military munitions had been located (Figure 2-23). This RAU contained the majority of the areas previously discussed in this PA report.
- **RAU 2:** This RAU consists of the areas where hazardous substances have been located, but not addressed through remedial actions. This RAU has been further divided into three subunits.
  - **RAU2A:** This RAU consists of the 21 small arms range areas (Figure 2-24).
  - **RAU2B:** This RAU consists of Demolition Areas (DA) 2 and 3 (Figure 2-25).
  - **RAU2C:** This RAU consists of the Landfill 4 area (Figure 2-26).
- **RAU 3:** This RAU consists of any area where military munitions may have come to be located (Figure 2-27).

Additionally, the enforcement order dictated the work and work schedule to be performed in each of the RAUs.

2.5.16 Expanded Site Inspection – Landfill 4

In 2003, URS Corporation completed an expanded site inspection (ESI) in Landfill 4 for the Corps. The ESI was conducted in response to the discovery of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) above screening criteria in two monitoring wells that were installed during the 1999 SWI Multi-Sites investigation. During the ESI, a total of eight new monitoring wells (L4-MW01B, L4-MW02B, L4-MW03A, L4-MW03B, L4-MW04A, L4-MW05A, L4-MW06A, and L4-MW07B) were installed at the landfill (Figure 2-28). One of these wells (L4-MW06A) was not developed due to lack of water. Other activities associated with the ESI included: well slug tests, a topographic survey from the landfill to North Fork Lacamas Creek, and ground water sampling from the new monitoring wells as well as two previously existing monitoring wells. Ground water sampling of the new wells was conducted approximately 2 weeks after installation, and in July 2001, October 2001, January 2002, and April 2002. Additionally, monitoring wells L4-MW01A and L4-MW02A, previously installed in 1999, also were sampled in these months (URS 2003).

Ground water data from this investigation was compared to MTCA Method A (for TPH only) and Method B cleanup levels for ground water, National Ambient Water Quality Criteria, EPA Region 9 Preliminary Remediation Goals (PRGs), and EPA Region 10 risk-based concentrations (RBCs). The ground water samples were analyzed for VOCs (EPA SW-846 Method 8260B), SVOCs (EPA SW-846 Method 8270C), herbicides (EPA SW-846 Method 8151A), total and dissolved metals (EPA SW-846 Method 6010B), TPH-Gx (Method NWTPH-Gx), TPH-Dx (Method NTWPH-Dx), water quality (alkalinity – SM 2320; sulfate, chloride, nitrite and nitrate – EPA Method 300.0; total cyanide – EPA Method 335.2; total suspended solids – EPA Method 160.2; and total and dissolved TOC – EPA Method 415.1), explosives (EPA SW-846 Method 8330A), nitroguanidine (EPA SW-846 Method 8330A modified), and ammonium perchlorate (Method 314.0; URS 2003).

Sample results for monitoring well MW-01A indicated the presence of perchlorate above regulatory criteria in January 2002; and total arsenic, total copper, and total lead above regulatory criteria in October 2001. Although there were detections above the method detection limits, there were no other results above regulatory criteria. Sample results for monitoring well MW-01B did not detect concentrations above the regulatory criteria in any of the sampling events (URS 2003).

Sample results for monitoring well MW-02A indicated RDX and perchlorate above regulatory criteria in all sampling rounds. No other analytes were detected above the regulatory criteria. Sample results for monitoring well MW-02B indicated the presence of 2,4-Dinitrotoluene, RDX, perchlorate, 1,1,1-trichloroethane (1,1,1-TCA), 1,1-dichloroethene, (1,1-DCA) and dichlorofluoromethane, above regulatory criteria for all sampling rounds. Additionally the following analytes were detected above the regulatory criteria on the specified sample dates, benzene in July 2001; tetrachloroethene in July 2001, October 2001, and April 2002; total arsenic, total copper, and total lead in July 2001 and April 2002; and dissolved arsenic in October 2001 (URS 2003).

Sample results for monitoring well MW-03A indicated RDX and perchlorate were detected above the regulatory criteria in all sampling rounds. Total iron was detected above the regulatory criteria in the sample collected in January 2002; and dissolved lead was detected above the regulatory criteria in the sample collected in October 2001. Sample results for monitoring well MW-03B indicate that perchlorate was detected above regulatory criteria in all sampling rounds; RDX was detected above the regulatory criteria in all but the sample collected in July 2001; total arsenic was detected above the regulatory criteria in the samples collected in October 2001 and January 2002; total copper was detected above the regulatory criteria in all the samples collected except for July 2001; total iron was detected above the regulatory criteria in the samples collected in January and April 2002; and total lead was detected above the regulatory criteria in the sample collected in April 2002 (URS 2003).

Sample results for monitoring well MW-04A indicated RDX, perchlorate, total iron, and total copper were detected above the regulatory criteria in all sampling rounds. Total arsenic was detected above the regulatory criteria in the samples collected in July and October 2001; and total lead was detected above the regulatory criteria in the sample collected in April 2002.

Sample results for monitoring well MW-05A indicated RDX and perchlorate were detected above the regulatory criteria in all sampling rounds. Also, total copper was detected above the regulatory criteria in the sample collected in October 2001.

Sample results for monitoring well MW-07B indicated the presence of total and dissolved arsenic above the regulatory criteria in the sample collected in January 2003 (URS 2003).

2.5.17 Small Arms Range Site Inspection

In September 2003, Atlanta Environmental Management, Inc. (AEM) conducted a site inspection of the small arms ranges for the Corps. The locations of the small arms ranges that were part of this investigation are presented in Figure 2-29. The purpose of the investigation was to (AEM 2003):

- Determine the concentration of lead residues in the top 0–6 inches of soil at 307 one-half acre grids within the firing ranges;
- Determine the background concentrations of lead in the top 0–6 inches of soil at 20 undisturbed/unused locations within Camp Bonneville;
- Determine the concentrations of explosive residues, including picric acid and PETN, in soil in the muzzle blast area of the firing ranges where the firing location is known; and
- Determine the concentrations of explosive residues, perchlorate residues, and metals in soil samples from Demolition Areas 2 and 3.

The sample results were compared to MTCA cleanup levels (the report does not specify Method A or Method B) and EPA Region 9 PRGs. Additionally, a total of 20 background soil samples were collected. Sampling grids that measured approximately 80 feet by 80 feet were created at each of the small arms ranges. Soil samples were collected from the center of the grid and one each from locations approximately 40 feet north, south, east, and west of the center. A total of 1,535 soil samples were collected from the grids and submitted to an off-site fixed laboratory for analysis of lead using EP Method 7420. Ten locations randomly selected from the range grids and from two randomly selected background locations from Demolition Area 2 and Demolition Area 3 were submitted for off-site fixed laboratory analysis of Priority Pollutant Metals by EPA Method 6010.

Arsenic and barium were detected at concentrations that exceeded at least one of the regulatory criteria. Additionally, samples were analyzed for explosive residues using EPA Method 8330 modified. The numbers of samples submitted for this analysis are not indicated in the report. Explosive residues were detected in the samples collected from the muzzle blast zone at the 25-meter and machine gun ranges but not above the regulatory criteria. Samples were collected from Demolition Area 2 and Demolition Area 3 (the number of samples is not specified in the report) and were submitted for off-site fixed laboratory analysis of perchlorate using EPA Method 314. Perchlorate was not detected above the method detection limit in any of the samples. No conclusions were included in the report prepared by AEM.

2.5.18 Interim Removal Action – Landfill 4/Demolition Area 1

In 2005, Tetra Tech, Inc. conducted an interim removal action at Landfill 4/Demolition Area 1 for the U.S. Department of the Army. The purpose of the removal action was to remove source contamination (2.5-acre footprint) within the landfill that was impacting downgradient ground water. Part of the removal action included a report that provided a compilation of ground water monitoring data and historical ground water information related to Landfill 4. The report consisted of a review of ground water monitoring data at Landfill 4 and established a baseline concentration for the primary ground water contaminants at the site. These contaminants included RDX, perchlorate, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, total chromium, total copper, and total zinc. It was recommended that ground water monitoring continue at the landfill following the removal of the 2.5 acre foot-print (Tetra Tech 2005).

2.5.19 Remedial Investigation/Feasibility Study of Remedial Action Unit 3

In 2004, Parsons Infrastructure and Technology Group conducted a remedial investigation/feasibility study (RI/FS) for the Corps of RAU3, which was any area where military munitions may have come to be located. The purpose of the RI/FS was to document and present munitions and explosives of concern (MEC); site characterization processes and findings; development of appropriate MEC risk assessment methods and results; develop MEC remediation levels; identification and screening of various cleanup actions; and rationale for selection of proposed cleanup action(s) for the different areas investigated. A total of six alternatives for cleanup were developed during this investigation. The cleanup alternative, or remedy, recommended for each area investigated was based on the specific characteristics of the area. The alternatives were as follows (Parsons 2004):

- **Alternative 1 – No Further** Action: No cleanup action would be implemented to reduce the potential explosive safety risk posed by different areas located within Camp Bonneville. This alternative, if implemented, would involve the continued use of the areas in their current condition.
- **Alternative 2 – Institutional Controls:** Institutional Controls (ICs) are measures undertaken to limit public exposure to residual explosives materials at Camp Bonneville. These preventive measures may include educational awareness and training programs, legally enforceable restrictions on future land use, and physical access controls.
- **Alternative 3 - Surface Clearance with Institutional Controls:** Surface clearance would require clearance of MEC items located on the ground surface. Prior to performing any MEC clearance activities at the site, control points would be established by a land surveyor for the areas that would undergo surface clearance. UXO-qualified personnel would perform a

magnetometer-assisted surface sweep to locate metallic objects. The sweep would be performed in fixed width intervals. During the surface sweep, metallic objects located on the ground surface would be identified as either benign metallic scrap or MEC items and removed.

- **Alternative 4 - Clearance to Frost Depth (14 inches) with Institutional Controls:** Clearance to frost depth would require clearance of MEC items located on the ground surface and within 14 inches bgs. Clearance to the published frost penetration depth of 14 inches was determined to be necessary due to the potential for frost heave to push buried items at or above this depth to the surface. Based on the minimal amount of UXO recovered to date, all being less than 18 inches bgs, it was anticipated that the majority of remaining UXO at the site was within this frost depth interval. During MEC clearance activities at the site, control points would be established by a land surveyor for the areas that would undergo surface clearance. Brush clearing crews would clear sufficient undergrowth so that the MEC clearance crews could adequately perform their work. The brush clearance crews would be accompanied by UXO-qualified safety personnel.
- **Alternative 5 - Subsurface Clearance with Institutional Controls:** Subsurface clearance would require clearance of MEC items to a specified depth based on the projected end use of the site and the resulting potential for exposure to MEC. Under this alternative, each anomaly would be intrusively investigated until the anomaly was identified or until the site-specific risk-based specified depth was reached. Implementation of this alternative would involve land surveying and brush clearing operations. This alternative would also involve a magnetometer-assisted surface sweep to remove all surface clutter which includes benign metallic scrap items and MEC items. The surface sweep would be performed by experienced UXO-qualified personnel.
- **Alternative 6 – Subsurface Clearance and Restoration:** Subsurface clearance and restoration would require excavation of the complete area in order to remove all metallic and MEC items located at the area. Under this alternative, prior to excavating any site soils all existing vegetation, including tree cover, would be cleared. No geophysical survey would be performed for this alternative. All the soils located at the site would be excavated to a depth of 10 feet and would be sifted to identify MEC items for proper disposal (based on the reuse of the site as being recreational). The soils free of any MEC items would be reused at the site for backfilling the excavations. As a result of the process, this alternative would require extensive repair of all ecological damages during the MEC removal action.

The remedy (cleanup alternative) recommended for selection by Parsons for each area within RAU3 is discussed in the following subsections along with the rationale for making the selection.

2.5.19.1 Target Areas

The five Target areas investigated included the 3.5-inch Rocket Range Target, the Rifle Grenade Range Target, the Hand Grenade (HE) Range Target, the M203 HE Range Target, and the 2.36-inch Rocket Range Target (Figure 2-30). Of these areas, the 3.5-inch Rocket Range Target, the Rifle Grenade Range Target, the HE

Range Target, and the 2.36-inch Rocket Range Target were deemed to have the highest relative explosive safety risk based on the type and likelihood of MEC occurrence. For all areas except the M203 HE Target area, alternative 4 (clearance to frost depth and institutional controls) was selected. For the M203 HE Target Area, alternative 2 (institutional controls) was selected. The clearance action was recommended to be conducted in the footprint of each of the target areas. The area and extent of the targets was based upon prior characterization and reconnaissance efforts. It was recommended to begin at the presumed center of the areas and proceed outward in a grid-based manner. The calculated total area for the removal action was approximately 10.6 acres and the total area of ICs was approximately 14.6 acres (Parsons 2004).

2.5.19.2 Central Impact Target Area

The Central Impact Target Area Ordnance and Explosive Area is located in the central portion of Camp Bonneville (Figure 2-31) and is comprised of three adjacent target areas known as the West Impact Area Car Target 2, Combined Impact Area 1, and Combined Impact Area 2. This Central Impact Area was deemed to have a high relative explosive risk based on the type and likelihood of MEC occurrence. There are no future reuse activities planned for this area. Alternative 2 (institutional controls) was selected for this area and included the construction of signage to inform the public of previous uses, and land use controls in the form of restrictive covenants to prohibit any future development and/or forestry activities in the area. The implementation of this alternative was recommended for the footprint of the area for a total of 83 acres (Parsons 2004).

2.5.19.3 Open Burn/Open Detonation Areas

The Open Burn/Open Detonation (OB/OD) MEC source area consists of three OB/OD areas known as Demolition Area 1, Demolition Area 2, and Demolition Area 3 (Figure 2-32). A wide range of explosives and ordnance were reportedly disposed of in the OB/OD areas. Demolition Area 1 is a low future reuse area as it is located in the proposed Wildlife Management Area. Demolition Area 2 is a high future reuse area since Clark County is proposing a "Logging Camp" for this area. Intrusive activities may be conducted in the logging camp. Demolition Area 3 is a medium future reuse area as it is near to the planned Environmental Study Area.

No subsurface clearance cleanup was recommended for Demolition Area 1 since it is co-located with Landfill 4 and the entire 2.5 acre footprint had been removed. Alternative 5 (subsurface clearance with institutional controls) was recommended for Demolition Areas 2 and 3 because it would eliminate substantially all of the explosive exposure risk. In addition, Alternative 3 was recommended as a "buffer area" surrounding all three OB/OD areas to address the potential from kick-out (which is the unintended dispersal of explosives during disposal activities and/or the inadvertent release of submunitions). The subsurface clearance was recommended to be performed in a 300-foot by 300-foot grid centered over the Demolition Areas 2 and 3. The removal was proposed to begin in the center and proceed outward in a grid-based manner. The total area of subsurface clearance for Demolition Areas 2 and 3 was estimated to be two acres each for a total of four acres (Parsons 2004).

2.5.19.4 Firing Points

The Firing Points MEC source area consist of six mortar firing positions, seven artillery firing positions, one rifle grenade range firing point, one 3.5-inch rocket range firing point, and one M20340-mm HE range (Figure 2-33). These areas have a medium relative explosive safety risk based on the type and likelihood of MEC occurrence. The firing points are accessible based on their proximity to roads and trails. The activities proposed for future reuse are surficial and non-intrusive. Alternative 2 (institutional controls) was selected for these areas because it would substantially eliminate the explosive exposure risk. The implementation of institutional controls would also provide the necessary public awareness of the former military use of the site to park visitors. The clearance action would be conducted in the footprint of each of the firing points. Although Alternative 2 does not include clearance actions, they were recommended for the firing points in addition to Alternative 2. The total area for the removal would be approximately 19 acres (Parsons 2004).

2.5.19.5 Training Areas

One training area (the M203 Practice Range co-located with the Mortar Practice Range) was determined to pose a potential MEC risk. Alternative 2 (institutional controls) was determined to be appropriate for this area. No further information regarding the recommendations for the implementation of this alternative in this area is provided in the report (Parsons 2004).

2.5.19.6 Range Safety Fans

The Range Safety Fans (RSF) Ordnance and Explosive (OE) area consists of a total of 16 range safety fans associated with each of the 16 Firing Point Locations. The majority of Camp Bonneville is overlain by one or more RSFs. The RSFs are designed to contain those single event items that fall at some distance from their intended targets. The likelihood of encountering UXO in an RSF is negligible, because of the infrequency of historical artillery firing practices and the large size of the RSFs. The report indicates that most of the proposed future reuse of the areas is considered low, except those areas that overlie a High Reuse Intensity Area. For these areas, Alternative 5 (subsurface clearance with institutional controls) was selected (Parsons 2004).

2.5.19.7 Storage Magazine/Transfer Points

The solitary Storage Magazine/Transfer Point MEC source is Building 2950 (Figure 2-34), consisting of three bunkers located approximately 1,000 feet northeast of the Bonneville cantonment. The likelihood of any non-deployed military munitions in this area is remote; therefore, it has a low relative explosive safety risk. Alternative 2 (institutional controls) was selected for this area (Parsons 2004).

2.5.19.8 Maneuver Areas
The Maneuver Areas MEC sources are those areas that were not specifically identified as troop training areas. Maneuver Areas overlay the vast majority of the site and included the roads and trails, bivouac, and maneuver areas, including the Camp Killpack and Bonneville cantonments. These areas were determined to have a very low relative explosive safety risk. Alternative 2 (institutional controls) was selected to remediate these areas (Parsons 2004).

2.5.19.9 Central Impact Area
The Central Impact Area is approximately 458 acres and comprised of the 83 acre Central Impact Target Area and 375 acres of associated RSFs. The area is fenced with a three-strand barbed wire fence encircling the entire area. Additionally, signage warning of the potential danger to trespassers is in place. People are not expected to venture into this area due to the fencing, signage, and steep terrain; therefore, the number of potential human receptors was determined to be negligible. Alternative 2 (ICs) was determined appropriate for remediation in this area (Parsons 2004).

2.5.19.10 Roads and Trails
There are approximately 46 miles of roads and trails throughout the site, of which 25 miles are located within the proposed Regional Park (Figure 2-35). The roads and trails have the same munitions related historical use and characteristics as the Maneuver Areas. The roads and trails have a low relative explosive safety risk. Alternative 4 (clearance to frost depth and institutional controls) was determined to be the most appropriate remediation. The clearance was recommended to include geophysical mapping of roads and trails. Area-specific institutional controls that were recommended included signs along the roads and trails to inform the public about past military use of the site (Parsons 2004).

2.5.19.11 High Intensity Reuse Areas
Areas of the proposed Regional Park that are High Intensity Reuse Areas comprise approximately 210 acres. It was assumed that the future visitors would conduct a wide range of recreational and educational activities within the footprint of the High Intensity Reuse Areas. Alternative 5 (subsurface clearance with institutional controls) was selected as the best remediation method for these areas, with some locations being cleared to 14 inches and some to 4 feet. The total area estimated for conducting the 14-inch clearance is approximately 160 acres. The area estimated for requiring the 4-foot clearance is approximately 50 acres and includes the following proposed future uses within the park: Rustic Retreat Future Expansion, Logging Camp, Tent and Yurt Camping sites, and an estimated additional 5 acres for other construction areas (Parsons 2004).

2.5.19.12 High-Accessible Medium Intensity Reuse Areas
Areas of the proposed Regional Park that are High-Accessible Medium Intensity Reuse Areas comprise those areas that are located between the High Intensity Reuse Areas, have a gentle topographic slope and low vegetative cover, and therefore provide the opportunity to draw people together for informal recreational activities. These areas cover approximately 180 acres along the

Lacamas Creek valley floor. Alternative 4 (clearance to frost depth and institutional controls) was selected for remediation efforts in these locations. The clearance action was recommended to be conducted in the footprint of the High-Accessible Medium Intensity Reuse Areas. The total area for conducting the clearance is approximately 180 acres (Parsons 2004).

2.5.19.13 Remaining Medium Reuse Intensity Areas

The remaining Medium Reuse Intensity Areas of the proposed Regional Park consist of those areas that are located between specific designated reuse areas, and do not have the high accessibility characteristics of gentle slope and low vegetation. These remaining Medium Reuse Intensity Areas comprise approximately 770 acres. Alternative 2 (institutional controls) was selected for these areas, including signage that would serve to inform visitors of the past military history of the site (Parsons 2004).

2.5.19.14 Wildlife Management Area

The Wildlife Management Area is comprised of approximately 2,000 acres in the eastern portion of the site and includes the Washington State Department of Natural Resources (DNR) leased lands (Figure 2-8). The Wildlife Management Area does not include the Central Impact Area nor the roads and trails located in the Wildlife Management Area. The majority of the Wildlife Management Area was used as maneuver areas and, therefore, has a low relative explosive safety risk. Alternative 2 (ICs) was recommended for remediation in this area (Parsons 2004).

2.5.20 Cultural and Historical Resources Protection Plan

In November 2006, Michael Baker Jr. Inc. (Baker) prepared a cultural and historical resources protection plan for the BCRRT. The goals and objectives of the protection plan included protecting and preserving the cultural resources at the site; implementation of cultural resource preservation as a regular component of site planning; identification of procedures to follow in the event that conservation actions have the potential to adversely affect cultural resources; and ensure that the identification of previously unidentified cultural resources at the site is comprehensive and consistent with state and federal regulations. The Cowlitz Indian Tribe declared the presence of a series of historic and prehistoric Indian villages, burial ground, and trails on or near the site that are considered sacred ground. The Cultural and Historical Resources Protection Plan indicated that any actions in these areas would not be endorsed by the Cowlitz Indian Tribe to take place without consultation with the tribe. The plan also concluded that the buildings associated with the Camp Bonneville and Killpack cantonments were not eligible for listing in the National Register of Historical Places (Baker 2006).

2.5.21 Remedial Investigation Demolition Areas 2 and 3

In 2006, Baker conducted an RI at Demolition Areas 2 and 3 for the BCRRT. The purpose of the remedial investigation was to determine the presence or absence of contamination in ground water discharging from Camp Bonneville at the base's boundary and at locations downgradient from Demolition Areas 2 and 3; to determine the presence or absence of contamination in ground water in the vicinity of Demolition Areas 2 and 3; to determine the presence or absence of soil contamination in Demolition Areas 2 and 3; and to determine the geologic/hydrogeologic conditions in the investigation areas (Figure 2-36). To meet these stated objectives, the investigation included the installation and sampling of 16 monitoring wells located in three areas and soil sampling in Demolition Areas 2 and 3. Three wells were installed in the shallow alluvium/weathered bedrock in a line normal to the direction of flow from Demolition Area 2 (Figure 2-37). One well pair (shallow and deep) and three shallow wells were installed at four compass points surrounding the Demolition Area 3 crater (Figure 2-38). In addition, four well pairs (shallow and deep) were installed in a transect across the Lacamas Creek valley near the boundary of Camp Bonneville and downgradient of Demolition Area 3 (Figure 2-39). Surface and subsurface soil samples were collected from Demolition Areas 2 and 3 (Baker 2006).

2.5.21.1 Demolition Area 2

The ground water from three shallow wells in Demolition Area 2 were sampled and analyzed for explosives, perchlorate, total and dissolved metals, and water quality parameters [chloride sulfate, total alkalinity, dissolved organic carbon (DOC), nitrite/nitrates as nitrogen, TOC and total suspended solids (TSS)]. Additionally, five soil samples at the ground surface, two feet bgs, and five feet bgs were collected (one from the center of DA 2 and one each from approximately 100 feet north, south, east, and west of the center) and were submitted for analysis of explosives, perchlorate, and metals. Sample results were compared to MTCA Method A cleanup levels for residential land use, MCLs, and EPA PRGs (Baker 2006).

No explosives, perchlorate, or total and dissolved metals were detected at concentrations at or above the regulatory criteria in the ground water samples. No explosives or perchlorate were present in the soil samples above the reporting limit. Arsenic was detected at concentrations that exceeded the regulatory criteria in all 15 of the soil samples; however, they were below the background concentration established for Clark County, Washington (Baker 2006).

2.5.21.2 Demolition Area 3

Five wells were installed in this demolition area, four shallow and one deep. Ground water samples were analyzed for explosives, perchlorate, total and dissolved metals, and the same water quality parameters as stated in the previous subsection. Soil samples were collected during the drilling of wells in Demolition Area 3. The soil samples were collected at the ground surface and at depths of two feet, five feet, and 15 feet bgs; however, the 15 foot interval was not sampled in one of the monitoring wells. Soil samples were analyzed for explosives, perchlorate, and total metals. Sample results were compared to MTCA Method A cleanup levels for residential land use, MCLs, and EPA PRGs (Baker 2006).

No explosives or total metals were detected at concentrations at or above the regulatory criteria in the ground water samples. Perchlorate and nitrate were detected above the regulatory criteria in one of the wells. As perchlorate may produce a false negative, additional samples were collected and submitted to two different laboratories for reanalysis. These analyses did not indicate the presence of perchlorate or nitrate above the regulatory criteria. It was determined that the initial analysis had reported a "false positive". Results for the soil samples did not indicate the presence of explosives, perchlorate, or metals at concentrations above the regulatory criteria (Baker 2006).

In addition, four well pairs (shallow and deep) were installed in a transect across the Lacamas Creek valley near the boundary of Camp Bonneville and downgradient of Demolition Area 3. Sample results did not indicate the presence of any metals or perchlorate at concentrations that exceeded the regulatory criteria.

During the RI, an area where corroded drums and shell debris had been encountered was excavated. Samples were collected from the sidewalls and bottom of the excavation area. The samples were analyzed for explosives, perchlorate, and picric acid. None of these constituents were detected in the excavation samples. (Baker 2006)

2.5.21.3 RI Conclusions and Recommendations

The constituents detected in ground water and soils in Demolition Areas 2 and 3 were deemed to be present at "relatively low concentrations that do not pose a threat to human health or the environment". It was recommended that Demolition Areas 2 and 3 be considered for no further action (Baker 2006).

2.5.22 Remedial Investigation/Feasibility Study Small Arms Ranges

In 2006, Baker conducted an RI/FS for 17 small arms ranges at Camp Bonneville for the BCRRT. The RI was conducted to characterize soils at 17 Small Arms Ranges in order to provide data upon which to base decisions for further actions. Based on the results of the RI, the FS was conducted to identify and evaluate cleanup action alternatives and select a cleanup action for the Small Arms Ranges (Baker 2006).

Surface soil samples were collected from half-acre grids across the Small Arms Ranges. All range samples were analyzed for lead by EPA Method 7420. A total of 307 half-acre plots were samples. Each of the grids consisted of five grab soil sample collected from 0 to 6 inches bgs. Samples were collected from near the center of each grid and at 40 feet from the center of four compass points. A total of 1,535 soil samples were collected from the grids. At ten of the Small Arms Range grid locations, ten samples were randomly selected from the range soils and analyzed for Priority Pollutant Metals by EPA Method 6010B (Baker 2006).

For ranges where the firing line had been determined, a muzzle blast zone was designated as a strip in front of and parallel to the firing line. Samples were collected along the strip at approximately 30-foot intervals and within 10 feet of the firing line. These samples were analyzed for explosive residues including picric acid and PETN by EPA Method 8330 Modified. Twenty (20) soil samples were collected and analyzed to identify the background levels of lead in the soil by EPA Method 6010. The soil samples collected from the Small Arms Ranges were compared to MTCA Method A cleanup criteria. Sample results indicated the presence of lead above the regulatory cleanup level at 14 of the 17 ranges. Approximately 12 percent of the samples collected had concentrations that exceeded the cleanup criteria. None of the samples collected from the muzzle blast zone contained concentrations of explosive residues at concentrations that exceeded the EPA Region 9 PRGs (there are no established MTCA criteria for explosive residues; Baker 2006).

As part of the investigation, five remedial alternatives were developed. The alternatives included no further action (Alternative 1), implementation of institutional controls such as signage (Alternative 2), capping (Alternative 3), consolidation and capping (Alternative 4), and excavation and off-site disposal or recycling (Alternative 5). Alternative 5 was recommended as the most permanent solution for the contaminated soils at the Small Arms Ranges (Baker 2006).

2.5.23 Soil and Sediment Investigation – Artillery/Mortar Firing Points, Artillery/Mortar Impact Areas, and "Pop-up" Pond

In October 2007, Baker conducted soil and sediment investigation of the artillery/mortar firing point, the artillery/mortar impact areas, and the "pop-up" pond for BCRRT. The report generated as on outcome of this work was reviewed by Ecology. The objectives of the artillery points and target areas were to determine the presence or absence of explosive constituents in surficial soil and to determine the likelihood that these contaminants are impacting site ground water. The objective of the "pop-up" pond was to determine the presence or absence of lead in sediments within the pond for the purpose of determining if cleanup actions are necessary. The pop-up pond was used in the 1970s for live-fire training with 30- and 50-caliber weapons in an automated pop-up target course.

A total of 435 soil samples were collected from 15 firing points. The samples were analyzed for explosives by EPA Method SW-8330. Additionally, the samples from the 3.5-inch Rocket Range Firing Point were analyzed for perchlorate by EPA Method 314.0. The sample results were compared to MTCA Method A, and when no value for a constituent was available, then the results were compared to the EPA Region 3 RBCs. No analytes were detected at concentrations that exceeded the regulatory criteria for any of the soil samples. Based on the samples results, a determination of "No Further Action" was recommended for all of the artillery/mortar firing points and the artillery/mortar impact areas sampled.

A total of 10 sediment samples were collected from the pop-up pond. The samples were analyzed for lead by EPA Method SW-846 6010. The sample results were compared to the MTCA Screening Level for the Ecological Indicator Soil Concentrations for protection of Terrestrial Plants and Animals. Lead was detected above instrument detection limits in all 10 of the samples; however, only one sample's result exceeded the most conservative screening criteria. Based on the sample results, a determination of "No Further Action" was recommended for the pop-up pond.

2.5.24 Public Health Assessment

In 2008, the Agency for Toxic Substances and Disease Registry (ATSDR) completed a public health assessment for the site as a result of a public petition. As part of the assessment, ATSDR met with the petitioner and community members. Based on these meetings, ten areas of concern were identified. These concerns are presented in the Public Health Assessment report for the Camp Bonneville Military Reservation prepared by ATSDR and are discussed below:

- **Concern 1 – Potential physical hazards from exposure to UXO**
  The Public Health Assessment states "UXO is present on Camp Bonneville. However, there are several factors that limit the public's access to the ordnance, including the location of the UXO, fences with warning signs, and UXO removal. Despite these efforts there is a small potential for people to encounter UXO. Therefore, it is very important to educate those who visit the future regional park about the dangers posed by UXO."
- **Concern 2 – Exposure to soil and ground water contamination for residents living within the Artillery Impact Fan and Range Safety Fan areas**
  The Public Health Assessment states "There was some discrepancy regarding the location of range safety fans at Camp Bonneville. Current maps do not show safety fan areas extending beyond Camp Bonneville's property line. However, older maps show safety fans extending offsite onto the property of residents living to the east of Camp Bonneville. Understandably, this has caused confusion and concern for the residents neighboring Camp Bonneville to the east. According to the WDOE, the historical maps showing range safety fans extending offsite contain cartographical errors and the safety fans never extended offsite. Therefore, there are no residents living within the Artillery Impact Fan and Range Safety Fan areas. In addition those residents to the east of Camp Bonneville are upgradient of any known groundwater contamination."
- **Concern 3 – Exposure to ground water contamination (specifically, perchlorate and RDX plumes)**
  The Public Health Assessment states "Ground water was sampled from 18 sites at Camp Bonneville. The only area found to contain ground water contamination was Landfill 4. The plume at Landfill 4 contains RDX, perchlorate, and 1,1,-dichloroethene. However, no one is drinking water from this area. Therefore, exposure to ground water contamination is an incomplete pathway."
- **Concern 4 – Exposure to contaminated soil (specifically, at the sewage pond/lagoon areas and the small arms firing areas)**
  The Public Health Assessment states "Soil at the Former Sewage Pond and Landfill 2 was sampled in 1998. None of the contaminants were detected at levels of health concern. People are not being exposed to the soil at the Central Impact Target Area because the area is fenced. Further, remediation is being conducted to remove soil containing elevated levels of lead around the former targets at the small arms firing ranges."

- **Concern 5 – Exposure to surface water and sediment contamination in Lacamas Creek, Lacamas Lake, and the Columbia River**
  The Public Health Assessment states "In 1998, a surface water investigation was conducted on Lacamas Creek and its tributaries at Camp Bonneville. The investigation concluded that, in general, site activities have not impacted the water quality of Lacamas Creek. Due to limited use of the creek and the minimal contamination found, ATSDR does not expect harmful health effects to result from exposure to surface water and sediment in Lacamas Creek."
- **Concern 6 – Exposure to runoff water and standing rainwater, particularly near the Open Burn/Open Detonation sites**
  The Public Health Assessment states "Even though standing water is sometimes seen in and around the Open Burn/Open Detonation (OB/OD) sites, exposure to it would be short-term and infrequent. Further, soil, ground water, and surface water at the OB/OD sites have been sampled and no chemicals were detected at levels of health concern."
- **Concern 7 – Inhalation exposure to agents used during past chemical warfare testing and training activities**
  The Public Health Assessment states "CS gas was the only chemical warfare agent used during training. It decomposes quickly and has no persistent metabolites. Therefore, ATSDR does not expect that past inhalation exposure to CS gas occurred off site. Further, the building and soil surrounding the gas chambers were sampled and no residual hazardous substances were detected."
- **Concern 8 – Hunting and eating wildlife on Camp Bonneville**
  The Public Health Assessment states "Hunting may have occurred on Camp Bonneville in the past, but is not expected to occur currently or in the future. Because of the lack of site data, it is indeterminate whether eating wildlife from Camp Bonneville in the past is expected to have caused harmful health effects. However, based on studies conducted at Army ammunition plants, it is unlikely that the wildlife at Camp Bonneville would have accumulated harmful levels of contaminants."
- **Concern 9 – Early property transfer as a public regional camping facility and potential exposures to future site users**
  The Public Health Assessment states "Camp Bonneville was transferred from DOD to Clark County, Washington in October 2006, prior to the completion of environmental cleanup (i.e., early transfer). BCRRT is responsible for continuing the cleanup of Camp Bonneville, with oversight by Ecology. The redevelopment or reuse of the facility is not likely to contribute to any existing release or threatened release, interfere with any remedial actions, or increase health risks at or in the vicinity of the site."
- **Concern 10 – Fire response and suppression at Camp Bonneville**
  The Public Health Assessment states "Even though UXO is present on Camp Bonneville, the Washington State Department of Natural Resources will respond to wildfires at the property in close coordination with BCRRT. There may be some areas (e.g., the Central Impact Target Area) that are too dangerous for fire fighters to enter, however, in those cases,

the fires will be carefully monitored and other methods of fire suppression may be employed."

Based on the health evaluation of each of these concerns, the recommendations by ATSDR state:

- "ATSDR recommends that Clark County educate future visitors to the regional park about the appearance of UXO and what to do if they encounter it. It should be emphasized that UXO should never be handled."
- "ATSDR recommends that ground water in the vicinity of ground water contamination at Landfill 4 not be used for drinking water in the future, and that ground water monitoring in the area continue. ATSDR also recommends continued monitoring of sentinel wells to prevent contamination of off-site drinking water wells."
- "Because hunting was not recommended as a future use of Camp Bonneville in the reuse plan, ATSDR recommends that "No Hunting" signs be posted on the Camp Bonneville property."
- "ATSDR does not recommend firing ranges as a future use in the regional park.

2.6 Potential Sources of Contamination

Based on a review of previous investigations and interviews with site representatives, the following are considered the most viable potential sources of contamination to ground water and surface water at and near the site.

2.6.1 Firing Target Areas

This source consists of a total of 25.2 acres (1,097,712 square feet) of lead contaminated soil. These areas are currently being remediated by BCRRT under Ecology's oversight. Historical sample results have indicated the presence of lead in these target areas.

2.6.2 Central Impact Target Area

This source consists of 83 acres (3,615,480 square feet) of contaminated soil. The area has been fenced and according to Mike Gage of BCRRT will not be accessible to the public during future use of the site. Contaminants of concern associated with this source include RDX and lead.

2.6.3 Open Burn/Open Detonation Area

This source consists of approximately 110 acres (4,791,600 square feet) of contaminated soil. Contaminants of concern associated with this source include lead, arsenic, and RDX.

2.6.4 Landfill 4

This source consists of approximately 2.5 acres (108,900 square feet). The 2.5 acres of the landfill have been removed; however, groundwater contamination is still present at the source area. Contaminants of concern associated with this source include perchlorate, 1,1,1-trichloroethane, 1,1-dichloroethane, chromium, copper, and zinc.

2.7 Superfund Technical Assessment and Response Team Site Visit

A site visit was conducted by the START on August 27, 2009. Upon arrival at the site, a presentation by Michael Gage (president of the BCRRT) was given that outlined some of the history of the site and provided an overview of cleanup work conducted to date. Following the presentation, the START was given a tour of the site. The features which were visited included Landfill 4, the Camp Killpack and Bonneville cantonments, the former sewage lagoons, some of the former firing ranges, the former location of the FBI firing range; and the perimeter of the Central Impact Target Area. Photographs of the site visit are presented in Appendix B.

Table 2-1 1997 BRAC Parcel Descriptions

BRAC PARCEL NUMBER AND LABEL	LOCATION (X,Y COORDINATES)	APPROXIMATE SIZE (ACRES)[b]	ENVIRONMENTAL CONDITION CATEGORY NUMBER	BASIS	REMEDIATION/ MITIGATION
1(1)	10,7	3,822.72	1	This area does not have a history of storage, release, or disposal, or migration from adjacent properties of hazardous substances or petroleum products.	No remediation is necessary.
2(7)HR(P) Historic Landfill	7,9	0.25	7	A cultural resources survey at this site noted disturbed ground with evidence of use as a sanitary type landfill. A specimen from this site dates the use to the early 1900s.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
3(7)HR(P) Sewage Lagoons and Historic Landfill	7,9	2.76	7	This parcel is associated with sewage lagoons in use since 1978. A landfill was discovered during excavation for the sewage lagoons. It is estimated that this landfill was used from the 1940s to 1950s; however, the type and quantity of material located at this site is unknown. Twelve percent sodium hypochlorite above reportable quantities is stored in Building 1995.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
4(7)HR(P) Historic Burn Area	7,9	0.25	7	This is a reported burn site. There is a lack of documentation supporting the existence of or the type and quantity of material burned at this site.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
5(7)HR(P) Trash Burial Site	8,9	0.25	7	This is a reported trash burial site. There is a lack of documentation supporting the existence of or the type and quantity of material buried at this site.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
6(7)HR(P) Grease Pit	6,9 and Camp Bonneville Cantonment Inset	0.25	7	These two grease pits, located across from Building 1828, are corrugated metal pipes that extend into an underground pit filled with gravel. They were designed to accept grease from the mess hall; however, there is a potential for other substances to have been discarded in these pits.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
7(2)PS Camp Bonneville Cantonment AST	6,9 and Camp Bonneville Cantonment Inset	2.50	2	This area contains twenty-four 275-gallon ASTs that store diesel to power the HVAC system associated with individual facilities. There is no history or reports of a release.	No remediation is currently planned.
8(7)HR(P) Former Buildings 1983 and 1962	6,9 and Camp Bonneville Cantonment Inset	0.37	7	Buildings 1983 and 1962 were located at this site and were destroyed by fire. There is a possibility of a release of lead or other substances associated with the use or design of the buildings.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.

Table 2-1 1997 BRAC Parcel Descriptions

BRAC PARCEL NUMBER AND LABEL	LOCATION (X,Y COORDINATES)	APPROXIMATE SIZE (ACRES)[b]	ENVIRONMENTAL CONDITION CATEGORY NUMBER	BASIS	REMEDIATION/ MITIGATION
9(7)HR(P) Building 1864	6,9 and Camp Bonneville Cantonment Inset	0.25	7	Building 1864 stored 55-gallon drums of 2,4,5-T; 2,4-D; and an unknown amount of DDT from 1977 to 1980. There is no evidence of a release of these chemicals. However, there is potential for past release of these chemicals.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
10(1) Building 1834	6,9 and Camp Bonneville Cantonment Inset	0.25	1	This facility is the gas mask training chamber and was used for an unknown period. This building was investigated for tear gas (o-chlorobenzal-malononitrile) residue.	Investigation results indicated no hazardous substances are present on building materials or in surrounding surface soils.
11(7)HR(P) Grease Pit	3,7 and Camp Killpack Cantonment Inset	0.25	7	This grease pit, located across from Building 4368, is a corrugated metal pipe that extends into an underground pit filled with gravel. It was designed to accept grease from the mess hall; however, there is a potential for other substances to have been discarded in this pit.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
12(7)PR(P)HR(P) Building 4475	3,7 and Camp Killpack Cantonment Inset	0.25	7	Building 4475 had a maintenance pit that reportedly received waste oil and antifreeze. The pit is now covered by the concrete floor of the building. Small scale pesticides mixing and loading occurred in front of the building. A three- to four-foot wide strip on the south side of Building 4475 has stressed vegetation and red staining, possibly from drainage off the galvanized metal roof.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
13(7)PR(P)/HR(P) Buildings 4476A and 4475B	3,7 and Camp Killpack Cantonment Inset	0.13	7	Building 4475B is used for storage. During the EBS visual inspection, four 5-gallon drums of oil, four 5-gallon drums of antifreeze, and eight 5-gallon drums of transmission oil were observed. Building 4476A is a storage shed that contains a 1,060-gallon AST with secondary containment. Although no evidence of releases was observed, the U.S. Army plans to sample soil at these locations because of potential past releases of these chemicals.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.

Table 2-1 1997 BRAC Parcel Descriptions

BRAC PARCEL NUMBER AND LABEL	LOCATION (X,Y COORDINATES)	APPROXIMATE SIZE (ACRES)[b]	ENVIRONMENTAL CONDITION CATEGORY NUMBER	BASIS	REMEDIATION/ MITIGATION
14(7)PR(P)/HR/(P) Former Vehicle Maintenance Rack and UST	3,7 and Camp Killpack Cantonment Inset	0.25	7	Building 4476 is a hazardous waste accumulation point used to store waste oil and other vehicle fluids. This former location of a vehicle maintenance rack reportedly received waste oil and antifreeze. A UST was removed without documentation at the location of Building 4476.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
15(5)PR Building 4475 LUST	3,7 and Camp Killpack Cantonment Inset	0.08	5	A 275-gallon AST and a 275-gallon UST located east of Building 4475 were removed in 1995. Evidence of soil contamination was noted during removal.	Additional soil removal was conducted in fiscal year 1997; however, closure documentation has not been finalized.
16(7)HR(P) Building 4126	3,7 and Camp Killpack Cantonment Inset	0.25	7	Building 4126 was used to store 55-gallon drums of 2,4,5-T; 2,4-D; and an unknown amount of DDT until 1977. There is no evidence of a release of these chemicals; however, there is potential for past release of these chemicals.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
17(7)HR(P) Former Sewage Pond	6,8 and Camp Bonneville Cantonment Inset	0.25	7	This area is the location of a former open sewage pond.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
18(7)HR(P) Suspected Drum Burial Site	3,7	0.25	7	This area reportedly contains buried drums of unknown contents.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
19(7)HR(P) Suspected Disposal Site	4,6	0.25	7	Waste paint and solvent was reportedly disposed of in this area.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
20(7)PR(P)/HR(P) Wash Point	3,7 and Camp Killpack Cantonment Inset	0.25	7	Vehicle washing may result in release of POLs, other vehicle fluids, and metals.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
21(7)HR(P) Demolition Area 1 and Landfill 4	9,12	4.60	7	This area was used for the demolition of UXO and reportedly used as a landfill for disposal of building demolition debris.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.

Table 2-1 1997 BRAC Parcel Descriptions

BRAC PARCEL NUMBER AND LABEL	LOCATION (X,Y COORDINATES)	APPROXIMATE SIZE (ACRES)[b]	ENVIRONMENTAL CONDITION CATEGORY NUMBER	BASIS	REMEDIATION/ MITIGATION
22(7)HR(P) Demolition Area 2	10,8	2.30	7	This area was used for the demolition of UXO.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.
23(2)HS Building 1815	6,9 and Camp Bonneville Cantonment Inset	0.25	2	Building 1815 stores greater than one pound reportable quantity of 12 percent sodium hypochlorite for water treatment.	No remediation is necessary.
24(2)HS Building 4522	2,8	0.25	2	Building 4522 stores greater than one pound reportable quantity of 12 percent sodium hypochlorite for water treatment.	No remediation is necessary.
25(7)HR(P)	6,7	0.25	7	The building was a tear gas mask training chamber and was used for an unknown period. The building was destroyed by fire.	Investigation and, if necessary, remediation are planned under the BRAC 95 Program.

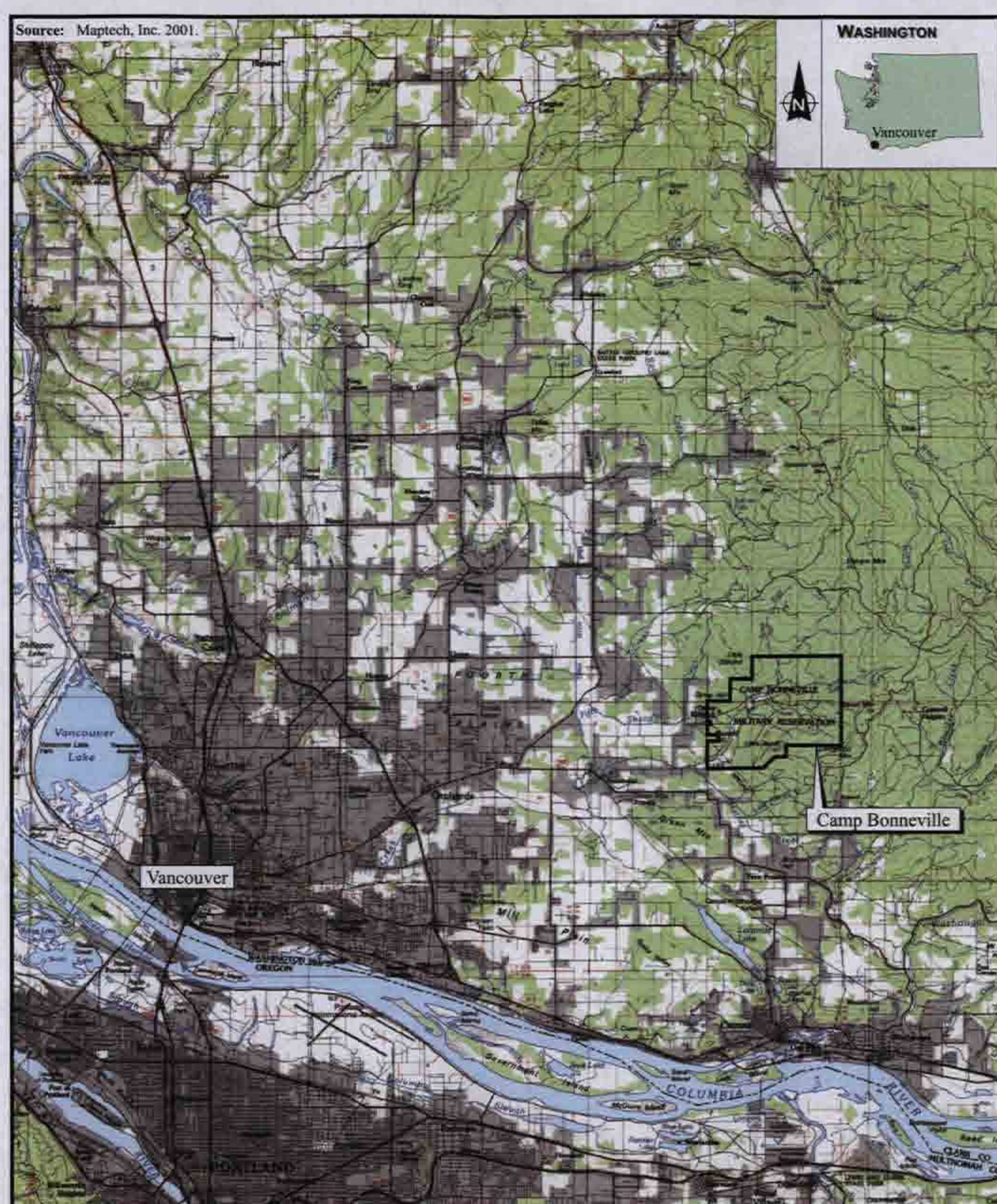
Source: Woodward Clyde 1997

Table 2-2 1999 Multi-Sites Investigation – Analytical Procedures

Analytical Parameter	Method
Total Petroleum Hydrocarbons	WTPH-HCID, WTPH-G, WTPH-D, WTPH-D Extended
Organochlorine Pesticides and Polychlorinated Biphenyls	EPA Method SW846-8081
Volatile Organic Compounds	EPA MethodSW846-8260A
Semivolatile Organic Compounds	EPA Method SW846-8270B
Organophosphorus Compounds	EPA Method SW846-8141A
Chlorinated Herbicides	EPA Method SW846-8150B
Nitroaromatics and Nitramines	EPA Method SW846-8330
Ammonium Picrate/Picric Acid	EPA Method SW-846-8321 modified
Pentaerythritol Tetranitrate	EPA Method SW846-8321
CS and Breakdown Products	EPA Method SW8468270C modified
Metals	EPA Method SW846-6020
Mercury	EPA Method SW846-7470A/7471A
Cyanide	EPA Method SW846-9012
Common Anions	EPA Method SW846-300.0
Common Cations	EPA Method SW846-6010A
Carbonate/Bicarbonate	EPA Method E310.1
Total Suspended Solids	EPA Method E130.2
Asbestos	EPA Method 600
Moisture	ASTM Method D2216
Total Organic Carbon	Walkey-Black
Fecal Coliform	Method SM Part 900
Fecal Streptococcus	Method SM Part 900

Source: SWI 1999

Key:
EPA = United States Environmental Protection Agency.



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Seattle, Washington

CAMP BONNEVILLE
Vancouver, Washington

0 1.5 3
Approximate Scale in Miles

Figure 2-1

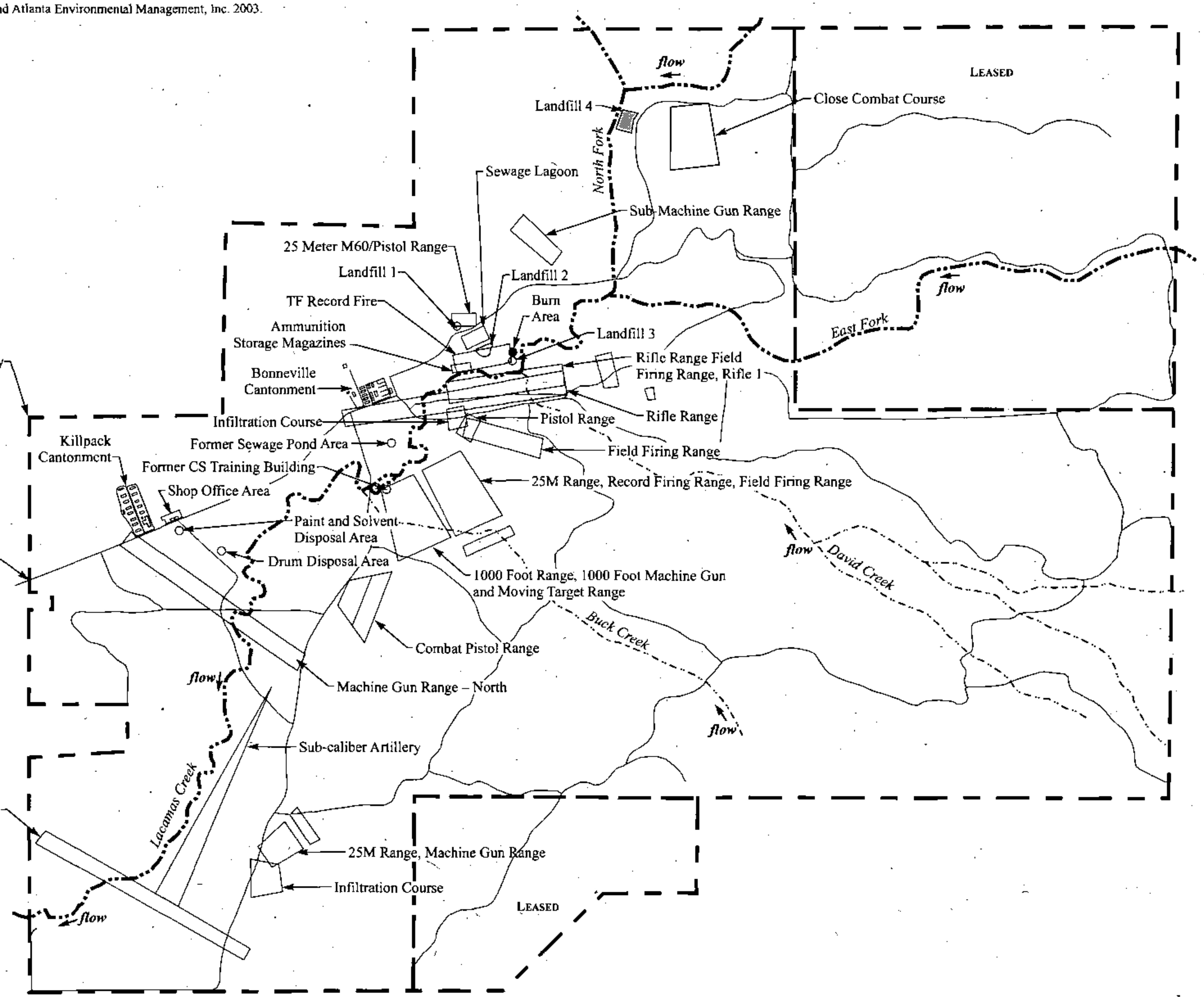
SITE VICINITY MAP

Date: 11-18-09

Drawn by: AES

10:START-3\09050003\fig 2-1

Base Map Reference: Shannon & Wilson, Inc. 1999 and Atlanta Environmental Management, Inc. 2003.



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Seattle, Washington

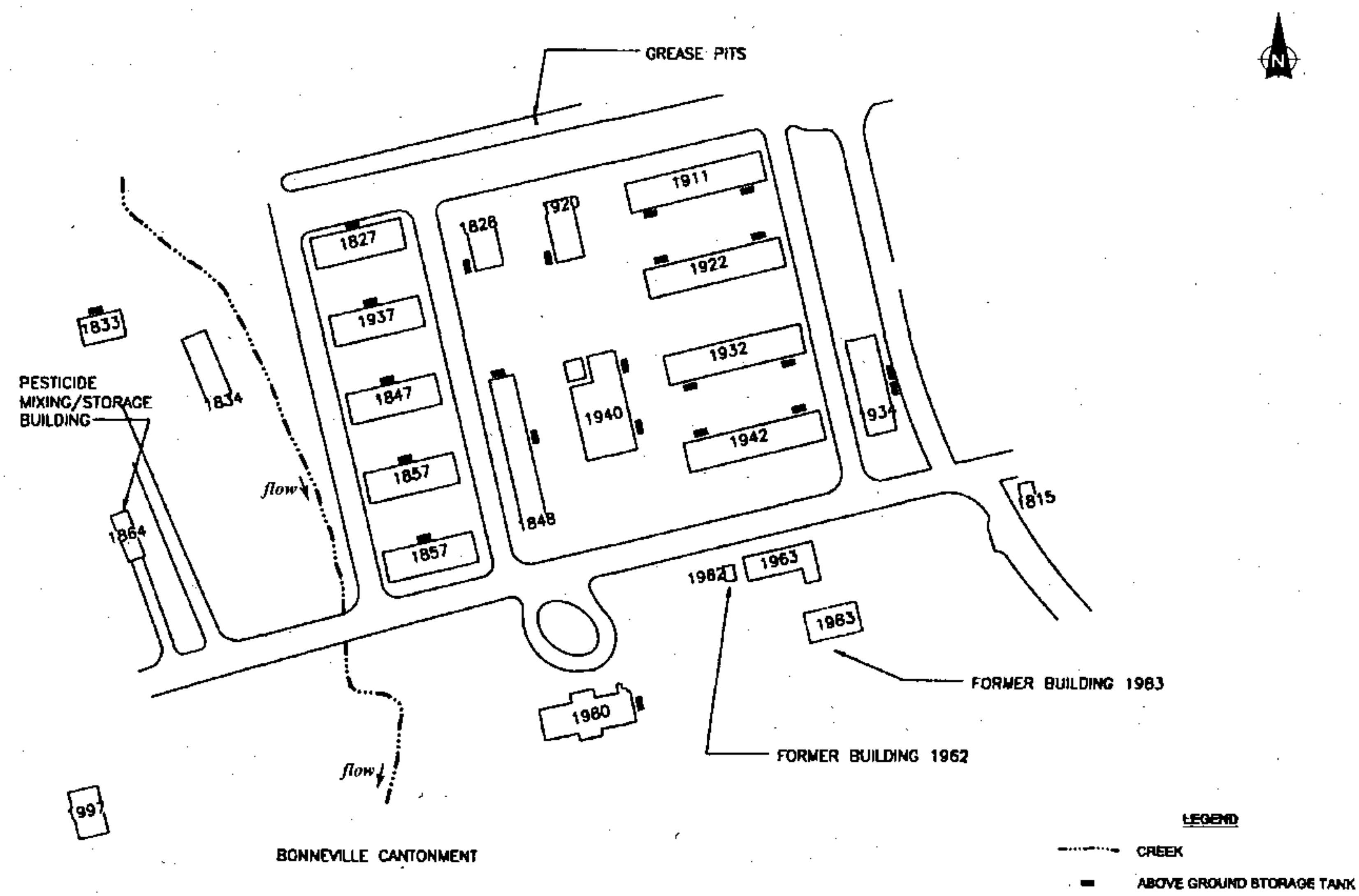
0 1600 3200
Approximate Scale in Feet

CAMP BONNEVILLE
Vancouver, Washington

Figure 2-2
OVERALL SITE MAP

Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-2

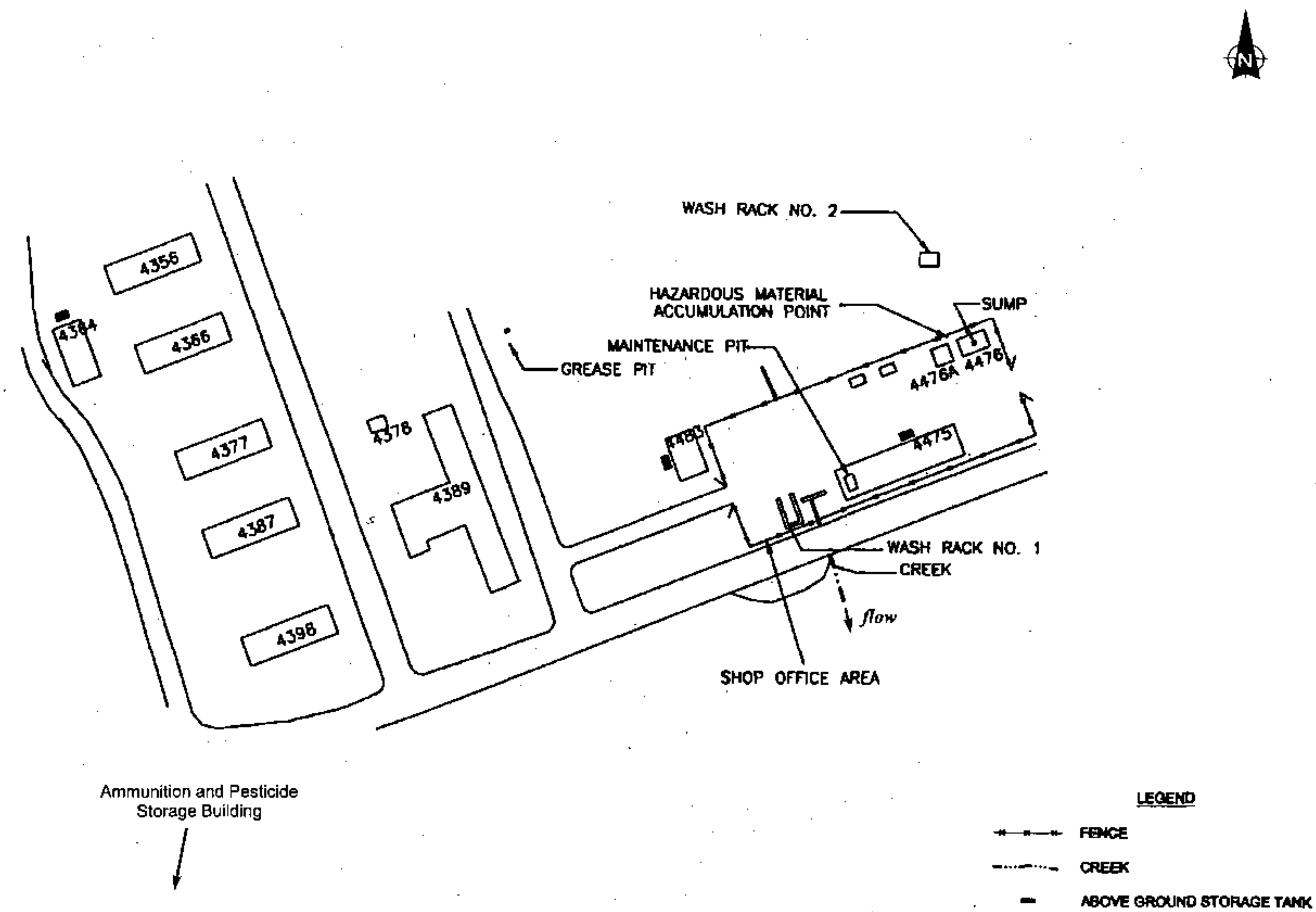
Base Map Reference: Shannon & Wilson, Inc. 1999.



2-57

ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-3 BONNEVILLE CANTONMENT SITE MAP		
	0 100 200 Approximate Scale in Feet	Date: 2/12/10	Drawn by: AES	10:START-3\09050003\fig 2-3

Base Map Reference: Shannon & Wilson, Inc. 1999.



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Vancouver, Washington

0 100 200
Approximate Scale in Feet

Figure 2-4
KILLPACK CANTONMENT SITE MAP

Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-4

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 SIXTH AVENUE
SEATTLE, WA 98101

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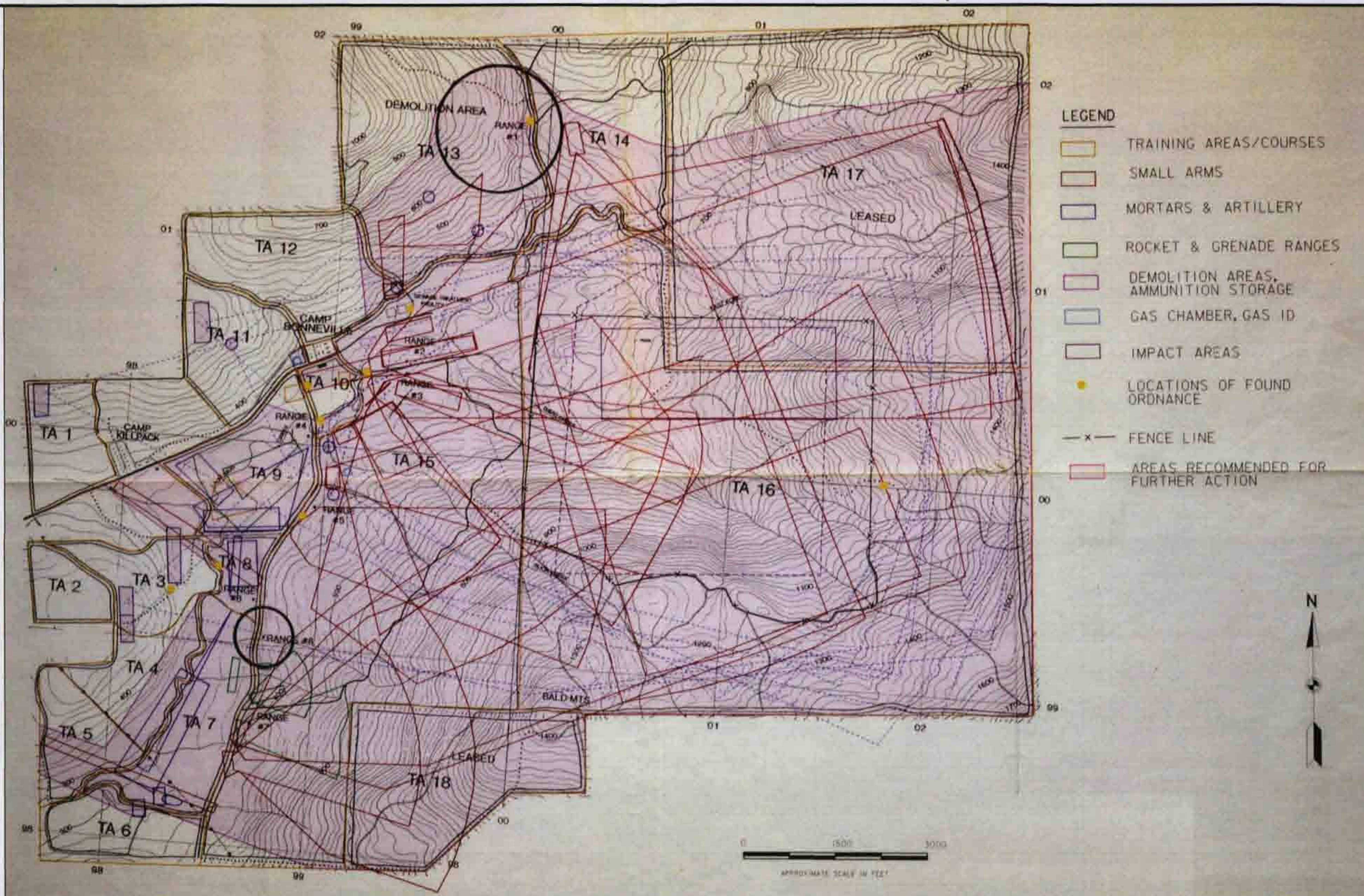
File #:	2.1
Site Name:	CAMDF

FIGURE 2-5
BRAC PARCEL DESIGNATION MAP
12/10/2009



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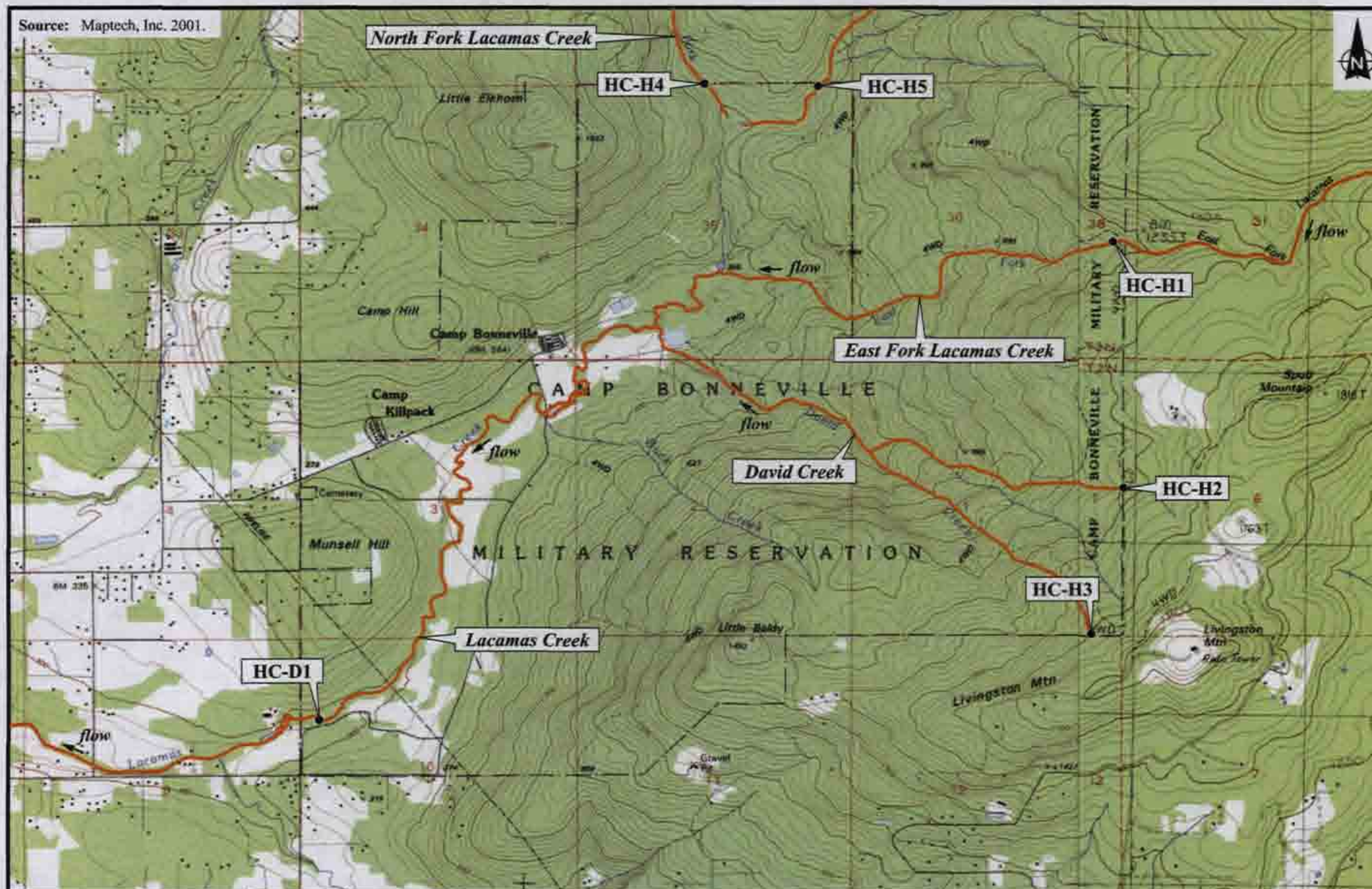
Base Map Reference: Corps, 1997.

CAMP BONNEVILLE
Vancouver, Washington

Figure 2-6
AREAS RECOMMENDED FOR FURTHER ACTION

Date:	Drawn by:	
12/11/09	AES	10:START-3\09050003\fig 2-6



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Vancouver, Washington

0 1333 2666
Approximate Scale in Feet

Figure 2-7
SURFACE WATER INVESTIGATION
SAMPLE LOCATIONS

Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-7

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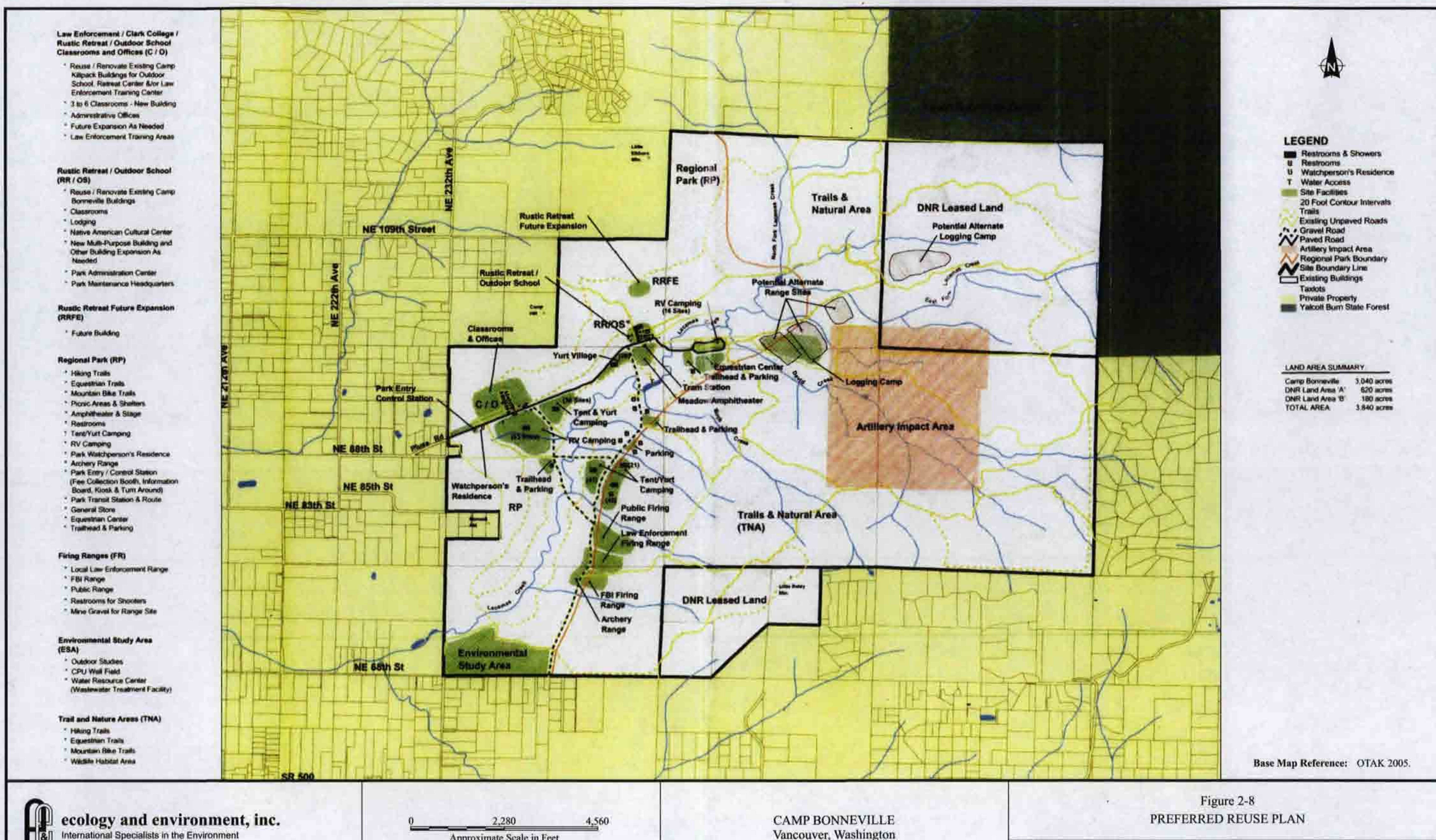

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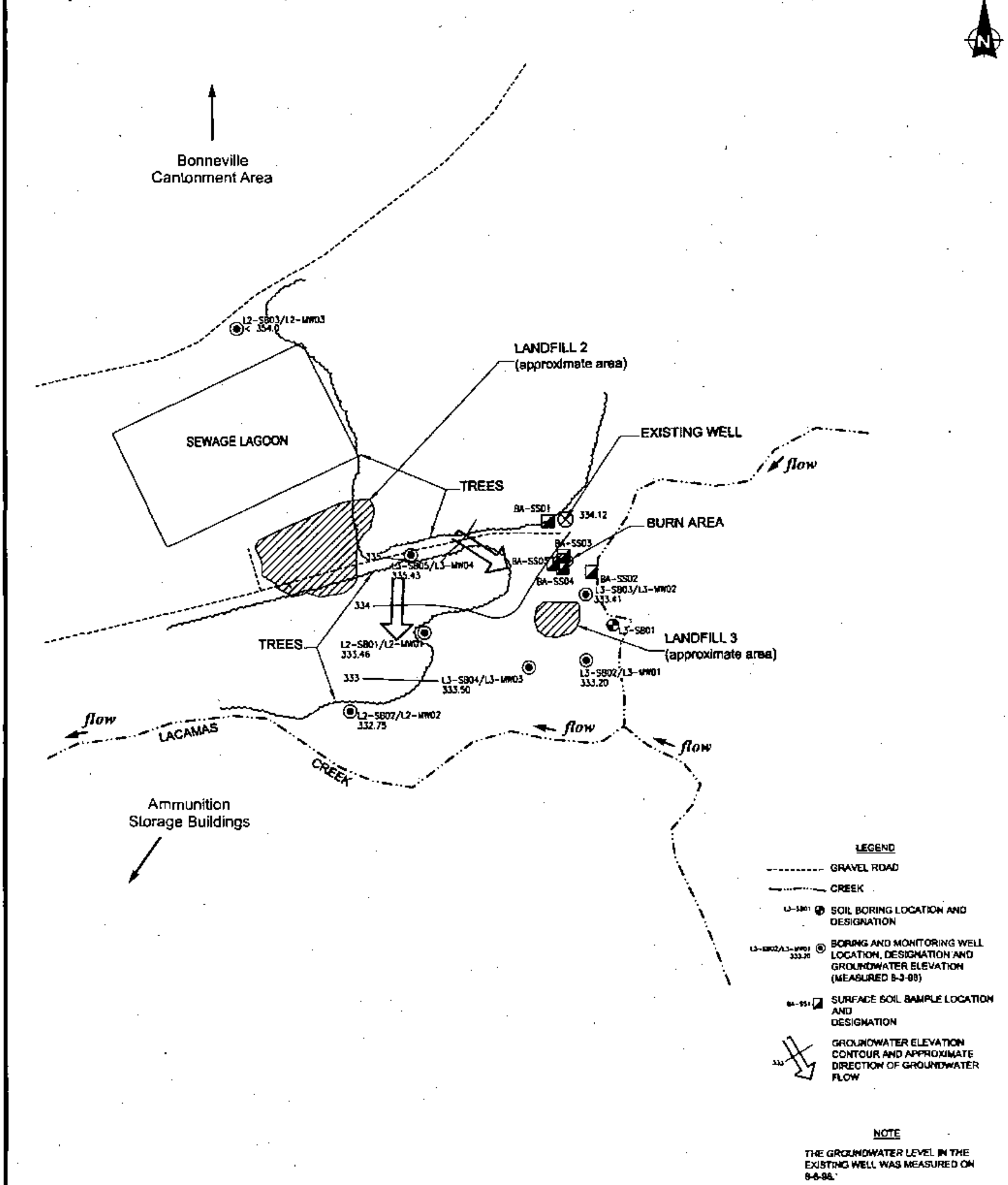
Vancouver, Washington

Figure 2-8
PREFERRED REUSE PLAN

Date:	Drawn by:	
12/10/09	AES	10:START-3\09050003\fig 2-8

Base Map Reference: Shannon & Wilson, Inc. 1999.



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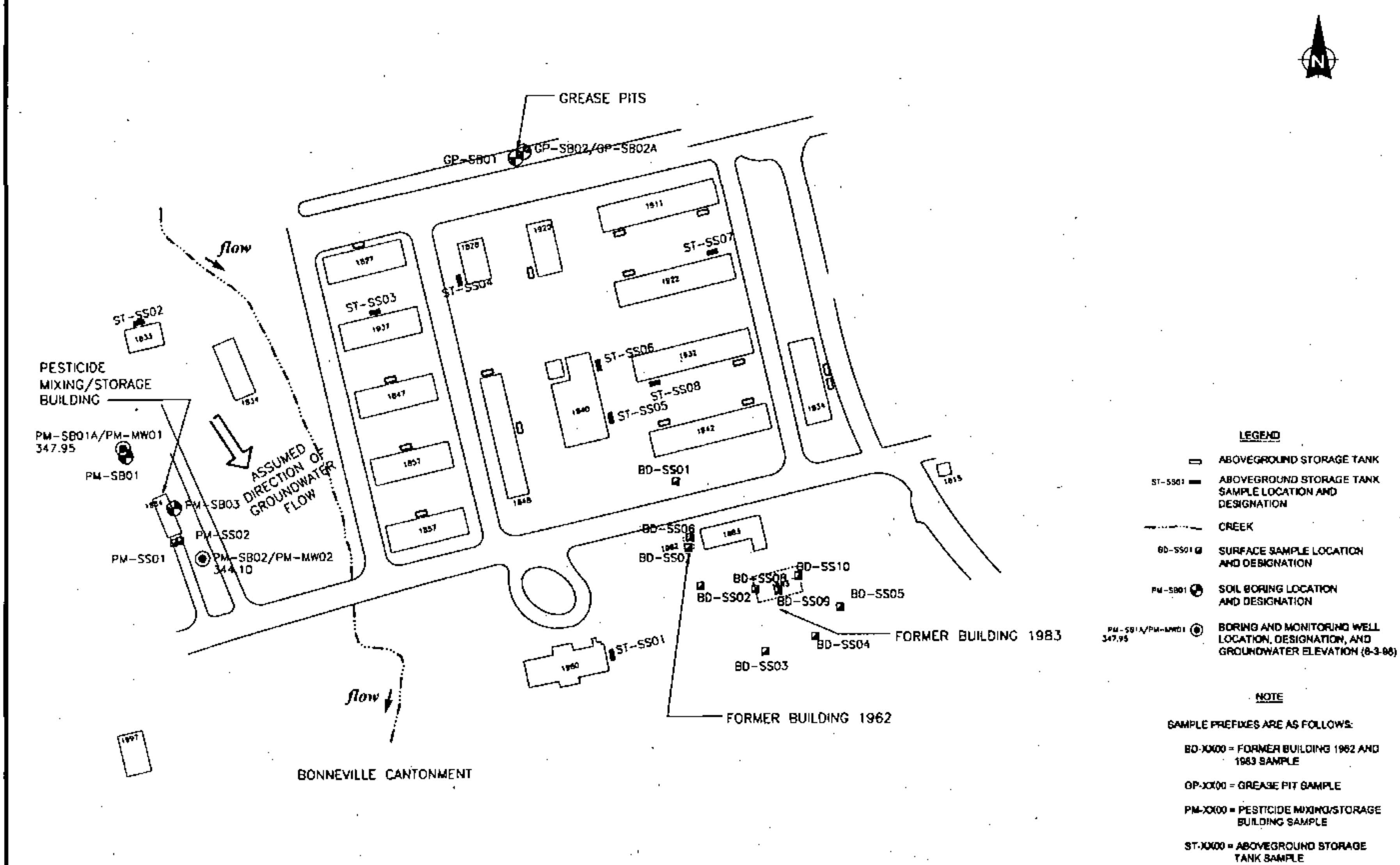
Vancouver, Washington

0 150 300
Approximate Scale in Feet

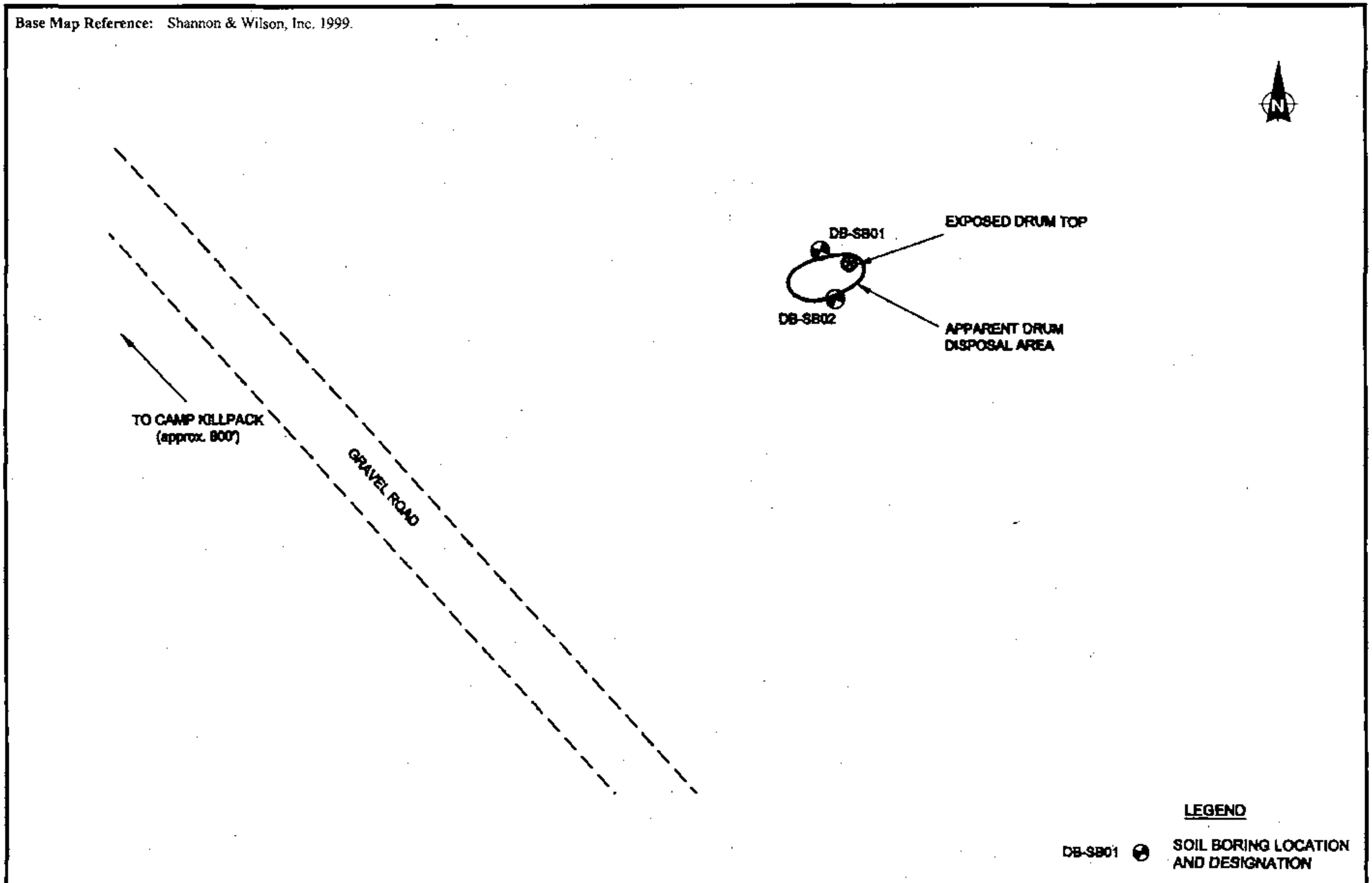
Figure 2-9
LANDFILLS 2 & 3 AND BURN AREA
EXPLORATION PLAN

Date:	Drawn by:	
2-12-10	AES	10:START-3\09050003\fig 2-9

Base Map Reference: Shannon & Wilson, Inc. 1999.

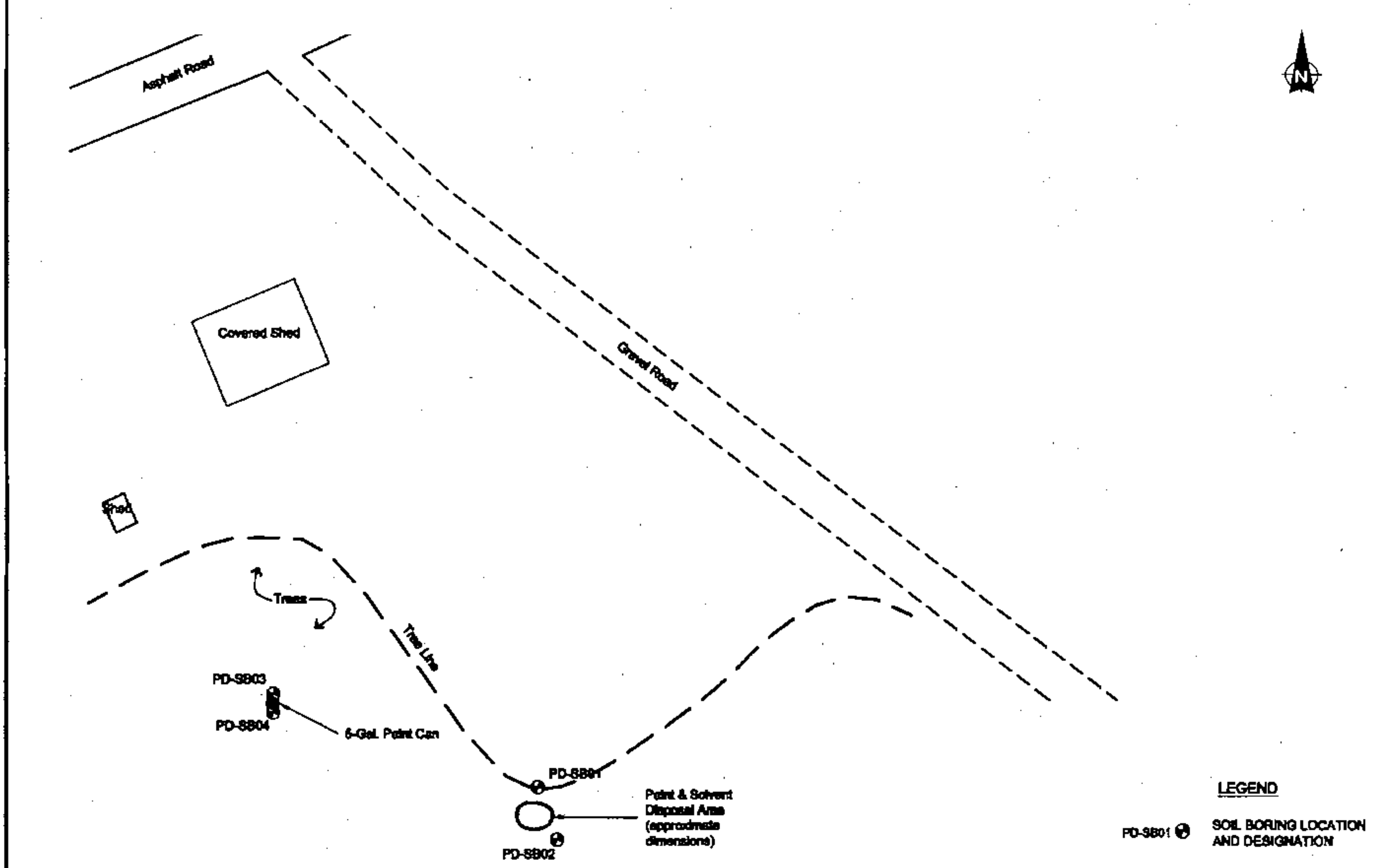


ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-10 BONNEVILLE CANTONMENT AREA EXPLORATION PLAN		
	0 40 80 Approximate Scale in Feet	Date: 2/12/10	Drawn by: AES	10:START-3\09050003\fig 2-10



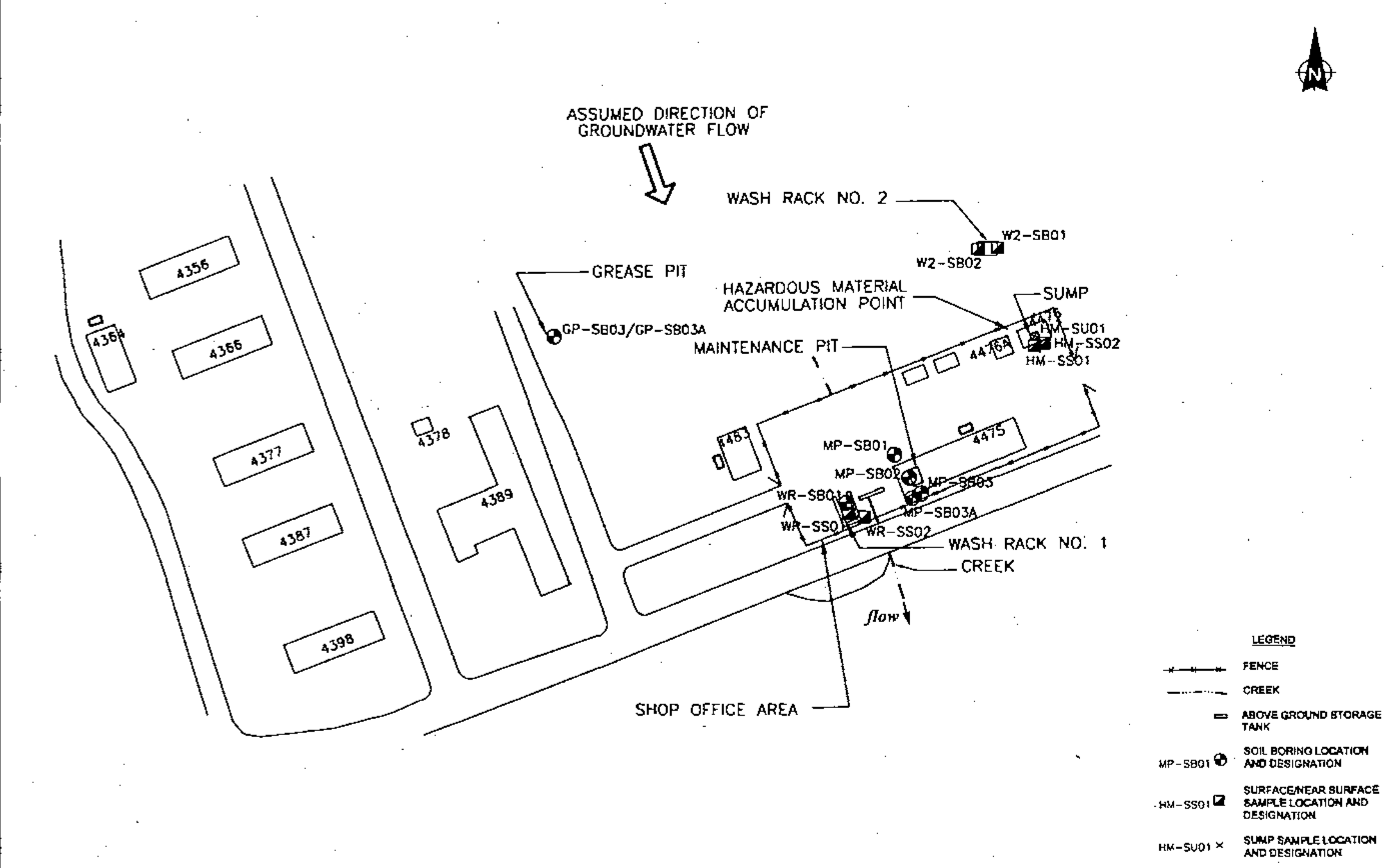
ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-11 DRUM DISPOSAL AREA EXPLORATION PLAN
	0 30 60 Approximate Scale in Feet	Date: 12/10/09 | Drawn by: AES | 10:START-3\09050003\fig 2-11

Base Map Reference: Shannon & Wilson, Inc. 1999.



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-12 PAINT & SOLVENT DISPOSAL AREA EXPLORATION PLAN
	Approximate Scale in Feet	Date: 12/10/09 | Drawn by: AES | 10:START-3\09050003\fig 2-12

Base Map Reference: Shannon & Wilson, Inc. 1999.



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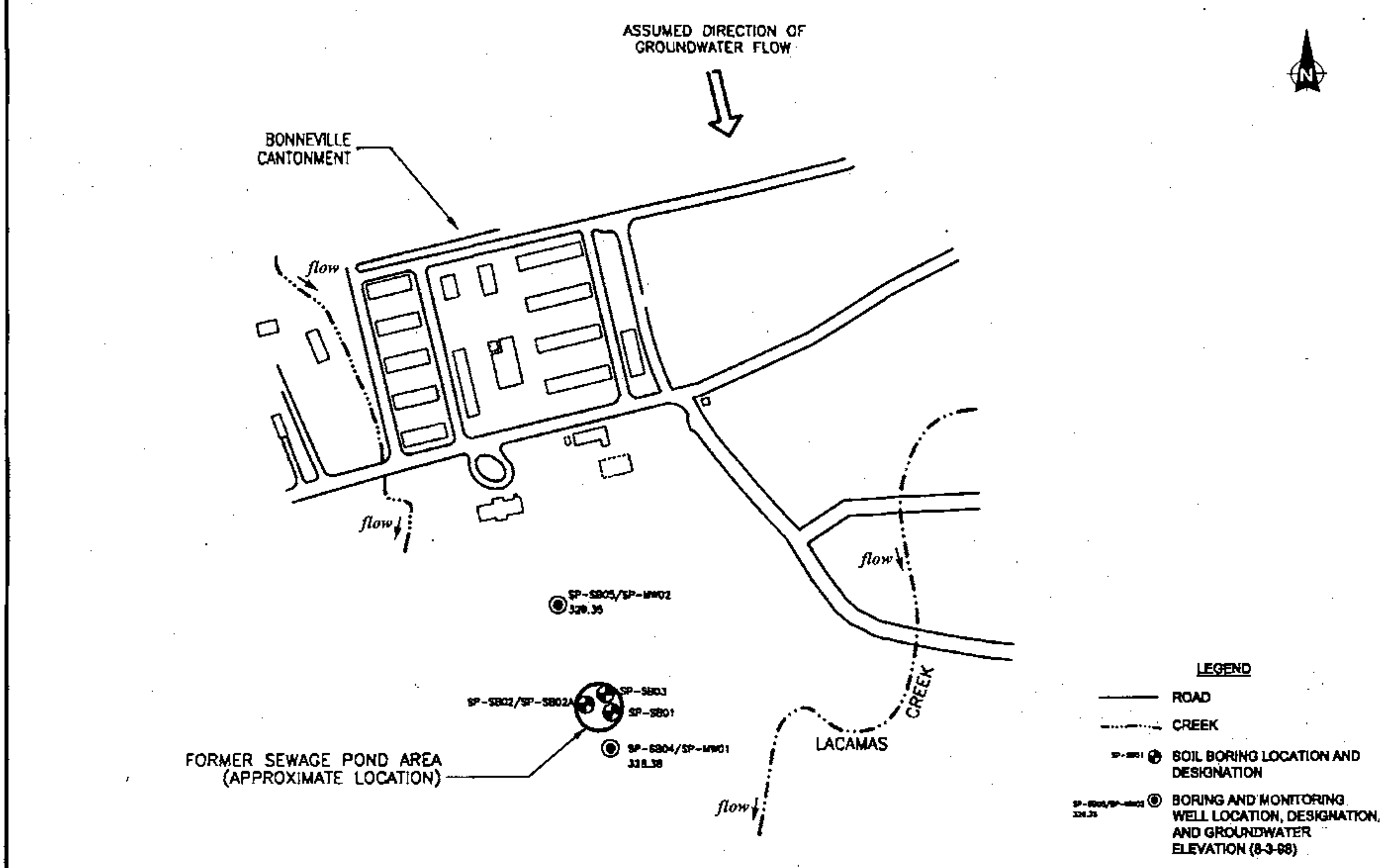
0 80 160
Approximate Scale in Feet

Figure 2-13
KILLPACK CANTONMENT AREA
EXPLORATION PLAN

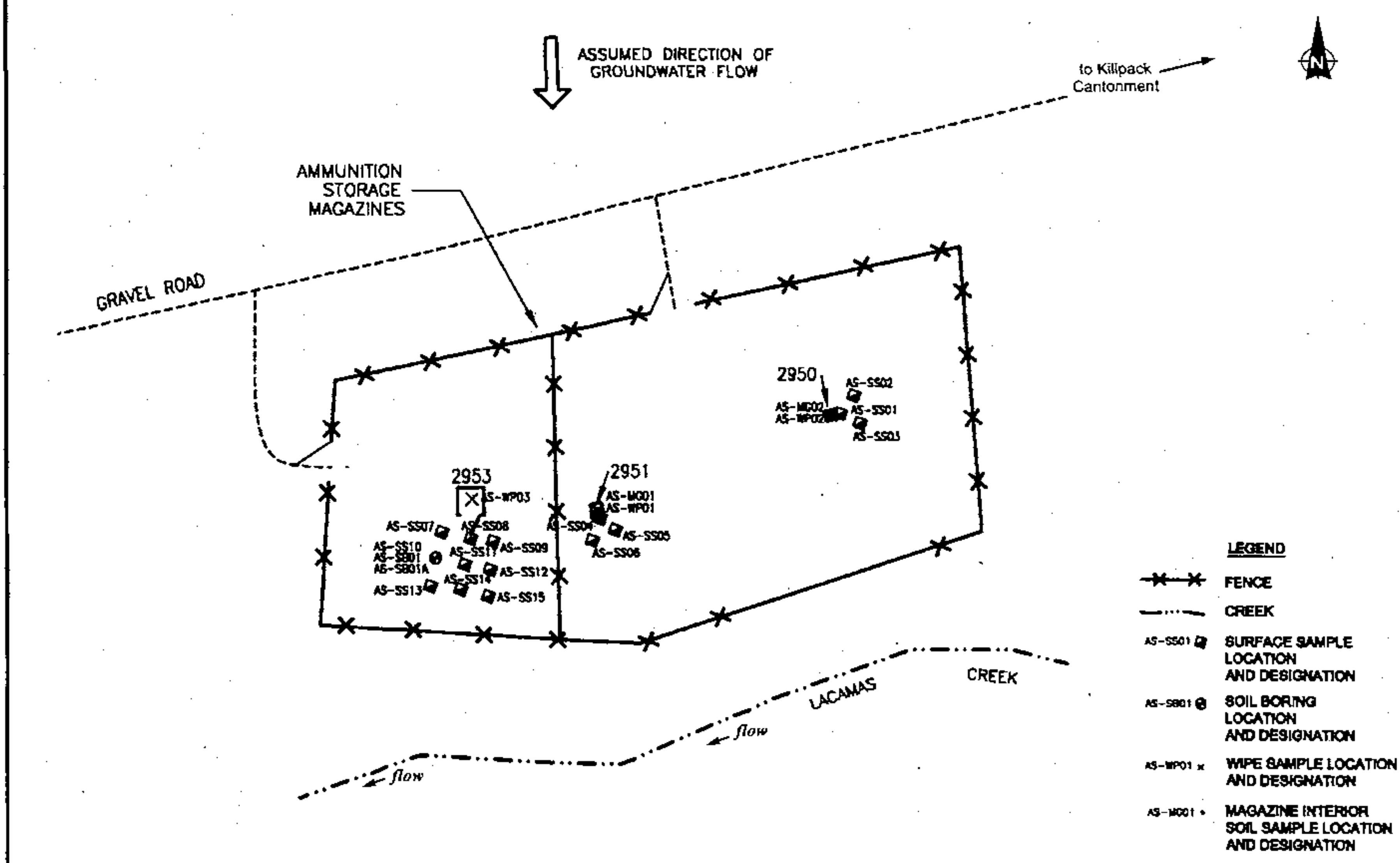
Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-13

Base Map Reference: Shannon & Wilson, Inc. 1999.



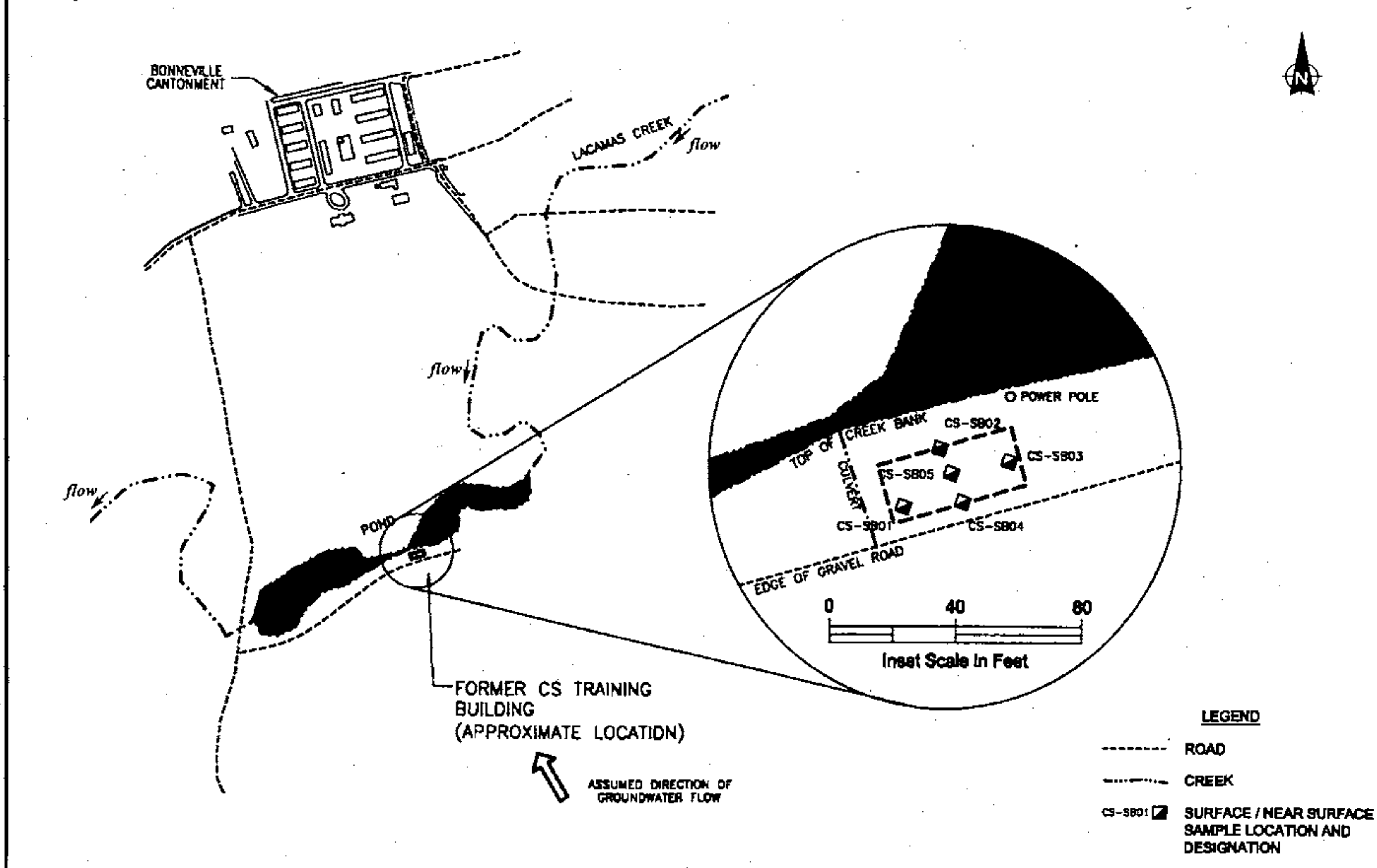
ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-14 FORMER SEWAGE POND EXPLORATION PLAN
	0 200 400 Approximate Scale in Feet	Date: 2/12/10 · Drawn by: AES · 10:START-3\09050003\fig 2-14

Base Map Reference: Shannon & Wilson, Inc. 1999.



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-15 AMMUNITION STORAGE MAGAZINES EXPLORATION PLAN		
	0 50 100 Approximate Scale in Feet	Date: 2/16/10	Drawn by: AES	10:START-3\09050003\fig 2-15

Base Map Reference: Shannon & Wilson, Inc. 1999.



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-16 CS TRAINING BUILDING AREA EXPLORATION PLAN		
	0 400 800 Approximate Scale in Feet	Date: 2/12/10	Drawn by: AES	10:START-3\09050003\fig 2-16

Base Map Reference: Garry Struthers Associates Inc., 2000.

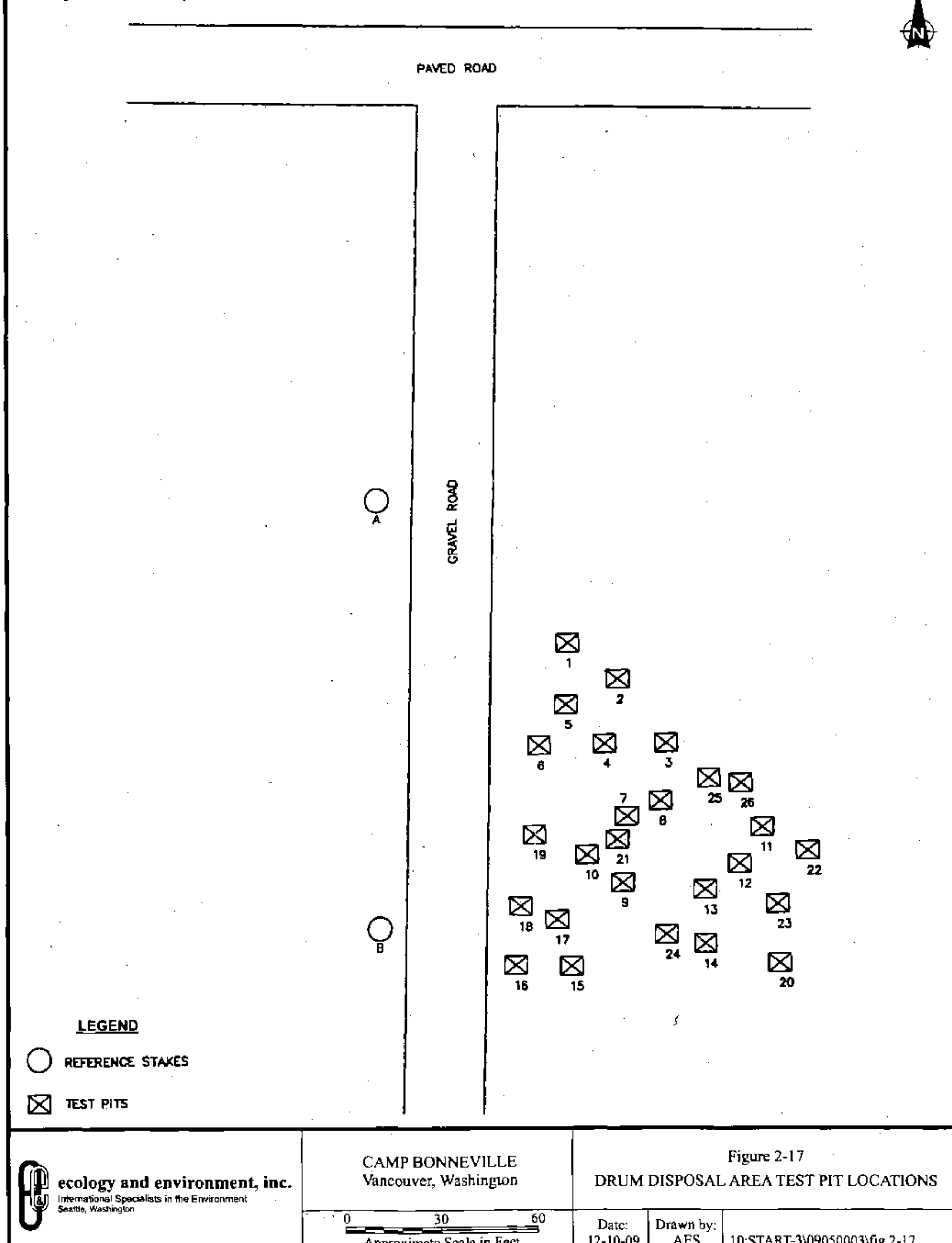


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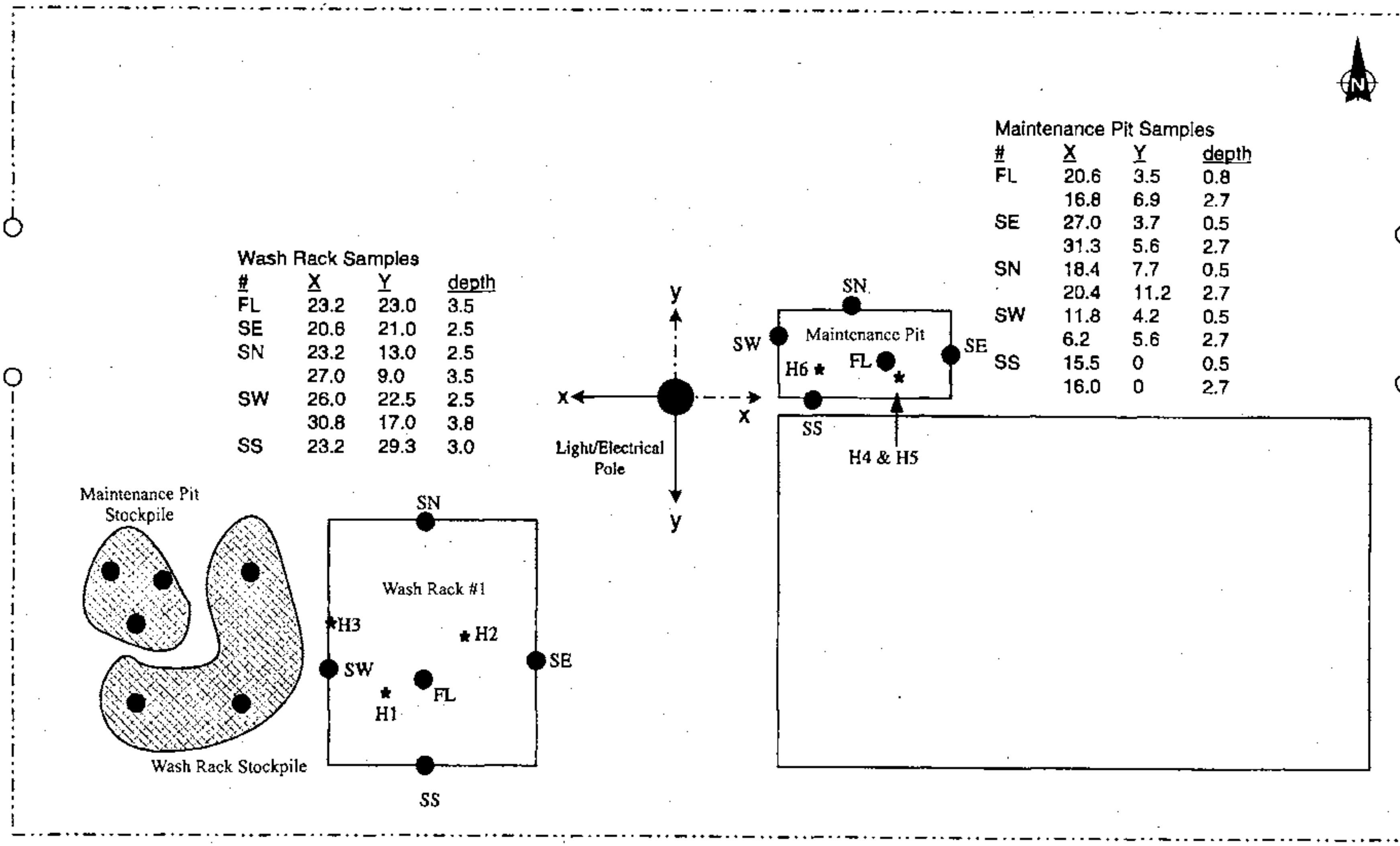
Figure 2-17
DRUM DISPOSAL AREA TEST PIT LOCATIONS

Date:	Drawn by:	
12-10-09	AES	10:START-3\09050003\fig 2-17



Wash Rack Samples

#	X	Y	depth
FL	23.2	23.0	3.5
SE	20.6	21.0	2.5
SN	23.2	13.0	2.5
	27.0	9.0	3.5
SW	26.0	22.5	2.5
	30.8	17.0	3.8
SS	23.2	29.3	3.0

Maintenance Pit Samples

#	X	Y	depth
FL	20.6	3.5	0.8
	16.8	6.9	2.7
SE	27.0	3.7	0.5
	31.3	5.6	2.7
SN	18.4	7.7	0.5
	20.4	11.2	2.7
SW	11.8	4.2	0.5
	6.2	5.6	2.7
SS	15.5	0	0.5
	16.0	0	2.7

All dimensions in feet and tenths of feet.
Depths are feet below ground surface (bgs).

● Sample Location
* Hanby Location

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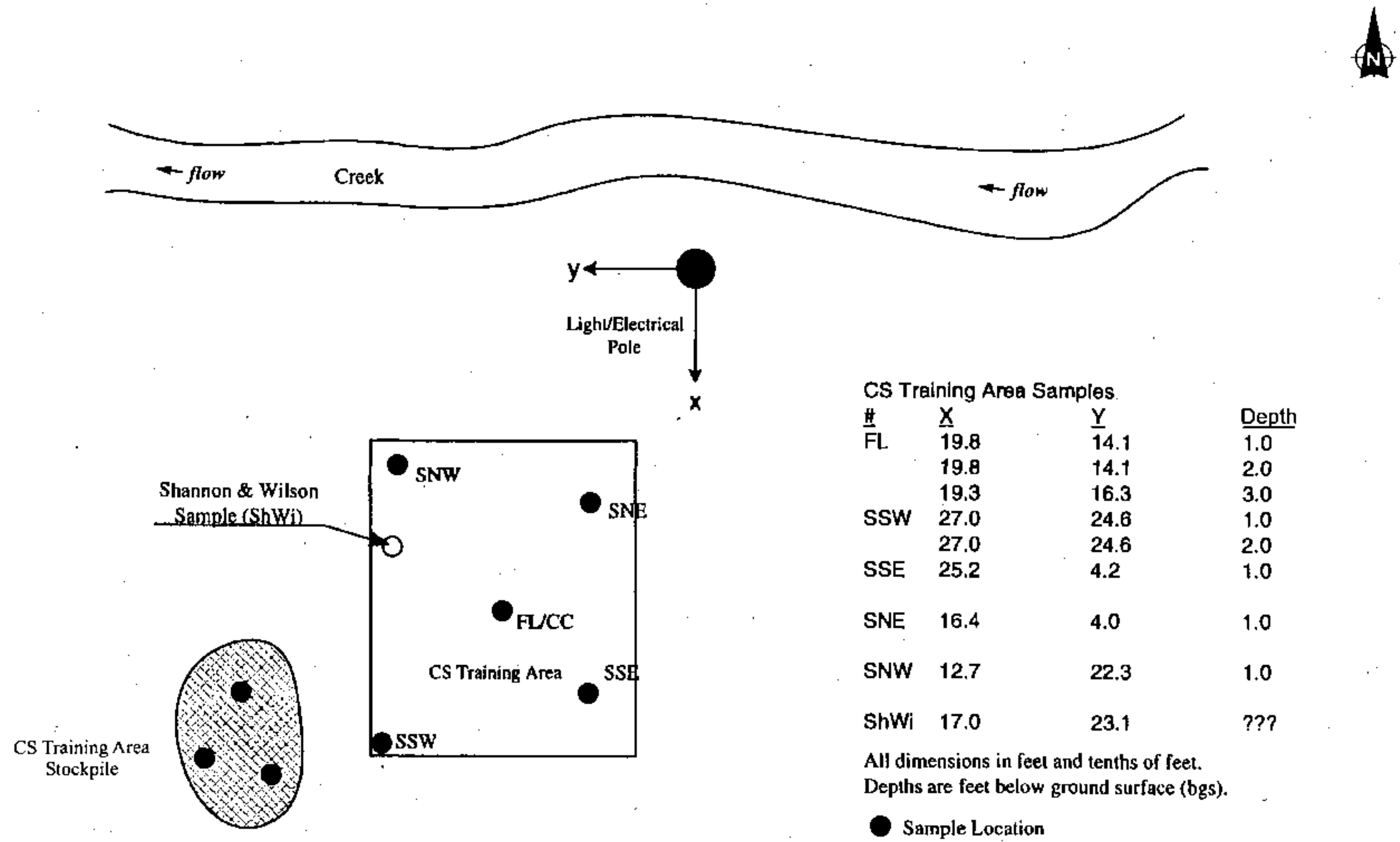
Figure 2-18
WASH RACK AND MAINTENANCE PIT SAMPLE LOCATIONS

Base Map Reference: Garry Struthers Associates Inc., 2000.

Date: 12/17/09

Drawn by: AES

10:START-3\09050003\fig 2-18



CS Training Area Samples

#	X	Y	Depth
FL	19.8	14.1	1.0
	19.8	14.1	2.0
	19.3	16.3	3.0
SSW	27.0	24.6	1.0
	27.0	24.6	2.0
SSE	25.2	4.2	1.0
SNE	16.4	4.0	1.0
SNW	12.7	22.3	1.0
ShWi	17.0	23.1	???

All dimensions in feet and tenths of feet.
Depths are feet below ground surface (bgs).

● Sample Location

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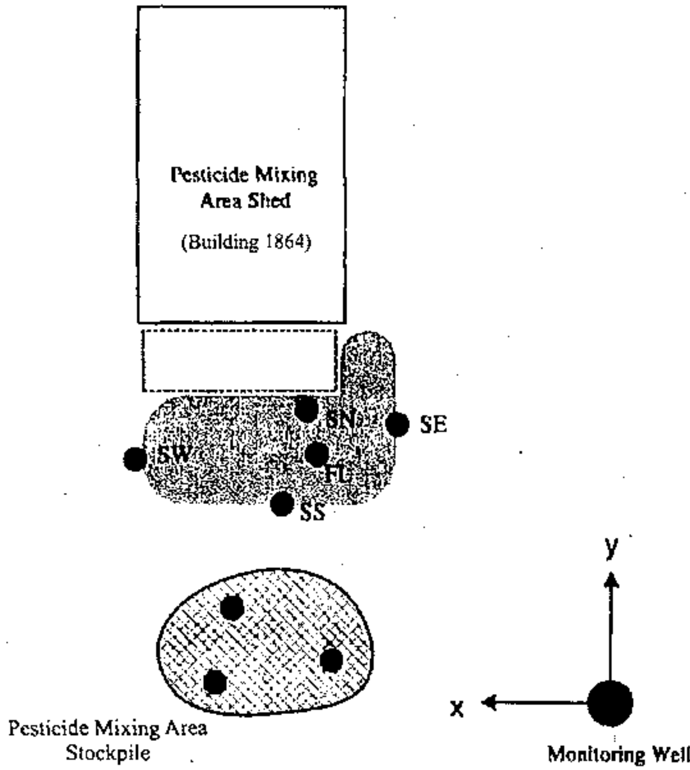
Vancouver, Washington

Base Map Reference: Garry Struthers Associates Inc., 2000.

Figure 2-19
CS TRAINING AREA
SAMPLE LOCATIONS

Date: 2/12/10
Drawn by: AES
10:START-3\09050003\fig 2-19



Pesticide Mixing Area Samples

#	X	Y	Depth
FL	10.3	20.1	2.5
SN	10.7	20.8	1.5
SE	7.0	20.3	1.5
SS	12.5	15.1	1.5
	10.0	12.4	2.3
SW	15.9	19.2	1.5

All dimensions in feet and tenths of feet.
Depths are feet below ground surface (bgs).

● Sample Location

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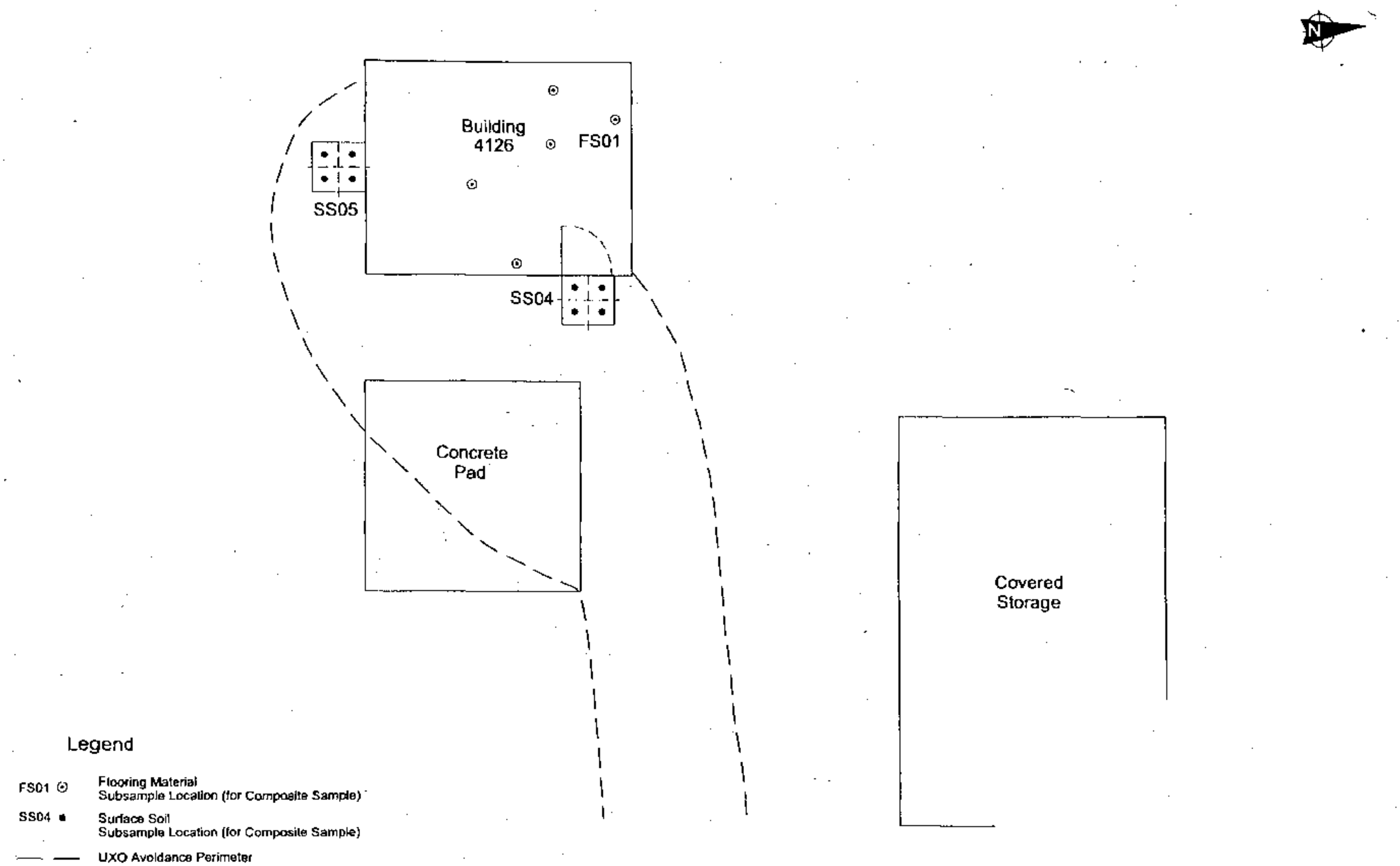
Figure 2-20
PESTICIDE MIXING/STORAGE AREA
SAMPLE LOCATIONS

Base Map Reference: Garry Struthers Associates Inc., 2000.	Date: 12/17/09	Drawn by: AES	10:START-3\09050003\fig 2-20

Base Map Reference: URS 2000.



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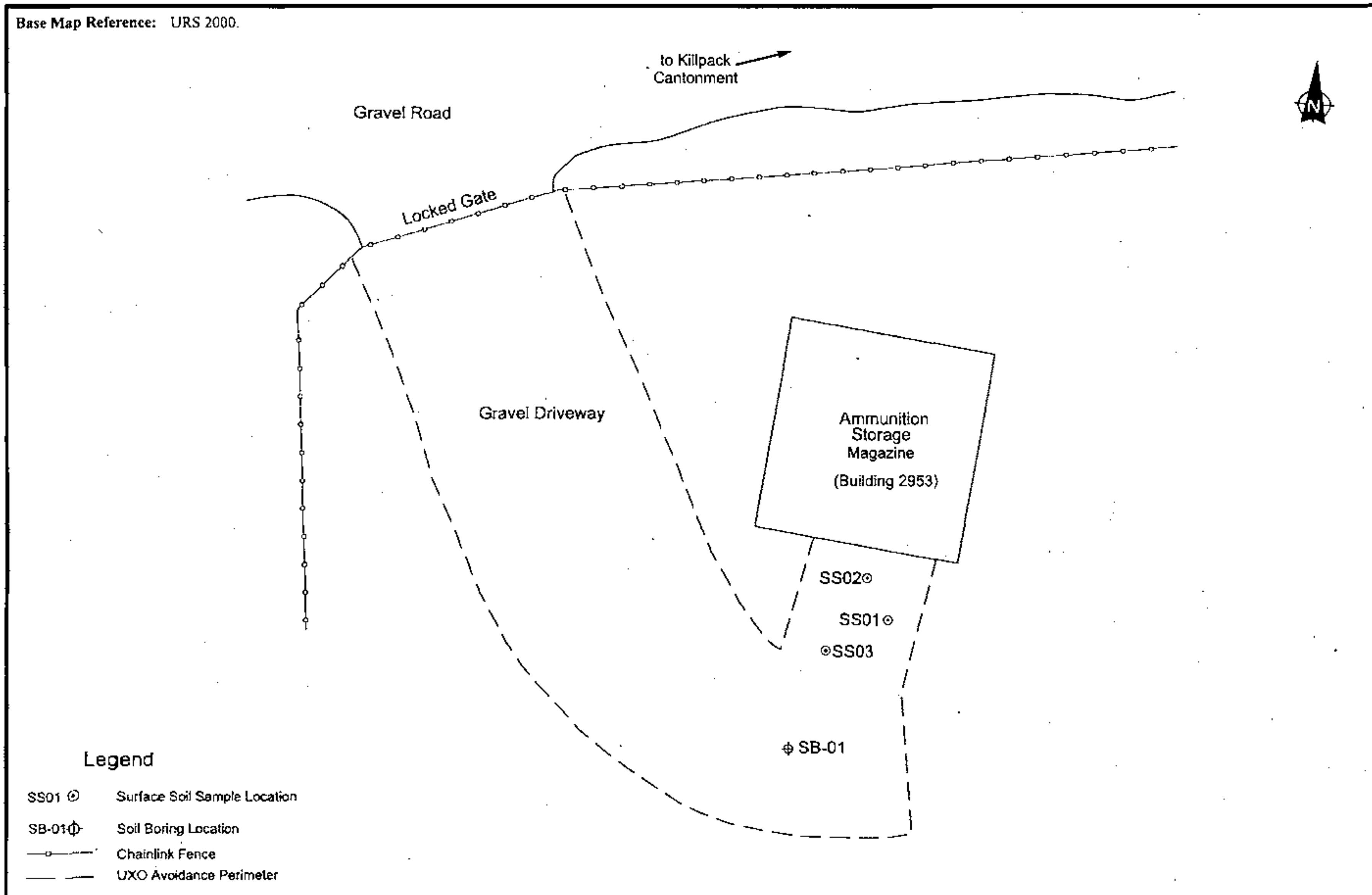
CAMP BONNEVILLE
Vancouver, Washington

0 5 10
Approximate Scale in Feet

Figure 2-21
PESTICIDE STORAGE AREA SAMPLE LOCATIONS

Date: 12/10/09
Drawn by: AES
10:START-3\09050003\fig 2-21



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Vancouver, Washington

0 5 10
Approximate Scale in Feet

Figure 2-22
AMMUNITION STORAGE MAGAZINES
SAMPLE LOCATIONS

Date:	Drawn by:	
12/17/09	AES	10:START-3\09050003\fig 2-22

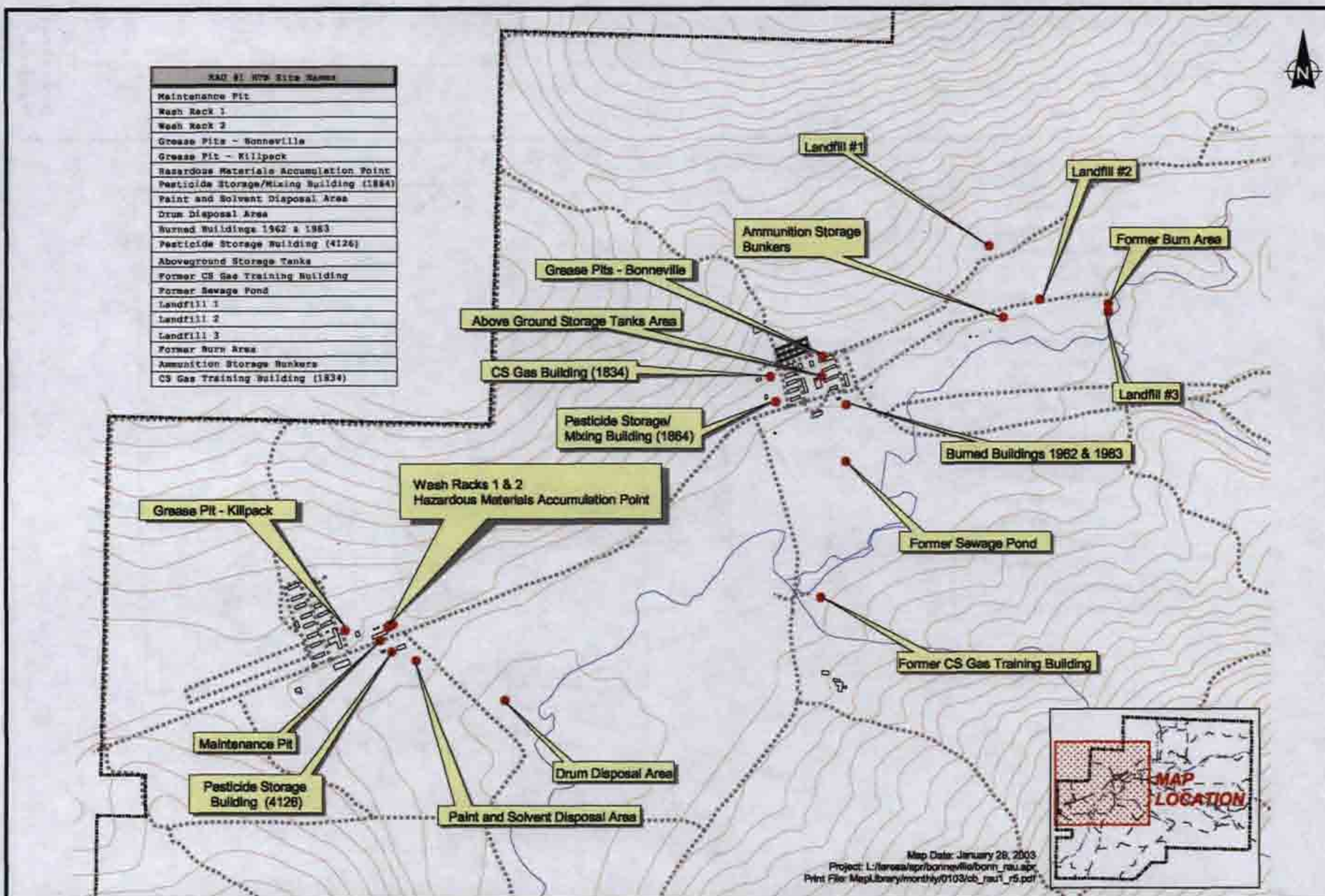

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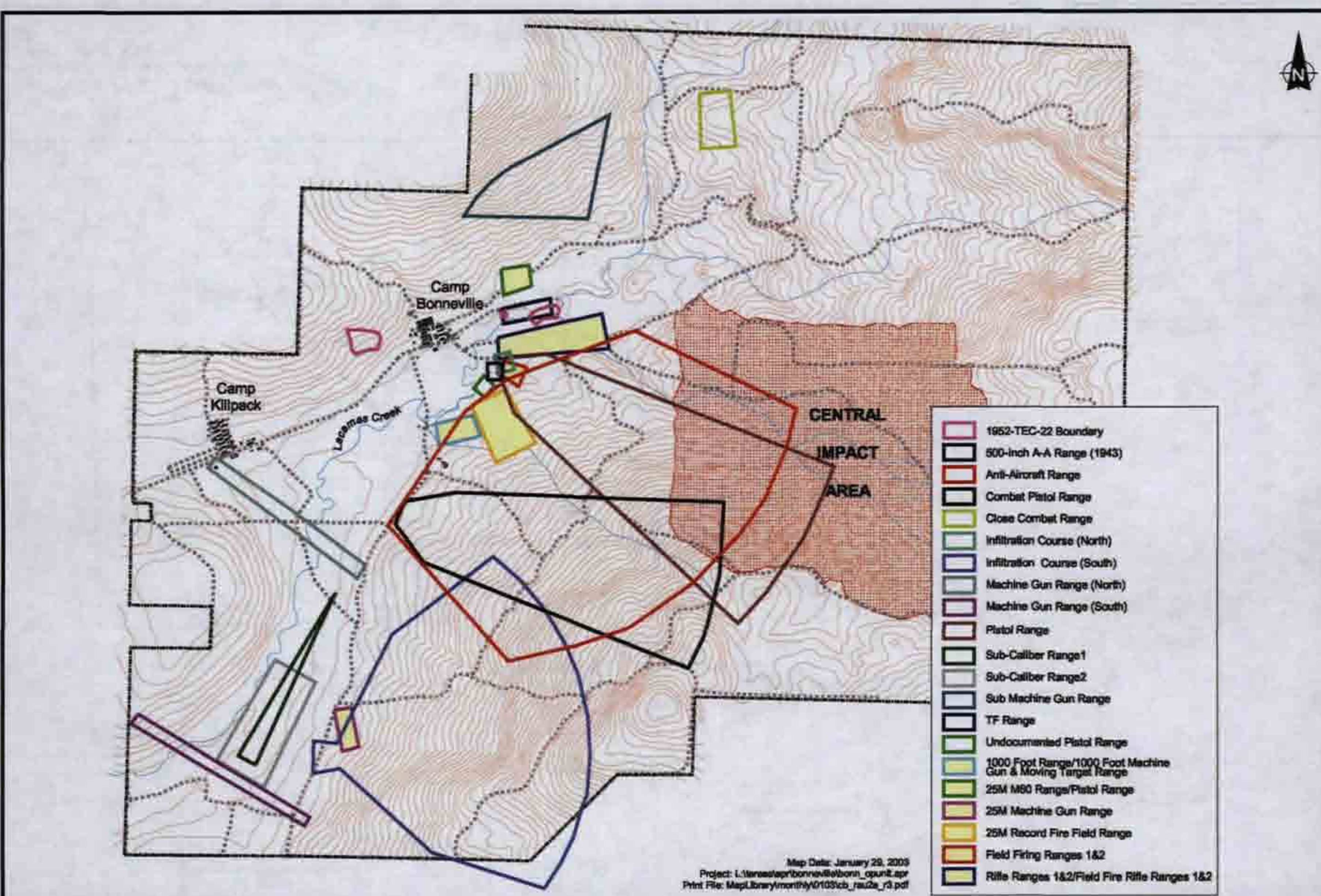
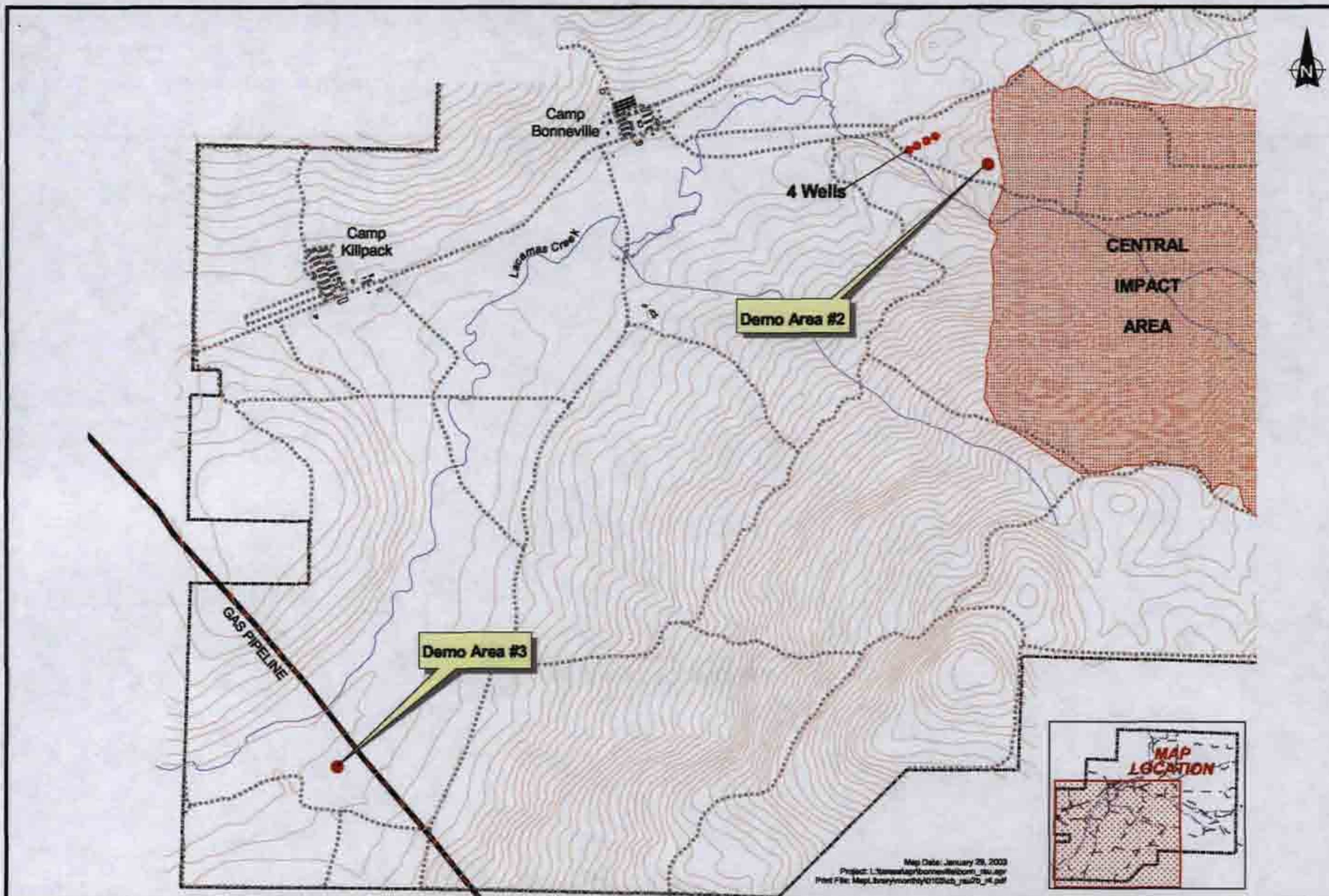
Figure 2-23
REMEDIAL ACTION UNIT #1

Base Map Reference: WADOE, 2003.

Date:	Drawn by:	
12/18/09	AES	10:START-3\09050003\fig 2-23



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-24 REMEDIAL ACTION UNIT #2A
	Base Map Reference: WADOE, 2003.	Date: 12/18/09 · Drawn by: AES · 10:START-3\09050003\fig 2-24



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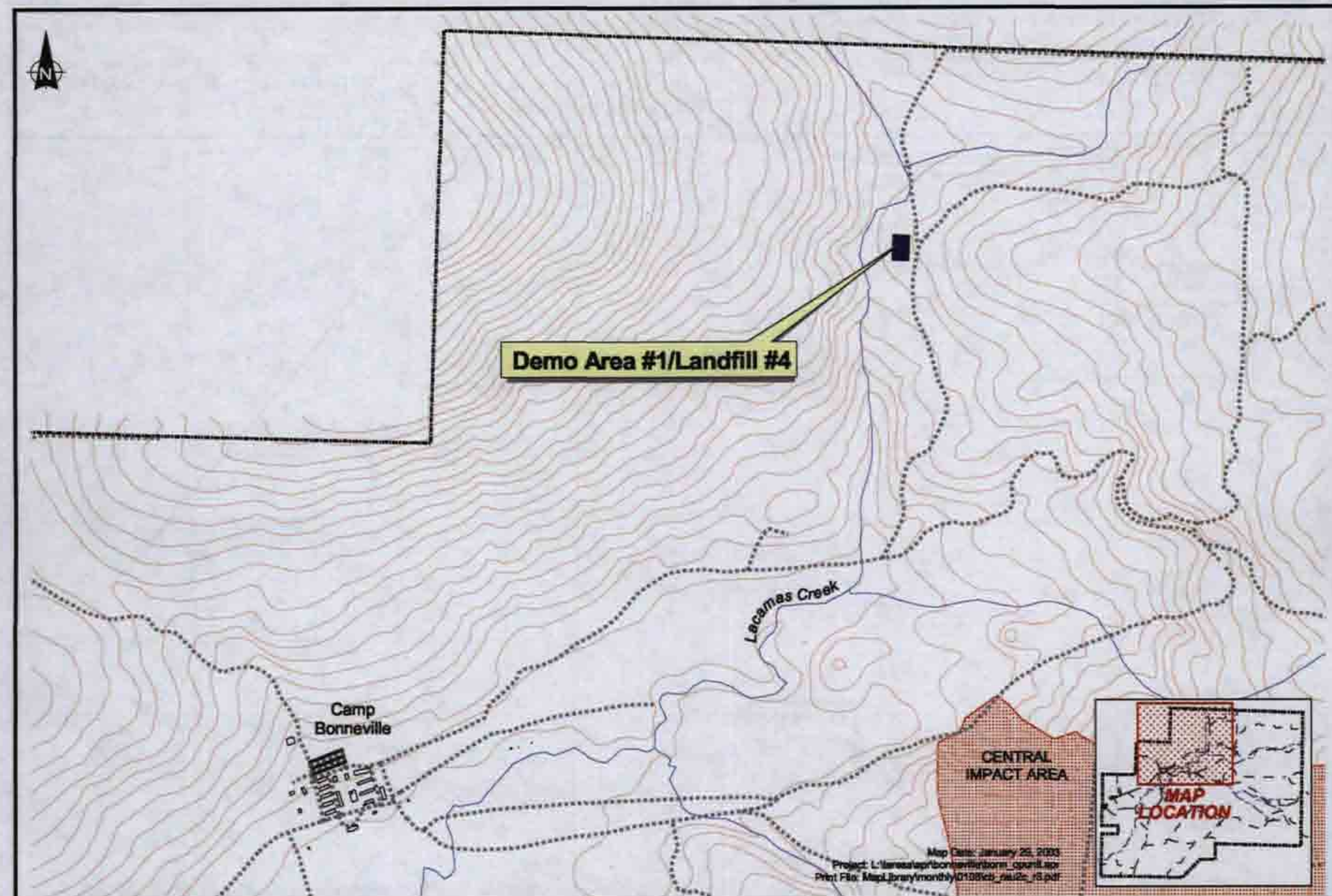
CAMP BONNEVILLE
Vancouver, Washington

Base Map Reference: WADOE, 2003.

Figure 2-25
REMEDIAL ACTION UNIT #2B

Date:	Drawn by:	
12/18/09	AES	10:START-3\09050003\fig 2-25



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-26 REMEDIAL ACTION UNIT #2C		
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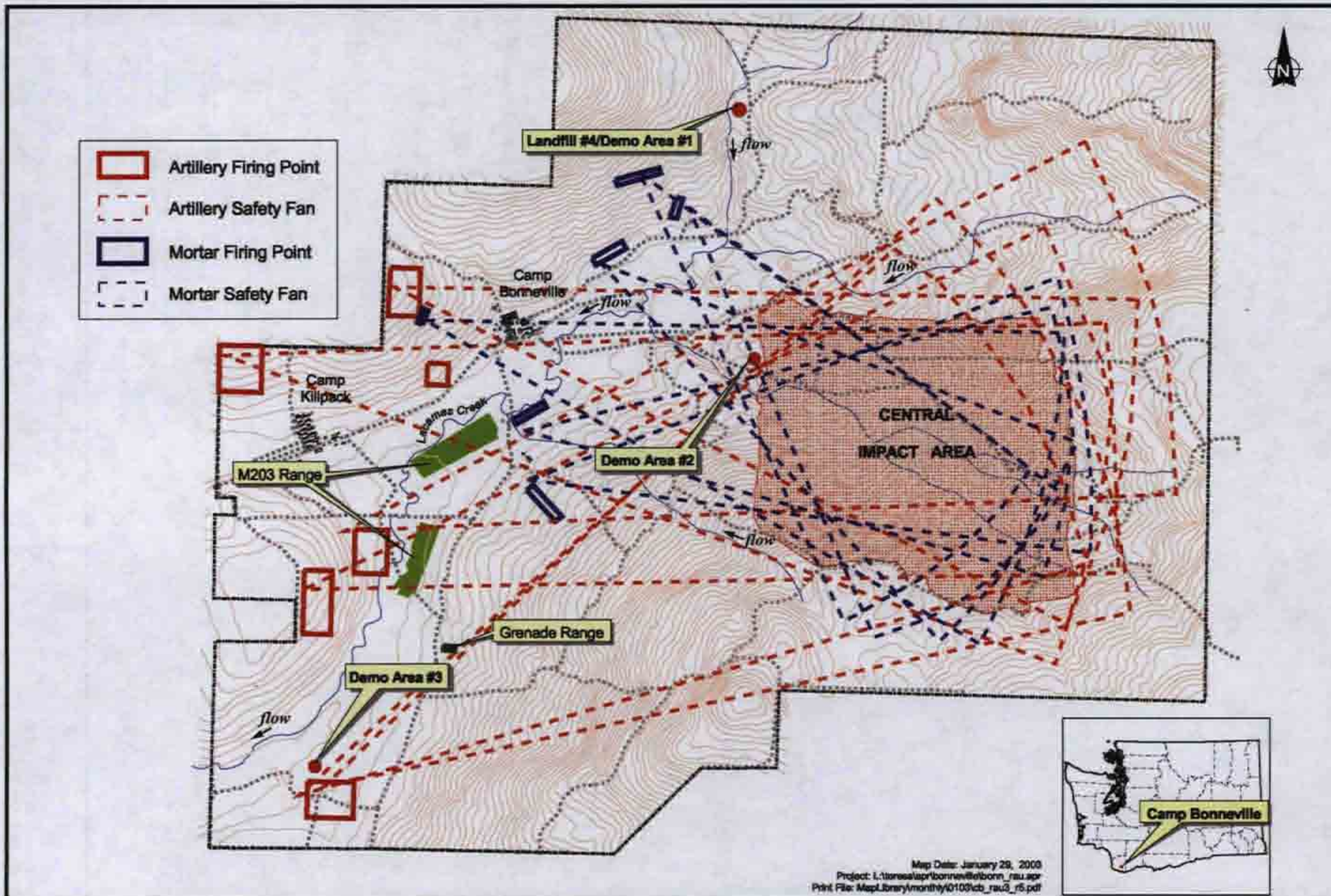
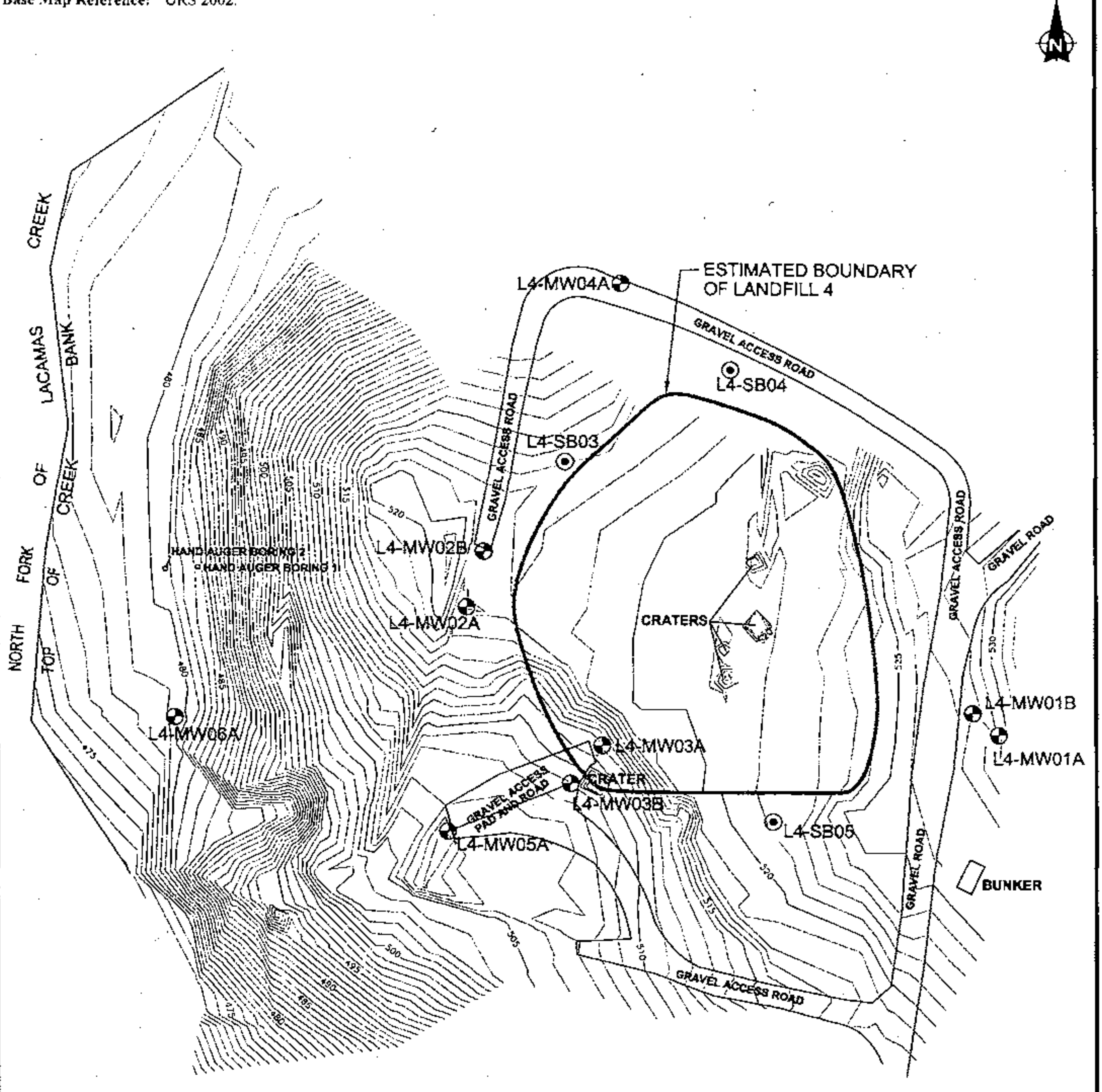


ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

CAMP BONNEVILLE Vancouver, Washington	Figure 2-27 REMEDIAL ACTION UNIT #3			
Base Map Reference: WADOE, 2003.	Date: 2/12/10	Drawn by: AES	10:START-3\09050003\fig 2-27	

Base Map Reference: URS 2002.



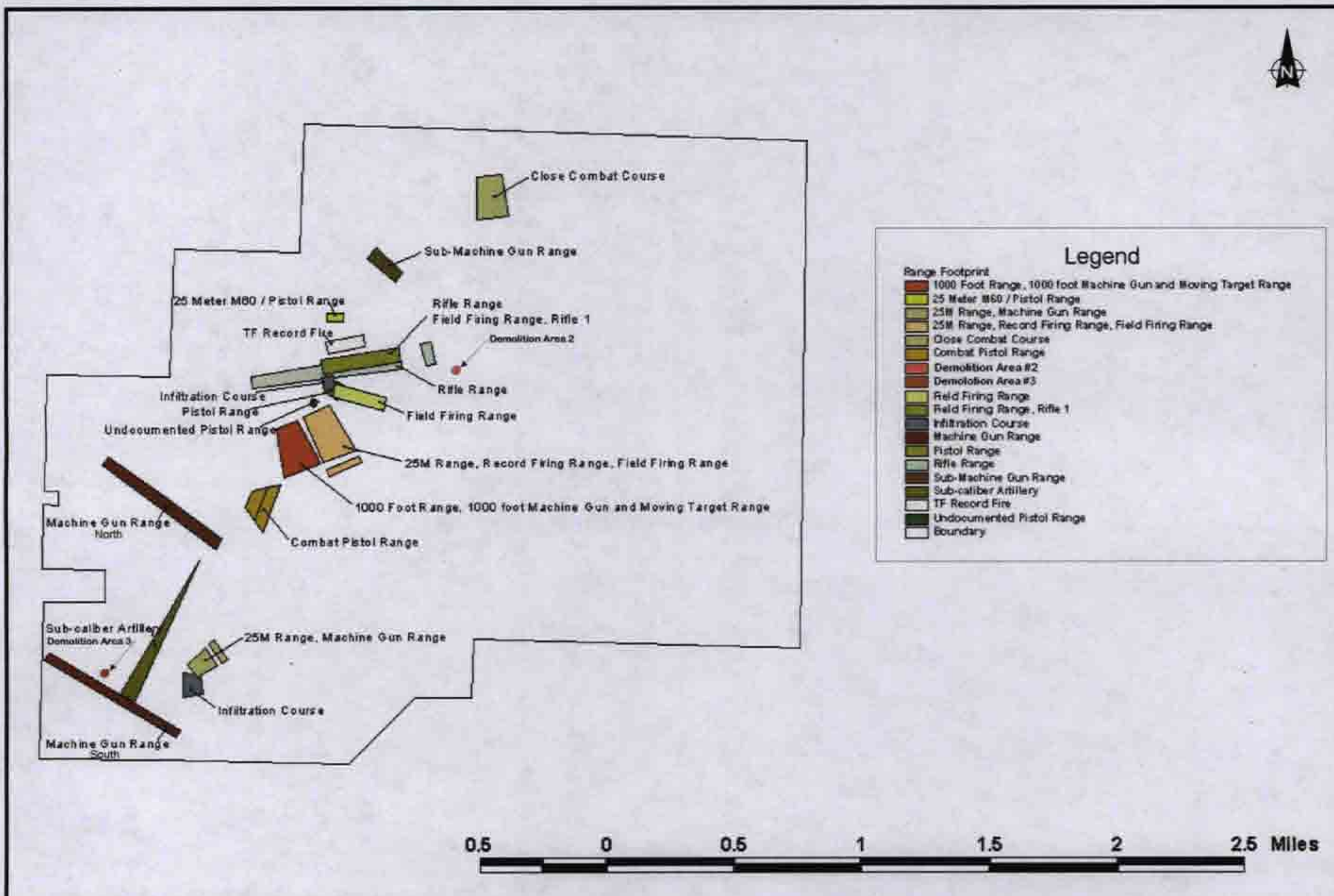
LEGEND

L4-MW04A	MONITORING WELL LOCATION AND DESIGNATION
L4-SB03	SOIL BORING LOCATION AND DESIGNATION

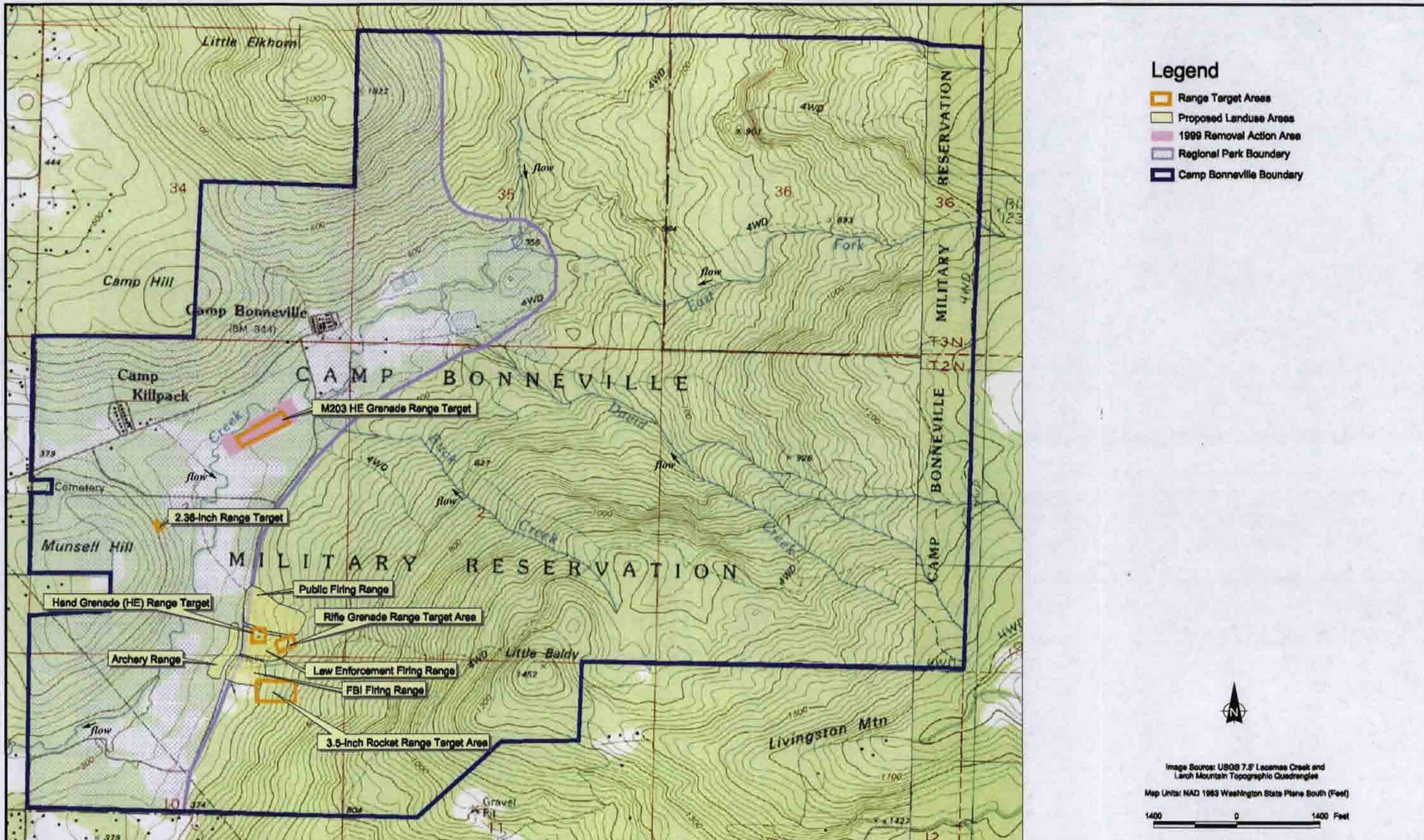
NOTES

1) WELLS L4-MW01A, L4-MW02A AND ALL SOIL BORINGS INSTALLED BY SHANNON & WILSON (1999).
2) TOPOGRAPHY PROVIDED BY OLSEN ENGINEERING
3) WELL L4-MW07B AND SOIL BORING L4-SB07A ARE LOCATED APPROXIMATELY 250 FT SOUTH OF LANDFILL 4

ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-28 LANDFILL 4 – SOIL BORINGS AND MONITORING WELL LOCATIONS		
	0 50 100 Approximate Scale in Feet	Date: 12-17-09	Drawn by: AES	10:START-3\09050003\fig 2-28



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-29 SMALL ARMS RANGE AND DEMOLITION AREAS 2 & 3
	Base Map Reference: Atlanta Environmental Management, Inc., 2003.	Date: 12/18/09 · Drawn by: AES · 10:START-3\09050003\fig 2-29



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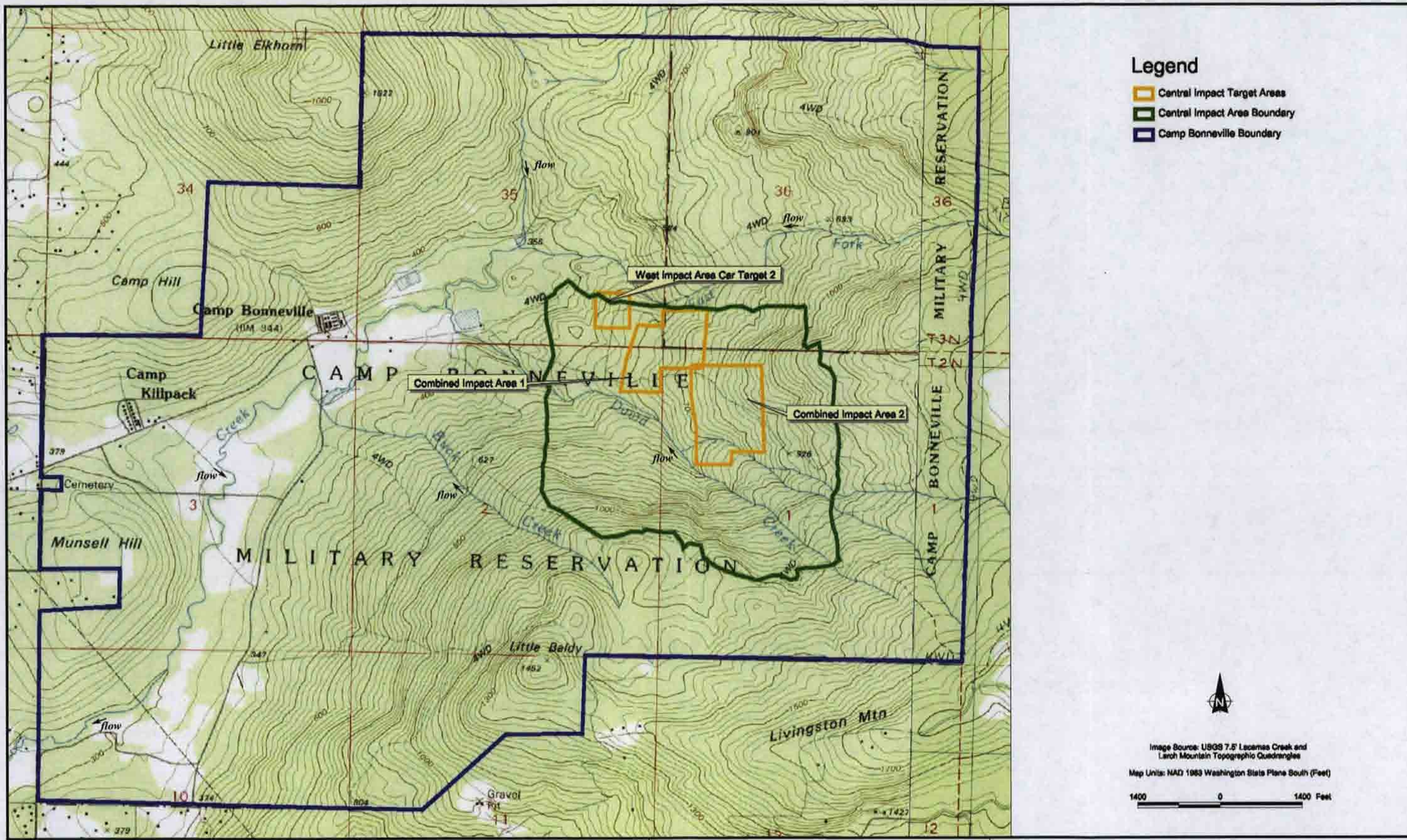
Seattle, Washington

Base Map Reference: Parsons, 2004.

CAMP BONNEVILLE
Vancouver, Washington

Figure 2-30
TARGET AREA LOCATION MAP

Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-30



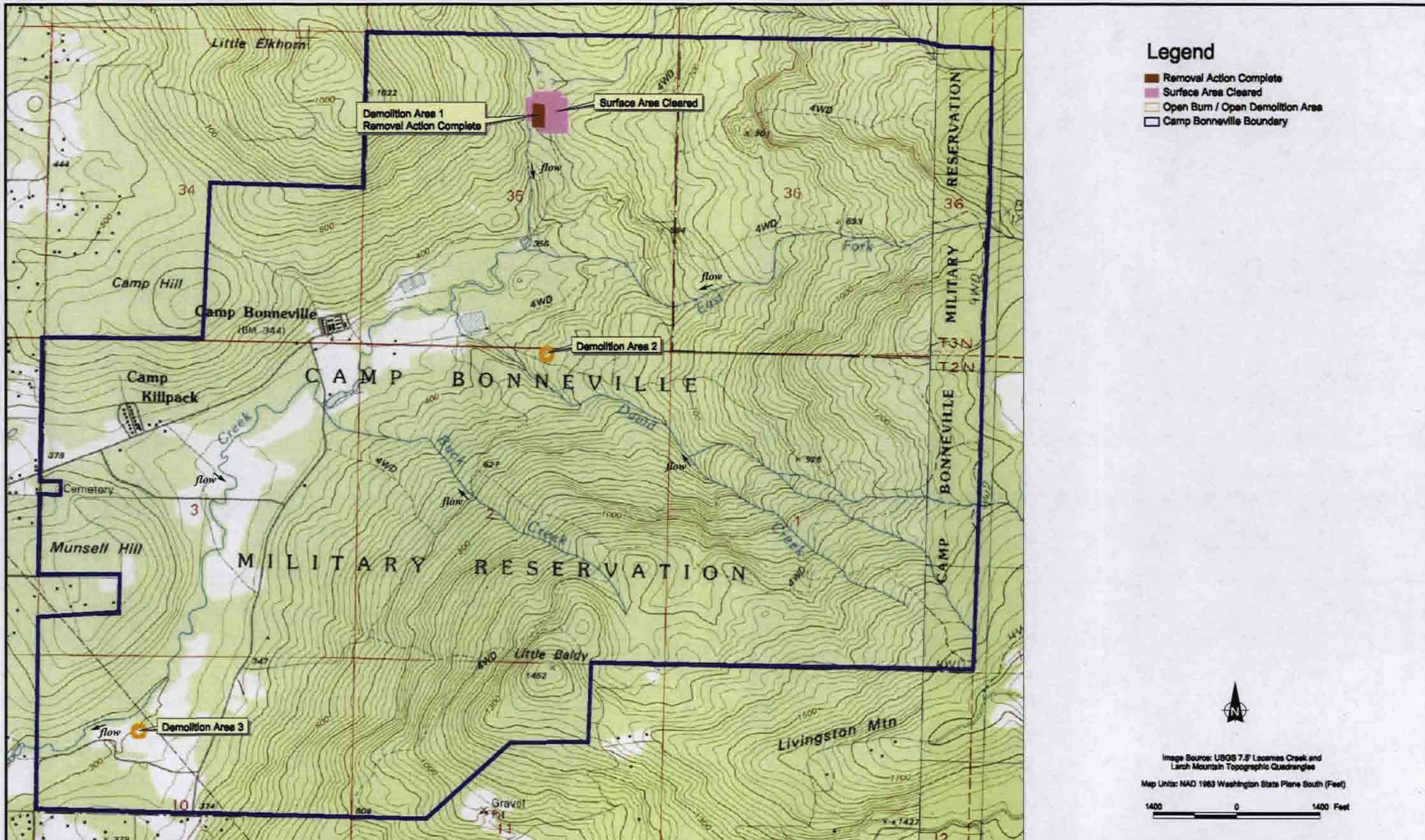
ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

Base Map Reference: Parsons, 2003.

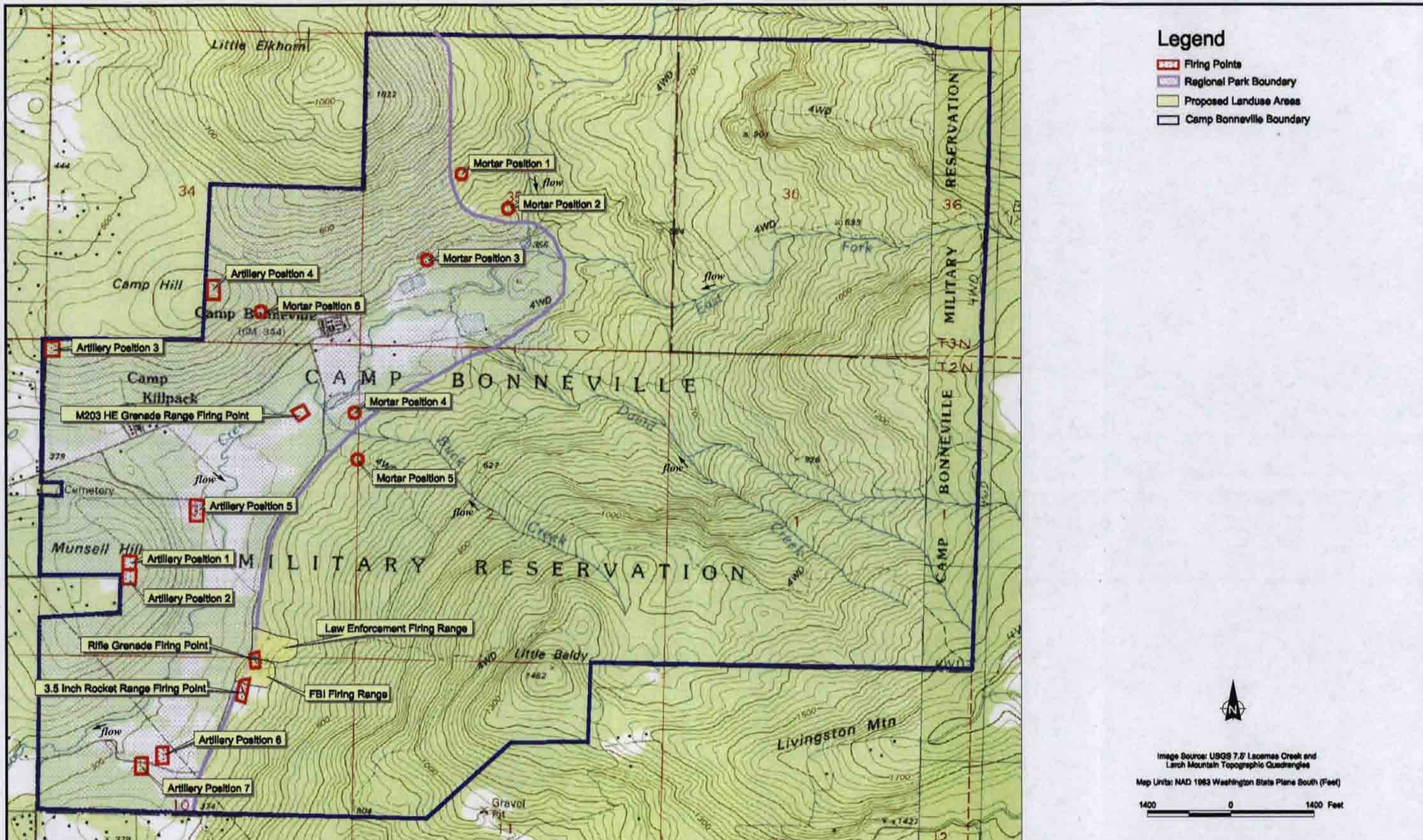
CAMP BONNEVILLE
Vancouver, Washington

Figure 2-31
CENTRAL IMPACT TARGET AREA LOCATION MAP

Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-31



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	**Base Map Reference:** Parsons, 2004.	CAMP BONNEVILLE Vancouver, Washington	Figure 2-32 OPEN BURN/OPEN DEMOLITION AREA LOCATION MAP
			Date: 2/12/10
			Drawn by: AES
			10:START-3\09050003\fig 2-32



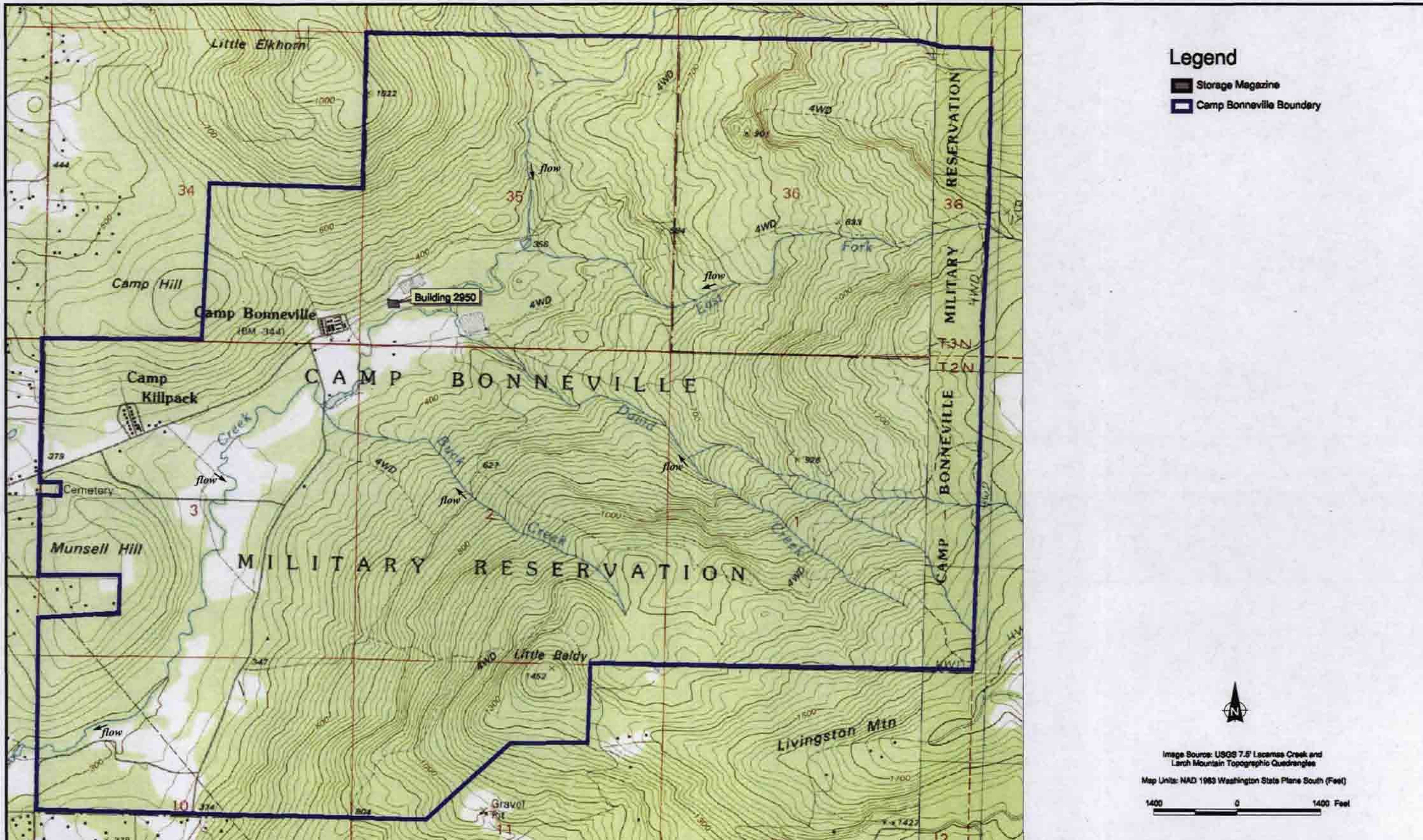
ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

Base Map Reference: Parsons, 2004.

CAMP BONNEVILLE
Vancouver, Washington

Figure 2-33
FIRING POINT LOCATION MAP

Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-33



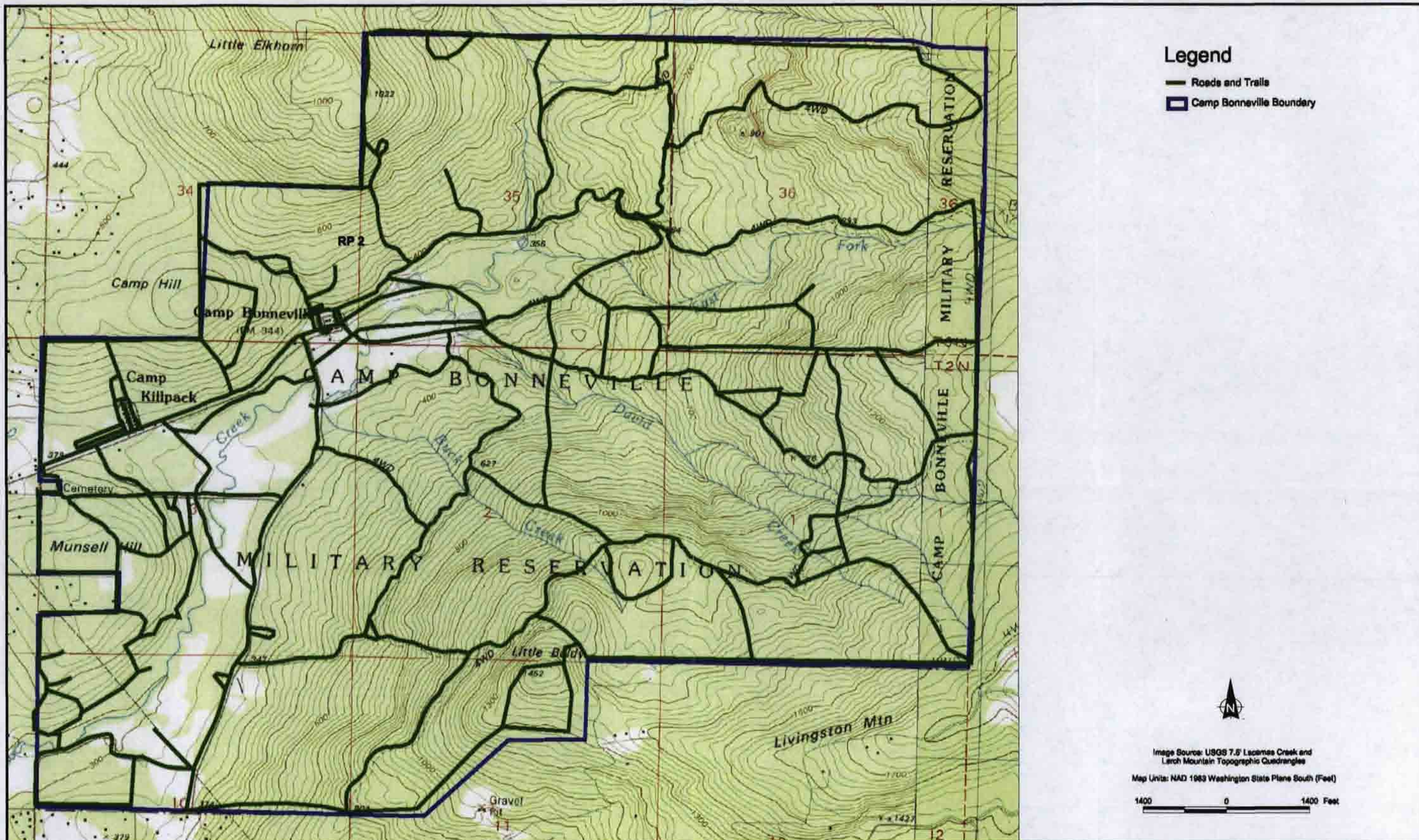
ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

Base Map Reference: Parsons, 2003.

CAMP BONNEVILLE
Vancouver, Washington

Figure 2-34
STORAGE MAGAZINE/TRANSFER POINT LOCATION MAP

Date:	Drawn by:	
2/12/10	AES	10:START-3\09050003\fig 2-34



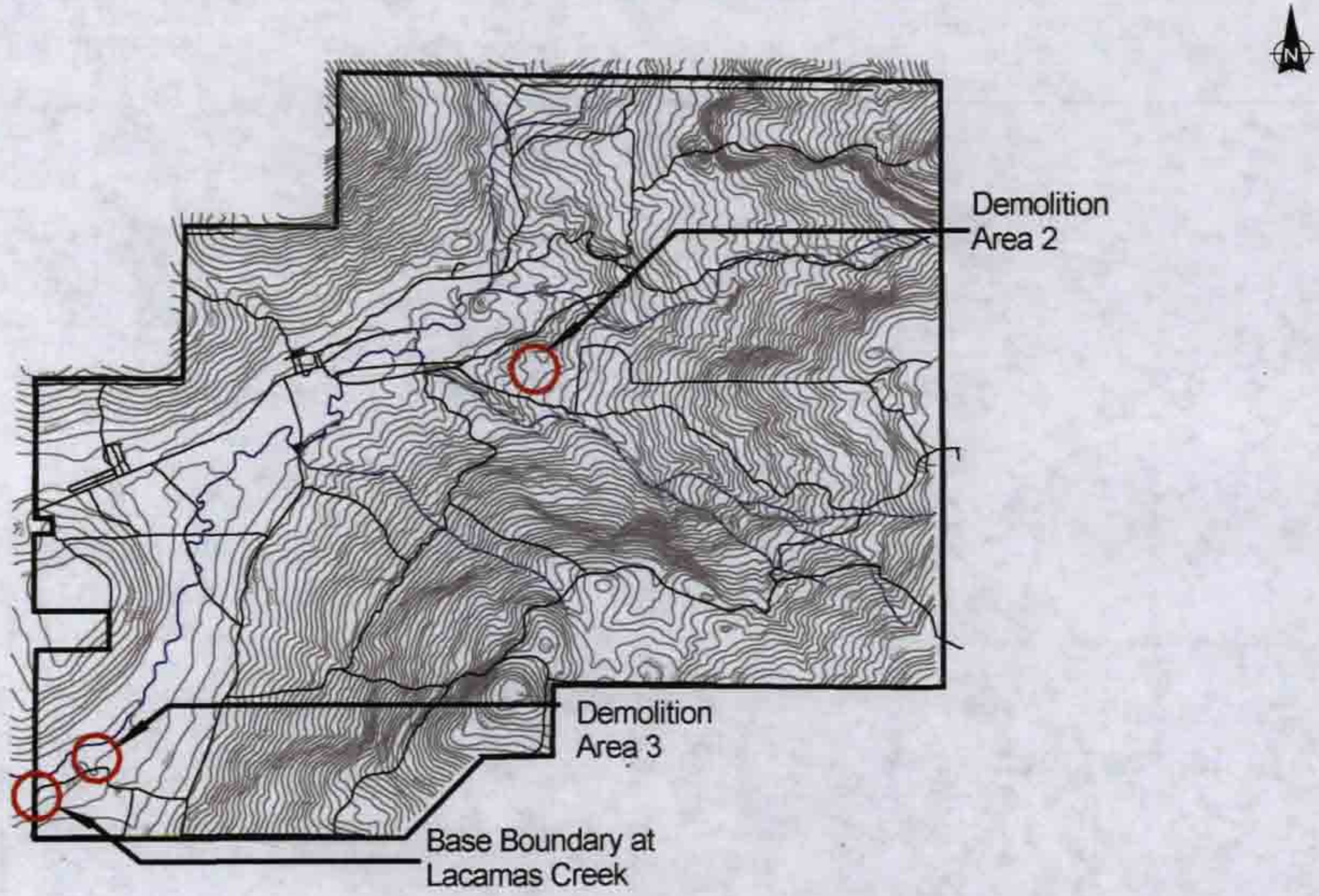
ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

Base Map Reference: Parsons, 2003.

CAMP BONNEVILLE
Vancouver, Washington

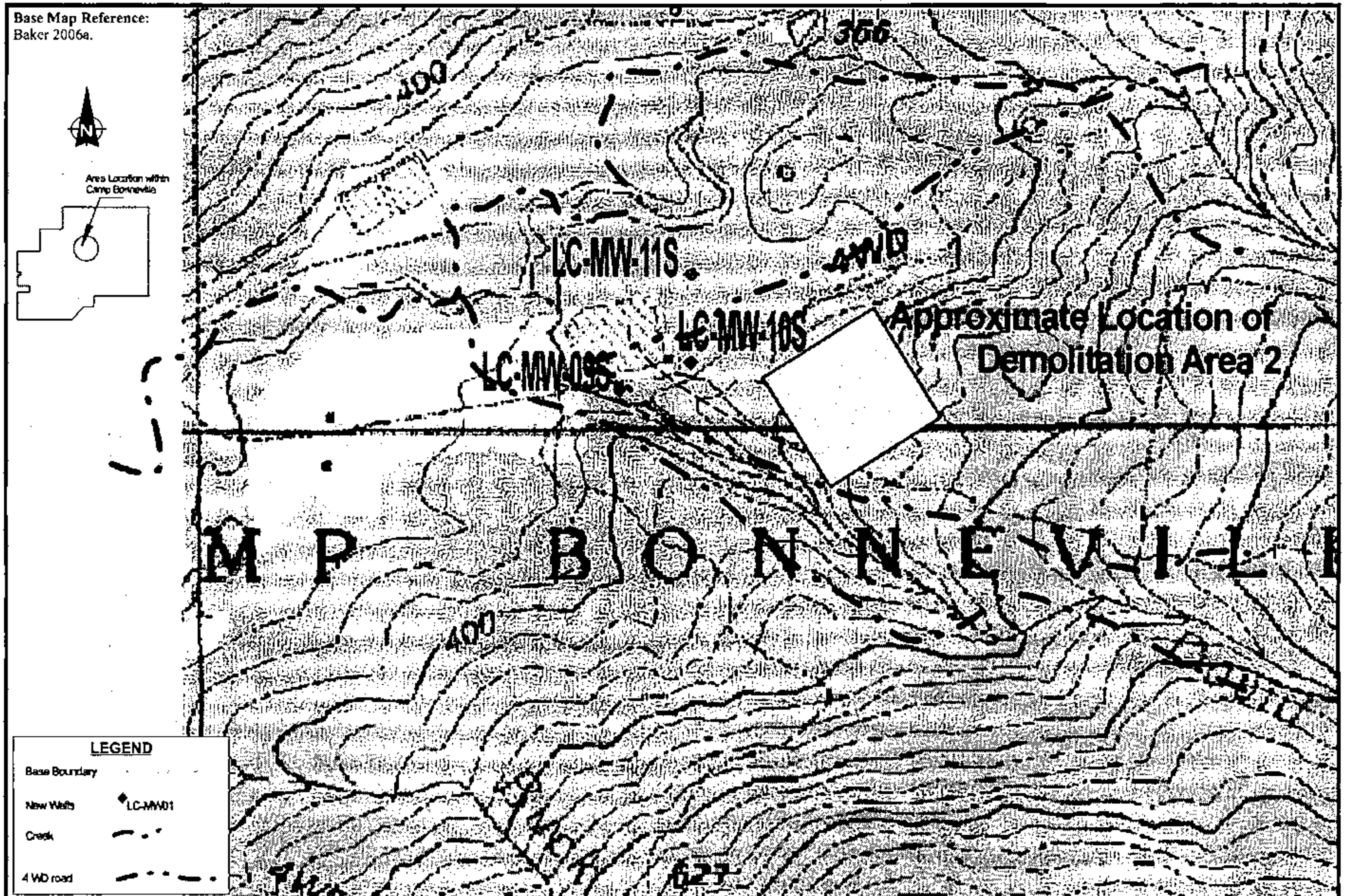
Figure 2-35
ROADS AND TRAILS

Date:	Drawn by:	
12/18/09	AES	10:START-3\09050003\fig 2-35



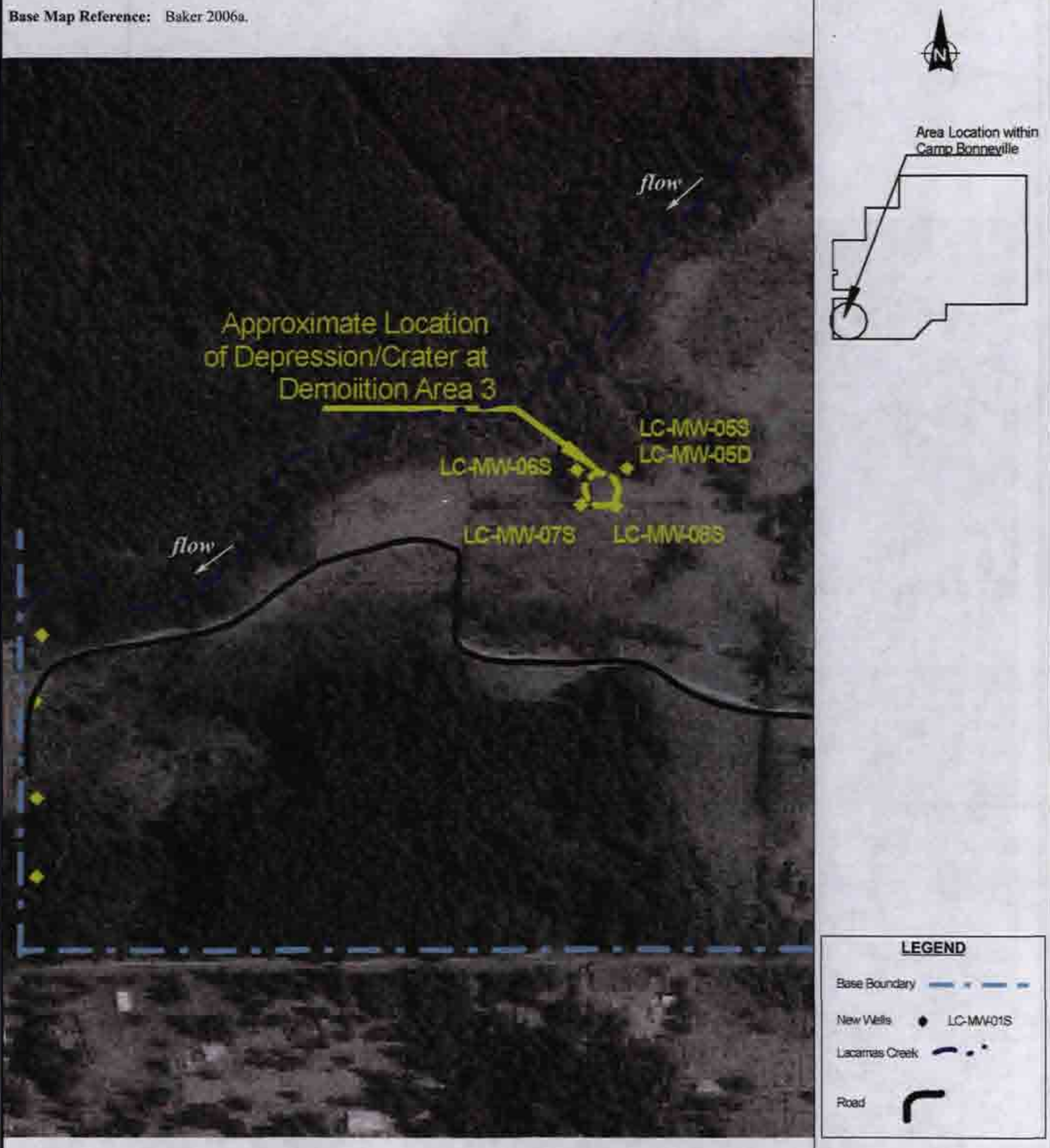
Base Map Reference:
Bonneville Conservation, Restoration & Renewal Team, LLC

ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-36 DEMOLITION AREAS 2 & 3 LOCATION MAP
	0 .5 1 Approximate Scale in Miles	Date: 12/18/09 | Drawn by: AES | 10:START-3\09050003\fig 2-36



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 2-37 DEMOLITION AREA 2 MONITORING WELL LOCATIONS		
	0 500 1,000 Approximate Scale in Feet	Date: 12/17/09	Drawn by: AES	10:START-3\09050003\fig 2-37

Base Map Reference: Baker 2006a.



ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

CAMP BONNEVILLE
Vancouver, Washington

0 250 500
Approximate Scale in Feet

Figure 2-38
DEMOLITION AREA 3
MONITORING WELL LOCATIONS

Date:	Drawn by:	
2-16-10	AES	10:START-3\09050003\fig 2-38

ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

CAMP BONNEVILLE
Vancouver, Washington

0 250 500
Approximate Scale in Feet

Figure 2-39
BOUNDARY WELL LOCATIONS

Date:	Drawn by:	
2/16/10	AES	10:START-3\09050003\fig 2-39

3 Migration/Exposure Pathways

The following sections describe the migration/exposure pathways and potential targets within the site's range of influence (Figures 3-1 and 3-2).

3.1 Ground Water Migration Pathway

The target distance limit (TDL) for the ground water migration pathway is a 4-mile radius that extends from the sources at the site. Figure 3-1 depicts the ground water 4-mile TDL.

3.1.1 Geologic Setting

Camp Bonneville lies within the Willamette Lowland portion of the Willamette Valley and Puget Sound Physiographic Province. The Willamette Lowland lies between the Cascade Mountains to the east and the Coast Range to the west. The Willamette Valley is part of an elongate alluvial plain whose elevation is near sea level in Portland, Oregon and at the Columbia River.

Camp Bonneville is located along the eastern edge of the Willamette Lowland near the foothills of the Cascade Mountains. The U.S. Geological Survey published a geologic map of the Lacamas Creek 7.5-minute quadrangle in 2006 (Evarts 2006). This map provides a more detailed description of the geology in the Camp Bonneville area. The following geologic units are present at Camp Bonneville in order from oldest to youngest: Basaltic Andesite of the Elkhorn Mountain, Sandy River Mudstone, Lower (Conglomerate) member of the Troutdale Formation, Landslide Deposits, and Alluvial Sediments.

The geologic history of the area includes the accretion of a submarine oceanic island archipelago (Orr and Orr 1999) as evidenced through the presence of Oligocene age tholeiitic basaltic andesite and basalt flows and flow breccia (Basaltic Andesite of Elkhorn Mountain) (Evarts 2006). The Basaltic Andesite of the Elkhorn Mountain unit is present as bedrock throughout Camp Bonneville. The uppermost bedrock is severely weathered as characterized by clay-rich materials described in boring logs from throughout the site.

The Sandy River Mudstone unconformably overlies the basaltic andesite and was formed when the Portland Basin was a lake fed by the ancestral Columbia and Willamette Rivers (Orr and Orr 1999; Evarts 2006). The mudstone is characterized in boring logs from throughout Camp Bonneville by clayey siltstone and fine-grained sandstone. At Camp Bonneville, the Sandy River Mudstone is present in a small valley that extends between Camp Killpack and Camp Bonneville cantonments (Figure 2-2 – BCRRT 2009).

The Troutdale Formation is the result of deposition of western flowing streams that crossed the Cascade Range; including the ancestral Columbia River. An older conglomerate member of the Troutdale Formation is present along the west - southwest portion of Camp Bonneville (Evarts 2006). In addition, a remnant of the conglomerate is present in the Landfill 4/Demolition Area 1. At Camp Bonneville, the conglomerate is deeply weathered. It is described as a weakly to moderately cemented pebble and cobble conglomerate with lenses of coarse sandstone (BCRRT 2009).

Recent alluvium and landslide deposits are present along Lacamas Creek, East Fork Lacamas Creek, North Fork Lacamas Creek, and David Creek (Evarts 2006). The alluvial deposits consist of unconsolidated silt, sand, and gravel. Well-rounded quartzite pebbles from the Troutdale Formation are present in these deposits (BCRRT 2009). Recent landslide deposits consist of diamictons of bedrock and surficial material that has been transported downslope. These landslide deposits are located in areas of steep bedrock terrain and appear to be the result of failed weathered, clay-rich, flow breccias (BCRRT 2009).

3.1.2 Aquifer System

Camp Bonneville lies within the Portland Basin portion of the Willamette Lowland Aquifer System. The Portland Basin is bounded to the east by the Cascade Mountains, to the north by the Lewis River, and to the west by the Coast Range.

The Basaltic Andesite of the Elkhorn Mountain unit generally has little capacity to store or transmit water. Where water is present, it is located at the soil/rock interface or in fractured zones within the rock (McFarland and Morgan 1996). At Camp Bonneville this unit is not considered to be a productive aquifer with some exceptions where potable water has been encountered in fracture zones.

The Sandy River Mudstone is a low permeability unit. As described in the Geology section above, this unit is only present in a small valley that extends between Camp Killpack and Camp Bonneville cantonments. It is not present at Landfill 4/Demolition Area 1.

The Troutdale Conglomerates generally are considered excellent water-bearing units and commonly serve as water sources for municipal, industrial, and irrigation supplies (McFarland and Morgan 1996). In 2006, EPA designated the Troutdale aquifer a sole-source aquifer in the Clark County, Washington area . This aquifer system provides approximately 99 percent of the available drinking water to the residents living over it. No other drinking water sources are available that would be economically feasible to supply these residents (EPA 2006). At Camp Bonneville the Conglomerate Member of the Troutdale Formation is present along the west - southwest portion of Camp Bonneville (Evarts 2006). In addition, a remnant of the conglomerate is present in the Landfill 4/Demolition Area 1. The remnant is disconnected/isolated from the Troutdale Conglomerate located at the west – southwest property line of Camp Bonneville. The remnant was most likely isolated from the rest of the unit to the west - southwest by the downcutting of Lacamas Creek. Camp Bonneville lies within the Streamflow Source Area of the Troutdale Aquifer. The Streamflow Source Area is defined by EPA as "the upstream headwaters area of streams that flow into the recharge area of the aquifer" (EPA 2006).

Movement of ground water in the Portland Basin is primarily controlled by topography (Morgan and McFarland 1996). Topography also appears to control ground water flow at Camp Bonneville (BCRRT 2009). Ground water typically discharges to Lacamas Creek and its tributaries. However, EPA has described ground water pumping in the Lacamas Creek watershed that has resulted in a lowering of the potentiometric surface. This lowering of ground water levels has resulted in losing reaches of Lacamas Creek and its tributaries (EPA 2006).

3.1.2.1 Troutdale and Unconsolidated Alluvium Aquifer System Sole Source Aquifer Designation

In November 2005, a petition was submitted to EPA to designate the Troutdale and Unconsolidated Alluvium Aquifer as a sole source of drinking water in the area of Clark County, Washington. The petitioners included: Columbia Riverkeeper, Rosemere Neighborhood Association, and eight independent Clark County citizens.

The Sole Source Aquifer Program is authorized by the Safe Drinking Water Act of 1974. EPA defines a sole or principal source aquifer as "an aquifer or aquifer system which supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer, and for which there is no alternative source or combination of alternative drinking water sources which could physically, legally, and economically supply those dependent upon the aquifer. For convenience, all EPA designated sole or principal source aquifer systems are often referred to simply as "sole source aquifers".

The aquifer system boundaries that were originally petitioned were slightly extended in the south, east, an northern sections of the area as recommended by EPA during their review of the petition. The final boundaries are presented in Figure 3-3. The Columbia River forms the southern and western boundaries of the Troutdale aquifer system. The northern boundary follows the North Fork of the Lewis River from its confluence with the Columbia River, east to the confluence of Cedar Creek. Cedar Creek is used as the northeast boundary between the Troutdale unit and the older rocks unit, and the creek also most likely acts as a local ground water divide for the upper parts of the aquifer system. The aquifer boundary follows Cedar Creek east where the boundary turns southeast and follows the mapped geologic contact between the Troutdale Formation and the older rock unit. The eastern boundary follows the geologic contact south to the Little Washougal River, then follows the Little Washougal River to its confluence with the Washougal River. The boundary then follows the Washougal River south to Woodburn Hill, where it turns northwest and follows the geologic contact along a small outcrop of the older rocks unit. The boundary follows the geologic contact through the City of Camas, and meets the Columbia River. In the northern part of the area, the aquifer system boundary is drawn around Bald

Mountain, which is excluded from the aquifer system because it is composed of the older rocks unit (EPA 2006).

Based on the information included in the petition and findings during its review, the EPA concluded "A sole source aquifer system must supply at least 50 percent of the drinking water consumed within the natural boundaries of the aquifer system, and there can be no economically or legally available alternative source that could supply the entire population living in the area. The Troutdale Aquifer System supplies over 99% of the drinking water to people living in the petitioned area, and there are no economical and legally available alternative sources of water. The political and legal constraints on available water supplies in the area cause even potentially adequate volumes to be unattainable within any reasonable timeframe. Given these conditions, the Troutdale Aquifer System meets the criteria or EPA designation as a sole or principle source aquifer under Section 1424(e) of the Safe Drinking Water Act." (EPA 2006).

3.1.2.2 On-Site Ground Water Monitoring

Twenty-seven monitoring wells exist at Camp Bonneville. Of these 27 wells, 19 are currently monitored. Monitoring wells at Demolition Area 2 and Demolition Area 3 are no longer sampled after previous quarters sampling events resulted in no exceedances of MTCA cleanup levels for site contaminants of concern. The majority of these wells are located in the valley that follows Lacamas Creek through Camp Bonneville (Central Valley). As described in Ground Water Sampling and Analysis Report for Camp Bonneville for the 4th quarter of 2006 (PBS 2007), the following wells are currently monitored at the site:

- Base Boundary at Lacamas Creek
    - Paired wells: LC-MW01S and LC-MW01D
    - Paired wells: LC-MW02S and LC-MW02D
    - Paired wells: LC-MW03S and LC-MW03D
    - Paired wells: LC-MW04S and LC-MW04D
- Landfill 4/Open Burning/Demolition Area 1 (A – shallow, B – deep)
    - Paired wells: L4-MW01A and L4-MW01B
    - Paired wells: L4-MW02A and L4-MW02B
    - Paired wells: L4-MW03A and L4-MW03B
    - L4-MW04A
    - L4-MW05A
    - L4-MW07B
    - L4-MW17 (bedrock)
    - L4-MW18 (alluvium)

Quarterly ground water sampling at Camp Bonneville includes well depth data as well as static water-level data in each monitoring well. In addition, ground water samples collected from Base Boundary at Lacamas Creek monitoring wells are analyzed for:

Field measurements (pH, specific conductance, temperature, and total dissolved solids), TPH-Gx (gasoline), TPH-Dx (diesel), VOCs, SVOCs, explosive compounds [including (HMX), RDX, NG, and PETN], picric acid, perchlorate, priority pollutant metals (total and dissolved), TOC, DOC, TSS, alkalinity, and inorganic ions.

Ground water samples collected from Landfill 4/Open Burning/Demolition Area 1 monitoring wells are analyzed for:

Field measurements (pH, specific conductance, temperature, and total dissolved solids), VOCs, explosive compounds (including HMX, RDX, NG, and PETN), and perchlorate.

Based on the quarterly monitoring report (PBS 2007) for Base Boundary wells at Lacamas Creek, metals concentrations have decreased over the period of monitoring. Petroleum hydrocarbons have not been detected in any samples over the period of monitoring with the exception of a single detection of diesel range petroleum hydrocarbons (0.14 milligrams per liter in January 2006). Perchlorate concentration trends in ground water samples has been variable despite Interim Removal Actions that have occurred at Landfill 4/Open Burning/Demolition Area 1.

Based on the 4th quarter 2006 monitoring report (PBS 2007), depth to ground water in the area of Landfill 4/Demolition Area 1 ranged from approximately 11 to 30.8 feet (note: all depths to ground water are described from top of casing rather than the land surface). Depth to ground water in monitoring well L4-MW07B located downstream of the landfill was approximately 30.32 feet. Depth to ground water in monitoring wells L4-MW17 and L4-MW18, along North Fork Lacamas Creek at the base of the stream ravine and downgradient of Landfill 4/Demolition Area 1 was 9.63 feet and 10.14 feet, respectively.

3.1.2.3 On-site Contaminant Fate and Transport Modeling

In 2009, Ecology completed contaminant fate and transport modeling for the site as a component of an RI/FS prepared by BCRRT. The modeling was completed for perchlorate and RDX in the vadose zone and in ground water flowing from Landfill 4/ Demolition Area 1 at Camp Bonneville. The software VLEACH (Ravi and Johnson 1997) was used for vadose zone modeling at Landfill 4/Demolition Area 1. The vadose zone in this area is predominantly composed of the Troutdale Conglomerate. The modeling was completed for post-excavation conditions. Results indicated that perchlorate in leachate would take over 100 years to reach concentrations less than 1 microgram per liter in ground water and that the peak concentration of RDX leaching to ground water would occur 24 years after excavation. (BCRRT 2009)

The Domenico analytical solute transport model (Domenico 1987) also was utilized to model contaminant fate and transport in ground water emanating from Landfill 4/Demolition Area 1. The Domenico model accounts for dispersion, retardation, and degradation (first-order decay) in solving the ground water mass transport equation. Modeling results for Landfill 4/Demolition Area 1 indicate that perchlorate and RDX should reach North Fork Lacamas Creek within 18 years. Considering the source of perchlorate was thought to have been introduced to the landfill in the late 1960's, perchlorate should have reached North Fork Lacamas Creek. The RI/FS reports that surface water in North Fork Lacamas Creek was sampled in 2008 and neither perchlorate nor RDX were detected in those samples. The RI/FS did not depict actual sample locations on a map and did not include the analytical data to support this assertion. The RI/FS speculated that the lack of perchlorate or RDX in surface water may be due to an under estimation of contaminant travel times by the model. For perchlorate it is speculated that a mechanism such as biodegradation, which is not accounted for in the model may explain the lack of perchlorate in surface water. (BCRRT 2009)

3.1.2.4 Review of On-site Contaminant Fate and Transport Modeling

The contaminant fate and transport modeling conducted as a part of the Ecology RI/FS were reviewed by E & E. A memorandum was generated to summarize this analysis. This memorandum is included as Appendix C to this report. This section is a summary of that information.

The existing vadose zone contaminant fate and transport model for Landfill 4/Demolition Area 1 at Camp Bonneville is a good screening-level tool. Vadose zone modeling indicates that both perchlorate and RDX will continue to migrate to ground water at Landfill 4/Demolition Area 4, in the case of perchlorate, for over 100 years.

The existing ground water contaminant fate and transport model for Landfill 4/Demolition Area 1 at Camp Bonneville is also a good screening-level tool. At the source area, ground water is within the deeply weathered basaltic andesite. Contaminant fate and transport modeling indicates that perchlorate and RDX should have reached North Fork Lacamas Creek given that the burial of explosives and fireworks in Landfill 4/Demolition Area 1 occurred in the late 1960s. However, reportedly, neither perchlorate nor RDX was detected in surface water samples collected in 2008 from North Fork Lacamas Creek, adjacent to Landfill 4/Demolition Area 1. This may be due to an underestimation of contaminant travel times by the model, dilution by surface water to non-detectable concentrations once contaminants reach Lacamas Creek, or no discharge of contaminated ground water to Lacamas Creek in the sampled area.

In general, both perchlorate and RDX tend to be persistent in the environment. Perchlorate biodegradation requires anaerobic conditions, the presence of sufficient carbon, and an active perchlorate degrading microbial population (Tipton, et al 2003 and Urbansky and Brown 2003). It is unlikely that biodegradation is occurring. However, if biodegradation is occurring, it could be demonstrated by the presence of intermediates of perchlorate degradation.

Adsorption is not a significant attenuation process for RDX since it has a low adsorption coefficient. In addition, anaerobic biodegradation of RDX has been observed to occur more readily and more completely than aerobic biodegradation. (Brannon and Pennington 2002)

The Domenico (1987) model for contaminant fate and transport in ground water is limited in that it assumes homogeneous aquifer properties and one-dimensional ground water flow, among other assumptions. Contaminated ground water from the landfill initially flows within the weathered andesitic basalt. As it migrates toward North Fork Lacamas Creek, it likely flows through alluvial sediments. These alluvial sediments would have different hydraulic and organic carbon properties.

In addition, monitoring wells LF4-MW02A and LF4-MW02B, located downgradient of Landfill 4/Demolition Area 1, show slightly increasing concentrations of perchlorate even afrer excavation of contaminated soils. This indicates that perchlorate is still migrating from the area.

To better understand the fate and transport of perchlorate and RDX from Landfill 4/Demolition Area 1, additional plume delineation may be required. This could be accomplished through additional borings and installation of a monitoring well pair between LF4-MW02A and LF4-MW02B and the North Fork Lacamas Creek, closer to the creek, and collection of water level and water quality data. A better understanding of ground water flow, particularly vertical ground water gradients, could be accomplished through the addition of a paired shallow and deeper monitoring well near the creek.

The Sole Source Troutdale Aquifer along the western edge of Camp Bonneville is of concern with respect to the potential for contamination from Camp Bonneville. The Landfill 4/Demolition Area 1 is around 1,000 feet to the northeast of the Troutdale Aquifer. A more robust model of ground water flow and contaminant fate and transport could be used to determine if perchlorate and RDX could reach the Troutdale Aquifer.

3.1.3 Drinking Water Targets

Approximately 9,627 people use ground water for drinking water purposes within the 4-mile TDL. A combination of Group A and Group B community water systems; and domestic wells are present. The Washington Administrative Code (WAC) defines the group designation for community water systems. The definitions as provided by the Washington state Department of Health are:

Group A: (WAC 246-290) Group A water systems are those with fifteen or more service connections, regardless of the number of people; or systems serving an average of twenty-five or more people per day for sixty or more days within a calendar year, regardless of the number of service connections. Group A water systems do not include systems serving fewer than fifteen single-family residences, regardless of the number of people.

Group B: (WAC 246-291) Group B water systems serve less than 15 residential connections and less than 25 people per day; or 25 or more people per day fewer than 60 days per year. Group B water systems are those public water systems that do not meet the definition of a Group A water system.

DOH maintains records of all active public water systems. Public water systems, regardless of group designation, indicate the total number of wells in the system, number of connections, and total population served. A search of the DOH Sentry Internet database revealed the presence of 18 Group A community wells serving a total population of 830 people and 182 Group B community wells serving a total population of 1,083 people (Sentry 2009).

Domestic drinking water well logs are maintained by the Washington State Department of Ecology (Ecology). A search of the Ecology well log database revealed the presence of a total of 3,269 domestic wells within the 4-mile TDL. Domestic wells do not record the actual number of people served by each well; therefore, each well is assigned the average number of people per household for Clark County, Washington of 2.36 for a total population served by domestic wells of 7,715 people (DOC 2001; Ecology 2009). Population figures were rounded the neared whole integer for reporting purposes. The number of drinking water wells and associated population within the 4-mile TDL by distance ring is presented in Table 3-1.

Given the surrounding land use, it is assumed that ground water is used for the irrigation of commercial livestock within the TDL. A wellhead protection area is present within the 4-mile TDL.

3.2 Surface Water Migration Pathway

The surface water migration pathway TDL begins at the probable point of entry (PPE) of surface water runoff from the site to a surface water body and extends downstream for 15 miles. Figure 3-2 depicts the surface water TDL.

The average annual precipitation for Vancouver, Washington is 39.48 inches (WRCC 2009). The 2-year 24-hour rainfall event for Vancouver, Washington is 2.5 inches (NOAA 1973). Portions of the site are located in a 100 year flood plain (FEMA 1980).

Soils at the site consist of Hesson clay loam (0 to 8 percent slopes) and McBee silty clay loam (0 to 3 percent slopes). The Hesson clay loam is the predominant soil type in the county. In a typical soil profile, the surface layer is a reddish-brown clay loam approximately 8 inches thick. The subsurface layer is dark reddish-brown clay loam approximately 4 inches thick. Below this layer is friable, dark reddish-brown clay loam approximately 10 inches thick. The next layer to a depth of approximately 91 inches is reddish-brown clay. The Hesson clay loam is well drained and has moderately slow permeability. The McBee clay loam occurs on depressions that are sometimes subject to flooding from nearby streams. In a typical profile, the surface layer is a silty clay loam approximately 11 inches thick. It is very dark brown in the upper portion and dark brown lower portion. The next layer is approximately 41 inches thick and is comprised as follows: 10 inches of friable very dark reddish-brown silty clay loam; 11 inches of firm dark brown silty clay loam and the lower 20 inches is firm grayish-brown and dark yellowish-brown silty clay loam. The underlying material to a depth of approximately 65 inches is gray and brown clay. The McBee silty clay loam is somewhat poorly drained and moderately permeable (USDA 1972).

3.2.1 Overland Route

Overland flow from sources at the site enters Lacamas Creek in the central valley floor. Lacamas Creek exits the site in the southwest corner of the post and flows for approximately 12.61 miles (through Lacamas Lake) to its confluence with the Washougal River, and then continues approximately 1.43 miles downstream to the confluence with the Columbia River. The 15-mile TDL concludes approximately 0.96 miles downstream in the Columbia River. Flow rates are not available for Lacamas Creek or Lacamas Lake. The flow rate for the Washougal River as measured at Washougal, Washington (near the confluence of Lacamas Creek and the Washougal River) is 800.5 cubic feet per second (cfs) and the flow rate for the Columbia River at Vancouver, Washington is reported to be 215,900 cfs (USGS 2009). Flow rates for Lacamas Creek and Lacamas Lake are estimated to be between 10 and 100 cfs.

3.2.2 Drinking Water Targets

Surface water is not used for drinking water purposes within the TDL. The Columbia River is a major recreation area.

3.2.3 Human Food Chain Targets

Two artificial impoundments on Lacamas Creek were created to support a trout sports fishery (WC 1997). These impoundments are no longer fished; however, they were actively used when the site was in operation. Fish catch is not reported for Lacamas Creek or Lacamas Lake; however, it was reported that these water bodies are known fishing locations for human consumption (Reynolds 2009). It is estimated that greater than 1 to 100 pounds of fish are caught annually from the creek or the lake for human consumption. Fishing is not known, nor expected, to occur above Lacamas Lake due to the presence of a dam which does not contain fish ladders to allow the passage of fish from the lake to the creek.

The most current sport catch data are from 2000 to 2001 (WDFW 2005). Fishing is reported for the entire Washougal River, of which approximately 1 percent lies within the TDL. Fish catch data is presented in numbers of fish caught; therefore, the average weight of each fish is used to determine the pounds of fish caught within the TDL. The total pounds of each fish species is then multiplied by 1% to determine the pounds of fish caught within the TDL. Fish catch for the Columbia River is reported from the Bonneville Dam to the Columbia River, of which approximately 0.5% is within the TDL. The same process for determining pounds of fish within the TDL as discussed above is used here. Fish catch data is presented in Table 3-2. In this table, fish catch estimates have been rounded to the nearest whole number.

3.2.4 Environmental Targets

State and Federal-listed threatened and endangered species are present within the TDL. The Federal-listed threatened Lower Columbia River Evolutionarily Significant Unit (ESU) Steelhead (*Oncorhynchus mykiss*), the Lower Columbia River ESU Chinook salmon (*Oncorhynchus tshawytscha*), and the Lower Columbia River ESU Chum salmon (*Oncorhynchus keta*) are present within Lacamas Creek, the Washougal River, and the Columbia River. The Federal-listed endangered Bradshaw's Lomatium (*Lomatium bradshawii*) is present within Lacamas Creek. Additionally, the State-listed threatened Dense Sedge (*Carex densa*), Hall's aster (*Aster hallii*), the Oregon coyote thistle (*Eryngium petiolatum*), and the Western Wahoo (*Euonymus occidentalis*) are present on Lacamas Creek (Maguire 2009). Table 3-3 provides a summary of the environmental targets within the TDL.

A total of 15.81 miles of wetland frontage are present along the TDL (Maguire 2009). Wetland frontages by surface water body within the TDL are as follows:
- Lacamas Creek – 15.08 miles (of which 6.84 miles are within the boundaries of the site);
- Washougal River – 0.61 mile, and
- Columbia River – 0.12 mile.

In 1998, Hart Crowser performed a limited surface water investigation of Lacamas Creek and its tributaries. A total of six surface water samples (HC-H1 though HC-H5 and HC-D1) and one blind duplicate sample (HC-D10) were collected during the investigation. Five samples were collected from near the headwaters of various tributaries to Lacamas Creek near their entry points to the post to determine concentrations upstream of the post: sample HC-H1 was collected from East Fork Lacamas Creek, sample HC-H2 was collected from an unnamed tributary to David Creek, sample HC-H3 was collected from David Creek, sample HC-H4 was collected from North Fork Lacamas Creek, and sample HC-H5 was collected from an unnamed tributary to the North Fork Lacamas Creek (see Figure 2-7). Samples HC-H1 through HC-H5 were composited at the laboratory into one sample. One sample was collected from Lacamas Creek downstream of the post (HC-D1) just before the creek exits the post. Sample results indicate that the dissolved metal barium and the total metals arsenic, barium, cadmium, chromium, copper, silver, and zinc were detected at concentrations above the composited up-post sample concentrations. (HC 1998)

Based on sample results from this investigation, a zone of actual contamination is present along Lacamas Creek within the boundaries of the site.

3.3 Soil Exposure Pathway

The soil exposure pathway is evaluated based on the threat to residents and nearby populations from soil contamination within the first two feet of the surface.

3.3.1 Site Setting and Exposed Sources

The site is surrounded by a maintained fence and security. The current use of the site does not include any recreational use.

3.3.2 Targets

A total of 2,780 people reside within a 1 mile travel distance of the site (Maguire 2009). The nearest residence is located on site. This residence is populated by two people. A total of between 2 and 30 people work at the site. Table 3-4 provides a summary of the population within the TDL.

The site is not used for commercial agriculture, commercial silviculture, commercial livestock production, or commercial livestock grazing.

The State-listed endangered Hairy-stemmed checker-mallow (*Sidalcea hirtipes)* is present on site (Maguire 2009).

3.4 Air Migration Pathway

The air migration pathway TDL is a 4-mile radius that extends from sources at the site (Figure 3-1).

3.4.1 Human Targets

A total of 29,873 people reside within the 4-mile TDL. The population by distance ring is presented in Table 3-4. Additionally, five schools with a total population of students and teachers of 3,319 people are present from 3 to 4 miles of the site.

Commercial agriculture, commercial silviculture, or a major or designated recreation area is not present within the TDL.

3.4.2 Environmental Targets

Federal- and State-listed threatened and endangered species and wetlands are present within the 4-mile TDL. The Federal-listed threatened Lower Columbia River ESU Steelhead (*Oncorhynchus mykiss*), the Lower Columbia River ESU Chinook salmon (*Oncorhynchus tshawytscha*), the Lower Columbia River ESU Chum salmon (*Oncorhynchus keta*), and the Federal-listed endangered Bradshaw's Lomatium (*Lomatium bradshawii*) are present within the TDL. Additionally, the State-listed threatened Dense Sedge (*Carex densa*), Hall's aster (*Aster hallii*), the Oregon coyote thistle (*Eryngium petiolatum*), the Western Wahoo (*Euonymus occidentalis*), the Western Gray Squirrel (*Sciurus griseus*), and the State-listed endangered Hairy-stemmed checker-mallow (*Sidalcea hirtipes)* are present within the TDL (Maguire 2009). Table 3-3 provides a summary of the environmental targets within the TDL.

A total of 1,489.77 acres of wetlands are present within the TDL (Maguire 2009). Wetland acreage by distance ring is presented in Table 3-4.

Table 3-1 Ground Water Drinking Water Population by Distance Ring

Distance Ring	Number of Wells	Well Population	Total Population for Distance Ring
0 to ¼ mile	Community B – 9	50	404
	Domestic – 150	354	
¼ to ½ mile	Community B – 6	40	335
	Domestic – 125	295	
½ to 1 mile	Community A – 2	21	1,168
	Community B – 24	163	
	Domestic – 417	984	
1 to 2 miles	Community A – 3	80	2,761
	Community B – 66	401	
	Domestic – 966	2,280	
2 to 3 miles	Community A – 6	493	2,345
	Community B – 35	193	
	Domestic – 703	1,659	
3 to 4 miles	Community A – 7	236	2,614
	Community B – 42	235	
	Domestic – 908	2,143	
TOTAL	**3,469**		**9,627**

Source: DOC 2001; Ecology 2009.

Table 3-2 Sport Catch Data

Species	Number Harvested	Average Pound per Fish	Pounds Harvested
Washougal River			
Chinook salmon (*Oncorhynchus tshawytscha*)	1,853 x 1% = 18.53	22	408
Coho salmon (*Oncorhynchus kisutch*)	172 x 1% = 1.72	10	17
Steelhead trout (*Oncorhynchus mykiss*)	1,076 x 1% = 10.76	7.5	81
Columbia River			
Chinook salmon (*Oncorhynchus tshawytscha*)	17,160 x 0.5% = 858	22	1,888
Coho salmon (*Oncorhynchus kisutch*)	2,501 x 0.5% = 1250.05	10	125
White sturgeon (*Acipenser transmontanus*)	2,934 x 0.5% = 146.7	67[a]	983
Steelhead trout (*Oncorhynchus mykiss*)	5,179 x 0.5% = 258.95	7.5	194
Total			**3,696**

Source: Coastangler.com 2008, Wydoski 2003, WDFW 2005.
[a] Average weight of sturgeon is calculated assuming an average catch length of 5'1".

Table 3-3 Threatened and Endangered Species by Distance Ring

Distance Ring	Species Name	Status
0 to ¼ mile	Hairy-stemmed Checker-mallow	State-listed threatened
	Small-flowered Trillium	Sate-listed Species of concern
¼ to ½ mile	None	
½ to 1 mile	Dense Sedge	State-listed Threatened
1 to 2 miles	Western Gray Squirrel	State-listed Threatened
	Western Wahoo	State-listed Threatened
	Lower Columbia River ESU Steelhead	Federal-listed Threatened
	Bradshaw's Lomatium	Federal-listed Endangered
	Dense Sedge	State-listed Threatened
	Hall's Aster	State-listed Threatened
	Oregon Coyote-thistle	State-listed Threatened
2 to 3 miles	Lower Columbia River ESU Steelhead	Federal-listed Threatened
3 to 4 miles	Lower Columbia River ESU Steelhead	Federal-listed Threatened
	Lower Columbia River ESU Chinook	Federal-listed Threatened
	Lower Columbia River ESU Chum	Federal-listed Threatened
	Bradshaw's Lomatium	Federal-listed Endangered
	Dense Sedge	State-listed Threatened

Table 3-4 Population by Distance Ring

Distance Ring	Population	Wetlands acreage
0 to ¼ mile	410	99.48
¼ to ½ mile	715	6.05
½ to 1 mile	1,655	103.95
1 to 2 miles	3,452	141.78
2 to 3 miles	6,500	546.41
3 to 4 miles	17,141 residents 3,319 students and teachers	592.1
TOTAL	**33,192**	**1,489.77**

Source: Maguire 2009

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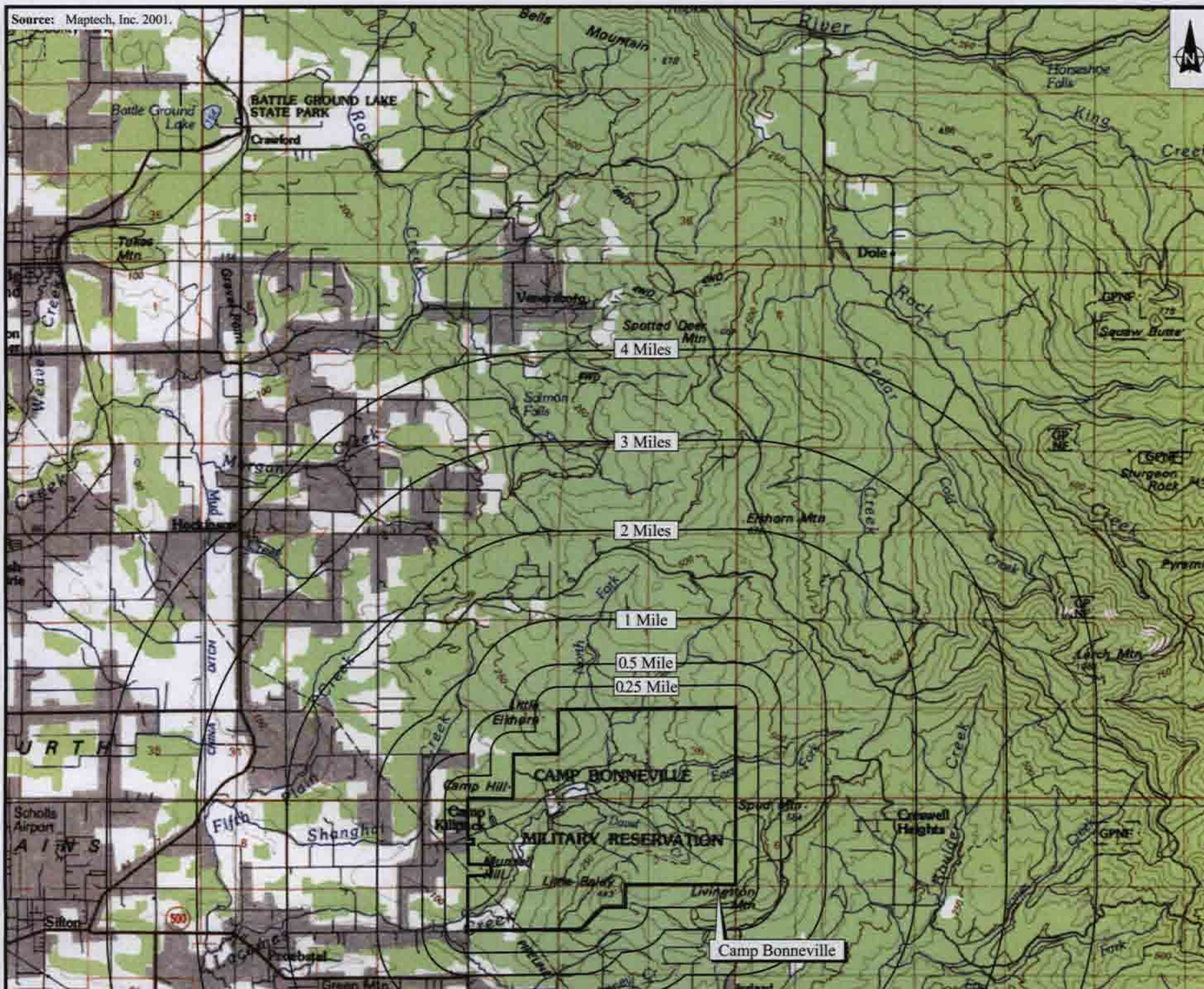


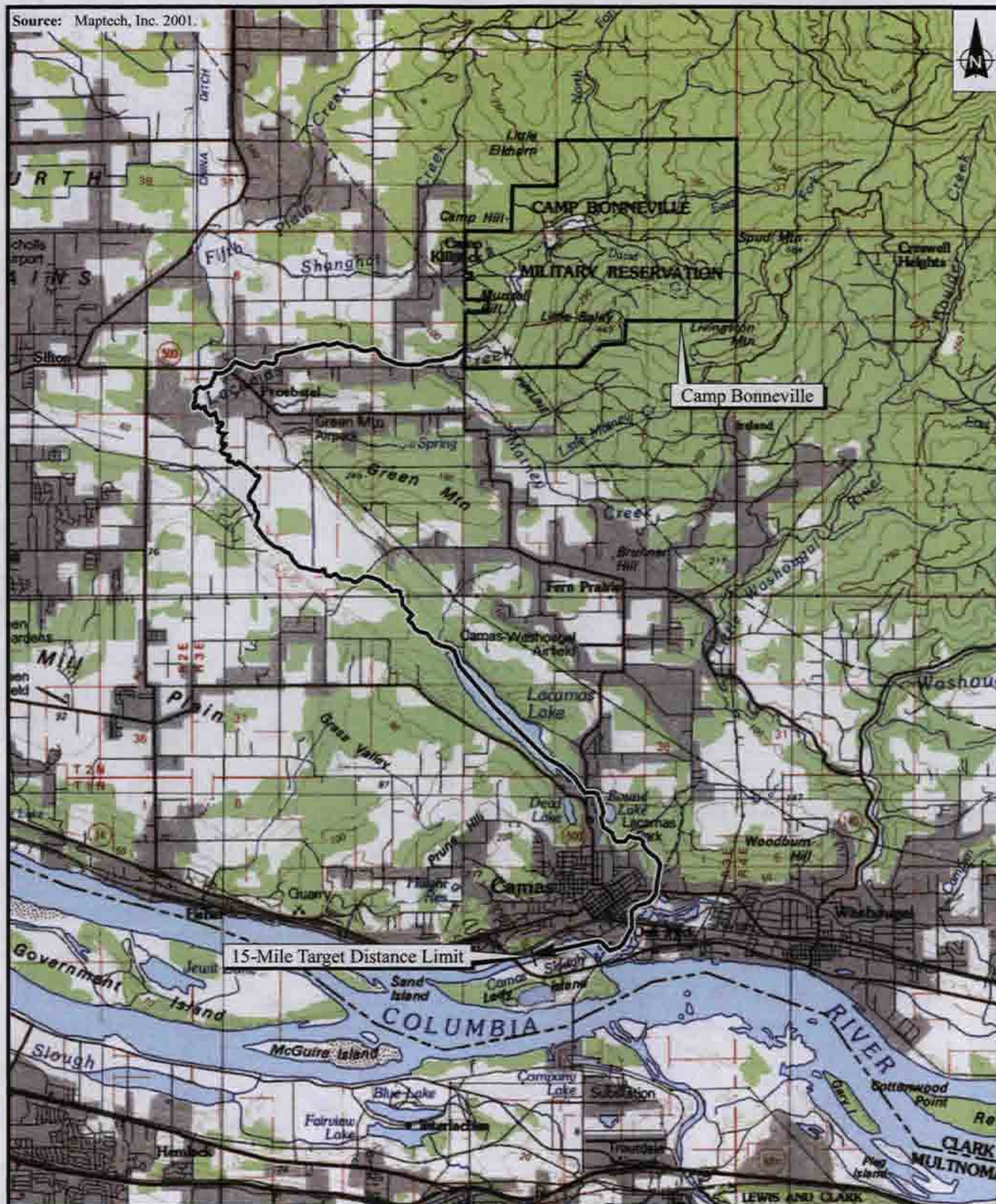
ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

CAMP BONNEVILLE
Vancouver, Washington

Figure 3-1
4-MILE TARGET DISTANCE LIMIT MAP

0 .5 1
Approximate Scale in Miles

Date:	Drawn by:	
12/18/09	AES	10:START-3\09050003\fig 3-1



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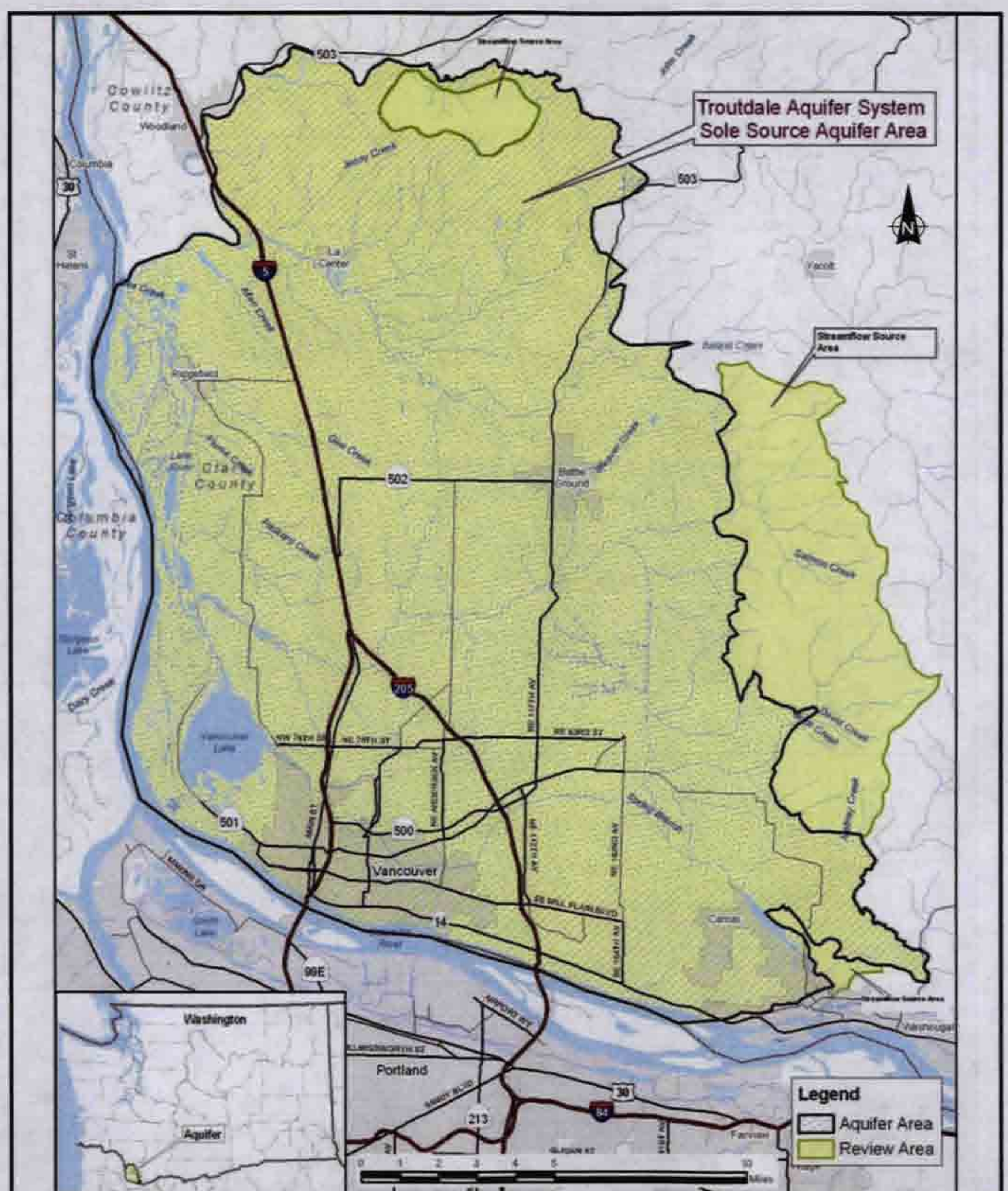
Vancouver, Washington

0 .75 1.5
Approximate Scale in Miles

Figure 3-2

15-MILE TARGET DISTANCE LIMIT MAP

Date:	Drawn by:	
12-18-09	AES	10:START-3\09050003\fig 3-2



ecology and environment, inc. International Specialists in the Environment Seattle, Washington	CAMP BONNEVILLE Vancouver, Washington	Figure 3-3 TROUTDALE AND UNCONSOLIDATED ALLUVIUM SOLE SOURCE AQUIFER BOUNDARY	
	Source: EPA, 2006.	Date: 2-16-10	Drawn by: AES	10:START-3\09050003\fig 3-3

4 Summary and Conclusions

Camp Bonneville is located in Clark County, approximately 12 miles northeast of Vancouver, Washington. Lacamas Creek flows generally through the middle of the site with a number of tributaries that feed it. Camp Bonneville is a sub-installation of the Vancouver Barracks which is a sub-installation of Fort Lewis. Camp Bonneville consists of approximately 3,840 acres of land that historically was used by the DOD to provide training for active Army, Army Reserve, National Guard, Marine Corps Reserve, Navy Reserve, Coast Guard Reserve units, and other DOD personnel. The installation consists of two cantonment areas (Bonneville cantonment and Killpack cantonment), 25 firing ranges, former sewage lagoons, and four historic landfills.

The site has been the source of a variety of investigations since the decision to close the military installation. Investigations at the site have centered on known or suspected areas of potential contamination, areas that were known to store hazardous substances, and/or areas where hazardous substances may have been spilled. Site information indicates that a number of these locations have been remediated and/or have been recommended for no further action. The areas at the site that are currently still undergoing investigation and/or cleanup activities include Landfill 4/Demolition Area 1 and the associated ground water contamination at this location; and various firing ranges.

The sources that appear to be most likely to contribute current or future contamination at the site are the firing target area, the Central Impact Target Area, the OB/OD area, and Landfill 4. The firing target areas are of concern because of previous detections of heavy metals in the soil and because UXO has historically been present in these areas. Although work is currently underway by BCRRT to clear UXO from the trails and a 10-foot buffer zone on either side of the trails, there is still the possibility that people may wander outside of cleared areas and encounter UXO. Hence, UXO outside of cleared areas would pose a safety threat to future potential visitors unless additional mitigation measures were taken (i.e., fencing, additional UXO clearing). The Central Impact Target area is of concern due to the confirmed presence of lead and RDX contaminated soil. Although this area will be fenced and is not likely to be accessed by the public, it is possible that contamination may migrate from this source through ground water or surface water runoff to Lacamas Creek. The OB/OD area is of concern due to the presence of historic RDX and arsenic contaminated soil. Landfill 4 is of concern due to the continued presence of perchlorate in the ground water and possible migration of contaminated ground water to Lacamas Creek.

Sampling of Lacamas Creek has been conducted at the headwaters of the tributaries that feed the creek and at the southwestern site boundary. A zone of actual contamination of Lacamas Creek has been established based on an evaluation of information from the previous surface water investigation. It is recommended that additional stream sampling be conducted to determine if contamination from the site is impacting streams and downstream targets which include a fishery in Lacamas Lake and wetlands along Lacamas Creek and within Lacamas Lake.

Ground water has been sampled on site and it appears that a perchlorate ground water plume is present at the site in the area surrounding Landfill 4/Demolition Area 1. Fate and transport of contaminant migration through the vadose zone and ground water from the Landfill 4/Demolition Area 1 has been modeled. The modeling methods used and resulting assumptions were reviewed by E & E. It was determined that the modeling techniques used may be inadequate to accurately predict contaminant trends and possible impacts to North Fork Lacamas Creek.

A more robust model of ground water flow and contaminant fate and transport could be used to determine if perchlorate and RDX could reach the Troutdale Aquifer. If a more robust model of ground water flow and contaminant fate and transport at the Camp Bonneville Military Reservation and adjacent Troutdale Sole Source Aquifer is required, a ground water flow model based on the program MODFLOW is recommended. MODFLOW is a finite-difference model that models ground water flow in three dimensions (USGS 1983). MODFLOW allows the user to simulate multiple aquifers, incorporate aquifer heterogeneities, and allows for water sources and sinks. If this type of modeling were to be developed for Camp Bonneville, it could be based on the existing USGS ground water flow model of the Portland Basin. This model could be refined in the Camp Bonneville area and include layers for the basaltic andesite, the weathered basaltic andesite, the Troutdale Conglomerate, and the alluvial deposits along Lacamas Creek. Such a model could indicate if and where water may be discharging to Lacamas Creek and also if any water is moving under the creek.

In addition, if MODFLOW were to be used for the site, the model MT3D is also recommended for simulating both the perchlorate and RDX fate and transport in ground water from the Landfill 4/Demolition Area 1. MT3D is a three-dimensional contaminant fate and transport modeling software package that can be used to simulate advection, anisotropic dispersion, first-order decay and product reactions, and linear and nonlinear sorption. Although many of these contaminant properties are modeled in Domenico 1987 based models, MT3D in combination with MODFLOW provides a more robust solution in part because they can account for more system variables.

Based on a review of available information and an evaluation of migration pathways and receptors, further investigation of the Camp Bonneville Site under CERCLA is recommended.

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A

Preliminary Assessment Petition

PUBLIC PETITION FOR PRELIMINARY ASSESSMENT

Elin Miller, Regional Administrator
Michelle Pirzadeh, Acting Regional Administrator
United States Environmental Protection Agency, Region X
1200 Sixth Avenue, Suite 900
Seattle, WA 98101

February 3, 2009

Fax: 206-553-1809
206-553-1234

Under the authority of CERCLA Section 105 (d), as amended, the petitioner,

(Name) : Dvija Michael Bertish, Rosemere Neighborhood Association, Columbia Riverkeeper

(Address) : Box 61471, Vancouver WA, 98666

We hereby request that Region X of the United States Environmental Protection Agency conduct a preliminary assessment of the known and suspected release of a hazardous substances, pollutants, or contaminants at the following location:

Camp Bonneville, Former US Military Installation, Clark County, WA (just outside Vancouver, WA)

Petitioners are affected by the [release (or) threatened release] because: Camp Bonneville, a surplus military property, is the subject of a dirty transfer from the US Dept. of Defense (DoD), to Clark County Government, via a non-profit "nature conservancy" known as the Bonneville Conservation, Restoration and Renewal Team (BCRRT). The property is currently under a cleanup program with supervision by Washington State Dept. of Ecology. EPA Region X staff are very familiar with the issues (both known and unknown) at the site. EPA was formerly involved with the clean-up project, but in an extremely rare occurrence, EPA opted out of the project in July 2003 citing a lack of adequate site assessment and a lack of collaboration on the US Army's part. Given various circumstances that have occurred since 2003, members of the public firmly believe that this project requires EPA to re-engage and list this site on the National Priorities List to achieve a higher level of oversight and to ensure public health and safety. As a former member of the Camp Bonneville Restoration Advisory Board, the petitioner is very concerned about ongoing groundwater contamination that has not been successfully mitigated. Landfill 4 was evacuated – military ordnance and great amounts of soil were removed and clean fill replaced. Ecology stated clearly that post evacuation increases in groundwater contaminant levels would indicate additional (unidentified) sources. Ammonium perchlorate concentrations have increased to above 500 ppb, and there are additional concerns with TCE, and RDX. RDX has a 100 year lifespan in the environment. The groundwater contamination plume abuts and flows toward Lacamas Creek, a salmon bearing stream that feeds into Lacamas Lake, and then into the Columbia River. Lacamas Creek flows through the heart of Camp Bonneville, including the Central Valley Floor where new pollutant discoveries have been made since the project ensued. The surrounding residents all use well water as their potable water supply, however the water on site is unsafe for human consumption. The site exists within the EPA designated Troutdale Sole Source Aquifer System, and petitioners are concerned that federal dollars being expended on this project are not being used to sufficiently protect against further damage to the vulnerable aquifer system and offsite migration of contamination. Since there is a direct federal funding nexus to the project, the petitioners request EPA to invoke its jurisdiction citing Sole Source Aquifer designation in order to evaluate these concerns, as there appears to have been insufficient containment and monitoring (placement of monitoring wells).

Faulty site characterization has long been a problem on this project, and since clean-up activity began, there have been at least 9+ new Area's of Concern (AOC) identified. The new AOCs include new firing points, burial pits and practice ranges. Despite public comments regarding the probability of 155 mm Howitzer's being armed and fired on site, officials denied this concern, only to discover and detonate a Howitzer in the Central Target Impact Area in May of 2007. The find was near existing residential neighborhoods that were apparently built directly over the firing fans for this kind of projectile. Petitioners understand that the Army Corps of Engineers and/or the Dept. of Defense advised neighboring residences on the periphery of the site not to dig a pond or drive stakes into the ground on their own properties, however, there has been no additional planning to evaluate this public safety concern. In a January 12, 2009 letter from Baker Engineering & Energy (subcontractor) to BCRRT, Ecology's comments on the Draft Cleanup Action Plan include: "It is apparent from MEC data collected at the CVF [Central Valley Floor] that MEC types and distributions as well as their corresponding Explosive Hazard Rankings developed for Maneuver and Training areas need to be re-evaluated. The findings completely discredit the prevailing concept in the RI/FS that maneuver areas have negligible explosion hazard risks." Ecology also states: "Based on current available field data it is obvious that the selected cleanup actions for Maneuver areas, especially within the Regional Park, fall short of protectiveness in terms oflong-term effectiveness. A more protective action should take into account surface contamination, and in some areas, subsurface contamination as well." In response to Ecology's concerns, BCRRT staff seems to indicate that risk from new anomalies is "unlikey," and that more empirical data is required to determine if the threat is real. The public insists that the project is well beyond the need to prove whether the threat is real or valid. Various parties of record were denied the opportunity to offer scoping comments on the supplemental RI/FS. To date, the public has not seen a supplemental RI/FS to offer public comment, even though cleanup activity is presumably still underway. Petitioners voiced concern through the RI/FS process that the site was inadequately characterized, and that such data gaps would elevate risk assessment for the intended re-use of the site as a public park and overnight campground, but these concerns were ignored or rebuffed by officials running the project.

In a January 31, 2009 Columbian Article [Army Contests Camp Bonneville Costs; Contractor defends dubious expenses, including large bar tabs], the BCRRT contractor, Mike Gage, states that BCRRT "[has]found several things on-site that we believe are Army-retained conditions that they did not disclose to us." It has now been publicly acknowledged by the contractor that the federal funds budgeted to this project are insufficient to achieve cleanup standards necessary for the intended re-use, and the contractor will be seeking additional federal funding to cover the data gaps that were pointed out by EPA and the public prior to the inception of this project. The Columbian article continues with descriptions of misappropriated federal funds from the project expense records, a lack of oversight between Clark County and the contractor, and the contractor claiming that the project is a private contract that allows him to spend federal cleanup dollars as he so chooses without oversight. In published responses to the Columbian Article, the public perceives these developments as project mismanagement, collusion, and greed.

It is important for EPA to list this site on the National Priorities List simply because the public needs better federal oversight to ensure that the clean-up standards are achieved for optimum risk assessment to protect the public health and safety on this project. Superfund listing would provide additional oversight and would require de-listing prior to release of the site for re-use implementation. The petitioners firmly believe this layer of protection is necessary due to unmitigated circumstances at the site. Clark County officials have openly stated that conditions on this site allow for an "acceptable risk" for the intended re-use as a public park, a position that many people from the public vehemently oppose. Institutional controls call for MEC to remain on site in perpetuity, to be cordoned off by a three strand barbed wire fence adjacent to planned public recreation facilities. Many members of the public have argued that Camp Bonneville is unsuitable for a public park and that they would never bring their children to the site. This public perception is detrimental to the public's interest in this project, especially in light of financial shortfalls currently forecast. The EPA would be better suited to manage additional federal resources and what's left of the current operating budget since financial oversight and accountability are lacking. It appears that Ecology is in need of assistance to bring clean-up standards to bear under CERCLA and MTCA regulations given the new discoveries.

Given that Camp Bonneville is a precedent setting project that sets an example for other military clean-ups of its kind, it is imperative that EPA help to establish improved protocols in order to protect other communities around the nation from experiencing the depth of confusion and largesse experienced on the ground in Clark County. The protocols noted in a Dept. of Defense/EPA document entitled "Management Principals for Implementing Response Actions at Closed, Transferring, or Transferred Ranges," clearly outline intended practices, including collaboration between EPA and DoD, that have been absent from Camp Bonneville's active clean-up. The petitioners hope that EPA can re-energize these much needed protocols and apply them with due diligence to Camp Bonneville's restoration efforts.

Type or characteristics of the substance(s) involved: Ammonium Perchlorate, Trichloroethane, Dichloroethene, Cyclotrimethylenetrinitramine (RDX), HMX, Lead, Chromium, Mercury and others. An extensive list of Militarized Ordnance including mortars, missiles, grenades, chemical warfare agents, and unknown contaminants located in new burial pits. Potential for radioactive materials.

Nature and history of any activities that have occurred regarding the release/threatened release: The sources of contamination are military landfills, target impact areas, firing ranges, burial pits and open burn pits, and documented groundwater contamination.

Federal, State and local authorities you have contacted about the release/threatened release and the response, if any: Washington State Dept. of Ecology , Barry Rogowski, Tim Nord, Ben Forson, Greg Johnson, Dawn Hooper; Martha Lentz, Sole Source Program, EPA Region X; Jonnie Hyde, Clark County Health Dept; Nancy Harney and Harry Craig, EPA Region X; Steve Stuart and Marc Boldt, Clark County Commissioners. Bill Barron, Clark County Administrator. Bill O'Donnell, US Dept. of Defense, Pentagon. Katherine Hanks, Environmental Health Scientist, Agency for Toxic Substances and Disease Registry; Jeroen Kok, Clark County Parks and Recreation; Pete Capell and Jerry Barnett, Clark County Public Works; Mike Gage, BCRRT Contractor; Taylor Aalvik and Nathan Reynolds, Cowlitz Tribe; Ed Marshman, FBI Portland, OR; Vancouver Fire Department District 5; Washington Department of Natural Resources; Camas/Washougal/Woodland Veterans of Foreign Wars and Veterans Administration Land Acquisitions, Willamette Cemetery Portland, OR; Gary Lucas, Clark County Sheriff; Department of Toxic Substances Bureau, San Francisco; Earl Blumenauer, Oregon Congressman; Brian Baird, Washington Congressman; Patty Murray and Maria Cantwell, Washington Senators; Governor Christine Gregoire, Washington.

B Photographic Documentation

Photo 1 Landfill 4 with wells in background.

Direction: West *Date: 8/26/09* *Time: 09:58*

Photo 2 Monitoring wells south of landfill.

Direction: West *Date: 8/26/09* *Time: 10:01*

Photo 3 East lagoon.

Direction: Northwest *Date: 8/26/09* *Time: 10:19*

Photo 4 East lagoon.

Direction: West *Date: 8/26/09* *Time: 10:19*

Photo 5 Soil stockpile West lagoon.

Direction: West Date: 8/26/09 Time: 10:21

Photo 6 Profile of shot crete in West Lagoon.

Direction: West Date: 8/26/09 Time: 10:22

Photo 7 West lagoon.

Direction: Northwest Date: 8/26/09 Time: 10:22

Photo 8 West lagoon with connection between lagoons.

Direction: Northwest Date: 8/26/09 Time: 10:22

Photo 9 State listed Stemmed Checker Mallow.

Direction: Down *Date: 8/26/09* *Time: 10:27*

Photo 10 State listed Stemmed Checker Mallow.

Direction: Down *Date: 8/26/09* *Time: 10:27*

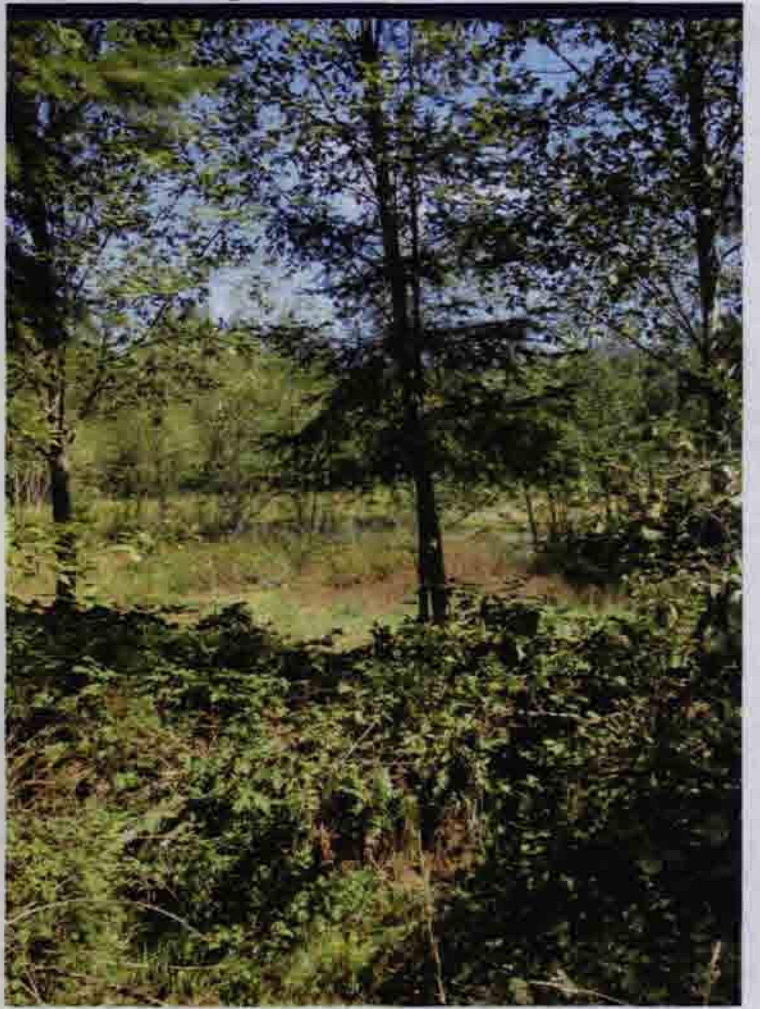

Photo 11 Davis (?) Creek dammed by beavers.

Direction: Northeast	Date: 8/26/09	Time: 10:45

Photo 12 Borrow pit flooded by beaver dam.

Direction: Northeast	Date: 8/26/09	Time: 10:46

Photo 13 Small arms firing range.

Direction: West	Date: 8/26/09	Time: 10:46

Photo 14 Flagged sampling area for lead.

Direction: West *Date: 8/26/09* *Time: 10:47*

Photo 15 Sign barracks close up.

Direction: West *Date: 8/26/09* *Time: 11:01*

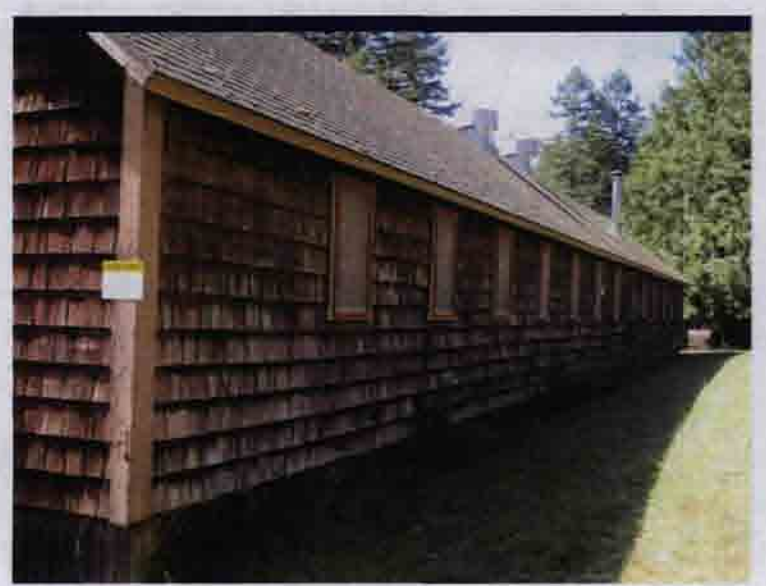

Photo 16 Signs on two sides of barracks.

Direction: Southwest *Date: 8/26/09* *Time: 11:01*

Photo 17 Pesticide storage building.

Direction: West *Date: 8/26/09* *Time: 11:02*

Photo 18 Ranch to southwest corner adjacent to Camp Bonneville.

Direction: Southwest *Date: 8/26/09* *Time: 11:13*

Photo 19 Suspected Demolition Area 3.

Direction: Down *Date: 8/26/09* *Time: 11:20*

Photo 20 Suspected Demolition Area 3.

Direction: Down *Date: 8/26/09* *Time: 11:20*

Photo 21 Gas pipeline corridor through site.

Direction: East *Date: 8/26/09* *Time: 11:22*

Photo 22 Stockpiled soil (800 tons)/Machine gun range.

Direction: North *Date: 8/26/09* *Time: 11:29*

Photo 23 Stockpiled soil (800 tons)/Machine gun range.

Direction: North *Date: 8/26/09* *Time: 11:29*

Photo 24 Lead contaminated area adjacent to Lacamas Creek at weir.

Direction: Southeast *Date: 8/26/09* *Time: 11:33*

Photo 25 Lead contaminated area adjacent to Lacamas Creek at weir.

Direction: Southeast *Date: 8/26/09* *Time: 11:33*

Photo 26 Sign on fuel contaminated building.

Direction: North	Date: 8/26/09	Time: 11:41

C

Fate and Transport Modeling Review

ecology and environment, inc.
International Specialists in the Environment
720 Third Avenue, Suite 1700
Seattle, Washington 98104
Tel: (206) 624-9537, Fax: (206) 621-9832

MEMORANDUM

DATE: February 24, 2010

TO: Monica Tonel, EPA Task Monitor, Seattle, WA Mail Stop ECL-112

FROM: Erin A. Lynch, START-3 Senior Hydrogeologist, E & E, Portland, OR

SUBJECT: Contaminant Fate and Transport Modeling Review for RAU2C (Landfill 4/ Demolition Area 1), Camp Bonneville Site, Clark County, Washington
EPA Site ID Number WAN001002030

REFERENCE: Contract Number: EP-S7-06-02
Technical Direction Document Number: 09-05-0001

cc: Renee Nordeen, E & E Project Manager, Seattle, WA

The United States Environmental Protection Agency (EPA) has tasked Ecology and Environment, Inc. (E & E) under Superfund Technical Assessment and Response Team (START)-3 Contract Number EP-S7-06-02, Technical Direction Document Number 09-05-0001, to provide technical support for completion of a Preliminary Assessment (PA) for the Camp Bonneville Site. The subject model review of contaminant fate and transport modeling of RAU2C (Landfill 4/ Demolition Area 1) is intended to support this work. All modeling reviewed in this document was completed by contractors to the Washington Department of Ecology (Ecology).

The following documents were reviewed for this technical memorandum:

- DRAFT Remedial Investigation/Feasibility Study RI/FS for Site-Wide Groundwater Remedial Action Unit 2C, Camp Bonneville Military Reservation, 2301 Northeast Pluss Road, Vancouver, WA 98682 (Bonneville Conservation Restoration & Renewal Team, August 2009); and
- DRAFT Perchlorate Evaluation Landfill 4/Demolition Area 1 (RAU 2C), Camp Bonneville Military Reservation, 2301 Northeast Pluss Road, Vancouver, WA 98682 (Bonneville Conservation Restoration & Renewal Team, February 2008).

Site Location and Layout

Camp Bonneville is located in Clark County, approximately 12 miles northeast of Vancouver, Washington (Figure 2-1). Camp Bonneville consists of approximately 3,840 acres of land that was historically used by the United States Department of Defense (DOD) to provide training for active Army, Army Reserve, National Guard, Marine Corps Reserve, Navy Reserve, Coast Guard Reserve units, and other DOD personnel. The installation consists of two cantonment areas (Bonneville Cantonment and Killpack Cantonment), 25 firing ranges, and several known or suspected disposal areas; including Landfill 4/Demolition Area 1 (Woodward Clyde Federal Services 1997).

On February 4, 2003 Enforcement Order 03TCPHQ-5286 was issued for Camp Bonneville. The enforcement order divided the site into three remedial action units (RAUs). The RAUs and their status are described below.

- **RAU 1:** This RAU consists of the 20 acres where hazardous substances other than military munitions have been located.
- **RAU 2:** This RAU consists of the areas where hazardous substances have been located, but not addressed through remedial actions. This RAU has been further subdivided into three subunits.
  - **RAU2A:** This RAU consists of the 21 small arms range areas.
  - **RAU2B:** This RAU consists of Demolition Areas 2 and 3.
  - **RAU2C:** This RAU consists of the Landfill 4 area.
- **RAU 3:** This RAU consists of any area where military munitions may have come to be located.

This technical memorandum focuses on contaminant fate and transport modeling completed for RAU2C Landfill 4/Demolition Area 1.

Hydrogeology and Contamination

Details of the regional and site geologic setting and aquifer system are contained in Section 3.1 of the PA report for the Camp Bonneville Site (E & E 2010). This section briefly summarizes the hydrogeology at Landfill 4/Demolition Area 1. The following hydrogeologic units are present in order from shallowest to deepest: Recent Alluvial Sediments, Lower (Conglomerate) member of the Troutdale Formation, and Basaltic Andesite of the Elkhorn Mountain (see attached USGS map of surficial deposits). Recent alluvium and landslide deposits are present along Lacamas Creek. The alluvial deposits consist of unconsolidated silt, sand, and gravel. Well-rounded quartzite pebbles from the Troutdale Formation are present in these deposits. The Troutdale Conglomerate is present along the west – southwest portion of Camp Bonneville and a remnant is present at Landfill 4/Demolition Area 1 (Figure 2-2, RI/FS RAU2C). The remnant of the Troutdale Conglomerate is not connected to the conglomerate located along the west – southwest portion of the Camp Bonneville. At Landfill 4/Demolition Area 1 the Troutdale Conglomerate reaches a maximum depth of 15 ft and is located above the water table. The Troutdale Aquifer is considered an excellent water-bearing aquifer and in the Camp Bonneville area it has been designated a sole source aquifer. Groundwater occurs in the heavily weathered Basaltic Andesite. This weathered basalt grades to increasingly larger grain sizes with depth. Zones are described as saturated sandy, silty, or clayey (angular) gravels. The Basaltic Andesite generally does not act as an aquifer since it has little capacity to store or transmit water. Fractures have been identified in the Andesite and are reported to be oriented nearly horizontal.

Groundwater flow regionally and at Camp Bonneville is thought to follow topography with Lacamas Creek serving as a discharge location for groundwater during most of the year. Where groundwater doesn't discharge to Lacamas Creek, it is thought to follow surface water flow to the south – southwest. Groundwater contours for the site are shown in Figure 2-3 from the RI/FS for RAU2C which is attached to this memorandum.

Perchlorate and Royal Demolition Explosive (RDX) have been identified in soil and groundwater at the Landfill 4/Demolition Area 1. The perchlorate is thought to be present from disposal of fireworks at the site in the 1960's (BCCRT 2009). Three pits were identified that had apparently been used for burning fireworks. The pits were dug well into the heavy clay soil and one pit was completed into the saturated zone. Based on site observations, it appears that excess fireworks were placed in the pits and soaked with diesel oil prior to ignition. Not all fireworks were combusted; intact fireworks were recovered during a removal action. Because the landfill area is not thought to have significant infiltration, the contamination of groundwater by perchlorate is thought to be the result of fireworks that were placed in the pit that encountered the saturated zone. An Interim Removal Action in which contaminated soils were removed was completed at Landfill 4/Demolition Area 1 however; some impacted soils containing residual perchlorate were left in place. Quarterly monitoring indicates perchlorate concentrations in groundwater samples from monitoring wells at and downgradient of the Landfill 4/Demolition Area 1 have been variable. As presented in the 4th Quarter groundwater sampling and analysis report from 2006 (PBS 2007) and in the draft RI/FS report for RAU2 - Landfill 4/Demolition Area 1 (BCRRT 2000) perchlorate concentrations appear to show both seasonal and longer term fluctuations. Monitoring well locations are indicated in Figure 3.8 from the RI/FS for RAU2C which is attached to this memorandum. Note monitoring well LF4-MW02 is considered to be hydraulically downgradient of the area where the highest perchlorate concentrations were found in soil. Quarterly groundwater sampling results for perchlorate are shown in an attachment (Appendix A, BCRRT 2008) to this memorandum. Perchlorate concentrations in groundwater from monitoring wells L4-MW 2A (shallow) and LF4-MW 2B (deep) are the highest of all of Landfill 4/Demolition Area 1 monitoring wells, fluctuate seasonally, and show a slightly increasing overall trend. All concentrations are greater than the 15 microgram per liter (ug/L) EPA Preliminary Remediation Goal (PRG) for tap water (EPA 2009).

Surface water samples were collected from the North Fork Lacamas Creek in 2009 from the following locations:

- Upstream/northwest of MW-4A;
- Directly across/west of LF4-MW2A&B pair; and
- Downstream/south where the creek goes through two 90 degree bends and the mapped remnant Troutdale conglomerate pinches out.

All samples resulted in nondetects for perchlorate.

Contaminant Fate and Transport Modeling

Two types of models have been used to evaluate the fate and transport of perchlorate and RDX in the vadose zone and in groundwater in Landfill 4/ Demolition Area 1 at Camp Bonneville. Model input and output for vadose zone modeling are contained in Appendix D (not provided for review) and groundwater mass transport modeling are contained in Appendix E of the RI/FS for RAU2C.

Vadose Zone Modeling

VLEACH was utilized for contaminant fate and transport modeling within the vadose zone at RAU2C (Ravi and Johnson 1997). VLEACH is a one-dimensional finite difference, vadose zone leaching model. The model is used to estimate impact on groundwater due to the mobilization and migration of organic contaminants located in the overlying vadose zone. VLEACH describes the movement of an organic contaminant within and between three different phases: as a solute dissolved in water, as a gas in the vapor phase, and as an adsorbed compound in the solid phase. The vadose zone is modeled by a series of polygons with input parameters that describe site conditions (e.g., area, height, recharge rate, effective porosity etc.). Distribution coefficients for the contaminant being modeled are defined by the modeler based on published data and are used by VLEACH to calculate the equilibration distribution of the contaminant between the phases.

Results of modeling with VLEACH are commonly used as a preliminary assessment of potential impacts to groundwater because a number of major assumptions are employed. The following assumptions are made in VLEACH:

- Linear isotherms describe the partitioning of the pollutant between the liquid, vapor and soil phases. Local or instantaneous equilibrium between these phases is assumed within each cell.
- The vadose zone is assumed to be in a steady-state condition with respect to water movement. More specifically, the moisture content profile within the vadose zone is assumed to be constant. This assumption will rarely occur in the field. Although moisture gradients cannot be simulated, the user can estimate the impact of various moisture contents by comparing results from several simulations that cover the common or possible ranges in soil moisture conditions.
- Liquid phase dispersion is neglected. Hence, the migration of the contaminant will be simulated as a plug. This assumption causes higher dissolved concentrations and lower travel time predictions than would occur in reality.
- The contaminant is not subjected to in-situ production or degradation. Since organic contaminants, especially hydrocarbons, generally undergo some degree of degradation in the vadose zone, this assumption results in conservative concentration values.
- Homogeneous soil conditions are assumed to occur within a particular polygon. This condition will rarely occur in the field. Although spatial gradients cannot be simulated, the user can estimate the impact of non-uniform soils by comparing results from several simulations covering the range of soil properties present at the site. However, initial contaminant concentrations in the soil phase can vary between cells.
- Volatilization from the soil boundaries is assumed to be either completely unimpeded or completely restricted. This assumption may be significant depending upon the depth of investigation and the soil type. In particular, after a depth of 1 meter volatilization to the atmosphere will decrease significantly.

In addition, the model does not account for non-aqueous phase liquids or any flow conditions derived from variable density.

Model inputs include :.

- *Number of Polygons*. The number of polygons used to conceptualize the site. Each polygon has a unique set of parameter data. For RAU2C, the vadose zone was modeled using three laterally distributed polygons for perchlorate and RDX impacted soil as indicated in the RI/FS for RAU2C. Polygon inputs include:
  - Area and height,
  - Recharge rate for groundwater through the vadose zone,
  - Dry bulk density of soil,

- Effective porosity of the soil,
- Water content in soil,
- Organic content of soil,
- Contaminant concentration in recharge water,
- Contaminant concentration in the atmosphere above the soil surface,
- Contaminant concentration in groundwater at the base of the vadose zone, and
- Initial contaminant concentration.

- *Model Timestep.* A model timestep given in years.
- *Simulation Time.* The simulation time is the total time length for model simulation in years.
- *Organic Carbon Distribution Coefficient (K_{oc}).* Organic carbon distribution coefficients were used for perchlorate and RDX.
- *Henry's Constant (K_h).* The Henry's constants were used for perchlorate and RDX.
- *Water Solubility.* Water solubilities were used for perchlorate and RDX.
- *Free Air Diffusion Coefficient.* The free air diffusion coefficients were used for perchlorate and RDX.

Site specific model inputs are indicated in model result summary sheets for both perchlorate and RDX simulating post-Interim Removal Action (post-excavation) attached to the RI/FS for RAU2C. However, these input values were not available for this review and therefore were not reviewed for this memorandum. Three laterally distributed polygons were modeled separately utilizing VLEACH.

Results of vadose zone modeling at Landfill 4/Demonstration Area 1 indicate for post-excavation that perchlorate in leachate would take over 100 years to reach concentrations less than 1 ug/L and that the peak concentration of RDX leaching to groundwater would occur 24 years after excavation.

Groundwater Modeling

For contaminant fate and transport modeling in groundwater at RAU2C, the Domenico analytical solute transport model (Domenico 1987) was utilized. The Domenico model is a commonly used analytical solution to the advection-dispersion partial-differential equation of organic transport processes in groundwater for a continuous release source.

The model is based on the advection-dispersion partial-differential equation for organic contaminant transport processes in groundwater. Model inputs include hydrogeologic data (seepage velocity, hydraulic conductivity, hydraulic gradient, effective porosity), source data (source thickness, width, and concentration), dispersivity data (longitudinal, transverse, and vertical dispersivity and estimated plume length), adsorption data (retardation factor, soil bulk density, organic carbon partition coefficient (K_{oc}), fraction organic carbon (foc)), biodegradation data (e.g., first-order decay coefficient, dissolved plume solute half-life, etc.).

The use of the analytical model requires contaminant temporal concentration data at a minimum of one source and one downgradient monitoring well. The model is calibrated by adjusting four model-input parameters to fit the pattern of groundwater temporal concentration distribution at the downgradient monitoring well. Once the model is calibrated, it can be used to estimate travel time to a receptor along the contaminant plume centerline given distance, for dissolved organic contaminants in groundwater.

Model assumptions include:
- Transient conditions,
- A continuous release source,
- Homogenous aquifer properties,
- One-dimensional groundwater flow,
- No change in groundwater flow direction or velocity,
- First order degradation rate,
- Contaminant concentration estimated at the centerline of the plume,
- Molecular diffusion based on concentration gradient is neglected, and
- Adsorption in transport process is neglected.

Site specific model inputs are indicated in model result summary sheets (attached) for both perchlorate and RDX simulating post-Interim Removal Action (post-excavation).

Modeling results indicate that perchlorate and RDX should have reached Lacamas Creek within 11.3 years of the disposal of explosives and fireworks in the late 1960's, if no dispersion or retardation had occurred. However, none has been detected in surface water as of the recent sampling. BCRRT attributes these results to another attenuation mechanism such as biodegradation in creek sediments and/or in the root zones of flora along the creek.

Summary and Recommendations

The existing vadose zone contaminant fate and transport model for Landfill 4/Demolition Area 1 at Camp Bonneville is a good screening-level tool. Vadose zone modeling indicates that both perchlorate and RDX will continue to be a source of groundwater contamination at Landfill 4/Demolition Area 4, in the case of perchlorate, for over 100 years.

The existing groundwater contaminant fate and transport model for Landfill 4/Demolition Area 1 at Camp Bonneville is also a good screening-level tool. At the source area, groundwater is within the deeply weathered basaltic andesite. Contaminant fate and transport modeling indicates that perchlorate and RDX should have reached North Fork Lacamas Creek since the burial of explosives and fireworks in Landfill 4/Demolition Area 1 in the late 1960's. However, neither perchlorate nor RDX was detected in surface water samples collected from North Fork Lacamas Creek, adjacent to Landfill 4/Demolition Area 1. This may be due to underestimation of contaminant travel times by the model, dilution by surface water to non-detectable concentrations once contaminants reach Lacamas Creek, or no discharge of contaminated groundwater to Lacamas Creek in the sampled area.

In general, both perchlorate and RDX tend to be persistent in the environment. Perchlorate biodegradation requires anaerobic conditions, the presence of sufficient carbon, and an active perchlorate degrading microbial population (Tipton, et al 2003 and Urbansky and Brown 2003). It is unlikely that biodegradation is occurring at this site. However if biodegradation is occurring, it could be demonstrated by the presence of intermediates of perchlorate degradation.

Adsorption is not a significant attenuation process for RDX since it has a low adsorption coefficient. In addition, anaerobic biodegradation of RDX has been observed to occur more readily and more completely than aerobic biodegradation. (Brannon and Pennington 2002)

The Domenico (1987) model for contaminant fate and transport in groundwater is limited in that it assumes homogeneous aquifer properties, one-dimensional groundwater flow, among other assumptions. Contaminated groundwater from the landfill initially flows within the weathered andesitic basalt as it migrates toward North Fork Lacamas Creek, it likely flows through alluvial sediments. These alluvial sediments would have different hydraulic and organic carbon properties.

In addition, monitoring wells LF4-MW02A&B, located downgradient of Landfill 4/Demolition Area 1, show slightly increasing concentrations of perchlorate even after excavation of contaminated soils. This indicates that perchlorate is still migrating from the area.

To better understand the fate and transport of perchlorate and RDX from Landfill 4/Demolition Area 1, additional plume delineation may be required. This could be accomplished through additional borings and installation of a monitoring well pair between LF4-MW02A&B and the North Fork Lacamas Creek, closer to the creek, and collection of water level and water quality data. A better understanding of groundwater flow, particularly vertical groundwater gradients, could be accomplished through the addition of a paired shallow and deeper monitoring well near the creek.

The Sole Source Troutdale Aquifer along the western edge of Camp Bonneville is of concern with respect to the potential for contamination from Camp Bonneville. The Landfill 4/Demolition Area 1 is several 1,000 feet to the northeast of the Troutdale Aquifer. A more robust model of groundwater flow and contaminant fate and transport could be used to determine if perchlorate and RDX could reach the Troutdale Aquifer. If a more robust model of groundwater flow and contaminant fate and transport at the Camp Bonneville Military Reservation and adjacent Troutdale Sole Source Aquifer is required, a groundwater flow model based on the program MODFLOW is recommended. MODFLOW is a finite-difference model that models groundwater flow in three dimensions (USGS 1983). MODFLOW allows the user to simulate multiple aquifers, incorporate aquifer heterogeneities, and allows for water sources and sinks. If this type of modeling were to be developed for Camp Bonneville, it could be based on the existing USGS groundwater flow model of the Portland Basin (USGS 1996). This model could be refined in the Camp Bonneville area and include layers for the basaltic andesite, the weathered basaltic andesite, the Troutdale Conglomerate, and the alluvial deposits along Lacamas Creek. Such a model could indicate if and where water may be discharging to Lacamas Creek and also if any water is moving under the creek.

In addition, if MODFLOW were to be used for the site, the model MT3D is also recommended for simulating both the perchlorate and RDX fate and transport in groundwater from the Landfill 4/Demolition Area 1. MT3D is a three-dimensional contaminant fate and transport modeling software package that can be used to simulate advection, anisotropic dispersion, first-order decay and product reactions, and linear and nonlinear sorption. Although many of these contaminant properties are modeled in Domenico 1987 based models, MT3D in combination with

MODFLOW provides a more robust solution in part because they can account for more system variables.

Attachments:

PA Report
Figure 2-1 – Site Vicinity Map, Camp Bonneville Preliminary Assessment.

BCCRT (2009)
Figure 2-2 – Site Geology Map
Figure 2-3 – Groundwater Contours
Figure 3.8 – Landfill 4/Demolition Area 1 (RAU 2C), Monitoring Well Locations, Geology Map
Appendix E Results of contaminant fate and transport modeling in groundwater using Domenico 1987 for perchlorate and RDX (post-excavation)

BCCRT (2008)
Appendix A - Plot of Landfill 4 Perchlorate Results

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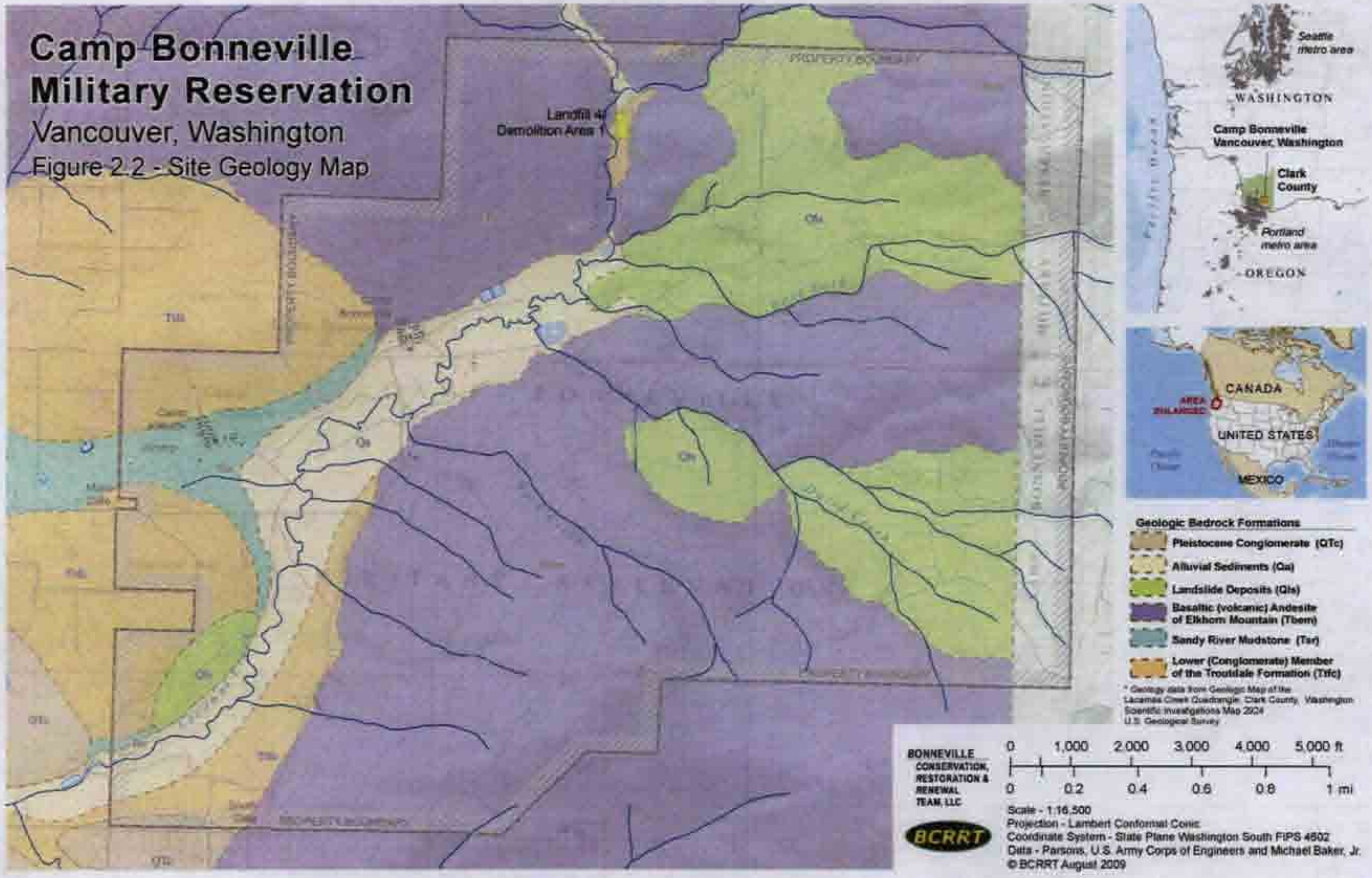
Geologic Map of the Lacamas Creek Quadrangle


Camp Bonneville
Military Reservation
Vancouver, Washington
Figure 2.2 - Site Geology Map
Landfill 4/
Demolition Area 1
Seattle metro area
WASHINGTON
Camp Bonneville
Vancouver, Washington
Clark County
Portland metro area
OREGON
CANADA
AREA ENLARGED
UNITED STATES
MEXICO
Geologic Bedrock Formations
Pleistocene Conglomerate (QTc)
Alluvial Sediments (Qa)
Landslide Deposits (Qls)
Basaltic (volcanic) Andesite of Elkhorn Mountain (Tbem)
Sandy River Mudstone (Tsr)
Lower (Conglomerate) Member of the Troutdale Formation (Ttfc)
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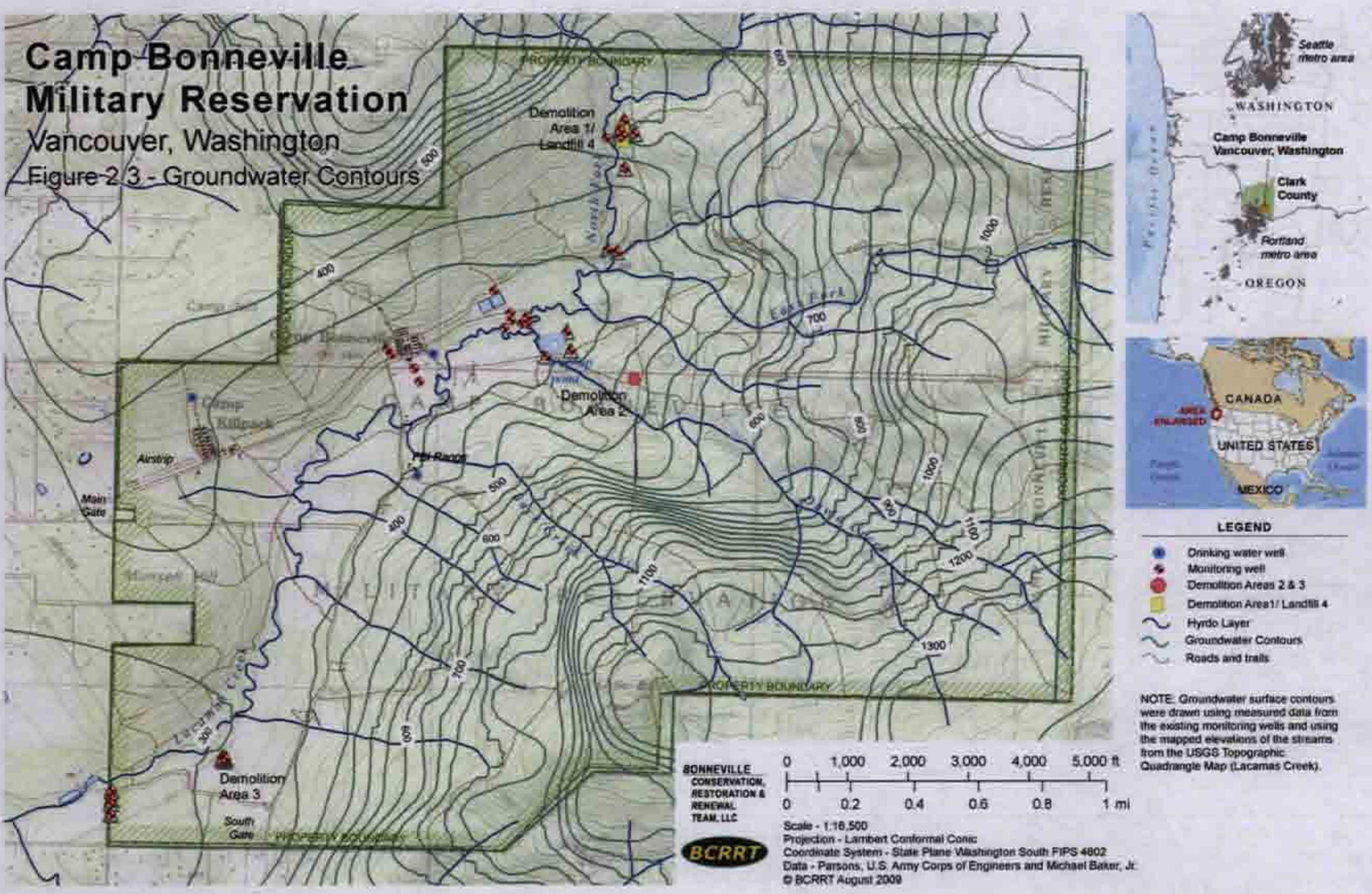
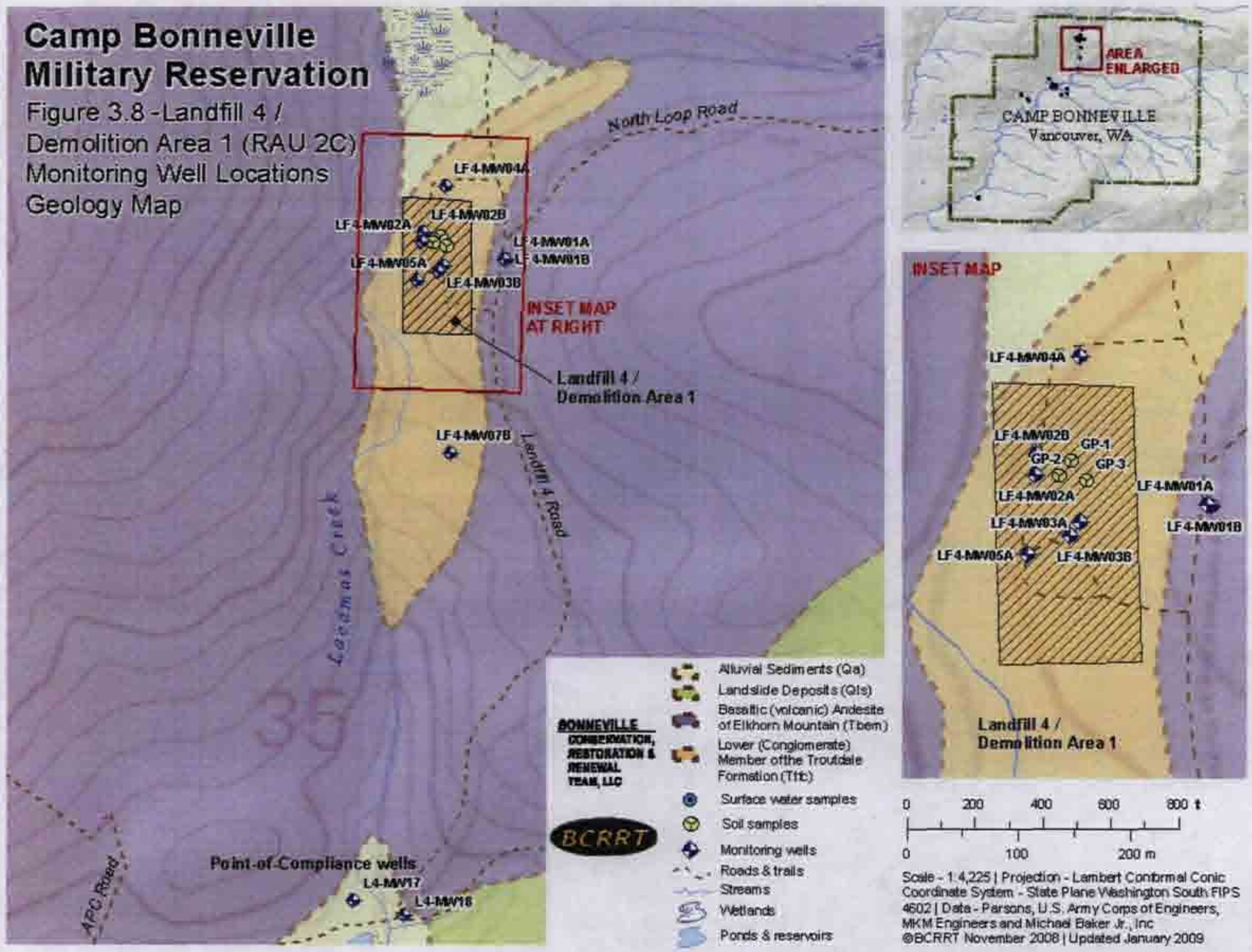
0 1,000 2,000 3,000 4,000 5,000 ft
0 0.2 0.4 0.6 0.8 1 mi
Scale - 1:16,500
Projection - Lambert Conformal Conic
Coordinate System - State Plane Washington South FIPS 4602
Data - Parsons, U.S. Army Corps of Engineers and Michael Baker, Jr.
© BCRRT August 2009


Camp Bonneville
Military Reservation
Vancouver, Washington
Figure 2.3 - Groundwater Contours
Demolition Area 1/ Landfill 4
Demolition Area 2
Demolition Area 3
PROPERTY BOUNDARY
Airstrip
Main Gate
South Gate
Seattle metro area
WASHINGTON
Camp Bonneville Vancouver, Washington
Clark County
Portland metro area
OREGON
CANADA
AREA ENLARGED
UNITED STATES
MEXICO
LEGEND
Drinking water well
Monitoring well
Demolition Areas 2 & 3
Demolition Area1/ Landfill 4
Hyrdo Layer
Groundwater Contours
Roads and trails
NOTE: Groundwater surface contours were drawn using measured data from the existing monitoring wells and using the mapped elevations of the streams from the USGS Topographic Quadrangle Map (Lacamas Creek).
BONNEVILLE CONSERVATION, RESTORATION & RENEWAL TEAM, LLC
0 1,000 2,000 3,000 4,000 5,000 ft
0 0.2 0.4 0.6 0.8 1 mi
Scale - 1:16,500
Projection - Lambert Conformal Conic
Coordinate System - State Plane Washington South FIPS 4602
Data - Parsons, U.S. Army Corps of Engineers and Michael Baker, Jr.
© BCRRT August 2009


Camp Bonneville
Military Reservation
Figure 3.8 - Landfill 4 / Demolition Area 1 (RAU 2C) Monitoring Well Locations Geology Map
North Loop Road
LF4-MW04A
LF4-MW02A
LF4-MW02B
LF4-MW01A
LF4-MW01B
LF4-MW05A
LF4-MW03B
INSET MAP AT RIGHT
Landfill 4 / Demolition Area 1
LF4-MW07B
Landfill 4 Road
Lacamas Creek
35
APC Road
Point-of-Compliance wells
L4-MW17
L4-MW18
Alluvial Sediments (Qa)
Landslide Deposits (Qls)
Basaltic (volcanic) Andesite of Elkhorn Mountain (Tbem)
Lower (Conglomerate) Member of the Troutdale Formation (Ttc)
Surface water samples
Soil samples
Monitoring wells
Roads & trails
Streams
Wetlands
Ponds & reservoirs
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AREA ENLARGED
CAMP BONNEVILLE
Vancouver, WA
INSET MAP
LF4-MW04A
LF4-MW02B
GP-1
GP-2
GP-3
LF4-MW02A
LF4-MW01A
LF4-MW01B
LF4-MW03A
LF4-MW05A
LF4-MW03B
Landfill 4 / Demolition Area 1
0 200 400 600 800 ft
0 100 200 m
Scale - 1:4,225 | Projection - Lambert Conformal Conic Coordinate System - State Plane Washington South FIPS 4602 | Data - Parsons, U.S. Army Corps of Engineers, MKM Engineers and Michael Baker Jr., Inc
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BACK CALCULATION TO SOURCE - ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION							
1ST ORDER DECAY AND RETARDATION							
Project:	Camp Bonneville, Vancouver, WA						
Date:	8/5/2009	Prepared by:	Daniel S. Fisher, P.G.				
	X	Contaminant:	Perchlorate				
RECEPTOR CONC (MG/L)	DISTANCE TO SOURCE(ft)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)
0.011	1900	31.65	31.65	31.65	0	80	40
Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity decimal frac	Soil Bulk Density (g/cm^3)	KOC	Frac Org. Carb.	Retard-ation (R)	V (=K*i/n) (ft/day)
2.33E-01	0.076923077	0.477	1.47	0	1.30E-03	1.000	0.0375
	RECEPTOR LOCATION						
x(ft)	y(ft)	z(ft)					
1900	0	0					
Projected Conc. at SOURCE		1900	0	0		1.30E+00	mg/l
at	steady state						

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MULTIDIMENSIONAL TRANSPORT OF A
DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to include Retardation
STEADY STATE CONDITIONS

BACK CALCULATION TO SOURCE - ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION							
1ST ORDER DECAY AND RETARDATION							
Project:	Camp Bonneville, Vancouver, WA						
Date:	8/5/2009	Prepared by:	Daniel S. Fisher, P.G.				
	X	Contaminant:	Perchlorate				
RECEPTOR	DISTANCE TO	Ax	Ay	Az	LAMBDA	SOURCE	SOURCE
CONC	SOURCE(ft)	(ft)	(ft)	(ft)		WIDTH	THICKNESS
(MG/L)				>=.001	day-1	(ft)	(ft)
0.011	1900	31.65	31.65	31.65	0	80	40
Hydraulic	Hydraulic		Soil Bulk		Frac	Retard-	V
Cond	Gradient	Porosity	Density	KOC	Org. Carb.	ation	(=K*i/n)
(ft/day)	(ft/ft)	decimal frac	(g/cm³)			(R)	(ft/day)
2.33E-01	0.076923077	0.477	1.47	423	1.30E-03	2.695	0.0139
	RECEPTOR LOCATION						
x(ft)	y(ft)	z(ft)					
1900	0	0					
Projected Conc. at SOURCE		1900	0	0		1.30E+00	mg/l
at	steady state						

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BACK CALCULATION TO SOURCE - ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION							
1ST ORDER DECAY AND RETARDATION							
Project:	Camp Bonneville, Vancouver, WA						
Date:	8/5/2009	Prepared by:	Daniel S. Fisher, P.G.				
	X	Contaminant:	Perchlorate				
RECEPTOR	DISTANCE TO	Ax	Ay	Az	LAMBDA	SOURCE	SOURCE
CONC	SOURCE(ft)	(ft)	(ft)	(ft)		WIDTH	THICKNESS
(MG/L)				>=.001	day-1	(ft)	(ft)
0.011	1900	31.65	31.65	31.65	0.002286	80	40
Hydraulic	Hydraulic		Soil Bulk		Frac	Retard-	V
Cond	Gradient	Porosity	Density	KOC	Org. Carb.	ation	(=K*i/n)
(ft/day)	(ft/ft)	decimal frac	(g/cm^3)			(R)	(ft/day)
2.33E-01	0.076923077	0.477	1.47	423	1.30E-03	2.695	0.0139
	RECEPTOR LOCATION						
x(ft)	y(ft)	z(ft)					
1900	0	0					
Projected Conc. at SOURCE		1900	0	0		1.00E+06	mg/l
at	steady state						

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MULTIDIMENSIONAL TRANSPORT OF A
DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation
STEADY STATE CONDITIONS

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION but NO 1ST ORDER DECAY or RETARDATION

Project: Landfill 4, Camp Bonneville, WA

Date: 8/7/2009 Prepared by: Daniel S. Fisher

Contaminant: Perchlorate

MAX SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE day
0.850	1900	31.65	31.65	31.65	0	80	40	N/A

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{OC} (L/kg)	f_{OC} Fraction Org. Carb.	Retardation (R_d)	V (=K*I/n*R) (ft/day)	V (=K*I/n*R) (ft/yr)	K_d (L/kg)	
2.33E-01	0.076923077	0.477	1.47	0	1.30E-03	1	0.03754338	13.7124276	0.00E+00	= K_{OC} f_{OC}
									5.50E-01	<== (for silt soil) Early et al, 2007
									7.60E-01	<== (for clay soil) Early et al, 2007
									8.30E-01	<== Susarla et al, 1999

	y(ft)	z(ft)	Time (days)	Time (years)	
1900	0	0	365,241,825	999,999	Years

Projected Conc. at	1900	0	0
at 365241824.8 days			
0.007 mg/l	< 0.011 mg/L		

AREAL MODEL	CALCULATION DOMAIN
Length (ft)	1900
Width (ft)	1900

	1900	380	570	760	950	1140	1330	1520	1710	1900	
1900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
0	0.007	0.035	0.024	0.018	0.014	0.012	0.010	0.009	0.008	0.007	< 0.011 mg/L
-950	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
-1900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

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Half-Life of perchlorate = 52 hours in agricultural soil

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ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION but NO 1ST ORDER DECAY or RETARDATION

Project: **Landfill 4, Camp Bonneville, WA**

Date: 8/7/2009 Prepared by: **Daniel S. Fisher**

Contaminant: **Perchlorate**

MAX SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE day
0.850	247	12.45	12.45	12.45	0	80	40	N/A

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{oc} (L/kg)	f_{oc} Fraction Org. Carb.	Retardation (R_d)	V (=K*I/n*R) (ft/day)	V (=K*I/n*R) (ft/yr)	K_d (L/kg)	
2.33E-01	0.076923077	0.477	1.47	0	1.30E-03	1	0.03754338	13.7124276	0.00E+00	= K_{oc} f_{oc}
									5.50E-01	<== (for silt soil) Early et al, 2007
									7.60E-01	<== (for clay soil) Early et al, 2007
									8.30E-01	<== Susarla et al, 1999

	y(ft)	z(ft)	Time (days)	Time (years)	
247	0	0	14,244	39	Years

Detectable after	5 years	at the creek (247 feet)
Time to exceed 0.011 mg/L	12 years	at the creek (247 feet)
Max conc. after 39 years	0.129 mg/L	at the creek (247 feet)

Projected Conc. at	247	0	0
at	14244.44541 days		
0.129 mg/l			

AREAL	CALCULATION
MODEL	DOMAIN
Length (ft)	247
Width (ft)	247

	1900	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3	247
247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
123.5	0.000	0.005	0.014	0.022	0.029	0.034	0.037	0.039	0.041	0.041
0	0.000	0.473	0.357	0.286	0.238	0.204	0.178	0.158	0.142	0.129
-123.5	0.000	0.005	0.014	0.022	0.029	0.034	0.037	0.039	0.041	0.041
-247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001

Clausen, J.L., Stephen Clough, Michael Gray, and Patrick Gwinn. 2007. Environmental Screening Assessment of Perchlorate Replacements. U.S. Army Corps of Engineers Engineer Research and Development Center. August 2007.

Early, J.S., R.J. Kondelin, and J.L. Conca. Development of Site-Specific Dilution-Attenuation Factor and Soil Screening Level for Perchlorate Soil Contamination A6. Risk Assessment and Risk-Based Approaches for BioremediationProceedings of the Ninth International In Situ and On-Site Bioremediation Symposium (Baltimore, Maryland; May 7-10, 2007). ISBN 978-57477-161-9, published by Battelle Press, Columbus, OH. www.battelle.org/bookstores.

Robles. H. 2000. *Risk Assessment in Biota, Soil, and Groundwater at Agricultural Site in Southern Californi* a, Chapter 20 in Perchlorate in the Environment, Urbansky, E.T. (ed.). Kluwer Academic/Plenum Publishing, New York
Half-Life of perchlorate = 52 hours in agricultural soil

Susarla, S., S.T. Bacchus, N.L. Wolfe, and S.C McCutcheon. 1999. Phytotransformation of Perchlorate and Identification of Metabolic Products in *Myriophyllum aquaticum* . International Journal of Phytoremediation, Vol. 1, Issue 1. pp. 97-107. http://www.informaworld.com/10.1080/15226519908500007

Miller, Joel P. and Bruce E. Logan. 2000. Sustained Perchlorate Degradation in an Autotrophic, Gas-Phase, Packed Bed Bioreactor. Environ. Sci. Technol. 2000, 34, 3018-3022 *Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802*

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION WITH RETARDATION but NO 1ST ORDER DECAY

Project: **Landfill 4, Camp Bonneville, WA**

Date: 8/7/2009 Prepared by: **Daniel S. Fisher**

Contaminant: **Perchlorate**

MAX SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE day
0.850	247	12.45	12.45	12.45	0	80	40	N/A

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{OC} (L/kg)	f_{OC} Fraction Org. Carb.	Retardation (R_d)	V (=K*i/n*R) (ft/day)	V (=K*i/n*R) (ft/yr)	K_d (L/kg)	
2.33E-01	0.076923077	0.477	1.47	423	1.30E-03	2.694660377	0.01393251	5.08874058	5.50E-01	$= K_{OC} f_{OC}$
									5.50E-01	<== (for silt soil) Early et al, 2007
	y(ft)	z(ft)	Time (days)	Time (years)					7.60E-01	<== (for clay soil) Early et al, 2007
									8.30E-01	<== Susarla et al, 1999
247	0	0	38,716	106	Years					

Projected Conc. at	247	0	0
at 38715.67214 days			
0.129 mg/l			

Detectable after	22 years	at the creek (247 feet)
Time to exceed 0.011 mg/L	32 years	at the creek (247 feet)
Max conc. after 106 years	0.129 mg/L	at the creek (247 feet)

AREAL MODEL	CALCULATION DOMAIN
Length (ft)	247
Width (ft)	247

	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3	247
247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
123.5	0.000	0.005	0.014	0.022	0.029	0.034	0.037	0.039	0.041	0.041
0	0.678	0.473	0.357	0.286	0.238	0.204	0.178	0.158	0.142	0.129
-123.5	0.000	0.005	0.014	0.022	0.029	0.034	0.037	0.039	0.041	0.041
-247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001

Clausen, J.L., Stephen Clough, Michael Gray, and Patrick Gwinn. 2007. Environmental Screening Assessment of Perchlorate Replacements. U.S. Army Corps of Engineers Engineer Research and Development Center. August 2007

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Miller, Joel P. and Bruce E. Logan. 2000. Sustained Perchlorate Degradation in an Autotrophic, Gas-Phase, Packed Bed Bioreactor. Environ. Sci. Technol. 2000, 34, 3018-3022 Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION, 1ST ORDER DECAY, AND RETARDATION

Project: **Landfill 4, Camp Bonneville, WA**
Date: 8/7/2009 Prepared by: **Daniel S. Fisher**
Contaminant: **Perchlorate**

SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE day	
0.850	247	12.45	12.45	12.45	0.00228647	80	40	303.2	<= Half-life as Ti salt - 0.83 yrs (Miller and Logan, 2000)

LAMBDA = LN(2)/HALF-LIFE

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{OC} (L/kg)	f_{OC} Fraction Org. Carb.	Retardation (R_f)	V (=K*i/n*R) (ft/day)	V (=K*i/n*R) (ft/yr)	K_d (L/kg)	
2.33E-01	0.076923077	0.477	1.47	423	1.30E-03	2.694660377	0.01393251	5.08874058	5.50E-01	$= K_{OC} f_{OC}$
									5.50E-01	<== (for silt soil) Early et al, 2007
	y(ft)	z(ft)	Time (days)	Time (years)					7.60E-01	<== (for clay soil) Early et al, 2007
									8.30E-01	<== Susarla et al, 1999
247	0	0	365,241,825	999,999 Years						

Projected Conc. at	247	0	0
at 365241824.8 days			
0.000 mg/l			

Detectable after	N/A years	at the plume (247 feet)
Time to exceed 0.011 mg/L	N/A years	at the plume (247 feet)
Max conc. after 999 years	0 mg/L	at the plume (247 feet)

Maximum Distance for detectable levels is 79 feet.

AREAL MODEL	CALCULATION DOMAIN
Length (ft)	247
Width (ft)	247

	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3	247
247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
123.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.091	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-123.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
-247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Clausen, J.L., Stephen Clough, Michael Gray, and Patrick Gwinn. 2007. Environmental Screening Assessment of Perchlorate Replacements. U.S. Army Corps of Engineers Engineer Research and Development Center. August 2007.

Early, J.S., R.J. Kondelin, and J.L. Conca. Development of Site-Specific Dilution-Attenuation Factor and Soil Screening Level for Perchlorate Soil Contamination A6. Risk Assessment and Risk-Based Approaches for BioremediationProceedings of the Ninth International In Situ and On-Site Bioremediation Symposium (Baltimore, Maryland; May 7-10, 2007). ISBN 978-57477-161-9, published by Battelle Press, Columbus, OH, www.battelle.org/bookstores.

Robles, H. 2000. *Risk Assessment in Biota, Soil, and Groundwater at Agricultural Site in Southern Californi a*, Chapter 20 in Perchlorate in the Environment, Urbansky, E.T. (ed.). Kluwer Academic/Plenum Publishing, Ne
Half-Life of perchlorate = 52 hours in agricultural soil

Susarla, S., S.T. Bacchus, N.L. Wolfe, and S.C McCutcheon. 1999. Phytotransformation of Perchlorate and Identification of Metabolic Products in *Myriophyllum aquaticum* . International Journal of Phytoremediation, Vol. 1, Issue 1. pp. 97-107. http://www.informaworld.com/10.1080/15226519908500007

Miller, Joel P. and Bruce E. Logan. 2000. Sustained Perchlorate Degradation in an Autotrophic, Gas-Phase, Packed Bed Bioreactor. Environ. Sci. Technol. 2000, 34, 3018-3022 Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802

BACK CALCULATION TO SOURCE - ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION							
1ST ORDER DECAY AND RETARDATION							
Project:	Camp Bonneville, Vancouver, WA						
Date:	8/5/2009	Prepared by:	Daniel S. Fisher, P.G.				
	X	Contaminant:	RDX				
RECEPTOR	DISTANCE TO	Ax	Ay	Az	LAMBDA	SOURCE	SOURCE
CONC	SOURCE(ft)	(ft)	(ft)	(ft)		WIDTH	THICKNESS
(MG/L)				>=.001	day-1	(ft)	(ft)
8.00E-04	1900	31.65	31.65	31.65	0	17	2
Hydraulic	Hydraulic		Soil Bulk		Frac	Retard-	V
Cond	Gradient	Porosity	Density	KOC	Org. Carb.	ation	(=K*i/n)
(ft/day)	(ft/ft)	decimal frac	(g/cm^3)			(R)	(ft/day)
2.33E-01	0.076923077	0.477	1.47	0	1.30E-03	1.000	0.0375
	RECEPTOR LOCATION						
x(ft)	y(ft)	z(ft)					
1900	0	0					
Projected Conc. at SOURCE		1900	0	0		9.49E-02	mg/l
at	steady state						

PA DEPARTMENT
OF ENVIRONMENTAL PROTECTION
FATBACK.XLS
"REVERSE MODE" SPREADSHEET
APPLICATION OF
"AN ANALYTICAL MODEL FOR
MULTIDIMENSIONAL TRANSPORT OF A
DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation
STEADY STATE CONDITIONS

BACK CALCULATION TO SOURCE - ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION
1ST ORDER DECAY AND RETARDATION

Project:	Camp Bonneville, Vancouver, WA						
Date:	8/5/2009	Prepared by:	Daniel S. Fisher, P.G.				
	X	Contaminant:	RDX				
RECEPTOR	DISTANCE TO	Ax	Ay	Az	LAMBDA	SOURCE	SOURCE
CONC	SOURCE(ft)	(ft)	(ft)	(ft)		WIDTH	THICKNESS
(MG/L)				>=.001	day-1	(ft)	(ft)
8.00E-04	1900	31.65	31.65	31.65	0	17	2
Hydraulic	Hydraulic		Soil Bulk		Frac	Retard-	V
Cond	Gradient	Porosity	Density	KOC	Org. Carb.	ation	(=K*i/n)
(ft/day)	(ft/ft)	decimal frac	(g/cm^3)			(R)	(ft/day)
2.33E-01	0.076923077	0.477	1.47	270	1.30E-03	2.082	0.0180
	RECEPTOR LOCATION						
x(ft)	y(ft)	z(ft)					
1900	0	0					
Projected Conc. at SOURCE		1900	0	0		**9.49E-02**	**mg/l**
at	steady state						

PA DEPARTMENT
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STEADY STATE CONDITIONS

BACK CALCULATION TO SOURCE - ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION							
1ST ORDER DECAY AND RETARDATION							
Project:	Camp Bonneville, Vancouver, WA						
Date:	8/5/2009	Prepared by:	Daniel S. Fisher, P.G.				
	X	Contaminant:	RDX				
RECEPTOR	**DISTANCE TO**	**Ax**	**Ay**	**Az**	**LAMBDA**	**SOURCE**	**SOURCE**
CONC	**SOURCE(ft)**	**(ft)**	**(ft)**	**(ft)**		**WIDTH**	**THICKNESS**
(MG/L)				**>=.001**	**day-1**	**(ft)**	**(ft)**
8.00E-04	1900	31.65	31.65	31.65	0.001116	17	2
Hydraulic	**Hydraulic**		**Soil Bulk**		**Frac**	**Retard-**	**V**
Cond	**Gradient**	**Porosity**	**Density**	**KOC**	**Org. Carb.**	**ation**	**(=K*i/n)**
(ft/day)	**(ft/ft)**	**decimal frac**	**(g/cm³)**			**(R)**	**(ft/day)**
2.33E-01	0.076923077	0.477	1.47	270	1.30E-03	2.082	0.0180
	RECEPTOR LOCATION						
x(ft)	**y(ft)**	**z(ft)**					
1900	0	0					
Projected Conc. at SOURCE		1900	0	0		**1.00E+06**	**mg/l**
at	**steady state**						

PA DEPARTMENT
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"REVERSE MODE" SPREADSHEET
APPLICATION OF
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MULTIDIMENSIONAL TRANSPORT OF A
DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation
STEADY STATE CONDITIONS

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION but NO 1ST ORDER DECAY or RETARDATION

Project: **Landfill 4, Camp Bonneville, WA**

Date: 8/7/2009 Prepared by: **Daniel S. Fisher**

Contaminant: RDX

MAX SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE day
6.341	1900	31.65	31.65	31.65	0	17	2	N/A

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{oc} (L/kg)	f_{oc} Fraction Org. Carb.	Retardation (R_f)	V (=K*i/n*R) (ft/day)	V (=K*i/n*R) (ft/yr)	K_d (L/kg)
2.33E-01	0.076923077	0.477	1.47	0	1.30E-03	1	0.03754338	13.7124276	0.00E+00

$= K_{oc} f_{oc}$

	y(ft)	z(ft)	Time (days)	Time (years)	
1900	0	0	86,562	237	Years

Reaches maximum concentration of 0.0006 mg/L in MW-17/18 after 237 years.

Projected Conc. at	1900	0	0
at 86562.39903 days			
0.0006 mg/l	< 0.0008 mg/L		

AREAL MODEL	CALCULATION DOMAIN
Length (ft)	1900
Width (ft)	1900

	190	380	570	760	950	1140	1330	1520	1710	1900	
1900	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
950	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
0	0.0057	0.0029	0.0019	0.0014	0.0011	0.0010	0.0008	0.0007	0.0006	0.0006	< 0.0008 mg/L
-950	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
-1900	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Clausen, J.L., Stephen Clough, Michael Gray, and Patrick Gwinn. 2007. Environmental Screening Assessment of Perchlorate Replacements. U.S. Army Corps of Engineers Engineer Research and Development Center. August 2007.

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ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION but NO 1ST ORDER DECAY or RETARDATION

Project: **Landfill 4, Camp Bonneville, WA**

Date: 8/7/2009 Prepared by: **Daniel S. Fisher**

Contaminant: RDX

MAX SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE day
6.341	247	12.45	12.45	12.45	0	17	2	N/A

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{OC} (L/kg)	f_{OC} Fraction Org. Carb.	Retardation (R_f)	V (=K*i/n*R) (ft/day)	V (=K*i/n*R) (ft/yr)	K_d (L/kg)	
2.33E-01	0.076923077	0.477	1.47	0	1.30E-03	1	0.03754338	13.7124276	0.00E+00	$= K_{OC} f_{OC}$

	y(ft)	z(ft)	Time (days)	Time (years)	
247	0	0	4,383	12	Years

Projected Conc. at	247	0	0
at 4382.90628 days			
0.0011 mg/l			

Detectable after	9 years	at the creek (247 feet)
Time to exceed 0.0000 mg/L	12 years	at the creek (247 feet)
Max conc. after 30 years	0.0111 mg/L	at the creek (247 feet)

AREAL MODEL	CALCULATION DOMAIN
Length (ft)	247
Width (ft)	247

	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3	247
247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
123.5	0.0000	0.0001	0.0006	0.0011	0.0014	0.0014	0.0012	0.0009	0.0006	0.0003
0	0.1078	0.0533	0.0340	0.0235	0.0164	0.0111	0.0071	0.0042	0.0023	0.0011
-123.5	0.0000	0.0001	0.0006	0.0011	0.0014	0.0014	0.0012	0.0009	0.0006	0.0003
-247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Clausen, J.L., Stephen Clough, Michael Gray, and Patrick Gwinn. 2007. Environmental Screening Assessment of Perchlorate Replacements. U.S. Army Corps of Engineers Engineer Research and Development Center. August 2007.

US Army. 1983. Environmental fate studies on certain munitions wastewater constituents: Phase IV--Lagoon model studies. Contract no. DAMD17-78-C-8081. Frederick, MD: U.S. Army Medical Research and Development Command, Fort Detrick. Document no. AD A138550. (authored by Spanggord RJ et al.)

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION WITH RETARDATION but NO 1ST ORDER DECAY

Project: Landfill 4, Camp Bonneville, WA

Date: 8/7/2009 Prepared by: Daniel S. Fisher

Contaminant: RDX

MAX SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE day
6.341	247	12.45	12.45	12.45	0	17	2	N/A

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{OC} (L/kg)	f_{OC} Fraction Org. Carb.	Retardation (R_f)	V (=K*I/n*R) (ft/day)	V (=K*I/n*R) (ft/yr)	K_d (L/kg)	
2.33E-01	0.076923077	0.477	1.47	270.0	1.30E-03	2.081698113	0.01803498	6.58713553	3.51E-01	$= K_{OC} f_{OC}$

	y(ft)	z(ft)	Time (days)	Time (years)	
247	0	0	29,219	80	Years

Projected Conc. at	247	0	0
at 29219.3752 days			
0.0111 mg/l			

Detectable after	17 years	at the creek (247 feet)
Time to exceed 0.0066 mg/L	24 years	at the creek (247 feet)
Max conc. after 80 years	0.0111 mg/L	at the creek (247 feet)

AREAL MODEL	CALCULATION DOMAIN
Length (ft)	247
Width (ft)	247

	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3	247
247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
123.5	0.0000	0.0001	0.0006	0.0013	0.0019	0.0024	0.0027	0.0030	0.0031	0.0032
0	0.1094	0.0552	0.0370	0.0278	0.0222	0.0185	0.0159	0.0139	0.0123	0.0111
-123.5	0.0000	0.0001	0.0006	0.0013	0.0019	0.0024	0.0027	0.0030	0.0031	0.0032
-247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001

Clausen, J.L., Stephen Clough, Michael Gray, and Patrick Gwinn. 2007. Environmental Screening Assessment of Perchlorate Replacements. U.S. Army Corps of Engineers Engineer Research and Development Center. August 2007.

US Army. 1983. Environmental fate studies on certain munitions wastewater constituents: Phase IV--Lagoon model studies. Contract no. DAMD17-78-C-8081. Frederick, MD: U.S. Army Medical Research and Development Command, Fort Detrick. Document no. AD A138550. (authored by Spanggord RJ et al.)

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION, 1ST ORDER DECAY, AND RETARDATION

Project:	Landfill 4, Camp Bonneville, WA		
Date:	8/7/2009	Prepared by:	Daniel S. Fisher
		Contaminant:	RDX

LAMBDA = LN(2)/HALF-LIFE

SOURCE CONC (MG/L)	X DISTANCE TO LOCATION OF CONCERN (ft)	A_x (ft)	A_y (ft)	A_z (ft) >=.001	LAMBDA day^{-1}	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	HALF-LIFE days	
6.341	247	12.45	12.45	12.45	0.00111634	17	2	620.9	<= Half-life by Hydrolysis (Clausen et al, 2007)

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity	Soil Bulk Density (g/cm^3)	K_{oc} (L/kg)	f_{oc} Fraction Org. Carb.	Retardation (R_f)	V (=K*i/n*R) (ft/day)	V (=K*i/n*R) (ft/yr)	K_d (L/kg)	
2.33E-01	0.076923077	0.477	1.47	270.0	1.30E-03	2.081698113	0.01803498	6.587135529	3.51E-01	$= K_{oc} f_{oc}$

	y(ft)	z(ft)	Time (days)	Time (years)	
247	0	0	365,241,825	999,999	Years

Projected Conc. at	247	0	0
at 365241824.8 days			
0.0000 mg/l			

Detectable after	N/A years	at the creek (247 feet)
Time to exceed 0.0008 mg/L	N/A years	at the creek (247 feet)
Max conc. after 999 years	0 mg/L	at the creek (247 feet)

Maximum Distance for detectable levels is 123 feet.

AREAL MODEL	CALCULATION DOMAIN
Length (ft)	247
Width (ft)	247

	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3	247
247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
123.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0	0.0397	0.0073	0.0018	0.0005	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
-123.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
-247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Clausen, J.L., Stephen Clough, Michael Gray, and Patrick Gwinn. 2007. Environmental Screening Assessment of Perchlorate Replacements. U.S. Army Corps of Engineers Engineer Research and Development Center. August 2007.

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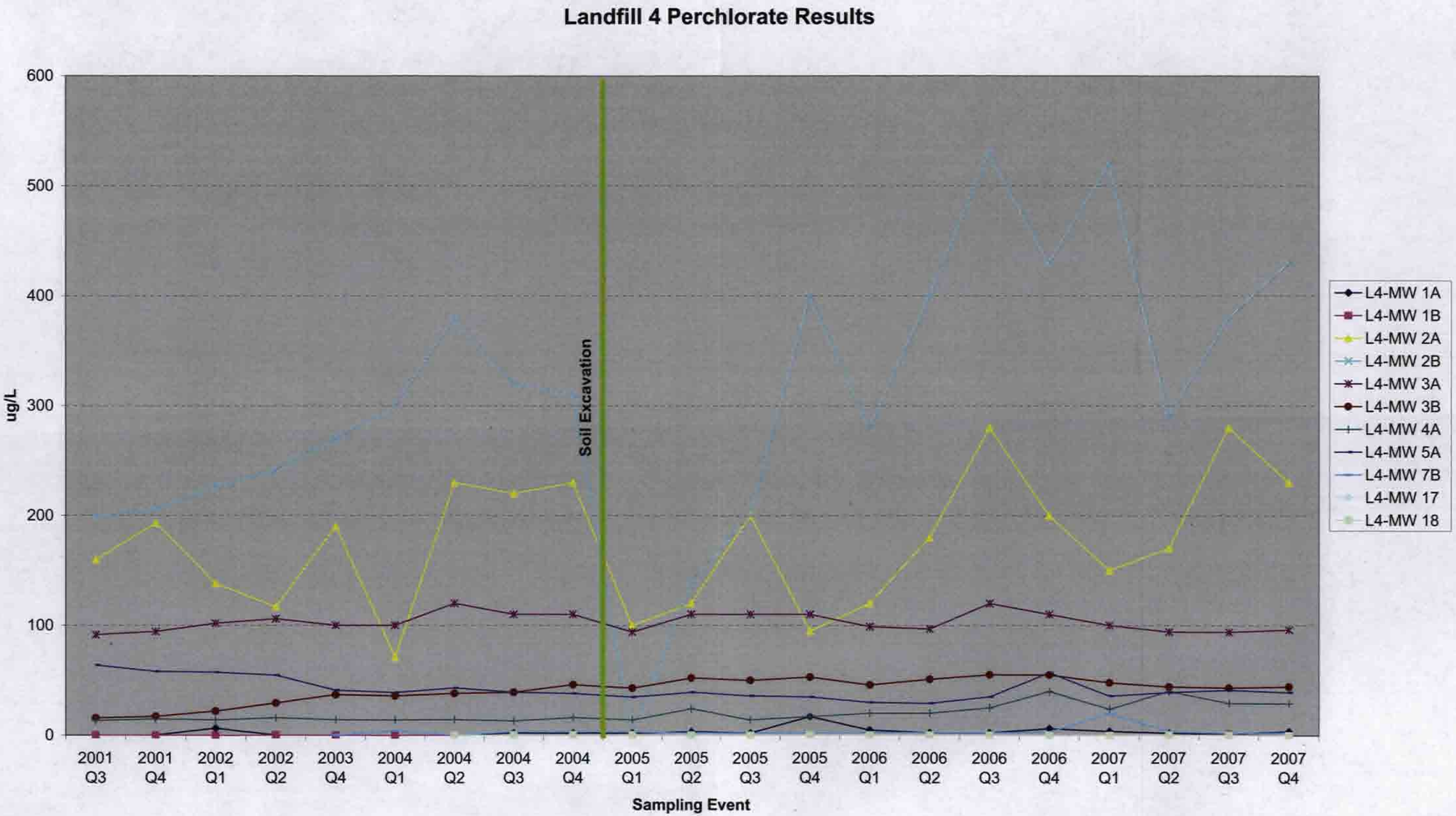

Landfill 4 Perchlorate Results
ug/L
600
500
400
300
200
100
0
Soil Excavation
2001 Q3
2001 Q4
2002 Q1
2002 Q2
2003 Q4
2004 Q1
2004 Q2
2004 Q3
2004 Q4
2005 Q1
2005 Q2
2005 Q3
2005 Q4
2006 Q1
2006 Q2
2006 Q3
2006 Q4
2007 Q1
2007 Q2
2007 Q3
2007 Q4
Sampling Event
L4-MW 1A
L4-MW 1B
L4-MW 2A
L4-MW 2B
L4-MW 3A
L4-MW 3B
L4-MW 4A
L4-MW 5A
L4-MW 7B
L4-MW 17
L4-MW 18