Final
Area of Investigation 6
Remedial Action Completion Report

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, CA

August 2016

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Prepared for:

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, CA

August 2016

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Table of Contents

List of Tables

List of Figures

List of Appendices

List of Acronyms

AOI 6	Area of Investigation 6
bgs	below ground surface
DMJM	Daniel, Mann, Johnson & Mendenhall
DN	Department of the Navy
DTSC	Department of Toxic Substances Control
EKI	Erler & Kalinowski, Inc.
EPA	Environmental Protection Agency
ERT	Earth Resources Technology, Inc.
MCL	maximum contaminant level
NASA	National Aeronautics and Space Administration
NASMF	Naval Air Station Moffett Field
OARF	Outdoor Aeronautics Research Facility
PAI	Professional Analysis, Inc.
PCB	polychlorinated biphenyl
SAIC	Science Applications International Corporation
STLC	soluble threshold limit concentration
TCLP	toxicity characteristic leaching procedure
TPH	total petroleum hydrocarbons
TTLC	total threshold limit concentration
VOC	volatile organic compound
WET	waste extraction test
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
µg/L	micrograms per liter

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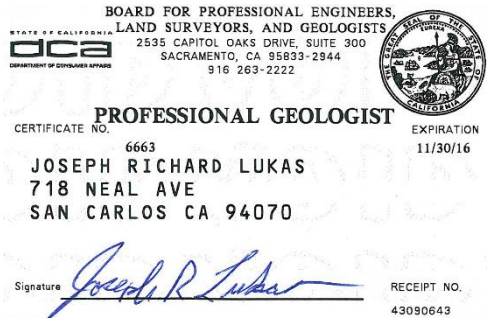

1.0 INTRODUCTION

On behalf of National Aeronautics and Space Administration (NASA) Ames Research Center (NASA Ames), Earth Resource Technology Inc. (ERT) has prepared this Remedial Action Completion Report for Area of Investigation 6 (AOI 6) at Moffett Field, California. Remediation of lead- and polychlorinated biphenyl (PCB)-contaminated soils within AOI 6 has been successfully completed through several voluntary remedial actions. This Report summarizes those soil remedial actions and the associated supportive groundwater monitoring tasks, which documents the current condition of the site and supports and determination by NASA that no further action is necessary to protect human health and the environment.

2.0 SITE BACKGROUND

NASA Ames is located at the southern end of the San Francisco Bay in Santa Clara County adjacent to the cities of Mountain View and Sunnyvale, California (Figure 1). NASA Ames is comprised of the NASA Ames Campus and portions of former Naval Air Station Moffett Field (NASMF), which includes the NASA Research Park. NASA Ames and the NASMF are shown on Figure 2.

2.1. Description of AOI 6

AOI 6 encompasses a former storm water drainage channel that paralleled Lindbergh Avenue, beginning north of Building N250B and terminating south of North Perimeter Road in the northern portion of NASA Ames (Figure 3). Historically, AOI 6 included the approximate 2,000-foot section of the former open storm drain channel and adjacent exposed soils that began near Building N250B (southern end of AOI 6) and terminated at the former diversion box. The AOI 6 boundary was extended north to the culvert outfall at North Perimeter Road based on soil sampling conducted in 2000 to determine the extent of near surface PCBs in the soils adjacent to the entire length of the former channel, and excavation and confirmation sampling of the area north of the former diversion box in 2001 (PAI, 2001a).

Historical aerial photographs dating from May 1940 indicate an open, unlined storm drain channel was used until the construction of a concrete-lined channel in the mid-1960s (EKI, 1994). The channel was approximately 18 inches deep and four feet wide at the top. The storm drain channel collected runoff from the areas along McCord Avenue, King Road, Severyns Avenue, the N211 aircraft ramp, and from the western portion of former NASMF including the area surrounding Hangar 1 (Figure 2). Runoff flowed down the storm drain channel to the former diversion box, where water could be directed west under Lindbergh Avenue into the Eastern Diked Marsh, east to the Building 191 lift station, or both. The former concrete diversion box, which was removed in 1994, was approximately six feet wide by 14 feet long by four feet deep (NASA, 1995).

In the past, the stormwater drainage channel also received periodic, unmonitored discharges of NASA Ames wastewater consisting primarily of cooling tower water, water containing

water treatment chemicals, and wastewater from shop sinks (EKI, 1994). For the last few years before its abandonment in 1993, only local rainwater and surface water from NASA Ames routinely flowed into the storm drain channel. Several documented upgradient spills and releases have also occurred that may have impacted the drainage channel between 1985 and 1990. Table 1 summarizes these documented spills.

A new storm drainage system composed of buried concrete pipe was built in early 1993. The new storm drain piping runs from Building N250B adjacent to Lindbergh Avenue to a settling basin located immediately northeast of the Outdoor Aeronautics Research Facility (OARF) (Figure 3). Upon completion of the new storm drain, the former open storm drain channel was abandoned but remained open and unused until its removal in 1994.

3.0 AOI 6 INVESTIGATIONS AND SOIL REMEDIAL ACTIONS

Beginning in 1990, NASA Ames conducted multiple investigations and soil remedial actions at AOI 6. These actions, summarized on Table 2, were conducted on a voluntary basis with reporting by NASA to the EPA and State. A detailed description of these actions is provided in the following sections of this Report. Supporting historical AOI 6 reports (including maps, laboratory analytical data and manifests) are included in Appendix B.

PCBs and lead were identified as the contaminants of concern in shallow soil within AOI 6 following comprehensive soil sampling conducted in 1994 upon removal of the concrete drainage channel (Section 3.1.2). Increasingly protective PCB and lead cleanup levels were applied to the AOI 6 soil remedial actions due to changing regulatory screening levels as well as site-specific cleanup levels applied at other areas of Moffett Field. Since site-specific cleanup levels had not been established for PCBs and lead at AOI 6 at the time of the first soil characterization sampling in 1994, Department of Toxic Substances Control (DTSC) residential screening levels were applied. Between 1995 and 1999, the total PCBs cleanup level applied for surface soils was an average concentration of less than 1 milligram per kilogram (mg/kg) with a not-to-exceed maximum concentration of 2 mg/kg based on residential screening levels (DTSC, 1998). Although the entire length of the AOI 6 drainage channel area and the area north of OARF Road is classified as "upland grassland," in 1999 a site-specific PCB soil cleanup level of 0.470 mg/kg was conservatively applied to potential "ecologically-sensitive areas" north of OARF Road based on the cleanup level developed for seasonal wetland habitat for Navy IR Site 25 (Tetra Tech EM Inc., 1999). For the area south of OARF Road, the DTSC not-to-exceed residential screening level of 2.0 mg/kg (average of 1.0 mg/kg) was applied for total PCBs (Figure 3).

From 1995 to 2005, a lead cleanup level of 50 mg/kg was applied for areas north and south of OARF Road. During this time, there was no site-specific lead soil cleanup level established for AOI 6 and the 50 mg/kg lead cleanup level was likely based on the value 10 times the Soluble Threshold Limit Concentration (STLC) concentration of 5 mg/kg. In 2005, revised cleanup levels of 0.210 mg/kg for total PCBs and 93.8 mg/kg for lead were conservatively applied for surface soils in potentially ecologically sensitive areas located north of OARF Road (SulTech & Tetra Tech EMI, 2007). These levels were based on the risk-based concentrations for ecological receptors of Navy IR Site 25 (SulTech & Tetra Tech EMI, 2007).

Soil containing lead and total PCBs concentrations greater than the applied cleanup levels was excavated and disposed of offsite at Class I and Class II landfills as appropriate. Following confirmation sampling, the excavated areas were backfilled with clean fill. Approximately 3,600 cubic yards of soil was removed from AOI 6 and disposed of offsite in multiple phases over the period 1995 through 2001. From 1995-1996, approximately 1,800 cubic yards were excavated based on the applied cleanup level of 50 mg/kg for lead and the 1995 DTSC residential screening levels of 2 mg/kg (average of 1 mg/kg) for total PCBs. Confirmation sampling conducted for this excavation indicated PCB- and lead-contaminated soil was successfully removed along the storm drain channel in 91 of the 100 sampling locations. The remaining 9 locations were approximately 8 to 9 feet below ground surface (bgs) where the underlying aquifer (permeable, water-bearing material) was encountered (SAIC, 1997b). At these remaining nine locations, excavation was conducted an additional one to two feet in depth, however additional confirmation samples were not collected.

Following additional soil sampling in 2001, an additional 1,800 cubic yards of soil was excavated from AOI 6 in two phases applying a lead cleanup level of 50 mg/kg (PAI, 2005) and the 1999 total PCBs cleanup levels of 0.47 mg/kg north of OARF Road and 2.0 mg/kg (average of 1.0 mg/kg) south of OARF Road. After the initial excavation, confirmation samples indicated PCB concentrations remained above the cleanup levels and a second phase of excavation was conducted (PAI, 2005). Lead and total PCBs concentrations were below the cleanup levels in all confirmation samples collected along the entire length of the former storm drain channel following the second phase of excavation. The excavated areas were then backfilled with clean fill.

Subsequently, in 2005, revised cleanup levels of 0.210 mg/kg for PCBs and 93.8 mg/kg for lead were applied to surface soils in potentially ecologically sensitive areas located north of OARF Road (SulTech & Tetra Tech EMI, 2007). Total PCBs and lead concentrations in the 2001 confirmation samples were below the 1999 cleanup levels and the revised 2005 cleanup levels in all but two sample locations north of OARF Road. Total PCBs concentrations in the two samples were 0.48 mg/kg (SS-13C-CON) and 0.33 mg/kg (SS-18) (Figure 5). No additional soil excavation or sampling was conducted at AOI 6 since the revised cleanup levels for PCBs and lead were adopted in 2005. The two sample locations are at a depth of approximately 3 feet bgs because the area was backfilled in 2001 following confirmation sampling. At the surface, these locations are heavily vegetated most of the year and are often inundated with water during the rainy season. The total PCBs levels at SS-13C-CON and SS-18 are not significant to ecological receptors because the depth does not present an exposure pathway for the ecological receptors for which the cleanup level is based (wetlands receptors). In addition, PCBs concentrations at the two locations at depth do not present significant potential exposure risk to borrowing owls, a California Species of Special Concern, based on low potential exposure frequency and potential exposure pathway (food chain ingestion). The PCBs ecological cleanup level of 0.210 mg/kg applied to AOI 6 beginning in 2005 was established for Navy IR Site 25 for the most sensitive receptor based on exposure to lead, zinc, and PCBs (SulTech & Tetra Tech EMI, 2007); burrowing owls were not included as a receptor because they do not inhabit Site 25. Also for reference, at Navy IR Site 27 (Northern Channel), a site-specific total PCBs cleanup level of 0.35 mg/kg was determined to be protective of all receptors at the site, including burrowing owls, which

inhabited the area between North Patrol Road ditch and the Northern Channel. The Site 27 total PCBs cleanup level is based on a food chain exposure model and pathway for the most sensitive ecological receptors with available data on chemical effects and associated toxicity values.

Environmental evaluations were previously conducted beyond the former diversion box in both down gradient drainage and discharge areas, which included the Stormwater Retention Pond, Eastern Diked Marsh and the Building 191 pump station discharge areas. Navy IR Site 25, which previously received storm water discharge from AOI 6, comprises the Eastern Diked Marsh and the Storm Water Retention Pond located to the north and west of AOI 6. Site 25 was evaluated in a Remedial Investigation/Feasibility Study completed by the Navy in 2010 (KCH, 2011). The Navy completed a remedial action of Site 25 in 2012, which consisted of sediment excavation and offsite disposal (ITSI Gilbane, 2013). Habitat restoration associated with the remedial action at Site 25 is ongoing. Navy IR Site 27, which includes the Building 191 pump station and the Northern Channel, was investigated in a Remedial Investigation/Feasibility Study by the Navy in 2004-2005. The Navy conducted remediation of Site 27 consisting of sediment excavation and offsite disposal in 2006/2007 (Tetra Tech, 2012).

3.1. Soil Investigations and Remedial Actions

3.1.1. 1990 Sediment Removal

In September 1990, 34 cubic yards of sediment contained within the original, open U-shaped, concrete-lined storm drain channel of AOI 6 were removed and deposited adjacent to the channel on a plastic tarp. The sediment pile was sampled and analyzed for total and soluble metal concentrations, oil and grease, PCBs, and fish toxicity. The sediment was characterized as hazardous waste because the total lead concentration exceeded the California Department of Health Services total threshold limit concentration of 1,000 mg/kg for lead (CWMI, 1990). The sediment was disposed of at the Kettleman Hills Facility, a Class I landfill in King City, California (CWMI, 1990). A copy of the sediment analytical reports and hazardous waste manifests are located in Appendix B.

3.1.2. 1994 Storm Drain Channel Removal and Soil Sampling

Metals, PCBs and petroleum hydrocarbons were detected in the former storm drain (Table 2) as part of the site-wide sampling conducted between 1989 and 1992 (EKI, 1994). Total PCBs and beryllium were the only analytes detected above their respective Total Threshold Limit Concentrations (TTLC). Total PCBs were detected at a maximum concentration of 83 mg/kg and beryllium was detected at a maximum concentration of 150 mg/kg. Based on these results and evidence of past spills (summarized in Table 1), a workplan was developed for a soil investigation following the decommissioning of the storm drain and the removal of the concrete lining. Following installation of the new storm drain system in 1993, the open storm drain was abandoned. In October 1994, the concrete diversion box and concrete lining along the entire length of the abandoned storm drain channel south of the diversion box were removed and soil samples were collected in accordance with the soil investigation

work plan (EKI, 1994).

In October 1994, 98 soil samples were collected at 20-foot intervals from the center of the channel along the length and at a depth of approximately 2 to 3 inches below the base of the former concrete channel (Figure 4). All samples were analyzed for priority pollutant metals, total petroleum hydrocarbons (TPH)-diesel, PCBs, and organochlorine pesticides. One-third of the samples were also analyzed for halogenated volatile organic compounds (VOCs by EPA Method 8015). The analytical results indicated the presence of PCBs, diesel-range petroleum hydrocarbons and metals (NASA, 1995). No VOCs or organochlorine pesticides were detected above laboratory reporting limits in any samples.

PCBs were detected in 56 samples, and nine samples contained PCBs concentrations above the 50 mg/kg TTLC for PCBs. Lead concentrations were greater than 10 times the STLC of 5 mg/L in 53 of 72 samples where lead was detected. All other detected metals, including beryllium, which was detected above the TTLC during the 1989-1992 site-wide sampling, were within or near normal background levels (Scott, 1991). TPH-diesel was detected above the cleanup level of 400 mg/kg (DN, 1994) in only one sample (NASA, 1995). Based on these concentrations, total PCBs and lead were identified as the contaminants of concern (NASA, 1995).

3.1.3. 1995 – 1996 Excavation and Soil Sampling

Based on the 1994 soil sampling results, extensive excavation and soil sampling took place beneath the footprint of the former concrete-lined storm drain channel between June 1995 and May 1996 applying the cleanup levels of 2.0 mg/kg (with an average of 1.0 mg/kg) for total PCBs and 50 mg/kg for lead (SAIC, 1997b). The entire length of the channel south of the former diversion box was over-excavated an additional one foot in depth (bringing the total excavation depth to approximately 3.5 feet bgs). Soil confirmation samples were collected from the bottom and sidewalls of the excavated areas and additional excavation and sampling was conducted at locations where PCBs and lead concentrations exceeded the cleanup levels. Approximately 1,800 cubic yards of soil were removed and 487 soil samples were collected from 100 locations from the former storm drain channel between June 1995 and May 1996 (SAIC, 1997b).

The confirmation samples were collected at the original 98 locations sampled in October 1994 and two additional locations at the former diversion box, for a total of 100 locations (Figure 4). Total PCBs concentrations were below the cleanup level of 1 mg/kg at 95 of the 100 sampling locations and lead concentrations were below the cleanup level of 50 mg/kg at 96 of the 100 locations. Total PCBs and lead were still present above the cleanup levels at the remaining nine locations even after several iterations of soil removal extending to depths to aquifer material (SAIC, 1997b). An additional one to two feet of soil was removed from the nine locations; however, due to the presence of saturated aquifer material at these depths, additional confirmation soil samples were not collected.

For disposal characterization, 45 composite samples were collected from the approximately

1,800 cubic yards of excavated soil and analyzed for lead and PCBs using the Toxicity Characteristic Leaching Procedure (TCLP). Of the 1,800 cubic yards of soil, 1,640 cubic yards was disposed off-site at Class I and Class II landfills. Soil containing total PCBs concentrations between below 50 mg/kg and TCLP lead concentrations less than 5 milligrams per liter (mg/L) was shipped by rail to a non-RCRA, non-TSCA Class II landfill in East Carbon, Utah. Soil containing total PCBs greater than 50 mg/kg or TCLP lead greater than 5 mg/L was transported to a Class I landfill in Beatty, Nevada. Approximately 360 cubic yards of soil with total PCBs concentration less than 1 mg/kg and lead concentrations less than 50 mg/kg were returned to the channel (SAIC, 1997b). The channel was subsequently backfilled to surface grade with clean, imported soil and compacted (SAIC, 1997b).

To verify that the PCBs present in the channel soil did not affect groundwater quality, two groundwater monitoring wells were installed in the immediate vicinity of the former channel in February 1997 (SAIC, 1997b). The wells were installed approximately five feet down-gradient of soil sample locations SD-77 and SD-88 where total PCBs concentrations were detected at 44 mg/kg at 7 feet bgs and 5.7 mg/kg at 8 feet bgs, respectively. Additional discussion related to these wells is included in Section 3.3. It is noted that PCBs were not detected in a groundwater sample collected on January 25, 1996 from a shallow aquifer well (WNB-9) located approximately 10-feet downgradient of the former diversion box (SAIC, 1997b).

3.1.4. 1997 Groundwater Monitoring Well Installation & Soil Sampling

Groundwater monitoring wells 10J08A/11M25A and 10J09A (Figure 3) were installed on February 28, 1997 down gradient from the locations of the two highest residual soil PCB concentrations (SAIC, 1997b). Results of groundwater monitoring are presented in Sections 3.3 and 3.5. Two soil samples were also collected from each well boring (four samples total) and were analyzed for PCBs, lead, and Total Extractable Petroleum Hydrocarbons (TEPH). Total PCBs were detected in both samples collected from well boring 10J08A/11M25A at concentrations of 58 mg/kg and 2.8 mg/kg for sample depths 2.0 to 2.5 feet bgs and 6.5 to 7.0 feet bgs, respectively. Lead was detected in all four samples with concentrations ranging from 5.5 mg/kg to 34 mg/kg. TEPH was detected in all four samples with concentrations ranging from 5.0 mg/kg to 44 mg/kg.

In July 1997, Daniel, Mann, Johnson & Mendenhall (DMJM) collected six soil samples at an approximate depth of 2 to 2.5 feet bgs to laterally characterize concentrations of near surface PCBs and metals in the immediate vicinity of the groundwater monitoring wells (DMJM, 1997a). The soil samples were analyzed for priority pollutant metals and PCBs. Lead was detected in all six samples, with concentrations ranging from 6.7 mg/kg to a maximum of 47 mg/kg (DMJM, 1997a). The PCB Aroclor 1254 was detected in two of the soil samples at concentrations of 0.23 mg/kg and 2.5 mg/kg (DMJM, 1997a).

Based on these soil sampling results, it was determined that the lateral PCBs soil concentrations were likely the result of periods of high stormwater flow when it was common for excess storm water to would flow beyond the limits of the channel and pond into the topographic low area adjacent to the newly installed wells (SAIC, 2000). As a result,

a soil sampling work plan to determine the extent of near surface PCBs in the soil along the northern portion of AOI 6 was developed (SAIC, 2000).

3.1.5. 2000 Soil Sampling

In June 2000, Professional Analysis, Inc. (PAI) collected 88 surface soil samples adjacent to and along the entire length of the former storm drain channel, extending north of the former diversion box (PAI, 2000). Samples were collected at depths between 0 to 6 inches at intervals of 50 feet north-south and 40 feet east-west, with sample locations measured 20 feet from the centerline (1994 samples) of the former storm drain channel (PAI, 2001a). Samples were collected from locations SD-SS-1 through SD-SS-88 (Figure 5) and were analyzed for PCBs, including Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262 and 1268.

Aroclors 1254, 1260, 1262 and 1268 were detected in the upper six inches of soil at 20 locations along the length of the former channel (PAI, 2001a). Total PCBs concentrations at these sample locations ranged from 0.8 mg/kg to 18.6 mg/kg and several areas of impacted soil were identified for excavation based on the PCB sampling results.

In the area north of OARF Road, PCBs concentrations in soil samples located within the entire area north of the former diversion box and five isolated areas located between the former diversion box and OARF Road were above the applied ecological cleanup level of 0.47 mg/kg (Figure 6; note that the shaded area immediately north of OARF Road is considered two separate but adjacent areas). Lead was also detected above the cleanup level of 50 mg/kg in the entire area north of the former diversion box, however lead concentrations were not detected above the cleanup level in the five isolated areas of elevated PCBs concentrations between the former diversion box and OARF Road.

Soil samples contained PCBs concentrations above the 2 mg/kg not-to-exceed residential screening level (DTSC, 1998) in three isolated areas south of OARF Road (Figure 6). Concentrations of lead above the cleanup level of 50 mg/kg were also detected in select soil samples. An excavation plan was developed to address these additional areas within AOI 6: north of OARF Road and south of OARF Road, as shown on Figure 6 and Figure 7 (PAI, 2001b).

After the areas requiring excavation were identified, additional soil samples were collected from these areas and formed into 11 composite samples for total lead analysis (PAI, 2001a). Six composite samples collected from locations north of the former diversion box and one sample collected south of the former diversion box and OARF Road contained concentrations of lead above the 50 mg/kg cleanup level, with concentrations ranging from 56 mg/kg to 210 mg/kg (PAI, 2001a).

3.1.6. 2001 Soil Sampling, Excavation and Confirmation Sampling

From September 2001 to October 2001, an additional 1,800 cubic yards of soil was excavated from AOI 6. The excavation plan, which was developed following the soil sampling

conducted in 2000, was implemented by removing the top one foot of soil from the entire area north of the former diversion box and eight areas located south of the former diversion box. The areas south of the former diversion box included five locations north of OARF Road and three locations south of OARF Road (see shaded areas on Figures 6 & 7; note that the shaded areas around sample locations 31 and 33 in Figure 7 are considered separate areas). The DTSC not-to-exceed total PCBs residential soil screening level of 2 mg/kg (with an average of 1 mg/kg) was applied south of OARF Road and the total PCBs cleanup level for ecologically sensitive areas of 0.47 mg/kg was applied north of OARF Road.

Excavation of the top one foot of soil from these areas (shown in green in Figure 7) was conducted followed by confirmation sampling at each excavation area. Lead was detected in the confirmation samples at concentrations ranging from 7.5 mg/kg to 410 mg/kg. PCBs were detected in 30 of the 76 total confirmation soil samples, with a maximum total PCBs concentration of 6 mg/kg.

Based on the confirmation soil sampling results, nine areas defined by the individual soil sample locations were identified for additional excavation (Figure 8, the nine areas requiring additional excavation are outlined in red). Six of these areas were north of the former diversion box and three were south of the former diversion box. Soil was excavated from these areas to a depth of one foot. Following excavation, confirmation samples were collected from the original confirmation sample locations. Lead and PCBs concentrations were either not detected or below the applied cleanup levels (PAI, 2005) in all samples.

Approximately 1,150 cubic yards of soil containing lead above 50 mg/kg, lead STLC concentrations above 5 mg/L or total PCBs concentrations above the PCBs cleanup levels was disposed of at the Kettleman Hills Class I Landfill in King City, California. The remaining approximately 650 cubic yards of soil was disposed of at the Altamont Class II Landfill near Livermore, California. Clean fill from an onsite reuse soil stockpile was used to backfill and compact the excavated areas.

As discussed in Section 3, two confirmation samples, SS-13C-CON and SS-18 (Figure 8), contain total PCBs concentrations greater than the revised ecological cleanup level of 0.210 mg/kg adopted in 2005 in the area north of OARF Road. The total PCBs concentrations are 0.48 mg/kg in sample SS-13C-CON and 0.33 mg/kg in sample SS-18. However, these concentrations are isolated and occur at depths of approximately 3 feet bgs because the area was backfilled with clean fill subsequent to the 2001 excavation. All other PCBs and lead concentrations in AOI 6 soil, which were reduced below the 1999 cleanup levels in 2001, meet the revised cleanup levels adopted in 2005.

3.2. Geology/Hydrology

Geologic cross-section A-A' (Figure 9) was generated for the local AOI 6 lithology using boring logs of wells 11M25A, 11E01A (destroyed), 10J09A, WNB-9, 11E02A, and WNB-02A1. The cross-section illustrates that the lithology in the AOI 6 area is predominantly clay and silt with discontinuous occurrences of clayey sand and clayey gravel lenses and interbeds of

silt and clayey gravels. The coarse-grained aquifer sediments underlying the AOI 6 area occur at depths of 9 feet bgs to 15 feet bgs, and range in thickness from approximately 3 to 7.5 feet. The depth to groundwater beneath AOI 6 varies from 1 to 3 feet. Groundwater at NASA Ames generally moves in a northeast direction (ERT, 2014). Due to the presence of the overlying low permeability clays and silts, downward migration of surface contamination into the underling aquifer materials beginning at 9 feet bgs is highly unlikely and therefore is not considered a potential path of contaminant migration.

Once encountered, the aquifer materials are comprised of relatively thin, apparently discontinuous lenses of well-graded clayey sands and interbeds of silt and clayey gravels. Horizontal migration of contaminants would be expected to be low.

Based on recent groundwater gauging events, the horizontal groundwater gradient across AOI 6 was 0.0016 foot/foot. This low horizontal gradient, combined with the relatively poor hydraulic conductivity associated with the aquifer materials, suggests that groundwater flow velocity in the vicinity of AOI 6 is low. Utilizing Darcy's Law, an approximate estimate of the average linear groundwater velocity in this area was calculated to be approximately one foot per year.

3.3. AOI 6 Groundwater Monitoring

Prior to 1996, AOI 6 area groundwater was not monitored for PCBs or lead. A groundwater sample was collected in January 1996 from Navy "A" aquifer monitoring well WNB-9, located approximately 10 feet to the north of the former diversion box (see Figure 3). The sample was analyzed for PCBs and VOCs only. The sample was non-detect for PCBs, but contained concentrations of 1,2-Dichloroethane, Tetrachloroethene and Trichloroethene below each respective cleanup level (SAIC, 1997b).

To determine if groundwater had been impacted, groundwater in the vicinity of AOI 6 was monitored for contaminants of concern. NASA groundwater monitoring wells 10J08A/11M25A and 10J09A (Figure 7) were installed in February 1997 down gradient from the locations of the two highest residual soil PCB concentrations detected during the 1996 confirmation sampling (Figure 3) (SD-77 and SD-88) (SAIC, 1997).

Existing wells 11E02A (installed during January 1991 to monitor shallow groundwater at AOI 6) and 10J08A (replaced by 11M25A in January 2002) were monitored on a semi-annual basis from 1997 to 2008 and 1995 to 2008, respectively, with analysis focusing on lead and PCBs. Sampling of well 10J09A was conducted periodically through 2004 and was terminated when semi-annual sampling of 11E02A and 11M25A was initiated. Well sampling results are detailed in Section 3.6.1.

The groundwater monitoring wells used to analyze groundwater impact are located directly down gradient from the locations of the two highest residual soil PCB concentrations (SAIC, 1996). Sampling of these wells provide sufficient data for evaluating AOI 6 area groundwater because these wells are directly down gradient of the previous contamination sources, with the groundwater flow direction normal to the historical AOI 6 soil sampling, excavation and

removal area. All other nearby groundwater wells are located hydraulically lateral to AOI 6 and are therefore not impacted by historical AOI 6 soil contamination.

3.4. Groundwater Quality

Federal and California Drinking Water Maximum Contaminant Levels (MCL) were used to evaluate groundwater quality. The current groundwater MCL for PCBs is 0.5 micrograms per liter (µg/L) and the MCL for lead is 15 µg/L, which replaced the previous MCL of 50 µg/L.

3.5. Groundwater Analytical Results

The following sections discuss the analytical results of groundwater sampling of AOI 6 area wells 10J08A/11M25A, 10J09A, and 11E02A. The results are summarized in Table 3 (Well 10J08A/11M25A), Table 4 (Well 10J09A), and Table 5 (Well 11E02A). The well locations are shown on Figures 3 and 7.

3.5.1. PCBs in Groundwater

Groundwater from well 10J08A/11M25A was analyzed for PCBs in 24 samples collected between September 1997 and September 2008 (Table 3). PCBs were detected in just three of the 24 sampling events. Aroclor 1260 was detected at 1.2 µg/L in the June 2001 sampling event, Aroclor 1254 was detected at 1.8 µg/L in the August 2001 sampling event, and Aroclor 1016 was detected at 1.5 µg/L in the March 2003 sampling event. PCBs were not detected in this well in the following 10 sampling events.

Groundwater from well 10J09A was analyzed for PCBs in 13 samples collected between September 1997 and September 2004 (Table 4). Aroclor 1260 was detected in one of the 13 sampling events at a concentration of 0.97 µg/L in March 2004.

Groundwater from well 11E02A was analyzed for PCBs in 28 samples collected between March 1995 and September 2008 (Table 5). PCBs were not detected in any of the samples.

3.5.2. Lead in Groundwater

Groundwater from well 10J08A/11M25A was analyzed for total lead in 24 samples collected between September 1997 and September 2008 (Table 3). The groundwater samples were not filtered prior to testing. Lead was detected in 10 of the initial 24 sampling events at concentrations ranging from 5.1 µg/L to 42 µg/L. The MCL of 15 µg/L was exceeded in six of the samples. Lead was not detected above the MCL in samples collected after September 2004. Lead was also not detected above the laboratory reporting limit (5.0 µg/L) in the last four sampling events.

Groundwater from well 10J09A was analyzed for lead in 14 samples collected between September 1997 and September 2004 (Table 4). Lead was detected in seven of the 14 samples at concentrations ranging from 6.9 µg/L to 33 µg/L. The MCL of 15 µg/L was exceeded in one of the samples (33 µg/L in September 2003).

Groundwater from well 11E02A was analyzed for lead in 25 samples collected between March 1995 and September 2008 (Table 5). Lead was detected in two of the samples at concentrations of 31 µg/L (March 2001) and 15 µg/L (September 2006). Lead was not detected above the reporting limit (5.0 µg/L) in the last four sampling events.

3.6. Groundwater Monitoring Summary

3.6.1. Analytical Results

As summarized in Table 6, PCBs were detected in groundwater in only 4 of 65 total samples. Although lead was detected with greater frequency (19 of 63 samples), it is also naturally occurring in the soil and groundwater at NASA Ames. In fact, the average background concentration (17 µg/L) exceeds the MCL for lead (15 µg/L) (Lacy, 1998). The highest reported concentration of lead in AOI 6 groundwater (42 µg/L) is within the concentration range of background levels of lead at NASA Ames (0.08 µg/L to 50 µg/L). Furthermore, lead was at or below the MCL during the last seven sampling events

4.0 CONTAMINANT FATE AND TRANSPORT

4.1. PCBs

PCBs are highly hydrophobic and tend to strongly adsorb to soil and sediment when released to soil and/or groundwater. Based on soil sorption coefficients and octanol/water coefficients, Chan and Griffen classify soil mobility for PCBs as "immobile" (Waid, 1986).

The presence of oil can increase the mobility of PCBs. There is little evidence for oil as a primary contaminant in AOI 6; mineral oil and hydraulic oil have not been identified as significant contaminants from samples collected within AOI 6. In addition, the historical age of the releases indicate that it is unlikely that significant concentrations of oils are present.

The presence of solvents can also increase the mobility of PCBs. However, during the initial phases of investigation at AOI 6, solvents were not detected in soils. Groundwater within AOI 6 contains low concentrations of the dissolved solvents tetrachloroethene, trichloroethene, *cis*-1,2-dichloroethene, and 1,1-dichloroethane. The maximum reported concentration of these solvents in the AOI 6 areas is 3.2 µg/L. These low levels of solvents are not expected to have any significant impact on the mobility of PCBs.

4.2. Lead

The background concentrations for lead in groundwater at NASA Ames range from 0.80 µg/L to 50 µg/L. The average background level for lead in groundwater at NASA Ames is 17 µg/L (Lacy, 1998). Background lead concentrations in soil ranges from 2 mg/kg to 200 mg/kg, with an average of 30 mg/kg (Marieta, 1992).

The majority of lead that is released to the environment is retained in surface soils. The primary processes influencing the fate of lead in soil include adsorption, ion exchange, precipitation, and complexation with sorbed organic material. These processes limit the

amount of lead that can be transported into the groundwater (GWRTAC, 1997). In general, lead will be retained in the upper one to two inches of soil, especially soils with at least 5% organic matter or a pH 5 or above. Leaching is not important under normal conditions (EPA, 2006).

Lead is effectively removed from groundwater by adsorption to organic matter and clay minerals contained in sediment, precipitation as insoluble salts, and reaction with hydrous iron and manganese oxide. Under most circumstances, adsorption predominates (EPA, 2006).

The conditions for adsorption of lead by surface soils are highly favorable within AOI 6 due to the presence of abundant organic matter and clay minerals in the surface and near surface soils. Adsorption of lead is also enhanced by a groundwater pH ranging from 7.4 to 7.9. Based on the high clay content of surface and near surface soils at AOI 6, the majority of lead was most likely adsorbed to the surface soils. In the situation where lead may have potentially migrated beyond the surface soils, the pH of groundwater along with the aquifer materials will enhance the retention of lead in the aquifer sediments.

5.0 CONCLUSIONS

Remediation of lead- and PCB-contaminated soils within AOI 6 has been successfully completed through several remedial actions. Most of the PCBs and lead detected in soil at AOI 6 were most likely adsorbed to soils that were subsequently removed within and adjacent to the former drainage channel. Extensive soil confirmation sampling indicates that remaining PCBs and lead concentrations are below the conservative soil cleanup levels adopted in 2005, except at two sample locations north of OARF Road (SS-13-CON and SS-18) where total PCBs concentrations are greater than the conservatively applied cleanup level of 0.210 mg/kg for the sensitive ecological receptors of Site 25. However, the concentrations of total PCBs at these two locations are not significant to potential ecological receptors because they are located in an area that is no longer part of the site drainage system and are at depths of approximately 3 feet bgs in areas that were backfilled to grade with clean fill. Groundwater monitoring also indicates PCBs and lead concentrations to be below reporting limits or groundwater MCLs. Based on these results, no further action is necessary to protect human health and the environment at AOI 6.

6.0 REFERENCES

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Waid, 1986, *PCBs and the Environment, Volume 1, CRC Press, Boca Raton, Florida.*

TABLES

Table 1
Summary of Spills and Accidents at the Storm Drain Channel

Date	Substance Spilled	Quantity	Action Taken
6/15/1985	Oil and grease	Unknown	Samples were collected for analysis; cleanup activities unknown.
12/11/1986	Copper Sludge	200 gallons	Sediment was flushed from channel using high pressure hoses and removed with a vacuum truck. Soil samples were collected before and after cleanup.
11/10/1986	Phosphates	Unknown	Unknown
12/30/1987	Petroleum oil	Unknown	Oil was removed from the water using a vacuum truck. Minor soil excavation. Water and soil samples were collected for analysis.
6/5/1990	Mercury	2 pounds	Mercury removed from storm drain vault.

EKI, 1994, *Center-Wide Sampling and Analysis Program, Volume VI: Work Plan for AOI 6*.
SAIC, 1996, *Work Plan for Soil Over-Excavation and Groundwater Monitoring Installations, Storm Drain Channel Remedial Activities.*

Table 2
Summary of AOI 6 Investigations and Soil Remedial Actions

Date	Task	Location	Chemicals of Concern	Associated Cleanup Levels	Relevant Report(s)
Sep. 1990	• Sediment removal from concrete-lined channel. • Sediment characterization sampling for disposal purposes.	Sediment was removed from the entire length of the inside of the former concrete-lined storm drain channel.	N/A	N/A	• Chemical Waste Management, Inc., 1990, *Analysis of Soil from the Storm Drain Channel*
1989 – 1992	• Sitewide sampling • Soil excavation subsequent to sampling	General AOI 6 vicinity	N/A	N/A	• EKI, 1994, *Center-Wide Sampling and Analysis Program, Volume VI: Work Plan for AOI 6*
Oct. 1994	• Soil characterization sampling subsequent to concrete channel removal (samples collected from 98 locations).	Samples were collected from native soil beneath the footprint of the former storm drain channel along the entire length of the channel.	1. PCBs 2. Lead	50 mg/kg (TTLC) 50 mg/L (10 times STLC)	• EKI, 1994, *Center-Wide Sampling and Analysis Program, Volume VI: Work Plan for AOI 6* • NASA, 1995, *Storm Drain Channel Soil Sampling*
Jun. 1995 – May 1996	• Excavation of native soil along the entire length of the former storm drain channel (approximately 1,800 cubic yards removed). • Soil confirmation sampling, used to delineate areas requiring additional excavation (487 samples collected).	Excavation and sampling occurred over the footprint of the entire length of the former storm drain channel, south of the diversion box. Soil samples were collected from the bottom and sidewalls of the open, unlined channel.	1. PCBs 2. Lead	1 mg/kg average, not-to-exceed maximum concentration of 2 mg/kg 50 mg/kg	• SAIC, 1996, *Work Plan for Soil Over-Excavation and Groundwater Monitoring Installations, Storm Drain Channel Remedial Activities, Area of Investigation 6* • SAIC, 1997b, *Soil Removal Project, Storm Drain Channel Remedial Activities, Area of Investigation 6*
Feb. 1997	• Monitoring well installation (2 wells installed). • Soil boring characterization sampling (4 samples total collected; 2 samples from each well).	Monitoring wells were installed between the diversion box and OARF Road.	1. PCBs 2. Lead	1 mg/kg average, not-to-exceed maximum concentration of 2 mg/kg 50 mg/kg	• SAIC, 1997a, *Groundwater Monitoring Well Installations, Area of Investigation 6* • DMJM, 1997b, *Installation of Monitoring Wells, Soil & Groundwater Sampling at AOIs 3, 6 & the OARF (AOI 11)*

Table 2 (Continued)
Summary of AOI 6 Investigations and Soil Remedial Actions

Date	Task	Location	Chemicals of Concern	Associated Cleanup Levels	Relevant Report(s)
Jul. 1997	• Soil characterization sampling (6 samples collected).	Samples were collected south of the diversion box in the vicinity of the newly installed monitoring wells.	1. PCBs	1 mg/kg average, not-to-exceed maximum concentration of 2 mg/kg	• DMJM, 1997a, *Results of Laboratory Analysis of Soil Samples at AOI 6*
			2. Lead	50 mg/kg	
Jun. 2000	• Soil characterization sampling (88 samples collected).	Surface soil samples were collected along the entire length of the former drainage ditch, adjacent to the previously excavated areas and north of the former diversion box.	1. PCBs	North of OARF Road: 0.470 mg/kg South of OARF Road: 1 mg/kg average, not-to-exceed maximum concentration of 2 mg/kg	• SAIC, 2000, *Surface Soil Sampling Workplan, PCB Investigation at Area of Investigation 6* • PAI, 2001a, *Surface Soil Sampling Report of Findings, Area of Investigation 6*
			2. Lead	50 mg/kg	
Sep. 2001 – Oct. 2001	• Soil excavation (approximately 1,800 cubic yards removed). • Soil confirmation sampling, used to delineate areas requiring additional excavation (76 samples collected).	The entire area north of the former diversion box and eight areas south of the former diversion box were excavated.	1. PCBs	North of OARF Road: 0.470 mg/kg South of OARF Road: 1 mg/kg average, not-to-exceed maximum concentration of 2 mg/kg	• PAI, 2001b, *Workplan for the Excavation of PCB-Contaminated Surface Soils, Area of Investigation 6* • PAI, 2005, *Draft Implementation Report, Area of Investigation 6, Surface Soils*
			2. Lead	50 mg/kg	
2005	• Revised cleanup levels adopted at AOI 6 based on risk-based concentrations for total PCBs in the salt marsh habitat of Navy IR Site 25.	The revised PCB cleanup level of 0.210 mg/kg affects the portion of AOI 6 north of OARF Road. The revised lead cleanup level of 93.8 mg/kg affects the entire length of AOI 6.	1. PCBs	North of OARF Road: 0.210 mg/kg South of OARF Road: 1 mg/kg average, not-to-exceed maximum concentration of 2 mg/kg	• SulTech & Tetra Tech EMI, 2007, *Draft Final Addendum to Revised Final Site-Wide Feasibility Study, Site 25, Former NAS Moffett Field, Santa Clara County, California.*
			2. Lead	93.8 mg/kg	

mg/kg = milligram per kilogram
PCBs = Polychlorinated Biphenyls
TPH-Diesel = Total Petroleum Hydrocarbons as Diesel

Table 3
Well 10J08A/11M25A
PCB and Lead Concentrations

Well	Date	Aroclor 1016 (µg/L)	Aroclor 1254 (µg/L)	Aroclor 1260 (µg/L)	Lead (µg/L)
10J08A[1]	9/8/1997	<0.50	<0.50	<0.50	<5.0
10J08A	12/11/1997	<5.0	<5.0	<5.0	---
10J08A	3/23/1998	<5.0	<5.0	<5.0	---
10J08A	6/3/1998	<0.50	<0.50	<0.50	---
10J08A	9/3/1998	---	---	---	<5.0
10J08A	12/9/1998	---	---	---	<5.0
10J08A	3/10/1999	---	---	---	<5.0
10J08A	5/28/1999	<5.0	<5.0	<5.0	---
10J08A	3/20/2000	<0.50	<0.50	<0.50	5.1
10J08A	12/4/2000	<0.50	<0.50	<0.50	<5.0
10J08A	3/29/2001	<0.2	<0.2	<0.2	<15.0
10J08A	6/5/2001	<0.50	<0.50	**1.2**	12
10J08A	8/27/2001	<0.50	**1.8**	<0.50	<5.0
11M25A	3/18/2002	<0.50	<0.50	<0.50	**28**
11M25A	6/11/2002	<0.50	<0.50	<0.50	**26**
11M25A	9/9/2002	---	---	---	**23**
11M25A	12/16/2002	<0.50	<0.50	<0.50	7.9
11M25A	3/10/2003	**1.5**	<0.50	<0.50	<50.0
11M25A	9/23/2003	<0.50	<0.50	<0.50	**42**
11M25A	3/23/2004	<0.50	<0.50	<0.50	**22**
11M25A	9/20/2004	<0.50	<0.50	<0.50	**23**
11M25A	3/28/2005	<0.50	<0.50	<0.50	<5.0
11M25A	3/29/2006	<0.50	<0.50	<0.50	<5.0
11M25A	9/25/2006	<0.50	<0.50	<0.50	7.9
11M25A	3/21/2007	<0.50	<0.50	<0.50	<5.0
11M25A	9/17/2007	<0.50	<0.50	<0.50	<5.0
11M25A	3/17/2008	<0.50	<0.50	<0.50	<5.0
11M25A	9/23/2008	<0.50	<0.50	<0.50	<5.0
MCL		**0.50**	**0.50**	**0.50**	**15**

Note 1: 10J08A was replaced by 11M25A in January 2002.
µg/L = micrograms per liter
--- = Not Analyzed

Table 4
Well 10J09A
PCB and Lead Concentrations

Well	Date	Aroclor 1016 (µg/L)	Aroclor 1254 (µg/L)	Aroclor 1260 (µg/L)	Lead (µg/L)
10J09A	9/8/1997	<0.50	<0.50	<0.50	<5.0
10J09A	12/11/1997	<5.0	<5.0	<5.0	---
10J09A	3/23/1998	<5.0	<5.0	<5.0	---
10J09A	6/3/1998	<0.50	<0.50	<0.50	---
10J09A	9/3/1998	---	---	---	<5.0
10J09A	12/9/1998	---	---	---	<5.0
10J09A	3/10/1999	---	---	---	<5.0
10J09A	5/28/1999	<5.0	<5.0	<5.0	---
10J09A	6/12/2000	---	---	---	<10
10J09A	6/5/2001	<0.50	<0.50	<0.50	8.4
10J09A	3/18/2002	<0.50	<0.50	<0.50	7.8
10J09A	6/11/2002	<0.50	<0.50	<0.50	7.2
10J09A	9/9/2002	---	---	---	12
10J09A	12/16/2002	<0.50	<0.50	<0.50	<5.0
10J09A	3/10/2003	<0.50	<0.50	<0.50	<50.0
10J09A	9/23/2003	<0.50	<0.50	<0.50	**33**
10J09A	3/23/2004	<0.50	<0.50	**0.97**	6.9
10J09A	9/20/2004	<0.50	<0.50	<0.50	7.0
MCL		**0.50**	**0.50**	**0.50**	**15**

µg/L = micrograms per liter
--- = Not Analyzed

Table 5
Well 11E02A
PCB and Lead Concentrations

Well	Date	Aroclor 1016 (µg/L)	Aroclor 1254 (µg/L)	Aroclor 1260 (µg/L)	Lead (µg/L)
11E02A	3/29/1995	---	---	---	<100
11E02A	3/11/1996	<0.50	<0.50	<0.50	---
11E02A	6/21/1996	<0.50	<0.50	<0.50	---
11E02A	9/12/1996	<0.50	<0.50	<0.50	---
11E02A	12/6/1996	<0.50	<0.50	<0.50	---
11E02A	9/8/1997	<0.50	<0.50	<0.50	<5.0
11E02A	12/11/1997	<0.50	<0.50	<0.50	---
11E02A	3/23/1998	<0.50	<0.50	<0.50	---
11E02A	6/3/1998	<0.50	<0.50	<0.50	---
11E02A	9/3/1998	---	---	---	<5.0
11E02A	12/9/1998	---	---	---	<5.0
11E02A	3/10/1999	---	---	---	<5.0
11E02A	5/28/1999	<0.50	<0.50	<0.50	---
11E02A	3/20/2000	<0.50	<0.50	<0.50	<5.0
11E02A	12/4/2000	<0.50	<0.50	<0.50	<5.0
11E02A	3/28/2001	<0.2	<0.2	<0.2	**31**
11E02A	8/27/2001	<0.50	<0.50	<0.50	<5.0
11E02A	3/18/2002	<0.50	<0.50	<0.50	<5.0
11E02A	6/11/2002	<0.50	<0.50	<0.50	<5.0
11E02A	9/9/2002	---	---	---	<5.0
11E02A	12/16/2002	<0.50	<0.50	<0.50	<5.0
11E02A	3/10/2003	<0.50	<0.50	<0.50	<50.0
11E02A	9/23/2003	<0.50	<0.50	<0.50	<25
11E02A	3/23/2004	<0.50	<0.50	<0.50	<25
11E02A	9/20/2004	<0.50	<0.50	<0.50	<5.0
11E02A	3/28/2005	<0.50	<0.50	<0.50	<5.0
11E02A	9/26/2005	<0.50	<0.50	<0.50	<5.0
11E02A	3/29/2006	<0.50	<0.50	<0.50	<5.0
11E02A	9/25/2006	<0.50	<0.50	<0.50	15
11E02A	3/21/2007	<0.50	<0.50	<0.50	<5.0
11E02A	9/17/2007	<0.50	<0.50	<0.50	<5.0
11E02A	3/17/2008	<0.50	<0.50	<0.50	<5.0
11E02A	9/23/2008	<0.50	<0.50	<0.50	<5.0
MCL		**0.50**	**0.50**	**0.50**	**15**

µg/L = micrograms per liter
--- = Not Analyzed

Table 6
Summary of AOI 6 Analytical Results for Groundwater

	PCBs	Lead
Number of Samples Analyzed	65	63
Number of Detections	4	19
Percent Detections	6%	30%
Number of MCL Exceedances[1]	4	8
Percent of MCL Exceedances[1]	6%	13%
Highest Concentration	1.8 µg/L	42 µg/L
Background Range	NA	0.80 µg/L – 50 µg/L
Background Average	NA	17 µg/L

µg/L = micrograms per liter
NA = Not Applicable
[1]PCB MCL is 0.50 µg/L; Lead MCL is 5.0 µg/L

FIGURES

Figure 1
Site Location Map

Figure 2
Aerial View of NASA Ames Research Center

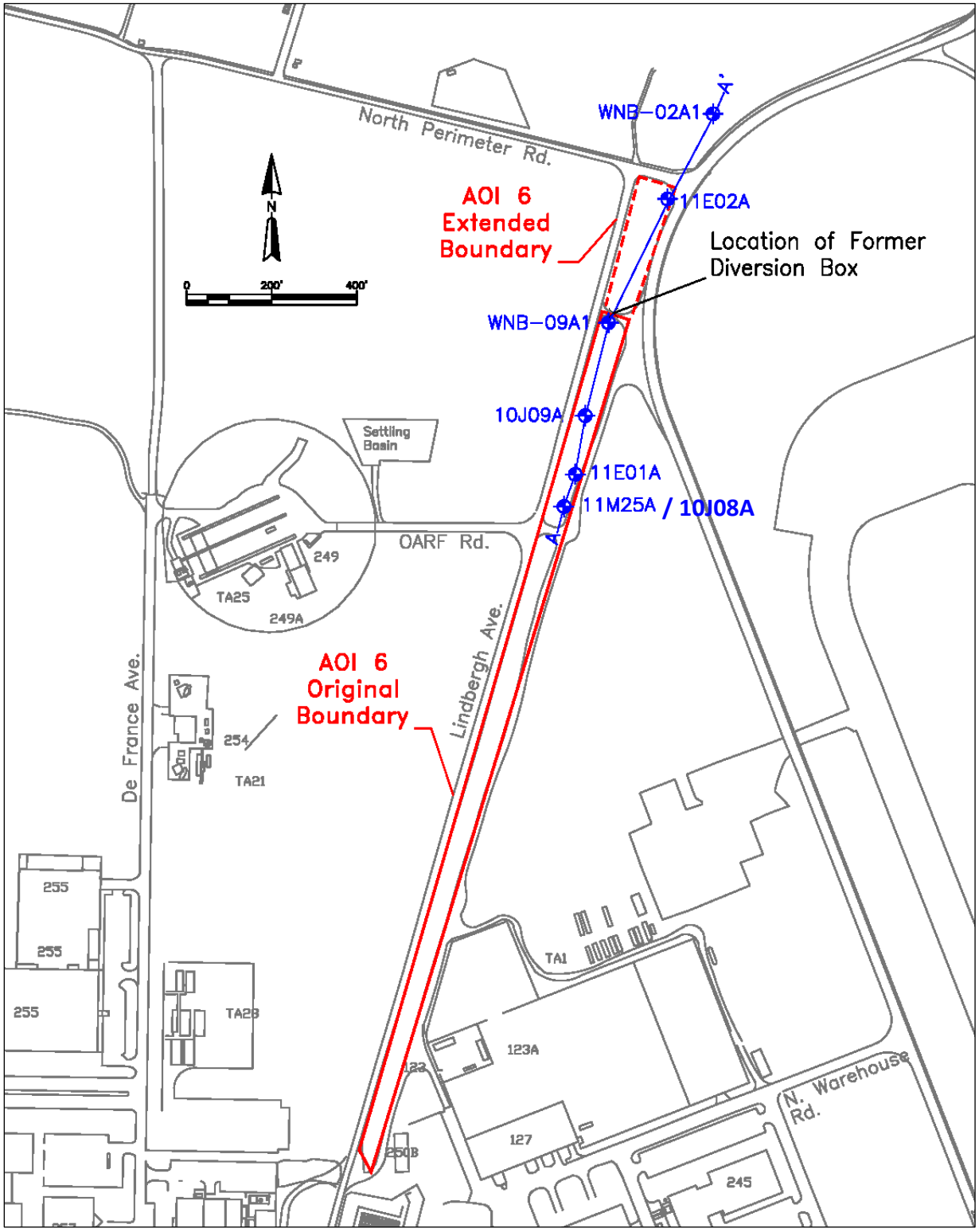

Figure 3
Location of AOI 6 and Monitoring Well

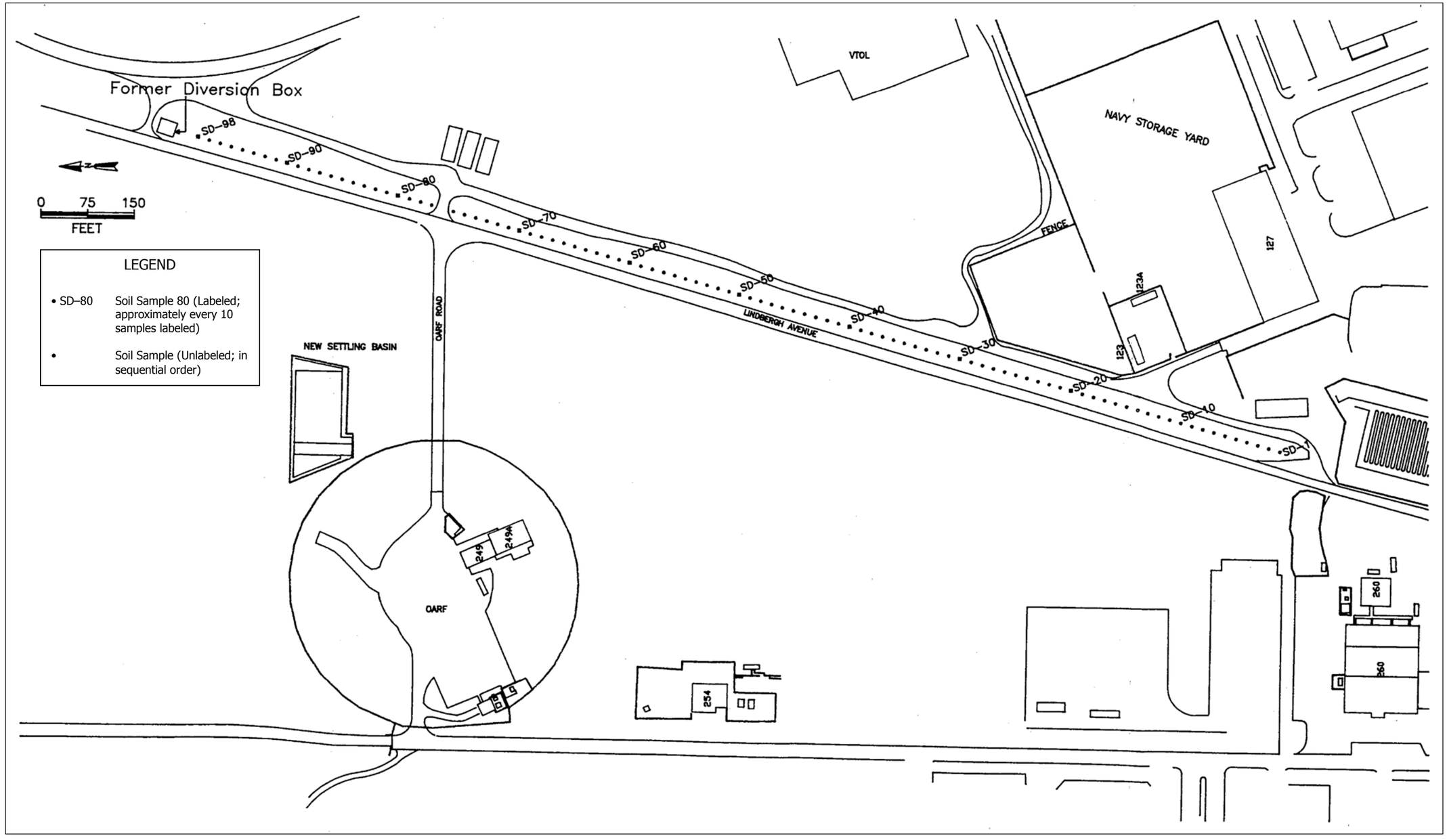

Figure 4
1994 Soil Sampling Location

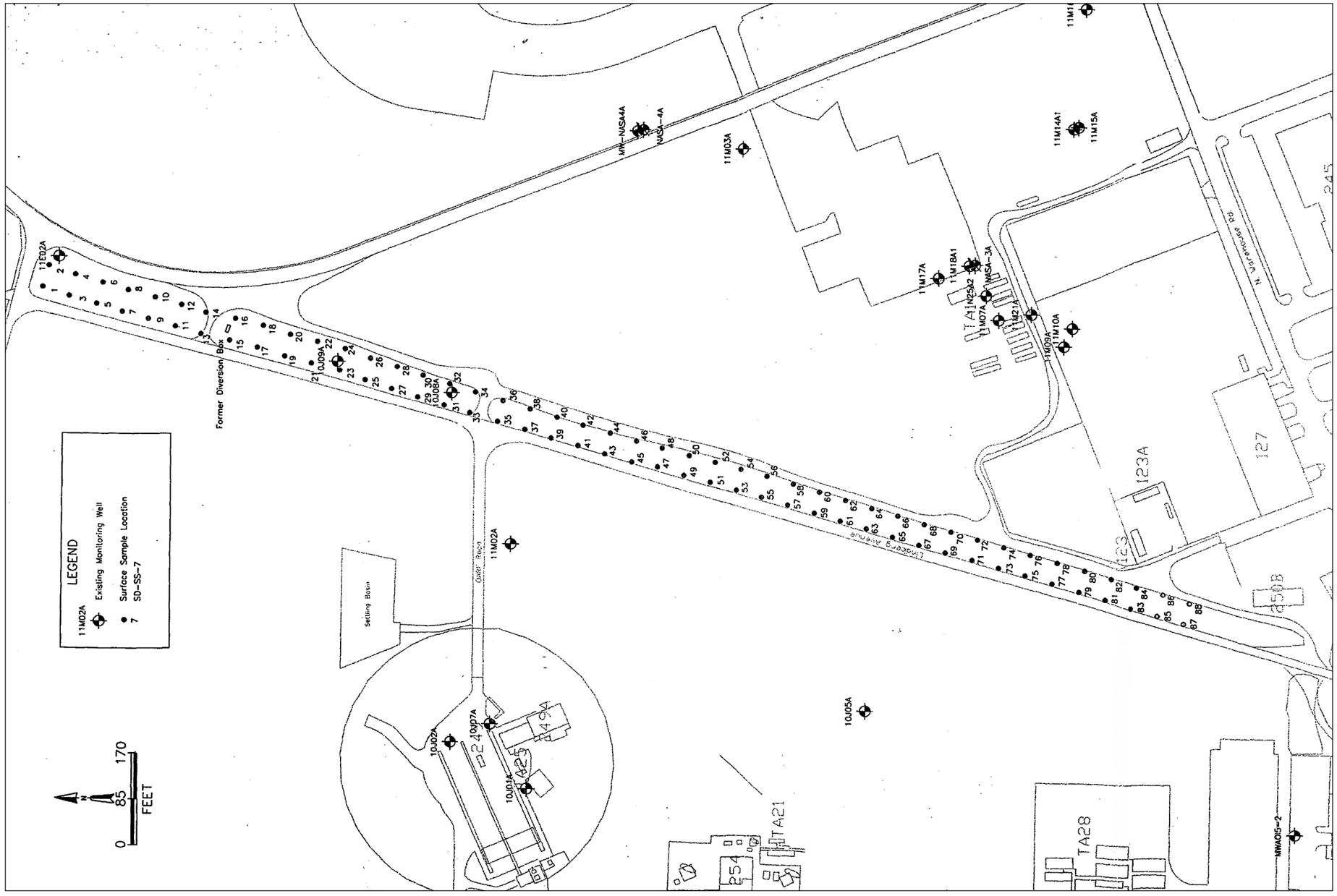

Figure 5
2000 Soil Sampling Location

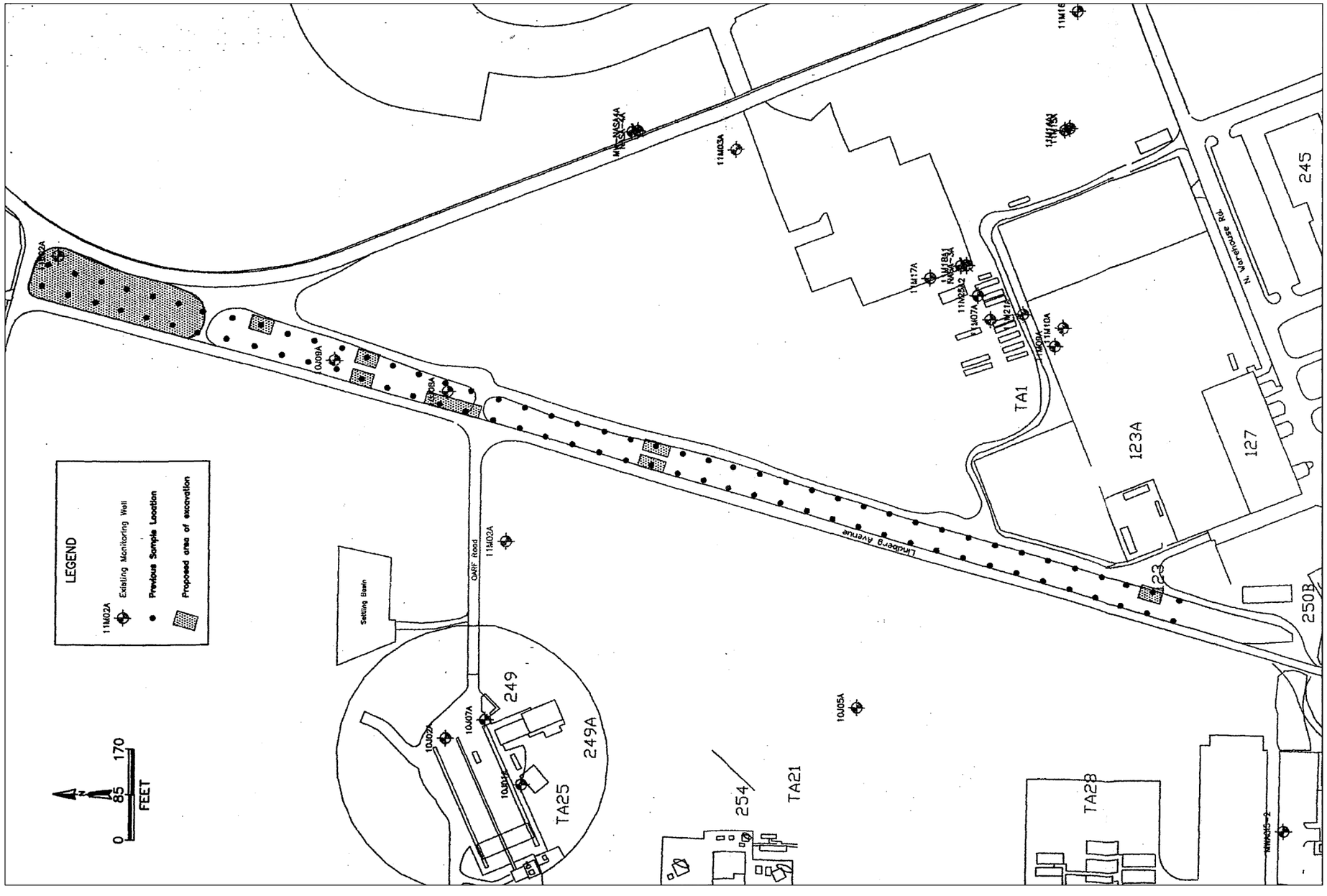

Figure 6
Surface Soil Excavation Locations from 2001 Excavation

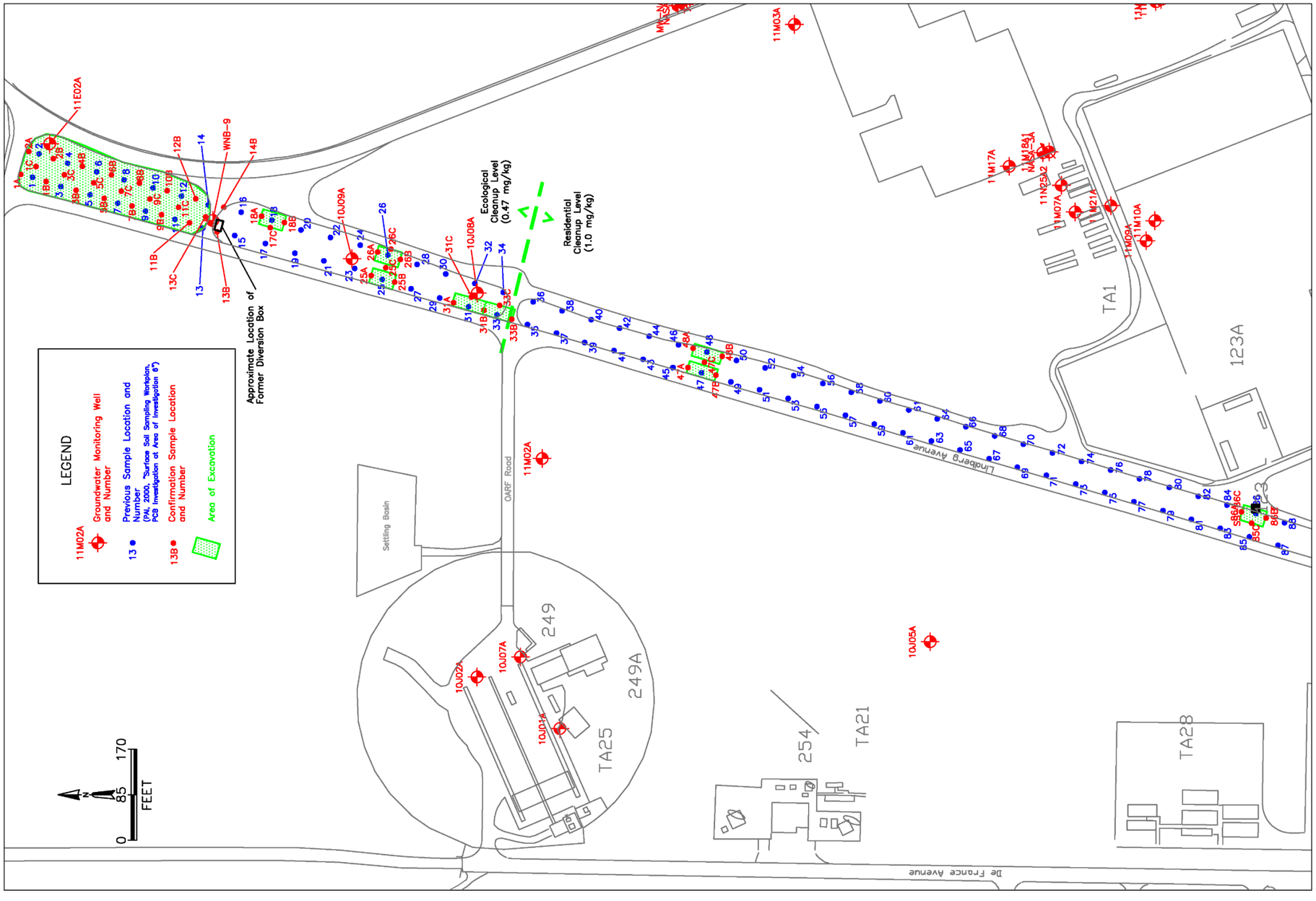

Figure 7
Sample Locations and Initial 2001 Excavation Areas

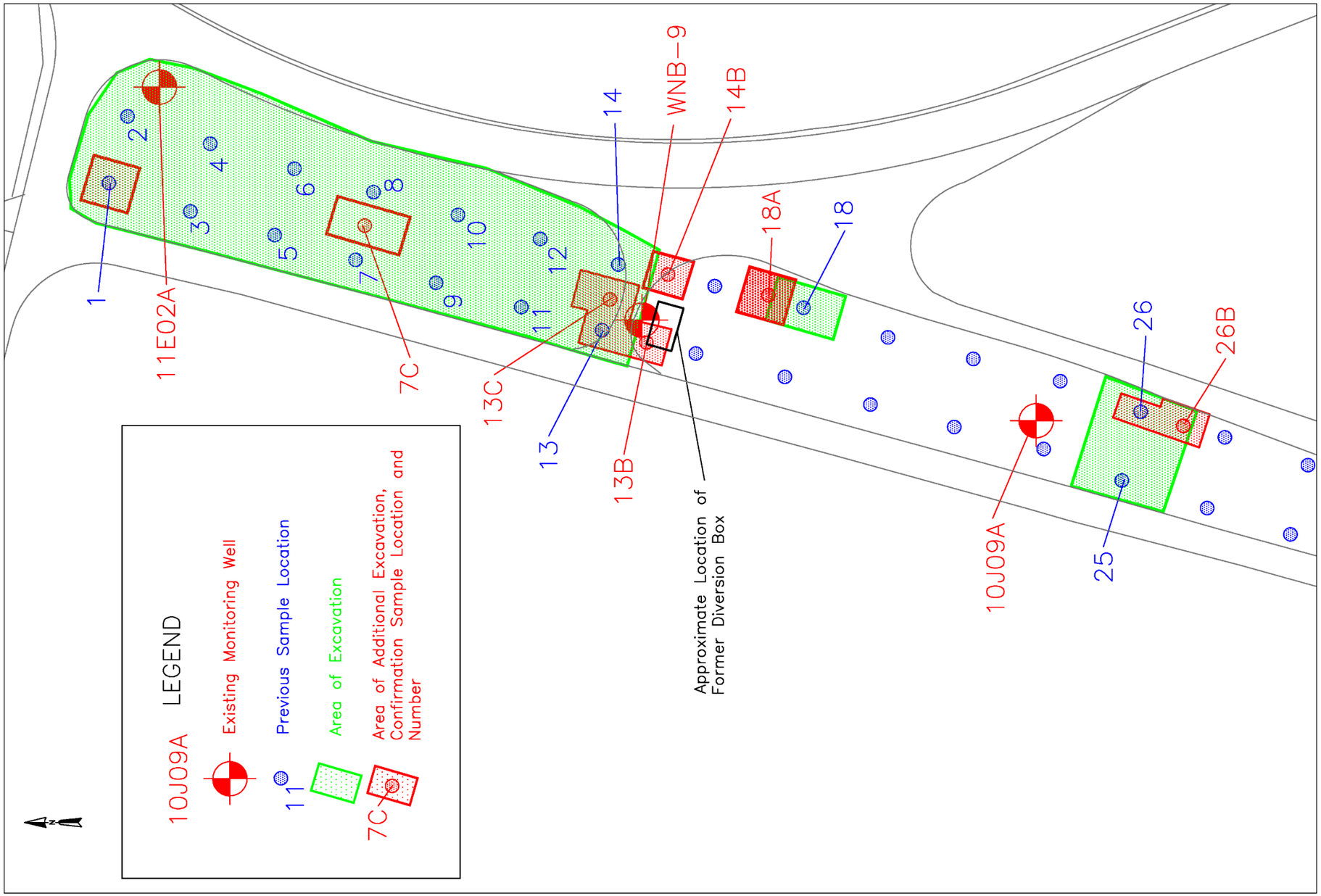

Figure 8
Sample Locations and Additional 2001 Excavation Area

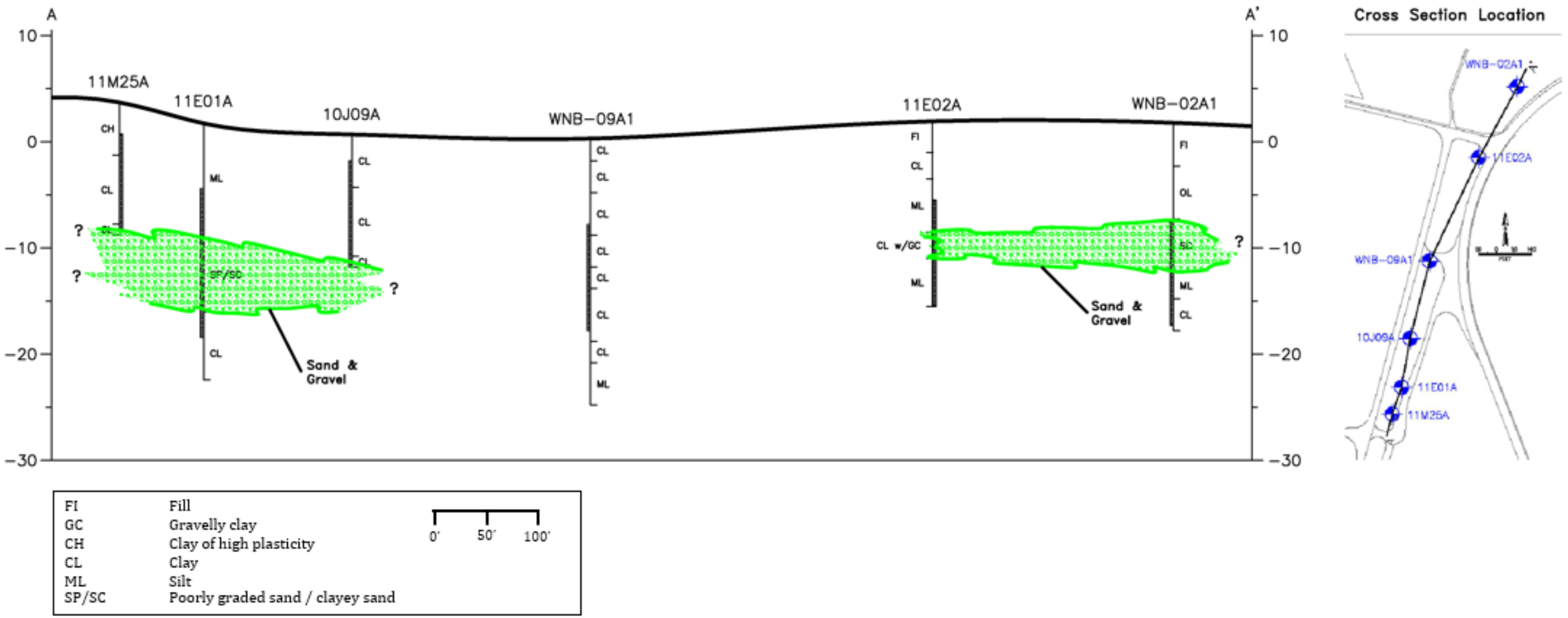

Figure 9
Geologic Cross Section A-A

APPENDIX A

RESPONSES TO COMMENTS FROM EPA AND WATER BOARD

Responses to Comments from EPA and Water Board

Draft Area of Investigation (AOI) 6 Remedial Action Completion Report, NASA Ames Research Center, Moffett Field, CA

The table below summarizes NASA Ames' responses to comments submitted by the U.S. Environmental Protection Agency (EPA) and the San Francisco Bay Regional Water Quality Control Board (Water Board) on the "Draft Area of Investigation 6 Remedial Action Completion Report, NASA Ames Research Center, Moffett Field, CA," dated October 28, 2015. Comments were received from EPA and the Water Board on March 4, 2016.

Comment No.	Comment	Response
Responses to Comments from EPA and Water Board		
General Comments		
General	Include brief description of what evaluation was conducted beyond the diversion box to confirm that all potential discharge points from the drainage channel have been assessed. Specifically, the stormwater and entrained sediment was discharged into the Eastern Diked Marsh to the west and under the runways through the Building 191 to the east. State what assessment and cleanup actions have been taken in these areas.	Environmental evaluations were previously conducted beyond the former diversion box in down gradient drainage and discharge areas of the Eastern Diked Marsh, Storm Water Retention Pond and the Building 191 pump station discharge areas. Navy IR Site 25, which previously received storm water discharge from AOI 6, comprises the Eastern Diked Marsh and the Storm Water Retention Pond located to the north and west of AOI6. Site 25 was evaluated in a Remedial Investigation/Feasibility Study completed by the Navy in 2010 (KCH, 2011). The Navy completed remediation of Site 25 in 2012 (ITSI Gilbane, 2013). The remedial action consisted of sediment excavation and offsite disposal. Habitat restoration associated with the remedial action is ongoing. Navy IR Site 27, which includes the Building 191 pump station and the Northern Channel, was investigated in a Remedial Investigation/Feasibility Study by the Navy in 2004—2005, followed by remediation via excavation and offsite disposal by the Navy in 2006/2007 (Tetra Tech, 2012). This information is added to the text at the end of Section 3.0.

Responses to Comments from EPA and Water Board (Continued)

Comment No.	Comment	Response
Responses to Comments from EPA and Water Board		
Specific Comments		
Specific 1.	Section 1.0, Introduction, page 1: In addition to summarizing the soil remedial actions and groundwater monitoring at the site, state that the RACR also documents the current condition of the site and supports a determination by NASA that no further action is necessary to protect human health and the environment.	The text is revised as requested in this comment.
Specific 2.	Section 2.1, Description of AOI 6, page 1: The last sentence of the first paragraph states that the boundary of the site was extended based on soil sampling. State when the boundary was extended and the (original) purpose of the soil sampling that resulted in the expansion of the site's boundary.	The text in Section 2.1 is revised to include the original purpose of the soil sampling that resulted in extension of the site boundary and the approximate date when the boundary was extended.
Specific 3.	Section 2.1, Description of AOI 6, page 1: Revise the RACR to include the approximate volume of wastewater that was historically discharged to the drainage channel.	The volume of wastewater historically discharged to the drainage channel was not monitored and the volume of wastewater discharged to the drainage channel is unknown. The text in Section 2.1 is revised to indicate that wastewater discharges were periodic and unmonitored as to the amount of discharge.

Responses to Comments from EPA and Water Board (Continued)

Comment No.	Comment	Response
Responses to Comments from EPA and Water Board		
Specific 4.	Section 3.0, AOI 6 Investigations and Soil Remedial Actions, page 5: The second paragraph of this section includes a summary of the various PCB and lead screening and cleanup levels historically applied to the site. Provide additional information on the development of the 0.47 mg/kg site-specific PCB soil cleanup level applied in 1999, the 50 mg/kg site-specific lead cleanup level applied from 1999-2005, and the revised cleanup levels (presumably, Navy IR Site 25 levels) established in 2005.	Section 3.0 is revised as requested in this comment. The 0.47 mg/kg total PCBs cleanup level applied in 1999 was developed for seasonal wetland habitat as part of the Final Station-Wide Feasibility Study of Navy IR Site 25 (Tetra Tech EMI, 1999). The 50 mg/kg cleanup level applied for lead between 1999 and 2005 was derived from the value 10 times the Soluble Threshold Limit Concentration (STLC) of 5.0 mg/L. The revised cleanup levels of 0.210 mg/kg for total PCBs and 93.8 mg/kg for lead were applied to potential ecologically sensitive areas of surface soil north of OARF Road, and were the ecological cleanup levels established for the salt marsh habitat of Navy IR Site 25 (SulTech & Tetra Tech EMI, 2007).

Responses to Comments from EPA and Water Board (Continued)

Specific 5.	Section 3.0, AOI 6 Investigations and Soil Remedial Actions, pages 5 and 6: This section presents an overview of the prior work conducted at the site; however, the discussion could be improved by several additions/modifications: a. In the second paragraph, state that PCBs and lead were identified as the contaminants of concern after the 1994 soil sampling discussed in Section 3.1.2; b. Include a separate table or add a column to Table 1 to indicate the chemicals of concern and associated remedial goals or screening levels applicable to a particular investigation or remediation effort; c. In the fourth paragraph, state the remediation goals applied to the removal of 1,800 cubic yards of soil in 2001 and briefly explain why the excavation occurred in two phases; d. In the fourth paragraph, clarify the current conditions at sampling locations SS-13C-CON and SS-18 and include a reference to Figure 5. The order in which the text is presented makes it unclear if these locations meet the 1999 cleanup level, meet the 2005 cleanup level, and/or were backfilled with clean fill; e. Lastly clarify why the remaining exceedances at the site are not significant. If the assertion is that there is no exposure pathway, then discuss the potential exposure to borrowing animals.	Section 3.0 is revised as follows for each addition/modification suggested: a. The text is revised as requested in this comment. b. Two columns are added to (now) Table 2 to include the chemicals of concern and associated cleanup levels. c. The cleanup levels applied for the 2001 soil excavation were 50 mg/kg for lead, and 0.47 mg/kg north of OARF road and 2.0 mg/kg (average of 1.0 mg/kg) south of OARF road for total PCBs (PAI, 2005). The excavation occurred in two phases because confirmation samples collected after the initial excavation phase indicated total PCBs concentrations remained above the cleanup levels. d. The exceedances at sampling locations SS-13C-CON and SS-18 were reduced below the 1999 cleanup level for PCBs (0.470 mg/kg) but are above the cleanup level adopted in 2005 (0.210 mg/kg). The sample locations are approximately 3 feet bgs because the area was backfilled with clean fill in 2001. At the surface, these locations are heavily vegetated most of the year and are often inundated with water during the rainy season. Section 3.0 is revised with this information to clarify the current conditions at these sample locations. e. The remaining two exceedances of the revised ecological cleanup level for total PCBs in the area north of OARF Road are not significant to potential ecological receptors, including burrowing animals (namely burrowing owls). The two sample locations are at a depth of approximately 3 feet bgs and the surface is heavily vegetated and often inundated with water during the rainy season. The total PCBs ecological cleanup level of 0.210 mg/kg applied to this area north of OARF Road in 2005 was adopted from the cleanup goal established for Navy IR Site 25 for the most sensitive receptor based on exposure to lead, zinc, and PCBs (SulTech & Tetra Tech EMI, 2007). Burrowing owls were not identified as potential receptors because they do not inhabit Site 25. PCBs concentrations at the two locations at depth do not present significant potential exposure risk to borrowing owls based on the low potential exposure frequency and potential exposure pathway (food chain ingestion). The text in Section 3.0 is revised with this additional explanation.

Responses to Comments from EPA and Water Board (Continued)

Comment No.	Comment	Response
Responses to Comments from EPA and Water Board		
Specific 6.	Table 1: Include columns in the table with the total number of samples taken at the varying intervals and the chemicals included in the analysis of those samples.	The information is not added to (now) Table 2 because this information is not sufficiently detailed in the historical AOI 6 reports.
Specific 7.	Section 3.1.1, 1990 Sediment Removal, page 7: State how much sediment was removed in 1990.	The text in Section 3.1.1 is revised to indicate a total of 34 cubic yards of sediment was removed in 1990.
Specific 8.	Section 3.1.2, 1994 Storm Drain Channel Removal and Soil Sampling, page 7: Revise the text to include a discussion of the 150 mg/kg beryllium result that exceeds background and the California Total Threshold Limit Concentration and is noted in Appendix A in the 1994 EKI documentation.	The 150 mg/kg beryllium result that exceeded the California Total Threshold Limit Concentration (TTLC) of 75 mg/kg was detected during the Site-Wide Sampling conducted between 1989 and 1992 in the vicinity of AOI 6. The results of the Site-Wide Sampling, in part, led to the soil investigation described in Section 3.1.2. that followed the decommission of the storm drain and removal of the concrete lining. Beryllium was not detected in the October 1994 samples. The text in Section 3.1.2 is revised to include this information.
Specific 9.	Section 3.1.3, 1995-1996 Excavation and Soil Sampling, page 9: Text in the first two paragraphs of this section appear to be out of order. The first paragraph discusses confirmation results that indicate the 1 mg/kg and 50 mg/kg cleanup levels were reached for PCBs and lead; however, the second paragraph indicates that PCBs and lead were still present above the cleanup goals at nine locations. Please clarify the text.	PCBs and lead concentrations were detected above the cleanup levels at nine locations following several phases of soil removal and confirmation sampling conducted from 1995 to 1996. An additional one to two feet of soil was removed from the nine areas but confirmation samples were not collected because the excavation depth extended into aquifer material. The following sentence is removed from Section 3.1.3: "Soil was removed incrementally from the former channel area until the soil confirmation results indicated cleanup levels of 1 mg/kg and 50 mg/kg were reached for PCBs and lead, respectively (SAIC, 1997b)."
Specific 10.	Section 3.1.3, 1995-1996 Excavation and Soil Sampling, page 9: The third paragraph indicates that NASA and EPA agreed on an approach to install two groundwater monitoring wells. Describe how this agreement was reached or include a reference/citation to the document supporting this agreement.	The agreement between NASA and EPA regarding the installation of the two groundwater monitoring wells was noted in *Soil Removal Project, Storm Drain Channel, Area of Investigation 6 (AOI 6)* (SAIC, 1997b); however, no document supporting this agreement was included in the text or Appendix of the report. The text in Section 3.1.3 is revised to remove the reference to the agreement made between NASA and EPA.

Responses to Comments from EPA and Water Board (Continued)

Comment No.	Comment	Response
Responses to Comments from EPA and Water Board		
Specific 11.	Section 3.1.3, 1995-1996 Excavation and Soil Sampling, page 9: State the total volumes of soil that were disposed of at Class 1 and Class 2 facilities.	Approximately 1,640 cubic yards of soil was disposed of at Class I and Class II landfills. However, the proportion of soil disposed of at each landfill is unknown; this information was not provided in *Soil Removal Project, Storm Drain Channel, Area of Investigation 6 (AOI 6)* (SAIC, 1997b). The text in Section 3.1.3 is revised with this information.
Specific 12.	Section 3.1.4, 1997 Groundwater Monitoring Well Installation and Soil Sampling, page 10: The second paragraph refers to six soil samples collected in July 1997. Show these locations on a figure along with the "topographic low area" described in the third paragraph.	A figure delineating the topographic low area in 1997 was not created for the Results of Laboratory Analyses of Soil Samples *At Area of Investigation (AOI) 6* (DMJM, 1997a) and current figures of AOI 6 do not accurately represent the topography of the area in 1997 due to the numerous excavations and backfills completed at the site since 1997. Also, since this sampling event was minor compared to other sampling efforts in the AOI 6 vicinity, a new figure showing these sampling locations and topographic low area is not included.
Specific 13.	Section 3.1.5, 2000 Soil Sampling, page 12: The text describes five isolated areas between the diversion box and OARF Road above the ecological cleanup level; however Figures 6 and 7 appear to show four areas between the diversion box and OARF Road. Clarify that the areas around sample locations 31 and 33 are considered two separate areas. This comment also applies to the first paragraph of Section 3.1.6.	The text in sections 3.1.5 and 3.1.6 is revised to clarify that the areas around sample locations 31 and 33 are two separate areas.
Specific 14.	Section 3.1.6, 2001 Soil Sampling, Excavation and Confirmation Sampling, page 12: The first paragraph refers to Figure 8 with regard to confirmation sampling; however, the entire excavation area is not depicted in Figure 8 but in Figure 7. Revise the text and figure to present all confirmation sampling conducted after the initial one foot excavation.	The text in section 3.1.6 correctly refers to Figure 8. Following the excavation of the top one foot of soil as shown in green in Figure 7, confirmation sampling was conducted and nine additional areas were identified as requiring additional excavation (PAI, 2005). The areas requiring additional excavation are shown in in red in Figure 8. The text of Section 3.1.6 is revised to clarify the sequence of excavation and sampling.

Responses to Comments from EPA and Water Board (Continued)

Comment No.	Comment	Response
Responses to Comments from EPA and Water Board		
Specific 15.	Figure 9: Provide a key or explanation of the abbreviations used to describe the lithology in the geologic cross-section A-A'. Include a horizontal scale for the cross section itself, and increase the size of the scale for the cross section location to make it easier to read.	The requested changes have been made to Figure 9.
Specific 16.	Section 3.5.2, Lead in Groundwater, page 19: State whether the groundwater samples analyzed for lead were filtered prior to testing to indicate whether the results are for total lead or dissolved lead.	The groundwater samples were not filtered prior to testing. The samples were analyzed for total lead. The text in section 3.5.2 is revised to include this information.
Specific 17.	Section 3.6.1, Analytical Results, page 23: The RACR does not include much discussion or analysis of the groundwater monitoring results beyond the summary of data in Table 5. Discuss the implications/conclusions of the monitoring data and explain how or in which previous document the background level for lead was established. Section 4.3 refers to Lacy, 1998 and Marieta, 1992. State whether these documents underwent review and concurrence by the regulatory agencies.	Neither document referencing background levels for lead underwent review and concurrence by the regulatory agencies because NASA performed the remediation work at AOI 6 on a voluntary basis. No changes are made to the text.
Specific 18.	Appendix A: The 1994 EKI Work Plan for the site includes details in Section 2.2 about prior releases and spills at the site. Include a discussion of these details in the RACR.	Section 2.2 is revised to include a brief discussion of the prior releases and spills at the site and new Table 1 summarizes this information.
Specific 19.	Appendix A: Page 21 of the 1997 SAIC document indicates Ms. Elizabeth Adams of EPA agreed no additional sampling was required at certain locations at the site. Indicate the method this was communicated or include a reference/citation in the document.	No additional information about the method of communication used by Ms. Elizabeth Adams of EPA is included in the 1997 SAIC report, and no additional information is included in the text.

Responses to Comments from EPA and Water Board (Continued)

Comment No.	Comment	Response
Responses to Comments from EPA and Water Board		
Minor Comments		
Minor 1.	Figure 2: The figure should be revised to also depict the western boundary of the Former Naval Air Station Moffett Field.	Figure 2 is revised as requested in this comment.
Minor 2.	Section 3.1.6, 2001 Soil Sampling, Excavation and Confirmation Sampling, page 16: The reference in the first full paragraph on the page incorrectly refers to Figure 7. The correct reference appears to be to Figure 8.	Please refer to the response for Specific Comment 14; the text correctly references Figure 8.
Minor 3.	Section 4.2, Lead, page 24: Add a “d” to “migrate” on the last line of the page.	Section 4.2 test is revised as requested in this comment.

Responses to Comments from EPA and Water Board (Continued)

The table below summarizes NASA Ames' responses to comments submitted by the U.S. Environmental Protection Agency (EPA) and the San Francisco Bay Regional Water Quality Control Board (Water Board) on the "Draft Final Area of Investigation 6 Remedial Action Completion Report, NASA Ames Research Center, Moffett Field, CA," dated May 2, 2016. Comments were received from EPA on July 20, 2016.

Comment No.	Comment	Response
Responses to Comments from EPA		
General Comments		
Specific 1.	In the last sentence of the first paragraph of Section 2.1, the letter "B" in "Based" should be changed to lower case.	Section 2.1 is revised as requested in this comment.
Specific 2.	As with the description of areas in Sections 3.1.5 and 3.1.6 (see Specific Comment 13 on the Draft RACR) that underwent excavation, clarify that the nine areas described in the third paragraph of Section 3.1.6 (and depicted in red in Figure 8) are each defined by one sampling location. As shown in Figure 8, adjacent areas appear to be a single contiguous area	The text in section 3.1.6 is revised to clarify that the nine areas that required additional excavation were each defined by one sample locations. These separate areas are outlined in red in Figure 8.

APPENDIX B

HISTORICAL AOI 6 REPORTS
(INCLUDING MAPS, ANALYTICAL DATA & MANIFESTS)

The contents of Appendix B are located on the enclosed CD-ROM