

Final

Remedial Investigation Report Area of Concern (AOC) I

Former Naval Ammunition Support Detachment
Vieques, Puerto Rico



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Prepared by

CH2MHILL

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Contract Task Order 007

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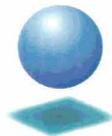
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CH2MHILL

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Acronyms and Abbreviations

amsl	Above Mean Sea Level
AOC	Area of Concern
AST	Above-ground Storage Tank
ASTM	American Society for Testing and Materials
BERA	Baseline Ecological Risk Assessment
bls	Below Land Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-Term Environmental Action Navy
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
DAF	Dilution Attenuation Factor
DGPS	Differential Global Positioning System
DNAPL	Dense Non-Aqueous Phase Liquid
DOI	U.S. Department of the Interior
DQE	Data Quality Evaluation
EBS	Environmental Baseline Survey
ELCR	Excess Lifetime Cancer Risk
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
ERM	Environmental Resource Management, Inc.
ERP	Environmental Restoration Program
FS	Feasibility Study
ft	Feet or Foot
ft/ft	Feet or Foot per Foot
GIS	Geographic Information System

HAH	Heterocyclic Aromatic Hydrocarbon
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IDW	Investigation-Derived Waste
IR	Installation Restoration
LCS	Laboratory Confirmation Sample
LNAPL	Light Non-Aqueous Phase Liquid
MCL	Maximum Contaminant Level
MEK	Methyl Ethyl Ketone (2-Butanone)
MIBK	4-Methyl-2-Pentanone
mg/kg	Milligrams per Kilogram
ml/min	Milliliters per Minute
MOV	Municipality of Vieques
NASD	Naval Ammunition Support Detachment
NAVFAC	Naval Facilities Engineering Command
NPL	National Priorities List
NRHP	National Register of Historic Places
ORP	Oxidation Reduction Potential
OVA	Organic Vapor Analyzer
OVM	Organic Vapor Monitor
PA/SI	Preliminary Assessment/Site Investigation
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene
PID	Photo-ionization Detector
PREQB	Puerto Rico Environmental Quality Board
PRG	Preliminary Remediation Goal
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride

QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
SERA	Screening Ecological Risk Assessment
SOP	Standard Operating Procedure
SSL	Site-Specific Screening Level
SVOC	Semi-volatile Organic Compound
TCE	Trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TPH-DRO	Total Petroleum Hydrocarbons - Diesel Range Organics
TPH-GRO	Total Petroleum Hydrocarbons - Gasoline Range Organics
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
UTL	Upper Tolerance Limit
VOC	Volatile Organic Compound
µg/kg	Micrograms per Kilogram
µg/L	Micrograms per Liter
1,1-DCE	1,1-Dichloroethene
1,2-DCA	1,2-Dichloroethane

Executive Summary

Area of Concern (AOC) I is a former asphalt plant, located on the former Naval Ammunition Support Detachment (NASD), that operated from the 1960s through 1988. Figure ES-1 shows the location of AOC I within the former NASD and with respect to other environmental sites. The asphalt plant comprised a large concrete pad for asphalt mixing, an earthen ramp used by front-end loaders to fill hoppers with aggregate, a concrete containment area for asphalt loading into trucks, and two diesel above-ground storage tanks (ASTs). A second concrete containment area, located north of the former plant, was presumably used to stage trucks prior to being loaded with asphalt. Once loaded with asphalt, the trucks would transport the asphalt to locations on the island where roads were being paved. Figure ES-2 shows the features associated with the former asphalt plant.

AOC I is approximately 900 feet (ft) south of Mosquito Pier and adjacent to an active rock quarry historically used, in part, to supply aggregate for the asphalt production. The AOC I area occupies approximately an acre, but the asphalt plant itself occupied a considerably smaller area. The topography of the site is relatively flat; stormwater at and in the immediate vicinity of the former asphalt plant was observed to pond at the site during a rain event rather than run off. At the northern, eastern, and southern margins of the site, the topography slopes downward to Route 200 (to the north), the quarry (to the south), and a drainage ditch for the quarry (to the east).

Currently, there is no human use of the site other than potentially as a passageway for trucks to/from the rock quarry from Route 200. Ecological habitat at the former asphalt plant is minimal, consisting primarily of scrub grass, brush, and small trees growing in and around the former asphalt plant structures and through the gravel-covered terrain. No federally-protected species or preferred habitats were observed at AOC I, nor are any cultural resources present at the site.

The surficial material at the site comprises gravel fill interspersed with silty clay and sand. Beneath the thin veneer of fill, the soil zone at the site is relatively thin (generally 2 to 9 ft thick) and consists of well-graded gravel with sand of the Qa geologic unit. Andesite bedrock lies below the soil, often weathered at its surface to a saprolite. The upper portion of the bedrock is unsaturated; groundwater was first observed during drilling at about 25 ft below the top of bedrock, but stabilized at about 15 ft below the top of bedrock. Groundwater at the site migrates through fractures in the bedrock in a north-northwest direction toward the coast. Figure ES-3 shows a conceptual model of AOC I, including the former asphalt plant, physical setting, environmental media, and movement of water within these media.

Although there is no record of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-related releases during operation of the asphalt plant, site visit observations and environmental media data indicate past releases did occur. The data were collected through a series of investigations during which surface soil, subsurface soil, bedrock, and groundwater samples were collected throughout, around, and downgradient of the former asphalt plant and analyzed for various constituents potentially present as a

result of asphalt plant operations. Figure ES-4 shows the locations of all soil and groundwater (monitoring well) sampling locations. Evaluation of the data collected from these locations indicates the following constituents likely associated with asphalt operations are present in soil and/or groundwater at the site:

Volatile Organic Compounds (VOCs)

- Degreasing solvents such as cyclohexane, dichlorobenzene, tetrachloroethene (PCE), and trichloroethene (TCE)
- Fuel-related constituents benzene, toluene, ethylbenzene, and xylenes (BTEX)

Semi-volatile Organic Compounds (SVOCs)

- Fuel-related polycyclic aromatic hydrocarbons (PAHs) such as pyrene, acenaphthene, and benzo(a)pyrene
- Fuel-related heterocyclic aromatic hydrocarbons (HAHs) carbazole and dibenzofuran
- Hydraulic oil-related bis(2-ethylhexyl)phthalate

Observations made during drilling through the bedrock indicate these types of contaminants may also be present in the unsaturated bedrock in a spatially limited area (i.e., directly below the former asphalt plant). Inorganics were also detected in site media, but comparison of the site-specific inorganic data to the west Vieques background inorganic data suggests most of the inorganic concentrations detected are likely attributable to background, especially considering the historical activity was asphalt production.

Tables ES-1 through ES-3 provide statistical summaries of the constituents detected in surface soil, subsurface soil, and groundwater, respectively. The data were evaluated not only to determine the nature and extent of contaminants present as a result of past releases, but were also compared to human health-based and ecological-based screening values to gain an understanding of the magnitude of the releases. This comparison shows that the constituent concentrations detected in both soil and groundwater are relatively low (i.e., most constituent concentrations below or just above screening values). This suggests that the past releases were likely the result of minor spills, drips, or leaks associated with normal asphalt plant operations.

Based on the physical setting and extent of contamination identified during the RI, the primary route of contaminant migration is likely vertical leaching through soil and bedrock to groundwater and subsequent transport with groundwater flow through fractures in the bedrock aquifer. The relatively flat topography and the assumed nature of releases (i.e., minor spills and leaks) suggest surface runoff is not a significant contaminant migration route at the site. Therefore, contamination in the soil and unsaturated bedrock fractures is likely spatially limited to the immediate vicinity of the former asphalt plant as a result of primarily vertical leaching of contaminants. Further, groundwater data collected from wells at the site indicate downgradient contaminant migration has been limited to less than approximately 100 ft of the former asphalt plant.

The fate and transport of contaminants present in the environmental media is dependant on many factors, such as the contaminant type, soil type, organic matter content, presence and

abundance of microorganisms, climatic conditions, chemistry of infiltrating water, and rate of groundwater migration. Degradation of the organic contaminants detected in the environmental media at AOC I can occur through biotic (biological-based [biodegradation]) or abiotic (non-biological-based) processes. Some of the contaminants detected at AOC I biodegrade primarily under anaerobic conditions (e.g., chlorinated ethenes [e.g., TCE] and 1,2-dichloropropane); others biodegrade primarily under aerobic conditions (e.g., chlorinated ethanes [e.g., 1,2-dichloroethane], BTEX, and dibenzofuran). Several of the contaminants have been shown to biodegrade under both aerobic and anaerobic conditions (e.g., 1,4-dichlorobenzene, naphthalene, and 2-methylnaphthalene). The rate at which biodegradation of these contaminants will occur is based on site-specific conditions, including the oxidation-reduction setting, presence and abundance of the proper microorganisms, and the concentrations of contaminants present. Typically, at higher concentrations levels, rates of biodegradation will be faster than at lower concentrations. As noted previously, organic contaminant concentrations at AOC I are already low. Consequently, rates of biodegradation are also expected to be low.

Based on the nature, extent, and concentrations of constituents detected in environmental media at AOC I, potential ecological and human health risks were assessed. As noted previously, the gravel-covered terrain, remnant asphalt plant structures, and sparse scrub vegetation provide minimal habitat. In fact, no preferred habitats were observed at AOC I, nor were any threatened or endangered species identified. Further, concentrations of inorganic constituents detected in surface soil were either comparable to background or were within acceptable ecological screening levels. Therefore, no unacceptable risks were identified for potential ecological receptors at AOC I.

For potential human receptors, it is noted that there is no current human presence at the site. However, exposures to various environmental media at the site were evaluated for hypothetical recreational users, maintenance workers, construction workers, industrial workers, and residents. Based on these evaluations, no unacceptable risk (over that attributable to background inorganics) was identified for exposure to soil by hypothetical human receptors. The only unacceptable risks were identified for potable use of groundwater by hypothetical future residents. The risk assessment identified benzene, bis(2-ethylhexyl)phthalate, 1,2-dichloroethane, 1,2-dichloropropane, 2-methylnaphthalene, and naphthalene as the groundwater chemicals of concern (COCs). Inorganics were eliminated as COCs because their presence is wholly or primarily attributable to background.

Based on the above information, it is concluded that CERCLA-related releases occurred during past asphalt plant operations, likely in the form of minor drips and spills. These releases resulted in contamination of soil, bedrock, and groundwater. However, the extent of contamination is generally limited to the immediate vicinity of the former asphalt plant, with vertical leaching to groundwater representing the primary transport pathway. Further, the contaminant levels present in environmental media are relatively low (with respect to human health-based and ecological-based screening values). In fact, potable groundwater use by residents is the only unacceptable risk identified for the site. In addition, only two organic constituents (benzene and bis(2-ethylhexyl)phthalate) were detected in groundwater above federal maximum contaminant levels (MCLs). Benzene concentrations declined between the 2004 and 2006 sampling events and bis(2-ethylhexyl)phthalate is a

common laboratory contaminant, so its single detection in groundwater is suspect. However, it is noted that all wells were sampled either once or twice, so the ability to evaluate trends is limited.

As summarized above, although contaminants are present in both soil and groundwater at the site, only the groundwater contamination poses an unacceptable risk (under the potable use scenario) to hypothetical future residents. Further, MCL exceedances have been identified for site groundwater. Because the groundwater contamination has been attributed to past releases from the former asphalt plant operations, it is recommended that a feasibility study (FS) be performed to evaluate whether there are technically and economically viable remedial alternatives to address the groundwater contamination. It is noted that the groundwater data suggest contaminant concentrations above MCLs have generally declined over time. However, at most, only two rounds of groundwater data (from 2004 and/or 2006) exist for any particular well. Because of this, and because groundwater contaminant concentrations are already low with respect to screening values, it is recommended that prior to performing the FS, another round of groundwater samples be collected from all site wells and analyzed for the following parameters:

- VOCs
- SVOCs
- Total and dissolved inorganics
- Nitrate, nitrite, sulfide, sulfate, total organic carbon (TOC), alkalinity, chloride, methane, ethane, ethane, ferrous iron, and functional gene testing for VOC and SVOC degrading microbes

The additional round of VOC and SVOC data will provide further information on temporal contaminant concentration changes, helping to confirm whether the general decline observed in the existing data is real or part of innate concentration variability. Although the inorganic concentrations in groundwater are likely attributable to background based on the existing data, an additional round of inorganic data will help confirm this supposition. The additional geochemical and microbial parameters will be used to determine the potential for natural attenuation of the organic compounds and the potential for mobilization of inorganics.

Based on the results of the additional round of groundwater data, the Navy may recommend that a fourth round be collected prior to performing the FS. For example, if the concentrations have declined to below MCLs, another round may be proposed to confirm this, which would be beneficial information for the FS. In addition, if the Navy determines that a pilot study would provide information beneficial to the evaluation of alternative(s) in the FS, the FS will be temporarily deferred and a pilot study work plan submitted for agency review.

Resumen Ejecutivo

El Área de Preocupación I (AOC, por sus siglas en inglés) es una antigua planta de asfalto localizada en el Antiguo Destacamento Naval de Apoyo de Municiones (NASD, por sus siglas en inglés), la cual operó desde los años 1960s hasta el 1988. La Figura ES-1 muestra la ubicación del AOC I dentro del Antiguo NASD y su localización con respecto a otros sitios ambientales. La planta de asfalto consiste de una loza grande de concreto para mezclar asfalto, una rampa de tierra utilizada para cargar, descargar y llenar costales con agregados, un área de contención de concreto para cargar el asfalto en los camiones, y dos tanques de almacenamiento de combustible diesel sobre tierra (AST, por sus siglas en inglés). Un área secundaria que contenía concreto, localizada al norte de la antigua planta, se presume fue usada para preparar los camiones antes de ser cargados con el asfalto. Una vez cargados con el asfalto, los camiones lo transportaban a los sitios en la isla donde se estaban pavimentando las carreteras. La Figura ES-2 muestra las características asociadas con la antigua planta de asfalto.

AOC I se encuentra aproximadamente a 900 pies al sur de Bahía Mosquito y adyacente a una cantera de roca activa que se usó en el pasado, en parte, para suplir agregados a la planta de asfalto. El área de AOC I es de aproximadamente un acre, aunque la planta de asfalto ocupa un área mucho más pequeña. La topografía del sitio es relativamente plana; se observó que en la antigua planta de asfalto y su vecindad, durante los eventos de lluvia, el agua se estancaba en vez de fluir. En los límites noreste y sur del sitio, la topografía se inclina hacia la Ruta 200 (al norte), la cantera (al sur), y a una zanja de drenaje para la cantera (al este).

En la actualidad no existe ningún uso humano del sitio que no sea el paso potencial de camiones desde la Ruta 200 hacia/desde la cantera. El hábitat ecológico en la antigua planta de asfalto es mínimo, y consiste principalmente de yerbas, arbustos y árboles pequeños que crecen dentro y en los alrededores de la estructura de la antigua planta de asfalto y a través del terreno pedregoso. No se encontraron especies protegidas bajo la ley federal o se observaron hábitats preferidos en el AOC I, tampoco se encontró ningún recurso cultural presente en el sitio.

El material superficial en el sitio se compone de un relleno de gravilla con arcilla fangosa y arena. Bajo la delgada cubierta del relleno, la zona de tierra es relativamente delgada (generalmente de 2 a 9 pies de espesor) y se compone de gravilla bien nivelada con arena de la unidad geológica Qa. El lecho de roca de andesita se encuentra bajo la tierra, a menudo desgastada en su superficie como saprolita. La porción superior del lecho de roca no está saturado; se observó agua subterránea por primera vez durante la perforación a 25 pies bajo el lecho de roca aunque se estabilizó a 15 pies. El agua subterránea en el sitio migra a través de las fracturas en el lecho de roca en dirección norte-oeste hacia la costa. La Figura ES-3

Note: This summary is presented in English and Spanish for the convenience of the reader. Every effort has been made for the translations to be as accurate as reasonably possible. However, readers should be aware that the English version of the text is the official version.

Nota: Este resumen se presenta en inglés y en español para la conveniencia del lector. Se han hecho todos los esfuerzos para que la traducción sea precisa en lo más razonablemente posible. Sin embargo, los lectores deben estar al tanto que el texto en inglés es la versión oficial.

muestra un modelo conceptual de AOC I, que incluye la antigua planta de asfalto, ubicación física, medio ambiental, y movimiento del agua dentro de este medio.

Aún cuando no existe ningún registro de escapes relacionados a la Ley de Respuesta Ambiental, Responsabilidad y Compensación Comprensiva (CERCLA, por sus siglas en inglés) durante las operaciones de la planta de asfalto, las observaciones durante las visitas al sitio y los datos ambientales indican que sí ocurrieron escapes en el pasado. Los datos fueron colectados a través de una serie de investigaciones durante las cuales se tomaron muestras de suelos de superficie, subsuelos, lecho de roca y aguas subterráneas en, alrededor y vertiente abajo de la antigua planta de asfalto, los que se analizaron para varios componentes potencialmente presentes como resultado de las operaciones de la planta de asfalto. La Figura ES-4 muestra las localizaciones de muestreo de todos los suelos y aguas subterráneas (pozos de monitoreo). La evaluación de los datos recolectados de todas estas localizaciones indica la presencia en suelos y/o aguas subterráneas de los siguientes componentes que probablemente están asociados con las operaciones de asfalto en el sitio:

Compuestos Volátiles Orgánicos (VOCs, por sus siglas en inglés)

- Solventes para remover grasa tales como ciclohexano, diclorobenceno, tetracloroetano (PCE por sus siglas en inglés), y tricloroetano (TCE por sus siglas en inglés)
- Compuestos relacionados con combustibles como benceno, tolueno, etilbenceno, y xilenos (BTEX por sus siglas en inglés)

Compuestos Orgánicos Semi-Volátiles (SVOCs, por sus siglas en inglés)

- Compuestos relacionados con combustibles hidrocarburos aromáticos policíclicos (PAHs por sus siglas en inglés) tales como pireno, acenaftaleno, y benzo(a)pireno
- Compuestos relacionados hidrocarburos aromáticos heterocíclicos (HAHs por sus siglas en inglés) carbazole y dibenzofuran
- Compuestos relacionados a aceite hidráulico bis(2-etilhexil)phthalate

Las observaciones hechas durante las perforaciones a través del lecho de roca indican que estos tipos de contaminantes podrían estar presentes en los lechos de roca no saturados en un área de espacio limitado (Ej., directamente debajo de la planta de asfalto antigua). También se detectaron inorgánicos (metales) en el medio del sitio, pero la comparación de datos inorgánicos para el sitio-específico con datos de trasfondo inorgánicos del oeste de Vieques sugiere que muchas de las concentraciones de metales detectadas probablemente sean atribuibles al trasfondo, considerando especialmente que la actividad histórica era la producción de asfalto. Las Tablas ES-1 a la ES-3 muestran un resumen estadístico de los componentes detectados en suelos de superficie, subsuelos y aguas subterráneas, respectivamente. Los datos se evaluaron no solamente para determinar la naturaleza y extensión de los contaminantes presentes como resultado de escapes pasados, sino para entender de una mejor manera la magnitud de los escapes comparando los datos con los valores de clasificación base para la salud humana y los ecológicos. Esta comparación

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muestra que las concentraciones de los componentes detectados tanto en suelos como en aguas subterráneas son relativamente bajas (Ej., la mayoría de las concentraciones de los componentes están por debajo o justo sobre los valores de clasificación). Esto sugiere que los escapes pasados probablemente fueron el resultado de derrames menores, goteos o filtraciones asociados a las operaciones normales de plantas de asfalto.

En base a la ubicación física y la extensión de la contaminación identificada durante la Investigación para la Remediación (RI por sus siglas en inglés), la ruta primaria de migración de contaminantes probablemente sea por lixiviación vertical a través de los suelos y lechos de roca al agua subterránea, la que es subsecuentemente transportada con el flujo de aguas subterráneas a través de las fracturas en el acuífero del lecho de roca. La topografía relativamente plana y la naturaleza de los escapes asumida (Ej., pequeños derrames y filtraciones) sugieren que la escorrentía de la superficie no es una ruta de migración de contaminación significativa en el sitio. Por lo tanto, la contaminación en los suelos y fracturas en los lechos rocosos no saturados probablemente están limitadas al espacio en las cercanías de la antigua planta de asfalto y es el resultado de la lixiviación vertical primaria de contaminantes. Además, los datos de aguas subterráneas colectados de los pozos en el sitio indican que la migración de contaminantes vertiente abajo se limita aproximadamente a menos de 100 pies de la antigua planta de asfalto. El destino y transporte de los contaminantes presentes en el ambiente depende de muchos factores, tales como el tipo de contaminación, tipo de suelo, contenido de la materia orgánica, la presencia y abundancia de microorganismos, condiciones climáticas, sustancias químicas en las aguas filtradas, y el índice de migración de las aguas subterráneas. La degradación de los componentes orgánicos detectados en los medios del ambiente de AOC I pueden ocurrir a través de procesos bióticos (con base biológica [biodegradable]) o abióticos (no biológica).

Algunos de los contaminantes detectados en el AOC I se biodegradan principalmente bajo condiciones anaeróbicas (Ej., etenos clorinados [Ej., TCE] y 1,2-dicloropropano); otros se biodegradan bajo condiciones aeróbicas (Ej., etenos clorinados [e.g., 1,2-dicloroetano], BTEX, y dibenzofuran). Varios de los contaminantes han demostrado biodegradación bajo condiciones aeróbicas y anaeróbicas (Ej., 1,4-diclorobenceno, naftaleno, y 2-metilnaftaleno).

El índice al cual la biodegradación de estos contaminantes podría ocurrir se basa en las condiciones específicas del sitio, incluyendo la posición de la reducción de la oxidación, presencia y abundancia de los propios microorganismos, y las concentraciones de contaminantes presentes. En niveles de concentraciones más altos, es típico, que los índices de biodegradación sean más rápidos que en concentraciones más bajas. Según lo que se observó anteriormente, las concentraciones de contaminantes orgánicos en el AOC I ya son bajas. Como consecuencia, se espera que los índices de biodegradación también sean bajos.

En base a la naturaleza, extensión y concentración de los constituyentes detectados en los medios ambientales de AOC I, se evaluaron los riesgos potenciales para la salud humana y los ecológicos.

Los riesgos potenciales para la salud humana y los ecológicos se determinaron en base a la naturaleza, extensión y concentración de los componentes detectados en los medios del

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ambiente en el AOC I. Según lo observado anteriormente, los terrenos cubiertos de gravilla, las estructuras remanentes de la planta de asfalto y la vegetación esparcida proveen un hábitat mínimo. De hecho, no se observaron hábitat preferidos en el AOC I, ni se identificó ninguna especie en peligro o amenazada. Más aún, las concentraciones de constituyentes inorgánicos detectados en suelos de superficie son comparables con el trasfondo y están dentro de los niveles de clasificación ecológicos aceptables. Por lo tanto, no se identificaron riesgos inaceptables para los receptores ecológicos potenciales en el AOC I.

Para receptores humanos potenciales, se anotó que no existe presencia humana en el sitio. Sin embargo, se evaluaron las exposiciones a varios medios ambientales en el sitio para usuarios de recreación, trabajadores de mantenimiento, trabajadores de construcción, trabajadores industriales y residentes hipotéticos. En base a estas evaluaciones, no se identificaron riesgos inaceptables (sobre aquellos atribuibles a los inorgánicos del trasfondo) por exposición a los suelos por receptores humanos hipotéticos. El único riesgo inaceptable fue identificado para el uso potable de las aguas subterráneas por residentes futuros hipotéticos. La evaluación de riesgo identificó benceno, bis(2-etilhexil)phthalate, 1,2-dicloroetano, 1,2-dicloropropano, 2-metilnaftaleno, y naftaleno como sustancias químicas de preocupación en aguas subterráneas (COC, por sus siglas en inglés). Se eliminaron los inorgánicos como COCs debido a que su presencia es en su totalidad o mayormente atribuible al trasfondo.

En base a la información anterior, se concluye que ocurrieron escapes relacionados a CERCLA durante las actividades pasadas de la planta de asfalto, probablemente en forma de goteras menores y derrames. Estos escapes resultaron en la contaminación de suelos, lechos de roca y aguas subterráneas. Sin embargo, la extensión de la contaminación se limita generalmente a la vecindad de la planta de asfalto antigua, con la lixiviación vertical hacia las aguas subterráneas que representa la ruta de exposición primaria. Además, las concentraciones de los contaminantes presentes en el medio ambiental son relativamente bajas (con respecto a los valores de clasificación para la salud humana y los ecológicos). De hecho, el uso de agua subterránea como agua potable por residentes es el único riesgo inaceptable identificado para el sitio. Además, sólo se detectaron dos compuestos orgánicos (benceno y bis(2-etilhexil)phthalate) en aguas subterráneas sobre el nivel de contaminación máximo federal (MCL, por sus siglas en inglés). Las concentraciones de benceno se redujeron en los eventos de muestreos entre el 2004 y 2006 y el bis(2-etilhexil)phthalate es un contaminante de laboratorio común, así que su única detección en agua subterránea es solo una sospecha. Sin embargo, se anota que todos los pozos fueron muestreados una o dos veces, por lo que la habilidad para evaluar las tendencias es limitada.

Según se resumió anteriormente, aunque haya presencia de contaminantes tanto en el suelo como en el agua subterránea en el sitio, sólo la contaminación de agua subterránea presenta un riesgo inaceptable (bajo un escenario de uso potable) a futuros residentes hipotéticos. Más aún, se han identificado los excedentes de los MCL para agua subterránea del sitio. Debido a que la contaminación de agua subterránea se ha atribuido a escapes pasados de las operaciones de la planta de asfalto antigua, se recomienda un estudio de viabilidad (FS, por

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sus siglas en inglés) para evaluar alternativas técnicas y costos viales para tratar la contaminación de agua subterránea. Se observa que los datos de agua subterránea sugieren que las concentraciones de contaminantes sobre los MCLs generalmente han disminuido con el tiempo. Sin embargo, mayormente, para un pozo en particular existen solo dos conjuntos de datos de agua subterránea (del 2004 y/o 2006). Debido a esto, y ya que las concentraciones de contaminantes en agua subterránea son muy bajas en relación a los niveles de clasificación, se recomienda que antes de realizar el FS, se recoja otro conjunto de muestras de agua subterránea de todos los pozos del sitio y que se analicen para los siguientes parámetros:

- VOCs
- SVOCs
- Inorgánicos (metales) totales y disueltos
- Nitrato, nitrito, sulfuros, sulfatos, carbón orgánico total (TOC por sus siglas en inglés), alcalinidad, cloruros, metano, etano, eteno, hierro férrico, y pruebas genéticas para los microorganismos de degradación de VOC y SVOC

El conjunto de datos adicionales de VOC y SVOC proveerán más información de los cambios en la concentración de contaminantes temporales, ayudando a confirmar si la reducción general observada en los datos existentes es real o parte de la variabilidad natural de las concentraciones. Aun cuando en base a los datos existentes, las concentraciones inorgánicas en agua subterránea probablemente sean atribuibles al trasfondo, un conjunto adicional de datos inorgánicos ayudarán a confirmar ésta suposición. Se utilizarán parámetros geo-químicos y microbianos adicionales para determinar el potencial de atenuación natural de los compuestos orgánicos y el potencial de movilización de los metales.

En base a los resultados del conjunto de datos adicionales de agua subterránea, la Marina podría recomendar que se colecte una cuarta ronda antes de llevar a cabo el FS. Por ejemplo, si las concentraciones se han reducido por debajo de los MCLs, se podría proponer otra ronda para confirmar esto, lo cual sería información beneficiosa para el FS. Además, si la Marina determina que un estudio piloto proveería información beneficiosa para la evaluación de alternativa(s) en el FS, el FS sería diferido temporalmente y se sometería para revisión de las agencias un plan de trabajo para un estudio piloto.

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TABLE ES-1
 Surface Soil Summary Statistics
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Chemical Name	Human Health Screening Value	Ecological Screening Value	Number of Analyses	Number of Detects ^z	Range of Concentrations ^z	Number of Detects Above Human Health Screening Value ^z	Number of Detects Above Ecological Screening Value ^z
Volatile Organic Compounds (µg/kg)							
1,1-Dichloroethene	12,000	100	26	2	0.43 - 0.47	0	0
1,2-Dichloroethane	280	20	26	1	1	0	0
2-Butanone	2,200,000	--	26	1	5	0	NA
4-Methyl-2-pentanone	530,000	--	26	1	2.8	0	NA
Acetone	1,400,000	--	26	1	6.7	0	NA
Benzene	640	10	29	2	0.27 - 1.2	0	0
Ethylbenzene	190,000	30	29	1	3.7	0	0
Methylene chloride	9,100	--	26	3	0.34 - 0.56	0	NA
Tetrachloroethene	480	2	26	1	0.27	0	0
Toluene	630,000	200,000	29	8	0.3 - 25	0	0
Trichloroethene	53	100	26	1	0.31	0	0
Xylene, total	27,000	--	29	6	0.2 - 27	0	NA
m- and p-Xylene	27,000	100	26	6	0.2 - 19	0	0
o-Xylene	27,000	100	26	4	0.18 - 7.8	0	0
Semi-volatile Organic Compounds (µg/kg)							
Acenaphthylene	370,000	--	40	1	104	0	NA
Anthracene	2,200,000	100	40	2	55.4 - 65	0	0
Benzo(a)anthracene	620	--	40	3	59 - 68	0	NA
Benzo(a)pyrene	62	100	40	4	33.6 - 145	2	1
Benzo(b)fluoranthene	620	--	40	2	142 - 203	0	NA
Benzo(g,h,i)perylene	2,300,000	--	40	2	47.6 - 174	0	NA
Benzo(k)fluoranthene	6,200	--	40	3	40.1 - 153	0	NA
Chrysene	62,000	--	40	1	68.3 - 135	0	NA
Dibenz(a,h)anthracene	62	--	40	1	43.7	0	NA
Fluoranthene	230,000	100	40	4	31.5 - 227	0	1
Indeno(1,2,3-cd)pyrene	620	--	40	2	39 - 138	0	NA
Pyrene	230,000	100	40	3	63.8 - 193	0	2
bis(2-Ethylhexyl)phthalate	35,000	--	40	13	43.5 - 3,880	0	NA
Inorganics (mg/kg)							
Aluminum	7,600	--	26	0	NA	0	NA
Antimony	3.1	78	26	0	NA	0	0
Arsenic	0.39	18	26	1	2.3	0	0
Barium	1,600	330	26	0	NA	0	0
Beryllium	15	40	26	0	NA	0	0
Cadmium	3.7	32	26	1	0.52	0	0
Calcium	--	--	26	1	52,000	NA	NA
Chromium	210	0.4	43	7	74.6 - 110	0	7
Chromium (hexavalent)	22	--	17	17	0.23 - 1.27	0	NA
Cobalt	140	13	26	0	NA	0	0
Copper	310	70	26	4	69 - 103	0	3
Iron	2,300	--	26	1	44,000	1	NA
Lead	400	120	26	4	8.7 - 22	0	0
Magnesium	--	--	26	16	13,000 - 15,000	NA	NA
Manganese	180	220	26	0	NA	0	0
Mercury	2.3	0.1	26	0	NA	0	0
Nickel	160	38	26	2	49 - 57	0	2
Potassium	--	--	26	0	NA	NA	NA
Selenium	39	1	26	0	NA	0	0
Silver	39	560	26	7	0.081 - 0.12	0	0
Sodium	--	--	26	0	NA	NA	NA
Thallium	0.52	1	26	2	0.73 - 0.93	2	0
Vanadium	7.8	2	26	1	140	1	1
Zinc	2,300	50	26	0	NA	0	0

Note:

¹ Lead action level

² For inorganics, it is number of detects above background, range of concentrations above background, and number of detects above screening values and background.

³ There is no background for hexavalent chromium; therefore, all detections are counted.

TABLE ES-2
Subsurface Soil Summary Statistics
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Chemical Name	Human Health Screening Value	Number of Analyses	Number of Detects ²	Range of Concentrations ²	Number of Detects Above Human Health Screening Value ²
Volatile Organic Compounds (µg/kg)					
1,1-Dichloroethene	12,000	26	1	0.42	0
1,2-Dichloroethane	280	26	1	1.2	0
2-Butanone	2,200,000	26	2	2.9 - 4.1	0
4-Methyl-2-pentanone	530,000	26	2	0.79 - 53	0
Ethylbenzene	190,000	26	2	0.89 - 96	0
Tetrachloroethene	480	26	1	0.29	0
Toluene	630,000	26	3	0.33 - 0.78	0
Trichloroethene	53	26	1	0.37	0
Xylene, total	27,000	26	3	1 - 4,460	0
m- and p-Xylene	27,000	26	3	0.79 - 2,970	0
o-Xylene	27,000	26	3	0.23 - 1,500	0
Semi-volatile Organic Compounds (µg/kg)					
2-Methylnaphthalene	31,000	26	1	4,630	0
Acenaphthene	370,000	26	1	331	0
Benzo(b)fluoranthene	620	26	2	31 - 39	0
Benzo(k)fluoranthene	6,200	26	1	32	0
Carbazole	24,000	26	1	158	0
Chrysene	62,000	26	1	129	0
Dibenzofuran	15,000	26	1	663	0
Fluoranthene	230,000	26	1	969	0
Fluorene	270,000	26	1	893	0
Naphthalene	5,600	26	1	2,550	0
Phenanthrene	230,000	26	1	2,620	0
Pyrene	230,000	26	1	469	0
Inorganics (mg/kg)					
Aluminum	7,600	26	1	32,000	1
Antimony	3.1	26	2	2.8 - 2.9	0
Arsenic	0.39	26	1	2.6	1
Barium	1,600	26	0	NA	0
Beryllium	15	26	0	NA	0
Calcium	--	26	0	NA	NA
Chromium	210	32	15	87 - 160	0
Chromium (hexavalent)	22	6	6 ³	0.255 - 0.662	0
Cobalt	140	26	0	NA	0
Copper	310	26	10	69 - 225	0
Iron	2,300	26	9	40,000 - 62,500	9
Lead	400	26	2	7.5 - 14	0
Magnesium	--	26	21	13,000 - 26,000	NA
Manganese	180	26	0	NA	0
Mercury	2.3	26	0	NA	0
Nickel	160	26	13	43 - 84	0
Potassium	--	26	0	NA	NA
Selenium	39	26	0	NA	0
Silver	39	26	7	0.081 - 0.12	0
Sodium	--	26	6	1,230 - 2,650	NA
Vanadium	7.8	26	6	136 - 188	6
Zinc	2,300	26	0	NA	0

Note:

¹ Lead action level

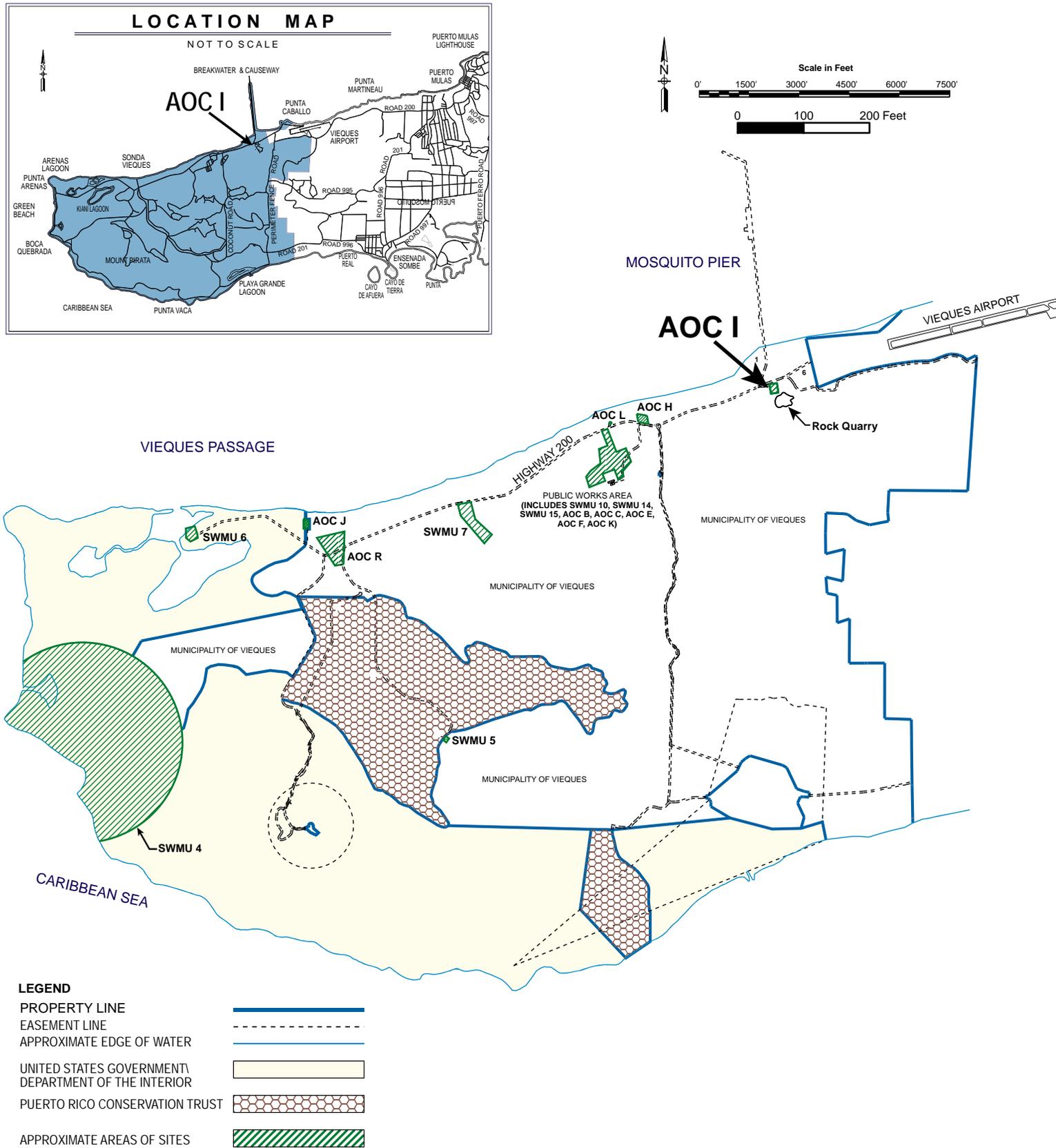
² For inorganics, it is number of detects above background, range of concentrations above background, and number of detects above screening values and background.

³ There is no background for hexavalent chromium; therefore, all detections are counted.

TABLE ES-3
Groundwater Summary Statistics
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Chemical Name	Human Health Screening Value	Maximum Contaminant Level (MCL)	2004					2006				
			Number of Analyses	Number of Detects ^a	Range of Concentrations ^b	Number of Detects Above Human Health Screening Value ^c	Number of Detects Above MCL ^c	Number of Analyses	Number of Detects ^c	Range of Concentrations ^b	Number of Detects Above Human Health Screening Value ^c	Number of Detects Above MCL ^c
Volatile Organic Compounds (µg/L)												
1,1-Dichloroethane	81	--	6	0	NA	0	NA	5	1	0.26	0	NA
1,2-Dichloroethane	0.12	--	6	0	NA	0	NA	5	0	1.2	0	0
1,2-Dichloropropane	0.16	--	6	0	0.53	0	0	5	0	NA	0	0
1,3-Dichlorobenzene	18	--	6	0	NA	0	NA	5	1	0.52	0	NA
1,4-Dichlorobenzene	0.5	75	6	0	NA	0	NA	5	1	0.52	1	0
1,1,1-Trichloroethane	200	--	6	0	14.9	0	NA	5	0	NA	0	0
4-Methyl-2-pentanone	0.35	--	6	4	0.62 - 59.3	4	2	5	2	4.6 - 28	2	1
Benzene	8.5	80	6	0	NA	0	0	5	1	0.13	0	0
Bromoform	16	--	6	0	0.51	0	0	5	0	NA	0	0
Chloromethane	1,000	--	6	4	1 - 41.6	0	NA	5	2	13 - 66	0	NA
Cyclohexane	130	700	6	3	0.45 - 14.4	0	0	5	2	0.41 - 7.9	0	0
Ethylbenzene	66	--	6	4	2.6 - 42.4	0	NA	5	2	7.1 - 47	0	0
Isopropylbenzene	520	--	6	3	1.2 - 29.7	0	NA	5	2	3.7 - 34	0	NA
Methylcyclohexane	230	1,000	6	2	1.4 - 1.9	0	0	5	2	0.3 - 1.9	0	0
Toluene	0.028	5	6	0	NA	0	0	5	2	0.17 - 1.4	2	0
Trichloroethene	--	--	6	0	NA	0	0	5	0	NA	0	0
Xylene, total	--	10,000	6	3	0.42 - 11.2	NA	0	5	2	0.8 - 10	NA	0
Semi-volatile Organic Compounds (µg/L)												
2-Methylnaphthalene	2.4	--	6	3	9.5 - 82.1	3	NA	5	2	3.8 - 110	2	NA
Acenaphthene	37	--	6	0	NA	0	NA	5	1	2.5	0	NA
Acetophenone	61	--	6	2	6.4 - 15.3	0	NA	5	0	NA	0	NA
Dibenzofuran	1.2	--	6	0	3.8 - 4.1	2	NA	5	2	1.2 - 5.5	1	NA
Fluorene	24	--	6	1	6.9	0	NA	5	2	1.7 - 8.3	0	NA
Naphthalene	0.62	--	6	2	46.2 - 81.4	2	NA	5	2	5.5 - 96	2	NA
Phenanthrene	18	--	6	2	4.8 - 5.9	0	NA	5	1	7	0	NA
bis(2-Ethylhexyl)phthalate	4.8	6	6	1	9.6	1	1	5	0	NA	0	0
Total Inorganics (µg/L)												
Aluminum	3,600	--	6	2	358 - 774	0	NA	5	2	275 - 461	0	NA
Antimony	1.5	6	6	0	NA	0	0	5	0	NA	0	0
Arsenic	0.045	10	6	2	17 - 19.7	2	2	5	2	4.3 - 4.5	2	0
Barium	730	2,000	6	6	19.2 - 104	0	0	5	5	23.9 - 89.6	0	0
Cadmium	1.8	5	6	1	8.72	1	1	5	0	NA	0	0
Calcium	--	--	6	1	93,400	NA	NA	5	0	NA	NA	NA
Chromium	11	100	6	4	1.6 - 3.1	0	0	5	0	NA	0	0
Cobalt	73	--	6	3	7.07 - 8.78	0	NA	5	0	NA	0	NA
Copper	150	1,300	6	2	8.54 - 8.64	0	0	5	1	3.4	0	0
Cyanide	73	200	6	1	11.6	0	0	5	0	NA	0	0
Iron	1,100	--	6	4	295 - 974	0	NA	5	3	290 - 1,840	1	NA
Lead	15	--	6	3	6.66 - 8.38	0	NA	5	0	NA	0	NA
Magnesium	--	--	6	4	47,500 - 59,300	NA	NA	5	0	NA	NA	NA
Manganese	88	--	6	6	57.2 - 1,930	5	NA	5	4	145 - 1,900	4	NA
Mercury	1.1	2	6	2	0.0462 - 0.0478	0	0	5	0	NA	0	0
Nickel	73	--	6	3	1.8 - 2.51	0	NA	5	1	2.5	0	NA
Potassium	--	--	6	1	1,290	NA	NA	5	1	1,240	NA	NA
Selenium	18	50	6	0	NA	0	0	5	4	1.8 - 3.8	0	0
Sodium	--	--	6	5	111,000 - 382,000	NA	NA	5	5	143,000 - 418,000	NA	NA
Vanadium	3.6	--	6	1	46.9	1	NA	5	0	NA	0	NA
Zinc	1,100	--	6	1	2.14	0	NA	5	2	10.3 - 12	0	NA
Dissolved Inorganics (µg/L)												
Aluminum	3,600	--	6	0	NA	0	NA	5	2	38.9 - 126	0	NA
Antimony	1.5	6	6	2	2.33 - 2.85	0	0	5	0	NA	0	0
Arsenic	0.045	10	6	2	15.4 - 20	5	5	5	1	6.2	0	0
Barium	730	2,000	6	6	19 - 103	0	0	5	5	25.4 - 94.4	0	0
Cadmium	1.8	5	6	1	8.72	1	1	5	0	NA	0	0
Calcium	--	--	6	1	92,600	NA	NA	5	0	NA	NA	NA
Chromium	11	100	6	2	1.46 - 1.65	0	0	5	3	1.1 - 7	0	0
Cobalt	73	--	6	1	8.61	0	NA	5	4	0.49 - 0.94	0	NA
Copper	150	1,300	6	0	NA	0	0	5	0	NA	0	0
Iron	1,100	--	6	2	99.8 - 188	0	NA	5	3	117 - 1,470	1	NA
Lead	151	--	6	2	7.83 - 7.95	0	NA	5	0	NA	0	0
Magnesium	--	--	6	4	46,700 - 58,400	NA	NA	5	0	NA	NA	NA
Manganese	88	--	6	6	44.9 - 1,920	5	NA	5	5	12.1 - 1,960	4	NA
Nickel	73	--	6	1	2.07	0	NA	5	5	0.65 - 1.6	0	NA
Potassium	--	--	6	1	1,340	NA	NA	5	1	1,270	NA	NA
Selenium	18	50	6	0	NA	0	0	5	1	2.2	0	0
Sodium	--	--	6	5	112,000 - 404,000	NA	NA	5	5	147,000 - 430,000	NA	NA
Vanadium	3.6	--	6	1	45.3	1	NA	5	0	NA	0	NA
Zinc	1,100	--	6	2	2.32 - 3.24	0	NA	5	2	10.7 - 12.4	0	NA

NA - Not Applicable



LEGEND

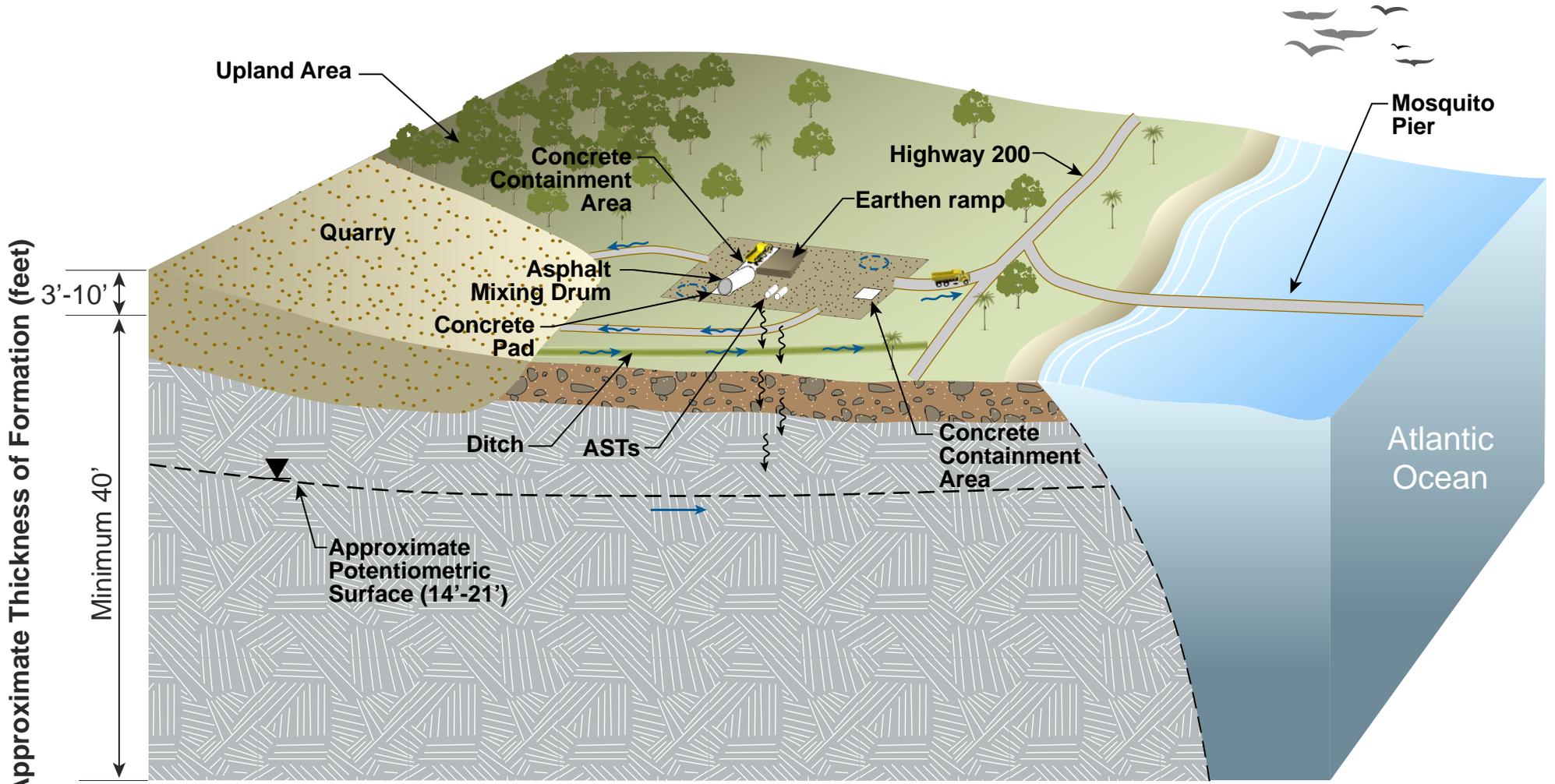
- PROPERTY LINE
- EASEMENT LINE
- APPROXIMATE EDGE OF WATER
- UNITED STATES GOVERNMENT/
DEPARTMENT OF THE INTERIOR
- PUERTO RICO CONSERVATION TRUST
- APPROXIMATE AREAS OF SITES

SOURCE:
VIEQUES NASD SURVEY LAND TRANSFER & DISPOSAL OVERALL LOCATION SURVEY
PREPARED BY GLENN & SADLER AND LUIS BERRIOS MONTES & ASSOCIATES

Figure ES-1
AOC I and Other Sites Location Map
AOC I Remedial Investigation Report
Vieques, Puerto Rico



Figure ES-2
1994 Aerial Photograph of AOC I
AOC I Remedial Investigation Report
Vieques, Puerto Rico



Approximate Thickness of Formation (feet)

3'-10'
Minimum 40'

Legend

-  Gravel with Sand, Silt, and Clay
-  Fractured Andesite
-  Surface water flow direction
-  Area of standing water during rain event
-  Direction of groundwater flow
-  Infiltration and leaching

Not to Scale

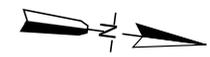
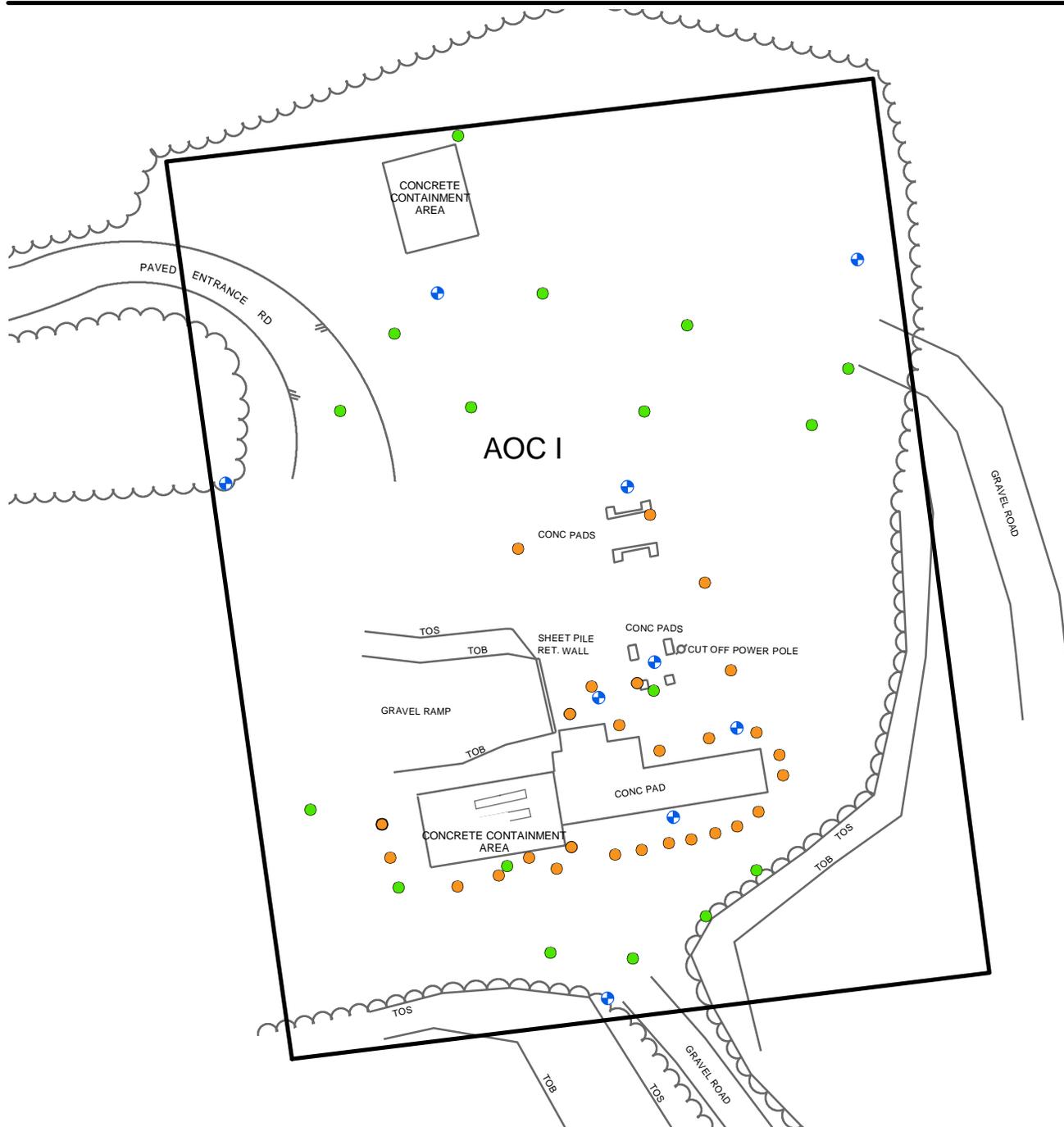


Figure ES-3
AOC I Conceptual Site Model
 AOC I RI Report
 Vieques, Puerto Rico



LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Surface and Subsurface Soil Location
- Surface Soil Location
- Monitoring Well Location



Figure ES-4
Surface Soil, Subsurface Soil,
and Monitoring Well Location Map
AOC I Remedial Investigation Report
Vieques, Puerto Rico
CH2MHILL

SECTION 1

Introduction

This report is the Remedial Investigation (RI) Report for Area of Concern (AOC) I, located at the former Naval Ammunition Support Detachment (NASD), Vieques, Puerto Rico. The report summarizes the historical activities and investigations that took place at AOC I, as well as the nature and extent of contamination and associated assessment of current and potential future risks to human health and the environment.

On March 14, 2005, Vieques was placed on the National Priority List (NPL), which required all subsequent environmental restoration activities for Navy Installation Restoration (IR) sites on Vieques be conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) unless and until removed from CERCLA authority.

This RI report has been prepared on behalf of the Naval Facilities Engineering Command, Atlantic (NAVFAC, Atlantic) by CH2M HILL under Navy Contract N62470-02-D-3052, Navy Comprehensive Long-Term Environmental Action (CLEAN III), Contract Task Order 007.

1.1 Objective

The objective of the RI is to sufficiently delineate the nature and extent of potential contamination from historic CERCLA-related release(s) at AOC I such that the potential human health and ecological risks can be appropriately assessed and remedial action determinations made. A "CERCLA-related release" is a release of hazardous substances, pollutants, and contaminants eligible for CERCLA response as defined in CERCLA Sections 101(14) and 101(33).

1.2 Scope of Work

The following scope of work was completed in order to achieve the objective of the RI:

- Review and incorporation of relevant results from previous investigations at AOC I. These investigations comprised the *Environmental Baseline Survey (EBS)* (Program Management Company, 2000) and the *Expanded Preliminary Assessment/Site Investigation (PA/SI), Phase II, Seven Sites* (CH2M HILL, 2002).
- Collection of surface soil, subsurface soil, and groundwater samples during the RI and supplemental RI to sufficiently delineate the nature and extent of contamination.
- Collection of lithologic data during soil borings to characterize the site geology.
- Collection of groundwater level and aquifer permeability data to characterize the site hydrogeology.

- Quantitative assessment of potential human health risks in accordance with the Human Health Risk Assessment Protocol contained within the *Master Quality Assurance Project Plan, Environmental Restoration Program, Vieques, Puerto Rico* (CH2M HILL, 2007).
- Quantitative assessment of potential ecological risks in accordance with the Ecological Risk Assessment Protocol contained within the *Master Quality Assurance Project Plan, Environmental Restoration Program, Vieques, Puerto Rico* (CH2M HILL, 2007).

The field data collection was completed in accordance with the following documents:

- *Work Plan, Sampling Plan, and Health and Safety Plan* in Appendix A of the EBS (Program Management Company, 2000). The Work Plan indicates that work was conducted in accordance with:
 - American Society for Testing and Materials (ASTM) Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process (ASTM Standard E 1527-97) (ASTM, 1997)
 - Naval Facilities Engineering Command, Environmental Baseline Survey Guidance (NAVFACENGCOM, 1995)
- *Site Specific Work Plan, U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico, Phase II, Seven Sites* (CH2M HILL, 2000a)
- *Master Work Plan for the U.S. Naval Ammunition Storage Detachment, Vieques, Puerto Rico* (CH2M HILL, 2000b)
- *Master Work Plan for the former U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico* (CH2M HILL, 2001)
- *Remedial Investigation/Feasibility Study Work Plan for AOC I and AOC R at the Former U.S. Naval Ammunition Support Detachment (NASD), Vieques Island, Puerto Rico* (CH2M HILL, 2004)
- *Supplemental Remedial Investigation Work Plan for Area of Concern (AOC) I, The Former U.S. Naval Ammunition Support Detachment (NASD), Vieques Island, Puerto Rico* (CH2M HILL, 2005a)

1.3 Organization of the RI Report

The RI Report is organized as follows:

Section 1, Introduction, presents a summary of the objective and scope of the RI and the organization of the RI Report.

Section 2, Site History, Physical Setting, and Previous Investigations, presents general information about AOC I, such as its former uses, climate, topography, geology and hydrogeology, and natural and cultural resources, as well as a discussion of the regulatory status of the site.

Section 3, Summary of Field Investigations, presents site-specific descriptions and summaries of the various tasks completed as part of the RI for AOC I. In addition, Section 3

presents the data management and quality control (QC) measures used during collection of AOC I-related data and the data quality evaluation (DQE).

Section 4, Nature and Extent of Contamination, discusses the nature and extent of soil and groundwater contamination present at AOC I.

Section 5, Contaminant Fate and Transport, presents an evaluation of the fate and transport of potential contaminants at the site in the context of the conceptual site model (CSM).

Section 6, Human Health Risk Assessment Summary, summarizes the results of the human health risk assessment (HHRA) for AOC I.

Section 7, Ecological Risk Assessment Summary, summarizes the results of the ecological (ERA) for AOC I.

Section 8, Remedial Investigation Conclusions and Recommendations, presents the conclusions drawn based on the investigation conducted at the site. This section also provides the recommendations for a path forward.

Section 9, References, presents a list of sources used in the development of this RI Report.

Appendices

Appendix A - Boring Logs: Surface and subsurface lithologic logging and drilling information.

Appendix B - Photographs of Rock Cores: Photographic log of characteristic rock core sections.

Appendix C - Video Logs of Borings: Three down hole videos taken prior to well installation.

Appendix D - Well Completion Diagrams: Schematic diagrams of well completions, including survey information.

Appendix E - Well Development: Logs of monitoring well development, including field parameters collected.

Appendix F - Groundwater Sampling: Data Sheets: Data sheets identifying volumes removed, rates, parameters collected, and other information collected during groundwater sampling.

Appendix G - In-Situ Permeability Test Data Sheets and Photographs: Data recorded during permeability testing of selected wells, and evaluation of those data. Photographs showing permeability test equipment.

Appendix H - Survey Data: Summary of survey information for surface and subsurface soil sampling locations and monitoring wells.

Appendix I - Investigation-Derived Waste (IDW) Disposal Information: Records associated with IDW disposal.

Appendix J - Habitat Characterization Report: The habitat characterization report completed for seven sites, including AOC I.

Appendix K - Validated Laboratory Data: Validated analytical data tables for surface and subsurface soil samples and groundwater samples.

Appendix L - Data Quality Evaluations: Data quality evaluation reports (one for the 2000 PA/SI and 2004 RI field investigations and one for the 2006 supplemental RI field investigation) that assess the overall quality and usability of the data.

Appendix M - Human Health Risk Assessment: Full, quantitative human health risk assessment upon which the summary in Section 6 is based.

Appendix N - Ecological Risk Assessment: Full, quantitative ecological risk assessment upon which the summary in Section 7 is based.

Appendix O - Final Responses to EPA and EQB Comments on Draft AOC I Report: Navy responses to EPA and EQB comments on the draft AOC I RI Report.

SECTION 2

Site History, Physical Setting, and Previous Investigations

This section presents a summary of the history, physical setting, and previous environmental investigations conducted at AOC I. Also contained in this section are descriptions of natural and cultural resources as they pertain to AOC I.

2.1 Site Location and Description

Vieques, Puerto Rico, is located in the Caribbean Sea, approximately 7 miles southeast across the Vieques Passage from the eastern tip of the main island of Puerto Rico, as illustrated in Figure 2-1. This island is located on the Antillean Island Arc separating the Caribbean Sea from the Atlantic Ocean and is approximately 21 miles long and 4.5 miles wide, with an area of approximately 33,100 acres, or 51 square miles. The location of AOC I within the former NASD and with respect to other sites is presented in Figure 2-2.

AOC I, a former asphalt plant, is located approximately 900 feet (ft) south of Mosquito Pier, adjacent to an active Public Works Department rock quarry on the western side of Vieques. The asphalt plant was in operation from the 1960s through 1988. The former asphalt plant comprised one large concrete pad containing the asphalt mixing drum, one earthen ramp with a sheet metal support wall, one concrete-paved containment area, and an area where two diesel fuel above-ground storage tanks (ASTs) were formerly located. An additional concrete containment area is located approximately 50 ft north of the former plant. Both the containment areas have sumps. Figure 2-3 shows the features associated with the former asphalt plant.

2.2 Site History and Past Operations

The former asphalt plant was a hot mix operation, which means asphalt material was heated and aggregate from the adjoining quarry was mixed with the asphalt. No blending of additives is known to have occurred at this facility. Trucks would enter the facility, be loaded with asphalt, and transport the asphalt to a location on the island where roads were being paved.

A concrete containment area located in the northern portion of the site (Figure 2-3 and the third photograph in Figure 2-4) is assumed to have been used as a staging area for the asphalt trucks prior to being loaded with asphalt. The large concrete pad (shown in the second photograph of Figure 2-4 and the top right photograph in Figure 2-5) is assumed to be where the asphalt mixing drum was located. The sheet metal retaining wall appears to have been used as support for an earthen ramp, presumably used by heavy equipment front-end loaders to fill hoppers that fed aggregate into the asphalt plant. The earthen ramp is shown as the dark feature in the upper right-hand side of the top right photograph in

Figure 2-5. It is also shown overgrown with vegetation adjacent to the concrete containment area in the top photograph in Figure 2-4. The concrete containment area to the south (shown in the top photograph of Figure 2-4 and the top left photograph of Figure 2-5) is assumed to have been used for transfer of asphalt to trucks.

2.2.1 AOC I Timeline

Table 2-1 lists the various studies/activities conducted at or relevant to the former asphalt plant. Each of these is summarized below.

- The EBS (Program Management Company, 2000) was performed by Environmental Resources Management (ERM) for the former NASD (including AOC I). The EBS Report documents the environmental condition of the property in support of land transfer from the Navy to the Municipality of Vieques (MOV), Department of the Interior (DOI), and the Puerto Rico Conservation Trust. AOC I was initially identified during the EBS site reconnaissance conducted on March 14, 2000. During the reconnaissance, two concrete-bermed containment areas, reportedly used for staging trucks (northern containment area) and loading (southern containment area), were observed. Each area was observed to have a sump at one end that contained what was reported to be asphalt-like material. One containment area had a drain pipe in the sump, but no evidence of a release was observed outside the containment area. During the site reconnaissance, ERM collected three surface soil samples – one each adjacent to areas where black staining was observed on the concrete surfaces of the two containment areas and one from stained soil at the location of the former diesel fuel ASTs, as shown on the bottom-most photograph of Figure 2-5. The analytical results of this sampling are discussed in Section 4 – Nature and Extent of Contamination.

For AOC I, the EBS concluded that it should be further investigated under the IR program. Additional information about the EBS can be found in the *Environmental Baseline Survey: Final, Naval Ammunition Support Detachment Vieques, Vieques Island, Puerto Rico* (Program Management Company, 2000).

- The Quitclaim Deed (Department of the Navy, 2001), which transferred the former NASD land to the MOV, DOI, and the Puerto Rico Conservation Trust. The property that contains AOC I was transferred to the MOV.
- The Expanded Preliminary Assessment/Site Investigation (PA/SI), Phase II, at AOC I (CH2M HILL, 2002) was conducted in November and December 2000 based on the recommendation for further investigation in the EBS Report. The PA/SI consisted of an ecological survey and expanded soil sampling that included 26 co-located surface soil samples (0 to 0.5 ft below land surface [bls]) and 26 subsurface soil samples (4 to 6 ft bls). The purpose of the soil sampling was to determine whether a release had occurred. The analytical results of this sampling are discussed in Section 4 – Nature and Extent of Contamination.

Due to the identification of a probable release(s), the Expanded PA/SI Report recommended the site be investigated further in an RI to delineate the extent of surface soil impacts at the site and conduct a risk assessment. Additional information about the Expanded PA/SI can be found in the *Expanded Preliminary Assessment/Site Investigation*,

Phase II, Seven Sites, Former U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico (CH2M HILL, 2002).

- Based on the recommendations of the Expanded PA/SI, an RI was performed in August/September 2004. Following completion of the initial RI fieldwork, the *Interim Remedial Investigation Report for Area of Concern (AOC) I at the Former U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico (CH2M HILL, 2005b)* was prepared to facilitate regulatory review of existing data and current representation of the nature and extent of contamination such that the scope of the supplemental RI fieldwork could be concurred upon. The supplemental RI was performed between November 2005 and January 2006. Details of the RI and supplemental RI activities are presented in Section 3 – Summary of Field Investigations. The analytical results for the RI and supplemental RI are discussed in Section 4 – Nature and Extent of Contamination.

2.3 Physical Setting

This subsection summarizes the regional environmental setting of AOC I, including weather and climate, topography, geology, and hydrogeology, including surface water drainage, ecological setting, and cultural resources. A number of activities were conducted to develop an understanding of the physical setting of AOC I. These activities included historical document research; an ecological investigation by Geo-Marine, Inc.; and field data collection activities such as soil borings, video logging, rock coring, and slug testing. The information gathered during these activities is summarized below.

2.3.1 Weather and Climate

The climate of Vieques is tropical-marine. Temperatures are nearly constant at an annual average temperature of about 79°F; August is the warmest month, with an average temperature of 82°F and February the coolest, with an average temperature of 76°F (Greenleaf/Telesca *et. al.*, 1984). Vieques lies directly in the path of the prevailing easterly trade winds, which regulate the climate of Puerto Rico. The trade winds result in a rainfall pattern characterized by a dry season from December through July and a rainy season from August through November. Heavy precipitation may result from tropical storms from June to November, which is considered normal for this area of the Caribbean. The western part of the island, where AOC I is located, averages approximately 43 inches of rainfall per year (Geo-Marine, Inc., 2003).

2.3.2 Topography

The topography of the former NASD is characterized by generally low hills and small valleys intersected by a series of ephemeral streams. The topography at AOC I is generally flat with only slight changes in elevation from a high of approximately 30 ft above mean sea level (amsl) in the southern portion of the site to a low of approximately 27 ft amsl toward the northern end (Figure 2-6).

2.3.3 Geology and Soils

The geology of Vieques is characterized by plutonic and volcanic rocks generally overlain by alluvial deposits and sedimentary rocks. The volcanic rocks, of Late Cretaceous age, were deposited in a marine environment. Later in the Cretaceous Period, a quartz-diorite/granodiorite plutonic complex intruded the volcanics, and is exposed over a large part of the island (U.S. Geological Survey [USGS], 1989).

In various locations on the former NASD, the bedrock is exposed and weathered. Because of the weathering of the bedrock, gravels, sands, and finer particles (silts and clays) have been transported downhill. Over the years, this material has gathered in valleys and near the ocean, forming alluvial deposits. The alluvial sedimentary deposits generally consist of a mixture of gravel, sand, silt, and clay. Based on the generalized geology of Vieques Island map (USGS, 1989), five general categories, based on geologic origin, are present in western Vieques:

1. Qa – Quaternary age alluvial deposits (sand, silt, and clay)
2. Qb – Quaternary age beach and dune deposits (calcite, quartz, volcanic rock fragments and minor magnetite)
3. Qs – Quaternary age swamp and marsh deposits, organic muck, sandy or silty, and peat
4. Tl – Tertiary age marine sedimentary rocks (report indicated variable limestones)
5. KTd – Cretaceous age plutonic rock made up largely of granodiorite and quartz diorite, locally deeply weathered

In addition, the following sixth category is mapped as outcropping on eastern Vieques:

6. Kv – Cretaceous age sandstone, siltstone, conglomerate, and volcanic rock (often andesite), tuff, and tuffaceous breccia.

The distribution of geologic zones in western Vieques is illustrated on Figure 2-7, which shows that AOC I lies within the Qa geologic zone, near the boundary of the KTd zone. Bedrock borings for monitoring wells installed in 2004 and 2005 as part of the RI, however, penetrated relatively thin beds of alluvial material and saprolite (weathered bedrock material) (2 to 15 ft thick, with the majority being less than 6 ft thick) and continued into bedrock composed of andesite. Andesite, a fine grained volcanic rock, is commonly found in the Kv geologic zone.

Rocks are the primary sources of the constituent materials that make up the unconsolidated deposits. Most rocks are formed from elements such as oxygen, silicon, aluminum, iron, magnesium, calcium, potassium, and sodium (USGS, 1997). Specifically, common bedrock types found on Vieques (granodiorite and quartz diorite) typically are composed of approximately 61 to 66 percent silicon dioxide, 16 to 17 percent aluminum oxide, 2 to 3 percent ferric oxide, 2 to 4 percent ferrous oxide, 1 to 3 percent magnesium oxide, 3 to 6 percent calcium oxide, 3 to 4 percent sodium oxide, and 2 to 3 percent potassium oxide (Travis, 1955).

Chemical and physical processes break down the rocks and form minerals that are characteristic of the parent material. The soil on Vieques is a direct product of the island's

bedrock which, as indicated previously, consists mostly of granodiorite, quartz diorite, some volcanic lavas (commonly andesites), and marine sedimentary deposits such as limestone. Soils on Vieques are primarily residual, because of both climatic conditions (i.e., warm temperatures and considerable precipitation that promotes chemical weathering) and parent rock type susceptible to chemical weathering. The eastern side of the island has less developed soil due to the relatively impermeable volcanic rock, the greater chemical stability of volcanic rocks under surface conditions, and less precipitation than the west side. Human influences, such as agricultural processes and air pollution, and other natural process, such as vegetative decay, also likely contribute to the constituents found in the soil.

Based on the soil borings completed at AOC I during the Expanded PA/SI and RI, the unconsolidated deposits beneath AOC I generally consist of a mixture of dark grayish brown, well-graded gravel with sand from ground surface to a depth of 2 ft to 9 ft bls, in some cases followed by saprolite (in-place weathered bedrock material) ranging from 4 to 15 ft bls. The leveled area representing the former asphalt plant has surficial material composed of angular gravel (crushed rock) fill mixed with silty clay and sand. Boring logs generated during the investigations are contained in Appendix A.

Exposed boulders of andesite are visible in the quarry adjacent to AOC I. Based on rock coring performed at locations NDAIMW01, NDAIMW04, NDAIMW06, and NDAIMW07 during installation of monitoring wells, the unconsolidated material is underlain by greenish-gray, highly fractured, fine grained, andesite, weathered at the surface, and along some fracture zones, with massive bedding and secondary quartz fracture infilling, to at least 45 ft bls, the maximum depth of borings. Rock samples recovered from cores generally consisted of pieces 1 inch to 4 inches in length, suggesting that the bedrock within the cored interval is well fractured. Iron staining was noted on joint surfaces in areas of the first encountered water, suggesting that these fractures are or at one point were open sufficiently to transmit water. At two monitoring well boring locations (NDAIMW05 and NDAIMW06), highly weathered fracture zones in the bedrock were encountered, containing zones of highly weathered joints with weathering products of the bedrock, consisting of lean clay with gravel sized pieces of residual bedrock. At boring locations NDAIMW01, NDAIMW03, NDAIMW04, NDAIMW06, and NDAIMW07, at times when the core drill device or the air hammer bit was removed from the borehole, loose rock fragments from the borehole wall fell from the borehole wall. This generally occurred between 32 and 37 ft bls. That this less competent interval of bedrock was identified at a fairly uniform depth across the site suggests it may represent a horizontally extensive fractured zone that may be more hydraulically conductive than other intervals encountered. It was also the interval where water was first observed during drilling and, subsequently, was the interval across which the well screens were installed. A geologic profile for AOC I (Figure 2-8) was developed based on information in the soil boring logs for monitoring well installation (Appendix A), rock cores (photographs in Appendix B), and video logs (Appendix C).

2.3.4 Hydrology and Hydrogeology

AOC I is relatively flat, with gentle slopes on the north, west, and south sides of the site. The site was visited during a substantial rain event on October 21, 2004, at which time the surface drainage patterns were observed. Regional surface water flow in the area is to the north toward Vieques Passage, which is located approximately 900 ft north-northeast of

AOC I. Figure 2-9 portrays the surface runoff drainage patterns observed during the major rain event of October 21, 2004. Within the area of the former asphalt plant, surface runoff was not appreciable due to the flat topography. Surface runoff was observed at the northern, southern, and eastern margins of AOC I, along the gravel roads leading into and out of the site and quarry and between the site and the eastern drainage ditch. There were no erosional features observed at the site; erosional features were observed only along sloped access roads adjacent to the site.

During the rain event, no surface runoff from AOC I was observed flowing toward the drainage ditch; a soil berm along the eastern side of the site appeared to prevent eastward runoff. The drainage ditch was observed to contain approximately 2 ft of water during the site visit. It was noted that surface drainage from at least part of the rock quarry was directed toward the drainage ditch. This drainage ditch does not appear to be an ephemeral stream because of its abrupt termination at Highway 200, where it discharges water during rain events onto the roadway. In fact, the agencies concurred it was not an ephemeral stream. This information, coupled with the lack of runoff from the site to the ditch, resulted in the ditch being eliminated from consideration for sampling.

USGS (1989) describes the Resolución Valley aquifer, which has alluvial deposits averaging 30 ft in thickness, in the northwestern portion of Vieques. As shown in Figure 2-10, this aquifer is not present beneath AOC I; neither are thick alluvial deposits, based on the soil borings collected. In fact, the first water-bearing zone at AOC I was encountered within the bedrock at approximately 34 ft bls during the drilling for monitoring well installation at well locations NDAIMW02, NDAIMW03, and NDAIMW05. This water-bearing zone was not identified in the six remaining borings because during the rock coring process at those borings, the addition of water was necessary to cool the coring bit, making it impossible to identify the water-bearing zone at that time. However, a highly fractured zone was encountered in all monitoring well boreholes at that approximate depth, so it is likely that first encountered groundwater would have been at approximately 34 ft bls in all wells.

Although the first identifiable water was encountered at approximately 34 ft bls, the stabilized water levels subsequently measured in the boreholes were at depths of approximately 14 ft to 22 ft bls. It is quite common for individual fractures to develop differential pressures resulting in a potentiometric surface at higher elevations than first observed groundwater. The geologic profile for AOC I (Figure 2-8) shows the elevation of the measured potentiometric surface.

The groundwater flow direction at AOC I was estimated based on groundwater elevations from the nine monitoring wells installed across the site. Groundwater level data were collected three times (Table 2-2) during the field monitoring, which helps assess variability in flow direction and gradient. As shown in Table 2-2, measured water levels in AOC I wells (except NDAIMW06) were similar during the monitoring events of September 2004 and January 2006. Between January 2006 and March 2006, the water levels in all wells declined between 4 and 5 ft.

The estimated groundwater flow direction, based on data collected on March 17, 2006, is presented on Figure 2-11. Lateral groundwater flow in andesite bedrock is complex because it is confined to fractures within the bedrock. The directions and rates of groundwater movement in bedrock are greatly confined by the size, frequency, and orientation of

fractures and by the hydraulic gradient and, therefore, can be quite variable on the small-scale. However, the general direction of groundwater flow at AOC I for all three rounds of water level measurements is northwest toward the Vieques Passage.

Based on the water levels from the March 2006 measurement, the horizontal hydraulic gradient appears to increase from south to north across AOC I (Figure 2-11). The estimated horizontal hydraulic gradient is approximately 0.0043 ft per foot (ft/ft) across the southern and central portion of AOC I, but increases to approximately 0.0330 ft/ft across the northern portion of AOC I. The steeper gradient in the northern area may indicate lower hydraulic conductivity in that area. Since hydraulic conductivity is controlled by fractures in the bedrock, a lower conductivity in this area may imply that there are fewer and/or less interconnected fractures, and/or fractures with smaller partings, in the northern portion of AOC I. However, the fact that NDAIMW06 boring encountered a highly fractured zone from 32 to 45 ft bls suggests that it is sufficiently connected to the fracture system to be representative of that area of the fractured rock aquifer.

Slug test data collected from monitoring wells NDAIMW06, NDAIMW08, and NDAIMW09, located closer to the northern boundary of AOC I, support a potentially lower hydraulic conductivity in this area. The average hydraulic conductivity measured at well NDAIMW06 is 0.1 ft per day (ft/day), at NDAIMW08 it is 0.3 ft /day, and at NDAIMW09 it is approximately 0.9 ft/day. Measured hydraulic conductivity in monitoring wells NDAIMW01, -02, -03, -04, and -05, in the southern and central portion of AOC I, average 4.1 ft/day. It should be noted, however, that the mathematics of slug test analyses were designed to simulate conditions in a porous media aquifer, not fractured rock. Hydraulic conductivity measurements via slug testing in fractured rock are prone to a high degree of uncertainty because the flow often does not simulate porous media flow for which the slug test analytical methods were designed. However, the data gathered at AOC I are helpful in estimating differences in hydraulic conductivity at locations relative to each other. Details of hydraulic conductivity calculations for slug tests performed at AOC I are included in Appendix G.

2.4 Ecological Setting

Most of the former NASD property is undeveloped and heavily vegetated with trees and low-lying thorny brush. AOC I, on the other hand, was developed for industrial use, and is located adjacent to an active rock quarry. The former asphalt plant area consists of several grassy areas, bare ground covered with gravel, several concrete pads, and gravel roads. Hurricane-grass (*Fimbristylis cymosa*) is the most abundant flora. Bitter bush (*Eupatorium odoratum*), button sage (*Lantana involucrata*), giant milkweed (*Calotropis procera*), silky sesban (*Sesbania sericea*), and wild-tantan (*Dismanthus virgatus*) are present in approximately 20 percent of the vegetated area in the adjacent shrub community. Several tree species, such as the white fig (*Ficus citrifolia*) and Gumbo-Limbo (*Bursea simarouba*), have recently invaded the area.

No federally-protected species or preferred habitats were observed at AOC I. Very few wildlife species were observed utilizing the abandoned asphalt plant at AOC I. However, a few species of birds, including bananaquit (*Coerba flaveola*), black-faced grassquit (*Tiaris bicolor*), northern mockingbird (*Mimus polyglottus*), and common ground doves (*Columbina*

passerina) were observed in the adjacent scrub. Common ground doves, gray kingbirds (*Tyrannus dominicensis*), and bananaquits were the most common birds in the adjacent areas. In addition, mongoose (*Herpestes auro punctatus*) and horse tracks were seen at AOC I. The ramp provided shade, foraging areas, and cover for a few common anoles (*Anolis* sp.). Marine toads (*Bufo marinus*) and marine toad tadpoles were observed in the water-filled concrete structure (CH2M HILL, 2002).

2.5 Cultural Resources

Although twelve archeological sites and districts are listed on the National Register of Historic Places (NRHP) for western Vieques (Geo-Marine, 1996), no cultural resources are located at AOC I.

TABLE 2-1
 Study/Activity Timeline
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Study/Activity	Author	Purpose of Study/Activity	Study Date(s)	Report Date
Environmental Baseline Survey (EBS)	Program Management Company	Characterize the existing environmental conditions on west Vieques prior to the planned property transfer.	March through October 2000	October 17, 2000
Quitclaim Deed	Department of the Navy	To transfer NASD property to the Municipality of Vieques, Department of the Interior (DOI), and the Puerto Rico Conservation Trust.	Not applicable	April 30, 2001
Expanded Preliminary Assessment/Site Investigation, Phase II, Seven Sites	CH2M HILL	Assess the environmental suitability of the property for transfer to the Municipality of Vieques. Determine whether a release of hazardous materials has occurred at each of the seven sites.	November 2000 through November 2002	November 18, 2002
Interim Remedial Investigation	CH2M HILL	Presentation of the nature and extent of constituents in AOC I media so that supplemental RI scope of work can be concurred upon.	November 2000 through January 2005	January 1, 2005

TABLE 2-2
 Summary of Monitoring Well Groundwater Elevations
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Monitoring Well ID	Top-of-casing Elevation (ft amsl)	September 22, 2004		January 10, 2006		March 17, 2006	
		Depth to Water (ft below TOC)	GW Elevation (ft amsl)	Depth to Water (ft below TOC)	GW Elevation (ft amsl)	Depth to Water (ft below TOC)	GW Elevation (ft amsl)
NDAIMW01	35.27	17.68	17.59	17.57	17.70	22.18	13.09
NDAIMW02	34.54	17.28	17.26	16.97	17.57	21.44	13.10
NDAIMW03	34.77	17.54	17.23	17.23	17.54	21.75	13.02
NDAIMW04	34.96	17.95	17.01	17.53	17.43	22.14	12.82
NDAIMW05	34.82	18.26	16.56	17.84	16.98	22.26	12.56
NDAIMW06	34.75	25.04	9.71	20.65	14.10	25.04	9.71
NDAIMW07	35.16	18.14	17.02	17.73	17.43	22.14	13.02
NDAIMW08	33.81	N/A		19.69	14.12	24.01	9.80
NDAIMW09	35.10	N/A		18.55	16.55	23.39	11.71

ft amsl = feet above mean sea level (NGVD 1929)

TOC = Top of Casing

N/A = Not applicable- NDAIMW08 and NDAIMW09 were installed in December 2005

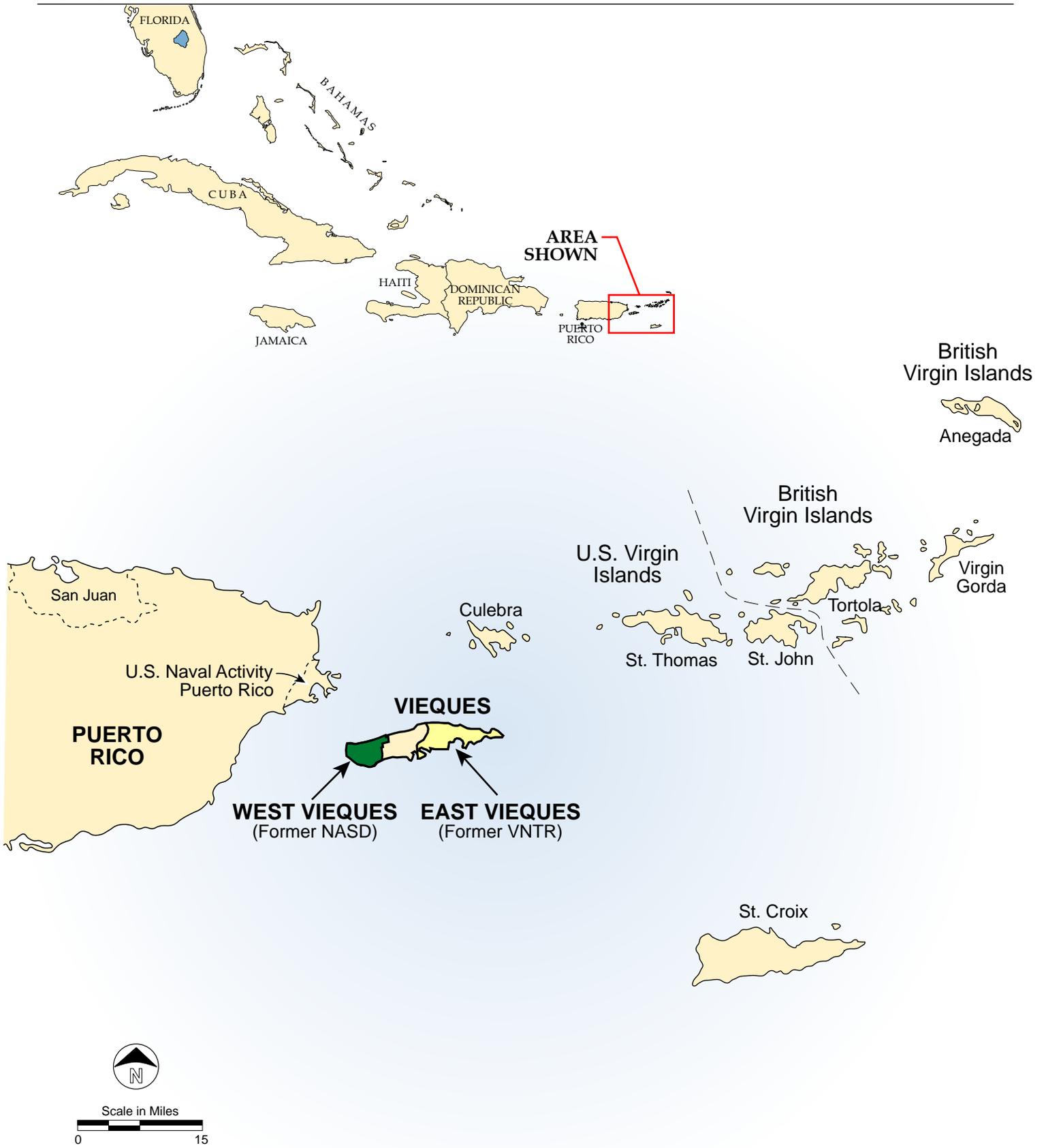


Figure 2-1
Regional Location Map
AOC I Remedial Investigation Report
Vieques, Puerto Rico

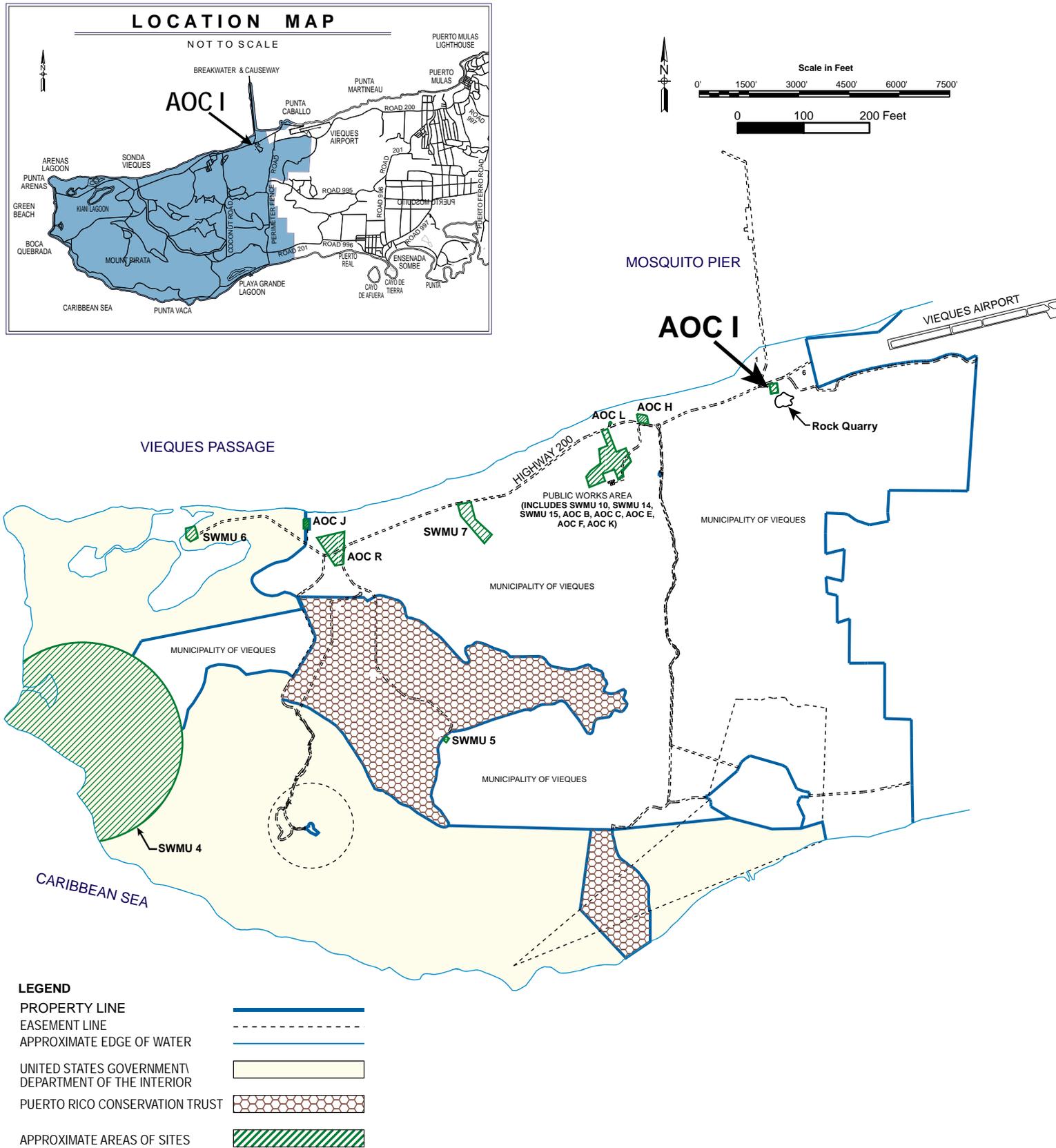


Figure 2-2
AOC I and Other Sites Location Map
AOC I Remedial Investigation Report
Vieques, Puerto Rico

SOURCE:
VIEQUES NASD SURVEY LAND TRANSFER & DISPOSAL OVERALL LOCATION SURVEY
PREPARED BY GLENN & SADLER AND LUIS BERRIOS MONTES & ASSOCIATES

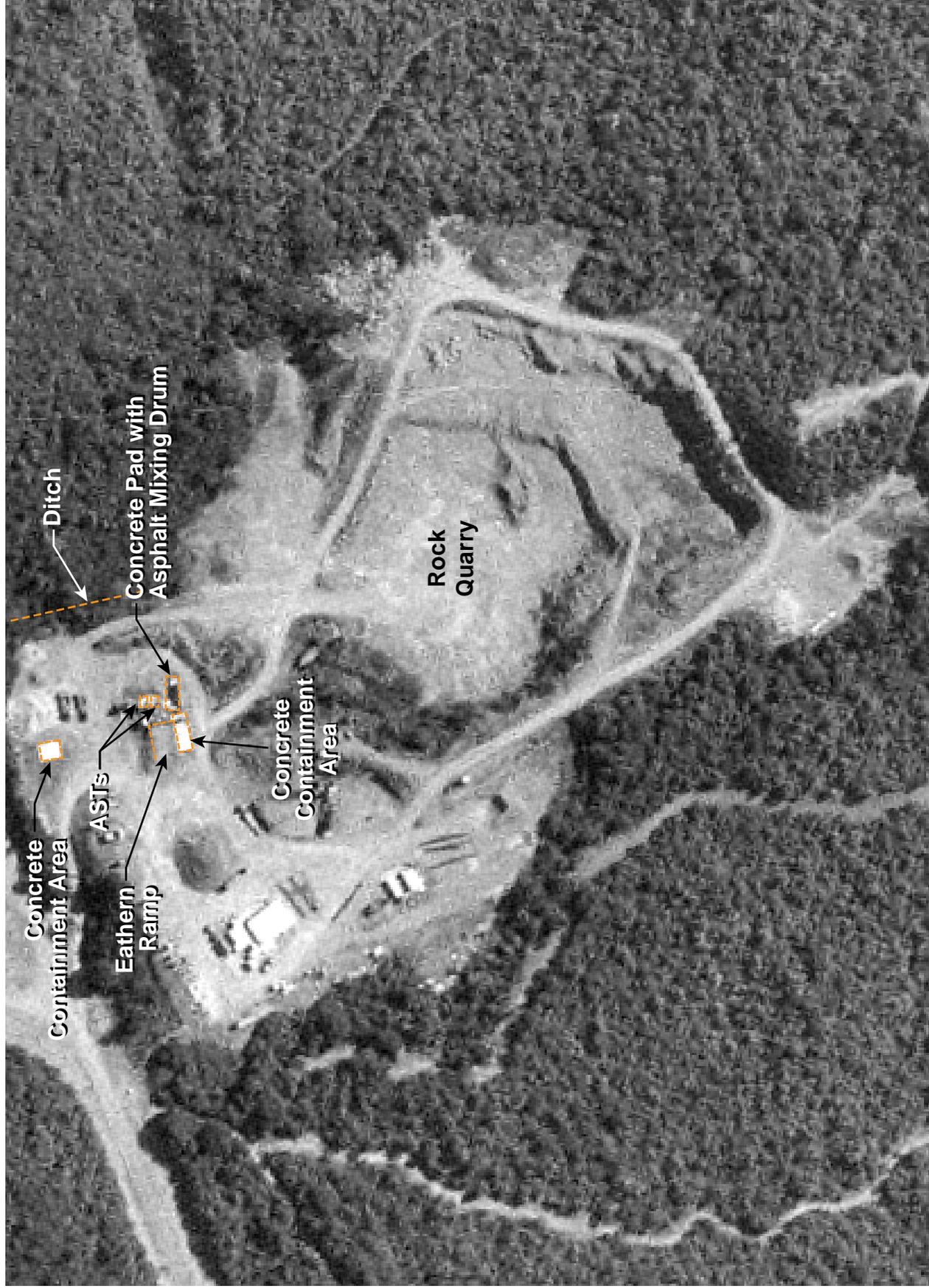


Figure 2-3
1994 Aerial Photograph of AOC I
AOC I Remedial Investigation Report
Vieques, Puerto Rico



Looking east at asphalt plant truck loading containment area

Source: RI Field Sampling Event (Aug/Sept. 2004)



Looking west at former asphalt plant concrete pad

Source: RI Field Sampling Event (Aug/Sept. 2004)



Concrete containment area on north side of site

Source: RI Field Sampling Event (Aug/Sept. 2004)

Figure 2-4
2004 RI Site Photographs
AOC I Remedial Investigation Report
Vieques, Puerto Rico



Asphalt plant truck loading containment area

Source: *Environmental Baseline Survey (Program Management Company, 2000)*



West view of the concrete pad, gravel area, and raised ramp

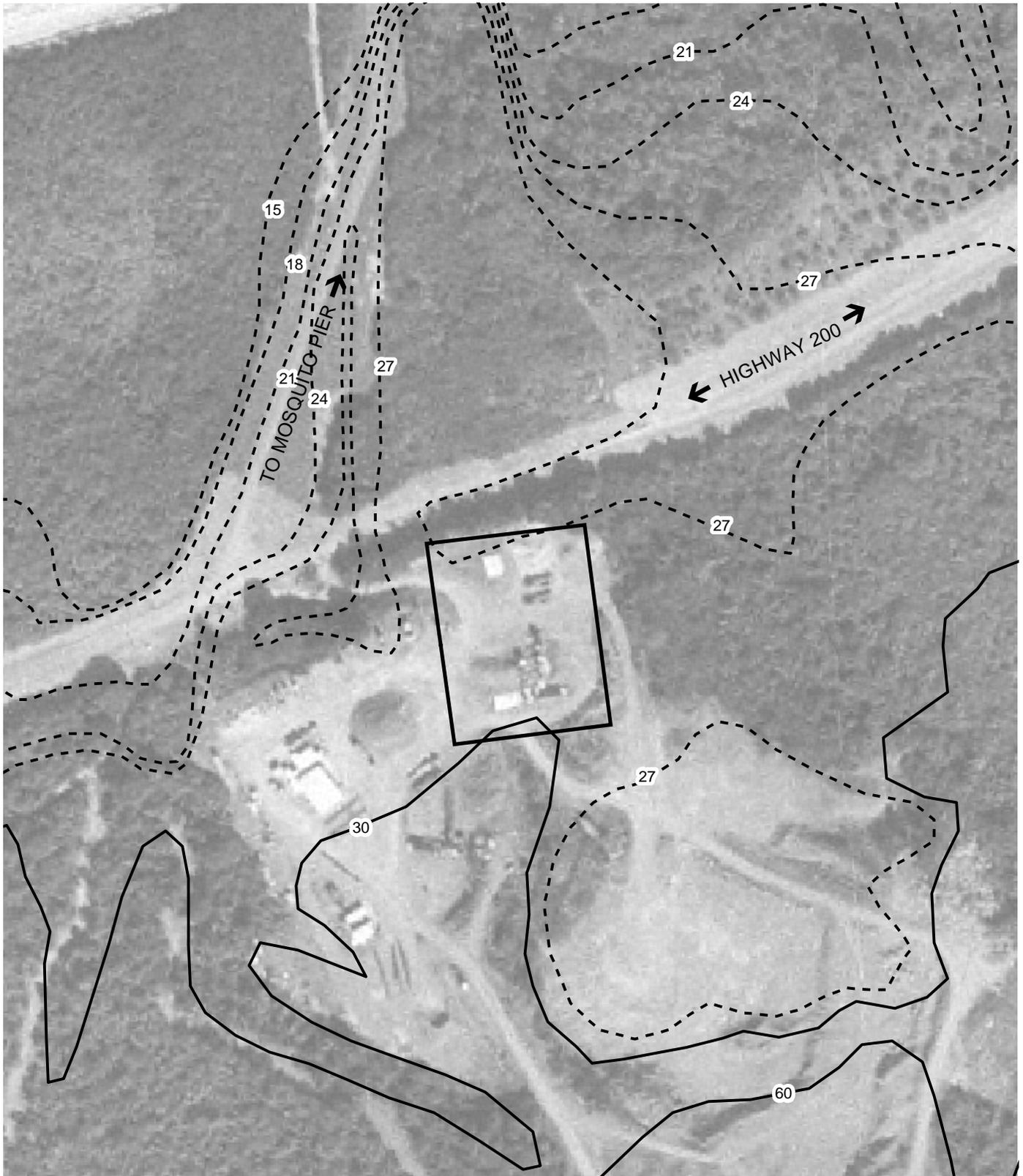
Source: *Expanded Preliminary Assessment/Site Investigation, Phase II, Seven Sites (CH2M HILL, 2002)*



Former AST storage area, soil staining, location of the EBS sample S-2

Source: *Expanded Preliminary Assessment/Site Investigation, Phase II, Seven Sites (CH2M HILL, 2002)*

Figure 2-5
Photographs of AOC I Features
AOC I Remedial Investigation Report
Vieques, Puerto Rico



Source: 1994 aerial; topographic contours from U.S. Geological 7.5 Minutes Quadrangle map of Vieques Island, Puerto Rico (1982)

Legend

-  Approximate Area of AOC I
-  3-ft Contours
-  30-ft Contours

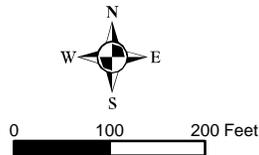
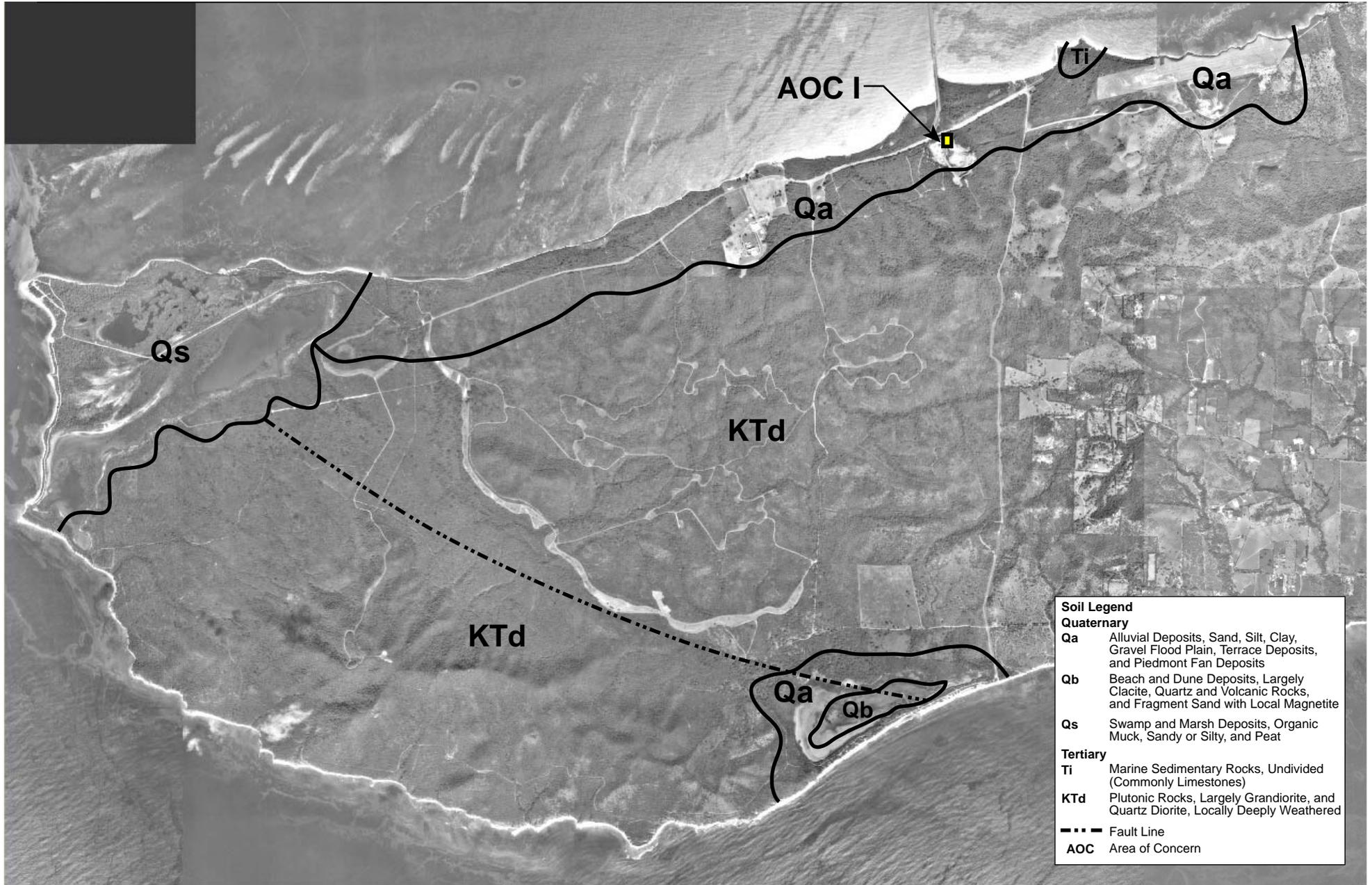


Figure 2-6
Topographic Map
AOC I Remedial Investigation Report
Vieques, Puerto Rico



Generalized Geology Source: (USGS, 1989)

Figure 2-7
Generalized Geology of Former NASD
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

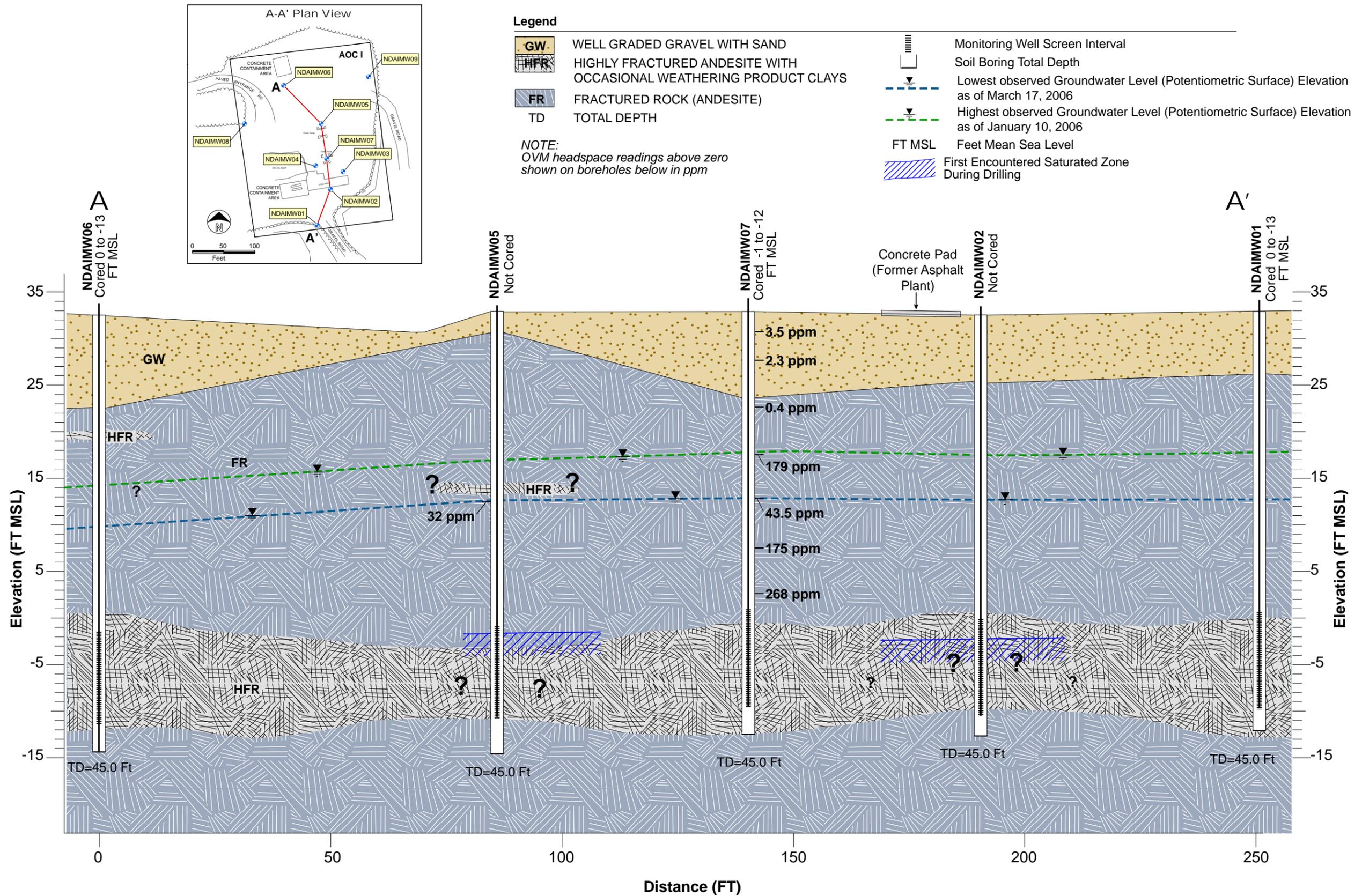


Figure 2-8
Geologic Cross Section A-A'
AOC I Remedial Investigation Report
Vieques, Puerto Rico



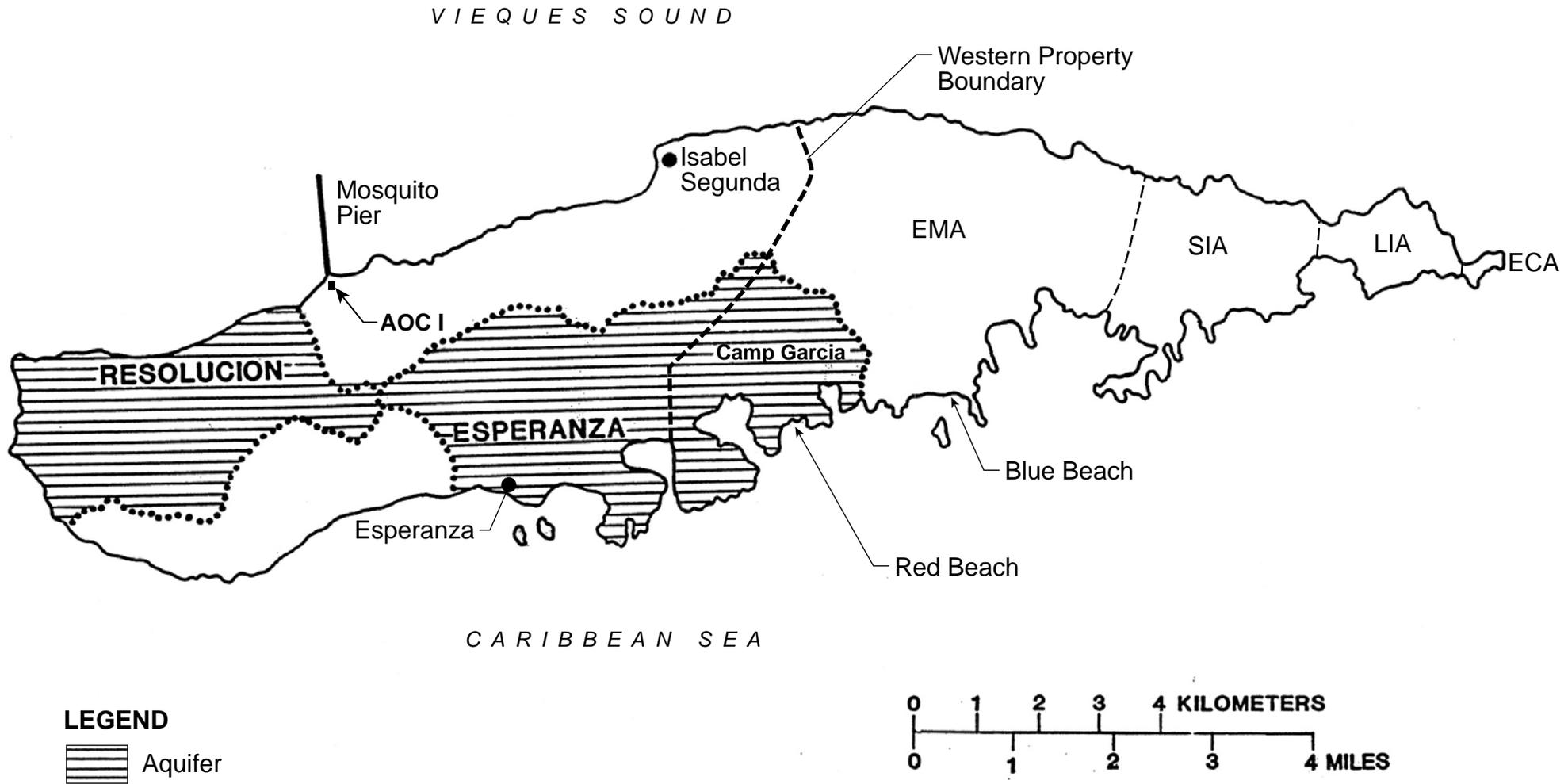
2000 Aerial Photograph



Legend

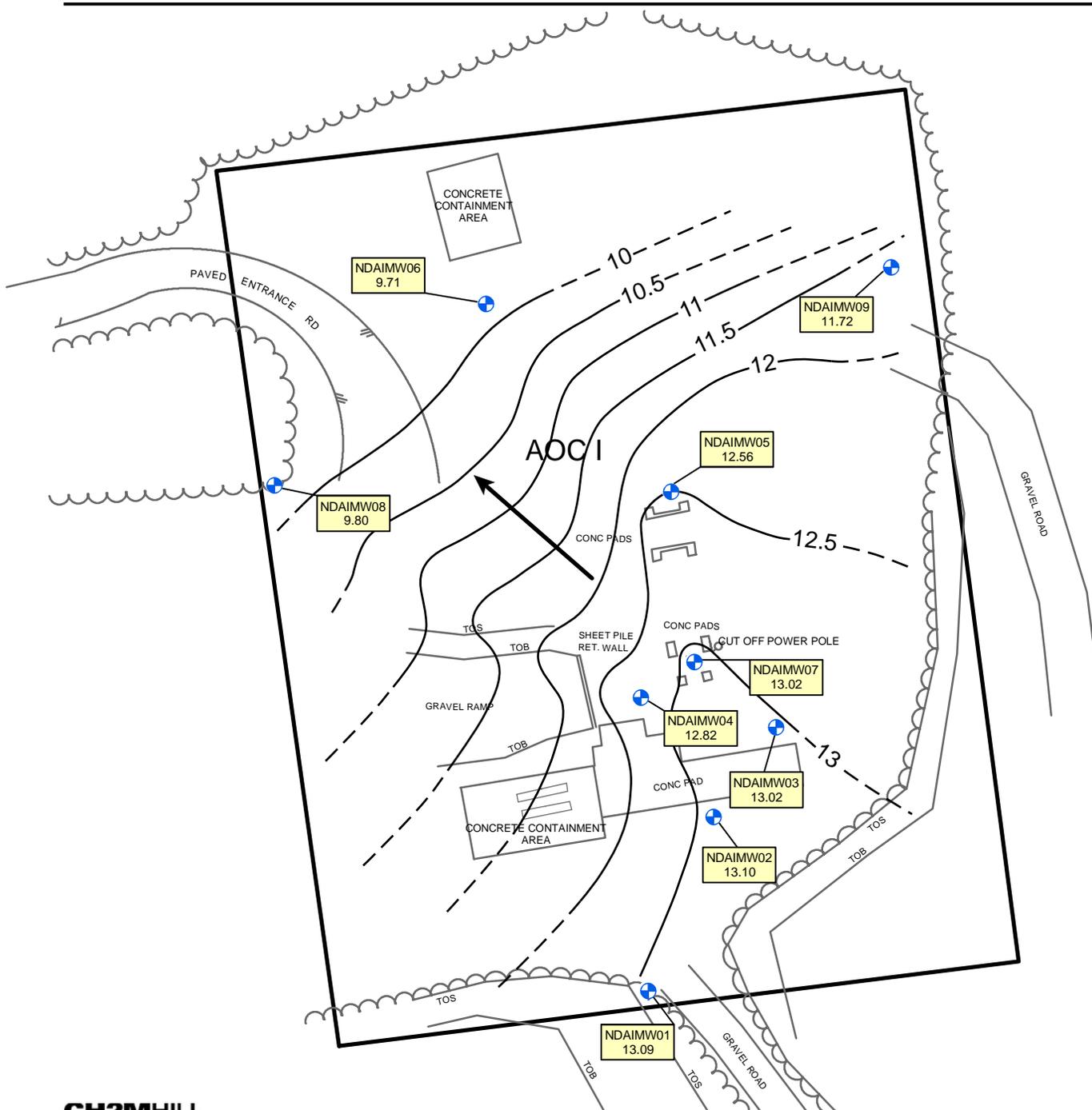
-  Surface water flow during October 21, 2007 rain event
-  Area of standing water during rain event

Figure 2-9
Surface Water Drainage Patterns
During an October 2004 Rain Event
AOC I Remedial Investigation Report
Vieques, Puerto Rico



(Reference: Torres - Gonzalez, 1989)

Figure 2-10
Resolución and Esperanza Aquifers
AOC I Remedial Investigation Report
Vieques, Puerto Rico



LEGEND

- AOC I Area from EBS 2000
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Location
- Estimated Groundwater Contours, dashed where inferred (0.5' Intervals)
- Estimated Direction of Groundwater Flow

Groundwater elevations in FT MSL.
Water Level readings taken on March 17, 2006

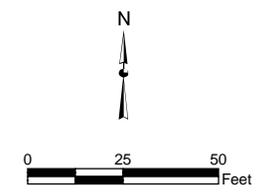


Figure 2-11
Estimated Potentiometric Surface
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

SECTION 3

Summary of Field Investigations

This section summarizes the procedures employed for data collection, analysis, and validation at AOC I during the EBS, PA/SI, and RI.

Table 3-1 summarizes the investigations and associated samples that were collected, the media sampled, analyses performed, sample identifications, and depth of sampling (for soil samples). As stated in the EBS Work Plan/Sampling Plan/Health and Safety Plan (Program Management Company, 2000), the following environmental media data collection activities took place at AOC I in May 2000:

- Surface soil sampling at three locations (Figure 3-1)

In accordance with the PA/SI Work Plan (CH2M HILL, 2000a), the following environmental media data collection activities took place at AOC I in November and December 2000:

- Surface and subsurface soil sampling at 26 locations (Figures 3-1 and 3-2)

In accordance with the Remedial Investigation/Feasibility Study (RI/FS) Work Plan for AOC I and AOC R (CH2M HILL, 2004), the following environmental media data collection activities took place at AOC I in August and September 2004:

- Surface soil sampling at 18 locations, subsurface soil sampling at 7 locations, and installation of seven monitoring wells and groundwater sampling at each well (Figures 3-1, 3-2, and 3-3)

In accordance with the Supplemental RI Work Plan for AOC I (CH2M HILL, 2005a), the following environmental media data collection activities took place at AOC I between November 2005 and January 2006:

- Installation of two monitoring wells and groundwater sampling at those two wells and four previously installed monitoring wells (Figure 3-3)

Prior to the PA/SI field work, a habitat characterization survey was completed to ensure no threatened or endangered species would be impacted by the vegetation clearing and sampling activities. The habitat characterization survey report was submitted in April 2001 and is included in Appendix J. No federally-protected species or preferred habitats were observed at AOC I.

Summaries of the various field activities during the 2000 EBS, 2000 PA/SI, 2004 RI, and 2005/2006 supplemental RI are provided in the following subsections. Samples were collected in general accordance with the standard operating procedures (SOPs) presented in the Work Plans available at the times the investigations were conducted: *Work Plan, Sampling Plan, and Health and Safety Plan, Naval Ammunition Storage Detachment, Vieques Island, Puerto Rico* (Program Management Company, 2000) for the EBS; *Master Work Plan for the U.S. Naval Ammunition Storage Detachment, Vieques, Puerto Rico* (CH2M HILL 2000b) for the 2000 PA/SI; and the *Master Work Plan for the U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico* (CH2M HILL 2001) for the 2004 and 2005/2006 RIs.

Where deviations from the above plans occurred and/or were necessary, they are discussed within the various field activities summarized in the following subsections.

3.1 Soil Sampling

The locations of surface soil samples and subsurface soil samples collected during the RI and previous investigations are shown in Figure 3-1 and Figure 3-2, respectively. The discussion in this subsection summarizes the soil sampling activities conducted during the EBS, PA/SI, and RI. For a more detailed summary of soil sampling activities conducted during the previous investigations (EBS and PA/SI), please refer to the *Environmental Baseline Survey: Final, Naval Ammunition Support Detachment Vieques, Vieques Island, Puerto Rico* (Program Management Company, 2000) and the *Expanded Preliminary Assessment/Site Investigation, Phase II, Seven Sites, Former U.S. Naval Ammunition Support Detachment, Vieques Island, Puerto Rico* (CH2M HILL, 2002).

3.1.1 Soil Sampling, Analysis, and Validation

Soil samples were screened in the field with a photo-ionization detector (PID), also known as an organic vapor monitor (OVM), for the EBS and PA/SI sampling and a flame ionization detector (FID), also known as an organic vapor analyzer (OVA), for the RI sampling. These instruments were used to provide qualitative data on the presence of potential contamination in the unsaturated zone during drilling and sampling activities, to aid in select soil sampling intervals, and to monitor the breathing zone during sampling activities. PA/SI breathing zone and above-borehole PID readings are recorded on the individual boring logs (Appendix A). Similarly, RI headspace, breathing zone, and above-borehole FID readings are recorded on individual soil boring logs included in Appendix A. The calibration and use of OVMs and OVAs used during the PA/SI and the RI were in general accordance with the Master Work Plan SOPs “Volatiles Monitoring with an OVM” and “Volatiles Monitoring with an OVA” (CH2M HILL, 2000b; CH2M HILL, 2001).

3.1.1.1 Surface Soil Sampling

Surface soil samples were collected during the EBS in 2000, the PA/SI in 2000, and the RI in 2004. All surface soil samples, analyses, nomenclature, and sampling depths are shown on Table 3-1. The table also includes explanations for the sampling depth intervals selected. Boring logs for soil samples are included in Appendix A.

3.1.1.1.1 EBS (2000)

Surface soil samples were collected using a stainless steel spoon. Samples were collected from 0 to 0.5 ft bls. It is important to note that the general areas of two of the three EBS sample locations were re-sampled during the PA/SI (EBS sample locations AOC-I-S1 and AOC-I-S2) and RI (EBS sample location AOC-I-S2).

3.1.1.1.2 PA/SI (2000)

Surface soil samples were collected at AOC I during the November/December 2000 sampling event. Surface soil samples were collected from ground surface to approximately 0.5 ft bls. Although the Work Plan indicated the samples were to be analyzed for, among other constituents, total petroleum hydrocarbons-gasoline range organics (TPH-GRO) and total petroleum hydrocarbons-diesel range organics (TPH-DRO), the samples were instead

analyzed for total petroleum hydrocarbons in the C8 to C40 range by the FL PRO method, which approximates the combined ranges of TPH-GRO and TPH-DRO.

In order to collect soil samples for volatile organic compound (VOC) analysis from the target interval using the En Core™ sampler, soil from within that interval was first removed from the ground with a stainless steel spoon or hand auger, placed into a stainless steel bowl, and then collected by pushing the En Core™ sampler into the soil several times to fill the sampler with soil from the target interval. After the VOC sample was collected, the soil in the bowl was homogenized with a stainless steel spoon, and soil for other parameters was then transferred into the appropriate sample containers.

Surface soil samples were collected in accordance with the SOPs “Soil Sampling,” “Shallow Soil Sampling,” “Soil Sampling for VOCs Using the EnCore Sampler,” and “Homogenization of Soil and Sediment Samples.” All soil borings were logged in the field using the Unified Soil Classification System (USCS) in accordance with the SOP “Logging of Soil Borings” (CH2M HILL, 2000b).

3.1.1.1.3 RI (2004)

Surface soil samples were collected at AOC I using a 3-inch diameter stainless steel hand auger during the August 2004 sampling event. In general, surface soil samples were collected from the surface to 2 ft bls. Because of the shallower depth to bedrock encountered in some borings, several of the surface soil samples were advanced to only 1.5 ft bls (i.e., SS27, SS31, SS32, SS35, and SS36). The top layer of gravel, asphalt, or vegetation (typically 1 inch) was scraped away before sampling began.

Surface soil samples were collected in accordance with the SOPs “Soil Sampling,” “Shallow Soil Sampling,” and “Homogenization of Soil and Sediment Samples.” All soil borings were logged in the field using the USCS in accordance with the SOP “Logging of Soil Borings” (CH2M HILL, 2001).

3.1.1.2 Subsurface Soil Sampling

Subsurface soil samples were collected during the PA/SI in 2000 and the RI in 2004. All subsurface soil samples, analyses, nomenclature, and sampling depths are shown on Table 3-1. The table also includes explanations for the sampling depth intervals selected. Boring logs for soil samples are included in Appendix A.

3.1.1.2.1 PA/SI (2000)

Subsurface soil samples were collected at AOC I using a direct push rig during the November/December 2000 sampling event. Subsurface soil samples were collected between 3 ft bls and 6 ft bls (Table 3-1). The variable sample depths were due to encountering bedrock at depths shallower than 6 ft bls (i.e., SB03, SB05, and SB07).

Like surface soil, the Work Plan indicated the samples were to be analyzed for, among other constituents, TPH-GRO and TPH-DRO. However, the samples were instead analyzed for total petroleum hydrocarbons in the C8 to C40 range by the FL PRO method, which approximates the combined ranges of TPH-GRO and TPH-DRO.

Subsurface soil samples were collected in accordance with the SOPs “Soil Sampling,” “Shallow Soil Sampling,” “Soil Sampling for VOCs Using the EnCore Sampler,” and “Homogenization of Soil and Sediment Samples.” All soil borings were logged in the field using the USCS in accordance with the SOP “Logging of Soil Borings” (CH2M HILL, 2000b).

3.1.1.2.2 RI (2004)

Subsurface soil samples were collected at AOC I using a 3-inch diameter stainless steel split-spoon during the August 2004 sampling event. Subsurface soil samples were collected at various intervals between 4 ft bls and 6 ft bls (Table 3-1). The variations in the subsurface intervals were due to bedrock being encountered at a shallower depth than 6 ft bls (i.e., SB04, SB06, SB19, SB20, SB21, and SB41).

Subsurface soil samples were collected in accordance with the SOPs “Soil Sampling,” “Shallow Soil Sampling,” “Soil Boring Sampling – Split Spoon,” and “Homogenization of Soil and Sediment Samples.” All soil borings were logged in the field using the USCS in accordance with the SOP “Logging of Soil Borings” (CH2M HILL, 2001).

3.2 Drilling and Monitoring Well Installation

The locations of the nine monitoring wells installed during the RI and supplemental RI are shown in Figure 3-3. The discussion in this subsection summarizes the monitoring well installation, rock coring, video logging, and groundwater sampling activities conducted during the RI and supplemental RI. All groundwater sample nomenclature and analyses are shown on Table 3-1.

3.2.1 Monitoring Well Installation

Nine monitoring wells (NDAIMW01 through NDAIMW09) were installed at AOC I during the 2004 and 2005 RI field work to assess potential effects on groundwater from activities associated with the former asphalt plant at AOC I. Monitoring wells NDAIMW01 through NDAIMW07 were installed in September 2004, and wells NDAIMW08 and NDAIMW09 were installed in December 2005. A summary of the monitoring well construction details, including survey data, is provided in Table 3-2.

Each boring was drilled with hollow-stem augers through the unsaturated, unconsolidated portion of the boring, followed by coring and/or air hammer/air rotary drilling techniques in the consolidated (bedrock) portion of the boring. The hollow-stem augers were used as temporary surface casings during air hammer/air rotary drilling to prevent caving of the unconsolidated material. The augers were removed during monitoring well grouting.

At NDAIMW08 and NDAIMW09, continuous split spoon sampling of the unconsolidated material was performed. At the remaining seven monitoring well locations, 2-ft split-spoon sampling was done from ground surface at 5-ft intervals until bedrock was encountered. Rock coring was performed at boring locations NDAIMW01, 04, 06, 07, 08, and 09 (see Section 3.2.2). Monitoring wells at AOC I were installed at the first encountered groundwater within the bedrock. The soil/rock boring logs are included in Appendix A. Appendix D presents well construction diagrams. Survey data are presented in Appendix H.

Each monitoring well was constructed following the SOPs “General Guidance for Monitoring Well Installation” and “Installation of Bedrock Monitoring Wells,” contained in the Master Work Plan (CH2M HILL, 2001). Each monitoring well was equipped with a concrete pad, protective bollards, and an aboveground protective casing with a locking cap.

The deviation from the Work Plan during monitoring well installation and construction at AOC I relates to the emplacement of the filter sand pack above the well screens. The SOP indicates a coarse-grained primary sand pack is to be installed up to 2 ft above the top of the screen, with a fine-grained secondary sand pack, 1 ft thick, above the primary sand pack. During the construction of monitoring wells NDAIMW01 through NDAIMW09, only a coarse grained primary sand pack was installed to at least 2 ft above the top of the screen. A hydrated bentonite seal, at least 2 ft thick, was installed above the sand pack. The bentonite seal was allowed to hydrate for at least 45 minutes prior to placing the cement-bentonite grout above the seal.

The installation of a secondary, fine-grained sand pack is intended to help inhibit downward migration of the cement-bentonite grout through the bentonite seal and into the screened interval (referred to as grout contamination), before the grout sets up. However, allowing the bentonite seal above the sand pack to sufficiently hydrate (which was done at all AOC I wells) allows for an impermeable seal, and thus obviates the necessity of a secondary, fine grained sand pack. The absence of grout contamination was verified during well development (Section 3.2.3) and groundwater sampling (Section 3.2.5), as the pH measurements in all wells were not indicative of grout contamination (i.e., none significantly above pH 7).

3.2.2 Borehole Video-Logging and Rock Coring

Three boring locations for monitoring well installation (NDAIMW01, NDAIMW06, and NDAIMW07) were video logged prior to monitoring well installation. The three borings for video logging were chosen because they are spatially distributed across the northern, central, and southern portions of AOC I (Figure 3-3). Borehole video logging was performed to collect information on the location (depth) and nature of the fractures and to observe whether flowing groundwater was visible in the fractures, in order to aid in screen interval selection. At each of the three borings, the drilling was stopped at 30 to 32 ft bls, near the assumed top of the saturated zone based on other borings. A color video camera was then lowered in the borehole by cable from ground surface to this depth. The camera was oriented straight down, giving a projection of 360 degrees in the borehole. A video monitor was located at the surface for real-time observation of the logging. The video recordings are included in Appendix C, along with audio identifying the depth of the video camera as it's being lowered into the borehole.

Rock cores were collected and logged at six locations (NDAIMW01, NDAIMW04, and NDAIMW06 through NDAIMW09), as noted in Table 3-3. Core samples from wells NDAIMW01, 04, 06, and 07 were intended to be collected within the targeted 10-ft screen intervals using a 5-ft long core barrel. However, because of the highly fractured rock encountered, retrieval of the rock cores through the full targeted screen interval was not possible. Further, use of potable water during coring to cool the core bit was necessary, which eliminated the possibility of determining the first encountered groundwater within the boreholes. The targeted coring interval and, hence, the targeted screen intervals, were determined by the first encountered groundwater from boring locations where rock coring did not occur (i.e., borings for wells NDAIMW02, NDAIMW03, and NDAIMW05). At NDAIMW08 and NDAIMW09, rock coring was attempted from the top of the weathered

bedrock zone to the boring terminus in an attempt to obtain lithologic information on the entire bedrock interval at these locations.

Cores were photographed and described in the field by a CH2M HILL geologist. The geologist noted the rock type, fractures, degree of weathering, joints, and other observable features, as shown in Appendix A. Rock core samples for the six monitoring wells are shown in photographs included as Appendix B.

3.2.3 Monitoring Well Development and Purging

Well development was conducted a minimum of 24 hours after the grout used to construct the wells had been allowed to set up in accordance with the Work Plan SOP “General Guidance for Monitoring Well Installation” (CH2M HILL, 2001). Well development activities were performed in accordance with the SOP “Installation of Shallow Monitoring Wells” in the Master Work Plan (CH2M HILL, 2001). Well development information is included in Appendix E.

Monitoring well development was performed with Whale[®], Grundfos[®], or Monsoon[®] submersible pumps using a combination of pumping and surging with the pump. In monitoring wells with abundant sediment, an actual surge block was used to minimize the potential for damage to the pumps. Development water was containerized in 55-gallon drums. See Section 3.2.8 for a discussion of testing and disposal of IDW.

3.2.4 Monitoring Well Purging and Sampling

During groundwater sampling, indicator parameters were monitored to help determine when it was appropriate to collect the groundwater samples. Table 3-4 summarizes the indicator parameter values for the 2004 and 2006 RI sampling events. Natural attenuation parameters sulfate and nitrate were added to the analyte list upon recommendation of the U.S. Environmental Protection Agency (EPA) for the 2006 RI groundwater sampling.

Samples for dissolved parameters were field-filtered prior to preservation using a 0.45-micron filter and followed procedures outlined in the Master Work Plan SOP “Field Filtering” (CH2M HILL, 2001). The wells were sampled with a Geopump[®] bladder pump during the 2004 sampling and a stainless steel Monsoon[®] pump during the 2006 sampling; both events used Teflon[®] tubing.

Water quality data, comprising temperature, conductivity, oxidation reduction potential (ORP), dissolved oxygen, turbidity, and pH, were monitored during purging and each well was sampled after the parameters had stabilized. Appendix F includes monitoring well groundwater sampling logs.

Groundwater sampling was performed in general accordance with the SOP “Groundwater Sampling Procedure Low Stress (Low Flow) Purging and Sampling” in the Master Work Plan (CH2M HILL, 2001), to the extent practicable. Deviations from the Low Flow sampling SOP during the 2004 and 2006 groundwater sampling events are summarized below:

- Samples for cyanide analysis were inadvertently omitted during initial sampling, but were instead collected the following day using a bailer
- Water level readings collected at intervals greater than every 5 minutes (2004 sampling event for NDAIMW01 through NDAIMW07)

- Water level drawdown during purging unavoidably exceeded 0.3 ft (2004 sampling event for NDAIMW01, 03, 05, 06, and 07; and 2006 sampling event for NDAIMW01, 06, 07, and 08) due to capacity of well (bedrock) being lower than the low flow rate
- Greater than 10 percent difference in redox potential during last three readings (2004 sampling event for NDAIMW02)
- Greater than 10 percent difference in turbidity during the last three readings (2004 sampling event for NDAIMW02, 04, 06, 07; and 2006 sampling event for NDAIMW01, 04, 06, 07, and 09)
- Sampling flow rate sometimes exceeded 250 milliliters per minute (ml/min) during sampling (2006 sampling event for NDAIMW01, 04, 07, and 08)

Although there were deviations from the low flow sampling procedures, it is unlikely the sampling methodology affected the quality of the data such that conclusions would be affected. The most substantive deviation listed above is the water level drawdown during purging exceeded 0.3 ft. However, this was unavoidable because of insufficient flow from the bedrock fractures. Care was taken to ensure loss of pressure in the tubing did not occur and the well did not go dry, as specified in the Low Flow SOP. Because parameter readings were generally stable during sampling, it is unlikely that the sample results were adversely affected by the above deviations. Further, as discussed in Section 8, an additional round of groundwater samples is recommended, which will help confirm previous data as well as provide temporal variability information.

3.2.5 Groundwater Level Measurements

Groundwater level measurements were obtained from all monitoring wells at AOC I on three occasions: September 2004 (NDAIMW01 through NDAIMW07), January 2006 (NDAIMW01 through NDAIMW09), and March 2006 (NDAIMW01 through NDAIMW09). An electronic water level meter was used to measure the depth to water from the top of casing of each monitoring well to the nearest 0.01 ft. Table 2-2 (presented previously) summarizes the groundwater level measurements and Section 2.3.4 discusses the potentiometric surface estimated from the water level measurements.

3.2.6 Hydraulic Conductivity Testing

In situ hydraulic conductivity (slug) tests were performed on monitoring wells NDAIMW01 through NDAIMW06 in September 2004 and on monitoring wells NDAIMW08 and NDAIMW09 in January 2006 to obtain estimates of the aquifer hydraulic conductivity. Monitoring well NDAIMW07 was not tested because of its close proximity to monitoring well NDAIMW04. All monitoring wells were tested in accordance with the *Final RI/FS Work Plan for AOC I and AOC R* (CH2M HILL, 2004) and the *Supplemental RI Work Plan for AOC I* (CH2M HILL, 2005a), and in accordance with the SOP “Aquifer Slug Testing” of the Master Work Plan (CH2M HILL, 2001).

The static depth to water and total depth of the well were determined with an electronic water level indicator before testing began on each well. Each test included installing a 0-to-15-pound-per-square-inch (psi) pressure transducer with a data logger programmed to measure and record water levels. Although the SOP did not require a falling head (or slug-

in) testing, slug-in and rising head (slug-out) tests were performed in monitoring wells NDAIMW01 through NDAIMW06. Rising head tests were performed in NDAIMW08 and DNAIMW09. For each slug-in test, after the initial water level was measured, a 1-inch-diameter by 5-ft-long solid PVC slug was lowered into the monitoring well. The rise and decline of the water level in the well were recorded until the water level recovered to within 90 percent of the original water level. The slug was then quickly removed from the monitoring well (slug-out test), causing the water level to drop rapidly. Once again, the decline and rise of the water level in the well were recorded until the water level had recovered to within 90 percent of the original water level. The tests were performed multiple times at each well to determine reproducibility and verify results. Only reproducible data from the tests were used to calculate hydraulic conductivity, as shown in Table 3-5. Raw data from the hydraulic conductivity testing are contained in Appendix G. Section 2.3.4 discusses the results of the testing.

It is noted that slug tests and the methodology developed to analyze slug test data are based on average flow through unconsolidated media; therefore, data inferred or calculated from slug tests in fractured bedrock wells should be viewed as providing a qualitative estimate of hydraulic conductivity. Further, slug tests are influenced by well construction; therefore, differences in measurements among wells may reflect not only hydraulic conductivity differences between the wells, but well construction influences as well (Fetter, 1988). Slug test data are useful if the fracture distribution in the tested borehole effectively represents the aquifer as a whole. Slug tests can also provide useful information on the relative hydraulic properties at borehole locations.

3.3 Surveying

The surveying work at AOC I was in general accordance with Master Work Plan SOP “Civil Surveying” (CH2M HILL, 2000b; CH2M HILL, 2001). The monitoring well and soil boring locations were surveyed by Glenn and Sadler for the 2000 PA/SI and TranSystems, Inc. for the 2004 and 2005 RI. TranSystems used differential global positioning system (DGPS) techniques, and Glenn and Sadler used a transit. The survey established the spatial northing and easting coordinates for each location. In addition, the elevation in ft amsl was established to the nearest 0.01 ft for the top of the monitoring well casings using traditional surveying techniques and DGPS techniques for remote areas. Survey data for the soil borings and monitoring well locations are contained in Appendix H.

The underlying premise of DGPS requires that a GPS receiver, known as the base station, be set up on a precisely known location. The base station receiver calculates its position based on satellite signals and compares this location to the locations of the individual borings and wells. The difference is applied to the GPS data recorded by the roving GPS receiver. These data survey points are included in the database and used for plotting sample locations on figures created using a geographic information system (GIS).

The ground elevations were not surveyed at NDAIMW08 and NDAIMW09. However, ground elevations are not used in calculating groundwater depths or elevations. The values of groundwater depths and elevations are measured relative to the top of casing elevations, which were surveyed in accordance with the Work Plan at all monitoring well locations.

3.4 Decontamination of Sampling Equipment and Investigation-derived Waste Management

Decontamination of equipment used during the EBS was in general accordance with the Sampling Plan Section “Equipment Decontamination” included in the EBS Appendix A (Program Management Company, 2000). During the PA/SI and RI sampling, drill rigs, hollow-stem auger flights, split spoons, hand augers, and bowls were decontaminated between sample locations in accordance with the SOP “Decontamination of Drilling Rigs and Equipment” of the Master Work Plan (CH2M HILL, 2000b; CH2M HILL, 2001). During the RI sampling events, decontamination of the well development and groundwater sampling equipment was conducted in accordance with the SOP “Decontamination of Personnel and Equipment” contained in the Master Work Plan (CH2M HILL, 2000b; CH2M HILL, 2001).

During the 2004 RI field event, soil and water IDW was collected in 55 gallon drums and temporarily stored in the Vieques Public Works Building 2016. Composite soil and water samples were collected from all the drums (17 water and 13 soil drums from concurrent investigations at multiple sites), including the AOC I drums, and analyzed for the full toxicity characteristic leaching procedure (TCLP) list and reactivity, corrosivity, and ignitability parameters. Analytical results of the soil and water IDW samples are in Appendix I. A generator waste profile sheet was submitted to BFI in Ponce with the analytical data. The drums of IDW were removed from Vieques on February 4, 2005, and transported to BFI in Ponce where they were disposed of as non-hazardous waste, as shown in the waste manifest in Appendix I.

The supplemental RI field effort ending in January 2006 generated 55 gallon drums of purge water, decontamination water, and soil cuttings that were temporarily stored in the Vieques Public Works Building 2016. Composite soil and water samples were collected from all the drums (41 water and 22 soil drums from concurrent investigations at multiple sites), including 14 water and 2 soil drums from AOC I and analyzed for the full TCLP list and reactivity, ignitability, and corrosivity. Analytical results of the soil and water IDW samples are in Appendix I. The analytical results indicated the water was non-hazardous; therefore, the drums were disposed of at the BFI Landfill facility in Ponce on May 2, 2006, along with soil from other investigations, as shown on the BFI Ponce drum receipt confirmation statements (Appendix I).

3.5 Field Sampling and Laboratory Analytical Protocol

Surface soil, subsurface soil, and groundwater samples collected for analyses were placed on ice and shipped via overnight courier to TEG Puerto Rico for the EBS samples, and to Progress Environmental Laboratories located in Tampa, Florida, for the 2000 PA/SI and 2004 RI samples. For the 2006 RI field event, groundwater samples were sent to CompuChem Laboratories in Cary, North Carolina. Packaging, shipping and chain of custody procedures followed the Master Work Plan SOPs “Packaging and Shipping Procedures” and “Chain of Custody” (CH2M HILL, 2000b; CH2M HILL, 2001).

3.5.1 Sample Analysis and Quality Assurance/Quality Control

Samples were analyzed for constituents shown in Table 3-1. All analytical tests were conducted in accordance with the appropriate analytical methods described in the Data Quality Evaluation Reports (Appendix L). Both Progress Environmental Laboratories and CompuChem laboratories fulfilled the requirements of the U.S. Navy's quality assurance/quality control (QA/QC) Program Manual and followed procedures outlined in the Master Quality Assurance Project Plans (QAPP) (CH2M HILL, 2000b; CH2M HILL, 2001).

The number and frequency of the QA/QC samples are also presented in the Data Quality Evaluation Reports. All raw laboratory data are included in Appendix K. Tables of detected constituents and screening value exceedances are included in Section 4 - Nature and Extent of Contamination. Preparation of equipment and field blanks was in accordance with the Master Work Plan SOPs "Equipment Blank and Field Blank Preparation" (CH2M HILL, 2000b; CH2M HILL, 2001).

3.6 Data Validation and Evaluation

Analytical data were validated in accordance with the *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (EPA, 2005) and *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA, 2002). Areas of review included (when applicable to the method) holding time compliance, calibration verification, blank results, matrix spike precision and accuracy, method accuracy as demonstrated by laboratory confirmation samples (LCSs), field duplicate results, surrogate recoveries, internal standard performance, and interference checks. A Region 2 data review worksheet was completed for each method of each data package and any non-conformance was documented. This data review and validation process was independent of the laboratory's checks and focused on the usability of the data to support the project data interpretation and decision-making processes. Data that were not within acceptance limits were appended with a qualifying flag. Data Quality Evaluation Reports are included in Appendix L.

The surface soil samples were collected at different depths during the different investigations. During the EBS and PA/SI, the surface soil samples were collected from 0 to 0.5 ft bls and during the RI, generally from 0 to 2 ft bls, depending on the depth to bedrock. This information is stated in Sections 3.1.1.1.1, 3.1.1.1.2, and 3.1.1.1.3. During the EBS the surface soil samples were collected with a stainless steel spoon, during the PA/SI with a stainless steel spoon or hand auger, and during the RI with a hand auger. Subsurface samples were collected during the PA/SI and the RI. The methods used to collect the samples were: a direct push rig with acetate liner during the PA/SI and a drill rig using split spoons during the RI. It is a common practice for data collection at a particular site to be step-wise, ultimately culminating in a comprehensive dataset comprising multiple investigation phases. All samples were collected using well-established, commonly accepted sampling methods.

Regarding changes in analytical methodology, unless a particular analytical method was found to provide unreliable results, the particular analytical method by which one dataset is analyzed is irrelevant with respect to its comparability with a dataset resulting from a

different analytical method. The data resulting from a particular analytical method are just as available for use as those from another analytical method. For AOC I, only the analytical method for thallium used during the 2004 RI groundwater sampling was shown to provide potentially unreliable results. However, this thallium analytical method tended to provide falsely elevated results, so use of the data from this method most likely overestimates thallium concentrations. A new analytical method for thallium (ILM05) was utilized during the 2006 supplemental RI, during which only groundwater samples were collected; thallium was not detected in groundwater during 2006 or previous sampling events.

What should be taken into consideration are the reporting limits associated with particular dataset compared to the reporting limits of a different dataset that is being combined for evaluation purposes. It is important to note that for the datasets generated at AOC I, there is very little overlap of analyses between events for soil, so comparability among particular constituents in different datasets is not of significant concern. As shown in Table 3-1, with respect to the major analyses (i.e., those included in risk assessment - VOCs, SVOCs, pesticides, PCBs, and metals), only SVOCs and chromium were analyzed in surface soil in more than one event (i.e., PA/SI and RI). All other major surface soil parameters were analyzed in only one event (i.e., VOCs, pesticides, and PCBs during the PA/SI and hexavalent chromium during the RI). Chromium was detected during both events, and the SVOCs were analyzed using the same analytical method (and target quantitation limits) during both events. For subsurface soil, there is no overlap of analyses between the PA/SI and RI. For groundwater, the quantitation limits for metals during the 2006 supplemental RI are generally higher than those during the 2004 RI. However, this is due to the regulatory requirement to use ILM05 in 2006, which has a higher, contract-required reporting limit. Pesticides and PCBs were analyzed only in 2004; the reporting limits for VOCs and SVOCs between the two events are approximately the same.

The 2000, 2004, and 2006 analytical data were validated using Region II guidelines and worksheets. Therefore, from a data validation standpoint, there are not comparability issues among the various datasets.

TABLE 3-1
 Site Sample Summary
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Site	Investigation Field Work and Associated Report	Media Samples ¹	Analytes	Sample Identification	Soil Sample Depth (ft bls)
AOC I	EBS sample collection May 2000 (Program Management Company, 2000)	3 SS	BTEX, TPH-GRO, TPH-DRO	AOC-I-S1, AOC-I-S2, AOC-I-S3	0 - 0.5
	PA/SI sample collection November/December 2000 (CH2M HILL, 2002)	26 SS	TCL VOCs, SVOCs, Pesticides, PCBs, Petroleum Hydrocarbons by FL PRO (range C8-C40), TAL Metals	AOCISB001 through AOCISB026	0 - 0.5; depth in accordance with Work Plan
		26 SB	TCL VOCs, SVOCs, Pesticides, PCBs, Petroleum Hydrocarbons by FL PRO (range C8-C40), TAL Metals	AOCISB001 through AOCISB026	3 - 4.5 (SB07); 4 - 5 (SB03); 4 - 6 (SB06, SB08 thru SB26); 4.5 - 5.5 (SB05); 5 - 6 (SB01, SB02, SB04). Sample depths in general accordance with Work Plan; depths shallower than 6 ft bls due to encountering bedrock above 6 ft bls.
	RI sample collection August/September 2004 (CH2M HILL, 2005)	14 SS	TCL SVOCs, Total Petroleum Hydrocarbons (C6-C10, C10-C28), hexavalent chromium, total chromium	NDAISS27 through NDAISS40	0 - 1.5 (SS27, SS31, SS32, SS35, SS36); 0 - 2 (SS28, SS29, SS30, SS33, SS34, SS37 through SS40). Sample depths in general accordance with Work Plan; depths shallower than 2 ft bls due to encountering bedrock above 2 ft bls.
		2 SS	hexavalent chromium, total chromium, TOC, pH	NDAISS20, NDAISS41	0 - 2; depth in accordance with Work Plan
		1 SS	hexavalent chromium, total chromium	NDAISS06	0 - 2; depth in accordance with Work Plan
		1 SS	TOC, pH	NDAISS22	0 - 2; depth in accordance with Work Plan
		4 SB	hexavalent chromium, total chromium	NDAISB04, NDAISB06, NDAISB19, NDAISB21	4 - 4.5 (SB06); 4 - 5 (SB04, SB21); 4 - 5.5 (SB19). Sample depths in general accordance with Work Plan; depths shallower than 6 ft bls due to encountering bedrock above 6 ft bls.
		2 SB	hexavalent chromium, total chromium, TOC, pH	NDAISB20, NDAISB22	4 - 5 (SB20); 4 - 6 (SB22). Sample depths in general accordance with Work Plan; bedrock was encountered at 5 ft bls at sample SB20 location.
		1 SB	TOC, pH	NDAISB41	4 - 5.5. Sample depth in general accordance with Work Plan; bedrock was encountered at 5.5 ft bls at sample SB41 location.
		7 GW	TCL VOCs, SVOCs, Pesticides, PCBs, TDS, total and dissolved TAL Metals and cyanide	NDAIMW01 through NDAIMW07	
	RI sample collection November 2005 - January 2006	6 GW	TCL VOCs, SVOCs, total and dissolved TAL Metals, cyanide, sulfate, nitrate, TDS, TOC	NDAIMW01, NDAIMW04, NDAIMW06, NDAUMW07, NDAIMW08, NDAIMW09	

Note: PA/SI surface and subsurface samples both used the "SB" sample identification.

Notes:

¹SS = surface soil; SB = subsurface soil; GW = groundwater

TABLE 3-2
 Summary of Monitoring Well Construction Details
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Well ID	Date Installed	Boring Depth (ft bls)	Well Depth (ft bls)	Screen Interval Depth (ft bls)	Screen Interval Depth (ft amsl)	Depth to Bentonite (ft bls)	Depth to Sand Pack (ft bls)	Ground Elevation (ft amsl)	Top of Casing Elevation (ft amsl)	Northing	Easting
NDAIMW01	8/27/2004	45	42	32 – 42	0.45 to -9.55	28	30	32.74	35.27	2006284.38	234301.33
NDAIMW02	8/20/2004	45	43	31 – 41	-0.36 to -10.36	29	31	32.36	34.54	2006302.03	234307.74
NDAIMW03	8/24/2004	45	34	24 – 34	5.58 to -4.42	20	22	32.58	34.77	2006310.74	234313.92
NDAIMW04	8/20/2004	45	40	30 – 40	2.81 to -7.19	26	28	32.81	34.96	2006313.68	234300.43
NDAIMW05	8/23/2004	45	42	32 – 42	0.22 to -9.78	28	30	32.44	34.82	2006334.24	234303.28
NDAIMW06	8/26/2004	45	42	33 – 43	-0.25 to -10.25	29	31	32.47	34.75	2006353.11	234284.75
NDAIMW07	9/02/2004	42	42	33 – 43	-0.27 to -10.27	29	31	32.64	35.16	2006317.16	234305.92
NDAIMW08	12/01/2005	45	43	33 - 43	0.81 to -9.19	27	29	NS	33.81	2006334.83	234263.57
NDAIMW09	12/02/2005	45	45	35 - 45	0.10 to -9.90	24	33	NS	35.10	2006356.87	234325.35

ft amsl = feet above mean sea level (NGVD 1929)

ft bls = feet below land surface

NS = not surveyed

Northing and Easting coordinates in UTM meters

TABLE 3-3
 Summary of Rock Coring and Well Screen Intervals
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Well ID	Coring Interval (feet bls)	Screen Interval (feet bls)	Core Diameter (in)
NDAIMW01	32-37	32-42	2
NDAIMW04	28-33	30-40	2
NDAIMW06	32-40	33-43	2
NDAIMW07	32-37	33-43	2
NDAIMW08	6-45	33-43	3
NDAIMW09	16-45	35-45	3

TABLE 3-4

Summary of Final Water Indicator Parameters Prior to Groundwater Sample Collection
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Event	Well ID	Purged Volume (gallons)	pH	Conductivity μ hos/cm	Temp. °C	DO mg/L	ORP mV	Turbidity NTUs	Salinity ppt
RI (2004)	MW-01	13.5	6.83	1008	29.7	3.31	490	7.7	NS
	MW-02	13.53	7.22	1083	30.5	5.3	142	4.31	NS
	MW-03	9.35	7.67	1100	30.4	0.46	460	99	NS
	MW-04	11.7	6.8	1131	29.8	0.21	376	5.28	NS
	MW-05	12.75	6.98	1257	30.1	0.42	366	8.79	NS
	MW-06	13	7.47	1853	30.5	1.21	401	29.9	NS
	MW-07	13.5	6.26	1159	30.1	0.36	494	2.95	NS
RI (2006)	MW-01	10	6.89	1384	29	9.5	61.7	0.98	0.69
	MW-02	NS	NS	NS	NS	NS	NS	NS	NS
	MW-03	NS	NS	NS	NS	NS	NS	NS	NS
	MW-04	15.5	6.81	1284	30.02	96.6	-41.1	7.53	0.63
	MW-05	NS	NS	NS	NS	NS	NS	NS	NS
	MW-06	14	7.04	2837	30.39	80	90.9	3.37	1.31
	MW-07	11.5	6.73	1271	29.83	128	-59.5	4.61	0.63
	MW-08	7	6.92	1587	30.37	4.4	201.6	7.36	0.71
	MW-09	5.75	6.81	1542	28.95	18.1	122.7	3.88	0.77

Notes:

°C = Degrees Celsius

 μ hos/cm = micromhos per centimeter

DO = Dissolved Oxygen

mg/L = milligrams per liter

mV = millivolts

NS = Not Sampled

NTUs = Nephelometric Turbidity Units

ORP = Oxidation-Reduction Potential

Temp. = Temperature

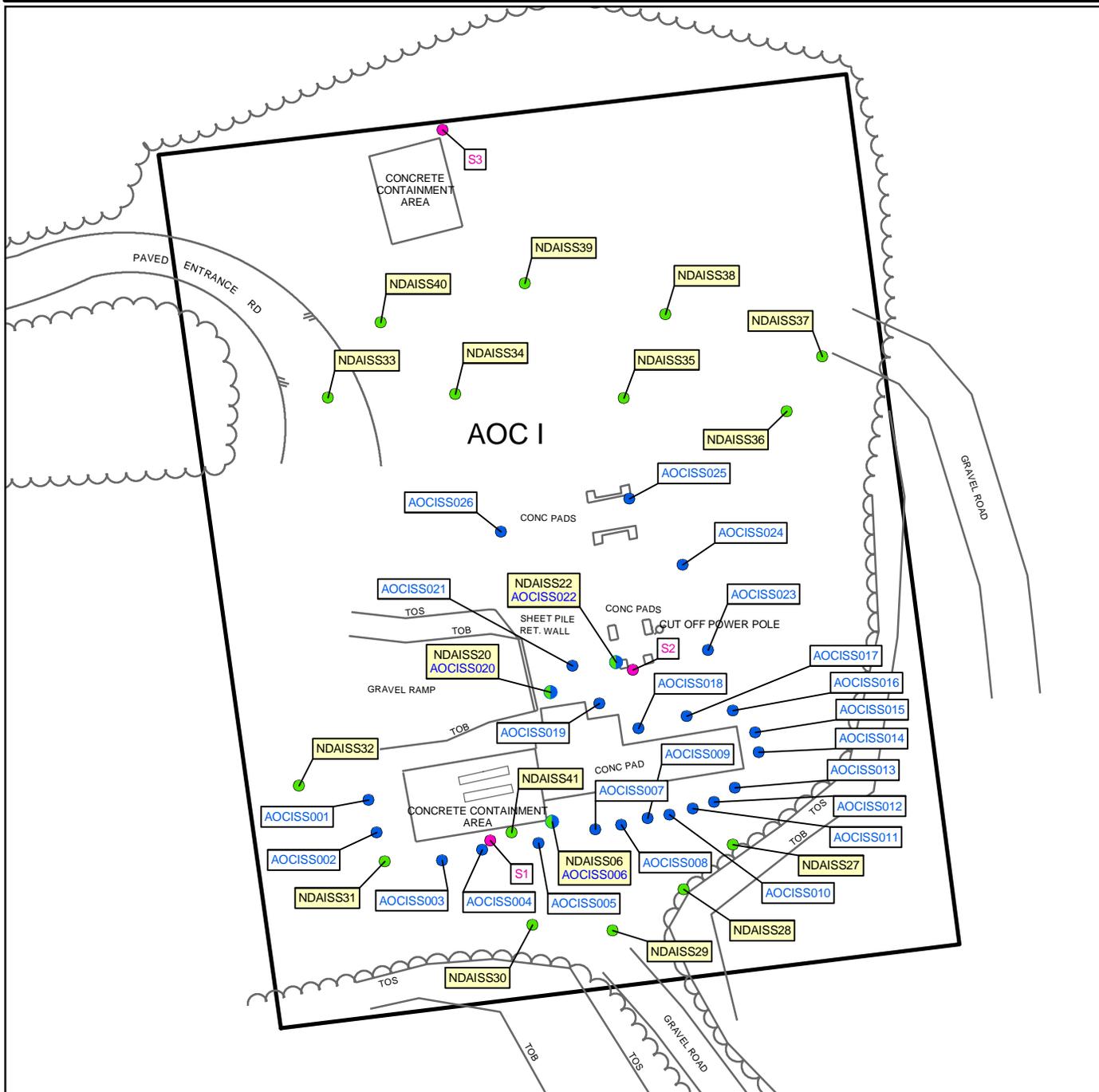
ppt = parts per thousand

TABLE 3-5
Monitoring Well Hydraulic Conductivity Test Results
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Monitoring Well & Test Type		Test Date	Test Duration ¹	Depth to Water (feet)	Hydraulic Conductivity (feet/day)
NDAIMW01	IN 1	09/23/04	6 min 55 sec	17.74	1.4
	OUT 1	09/23/04	6 min 20 sec.	17.74	1.0
	IN 2	09/23/04	3 min 25 sec	17.74	1.5
	OUT 2	09/23/04	7 min 58 sec	17.74	1.0
NDAIMW02	IN 1	09/23/04	1 min 15 sec	17.33	7.7
	IN 2	09/23/04	4 min 35 sec	17.33	7.4
	OUT 2	09/23/04	3 min 58 sec	17.33	6.8
NDAIMW03	IN 1	09/24/04	13 min 25 sec	17.69	3.7
	OUT 1	09/24/04	17 min 40 sec	17.69	3.7
NDAIMW04	IN 1	09/24/04	11 min 0 sec	18.05	6.4
	OUT 1	09/24/04	4 min 5 sec	18.05	8.6
NDAIMW05	IN 1	09/24/04	7 min 45 sec	18.45	2.1
	OUT 1	09/24/04	7 min 50 sec	18.45	2.2
NDAIMW06	IN 1	09/24/04	28 min 20 sec	26.01	0.1
	OUT 1	09/24/04	46 min 45 sec	26.01	0.1
NDAIMW08	OUT 1	1/16/06	19 min 20 sec	19.52	0.3
	OUT 2	1/16/06	18 min 51 sec	19.52	0.3
	OUT 3	1/16/06	18 min 45 sec	19.52	0.3
NDAIMW09	OUT 1	1/13/06	16 min 15 sec	18.61	0.9
	OUT 2	1/13/06	28 min 0 sec	18.53	1.0
	OUT 3	1/13/06	24 min 12 sec	18.57	0.9

¹ Time required to attain 90 percent water level recovery

Note: Only successful tests were captured in the above table. Only slug out tests were performed on monitoring wells NDAIMW08 and NDAIMW09.

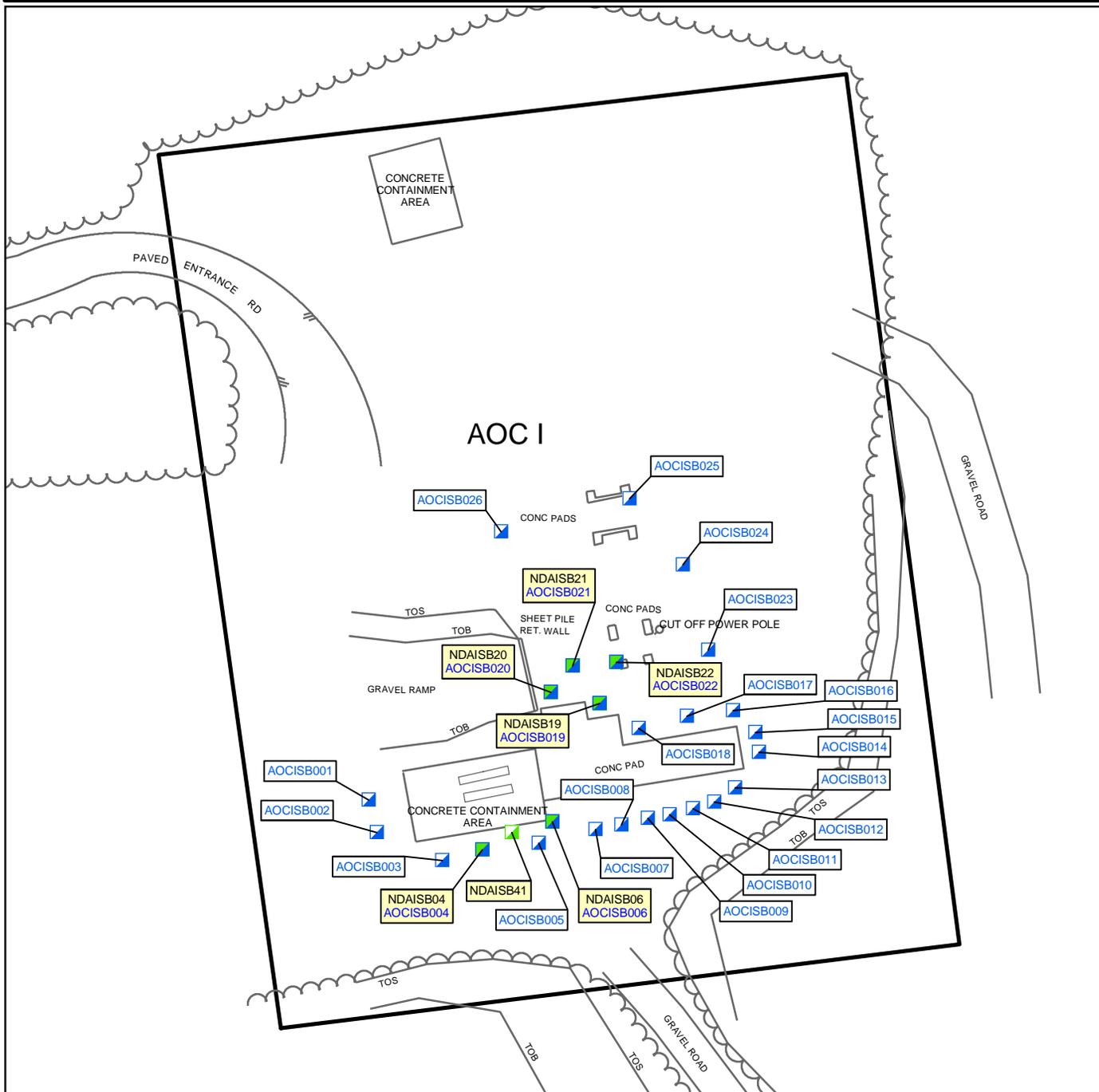


LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- PA/SI and RI Surface Soil Location (2000/04)
- RI Surface Soil Location (2004)
- PA/SI Surface Soil Location (2000)
- Approximate EBS Surface Soil Location (2000)



Figure 3-1
Surface Soil Location Map
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

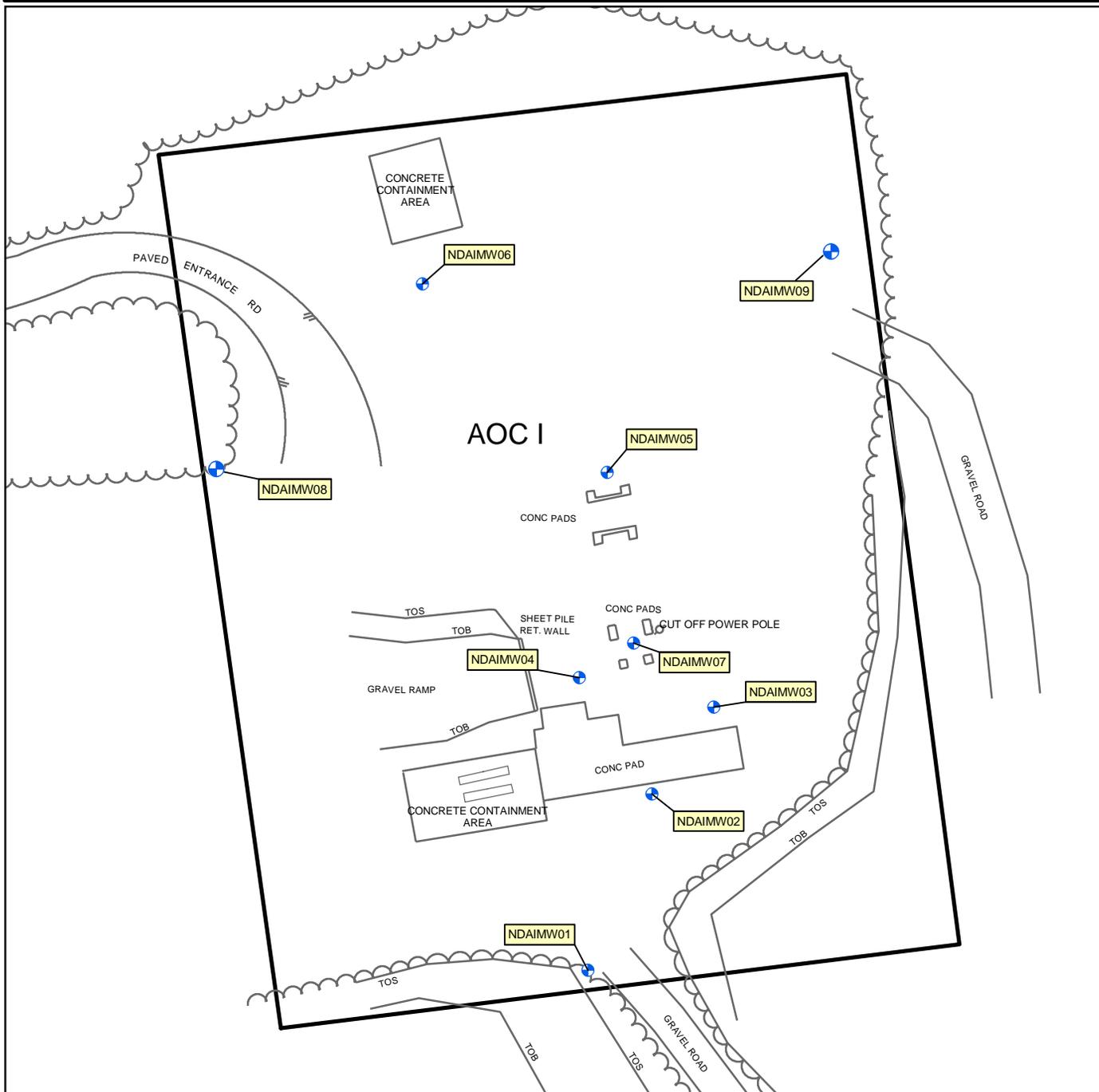


LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- PA/SI and RI Subsurface Soil Sample Location (2000/04)
- RI Subsurface Soil Sample Location (2004)
- ▣ PA/SI Subsurface Soil Sample Location (2000)



Figure 3-2
Subsurface Soil Sample Location Map
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico



LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Installed During the RI



Figure 3-3
Monitoring Well Location Map
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

SECTION 4

Nature and Extent of Contamination

This section discusses the nature and extent of contamination detected in AOC I media. While the discussion touches upon all constituents detected at the site, it focuses primarily on those constituents potentially attributable to contamination. In other words, it is those inorganics above background and non-inorganics that are potential contaminants. Therefore, the discussion in this section focuses on those constituents, with particular emphasis on those that exceed regulatory screening values. It is noted here that although background is incorporated into the evaluation of the nature and extent of contamination in order to be able to distinguish background inorganics concentrations from those potentially attributable to contamination, background is not considered in the risk assessment process (Section 6 - Human Health and Section 7 - Ecological) until the risk assessments are completed. In other words, all detected constituents above screening levels are considered in the risk assessments, regardless of whether they exceed background.

4.1 Summary of Detected Constituents

Tables 4-1 through 4-3 summarize the constituents detected in surface soil, subsurface soil, and groundwater, respectively, at AOC I. The tables also identify screening value exceedances (over that of background for inorganics). Appendix K contains the raw analytical for the soil and groundwater samples.

The screening values provided in Tables 4-1 through 4-3 are those documented in the Master QAPP (CH2M HILL, 2007), hereafter referred to as the Master QAPP. Since the Master QAPP was submitted, several screening values have been updated, so they have been substituted for the screening values provided in the Master QAPP. Table 4-4 provides a list of the updated screening values used for data screening in this RI Report. The screening values provided in Tables 4-1 through 4-3 comprise, as applicable:

- Preliminary Remediation Goals (PRGs), adjusted as appropriate
- Ecological screening values
- Site-specific soil screening levels (SSLs), as discussed below
- Federal Maximum Contaminant Levels (MCLs)
- Soil screening values for TPH provided in the *Underground Storage Tank Control Regulation* (Puerto Rico Environmental Quality Board [PREQB], 1990)
- West Vieques background soil inorganics upper tolerance limits (UTLs) from CH2M HILL (2002)

Site-specific SSLs were calculated for AOC I. Information on how the site-specific SSLs and dilution attenuation factor (DAF) of 1.5 were developed is shown in Tables 4-5 and 4-6. The DAF calculation (also known as the Summers Model) is a mass balance approach that dilutes the soil leachate (infiltrating rainwater) by the lateral flow through the groundwater-bearing unit. The following is a brief discussion of the uncertainties of the model:

- A primary component of the model is the rate of infiltration, which is based on soil type and precipitation. The algorithm used is an empirical solution based on a broad range of soil types. The soil at AOC I is described as “gravely” and “sandy,” but small percentages of silt or clay will have large effects on the rate of infiltration. Therefore, it is conceivable that the calculated rate of infiltration is high. The DAF is inversely proportion to the rate of infiltration; therefore, overestimating the infiltration will reduce the DAF.
- The thickness of the water-bearing unit is directly related to the DAF. As the thickness increases, more water is available for dilution from lateral flow. Therefore, as thickness increases so does the DAF. A relatively low thickness of 20 ft was chosen as a conservative value for thickness.
- The affected area, represented in the equation as the length of the site relative to the direction of groundwater flow, is inversely proportional to the DAF. As the length decreases, the DAF increases. The maximum distance (minimal DAF) was chosen as a conservative estimate of the affected area. The application of the DAF to the whole area assumes that there is an equal distribution of the chemicals of concern across the whole area. This assumption most likely overestimates the contaminant mass entering the groundwater-bearing unit.

4.2 Nature and Extent of Contamination

This subsection discusses the nature and extent of contamination based on the summary of analytical results presented in Tables 4-1 through 4-3. The spatial distribution of samples collected at AOC I, shown in Figures 3-1 through 3-3, provides sufficient coverage of the environmental media at the site. As shown in Figures 3-1 and 3-2, the PA/SI soil sample collection focused on the primary areas of suspected contamination based on the site history, the visual inspection, and EBS sampling results (i.e., the concrete pad where asphalt mixing took place, the southern concrete containment area where asphalt was transferred to trucks, and the location of the two former diesel ASTs). In these areas, both surface soil and subsurface soil samples were collected to the approximate depth of bedrock (between approximately 2 and 6 ft bls across the area). Sampling conducted during the RI further evaluated some of the PA/SI findings, specifically, the fraction of chromium present in the soil as hexavalent chromium. In addition, RI surface soil sampling was conducted between the asphalt mixing area and the plant entrance to evaluate whether trucks leaving the site spread contaminants from the mixing area. Bedrock in this area is relatively shallow; bedrock was encountered at 1.5 feet bls in two locations in this area. Monitoring wells, installed and sampled during the RI (2004) and/or supplemental RI (2006), were spatially located to represent upgradient groundwater conditions, as well as conditions immediately within and downgradient of the main asphalt plant and former AST areas (Figure 3-3).

4.2.1 Soil

Tables 4-1 and 4-2 show that VOCs, semi-volatile organic compounds (SVOCs), TPH, and inorganics were detected in the surface and subsurface soil at AOC I. However, the tables also show that the nature, extent, and concentrations of contamination in soil are relatively low, as discussed below.

4.2.1.1 Volatile Organic Compounds

Figures 4-1 and 4-2 display the concentrations of the VOCs detected in surface soil and subsurface soil, respectively, at AOC I and identify screening value exceedances. Twelve VOCs were detected in surface soil. Nine of the same VOCs were also detected in subsurface soil. However, as shown in the figures and in Tables 4-1 and 4-2, most were detected in only one, two, or three samples and none of the concentrations exceeds human health, ecological, or site-specific SSL screening levels. In fact, all concentrations are less than the screening levels by a minimum of a factor of 2 up to about 6 orders of magnitude below the screening levels. However, several of the same VOCs (1,2-dichloroethane [1,2-DCA]; 4-methyl-2-pentanone [MIBK]; benzene; ethylbenzene; toluene; trichloroethene [TCE]; and xylene) were detected in groundwater (see Section 4.2.2 below).

With a few exceptions, where VOCs were detected in the surface soil, they were either not detected or were detected at lower concentrations in the subsurface soil. The only notable exception to this occurred at sample location SB21, which was collected adjacent to the gravel ramp and concrete pad where asphalt mixing occurred. At this location, only tetrachloroethene (PCE; 0.27 µg/kg) was detected in the surface soil. However, 2-butanone (a.k.a. methyl ethyl ketone or MEK; 2.9 µg/kg), MIBK (53 µg/kg), ethylbenzene (96 µg/kg), and xylene (4,460 µg/kg) were detected in the subsurface soil sample. Surface and subsurface soil samples collected in the vicinity of this sample (i.e., SB19, SB20, and SB22) either did not contain these constituents or contained them at concentrations orders of magnitude below those detected in SB21.

The VOCs detected in soil at AOC I generally fall into one or both of two categories: solvents and petroleum-related constituents. Of the 12 VOCs detected, 8 (acetone; MEK; 1,1-dichloroethene [1,1-DCE]; 1,2-DCA; MIBK; methylene chloride; PCE; and TCE) are common solvents available during the operational period of the asphalt plant. The solvents were likely used to clean asphalt from machinery. The remaining 4 VOCs (benzene, toluene, ethylbenzene, and xylenes, often referred to as BTEX) are components of gasoline and other petroleum-related products and are likely present as a result of fuel usage at the site.

Figures 4-1 and 4-2 show that the distribution of constituents and the relatively low associated concentrations in the surface and subsurface soil are not indicative of a substantial release, but appear to be more representative of minor drips and spills likely associated with asphalt plant operations. Further, as discussed in Section 4.2.2, the concentrations in groundwater are also relatively low with respect to screening criteria, which tend to indicate no substantial release occurred.

4.2.1.2 Semi-volatile Organic Compounds

Figures 4-3 and 4-4 display the concentrations of the SVOCs detected in surface soil and subsurface soil, respectively, at AOC I and identify screening value exceedances. Thirteen SVOCs were detected in surface soil. Five of the same SVOCs were detected in subsurface soil; an additional seven SVOCs were detected in subsurface soil. As shown in Tables 4-1 and 4-2, all 20 SVOCs, except bis(2-ethylhexyl)phthalate, are either polycyclic aromatic hydrocarbons (PAHs) or heterocyclic aromatic hydrocarbons (HAHs), which are common components of crude oil and petroleum product production. Bis(2-ethylhexyl)phthalate is used as hydraulic fluid in brakes, power steering, and transmissions and is also a plasticizer used in making polyvinyl chloride (PVC).

Table 4-1 shows that the most common SVOC detected in surface soil was bis(2-ethylhexyl)phthalate, which was detected in 13 of 40 surface soil samples. However, none of the concentrations exceeds human health, ecological, or site-specific SSL screening levels. It is noted that bis(2-ethylhexyl)phthalate was detected in groundwater from one monitoring well (NDAIMW05; see Section 4.2.2 below). Other than sporadic detections bis(2-ethylhexyl)phthalate, no SVOCs were detected in any of the Expanded PA/SI surface soil samples nor 9 of the 14 RI surface soil samples analyzed for SVOCs. The remaining SVOCs detected in surface soil are PAHs, which were detected in only five samples (SS32, SS36, SS37, SS38, and SS39). However, only two detections of benzo(a)pyrene (86 µg/kg in SS32 and 145 µg/kg in SS39), one detection of fluoranthene (227 µg/kg in SS36), and two detections of pyrene (193 µg/kg in SS36 and 118 µg/kg in SS39) exceed human health and/or ecological screening levels. No SVOC concentrations in surface soil exceed the site-specific SSLs.

In subsurface soil, SVOCs were detected in only two samples (SB21 and SB23), although 11 of the 12 SVOCs were detected in only sample SB21 (Table 4-2). None of the concentrations exceeds a human health screening criterion, but three SVOC detections (158 µg/kg carbazole, 663 µg/kg dibenzofuran, and 2,550 µg/kg naphthalene, all in sample SB21) exceed their respective site-specific SSLs. Two of these three SVOCs (dibenzofuran and naphthalene) were detected in groundwater (NDAIMW04, NDAIMW05, and NDAIMW07 for dibenzofuran; NDAIMW04 and NDAIMW07 for naphthalene; see Section 4.2.2 below).

Figures 4-3 and 4-4 show that there is not widespread SVOC contamination in soil at AOC I. The majority of SVOC detections occur in relatively few samples and their concentrations are relatively low with respect to screening criteria. Similar to VOCs, this information suggests there was not a substantial release, but more likely minor drips and spills of oil and asphalt associated with asphalt plant operations. Further, as discussed in Section 4.2.2, the concentrations in groundwater are also relatively low with respect to screening criteria.

4.2.1.3 Total Petroleum Hydrocarbons (TPH)

Figures 4-5 and 4-6 display the concentrations of TPH detected in surface and subsurface soil samples collected during the EBS, Expanded PA/SI, and RI and identify screening value exceedances. Table 4-1 and Figure 4-5 show that TPH was detected in 35 of the 43 surface soil samples, and that 17 of the 35 detections are above the PREQB screening criterion of 100 milligrams per kilogram (mg/kg). The highest concentration (SB10; 1,200 mg/kg) was detected adjacent to the concrete pad where asphalt mixing took place (Figure 4-5).

Table 4-2 and Figure 4-6 show that fewer detections and lower concentrations of TPH were detected in subsurface soil samples. TPH was detected in 13 of 26 subsurface soil samples, but only one detection (SB21; 232 mg/kg) exceeds the PREQB screening criterion of 100 mg/kg.

Petroleum hydrocarbons are associated with asphalt, truck fuel and oil, and hydraulic fluids, so the distribution of TPH in soil, both vertically and horizontally, is consistent with what might be anticipated for asphalt plant operations, where open-air asphalt mixing was taking place and truck traffic through the site was transporting the asphalt to road construction locations on the island.

It is noted here that 100 mg/kg was provided only for comparative purposes because the value is from the PREQB Underground Storage Tank Control Regulation (PREQB, 1990), which is not applicable to asphalt plant operations. Rather, the constituents of the petroleum products used and produced at the former asphalt plant that have risk-based levels (i.e., VOCs, SVOCs, inorganics) are included in the human health and ecological risk assessments performed for AOC I (see Sections 6 and 7).

4.2.1.4 Inorganic Constituents

The inorganics (also referred to as “metals” in this RI Report) detected at AOC I have both non-site-related origins as well as a potential site-related source. The concentrations of those inorganics that may be associated with site-specific releases are determined by comparing the site concentrations to concentrations from the applicable background inorganics dataset. For AOC I, which lies within the Qa geologic zone, the inorganics concentrations from the site samples are compared to the Qa dataset from the former NASD background soil inorganics study (CH2M HILL, 2002). The remainder of this discussion focuses on those inorganics potentially attributable to site-related contamination.

Figures 4-7 and 4-8 display the concentrations of the inorganics in surface and subsurface soil above background UTLs (not including calcium and magnesium). The figures also identify screening value exceedances. As shown in Figure 4-7 and Table 4-1, 12 inorganics (arsenic, cadmium, calcium, chromium, copper, iron, lead, magnesium, nickel, silver, thallium, and vanadium) were detected in surface soil above background UTLs. Figure 4-8 and Table 4-2 show that 12 inorganics (aluminum, antimony, arsenic, chromium, copper, iron, lead, magnesium, nickel, silver, sodium, and vanadium) were detected in subsurface soil above background UTLs. The presence of calcium and magnesium above background UTLs supports the supposition that just because constituents are detected above background UTLs, they are not necessarily associated with a release.

In surface soil, only one detection each of arsenic (SB20; 2.3 mg/kg), cadmium (SB22; 0.52 mg/kg), iron (SB20; 44,000), and vanadium (SB20; 140 mg/kg) exceed their background UTLs (2.2 mg/kg, 0.036 mg/kg, 39,000 mg/kg, and 130 mg/kg, respectively). Of these, the arsenic, iron, and vanadium concentrations exceed the human health screening values (0.39 mg/kg, 2,300 mg/kg, and 7.8 mg/kg, respectively) and site-specific SSLs (0.47 mg/kg, 414 mg/kg, and 55 mg/kg, respectively). However, the arsenic, iron, and vanadium concentrations in the second sample of the SB20 duplicate pair do not exceed the background UTLs. Further, the cadmium concentration in sample SB22 is below its screening values. The above information suggests that the presence of arsenic, cadmium, iron, and vanadium in surface soil is likely attributable to background conditions and not a site-specific release.

Other than the single detection each of arsenic, iron, and vanadium above their respective human health screening values and background UTLs, only one other constituent was detected in surface soil above its human health screening value (0.52 mg/kg) and background UTL (0.67 mg/kg); it was two detections of thallium (SB18; 0.93 mg/kg and SB20; 0.73 mg/kg). Similarly, only two detections of nickel (SB06; 49 mg/kg and SB20; 57 mg/kg) exceed its background UTL (40 mg/kg) and ecological screening value (38 mg/kg), but by a relatively small amount. Like arsenic, cadmium, iron, and vanadium, the presence of nickel and thallium in surface soil is likely attributable to background.

Of the remaining inorganics in surface soil, seven detections of chromium, three detections of copper, four detections of lead, and eight detections of silver exceed their respective background UTLs and one or more screening value. Seven out of 43 surface soil samples analyzed for chromium contained chromium above the background UTL (74 mg/kg) and its ecological screening value (0.4 mg/kg). Of these seven, only three concentrations exceed the background UTL by more than 3 mg/kg (SB20; 110 mg/kg, SS20; 88 mg/kg, and SS29; 92 mg/kg). No chromium concentrations in surface soil exceed the human health screening value (210 mg/kg). Total chromium is made up primarily of trivalent chromium (chromium III) and hexavalent chromium (chromium VI); elemental chromium is the third most common form, but is not likely found in nature (Irwin *et. Al*, 1997). Elemental chromium, chromium (0), is used to make steel. Trivalent chromium occurs naturally in the environment and is an essential nutrient. Hexavalent chromium can occur naturally in minor amounts, but also has anthropogenic origins in chrome plating, in dyes and pigments, and in leather tanners and wood preservatives (ATSDR, 2001). Chromium can also be released during combustion of oil and coal (State of California Air Resources Board, 1985). During the RI, 17 surface soil samples were analyzed for total chromium and hexavalent chromium to evaluate the contribution of hexavalent chromium to the total chromium concentrations. Based on these results, hexavalent chromium makes up between 0 and about 3 percent of the total chromium concentrations in surface soil at AOC I, which is less than the 1:6 ratio cited on the EPA Region IX website for hexavalent chromium:trivalent chromium. The above information suggests that chromium is present in AOC I surface soil primarily as a result of background.

Only three detections of copper in surface soil exceed its background UTL and at least one screening value. Copper was detected in three samples (SB03; 77 mg/kg, SB05; 103 mg/kg; and SB23; 82 mg/kg) above the background UTL (68 mg/kg) and ecological screening value (70 mg/kg); two of the copper concentrations also exceed the site-specific SSL (77 mg/kg). However, copper was not detected in groundwater above its tap water PRG or MCL. Anthropogenic sources of copper include wire, plumbing pipes, sheet metal, and as a preservative for wood, leather, and fabrics (ATSDR, 2004). Based on this information, as well as the relatively few detections above the background UTL (6 of 26 surface soil samples, most by less than 10 mg/kg), copper is present in AOC I surface soil likely as a result of background.

Four of 26 surface soil samples contained lead (SB20; 8.7 mg/kg, SB22; 22 mg/kg, SB24; 8.8 mg/kg, and SB25; 9.9 mg/kg) above the background UTL (6.9 mg/kg). These same four concentrations exceed the site-specific SSL (5.3 mg/kg). However, lead was not detected in groundwater above its action level. Because lead is found in fossil fuels, the one lead concentration uniquely higher than the background UTL (22 mg/kg in SB22) may be attributable to the production of asphalt at AOC I or the potential use of leaded gasoline during plant operations. However, when considered as a whole, the lead data suggest lead is present in AOC I surface soil primarily as a result of background.

Silver was detected in 8 of 26 surface soil samples (maximum concentration of 0.12 mg/kg) above its background UTL (0.08 mg/kg). However, all concentrations are more than two orders of magnitude below the human health screening level (39 mg/kg) and site-specific SSL (30 mg/kg). However, because silver does not likely have a site-related source, because it was detected in only eight samples above the background UTL, and because its maximum

detected concentration is within 0.04 mg/kg of the background UTL, the presence of silver in AOC I surface soil is likely attributable to background.

In subsurface soil, only one detection each of aluminum (SB01; 32,600 mg/kg) and arsenic (SB20; 2.6 mg/kg), and two detections each of antimony (SB04; 2.8 mg/kg and SB19; 2.9 mg/kg) and lead (SB21; 14 mg/kg and SB24; 7.5 mg/kg) exceed their background UTLs (29,000 mg/kg, 2.2 mg/kg, 2.3 mg/kg, and 6.9 mg/kg, respectively). Of these, only the aluminum and arsenic concentrations exceed the human health screening values (7,600 mg/kg and 0.39 mg/kg, respectively). The concentrations of antimony, arsenic, and lead exceed the site-specific SSLs (0.99 mg/kg, 0.47 mg/kg, and 5.3 mg/kg, respectively). Because of the few detections above background UTLs and because these detections are not substantially above the background UTLs (other than the detection of lead at approximately twice the background UTL), the presence of aluminum, antimony, arsenic, and lead in surface soil is primarily attributable to background conditions and not a site-specific release.

Of the remaining constituents detected in subsurface soil above background UTLs (chromium, copper, iron, nickel, silver, and vanadium), none of the concentrations of chromium, nickel, and silver exceeds its human health screening levels or site-specific SSLs. Several concentrations of iron and vanadium exceed background UTLs and both human health screening levels and site-specific SSLs. However, the elevated concentrations of both iron and vanadium do not demonstrate a pattern of correspondence with elevated levels of other constituents in the same samples. Therefore, it is possible that their presence is attributable to background. However, it is noted that both iron and vanadium are associated with steel, and both can be released from burning of fuel oils.

Several concentrations (maximum of 225 mg/kg, but three of four between 80 mg/kg and 85 mg/kg) of the remaining inorganic (copper) detected in subsurface soil above its background UTL (68 mg/kg) exceed its site-specific SSL (77 mg/kg). However, copper was not detected in groundwater above its tap water PRG or MCL.

4.2.2 Groundwater

Table 4-3 shows that VOCs, SVOCs, and inorganics were detected in the groundwater at AOC I. However, the tables also show that the nature, extent, and concentrations of contamination in groundwater are relatively low, as discussed below.

4.2.2.1 Volatile Organic Compounds (VOCs)

Figure 4-9 displays the concentrations of the VOCs detected in groundwater at AOC I and identifies screening value exceedances. Sixteen VOCs were detected in groundwater. However, as shown in the Figure 4-9 and Table 4-3, no VOCs were detected in monitoring wells NDAIMW02, NDAIMW06 (other than 0.13 micrograms per liter ($\mu\text{g/L}$) of bromoform), NDAIMW08, and NDAIMW09, which are the wells located near the upgradient end of the site (NDAIMW02) and downgradient end of the site (NDAIMW06, NDAIMW08, and NDAIMW09). This information, together with SVOC and inorganic data (discussed below), suggests groundwater contamination associated with historical activities at AOC I is confined to a relatively small area around the former asphalt plant.

The highest concentrations of VOCs were detected in wells NDAIMW04 and NDAIMW07, which are the two centrally located wells at the site. In fact, these two wells are the only

wells at the site where a VOC was detected above its MCL. In 2004, benzene was detected in wells NDAIMW04 (34 µg/L) and NDAIMW07 (59 µg/L) above the MCL of 5 µg/L. However, it is notable that the samples collected from these wells in 2006 contained benzene at lower concentrations. The 2006 benzene concentration in well NDAIMW04 (4.6 µg/L) is below the MCL; the 2006 benzene concentration in well NDAIMW07 is approximately half the 2004 benzene concentration and is the only VOC MCL exceedance from 2006. While it is possible this information represents a continuing decline in benzene concentrations, it may also be representative of innate fluctuations.

Although 15 other VOCs were detected in groundwater, none exceeds an MCL. The concentrations of 1,2-DCA (NDAIMW07), 1,2-dichloropropane (NDAIMW07), 1,4-dichlorobenzene (NDAIMW07), benzene (NDAIMW03, NDAIMW04, NDAIMW05, and NDAIMW07), and TCE (NDAIMW04 and NDAIMW07) detected during in 2004 and/or 2006 exceed their respective tap water PRGs.

Like the VOCs detected in soil, the VOCs detected in groundwater fall into one or both of two categories: solvents and petroleum-related constituents. Of the 16 VOCs detected, 10 (1,1-DCA; 1,2-DCA; 1,2-dichloropropane; 1,3-dichlorobenzene; 1,4-dichlorobenzene; MIBK; bromoform; cyclohexane; methylcyclohexane; and TCE) are common solvents. The remaining 6 VOCs (BTEX, chloromethane, and isopropylbenzene) are components of gasoline and other petroleum-related products. The VOC groundwater data tend to support the supposition stated above for VOCs in soil; that is, the data are not indicative of a substantial release, but appear to be more representative of minor drips and spills likely associated with asphalt plant operations, especially considering that contamination is localized around the immediate area of the former asphalt plant.

4.2.2.2 Semi-volatile Organic Compounds

Figure 4-10 displays the concentrations of the SVOCs detected in groundwater at AOC I and identifies screening value exceedances. Eight SVOCs were detected in groundwater. Similar to VOCs in groundwater, the highest concentrations of most SVOCs were detected in wells NDAIMW04 and NDAIMW07. No SVOCs were detected in wells NDAIMW02, NDAIMW03, NDAIMW06, NDAIMW08, and NDAIMW09. Bis(2-ethylhexyl)phthalate, the most common SVOC detected in surface soil, is the only SVOC detected in groundwater (NDAIMW05; 9.6 µg/L) above its respective MCL (6 µg/L). However, this constituent is a common laboratory contaminant, so its presence may not be attributable to historic releases, especially considering the low concentration detected. Three other SVOCs (2-methylnaphthalene, dibenzofuran, and naphthalene) were detected above their respective tap water PRGs. All three of these SVOCs are common components of crude oil and petroleum product production. The concentrations of these three SVOCs do not show any obvious pattern of change between 2004 and 2006. However, the data tend to support the supposition that there was not a substantial release associated with past asphalt plant operations.

4.2.2.3 Inorganic Constituents

While upgradient well NDAIMW01 was used for comparisons of groundwater inorganics at AOC I, it is important to note that the inorganics data for this well represent a single point in a range of inorganics representative of background groundwater conditions. Therefore,

other information, such as soil data, other constituents detected or not detected, and the constituent type, is used to help interpret the site-specific groundwater inorganics data.

While the concentrations of most inorganics (total) exceed their respective background well concentrations in at least one well, only total concentrations of arsenic, cadmium, iron, manganese, and vanadium also exceed their respective human health screening levels (PRGs or adjusted PRGs, as appropriate) or MCLs as shown in Figure 4-11. For the dissolved phase, concentrations of the same constituents plus antimony exceed their respective background values, human health screening levels, and MCLs. Each of these is further discussed below.

The dissolved antimony concentrations in two wells (NDAIMW02; 2.85 µg/L and NDAIMW06; 2.33 µg/L) exceed the background (non-detect at a reporting limit of 2.3 µg/L) and adjusted tap water PRG (1.5 µg/L). However, as discussed previously, the antimony concentrations in soil at the site are likely attributable to background. For these reasons, the antimony concentrations in groundwater at the site are likely attributable to background.

The total arsenic concentrations detected in site wells (maximum of 18.7 µg/L in 2004; maximum of 4.5 µg/L in 2006) are similar to the background total arsenic concentrations (15.6 µg/L in 2004 and 10 U µg/L in 2006). Similarly, the dissolved arsenic concentrations in site wells (maximum of 20 µg/L in 2004; maximum of 6.2 µg/L in 2006) are comparable to the background dissolved arsenic concentrations (14 µg/L in 2004 and 10 U µg/L in 2006). In addition, as discussed previously, the arsenic concentrations in soil at the site are likely attributable to background. For these reasons, the arsenic concentrations in groundwater at the site are likely attributable to background.

Total and dissolved cadmium were detected in well NDAIMW02 above the background concentrations. This well did not contain any VOCs or SVOCs. In addition, the cadmium concentrations detected in well NDAIMW02 (maximum of 8.7 µg/L) are only about 2 µg/L above the background concentrations (maximum of 6.4 µg/L). Further, as discussed previously, cadmium was detected in only one surface soil sample and was not detected in subsurface soil. For these reasons, the cadmium concentrations in groundwater are likely attributable to background.

Iron (total and dissolved) was detected in only one well in 2006 (NDAIMW07; 1,840 µg/L and 1,470 µg/L) above background (non-detect at a reporting limit of 100 µg/L) and the adjusted tap water PRG (1,100 µg/L). The concentrations represent an increase from the 2004 iron concentration, which is below the adjusted tap water PRG. While iron in soil may be attributable to background, its presence may also be the result of releases because it can be associated with the burning of fuel oils. However, if present as a result of a release, its spatial extent above the adjusted PRG appears to be limited to a relatively small area around NDAIMW07.

Total and dissolved manganese (concentrations between 126 µg/L and 1960 µg/L) were detected in all wells (other than NDAIMW06) above background (41 µg/L) and the adjusted PRG (88 µg/L). However, as stated previously, no manganese was detected in soil above the background UTL. This information suggests the manganese present in AOC I groundwater is attributable to background.

Total (47 µg/L) and dissolved (45 µg/L) vanadium were detected in only one well (NDAIMW06) above background (approximately 37 µg/L) and the adjusted tap water PRG (3.6 µg/L). All other detected concentrations are below the background concentrations. Well NDAIMW06 is the most downgradient well, and it did not contain other constituents attributed to site-related releases. This information suggests the vanadium concentration in this well is not likely attributable to a site-related release, but is instead attributable to background.

4.2.3 Unsaturated Bedrock Fractures

Sections 4.2.1 and 4.2.2 discuss the nature and extent of contamination in soil and groundwater, respectively. However, between the unsaturated, unconsolidated (i.e., soil) zone and the saturated, consolidated (i.e., bedrock) zone at AOC I there is an unsaturated zone within the bedrock. In order for contamination released during historical asphalt plant operations to reach groundwater, it has to migrate through not only the unsaturated soil zone, but also the unsaturated portion of the bedrock. Like the saturated portion of andesite bedrock, contaminant migration through the unsaturated portion of the bedrock is via fractures. During drilling through unsaturated bedrock at monitoring well locations NDAIMW04 and NDAIMW07, elevated OVA readings were observed from the rock fragments collected (Appendix A). Figure 2-8 shows the OVA readings observed from the rock fragments collected during drilling of the wells used to create the cross section. Elevated OVA readings were also observed during the drilling of NDAMW04. This contamination likely represents an ongoing source of contamination to the groundwater, periodically flushed through as precipitation percolates through the unsaturated fractures and into the bedrock aquifer. However, given the considerable time between operation of the plant and installation of wells NDAMW04 and 07 (i.e., between 16 and 44 years), it is likely that the groundwater data from these wells suitably represent the continuing contribution from leaching of concentrations from the unsaturated bedrock.

TABLE 4-1
Surface Soil Detection and Exceedance Results
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Station ID Sample ID Sample Date	Site Specific SSL - DAF 1.5	Vieques HHRA SO	Vieques Eco SO	PREQB UST Corrective Action Criteria	Vieques (West) Background Zone Qa SO	AOC-I-S1	AOC-I-S2	AOC-I-S3	AOC-I-S3D	AOCISB001	AOCISB002	AOCISB003	AOCISB004	AOCISB005	AOCISB006	AOCISB007	AOCISB008	AOCISB009	AOCISB010	AOCISB011		AOCISB012	AOCISB013	AOCISB014	AOCISB015	AOCISB016	AOCISB017	
						May 2000	May 2000	May 2000	May 2000	NDE043 11/29/00	NDE045 11/29/00	NDE047 11/29/00	NDE049 11/29/00	NDE051 11/29/00	NDE053 11/30/00	NDE055 11/30/00	NDE057 11/30/00	NDE059 11/30/00	NDE061 11/30/00	NDE062FD1 11/30/00	NDE064 11/30/00	NDE066 11/30/00	NDE068 11/30/00	NDE070 11/30/00	NDE072 11/30/00	NDE075 11/30/00	NDE077 11/30/00	
Chemical Name																												
Volatile Organic Compounds (µg/kg)																												
1,1-Dichloroethene	197	12,000	100	--	--	NA	NA	NA	NA	10 U	10 UJ	10 UJ	10 U	0.43 J	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U					
1,2-Dichloroethane	2.40	280	20	--	--	NA	NA	NA	NA	10 U	10 UJ	10 UJ	10 U	10 U	10 U	10 UJ	10 U											
2-Butanone	2,198	2,200,000	--	--	--	NA	NA	NA	NA	10 R	10 R	10 R	10 R	5 J	10 R	10 R	10 R	10 R	10 R	10 R	10 R	10 R	10 R					
4-Methyl-2-pentanone	685	530,000	--	--	--	NA	NA	NA	NA	10 U	2.8 J	10 U	10 U	10 U	10 U	10 UJ	10 UJ	10 U	10 U	10 U	10 UJ	10 U						
Acetone	1,686	1,400,000	--	--	--	NA	NA	NA	NA	10 R	10 R	11 R	12 R	13 R	16 R	16 R	14 R	30 R	19 R	10 R	10 R	10 R	10 R	10 R	6.7 J	10 R	10 R	10 U
Benzene	4.92	640	10	5,000	--	ND	ND	ND	ND	10 U	10 U	1.2 J	10 U	10 U	10 UJ	10 UJ	10 UJ	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U
Ethylbenzene	3,197	190,000	30	10,000	--	ND	ND	ND	ND	10 U	10 U	3.7 J	10 U	10 U	10 UJ	10 UJ	10 UJ	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U
Methylene chloride	--	9,100	--	--	--	NA	NA	NA	NA	10 U	10 UJ	10 UJ	10 UJ	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U				
Tetrachloroethene	4.09	480	2	--	--	NA	NA	NA	NA	10 U	10 UJ	10 UJ	10 UJ	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U				
Toluene	1,394	630,000	200,000	10,000	--	ND	ND	ND	ND	10 U	10 U	16	10 U	25	1.4 J	1.7 J	0.59 J	0.3 J	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U
Trichloroethene	3.11	53	100	--	--	NA	NA	NA	NA	10 U	10 U	10 U	0.31 J	10 U	10 U	10 UJ	10 UJ	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U
Xylene, total	20,843	27,000	--	10,000	--	ND	ND	ND	ND	10 U	10 U	27	10 U	10 U	10 U	10 UJ	0.83 J	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U
m- and p-Xylene	--	27,000	100	10,000	--	NA	NA	NA	NA	10 U	10 U	19	10 U	10 U	10 UJ	0.65 J	10 U	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U
o-Xylene	--	27,000	100	10,000	--	NA	NA	NA	NA	10 U	10 U	7.8 J	10 U	10 U	10 UJ	0.18 J	10 U	10 U	10 U	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U
Semi-volatile Organic Compounds (µg/kg)																												
Acenaphthylene	--	370,000	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Anthracene	147,420	2,200,000	100	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Benzo(a)anthracene	83.96	620	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Benzo(a)pyrene	621	62	100	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Benzo(b)fluoranthene	282	620	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Benzo(g,h,i)perylene	--	2,300,000	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Benzo(k)fluoranthene	2,860	6,200	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Chrysene	8,577	62,000	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Dibenz(a,h)anthracene	95.19	62	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Fluoranthene	408,808	230,000	100	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Indeno(1,2,3-cd)pyrene	974	620	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
Pyrene	50,020	230,000	100	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 U	353 U	379 U	448 U	408 U	430 U	392 U	368 U	
bis(2-Ethylhexyl)phthalate	3,907	35,000	--	--	--	NA	NA	NA	NA	364 U	331 U	344 U	340 U	363 U	408 U	376 U	356 U	353 U	344 U	376 UJ	3,880 J	379 U	448 U	408 U	430 U	392 U	368 U	
Pesticide/Polychlorinated Biphenyls (µg/kg)																												
No Detections																												
Total Metals (mg/kg)																												
Aluminum	1,000,000	7,600	--	--	29,000	NA	NA	NA	NA	17,700	15,600	18,200	14,400	16,700	21,000	17,000	14,000	15,000	20,000	18,000	18,000	17,000	17,000	17,000	18,000	15,000	16,000	
Antimony	0.99	3.1	78	--	2.3	NA	NA	NA	NA	1.1 J	1 J	1.5 J	1.1 J	1.3 J	1.4 J	1.3 J	0.86 J	0.99 J	1.4 J	0.95 J	1.1 J	1.5 J	1.2 J	1.3 J	1 J	1.2 J	1.2 J	
Arsenic	0.468	0.39	18	--	2.2	NA	NA	NA	NA	1.1 J	1.2 J	0.86 J	0.91 J	1.1 J	2 J	1.6 J	0.77 J	0.8 J	1.2 J	0.97 J	1.1 J	1.3 J	1.6 J	1.4 J	1.4 J	1.1 J	1.1 J	
Barium	200	1,600	330	--	320	NA	NA	NA	NA	39 J	30 J	39 J	40 J	35 J	62	42 J	26 J	28 J	42	31 J	39 J	39 J	47	51	40 J	37 J	30 J	
Beryllium	11,000	15	40	--	0.45	NA	NA	NA	NA	0.15 J	0.11 J	0.15 J	0.11 J	0.14 J	0.26 J	0.14 J	0.03 U	0.03 U	0.14 J	0.03 U	0.11 J	0.18 J	0.17 J	0.2 J	0.14 J	0.19 J	0.13 J	
Cadmium	--	3.7	32	--	0.036	NA	NA	NA	NA	0.02 U	0.11 U	0.02 U	0.02 U	0.02 U	0.03 U	0.03 U	0.02 U	0.02 U	0.02 U									
Calcium	--	--	--	--	45,000	NA	NA	NA	NA	20,800	15,100	18,700	18,400	13,700	16,000	14,000	15,000	14,000	20,000	15,000	17,000	17,000	17,000	16,000	15,000	52,000	21,000	
Chromium	1,000,000	210	0.4	--	74	NA	NA	NA	NA	34	33	47	31	55	77	57	40	35	47	36	45	42	52	63	48	42	39	
Chromium (hexavalent)	2.33	22	--	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Cobalt	49.49	140	13	--	33	NA	NA	NA	NA	16	15	17	13	16	27	19	12	14	18	16	17	15	18	19	18	14	16	
Copper	77.09	310	70	--	68	NA	NA	NA	NA	70	55	77	48	103	68	59	40	62	55	51	52	49	46	43	48	48	53	
Iron	414	2,300	--	--	39,000	NA	NA	NA	NA	29,600	26,300	29,800	23,400	28,000	37,000	30,000	22,000	24,000	31,000	28,000	29,000	28,000	29,000	29,000	30,000	25,000	29,000	
Lead	5.27	400	120	50	6.9	NA	NA	NA	NA	1	0.47 J	0.96	0.98	0.91	1.5	0.85	1.7	1.8	1.8	1.1	1.9	1.7	1.2	2.1	2.3	3.2	1.4	
Magnesium	--	--	--	--	12,834	NA	NA	NA	NA	13,500	12,700	13,900	10,600	13,200	14,000	13,000	11,000	12,000	15,000	14,000	14,000	12,000	12,000	10,000	14,000	12,000	14,000	
Manganese	86	180	220	--	1,200	NA	NA	NA	NA	593	490	574	465	530	980	680	440	490	670	590	640	570	660	730	670	520	600	
Mercury	3.29	2.3	0.1	--	0.031	NA	NA	NA	NA	0.004 J	0.006																	

TABLE 4-1
Surface Soil Detection and Exceedance Results
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Station ID Sample ID Sample Date	Site Specific SSL - DAF 1.5	Vieques HHRA SO	Vieques Eco SO	PREQB UST Corrective Action Criteria	Vieques (West) Background Zone Qa SO	AOCISB018		AOCISB019		AOCISB020		AOCISB021		AOCISB022		AOCISB023		AOCISB024		AOCISB025		AOCISB026		NDAISS06		NDAISS20		NDAISS22		NDAISS27		NDAISS28		NDAISS29		NDAISS30		NDAISS31		NDAISS32		NDAISS33			
						NDE074FD1 12/01/00	NDE079 12/01/00	NDE081 12/01/00	NDE083 12/01/00	NDE084FD1 12/01/00	NDE086 12/01/00	NDE088 12/01/00	NDE090 12/01/00	NDE091FD1 12/01/00	NDE093 12/01/00	NDE095 12/01/00	NDE097 12/01/00	NDE099FD1 12/01/00	NDAISS06-R02 08/20/04	NDAISS20-R02 08/20/04	NDAISS22-R01-B 08/20/04	NDAISS27-R01 08/18/04	NDAIFD03P-R01 08/18/04	NDAISS28-R01 08/18/04	NDAISS29-R01 08/18/04	NDAISS30-R01 08/18/04	NDAISS31-R01 08/18/04	NDAISS32-R01 08/18/04	NDAISS33-R01 08/19/04																
Chemical Name																																													
Volatile Organic Compounds (µg/kg)																																													
1,1-Dichloroethene	197	12,000	100	--	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	0.47 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA			
1,2-Dichloroethane	2.40	280	20	--	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		
2-Butanone	2,198	2,200,000	--	--	--	10 UJ	10 UJ	10 R	12 R	12 UJ	10 R	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 R	10 R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
4-Methyl-2-pentanone	685	530,000	--	--	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Acetone	1,686	1,400,000	--	--	--	10 R	10 R	22 R	14 R	12 R	16 R	10 R	34 R	10 R	10 R	10 R	10 R	10 R	10 R	10 R	10 R	10 R	25 R	25 R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Benzene	4.92	640	10	5,000	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	0.27 J	10 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Ethylbenzene	3,197	190,000	30	10,000	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Methylene chloride	--	9,100	--	--	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	0.34 J	0.36 J	0.56 J	10 UJ	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	4.09	480	2	--	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Toluene	1,394	630,000	200,000	10,000	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	1.5 J	1.5 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Trichloroethene	3.11	53	100	--	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Xylene, total	20,843	27,000	--	10,000	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	2 J	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	0.22 J	0.22 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
m- and p-Xylene	--	27,000	100	10,000	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	1.4 J	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	0.22 J	0.22 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		
o-Xylene	--	27,000	100	10,000	--	10 UJ	10 UJ	10 U	12 UJ	12 UJ	10 UJ	10 UJ	0.62 J	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	10 UJ	0.34 J	0.34 J	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Semi-volatile Organic Compounds (µg/kg)																																													
Acenaphthylene	--	370,000	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U				
Anthracene	147,420	2,200,000	100	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
Benzo(a)anthracene	83.96	620	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
Benzo(a)pyrene	621	62	100	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
Benzo(b)fluoranthene	282	620	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
Benzo(g,h,i)perylene	--	2,300,000	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 R	346 R	344 R	371 R	358 R	337 R	350 R	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U				
Benzo(k)fluoranthene	2,860	6,200	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U				
Chrysene	8,577	62,000	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U				
Dibenz(a,h)anthracene	95.19	62	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 UJ	346 UJ	344 UJ	371 UJ	358 UJ	337 UJ	350 UJ	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U				
Fluoranthene	408,800	230,000	100	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
Indeno(1,2,3-cd)pyrene	974	620	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
Pyrene	50,020	230,000	100	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
bis(2-Ethylhexyl)phthalate	3,907	35,000	--	--	--	428 UJ	451 UJ	420 UJ	604 UJ	531 UJ	440 UJ	598 UJ	486 U	468 U	468 U	946 U	803 U	808 U	NA	NA	NA	336 U	346 U	344 U	371 U	358 U	337 U	350 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U	381 U			
Pesticide/Polychlorinated Biphenyls (µg/kg)																																													
No Detections																																													
Total Metals (mg/kg)																																													
Aluminum	1,000,000	7,600	--	--	29,000	18,000	15,000	20,000	25,000	23,000	16,000	18,000	16,000	18,000	17,000	18,000	15,000	17,000	NA	NA																									

TABLE 4-1
Surface Soil Detection and Exceedance Results
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Station ID Sample ID Sample Date	Site Specific SSL - DAF 1.5	Vieques HHRA SO	Vieques Eco SO	PREQB UST Corrective Action Criteria	Vieques (West) Background Zone Qa SO	NDAISS34	NDAISS35	NDAISS36	NDAISS37		NDAISS38	NDAISS39	NDAISS40	NDAISS41
						NDAISS34-R01 08/19/04	NDAISS35-R01 08/19/04	NDAISS36-R01 08/19/04	NDAIFD02P-R01 08/19/04	NDAISS37-R01 08/19/04	NDAISS38-R01 08/19/04	NDAISS39-R01 08/20/04	NDAISS40-R01 08/20/04	NDAISS41-R01 08/20/04
Chemical Name														
Volatile Organic Compounds (µg/kg)														
1,1-Dichloroethene	197	12,000	100	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	2.40	280	20	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone	2,198	2,200,000	--	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	685	530,000	--	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetone	1,686	1,400,000	--	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	4.92	640	10	5,000	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	3,197	190,000	30	10,000	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	--	9,100	--	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	4.09	480	2	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	1,394	630,000	200,000	10,000	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene	3.11	53	100	--	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Xylene, total	20,843	27,000	--	10,000	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
m- and p-Xylene	--	27,000	100	10,000	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	--	27,000	100	10,000	--	NA	NA	NA	NA	NA	NA	NA	NA	NA
Semi-volatile Organic Compounds (µg/kg)														
Acenaphthylene	--	370,000	--	--	--	351 U	343 U	357 U	356 U	349 U	344 U	104 J	354 U	NA
Anthracene	147,420	2,200,000	100	--	--	351 U	343 U	65 J	356 U	349 U	344 U	55.4 J	354 U	NA
Benzo(a)anthracene	83.96	620	--	--	--	351 U	343 U	62.4 J	356 U	349 U	344 U	68 J	354 U	NA
Benzo(a)pyrene	621	62	100	--	--	351 U	343 U	33.6 J	356 U	349 U	42.5 J	116 J	354 U	NA
Benzo(b)fluoranthene	282	620	--	--	--	351 U	343 U	357 U	356 U	349 U	344 U	203 J	354 U	NA
Benzo(g,h,i)perylene	--	2,300,000	--	--	--	351 U	343 U	357 U	356 U	349 U	47.6 J	174 J	354 U	NA
Benzo(k)fluoranthene	2,860	6,200	--	--	--	351 U	343 U	357 U	356 U	349 U	40.1 J	130 J	354 U	NA
Chrysene	8,577	62,000	--	--	--	351 U	343 U	68.3 J	356 U	349 U	344 U	135 J	354 U	NA
Dibenz(a,h)anthracene	95.19	62	--	--	--	351 U	343 U	357 U	356 U	349 U	344 U	43.7 J	354 U	NA
Fluoranthene	408,800	230,000	100	--	--	351 U	343 U	227 J	356 U	349 U	31.5 J	344 U	62.7 J	354 U
Indeno(1,2,3-cd)pyrene	974	620	--	--	--	351 U	343 U	357 U	356 U	349 U	344 U	138 J	354 U	NA
Pyrene	50,020	230,000	100	--	--	351 U	343 U	193 J	356 U	349 U	344 U	118 J	354 U	NA
bis(2-Ethylhexyl)phthalate	3,907	35,000	--	--	--	351 U	192 J	664	43.5 J	82.8 J	233 J	182 J	48.9 J	NA
Pesticide/Polychlorinated Biphenyls (µg/kg)														
No Detections														
Total Metals (mg/kg)														
Aluminum	1,000,000	7,600	--	--	29,000	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	0.99	3.1	78	--	2.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.468	0.39	18	--	2.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barium	200	1,600	330	--	320	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beryllium	11,000	15	40	--	0.45	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	--	3.7	32	--	0.036	NA	NA	NA	NA	NA	NA	NA	NA	NA
Calcium	--	--	--	--	45,000	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	1,000,000	210	0.4	--	74	51.2 J	34.6 J	51.5 J	33 J	37.5 J	36.4 J	53	57.6	75.3
Chromium (hexavalent)	2.33	22	--	--	--	0.685 J	0.499 J	0.52 J	0.647 J	1.27 J	1.17 J	0.543 J	0.728 J	0.593 J
Cobalt	49.49	140	13	--	33	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	77.09	310	70	--	68	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron	414	2,300	--	--	39,000	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	5.27	400	120	50	6.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
Magnesium	--	--	--	--	12,834	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	86	180	220	--	1,200	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	3.29	2.3	0.1	--	0.031	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nickel	2,100	160	38	--	40	NA	NA	NA	NA	NA	NA	NA	NA	NA
Potassium	--	--	--	--	1,700	NA	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	0.657	39	0.52	--	2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Silver	30.17	39	560	--	0.077	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	--	--	--	--	1,200	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thallium	0.348	0.52	1	--	0.67	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	55	7.8	2	--	130	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	8,700	2,300	120	--	71	NA	NA	NA	NA	NA	NA	NA	NA	NA
Wet Chemistry (mg/kg)														
Total organic carbon (TOC)						NA	NA	NA	NA	NA	NA	NA	NA	97.4 U
pH						NA	NA	NA	NA	NA	NA	NA	NA	9.06
Total Petroleum Hydrocarbons (mg/kg)														
TPH - DRO				100		NA	NA	NA	NA	NA	NA	NA	NA	NA
TPH - GRO				100		NA	NA	NA	NA	NA	NA	NA	NA	NA
Petroleum hydrocarbons*				100		NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Petroleum Hydrocarbons, C10-C28				100		76.6	33.2	50.6	147	137	14.9	23.9	132 J	NA
Total Petroleum Hydrocarbons, C6-C10				100		0.0408 U	0.036 U	0.0365 U	0.043 U	0.0408 U	0.0356 U	0.041 U	0.043 U	NA

- Notes:
 NA - Not analyzed / Not Applicable
 U - Analyte not detected
 J - Result may be estimated
 R - Unreliable result
 UJ - Analyte not detected, result may be estimated
 -- Not applicable
 * Petroleum hydrocarbons analyzed by FL PRO (allows for range C8 to C40)
- Exceeds Background and Eco Criteria
 - Exceeds Background, Eco and HHRA Criteria
 - Exceeds Background and HHRA Criteria
 - Exceeds Background and DAF 1.5 Criteria
 - Exceeds Background, HHRA, DAF 1.5 Criteria
 - Exceeds Background, Eco, and DAF 1.5 Criteria
 - Exceeds Background, HHRA, Eco, DAF 1.5 Criteria
 - Exceeds PREQB UST Corrective Action Criteria

TABLE 4-2
Subsurface Soil Detection and Exceedance Results
AOC Remedial Investigation Report
Vieques, Puerto Rico

Station ID	Site Specific SSL - DAF 1.5	Vieques HHRA SO	PREQB UST Corrective Action Criteria	Vieques (West) Background Zone Qa SO	AOCISB001	AOCISB002	AOCISB003	AOCISB004	AOCISB005	AOCISB006	AOCISB007	AOCISB008	AOCISB009	AOCISB010	AOCISB011	AOCISB012	AOCISB013	AOCISB014	AOCISB015	AOCISB016
Sample ID					NDE044	NDE046	NDE048	NDE050	NDE052	NDE054	NDE056	NDE058	NDE060	NDE063	NDE065	NDE067	NDE069	NDE071	NDE073	NDE076
Sample Date					11/29/00	11/29/00	11/29/00	11/29/00	11/29/00	11/30/00	11/30/00	11/30/00	11/30/00	11/30/00	11/30/00	11/30/00	11/30/00	11/30/00	11/30/00	11/30/00
Chemical Name																				
Volatile Organic Compounds (µg/kg)																				
1,1-Dichloroethene	197	12,000	--	--	11 U	11 U	10 U	11 U	10 U	12 U	10 U	0.42 J	10 U	10 U	10 UJ					
1,2-Dichloroethane	2.40	280	--	--	11 U	11 U	10 U	11 U	10 U	12 U	10 UJ									
2-Butanone	2,198	2,200,000	--	--	11 R	11 R	10 R	11 R	10 R	12 R	10 R	4.1 R	4.1 J	10 R						
4-Methyl-2-pentanone	685	530,000	--	--	11 U	11 U	10 U	11 U	10 U	12 U	10 UJ									
Ethylbenzene	3,197	190,000	10,000	--	11 U	11 U	10 U	11 U	10 U	12 U	10 UJ	10 UJ	10 UJ	0.89 J	10 UJ	10 UJ				
Tetrachloroethene	4.09	480	--	--	11 U	11 U	10 U	11 U	10 U	12 U	10 UJ	10 UJ	10 UJ	0.29 J	10 UJ	10 UJ				
Toluene	1,394	630,000	10,000	--	11 U	11 U	10 U	11 U	10 U	0.67 J	0.78 J	10 U	10 U	10 U	10 UJ					
Trichloroethene	3.11	53	--	--	0.37 J	11 U	10 U	11 U	10 U	12 U	10 UJ									
Xylene, total	20,843	27,000	10,000	--	11 U	11 U	10 U	11 U	10 U	12 U	10 UJ	10 UJ	10 UJ	4.8 J	10 UJ	10 UJ				
m- and p-Xylene	--	27,000	10,000	--	11 U	11 U	10 U	11 U	10 U	12 U	10 UJ	10 UJ	10 UJ	3.6 J	10 UJ	10 UJ				
o-Xylene	--	27,000	10,000	--	11 U	11 U	10 U	11 U	10 U	12 U	10 UJ	10 UJ	10 UJ	1.2 J	10 UJ	10 UJ				
Semi-volatile Organic Compounds (µg/kg)																				
2-Methylnaphthalene	--	31,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Acenaphthene	8,926	370,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Benzo(b)fluoranthene	292	620	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Benzo(k)fluoranthene	2,860	6,200	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Carbazole	151	24,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Chrysene	8,577	62,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Dibenzofuran	546	15,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Fluoranthene	408,800	230,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Fluorene	10,921	270,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Naphthalene	46.8	5,600	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Phenanthrene	--	230,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Pyrene	50,020	230,000	--	--	469 U	416 U	347 U	410 U	353 U	354 U	364 U	448 U	358 U	386 U	371 U	382 U	371 U	397 U	397 U	365 U
Pesticide/Polychlorinated Biphenyls (µg/kg)																				
No Detections																				
Total Metals (mg/kg)																				
Aluminum	1,000,000	7,600	--	29,000	32,600	27,600	27,000	25,400	22,100	18,000	15,000	21,000	18,000	18,000	18,000	16,000	13,000	17,000 J	23,000	20,000
Antimony	0.99	3.1	--	2.3	1.8 J	1.7 J	2.3 J	2.8 J	2.3 J	1.9 J	1.3 J	1.3 J	1.1 J	1.2 J	0.98 J	0.96 J	0.9 J	1.1 J	1.7 J	1.3 J
Arsenic	0.468	0.39	--	2.2	1.9 J	0.85 J	1.2 J	1.2 J	1.3 J	1.1 J	1.3 J	1.7 J	1.6 J	1.2 J	1.1 J	1.2 J	0.59 J	1.2 J	1.6 J	1.3 J
Barium	200	1,600	--	320	88	42 J	60	57	22 J	14 J	20 J	57	65	41 J	41 J	38 J	23 J	40 J	43 J	49
Beryllium	11,000	15	--	0.45	0.33 J	0.22 J	0.16 J	0.22 J	0.11 J	0.12 J	0.13 J	0.21 J	0.21 J	0.14 J	0.15 J	0.18 J	0.11 J	0.17 J	0.19 J	0.19 J
Calcium	--	--	--	45,000	4,650	5,520	5,410	6,090	6,900	5,600	7,600	21,000	13,000	17,000	20,000	23,000	24,000	38,000	28,000	22,000
Chromium	1,000,000	210	--	74	96	71	105	156	106	110	50	47	69	43	38	41	40	36	64	46
Chromium (hexavalent)	2.33	22	--	--	NA															
Cobalt	49.5	140	--	33	27	28	29	31	26	23	24	21	18	16	15	12	15	24	18	18
Copper	77.1	310	--	68	225	18	67	45	40	69	77	70	52	74	53	49	31	51	85	59
Iron	414	2,300	--	39,000	62,500	40,000	51,700	47,000	38,300	32,000	26,000	35,000	31,000	30,000	28,000	26,000	20,000	27,000	42,000	31,000
Lead	5.27	400	50	6.9	0.48 J	0.18 U	0.17 U	1.3	1.5	0.43 J	0.45 J	0.5 J	0.51 J	1.8	1.8	0.82				
Magnesium	--	--	--	12,834	18,900 J	23,200	23,600	23,300	21,600	18,000	14,000	16,000	9,400	15,000	14,000	13,000	10,000	13,000	21,000	17,000
Manganese	85.7	180	--	1,200	898	802	972	938	786	680	760	750	1,100	620	660	620	460	710	750	730
Mercury	3.29	2.3	--	0.031	0.009 J	0.005 J	0.004 J	0.0027 U	0.0027 U	0.0026 UJ	0.0027 UJ	0.0038 J	0.0057 J	0.0053 J	0.006 J	0.0026 U	0.0027 U	0.0027 U	0.0027 U	0.0027 U
Nickel	2,100	160	--	40	71	61	64	84	66	60	38	37	38	31	25	24	22	23	37	30
Potassium	--	--	--	1,700	702 J	203 J	241 J	266 J	450 J	150 J	120 J	690 J	570 J	640 J	730 J	770 J	440 J	730 J	790 J	670 J
Selenium	0.657	39	--	2	1.4 J	0.78 J	1.2 J	0.76 J	1.2	1.2 J	0.91 J	0.94 J	1.5 J	0.96 J	0.88 J	0.62 J	0.77 J	0.88 J	1.1 J	0.94 J
Silver	30.2	39	--	0.077	0.092 J	0.083 J	0.087 J	0.081 J	0.064 J	0.06 U	0.11 J	0.06 U	0.06 U							
Sodium	--	--	--	1,200	2,650	1,230	1,550	1,580	21 U	760 J	780 J	360 J	330 J	370 J	360 J	350 J	250 J	440 J	450 J	470 J
Vanadium	54.8	7.8	--	130	188	136	162	143	112	89	82	98	100	84	82	77	53	81	120	89
Zinc	8,700	2,300	--	71	55	51	57	57	48	43	40	50	40	40	39	38	32	34	52	43
Wet Chemistry (mg/kg)																				
pH					NA															
Total Petroleum Hydrocarbons (mg/kg)																				
Petroleum hydrocarbons*	--	--	100	--	21 U	20 UJ	18 U	19 U	16 UJ	16 UJ	16 UJ	23 J	75 J	25 J	78 U	16 U	11 J	16 UJ	16 U	16

Notes:
 NA - Not analyzed / Not Applicable
 U - Analyte not detected
 J - Result may be estimated
 R - Unreliable result
 UJ - Analyte not detected, result may be estimated
 -- Not applicable
 * Petroleum hydrocarbons analyzed by FL PRO (allows for range C8 to C40)

Exceeds Background and HHRA Criteria
Exceeds Background and DAF 1.5 Criteria
Exceeds Background, HHRA, DAF 1.5 Criteria
Exceeds PREQB UST Corrective Action Criteria

TABLE 4-2
Subsurface Soil Detection and Exceedance Results
AOC Remedial Investigation Report
Vieques, Puerto Rico

Station ID Sample ID Sample Date	Site Specific SSL - DAF 1.5	Vieques HHRA SO	PREQB UST Corrective Action Criteria	Vieques (West) Background Zone Qa SO	AOCISB017	AOCISB018	AOCISB019	AOCISB020	AOCISB021	AOCISB022	AOCISB023	AOCISB024	AOCISB025	AOCISB026	NDAISB04	NDAISB06	NDAISB19	NDAISB20		NDAISB21	NDAISB22	NDAISB41
					NDE078 11/30/00	NDE080 12/01/00	NDE082 12/01/00	NDE085 12/01/00	NDE087 12/01/00	NDE089 12/01/00	NDE092 12/01/00	NDE094 12/01/00	NDE096 12/01/00	NDE098 12/01/00	NDAISB04-R02 09/09/04	NDAISB06-R02 09/09/04	NDAISB19-R02 09/09/04	NDAIFD04P-R01 09/09/04	NDAISB20-R02 09/09/04	NDAISB21-R02 09/09/04	NDAISB22-R02 09/09/04	NDAISB41-R01-C 09/09/04
Chemical Name																						
Volatile Organic Compounds (µg/kg)																						
1,1-Dichloroethene	197	12,000	--	--	10 UJ	11 UJ	10 UJ	10 UJ	12 UJ	11 U	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	2.40	280	--	--	10 UJ	11 UJ	10 UJ	10 UJ	12 UJ	11 U	10 UJ	10 UJ	11 U	1.2 J	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone	2,198	2,200,000	--	--	10 R	11 UJ	10 R	10 UJ	2.9 J	11 R	10 UJ	10 R	11 R	10 R	NA	NA	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	685	530,000	--	--	10 UJ	11 UJ	10 UJ	0.79 J	53 J	11 U	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	3,197	190,000	10,000	--	10 UJ	11 UJ	10 UJ	10 UJ	96 J	11 U	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	4.09	480	--	--	10 UJ	11 UJ	10 UJ	10 UJ	12 UJ	11 U	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
Toluene	1,394	630,000	10,000	--	10 UJ	11 UJ	10 UJ	10 UJ	12 UJ	11 U	10 UJ	10 UJ	11 U	0.33 J	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene	3.11	53	--	--	10 UJ	11 UJ	10 UJ	10 UJ	12 UJ	11 U	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
Xylene, total	20,843	27,000	10,000	--	10 UJ	11 UJ	10 UJ	10 UJ	4,460 J	1 J	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
m- and p-Xylene	--	27,000	10,000	--	10 UJ	11 UJ	10 UJ	10 UJ	2,970 J	0.79 J	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	--	27,000	10,000	--	10 UJ	11 UJ	10 UJ	10 UJ	1,500 J	0.23 J	10 UJ	10 UJ	11 U	10 U	NA	NA	NA	NA	NA	NA	NA	NA
Semi-volatile Organic Compounds (µg/kg)																						
2-Methylnaphthalene	--	31,000	--	--	372 U	517 UJ	433 UJ	436 UJ	4,630 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	8,926	370,000	--	--	372 U	517 UJ	433 UJ	436 UJ	331 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	292	620	--	--	372 U	517 UJ	433 UJ	436 UJ	39 J	512 UJ	31 J	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	2,860	6,200	--	--	372 U	517 UJ	433 UJ	436 UJ	32 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Carbazole	151	24,000	--	--	372 U	517 UJ	433 UJ	436 UJ	158 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Chrysene	8,577	62,000	--	--	372 U	517 UJ	433 UJ	436 UJ	129 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Dibenzofuran	546	15,000	--	--	372 U	517 UJ	433 UJ	436 UJ	663 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	408,800	230,000	--	--	372 U	517 UJ	433 UJ	436 UJ	969 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	10,921	270,000	--	--	372 U	517 UJ	433 UJ	436 UJ	893 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	46.8	5,600	--	--	372 U	517 UJ	433 UJ	436 UJ	2,550 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	--	230,000	--	--	372 U	517 UJ	433 UJ	436 UJ	2,620 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Pyrene	50,020	230,000	--	--	372 U	517 UJ	433 UJ	436 UJ	469 J	512 UJ	484 U	468 U	505 U	429 U	NA	NA	NA	NA	NA	NA	NA	NA
Pesticide/Polychlorinated Biphenyls (µg/kg)																						
No Detections																						
Total Metals (mg/kg)																						
Aluminum	1,000,000	7,600	--	29,000	15,000	24,000	26,000	28,000	23,000	25,000	17,000	19,000	20,000	14,800	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	0.99	3.1	--	2.3	0.91 J	1.7 J	2.9 J	2.2 J	2 J	2.1 J	1.4 J	1.4 J	1.2 J	2 J	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	0.468	0.39	--	2.2	1.3 J	2 J	2.1	2.1 J	1.9 J	2.6	2.1 J	1.4 J	1.6 J	1.7 J	NA	NA	NA	NA	NA	NA	NA	NA
Barium	200	1,600	--	320	54	57	44	26 J	40 J	47 J	41 J	59	66	52	NA	NA	NA	NA	NA	NA	NA	NA
Beryllium	11,000	15	--	0.45	0.14 J	0.32 J	0.23 J	0.27 J	0.32 J	0.29 J	0.22 J	0.26 J	0.21 J	0.14 J	NA	NA	NA	NA	NA	NA	NA	NA
Calcium	--	--	--	45,000	18,000	9,900	6,500	6,200	5,700	17,000	20,000	41,000	30,000	10,200	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	1,000,000	210	--	74	39	87 J	160 J	130 J	110 J	130 J	68 J	38 J	40 J	86 J	197 J	69.8 J	112 J	137 J	157 J	168 J	131 J	NA
Chromium (hexavalent)	2.33	22	--	--	NA	0.305 J	0.255 J	0.515 J	0.311 J	0.662 J	0.644 J	0.43 J	NA									
Cobalt	49.5	140	--	33	15	27	31	29	26	25	18	19	21	25	NA	NA	NA	NA	NA	NA	NA	NA
Copper	77.1	310	--	68	53	84	43	49	59	80	43 J	70 J	72 J	20 J	NA	NA	NA	NA	NA	NA	NA	NA
Iron	414	2,300	--	39,000	27,000	41,000	60,000	61,000	41,000	39,000	28,000	33,000	34,000	26,100	NA	NA	NA	NA	NA	NA	NA	NA
Lead	5.27	400	50	6.9	0.26 J	1.6	0.17 U	0.17 U	14	1.3	1.7 J	7.5 J	4.6 J	1.3 J	NA	NA	NA	NA	NA	NA	NA	NA
Magnesium	--	--	--	12,834	12,000	19,000	26,000	26,000	23,000	17,000	12,000	14,000	15,000	12,000	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	85.7	180	--	1,200	590	850	1,100	900	840	810	600	790	860	694	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	3.29	2.3	--	0.031	0.0027 U	0.0047 J	0.0032 U	0.0033 U	0.0032 U	0.0089 J	0.0097 J	0.0028 UJ	0.0028 UJ	0.0027 UJ	NA	NA	NA	NA	NA	NA	NA	NA
Nickel	2,100	160	--	40	24	56 J	83 J	78 J	66 J	60 J	43	26	27	65	NA	NA	NA	NA	NA	NA	NA	NA
Potassium	--	--	--	1,700	510 J	380 J	400 J	220 J	390 J	550 J	460 J	570 J	650 J	77 J	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	0.657	39	--	2	1.1 J	0.59 U	0.49 U	0.5 U	0.49 U	0.56 U	0.76 J	0.8 J	1.2 J	1.2 J	NA	NA	NA	NA	NA	NA	NA	NA
Silver	30.2	39	--	0.077	0.06 U	0.07 U	0.11 J	0.06 U	0.12 J	0.06 U	NA	NA	NA	NA	NA	NA	NA	NA				
Sodium	--	--	--	1,200	360 J	140 J	1,400	1,200	1,400	310 J	470 J	320 J	300 J	21.4 U	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	54.8	7.8	--	130	75	130	170	140	130	130	90 J	94 J	100 J	65 J	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	8,700	2,300	--	71	35	58	60	55	52	52	40 J	47 J	47 J	39 J	NA	NA	NA	NA	NA	NA	NA	NA
Wet Chemistry (mg/kg)																						
pH					NA	NA	NA	8.36	NA	8.46	9.08											
Total Petroleum Hydrocarbons (mg/kg)																						
Petroleum hydrocarbons*	--	--	100	--	16 U	16 J	11 J	11 J	232 J	17 J	20 J	40 J	22 J	16 UJ	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
 NA - Not analyzed / Not Applicable
 U - Analyte not detected
 J - Result may be estimated
 R - Unreliable result
 UJ - Analyte not detected, result may be estimated
 -- Not applicable
 * Petroleum hydrocarbons analyzed by FL PRO (allows for range C8 to C40)

Exceeds Background and HHRA Criteria
Exceeds Background and DAF 1.5 Criteria
Exceeds Background, HHRA, DAF 1.5 Criteria
Exceeds PREQB UST Corrective Action Criteria

TABLE 4-3
Groundwater Detection and Exceedance Results
AOC I Remedial Investigation Results
Vieques, Puerto Rico

Station ID	Vieques HHRA GW	MCL-GW	PREQB UST Corrective Action Criteria	Vieques NDAIMW01 Background 2004	Vieques NDAIMW01 Background 2006	Vieques NDAIMW01 Background 2006 Dup	NDAIMW02		NDAIMW03	NDAIMW04		NDAIMW05	NDAIMW06		NDAIMW07		WAI-MW08	WAI-MW09
							NDAIFD01P-R01	NDAIGW02-R01	NDAIGW03-R01	NDAIGW04-R01	WAI-GW04-06A	NDAIGW05-R01	NDAIGW06-R01	WAI-GW06-06A	NDAIGW07-R01	WAI-GW07-06A	WAI-GW08-06A	WAI-GW09-06A
Sample ID							09/21/04	09/21/04	09/21/04	09/23/04	01/10/06	09/22/04	09/22/04	01/10/06	09/24/04	01/10/06	01/10/06	01/11/06
Sample Date																		
Chemical Name																		
Total Metals (µg/L)																		
Aluminum	3,600	--	--	209	249	200 U	70.6 J	70.3 J	358	56.2 J	200 U	54 J	774	200 U	69.9 J	275	461	200 U
Antimony	1.5	6	--	3.46 J	60 U	60 U	60 U	3.16 J	2.99 J	2.3 U	60 U	2.3 U	2.3 U	60 U	3.39 J	60 U	60 U	60 U
Arsenic	0.045	10	--	15.6 J	10 U	10 U	15.1	17	15.5 J	15.6 J	4.3 J	18.7	12.1	10 U	13.5 J	4.5 J	10 U	10 U
Barium	730	2,000	--	16 J	17.6 J	17.4 J	52.2 J	52.8 J	69.4 J	104 J	89.6 J	72.3 J	19.2 J	23.9 J	40.4 J	51.6 J	63.3 J	36 J
Cadmium	1.8	5	--	6.35	5 U	5 U	8.72	7.7 J	5.8	5.66	5 U	3.81 J	3.19 J	5 U	4.8 J	5 U	5 U	5 U
Calcium	--	--	--	78,900	97,800	97,300	93,200	93,400	70,600	64,600	60,600	47,700	45,600	58,500	61,200	64,500	71,300	61,600
Chromium	11	100	--	1.47 J	10 U	10 U	1.6 J	1.62 J	3.1 J	1.35 J	10 U	1.74 J	2 J	10 U	1.3 U	10 U	10 U	10 U
Cobalt	73	--	--	6.99 J	50 U	50 U	8.68 J	8.78 J	7.28 J	7.07 J	50 U	5.18 J	4.04 J	50 U	6.24 J	50 U	50 U	50 U
Copper	150	1,300	--	7.9 J	25 U	25 U	8.64 J	8.48 J	8.54 J	4.43 J	25 U	4.75 J	6.73 J	25 U	4.47 J	25 U	3.4 J	25 U
Cyanide	73	200	--	9.9 U	10 U	10 U	9.9 U	11.6	9.9 U	9.9 U	10 U	9.9 U	9.9 U	10 U	9.9 U	10 U	10 U	10 U
Iron	1,100	--	--	210 J	281	100 U	84.8 J	76.5 J	684 J	72.7 J	290	100 J	974 J	126	295 J	1,840	715	151
Lead	15 ¹	--	50	6.5 J	10 U	10 U	6.32	4.54 J	6.32	4.4 J	10 U	6.66	5.87	10 U	8.38	10 U	10 U	10 U
Magnesium	--	--	--	44,700	54,500	54,500	59,000	59,300	50,400	54,700	50,800	36,800	21,800	27,100	47,500	50,200	37,600	54,300
Manganese	88	--	--	40.7	20.3	13.3 J	888	891	1,330	1,930	1,900	1,110	57.2	15 U	1,280	1,660	145	283
Mercury	1.1	2	--	0.025 U	0.2 U	0.2 U	0.025 U	0.025 U	0.025 U	0.025 U	0.2 U	0.0478 J	0.0462 J	0.2 U	0.025 U	0.2 U	0.2 U	0.2 U
Nickel	73	--	--	1.7 U	1.6 J	40 U	1.92 J	1.8 J	2.17 J	1.7 U	1.4 J	1.7 U	2.51 J	40 U	1.7 U	40 U	2.5 J	1.2 J
Potassium	--	--	--	943 J	899 J	915 J	617 J	614 J	614 J	537 J	287 J	308 J	1,290 J	1,240 J	451 J	315 J	527 J	384 J
Selenium	18	50	--	2.6 U	35 U	35 U	2.6 U	2.6 U	2.6 U	2.6 U	1.8 J	2.6 U	2.6 U	3.8 J	2.6 U	1.8 J	2.3 J	35 U
Sodium	--	--	--	94,600	101,000	101,000	79,500	79,700	111,000	151,000	143,000	238,000	382,000	418,000	159,000	155,000	207,000	249,000
Vanadium	3.6	--	--	37.1 J	50 U	50 U	26.9 J	26.9 J	11.3 J	13.9 J	50 U	3.48 J	46.9 J	50 U	7.3 J	50 U	50 U	50 U
Zinc	1,100	--	--	0.94 U	60 U	60 U	0.94 U	0.94 U	0.94 U	0.94 U	60 U	0.94 U	2.14 J	12 J	0.94 U	60 U	10.3 J	60 U
Dissolved Metals (µg/L)																		
Aluminum	3,600	--	--	84.2 J	200 U	200 U	37.7 J	42.4 J	38.2 J	15 U	200 U	34.7 J	73.1 J	200 U	15 U	38.9 J	128 J	200 U
Antimony	1.5	6	--	2.3 U	60 U	60 U	2.85 J	2.3 U	2.3 U	2.3 U	60 U	2.3 U	2.33 J	60 U	2.3 U	60 U	60 U	60 U
Arsenic	0.045	10	--	14 J	10 U	10 U	15.9	15.4	20 J	18.1 J	10 U	18.1	10.6	10 U	16 J	6.2 J	10 U	10 U
Barium	730	2,000	--	16 J	17.5 U	18 J	51.3 J	51.6 J	66.7 J	103 J	94.4 J	70.9 J	19 J	25.4 J	39.9 J	55.1 J	61.9 J	35.4 J
Cadmium	1.8	5	--	6.31	5 U	5 U	8.17	8.23 J	6.24	5.82	5 U	3.82 J	3.07 J	5 U	4.9 J	5 U	5 U	5 U
Calcium	--	--	--	81,400	98,700	101,000	92,600	91,700	69,500	64,500	61,700	46,400	47,300	58,700	60,000	67,800	71,800	62,100
Chromium	11	100	--	1.3 U	10 U	10 U	1.3 U	1.3 U	1.3 U	1.65 J	10 U	1.46 J	1.3 U	7 J	1.3 U	1.1 J	2.4 J	10 U
Cobalt	73	--	--	7.06 J	50 U	50 U	8.52 J	8.61 J	6.93 J	6.97 J	0.8 J	5.28 J	3.64 J	50 U	6.33 J	0.94 J	0.49 J	0.93 J
Copper	150	1,300	--	8.79 J	25 U	25 U	8.08 J	7.77 J	5.22 J	4.24 J	25 U	3.35 J	5.18 J	25 U	4.4 J	25 U	25 U	25 U
Iron	1,100	--	--	83.3 J	100 U	100 U	33.4 J	32.5 J	99.8 J	17 J	117	77.3 J	68.9 J	100 U	188 J	1,470	241	100 U
Lead	15	--	--	7.55 J	10 U	10 U	6.17	7.95	7.54 J	5.83 J	10 U	6.15	4.75	10 U	7.2	10 U	10 U	10 U
Magnesium	--	--	--	46,200	54,400	56,000	58,400	58,000	51,100	54,700	51,800	36,300	22,600	27,000	46,700	53,400	37,700	54,500
Manganese	88	--	--	37.9	11.5 J	10.9 J	865	859	1,290	1,920	1,960	1,090	44.9	12.1 J	1,240	1,760	126	279
Nickel	73	--	--	1.99 J	0.58 J	40 U	1.77 J	1.76 J	2.07 J	1.7 U	0.69 J	1.7 U	1.98 J	0.65 J	1.7 U	1.2 J	1.6 J	0.99 J
Potassium	--	--	--	1090 J	917 J	932 J	613 J	585 J	719 J	477 J	295 J	348 J	1,340 J	1,270 J	427 J	339 J	515 J	373 J
Selenium	18	50	--	2.92 J	35 U	35 U	2.6 U	2.6 U	2.6 U	2.6 U	35 U	2.6 U	2.6 U	35 U	2.6 U	35 U	2.2 J	35 U
Sodium	--	--	--	98,400	102,000	104,000	79,300	78,500	112,000	150,000	147,000	235,000	404,000	430,000	156,000	164,000	209,000	248,000
Vanadium	3.6	--	--	37.6 J	50 U	50 U	26.2 J	26.3 J	9.78 J	13.5 J	50 U	2.94 J	45.3 J	50 U	7.15 J	50 U	50 U	50 U
Zinc	1,100	--	--	0.95 J	60 U	60 U	0.94 U	0.94 U	0.94 U	0.94 U	60 U	0.94 U	2.32 J	12.4 J	3.24 J	60 U	10.7 J	60 U
Wet Chemistry (mg/L)																		
Nitrate							NA	NA	NA	NA	0.05 U	NA	NA	1.86	NA	0.05 U	0.77	0.05 U
Sulfate							NA	NA	NA	NA	10.2	NA	NA	52	NA	2.37 J	17.8	1.85 J
Total dissolved solids (TDS)							718	721	646	717	142	859	1,170	1,320	732	6,710	814	905
Total organic carbon (TOC)							NA	NA	NA	NA	3.79 J	NA	NA	9.87	NA	7.28	7.14	8.1

Notes:
 NA - Not analyzed / Not Applicable
 U - Analyte not detected
 J - Result may be estimated
 -- Not applicable
¹ EPA action level
 * - Background criteria was obtained from the most conservative results of all samples collected at NDAIMW01

Exceeds Background andr HHRA Criteria
Exceeds Background, HHRA and MCL Criteria
Exceeds PREQB UST Corrective Action Criteria
Exceeds Background, HHRA, MCL and PREQB UST Corrective Action Criteria

TABLE 4-4
Updated Human Health and Ecological Screening Values
AOC I Remedial Investigation Report
Vieques, Puerto Rico

	Human Health Screening Value		Ecological Screening Value		Reference
	Previous Value ¹	New Value ²	Previous Value ¹	New Value ²	
Soil					
VOCs					
Toluene	66,000 µg/kg	630,000 µg/kg			Updated toxicity values in Integrated Risk Information System (IRIS)
SVOCs					
2-Methylnaphthalene	160,000 µg/kg	31,000 µg/kg			Updated toxicity values in Integrated Risk Information System (IRIS)
Pentachlorophenol			3,000 µg/kg	5,000 µg/kg	EPA. 2005. <i>Ecological Soil Screening Levels for Pentachlorophenol</i> . OSWER Directive 9285.7-58. March.
Explosives					
Perchlorate	0.78 mg/kg	55 mg/kg			Updated toxicity values in Integrated Risk Information System (IRIS)
Metals					
Barium	540 mg/kg	1,600 mg/kg			Updated toxicity values in Integrated Risk Information System (IRIS)
Copper			50 mg/kg	70 mg/kg	EPA. 2007. <i>Ecological Soil Screening Levels for Copper</i> . OSWER Directive 9285.7-68. February.
Manganese			100 mg/kg	220 mg/kg	EPA. 2007. <i>Ecological Soil Screening Levels for Manganese</i> . OSWER Directive 9285.7-71. April.
Nickel			30 mg/kg	38 mg/kg	EPA. 2007. <i>Ecological Soil Screening Levels for Nickel</i> . OSWER Directive 9285.7-76. March.
Silver			2 mg/kg	560 mg/kg	EPA. 2006. <i>Ecological Soil Screening Levels for Silver</i> . OSWER Directive 9285.7-77. September.
Groundwater and Surface Water					
VOCs					
Toluene	72 µg/L	230 µg/L			Updated toxicity values in Integrated Risk Information System (IRIS)
SVOCs					
Acetophenone	42 µg/L	61 µg/L			Updated toxicity values in Integrated Risk Information System (IRIS)
2-Methylnaphthalene	12 µg/L	2.4 µg/L			Updated toxicity values in Integrated Risk Information System (IRIS)
Explosives					
Perchlorate	24 µg/L	26 µg/L			Updated toxicity values in Integrated Risk Information System (IRIS)
Metals					
Barium	260 µg/L	730 µg/L			Updated toxicity values in Integrated Risk Information System (IRIS)
Notes:					
¹ From the <i>Final Master Quality Assurance Project Plan, Environmental Restoration Program, Vieques, Puerto Rico</i> (CH2M HILL, May 2007)					
² Value used for screening in RI Report					

TABLE 4-5
 Site Specific Soil Screening Level Algorithm
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Governing Equation:

$$SSL(mg / kg) = C_w \left[K_d + \frac{(\theta_w + \theta_a H')}{\rho_b} \right] DAF$$

Symbol Definitions:

<i>SSL</i>	<i>soil screening level (mg/kg)</i>
<i>C_w</i>	<i>target soil leachate concentration (mg/L); hierarchy is Federal MCL, Federal MCLG, and EPA Region IX Tap Water PRG</i>
<i>K_d</i>	<i>soil-water partition coefficient (L/kg)</i>
<i>θ_w</i>	<i>water-filled porosity (L_{water}/L_{soil})</i>
<i>θ_a</i>	<i>air-filled soil porosity (L_{air}/L_{soil}); [n - θ_w]</i>
<i>ρ_b</i>	<i>dry soil bulk density (kg/L)</i>
<i>n</i>	<i>soil porosity (L_{pore}/L_{soil})</i>
<i>ρ_s</i>	<i>soil particle density (kg/L)</i>
<i>H'</i>	<i>dimensionless Henry's Law Constant, from Oak Ridge National Laboratory Risk Assessment Information System (on-line)</i>

Numeric Soil Descriptors:

Variable	Value	Definition
<i>f_{oc}</i>	0.00263	<i>fraction organic carbon in soil (g/g) (site specific data), K_d = k_{oc} x f_{oc}; k_{oc} (organic carbon/water partitioning coefficient) values from Oak Ridge National Laboratory Risk Assessment Information System (on-line)</i>
<i>θ_w</i>	0.30	<i>water-filled porosity (L_{water}/L_{soil})</i>
<i>ρ_b</i>	1.50	<i>dry soil bulk density (kg/L)</i>
<i>ρ_s</i>	2.65	<i>soil particle density (kg/L)</i>
<i>n</i>	0.43	<i>soil porosity (L_{pore}/L_{soil}); [1 - ρ_b/ ρ_s]</i>
<i>θ_a</i>	0.13	<i>air-filled soil porosity (L_{air}/L_{soil})</i>
<i>Soil pH</i>	8	<i>From site specific values (Used for K_d calculations)</i>
<i>Soil type</i>	Sandy	<i>Sandy, loamy or clayey (Used for K_d aluminum and lead)</i>

Notes:

EPA (1996). Superfund Soil Screening Guidance: User's Guide. Pub No. 9355.4-23 (second edition), page 29.

TABLE 4-6
 Dilution Attenuation Factor Parameters
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Governing Equation:

$$DAF = 1 + \frac{Kid}{IL}$$

$$I = 0.0018(P^2) \left(\frac{in}{2.54cm} \right) \left(\frac{ft}{12in} \right) \left(\frac{yr}{365d} \right)$$

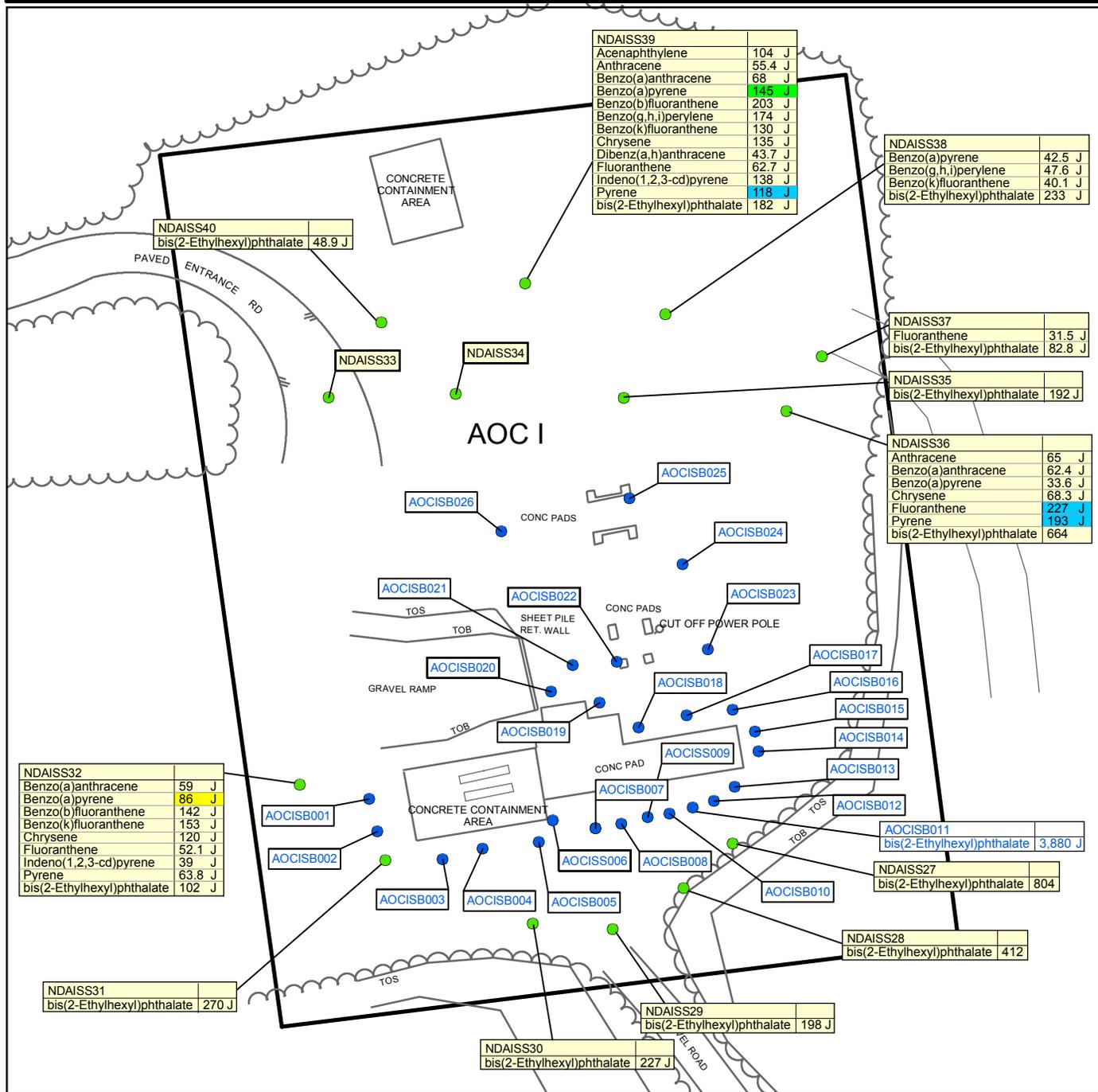
Symbol Definitions:

DAF	soil leachate dilution factor (unitless)
K	hydraulic conductivity of the groundwater bearing unit (feet/day)
i	hydraulic gradient (unitless)
d	saturated thickness of the groundwater bearing unit (ft)
I	infiltration rate (feet/day)
L	length of the affected soil area parallel to the direction of groundwater flow (feet)
P	precipitation (cm/year)

Numeric Soil Descriptors:

Parameter	Value	Estimation Method
Hydraulic Conductivity (K)	1.1 ft/d	Geometric mean of hydraulic conductivity measurements made from site specific slug tests.
Hydraulic Gradient (i)	0.009	Measured from the September 2004 potentiometric surface map.
Saturated Thickness (d)	20 ft	Professional judgment
Infiltration Rate (I)	8.4 in/yr 0.023 in/d	The estimate of infiltration (I) uses an algorithm developed in Soil Attenuation Model for Derivation of Risk-Based Soil Remediation Standards (J. A. Connor, R. L. Bowers, S. M. Paquette, C. J., Groundwater Services, Inc., July 1997).
Site Length (L)	200 ft	
Precipitation (P)	109 cm/yr	

Note: A site specific soil leachate dilution attenuation factor (DAF) was developed for AOC-I using the process described in Soil Screening Guidance: User's Guide (USEPA 1996) as follows:



LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- RI Surface Soil Location (2004)
- PA/SI Surface Soil Location (2000)

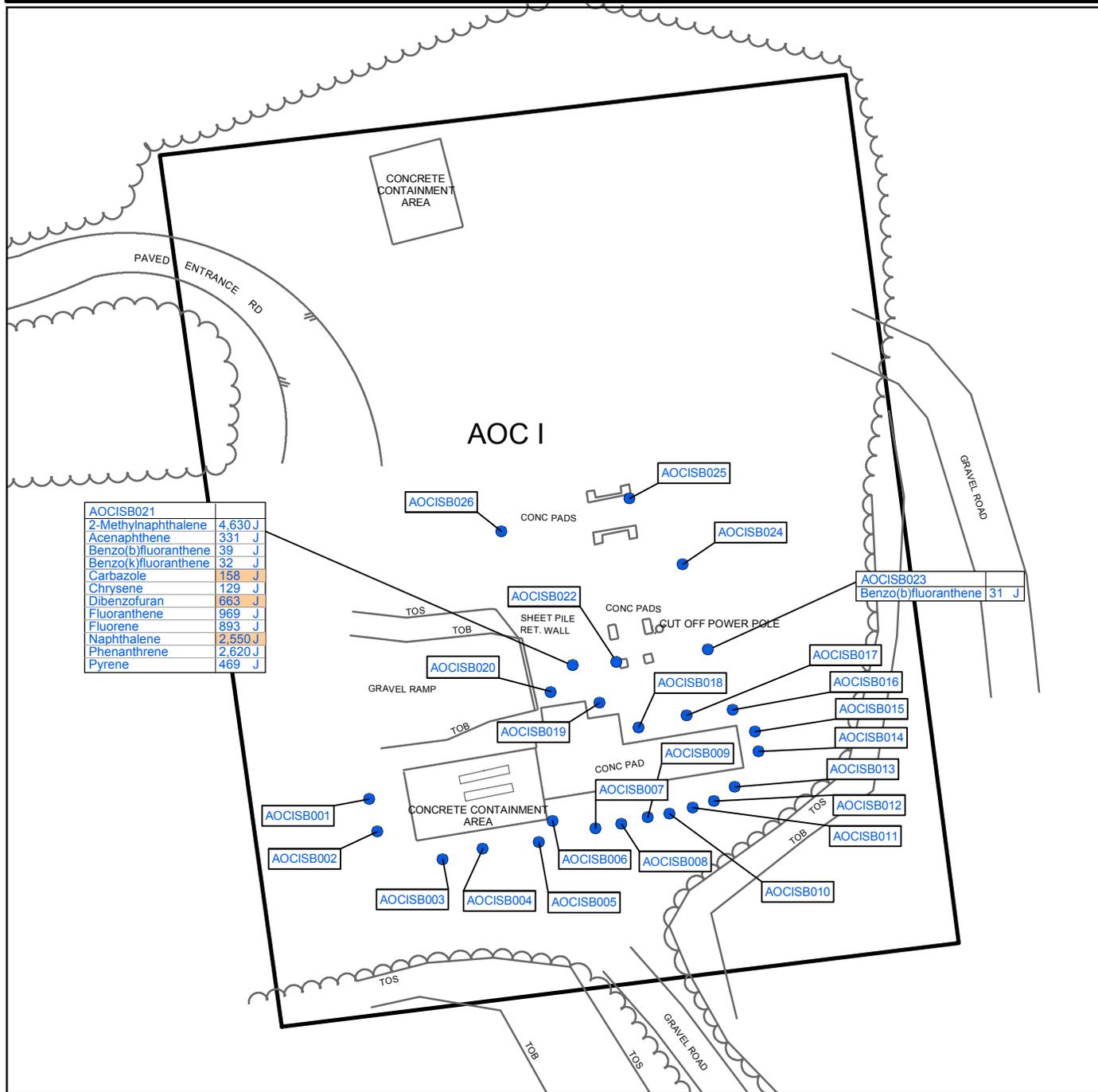
All constituent concentrations in (µg/kg).
J - Estimated Result

Exceeds Eco Criteria
Exceeds Eco and HHRA Criteria
Exceeds HHRA Criteria

Text in black lettering constitutes RI samples and text in blue lettering constitutes PA/SI samples



Figure 4-3
SVOC Detections and Exceedances
in Surface Soil
AOC I Remedial Investigation Report
Vieques, Puerto Rico
CH2MHILL



LEGEND

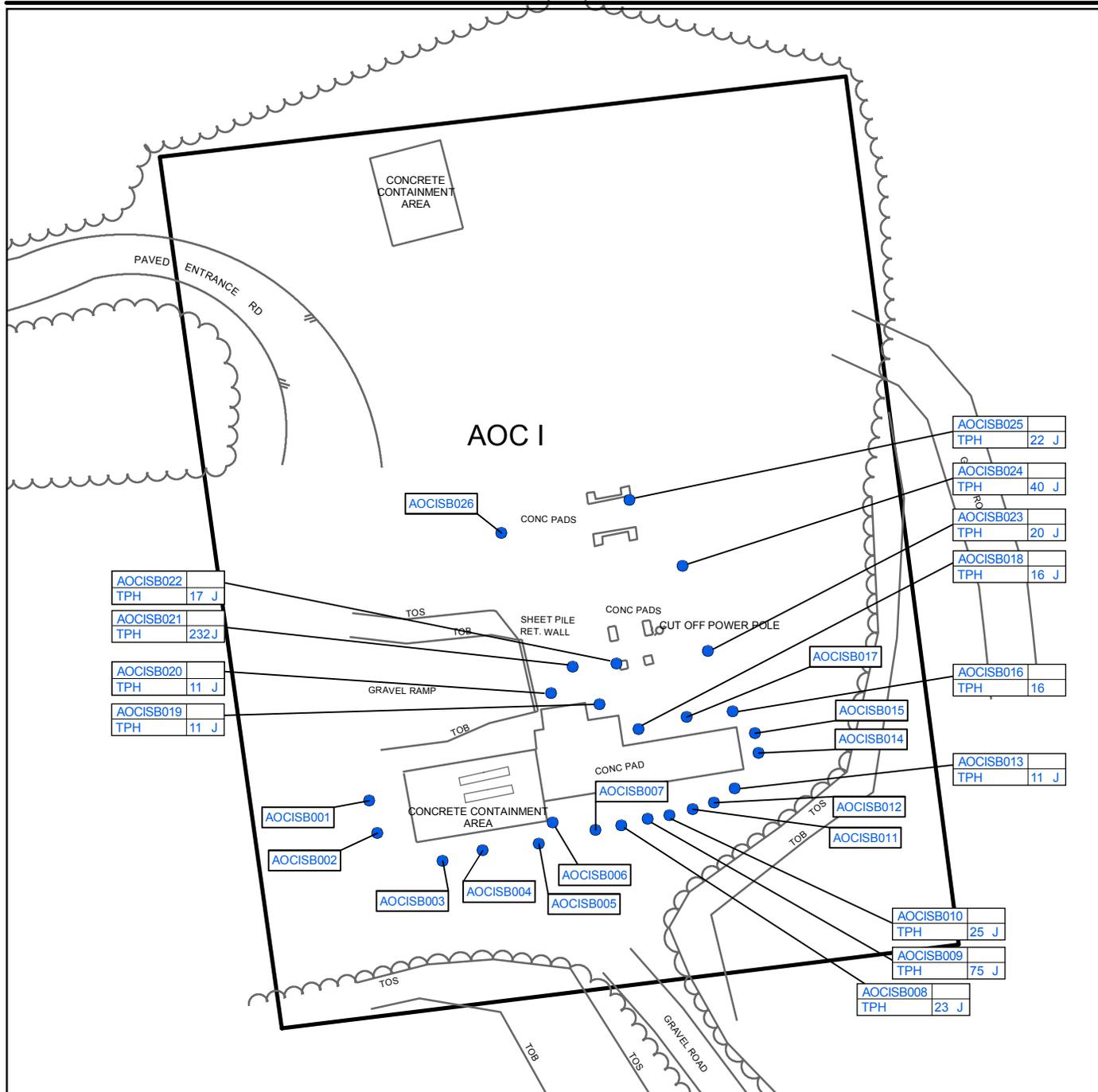
- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- PA/SI Subsurface Soil Location (2000)

All constituent concentrations in (µg/kg).
J - Estimated Result

Exceeds Site Specific SSL Criteria



Figure 4-4
SVOC Detections and Exceedances
in Subsurface Soil
AOC I Remedial Investigation Report
Vieques, Puerto Rico
CH2MHILL



LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- PA/SI Surface Soil Location (2000)

All constituent concentrations in (µg/kg).
 J - Estimated Result
 TPH refers to TPH-DRO (EBS); TPH FL PRO, C8-C40 (PA/SI); TPH C6-C10 and C10-C28 (RI)

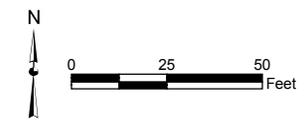
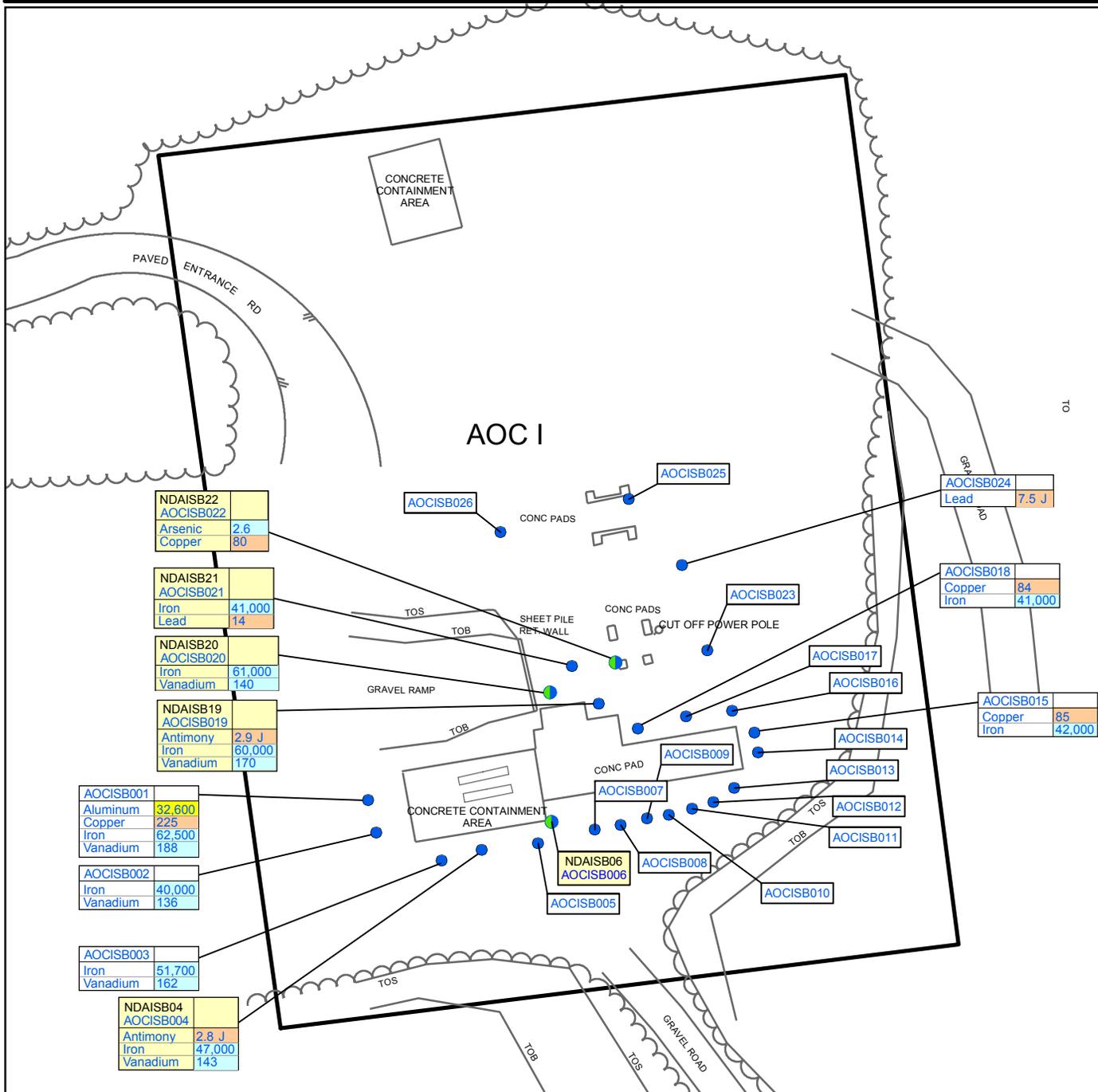


Figure 4-6
TPH Detections in Subsurface Soil
AOC I Remedial Investigation Report
Vieques, Puerto Rico



LEGEND

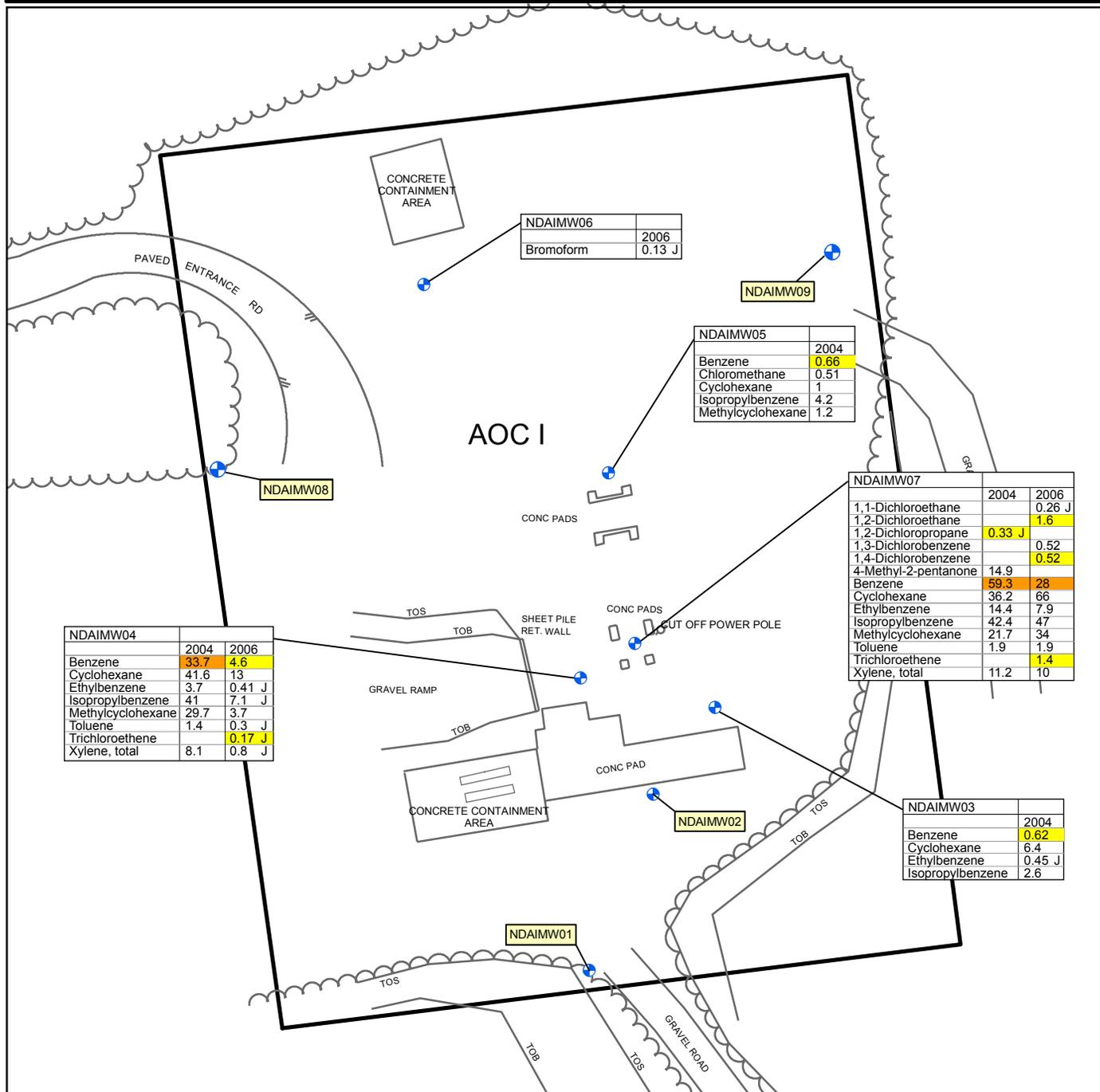
- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- PA/SI and RI Subsurface Soil Location (2000/04)
- PA/SI Subsurface Soil Location (2000)

All constituent concentrations in (µg/kg).
 J - Estimated Result
 Text in black lettering constitutes RI samples and text in blue lettering constitutes PA/SI samples
 RI samples analyzed for total chromium and hexavalent chromium only

Exceeds Background and HHRA Criteria
Exceeds Background and Site Specific SSL Criteria
Exceeds Background, HHRA, and Site Specific SSL Criteria



Figure 4-8
Inorganic Exceedances
in Subsurface Soil
AOC I Remedial Investigation Report
Vieques, Puerto Rico
CH2MHILL



LEGEND

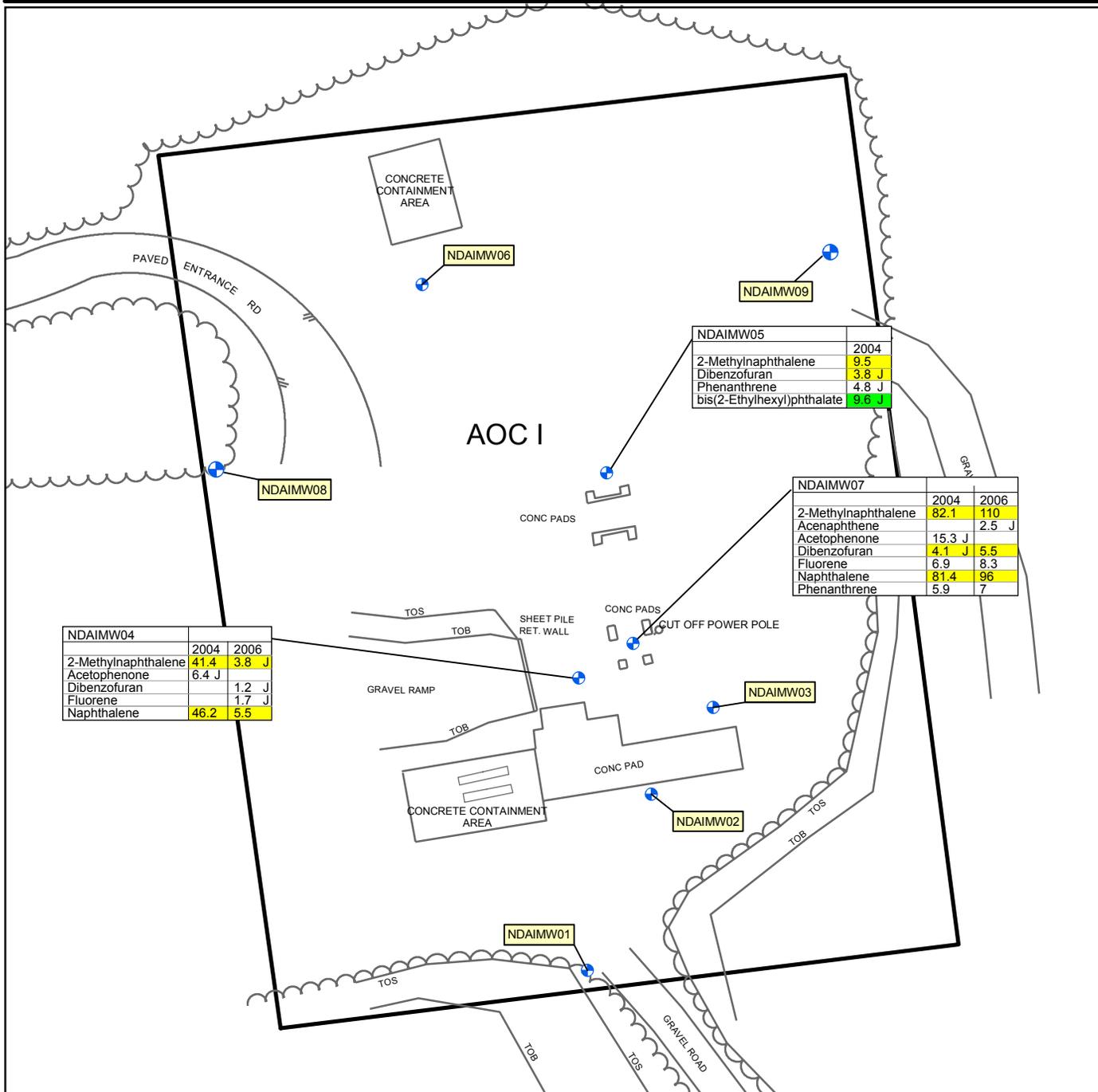
- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Installed During the RI

All constituent concentrations in (µg/kg).
J - Estimated Result

Exceeds HHRA Criteria
Exceeds HHRA and MCL Criteria



Figure 4-9
VOC Detections and Exceedances
in Groundwater
AOC I Remedial Investigation Report
Vieques, Puerto Rico



LEGEND

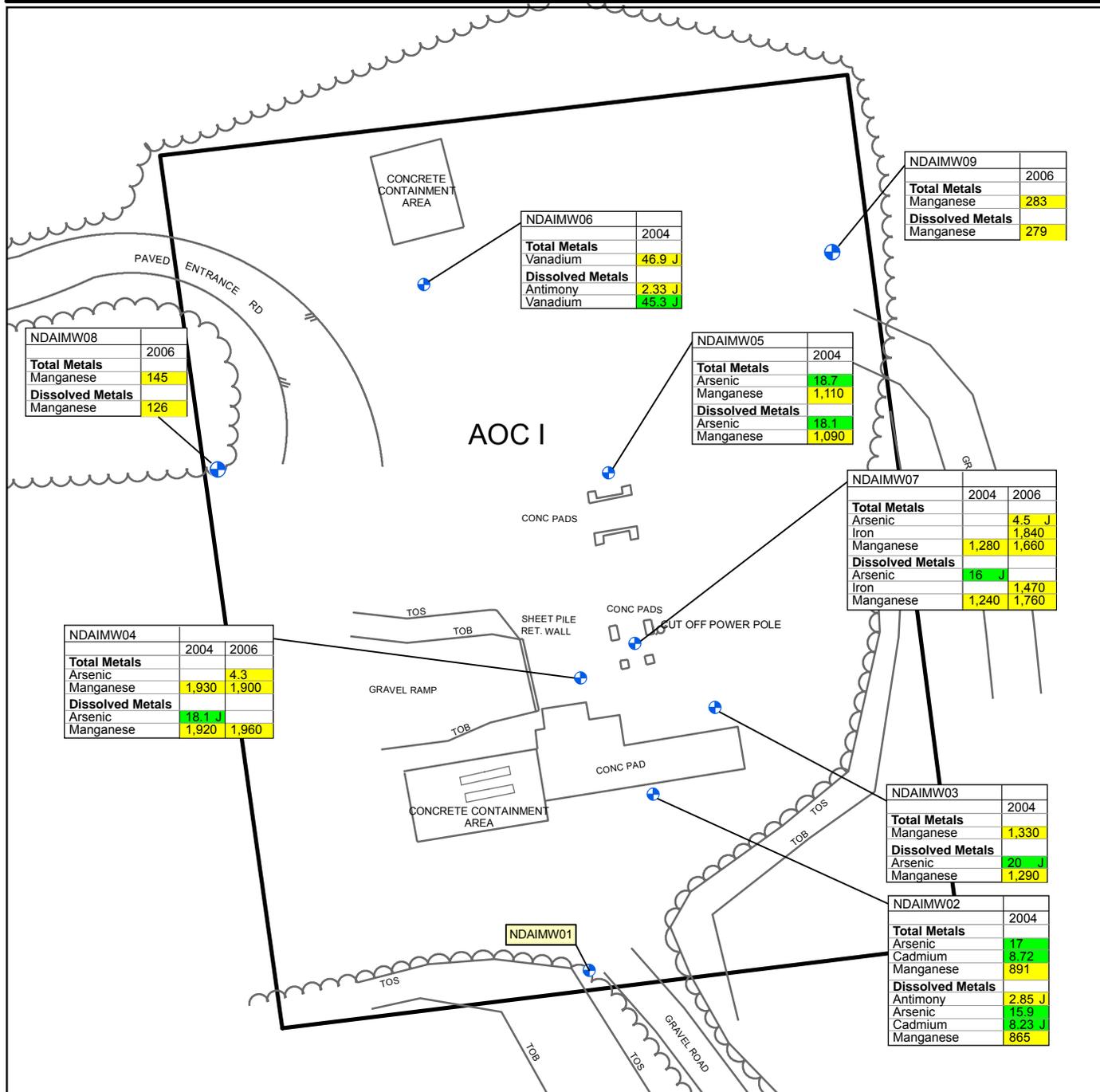
- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Installed During the RI

All constituent concentrations in (µg/kg).
J - Estimated Result

Exceeds HHRA Criteria
Exceeds HHRA and MCL Criteria



Figure 4-10
SVOC Detections and Exceedances
in Groundwater
AOC I Remedial Investigation Report
Vieques, Puerto Rico



LEGEND

- Approximate Area of AOC I
- TOB Top of Berm
- TOS Toe of Slope
- Wooded Area
- Monitoring Well Installed During the RI

All constituent concentrations in (µg/kg).
J - Estimated Result

Exceeds Background and HHRA Criteria
Exceeds Background, HHRA and MCL Criteria



Figure 4-11
Inorganic Exceedances
in Groundwater
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Contaminant Fate and Transport

This section discusses conceptually the fate and transport of representative contaminants or potential contaminants in soil and groundwater identified in Section 4. This section also presents a CSM for AOC I that forms the basis of the contaminant fate and transport evaluation.

5.1 Conceptual Site Model

Key components of the CSM are:

- **Source of contamination:** The probable sources of contamination at AOC I are the former asphalt plant operations (mixing/loading of asphalt into trucks, movement of trucks and other heavy machinery in and out of site, and two diesel fuel ASTs).
- **Release(s):** The probable release mechanisms were relatively minor spills and leaks from the mixing/loading operations, truck traffic, and the ASTs.
- **Migration routes:** Based on the extent of contamination identified during the RI, the primary route of contaminant migration is likely vertical leaching through soil and bedrock to groundwater and subsequent transport with groundwater flow through fractures in the bedrock aquifer. Overland transport via wind is not likely an important contaminant migration route due to the gravel-covered nature of the site. Runoff is also not likely an important contaminant migration route due to the relatively flat site topography.
- **Contaminated media:** Sampling and analysis conducted at AOC I indicate that relatively low levels (with respect to risk-based screening levels) of organic (and potentially inorganic) contamination exist in surface and subsurface soil and groundwater at the site. Contamination may also exist in the unsaturated fractures of the bedrock. Contamination is generally localized around the immediate area of the former asphalt plant.
- **Exposure:** Because the site is currently not being used for residential, commercial, or industrial use, there are no current human exposures. Although limited habitat is present, ecological receptors could be exposed to surface soil contaminants.

Figure 5-1 graphically depicts the key components of the CSM described above. Based on this conceptual understanding, the fate and transport of the following representative contaminants and potential contaminants at the site are discussed in the remainder of this section.

5.1.1 Volatile Organic Compounds

As noted in Section 4, the VOCs detected at AOC I fall into two categories: solvents and fuel-related constituents. Representative contaminants in each category are as follows:

- Solvents such as cyclohexane, dichlorobenzene, PCE, and TCE
- Fuel-related constituents benzene, toluene, ethylbenzene, and xylene (BTEX)

5.1.2 Semi-volatile Organic Compounds

As noted in Section 4, the SVOCs are all associated with fuel and/or oil, and fall into one of three categories:

- Fuel-related PAHs such as pyrene, acenaphthene, benzo(a)pyrene
- Fuel-related HAHs carbazole and dibenzofuran
- Hydraulic oil-related bis(2-ethylhexyl)phthalate

5.1.3 Inorganics

As noted in Section 4, most, if not all, of the inorganic concentrations detected in surface soil, subsurface soil, and groundwater at AOC I are likely attributable to background. There were only seven inorganics detected in surface and/or subsurface soil above background UTLs in more than two samples: chromium, copper, iron, lead, nickel, silver, and vanadium. Of these seven inorganics, the concentrations of only five were above one or more screening values: chromium, copper, iron, lead, and vanadium. For the purposes of this discussion, the following inorganics are considered representative potential contaminants. It is noted, however, that the concentrations of these constituents detected in site media may be wholly or primarily attributable to background.

- Chromium, copper, iron, lead, and vanadium

5.2 Fate and Transport Mechanisms

There are likely four probable fate and transport mechanisms for contaminants at AOC I:

- Volatilization: This mechanism can be an important factor for VOCs, less so for SVOCs, and is not a viable transport mechanism for inorganics.
- Leaching by infiltrating water: Due to the nature of releases (surficial), this mechanism accounts for the presence of site-related contaminants in soil and groundwater at AOC I. Leaching generally occurs through complex, successive sorption to/desorption from soil particles and varies depending on such factors as the contaminant type (e.g., inorganics versus VOCs), soil type (e.g., clay versus sand), organic matter content, and the chemistry of the infiltrating water.
- Transport in groundwater: Once contaminants reach groundwater via leaching, they can be transported downgradient via groundwater flow (advection) or from areas of higher concentration to lower concentration (dispersive mass flux or “dispersion”). While these mechanisms surely exist at AOC I, the rate of migration appears to be low because of the general absence of contaminants in groundwater monitoring wells downgradient of the former operational (source) area (i.e., asphalt plant in the southern portion of AOC I). It is also possible that the rate of contaminant migration is not significant relative to the low contaminant levels and natural attenuation mechanisms.
- Transformation and degradation of contaminants in soil and groundwater: Within environmental media, contaminants may be subject to biotic (biological-based) and

abiotic (non-biological-based) reactions that transform and degrade them into other constituents.

Each of the above mechanisms is discussed below with respect to representative contaminants/potential contaminants. It is important to emphasize that while this section discusses potential fate and transport mechanisms for the contaminants and potential contaminants at AOC I, the concentrations detected, especially in groundwater, are already very low (with respect to screening criteria).

5.2.1 Volatilization

Volatilization occurs when a constituent transfers to the gas phase (i.e., evaporates). A conventional measure of volatility is Henry's Law Constant (K_h). Values of K_h for representative volatile and semi-volatile contaminants at AOC I are provided in Table 5-1. Inorganics are not volatile under normal temperature and pressure conditions and thus are not included in Table 5-1.

Compounds with higher K_h values volatilize more readily than those with lower K_h values. As shown in Table 5-1, the solvent-related VOCs detected at AOC I tend to be more volatile than the fuel-related VOCs, which, in turn, are more volatile than the SVOCs.

The relatively high K_h values for the representative VOCs (and SVOCs to a lesser degree) suggest that volatilization could be an important fate mechanism in soil and groundwater at AOC I. Volatilization from soil tends to occur more readily than from groundwater for several reasons. In unsaturated soil, especially shallow soil, the soil gas pressure generally approximates the ambient air pressure. With depth, the soil gas pressure tends to increase and it becomes more difficult for the gas to escape and equalize with the ambient air pressure. In groundwater, volatilization can occur only at the air/water interface between the saturated and unsaturated zones, and movement of aqueous-phase contaminants from bulk groundwater to the interface is largely diffusion-limited. Volatilization from groundwater in fractured bedrock, such as that at AOC I, is likely further complicated by the frequency and spacing of fractures in contact with the unsaturated zone.

5.2.2 Leaching

As noted previously, leaching is one of the primary transport mechanisms at AOC I. The contaminants detected in groundwater are the result of leaching from the surface soil, through the unsaturated zone (soil and bedrock), and into groundwater. The degree of leaching of a particular contaminant is primarily a function of the amount of organic matter in the subsurface, the contaminant's water solubility, the amount of the contaminant present, the physical and chemical properties of the matrix through which the contaminant is leaching, and the chemistry of the water infiltrating the soil matrix.

Sorption occurs when a constituent adheres to and becomes associated with solid particles in the formation (sorbed phase). The subsurface materials likely to sorb chemicals typically are clays and organic matter. In addition, some inorganics, such as arsenic, can sorb to iron oxyhydroxide or oxide coatings on soil grains. The soil borings collected at AOC I indicate the unconsolidated material is primarily gravel mixed with sand, with fill material of gravel, sand, and clay at the ground surface. The bedrock was noted to be weathered at its surface and along fractures due to the observed presence of saprolite (clayey material). The presence

of gravel and sand (which tend to have low sorption properties) and variable clay content of the soil and along the rock fractures suggest sorption of leaching constituents may be quite variable.

The conventional measure of sorption is the distribution coefficient (K_d). The K_d for organic chemicals is the product of the soil organic carbon partition coefficient (K_{oc}) of the chemical and the fraction of organic carbon (f_{oc}) in the soil. In general, higher K_{oc} values indicate a greater degree of sorption and lower chemical mobility. The K_d for inorganic chemicals is a complex function of pH, organic content, oxide coatings, and other factors; therefore, K_d is not easily estimated by methods other than site-specific testing. For VOCs and SVOCs detected in AOC I media, the ranges of K_{oc} values are shown in Table 5-1. Other factors being equal (e.g., f_{oc}), the values indicate that SVOCs have a higher affinity for sorbing onto organic matter than do VOCs.

Solubility is a measure of the degree to which a constituent will dissolve in water, which is the transporting medium for the leaching process. It is noted here that leaching of light or dense non-aqueous phase liquids (LNAPLs or DNAPLs) can occur in the absence of infiltrating water, but none of the constituent concentrations in soil or groundwater at AOC I is indicative of the presence of NAPL.

Solubilities of site contaminants in pure water are shown on Table 5-1. VOCs tend to have higher solubilities than SVOCs, but both VOCs and SVOCs have a broad range of solubilities. VOCs toward the lower end of the solubility range are the dichlorobenzenes and cyclohexanes, while VOCs with relatively high solubilities include acetone, 2-butanone, and 4-methyl-2-pentanone. SVOCs toward the lower end of the solubility range include most of the PAHs. More than half of the PAHs have solubilities of 10^1 or less. VOCs representing the full range of solubilities shown in Table 5-1 were detected in groundwater at AOC I; however, only SVOCs with solubilities of 10^2 or higher were detected in groundwater, indicating that aqueous solubility is a major factor contributing to the leaching of contaminants to groundwater.

Other factors, such as organic matter content and the physical and chemical properties of the matrix, also control leaching. The solubilities of inorganics are not included in Table 5-1 because they are highly dependent on their oxidation state, which, in turn, is dependent on the reduction-oxidation (redox) conditions and/or pH of the subsurface environment in addition to the chemical characteristics of the infiltrating water. Under most environmental conditions, Cr^{+6} is expected to be more soluble and, therefore, more mobile than Cr^{+3} . However, as noted in Section 4, Cr^{+6} accounts for less than about 3 percent of the total chromium present. Further, the chromium concentrations detected in groundwater are comparable to background. Therefore, if chromium was released as part of historic asphalt production activities, it likely remains relatively immobile in soil.

Copper in soil and rocks is likely to be more mobile under acidic than alkaline conditions (Seiler *et al.*, 1988). Based on the surface and subsurface soil pH analyses at AOC I, soil at AOC I is alkaline (pH greater than 8.4), indicating the copper is likely to be relatively immobile and therefore will persist in the surface soil. Copper binds strongly to soil containing high organic content and is less affected by pH changes than other inorganics. It will also adsorb to carbonate minerals, clay minerals, or hydrous iron and manganese oxides (ATSDR, 2004). The groundwater data for AOC I tend to support the assertion that if

released by past activity, copper has likely remained sorbed to the unsaturated soil, as the copper concentrations detected in the wells are comparable to background.

Like copper, the higher the pH, the less mobile iron tends to be (Gerritse *et. al.*, 1982). Based on the alkaline nature of site soils, iron will likely be adsorbed onto soil particles and remain relatively immobile. The same is true for lead (ATSDR, 1997). Relative to the above inorganics, vanadium is mobile in alkaline soils and becomes less mobile with increased acidity (Van Zinderen Bakker and Jaworski, 1980). The concentrations of vanadium in the subsurface soil at AOC I are generally higher than those in the surface soil, and the vanadium concentration in one well was found to be higher than the background concentration in 2004. This information suggests that if vanadium is present as a result of a release, it may leach downward to groundwater. It is also recognized, however, that the background exceedance is for only one well, is relatively low (i.e., by less than 10 µg/L), and that background groundwater is represented by only a single data point. Therefore, it is more likely that the vanadium concentrations in groundwater are attributable to background.

As noted previously, leaching is controlled by many chemical-specific and site-specific factors, so the information presented above regarding constituent leaching should be considered qualitative generalizations, not quantitative predictors of contaminant fate, especially considering the complex nature of the media at AOC I (e.g., relatively shallow and heterogeneous unconsolidated interval, unsaturated bedrock interval, and fractured bedrock saturated zone).

5.2.3 Groundwater Transport

Once in groundwater, contaminants typically will not move as rapidly as groundwater because of adsorption of the contaminant to the solid media. This process, known as retardation, is chemical-specific. Rates of retardation for specific contaminants are not easily estimated for fractured bedrock, such as that encountered at AOC I, due to the nature of flow (i.e., through fractures rather than through the pore spaces of unconsolidated media).

Contaminants in groundwater are moved through advection and dispersion. Advection is the transport of dissolved contaminants by the bulk motion of flowing groundwater. It is the primary transport mechanism for dissolved contamination along the hydraulic gradient. Advective contaminant transport is a function of the groundwater flow, as modified by the retardation factor of the specific contaminant. Dispersion is the spreading of dissolved contaminants from the path they would be expected to follow during advection. It results from the spatial variation in aquifer permeability, fluid mixing, and molecular diffusion. Dispersion primarily controls the concentration of the contaminant at any point in the flow system.

As noted above, groundwater flow through fractured bedrock is complex. On a small scale, rates and directions of flow can be variable due to the orientations and spacings of the fractures. At AOC I, groundwater data suggest that there has been minimal transport of contaminants downgradient. Several organic contaminants were detected in well NDAIMW05, but these constituents were not detected in wells located further downgradient (NDAIMW06, NDAIMW08, and NDAIMW09). Therefore, it can be concluded that contaminants have migrated no more than 100 ft downgradient of the

asphalt plant area in the approximately 20 years since facility use was discontinued, indicating a contaminant migration rate of less than 5 ft/year, or less than 0.0137 ft/day.

5.2.4 Transformation and Degradation

Transformation and degradation are also likely to be significant factors in the fate and transport of contaminants at AOC I.

5.2.4.1 Transformation

Transformation of inorganics occurs when the valence state and/or species is changed due to changes in redox potential and/or pH. Transformation may have a significant effect on the mobility of inorganics. The majority of chromium present in soil at AOC I is likely in the form of Cr^{+3} , as the oxide Cr_2O_3 (ATSDR, 2000). The hexavalent form (Cr^{+6}) is more mobile than the Cr^{+3} form, but as noted in Section 4, makes up less than about 3 percent of the chromium present in soil at AOC I. Further, the chromium concentrations in groundwater are comparable to background and below the most conservative screening value (11 $\mu\text{g}/\text{L}$ for hexavalent chromium).

Essentially all lead released to soil from anthropogenic sources is transformed by biotic and abiotic processes to adsorbed forms in soil. This transformation primarily comprises formation of lead complexes on clay minerals, organic matter, and hydrous iron oxides (ATSDR, 1997). Therefore, if lead was released by historic activities at AOC I, it would likely be primarily bound in the soil. The groundwater data for the site tend to support this as the lead concentrations in groundwater are comparable to background.

Vanadium from anthropogenic sources is almost entirely in the form of vanadium oxides. Vanadium has six oxidation states, with V^{+4} and V^{+5} being the most common. The trivalent form (V^{+3}) is less soluble than the pentavalent form (V^{+5}). In general, vanadium exists in the V^{+4} form under reducing conditions and the V^{+5} form under oxidizing conditions. Both forms bind strongly to mineral and organic matter (ATSDR, 1992).

As indicated above, iron is relatively immobile at alkaline pHs such as those found in unsaturated soils at AOC I. Concentrations of iron in groundwater at AOC I are not elevated in the immediate vicinity of the areas of elevated iron in soil or downgradient of these areas. Therefore, iron in groundwater is not likely the result of leaching from soil. Naturally occurring iron is typically found as a part of ferric iron oxyhydroxide minerals in systems with high redox potentials, but can be released to groundwater in systems with lower redox potential. Iron was detected at a concentration greater than background and an HHRA screening value in only one well (NDAIMW07) during the most recent sampling event. Because there were no elevated concentrations of iron in soil at this location, it is possible that the iron was released from the andesitic fractured bedrock under reducing conditions. Under low redox potential, ferric iron is converted to ferrous iron, which does not sorb to oxyhydroxide minerals and is therefore, more mobile. During the 2004 sampling event, the ORP values collected during purging of NDAIMW07 ranged from 395 mV to 494 mV, indicative of highly oxidizing conditions. During that event, iron was detected at an estimated concentration of 295 $\mu\text{g}/\text{L}$. During the 2006 sampling event, ORP values collected during purging of NDAIMW07 ranged from -42 mV to -106 mV, indicating slightly reducing conditions. During that event, iron was detected at a concentration of 1,840 $\mu\text{g}/\text{L}$. It is possible that the reason for difference between the 2004 and 2006 concentrations is that

the groundwater conditions at NDAIMW07 in 2004 were influenced by the potable water added during drilling, which would not have been present during the 2006 sampling. In 2004, approximately 275 gallons of potable water were added to the borehole during drilling. The well was pumped dry several times during development, but not all of the added water was able to be recovered. However, the well was sampled approximately 2 weeks after installation. It is possible that geochemical conditions had not re-equilibrated prior to this sampling event. However, it should be noted that the concentrations of the organics and the majority of the inorganics were comparable between the 2004 and 2006 sampling events. Regardless of the reason for the shift to reducing conditions in 2006, the reducing conditions may have resulted in the mobilization of iron from the andesite.

5.2.4.2 Degradation of Organic Compounds

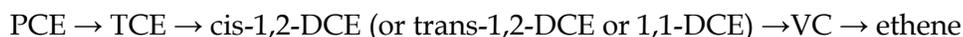
Degradation is the transformation of a chemical either abiotically through such processes as hydrolysis and photolysis or biologically (biodegradation). Biodegradation occurs when microorganisms transform a chemical as part of their metabolic processes. Hydrolysis is the reaction of a chemical with water and photolysis is the result of exposing a chemical to light.

It should be noted that degradation rates are typically dependent on the concentrations of constituents present. Typically, at higher concentration levels, rates of biodegradation will be faster, and as concentrations decrease, rates become slower. At AOC I, organic contaminant concentrations are already low (with respect to screening criteria), and consequently, rates of degradation are also expected to be low.

5.2.4.2.1 Chlorinated Ethenes

Biodegradation of chlorinated ethenes is a well-understood process whereby these VOCs undergo biodegradation through one of three different pathways: use as an electron acceptor by dehalorespiring organisms (reductive dechlorination), direct intracellular oxidation by oxygen-dependent microbes that can use the contaminant as an energy source (most effective for vinyl chloride), or co-metabolism (a fortuitous destruction of contaminants by organisms intending to metabolize other organic compounds). Co-metabolism provides no direct benefit to the biodegrading organism.

Biodegradation via reductive dechlorination is often the principal attenuation mechanism for PCE and other chlorinated ethenes in groundwater. Biological reductive dechlorination is a microbially-mediated process in which chlorinated VOCs serve as the electron acceptor for metabolism, coupled with oxidation of an available electron donor. Anthropogenic (e.g., fuel hydrocarbons) or natural organic carbon sources can serve as electron donors. Reductive dechlorination results in the sequential replacement of a chlorine atom on the chlorinated VOC molecule with hydrogen (see reaction pathway below), and can ultimately lead to complete dechlorination to innocuous end-products, such as chloride and ethene.



As shown above, PCE can be the parent compound for TCE. TCE itself, however, is also a common solvent and, therefore, can be the initial parent compound.

The rate of reductive dechlorination tends to decrease as the degree of chlorination decreases. Thus, TCE tends to degrade more rapidly than cis-1,2-DCE and VC, which can result in accumulation of daughter products, at least temporarily. However, whereas

biodegradation of TCE is largely limited to occurring via reductive dechlorination under deeply anaerobic conditions, the less chlorinated products, particularly vinyl chloride, have been found to biodegrade by either anaerobic reductive dechlorination or aerobic direct oxidation. The importance of this is that biodegradation of daughter products is possible if they migrate to an area of aerobic conditions, such as sometimes occurs at the edge of a plume or after the electron donor supply has been exhausted. Aquifer conditions at AOC I range from slightly oxidizing to reducing across the site. At AOC I, no daughter products of TCE were detected in groundwater; therefore, it cannot be determined whether reductive dechlorination is occurring at the site. It may be, however, that the concentrations of TCE in groundwater are so low that the degradation products are not detected. Further, the presence of fuel-related constituents with the chlorinated ethenes may enhance the reductive dechlorination process if the proper microorganisms are present in sufficient quantity and under the proper conditions.

5.2.4.2.2 Chlorinated Ethanes

1,1-DCA and 1,2-DCA were detected in AOC I groundwater. Only 1,2-DCA was detected at a concentration greater than a human health screening value. Further, it was detected in only one well (NDAIMW07). 1,2-DCA is capable of degrading via a series of bacterial hydrolytic dehalogenation reactions facilitated by the aerobic species *Xanthobacter autotrophicus*, which uses the end product, glycolate, as an energy source. The degradation pathway for 1,2-DCA is shown below:

1,2-DCA → 2-chloroethanol → chloroacetaldehyde → chloroacetic acid → glycolate

A modified version of this process is believed to occur for other chlorinated alkanes, but the exact pathway for this degradation is unknown. Based on the 2006 sampling event, aquifer conditions are slightly reducing in groundwater from the only well in which 1,2-DCA was detected (NDAIMW07). There are no known degradation pathways for this compound under anaerobic conditions.

5.2.4.2.3 Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)

Benzene, toluene, ethylbenzene, and xylenes are present in groundwater at AOC I. Benzene was the only one of the BTEX compounds detected at a concentration greater than a human health screening value. BTEX constituents generally degrade under aerobic conditions to catechol (benzene only), methylcatechols (toluene and xylenes), or ethylcatechols (ethylbenzene only), which can be further degraded into organic fatty acids. Toluene and ethylbenzene are known to degrade under anaerobic conditions by the formation of benzoyl-CoA, which can be readily transformed to acetyl-CoA. No single organism has been shown to completely mineralize benzene under anaerobic conditions. However, it has been shown to be degraded by enrichment cultures containing multiple organisms. This metabolic pathway is unknown and is being investigated (Harwood *et. al.*, 1997). Few organisms are capable of anaerobically metabolizing xylene. They include strains of denitrifying bacteria capable of using *m*-xylene as a growth substrate (Harwood *et. al.*, 1997). The pathway(s) of anaerobic xylene biodegradation are not well-known.

5.2.4.2.4 1,2-Dichloropropane

1,2-dichloropropane was detected in groundwater from one monitoring well (NDAIMW07) during the 2004 sampling event only. The exact process by which this contaminant is degraded is not known. However, 1,2-dichloropropane has been shown to dechlorinate to

monochlorinated propanes under iron-reducing conditions, similar to the dechlorination process described for chlorinated ethenes, but has not been shown to degrade under aerobic conditions (Tesoriero *et. al.*, 2001).

5.2.4.2.5 1,4-Dichlorobenzene

1,4-Dichlorobenzene was detected at a concentration exceeding a human health screening value in groundwater from one AOC I well (NDAIMW07). Like benzene, this compound can be degraded under aerobic conditions. The aerobic microbe, *Xanthobacter flavus* 14pl, uses 1,4-dichlorobenzene as the sole source of carbon and energy but has not been shown to grow on other (chloro)aromatic compounds. 1,4-dichlorobenzene is attacked by chlorobenzene dioxygenase produced by the organism, and after rearomatization, the resulting dichlorocatechol can be further degraded and used for energy by the microbe, as described by Sommer and Gorisch (1997).

Under anaerobic conditions, some methanogenic microbial consortia are able to transform 1,4-dichlorobenzene by reductive dechlorination via monochlorobenzene to benzene. The benzene may then mineralize as described above providing the right mixture of organisms is present.

5.2.4.2.6 Naphthalene and 2-Methylnaphthalene

The aromatic compounds naphthalene and 2-methylnaphthalene degrade readily under aerobic conditions via a number of complex reactions facilitated by various bacteria which result in degradation of these compounds to salicytic compounds and catechols. These chemicals can be further degraded into organic fatty acids. These reactions are usually initiated in both naphthalene and 2-methylnaphthalene by varieties of the *Pseudomonas* bacteria which can produce an enzyme called “naphthalene dioxygenase.”

Although it was previously thought that naphthalene and 2-methylnaphthalene were recalcitrant under anaerobic conditions, some recent studies indicate that these compounds can degrade under sulfate reducing conditions (Coates *et. al.*, 1997). The pathway for this degradation is not yet defined.

5.2.4.2.7 Dibenzofuran

Dibenzofuran was detected in samples from two wells (NDAIMW05 and NDAIMW07) at concentrations greater than human health screening values. Dibenzofuran degradation is initiated under aerobic conditions by the production of dibenzofuran 4,4a dioxygenase by the three species, *Sphingomonas sp.*, *Brevibacterium sp.* DPO 1361, and *Terrabacter sp.* DPO360. A complex series of biologically-mediated reactions follows, which result in the ultimate production of organic fatty acids. It should be noted that dibenzofuran was not identified as a risk driver in the HHRA (Section 6 and Appendix M).

5.2.4.2.8 Bis(2-ethylhexyl)phthalate

Phthalates have been shown to be resistant to bacterial degradation in nature. However, this constituent was detected in only the 2004 round of monitoring in one monitoring well and may be attributable to laboratory contamination.

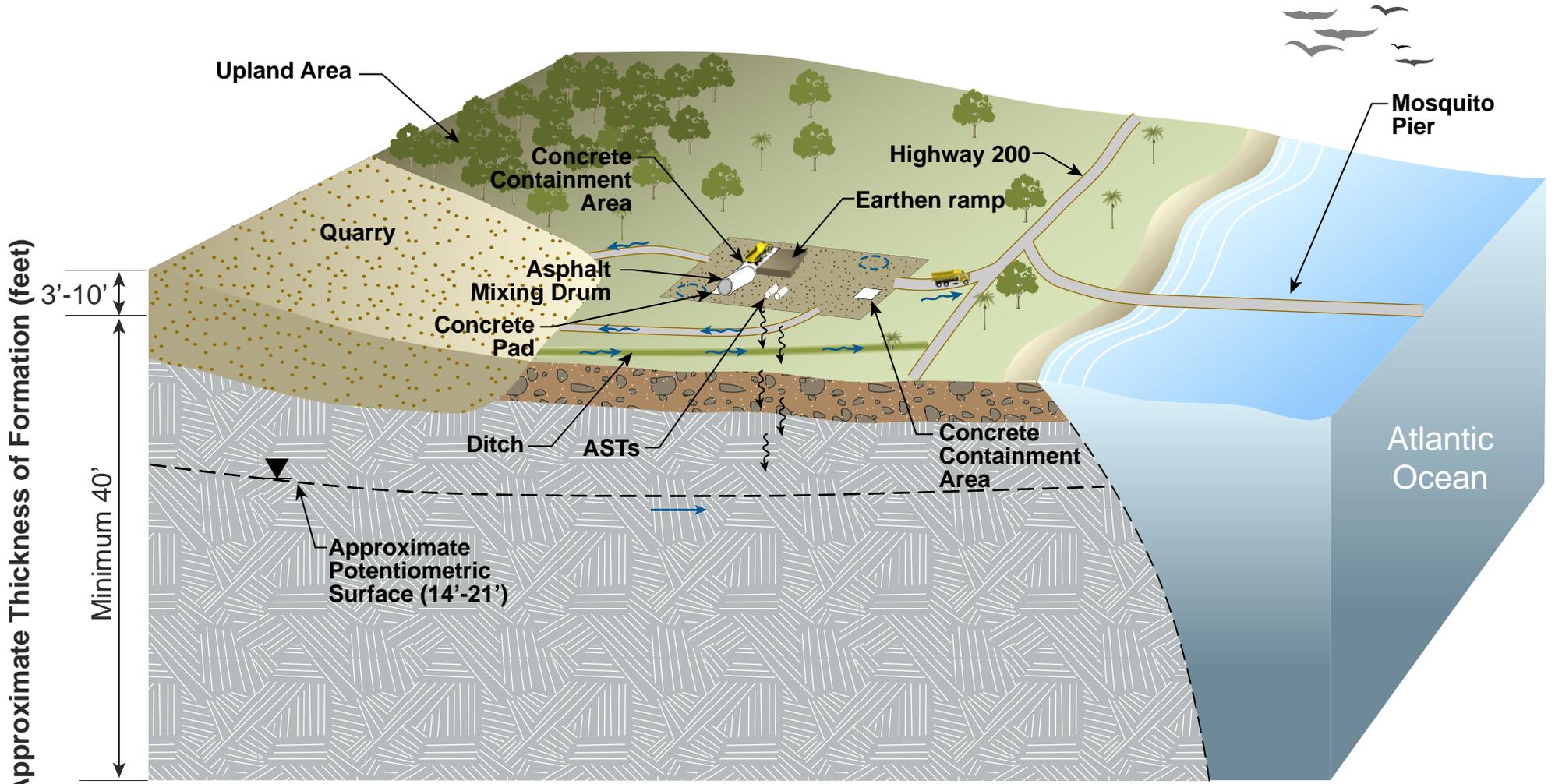
TABLE 5-1

Physical Properties of VOCs and SVOCs Detected at AOC I

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Contaminant Type	Representative Contaminants	Henry's Law Constant (atm-m ³ /mole)	Solubility (µg/L)	K _{oc}
VOCs				
Solvents	cyclohexane, methylcyclohexane, TCE, DCE, dichlorobenzene	10 ⁻³ to 10 ⁻¹	10 ⁴ to 10 ⁸	10 ⁻¹ to 10 ³
Fuel Constituents	benzene, ethylbenzene, toluene, xylene	10 ⁻³	10 ⁵ to 10 ⁶	10 ¹ to 10 ²
SVOCs				
Fuel-related PAHs ¹	acenaphthene, fluoranthene, pyrene, benzo(a)pyrene	10 ⁻⁴ to 10 ⁻⁷	10 ⁻¹ to 10 ⁴	10 ³ to 10 ⁷
Fuel-related HAHs ²	dibenzofuran, carbazole	10 ⁻⁵ to 10 ⁻⁸	10 ³	10 ³
Hydraulic Oil Phthalate	bis(2-ethylhexyl)phthalate	10 ⁻⁵	10 ²	10 ⁴
<p>Notes</p> <p>¹PAH = polycyclic aromatic hydrocarbon</p> <p>²HAH = heterocyclic aromatic hydrocarbon</p> <p>Sources of Henry's Law Constants:</p> <p>Lide (ed.), 2007</p> <p>Montgomery. 2007</p> <p>TOXNET Hazardous Substances Data Bank</p> <p>Source of Solubilities:</p> <p>Montgomery. 2007</p> <p>Sources of K_{oc} Values:</p> <p>EPA Region IX PRG (EPA, 2004a)</p> <p>EPA Soil Screening Guidance (EPA, 1996)</p> <p>Risk Assistant (Environment Agency, 2003)</p> <p>Gustafson, J., J. Griffith Tell, and D. Orem. 1997.</p>				



Approximate Thickness of Formation (feet)

3'-10'
Minimum 40'

Legend

-  Gravel with Sand, Silt, and Clay
-  Fractured Andesite
-  Surface water flow direction
-  Area of standing water during rain event
-  Direction of groundwater flow
-  Infiltration and leaching

Not to Scale

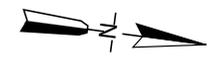


Figure 5-1
AOC I Conceptual Site Model
 AOC I RI Report
 Vieques, Puerto Rico

SECTION 6

Human Health Risk Assessment Summary

A baseline HHRA was conducted for AOC I. The HHRA evaluated potential future health risks (the site is currently vacant) from exposure to site media potentially affected by former operations at the site. The HHRA was conducted in accordance with the protocol in the Final Master QAPP for sites in the Environmental Restoration Program (ERP) (CH2M HILL, 2007), which is consistent with EPA Region II policy and EPA guidance documents, primarily: *Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual, Parts A, D, and E* (EPA, 1989, 2001, and 2004b); *Exposure Factors Handbook* (EPA, 1997a), and *Human Health Evaluation Manual, Standard Default Exposure Factors* (EPA, 1991). The complete HHRA is presented in Appendix M of this RI Report. This section summarizes the key components and findings of the HHRA.

6.1 Chemicals of Potential Concern

The soil dataset used in the HHRA consists of soil samples collected during field investigations in November/December 2000 (Expanded PA/SI) and August/September 2004 (RI). The dataset consists of soil samples collected within the 0 to 6 ft interval, including 44 surface soil samples (26 samples 0 to 6 inches; 18 samples 0 to 2 ft) and 33 subsurface soil samples collected at various intervals within 2 to 6 ft bls.

The groundwater dataset used in the HHRA consists of groundwater samples collected during September 2004 and January 2006. Groundwater samples were collected from seven monitoring wells in 2004 (NDAIMW01 through NDAIMW07) and six monitoring wells in 2006 (NDAIMW01, NDAIMW04, and NDAIMW06 through NDAIMW09). Analytical data from NDAIMW08 and NDAIMW09 were not used in the HHRA because these wells were installed outside of the groundwater plume to confirm plume delineation, and organic analytes were not detected in these samples.

Chemicals of potential concern (COPCs) were identified for soil and groundwater using the screening process presented in the Final Master QAPP HHRA protocol (CH2M HILL, 2007). The following COPCs were identified for the indicated receptors and data groupings:

- **Recreational User/ Resident (Soil; 0 to 2 ft)** - benzo(a)pyrene, aluminum, arsenic, iron, manganese, thallium, and vanadium
- **Maintenance Worker (Soil; 0 to 2 ft)** - arsenic, iron, and vanadium
- **Resident (Soil; 0 to 6 ft)** - benzo(a)pyrene, aluminum, arsenic, iron, manganese, thallium, and vanadium
- **Industrial/Construction Worker (Soil; 0 to 6 ft)** - arsenic, iron, and vanadium

- **Resident/Industrial Worker (Groundwater)** – antimony, arsenic, cadmium, iron, manganese, vanadium, 1,2-dichloroethane, 1,2-dichloropropane, benzene, trichloroethene, 1,4-dichlorobenzene, 2-methylnaphthalene, bis(2-ethylhexyl)phthalate, dibenzofuran, and naphthalene

6.2 Exposure Evaluation

Potential current and future receptors were evaluated in the HHRA. There are no current potential receptors at AOC I; therefore, only future potential receptors were evaluated in the HHRA. As noted in Section 6.1 and in the conceptual model for potential human receptors (Figure 6-1), future receptors evaluated in the HHRA consisted of maintenance workers, industrial workers, construction workers, recreational users (adult, youth, and child) and residents (adult and child).

The potential exposure pathways quantified for future recreators (adult, youth, and child) were:

- Ingestion, dermal contact, and inhalation of surface soil (0 to 2 ft bls)

The potential exposure pathways quantified for future maintenance workers were:

- Ingestion, dermal contact, and inhalation of surface soil (0 to 2 ft bls)

The potential exposure pathways quantified for hypothetical future residents (child and adult) were:

- Ingestion, dermal contact, and inhalation of surface soil (0 to 2 ft bls) and total soil (0 to 6 ft bls)
- Ingestion and dermal contact with groundwater from hypothetical potable use
- Inhalation of bathroom air (as a result of adult showering and child bathing) from hypothetical tap water use

The potential exposure pathways quantified for future industrial workers were:

- Ingestion, dermal contact, and inhalation of total soil (0 to 6 ft bls)
- Ingestion and dermal contact with groundwater from hypothetical potable use

The potential exposure pathways quantified for future construction workers were:

- Ingestion, dermal contact, and inhalation of total soil (0 to 6 ft bls)

6.3 Risk Estimates

EPA's target range for excess lifetime cancer risk (ELCR) associated with CERCLA is 1-in-10,000 (1×10^{-4}) to 1-in-1,000,000 (1×10^{-6}). Similarly, the target non-cancer hazard index (HI) is 1.0 or less. Risk estimates were calculated for receptors and exposure pathways using conservative assumptions for exposure factors and exposure point concentrations. Results of the risk estimates are summarized as follows:

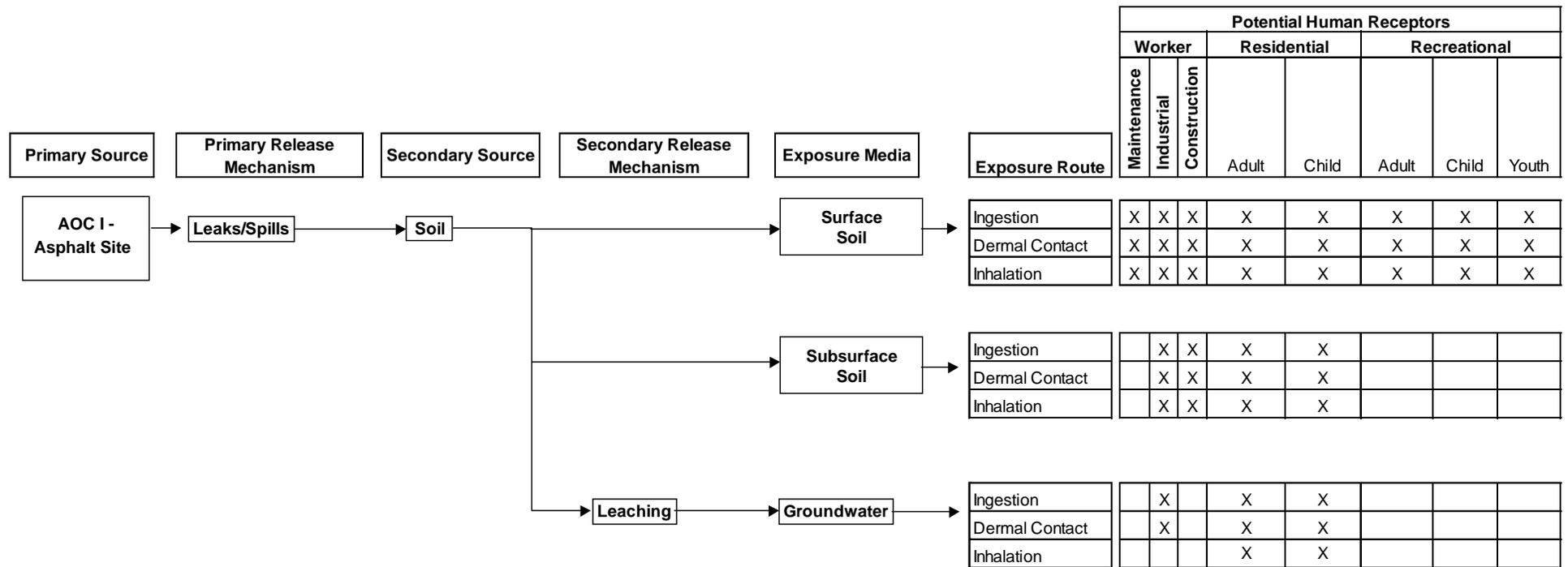
- **Future Recreational Adult/Youth**
 - ELCR $<1 \times 10^{-6}$ and all target organ-specific HIs < 1
- **Future Recreational Child**
 - 3×10^{-6} ELCR and all target organ-specific HIs < 1
- **Future Maintenance Worker**
 - ELCR $<1 \times 10^{-6}$ and all target organ-specific HIs < 1
- **Future Residential Adult/Child**
 - Three target organ-specific HIs > 1.0 for an adult
 - Six target organ-specific HIs > 1.0 for a child
 - 4×10^{-4} ELCR
- **Future Construction Worker**
 - ELCR $<1 \times 10^{-6}$ and all target organ-specific HIs < 1
- **Future Industrial Worker**
 - 8×10^{-5} ELCR and all target organ-specific HIs < 1

6.4 Chemicals of Concern

Chemicals of concern (COCs) were identified where the ELCR or HI exceeded threshold values (a total ELCR greater than 1×10^{-4} or a target organ-specific HI greater than 1.0). When an ELCR of 1×10^{-4} was exceeded for a receptor, the COPCs posing an individual ELCR greater than 1×10^{-6} in the environmental medium responsible for the unacceptable risks were identified as COCs. When a target organ-specific HI exceeded 1.0 for a receptor, the COPCs posing an individual hazard quotient (HQ) greater than 0.10 for that target organ in the environmental medium responsible for the unacceptable risk were identified as COCs. It should be noted that although background was not used to eliminate inorganic constituents prior to evaluation in the quantitative risk assessment, background concentrations were considered when identifying COCs following the quantitative risk assessment. Inorganics identified as COPCs that are wholly or primarily attributable to background levels were not identified as COCs.

Although several inorganics were identified as COPCs and were therefore carried through the quantitative risk assessment, after considering background levels, no inorganic COPCs were identified as COCs for future recreational users, industrial workers, construction workers, or maintenance workers. For hypothetical future residents, no COCs were identified for soil, but the following COCs were identified for groundwater:

- Benzene, bis(2-ethylhexyl)phthalate, 1,2-dichloroethane, 1,2-dichloropropane, 2-methylnaphthalene, and naphthalene.



Notes:

X - Potentially complete exposure pathways identified

Figure 6-1
Human Health Conceptual Model
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

SECTION 7

Ecological Risk Assessment Summary

A screening ecological risk assessment (SERA), constituting Steps 1 and 2 of the ERA process, and the first step (Step 3A) of a baseline ecological risk assessment (BERA), were conducted for AOC I. The ERA was conducted to evaluate the potential for adverse effects to the environment at AOC I. The complete ERA is presented in Appendix N of this RI Report. This section summarizes the key components and findings of the ERA.

7.1 ERA Process and Objectives

The ERA was conducted in accordance with the protocol in the Final Master QAPP for sites in the ERP (CH2M HILL, 2007), which is consistent with the *Navy Policy for Conducting Ecological Risk Assessments* (CNO, 1999), the Navy guidance for implementing this ERA policy (NAVFAC, 2003), and the EPA *Ecological Risk Assessment Guidance for Superfund* (EPA, 1997b). These guidance documents describe a process consisting of eight steps, of which Steps 1, 2, and 3A were conducted for this ERA. Steps 1 and 2 of the ERA process comprise the SERA, which is conducted using intentionally conservative assumptions. If the results of the SERA indicate that unacceptable risks are possible, the site normally continues on to Step 3A, the first step in the BERA.

The objectives of a SERA are to:

- Determine if potential risks to ecological receptors warrant either: (1) additional assessment beyond the conservative screening steps of the ERA process (unacceptable ecological risks are possible); or (2) the removal of the site from further ecological consideration (no unacceptable ecological risks likely).
- Focus subsequent steps of the ERA process on the specific chemicals, pathways, and receptors of potential concern if unacceptable ecological risks are possible.
- Identify any data gaps or areas of unacceptable uncertainty that may require the collection of additional data to support ERA evaluations beyond the screening level.

The general objectives of a Step 3 ERA are to:

- Refine the risk estimates from the SERA to determine if risks to ecological receptors from site-related chemicals are likely to be unacceptable based upon realistic exposure scenarios.
- Focus subsequent data collection activities if potentially unacceptable risks are indicated, uncertainties are unacceptably high, and/or data gaps are identified.

7.2 Environmental Setting

AOC I, a former asphalt plant, is located approximately 900 ft south of the Mosquito Pier adjacent to an active Public Works Department rock quarry on the western side of Vieques Island. The plant was in operation from the 1960s to 1988. AOC I, which is approximately 1 acre in size, includes one large concrete pad, one earthen ramp with a sheet metal support wall, two concrete-paved containment areas, and an area where two diesel fuel ASTs were formerly located. Both containment areas have sumps.

The general topography of AOC I and the immediately surrounding area is relatively flat with only slight changes in elevation. Perennial surface water bodies are not present at AOC I or the immediate surrounding area. A drainage ditch that terminates at Route 200 is located adjacent to the east side of the site.

The description of the vegetative and wildlife communities at AOC I is based upon the detailed habitat characterization conducted at AOC I by Geo-Marine (2001). AOC I consists of several grassy areas, bare ground covered with gravel, and concrete pads. The site is surrounded by a former gravel parking area with gravel roads leading north and south through the former asphalt plant to the quarry. Approximately 80 percent of the site consists of bare ground, concrete, and gravel mixed with scattered weeds and grasses. Hurricane-grass (*Fimbristylis cymosa*) was the most abundant flora observed. In the adjacent shrub community, bitter bush (*Eupatorium odoratum*), button sage (*Lantana involucrata*), giant milkweed (*Calotropis procera*), silky sesban (*Sesbania sericea*), and wild-tantan (*Dismanthus virgatus*) were present in approximately 20 percent of the vegetated area. Several tree species, such as the white fig (*Ficus citrifolia*) and Gumbo-Limbo (*Bursea simarouba*), have recently invaded the area. A few species of birds, including bananaquit (*Coerba flaveola*), black-faced grassquit (*Tiaris bicolor*), northern mockingbird (*Mimus polyglottus*), and common ground doves (*Columbina passerina*), were observed onsite. Common ground doves, gray kingbirds (*Tyrannus dominicensis*), and bananaquits were the most common birds in the adjacent areas. In addition, mongoose (*Herpestes auropunctatus*) and horse tracks were seen at the site. The ramp provided shade, foraging areas, and cover for a few common anoles (*Anolis* sp.). Marine toads (*Bufo marinus*) and marine toad tadpoles were observed in a concrete structure partially filled with water; however, this is an intermittent water source fed only by direct rainfall and is therefore not an aquatic habitat. Invertebrates using the site included diving beetles, dragonflies, bees, and butterflies (Geo-Marine, 2001).

No endangered or threatened species, or preferred habitats, were observed within the AOC I area, nor are any expected to use the site as habitat. Figure 7-1 illustrates a diagrammatic conceptual model for potential ecological exposure.

7.3 Analytical Data Used in the ERA

Twenty-six surface soil samples (0 to 6 inches bls) were collected at AOC I throughout the former asphalt plant and analyzed for VOCs, SVOCs, inorganics, pesticides, polychlorinated biphenyls (PCBs), and TPH. An additional 18 surface soil samples (0 to approximately 2 ft bls) were collected during the RI to refine the understanding of the horizontal extent of surface soil constituents. These samples were analyzed variously for TPH, SVOCs, hexavalent and total chromium, total organic carbon (TOC), and pH.

As noted above, all surface soil samples used in the ERA were obtained from a depths of 6 to up to 24 inches bls. Subsurface soils (deeper than 2 ft) and groundwater were also sampled on the site. However, these media were not evaluated in this ERA due to the lack of complete exposure pathways to these media.

7.4 Results

Seven metals (aluminum, chromium, cobalt, iron, manganese, selenium, and vanadium) were identified as COPCs in surface soils from AOC I. On-site surface soil concentrations for these metals were compared to background UTL concentrations. The maximum concentrations of aluminum, manganese, and selenium do not exceed the background UTL in any sample. The maximum concentrations of iron and vanadium exceed the background UTLs in a single sample by very small amounts (maximum ratio of 1.17 and 1.08, respectively). Similarly, cobalt exceeds the background UTL in 2 of 26 samples at a maximum ratio of 1.08. Total chromium exceeds the background UTL in 7 of 43 samples, but the maximum ratio is less than 1.5 (in sample SB020). The chromium concentration in the field duplicate does not exceed the background UTL. The ratios for all other samples are less than 1.25. Thus, the concentrations of all seven of these metals are generally consistent with background conditions and these chemicals were not retained as COCs.

Although the maximum and/or mean concentrations of three PAHs (fluoranthene, pyrene, and benzo[a]pyrene) exceed ecological soil screening values, these exceedances are limited to one, one, and two samples, respectively, and HQs are about 2 or less. The soil screening toxicity values for these PAHs are based on non-site-specific background values (Beyer, 1990), not toxicity to organisms, and thus have limited utility in evaluating risk. However, the total PAH concentration in the five samples with detected PAHs (maximum of 1,377 $\mu\text{g}/\text{kg}$, mean of 73 $\mu\text{g}/\text{kg}$) is less than an eco-SSL for total higher molecular-weight PAHs based upon exposures to soil invertebrates (18,000 $\mu\text{g}/\text{kg}$) and none of the PAHs has an HQ exceeding 1 based upon food web exposures. Thus, none of the PAHs (including those without individual soil screening values) was identified as COCs.

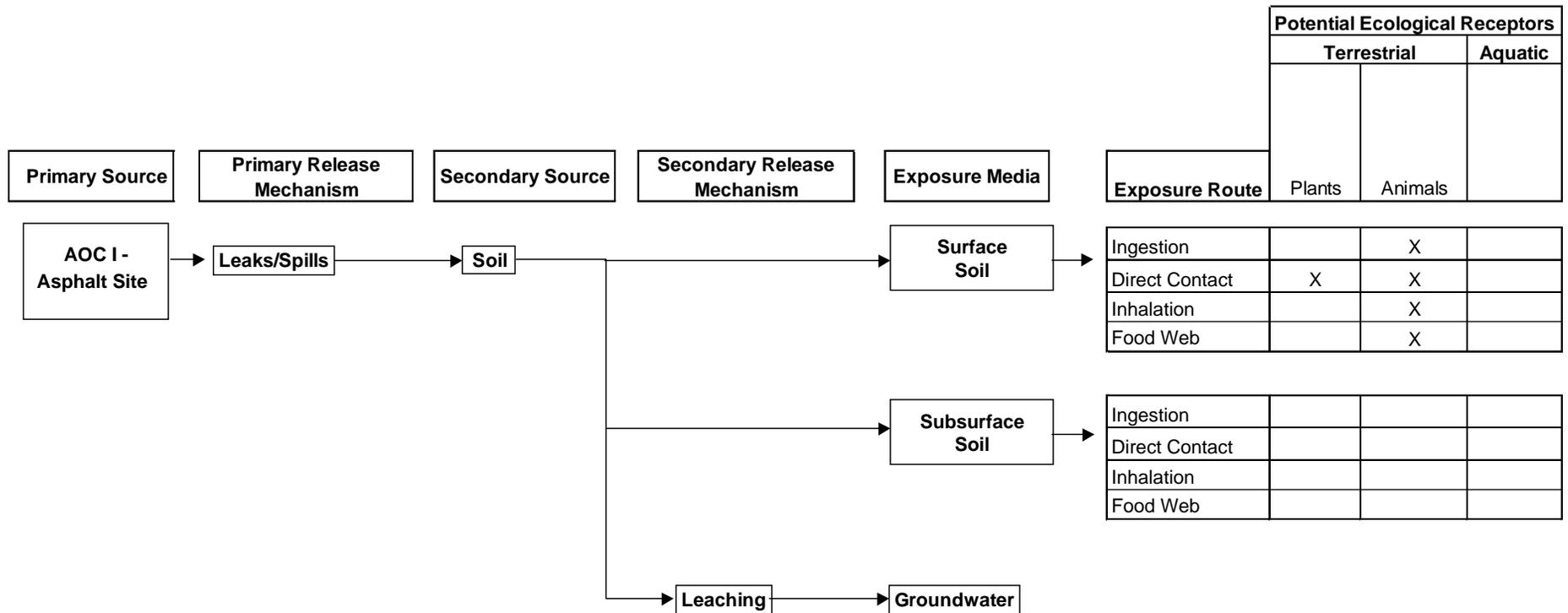
Four VOCs (2-butanone, 4-methyl-2-pentanone, acetone, and methylene chloride) were detected but were not evaluated quantitatively because screening values are not available. However, maximum concentrations of the four VOCs are less than screening values for other, similar VOCs. Thus, none of the VOCs was identified as a COC.

TPH was detected but was not evaluated quantitatively because there are no available soil screening values. However, PAHs (which are typically the most toxic fraction of the TPH) were not identified as COCs in surface soil. Thus, TPH was not retained as a COC.

No COPCs were identified for terrestrial food web exposure pathways.

7.5 ERA Summary and Conclusions

In summary, none of the COPCs carried forward from Step 2 were retained as COCs following the Step 3A refinement. Thus, no unacceptable risks were identified for ecological receptors at AOC I and no further evaluation is warranted with respect to ecological receptors.



Notes:

X - Potentially complete exposure pathways identified

Figure 7-1
Ecological Conceptual Model
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Summary, Conclusions, and Recommendations

This section presents the summary and conclusions of the RI conducted at AOC I and the recommendations for the path forward at the site.

8.1 Summary

AOC I, the former asphalt plant located on the former NASD, operated from the 1960s through 1988. The asphalt plant comprised a large concrete pad for asphalt mixing, an earthen ramp used by front-end loaders to fill hoppers with aggregate, a concrete containment area for asphalt loading into trucks, and two diesel ASTs. A second concrete containment area, located north of the former plant, was presumably used to stage trucks prior to being loaded with asphalt. Once loaded with asphalt, the trucks would transport the asphalt to locations on the island where roads were being paved.

AOC I is approximately 900 ft south of Mosquito Pier and adjacent to an active rock quarry historically used, in part, to supply aggregate for the asphalt production. The AOC I area occupies approximately an acre, but the asphalt plant itself occupied a considerably smaller area. The topography of the site is relatively flat; stormwater at and in the immediate vicinity of the former asphalt plant was observed to pond at the site during a rain event rather than run off. At the northern, eastern, and southern margins of the site, the topography slopes downward to Route 200 (to the north), the quarry (to the south), and a drainage ditch for the quarry (to the east).

Currently, there is no human use of the site other than potentially as a passageway for trucks to/from the rock quarry from Route 200. Ecological habitat at the former asphalt plant is minimal, consisting primarily of scrub grass, brush, and small trees growing in and around the former asphalt plant structures and through the gravel-covered terrain. No federally-protected species or preferred habitats were observed at AOC I, nor are any cultural resources present at the site.

The surficial material at the site comprises gravel fill interspersed with silty clay and sand. Beneath the thin veneer of fill, the soil zone at the site is relatively thin (generally 2 to 9 ft thick) and consists of well-graded gravel with sand of the Qa geologic unit. Andesite bedrock lies below the soil, often weathered at its surface to a saprolite. The upper portion of the bedrock is unsaturated; groundwater was first observed during drilling at about 25 ft below the top of bedrock, but stabilized at about 15 ft below the top of bedrock. Groundwater at the site migrates through fractures in the bedrock in a north-northwest direction toward the coast.

Although there is no record of CERCLA-related releases during operation of the asphalt plant, site visit observations and environmental media data indicate past releases did occur. The data were collected through a series of investigations during which surface soil, subsurface soil, bedrock, and groundwater samples were collected throughout, around, and downgradient of the former asphalt plant and analyzed for various constituents potentially present as a result of asphalt plant operations. Evaluation of the data collected from these

locations indicates the following constituents likely associated with asphalt operations are present in soil and/or groundwater at the site:

Volatile Organic Compounds (VOCs)

- Degreasing solvents such as cyclohexane, dichlorobenzene, PCE, and TCE
- Fuel-related constituents (BTEX)

Semi-volatile Organic Compounds (SVOCs)

- Fuel-related PAHs such as pyrene, acenaphthene, and benzo(a)pyrene
- Fuel-related heterocyclic aromatic hydrocarbons (HAHs) carbazole and dibenzofuran
- Hydraulic oil-related bis(2-ethylhexyl)phthalate

Observations made during drilling through the bedrock indicate these types of contaminants may also be present in the unsaturated bedrock in a spatially limited area (i.e., directly below the former asphalt plant). Inorganics were also detected in site media, but comparison of the site-specific inorganic data to the west Vieques background inorganic data suggests most of the inorganic concentrations detected are likely attributable to background, especially considering the historical activity was asphalt production.

Tables 8-1 through 8-3 provide statistical summaries of the constituents detected in surface soil, subsurface soil, and groundwater, respectively. The data were evaluated not only to determine the nature and extent of contaminants present as a result of past releases, but were also compared to human health-based and ecological-based screening values to gain an understanding of the magnitude of the releases. This comparison shows that the constituent concentrations detected in both soil and groundwater are relatively low (i.e., most constituent concentrations below or just above screening values). This suggests that the past releases were likely the result of minor spills, drips, or leaks associated with normal asphalt plant operations.

Based on the physical setting and extent of contamination identified during the RI, the primary route of contaminant migration is likely vertical leaching through soil and bedrock to groundwater and subsequent transport with groundwater flow through fractures in the bedrock aquifer. The relatively flat topography and the assumed nature of releases (i.e., minor spills and leaks) suggest surface runoff is not a significant contaminant migration route at the site. Therefore, contamination in the soil and unsaturated bedrock fractures is likely spatially limited to the immediate vicinity of the former asphalt plant as a result of primarily vertical leaching of contaminants. Further, groundwater data collected from wells at the site indicate downgradient contaminant migration has been limited to less than approximately 100 ft of the former asphalt plant.

The fate and transport of contaminants present in the environmental media is dependant on many factors, such as the contaminant type, soil type, organic matter content, presence and abundance of microorganisms, climatic conditions, chemistry of infiltrating water, and rate of groundwater migration. Degradation of the organic contaminants detected in the environmental media at AOC I can occur through biotic (biological-based [biodegradation]) or abiotic (non-biological-based) processes. Some of the contaminants detected at AOC I

biodegrade primarily under anaerobic conditions (e.g., chlorinated ethenes [e.g., TCE] and 1,2-dichloropropane); others biodegrade primarily under aerobic conditions (e.g., chlorinated ethanes [e.g., 1,2-DCA], BTEX, and dibenzofuran). Several of the contaminants have been shown to biodegrade under both aerobic and anaerobic conditions (e.g., 1,4-dichlorobenzene, naphthalene, and 2-methylnaphthalene). The rate at which biodegradation of these contaminants will occur is based on site-specific conditions, including the oxidation-reduction setting, presence and abundance of the proper microorganisms, and the concentrations of contaminants present. Typically, at higher concentrations levels, rates of biodegradation will be faster than at lower concentrations. As noted previously, organic contaminant concentrations at AOC I are already low. Consequently, rates of biodegradation are also expected to be low.

Based on the nature, extent, and concentrations of constituents detected in environmental media at AOC I, potential ecological and human health risks were assessed. As noted previously, the gravel-covered terrain, remnant asphalt plant structures, and sparse scrub vegetation provide minimal habitat. In fact, no preferred habitats were observed at AOC I, nor were any threatened or endangered species identified. Further, concentrations of constituents detected in surface soil were either comparable to background or were within acceptable ecological screening levels. Therefore, no unacceptable risks were identified for potential ecological receptors at AOC I.

For potential human receptors, it is noted that there is no current human presence at the site. However, exposures to various environmental media at the site were evaluated for hypothetical recreational users, maintenance workers, construction workers, industrial workers, and residents. Based on these evaluations, no unacceptable risk (over that attributable to background) was identified for exposure to soil by hypothetical human receptors. The only unacceptable risks were identified for potable use of groundwater by hypothetical future residents. The risk assessment identified benzene, bis(2-ethylhexyl)phthalate, 1,2-DCA, 1,2-dichloropropane, 2-methylnaphthalene, and naphthalene as the groundwater COCs. Inorganics were eliminated as COCs because their presence is wholly or primarily attributable to background.

8.2 Conclusions

Based on the above information, it is concluded that CERCLA-related releases occurred during past asphalt plant operations, likely in the form of minor drips and spills. These releases resulted in contamination of soil, bedrock, and groundwater. However, the extent of contamination is generally limited to the immediate vicinity of the former asphalt plant, with vertical leaching to groundwater representing the primary transport pathway. Further, the contaminant levels present in environmental media are relatively low (with respect to human health-based and ecological-based screening values). In fact, potable groundwater use by residents is the only unacceptable risk identified for the site. In addition, only two organic constituents (benzene and bis(2-ethylhexyl)phthalate) were detected in groundwater above MCLs. Benzene concentrations declined between the 2004 and 2006 sampling events and bis(2-ethylhexyl)phthalate is a common laboratory contaminant, so its single detection in groundwater is suspect. However, it is noted that all wells were sampled either once or twice, so the ability to evaluate trends is limited.

8.3 Recommendations

As summarized above, although contaminants are present in both soil and groundwater at the site, only the groundwater contamination poses an unacceptable risk (under the potable use scenario) to hypothetical future residents. Further, MCL exceedances have been identified for site groundwater. Because the groundwater contamination has been attributed to past releases from the former asphalt plant operations, it is recommended that a feasibility study (FS) be performed to evaluate whether there are technically and economically viable remedial alternatives to address the groundwater contamination. It is noted that the groundwater data suggest contaminant concentrations above MCLs have generally declined over time. However, at most, only two rounds of groundwater data (from 2004 and/or 2006) exist for any particular well. Because of this, and because groundwater contaminant concentrations are already low with respect to screening values, it is recommended that prior to performing the FS, another round of groundwater samples be collected from all site wells and analyzed for the following parameters:

- VOCs
- SVOCs
- Total and dissolved inorganics
- Nitrate, nitrite, sulfide, sulfate, TOC, alkalinity, chloride, methane, ethane, ethene, ferrous iron, and functional gene testing for VOC and SVOC degrading microbes

The additional round of VOC and SVOC data will provide further information on temporal contaminant concentration changes, helping to confirm whether the general decline observed in the existing data is real or part of innate concentration variability. Although the inorganic concentrations in groundwater are likely attributable to background based on the existing data, an additional round of inorganic data will help confirm this supposition. The additional geochemical and microbial parameters will be used to determine the potential for natural attenuation of the organic compounds and the potential for mobilization of inorganics. In addition, to evaluate potential tidal influences on groundwater flow directions at AOC I, groundwater-level readings will be obtained that correspond with low tide and a high tide during the groundwater sampling event.

Based on the results of the additional round of groundwater data, the Navy may recommend that a fourth round be collected prior to performing the FS. For example, if the concentrations have declined to below MCLs, another round may be proposed to confirm this, which would be beneficial information for the FS. In addition, if the Navy determines that a pilot study would provide information beneficial to the evaluation of alternative(s) in the FS, the FS will be temporarily deferred and a pilot study work plan submitted for agency review.

TABLE 8-1
 Surface Soil Summary Statistics
 AOC I Remedial Investigation Report
 Vieques, Puerto Rico

Chemical Name	Human Health Screening Value	Ecological Screening Value	Number of Analyses	Number of Detects ^z	Range of Concentrations ^z	Number of Detects Above Human Health Screening Value ^z	Number of Detects Above Ecological Screening Value ^z
Volatile Organic Compounds (µg/kg)							
1,1-Dichloroethene	12,000	100	26	2	0.43 - 0.47	0	0
1,2-Dichloroethane	280	20	26	1	1	0	0
2-Butanone	2,200,000	--	26	1	5	0	NA
4-Methyl-2-pentanone	530,000	--	26	1	2.8	0	NA
Acetone	1,400,000	--	26	1	6.7	0	NA
Benzene	640	10	29	2	0.27 - 1.2	0	0
Ethylbenzene	190,000	30	29	1	3.7	0	0
Methylene chloride	9,100	--	26	3	0.34 - 0.56	0	NA
Tetrachloroethene	480	2	26	1	0.27	0	0
Toluene	630,000	200,000	29	8	0.3 - 25	0	0
Trichloroethene	53	100	26	1	0.31	0	0
Xylene, total	27,000	--	29	6	0.2 - 27	0	NA
m- and p-Xylene	27,000	100	26	6	0.2 - 19	0	0
o-Xylene	27,000	100	26	4	0.18 - 7.8	0	0
Semi-volatile Organic Compounds (µg/kg)							
Acenaphthylene	370,000	--	40	1	104	0	NA
Anthracene	2,200,000	100	40	2	55.4 - 65	0	0
Benzo(a)anthracene	620	--	40	3	59 - 68	0	NA
Benzo(a)pyrene	62	100	40	4	33.6 - 145	2	1
Benzo(b)fluoranthene	620	--	40	2	142 - 203	0	NA
Benzo(g,h,i)perylene	2,300,000	--	40	2	47.6 - 174	0	NA
Benzo(k)fluoranthene	6,200	--	40	3	40.1 - 153	0	NA
Chrysene	62,000	--	40	1	68.3 - 135	0	NA
Dibenz(a,h)anthracene	62	--	40	1	43.7	0	NA
Fluoranthene	230,000	100	40	4	31.5 - 227	0	1
Indeno(1,2,3-cd)pyrene	620	--	40	2	39 - 138	0	NA
Pyrene	230,000	100	40	3	63.8 - 193	0	2
bis(2-Ethylhexyl)phthalate	35,000	--	40	13	43.5 - 3,880	0	NA
Inorganics (mg/kg)							
Aluminum	7,600	--	26	0	NA	0	NA
Antimony	3.1	78	26	0	NA	0	0
Arsenic	0.39	18	26	1	2.3	0	0
Barium	1,600	330	26	0	NA	0	0
Beryllium	15	40	26	0	NA	0	0
Cadmium	3.7	32	26	1	0.52	0	0
Calcium	--	--	26	1	52,000	NA	NA
Chromium	210	0.4	43	7	74.6 - 110	0	7
Chromium (hexavalent)	22	--	17	17	0.23 - 1.27	0	NA
Cobalt	140	13	26	0	NA	0	0
Copper	310	70	26	4	69 - 103	0	3
Iron	2,300	--	26	1	44,000	1	NA
Lead	400	120	26	4	8.7 - 22	0	0
Magnesium	--	--	26	16	13,000 - 15,000	NA	NA
Manganese	180	220	26	0	NA	0	0
Mercury	2.3	0.1	26	0	NA	0	0
Nickel	160	38	26	2	49 - 57	0	2
Potassium	--	--	26	0	NA	NA	NA
Selenium	39	0.52	26	0	NA	0	0
Silver	39	560	26	7	0.081 - 0.12	0	0
Sodium	--	--	26	0	NA	NA	NA
Thallium	0.52	1	26	2	0.73 - 0.93	2	0
Vanadium	7.8	2	26	1	140	1	1
Zinc	2,300	120	26	0	NA	0	0

Note:

¹ Lead action level

² For inorganics, it is number of detects above background, range of concentrations above background, and number of detects above screening values and background.

³ There is no background for hexavalent chromium; therefore, all detections are counted.

TABLE 8-2
Subsurface Soil Summary Statistics
AOC I Remedial Investigation Report
Vieques, Puerto Rico

Chemical Name	Human Health Screening Value	Number of Analyses	Number of Detects ²	Range of Concentrations ²	Number of Detects Above Human Health Screening Value ²
Volatile Organic Compounds (µg/kg)					
1,1-Dichloroethene	12,000	26	1	0.42	0
1,2-Dichloroethane	280	26	1	1.2	0
2-Butanone	2,200,000	26	2	2.9 - 4.1	0
4-Methyl-2-pentanone	530,000	26	2	0.79 - 53	0
Ethylbenzene	190,000	26	2	0.89 - 96	0
Tetrachloroethene	480	26	1	0.29	0
Toluene	630,000	26	3	0.33 - 0.78	0
Trichloroethene	53	26	1	0.37	0
Xylene, total	27,000	26	3	1 - 4,460	0
m- and p-Xylene	27,000	26	3	0.79 - 2,970	0
o-Xylene	27,000	26	3	0.23 - 1,500	0
Semi-volatile Organic Compounds (µg/kg)					
2-Methylnaphthalene	31,000	26	1	4,630	0
Acenaphthene	370,000	26	1	331	0
Benzo(b)fluoranthene	620	26	2	31 - 39	0
Benzo(k)fluoranthene	6,200	26	1	32	0
Carbazole	24,000	26	1	158	0
Chrysene	62,000	26	1	129	0
Dibenzofuran	15,000	26	1	663	0
Fluoranthene	230,000	26	1	969	0
Fluorene	270,000	26	1	893	0
Naphthalene	5,600	26	1	2,550	0
Phenanthrene	230,000	26	1	2,620	0
Pyrene	230,000	26	1	469	0
Inorganics (mg/kg)					
Aluminum	7,600	26	1	32,000	1
Antimony	3.1	26	2	2.8 - 2.9	0
Arsenic	0.39	26	1	2.6	1
Barium	1,600	26	0	NA	0
Beryllium	15	26	0	NA	0
Calcium	--	26	0	NA	NA
Chromium	210	32	15	87 - 160	0
Chromium (hexavalent)	22	6	6 ³	0.255 - 0.662	0
Cobalt	140	26	0	NA	0
Copper	310	26	10	69 - 225	0
Iron	2,300	26	9	40,000 - 62,500	9
Lead	400 ¹	26	2	7.5 - 14	0
Magnesium	--	26	21	13,000 - 26,000	NA
Manganese	180	26	0	NA	0
Mercury	2.3	26	0	NA	0
Nickel	160	26	13	43 - 84	0
Potassium	--	26	0	NA	NA
Selenium	39	26	0	NA	0
Silver	39	26	7	0.081 - 0.12	0
Sodium	--	26	6	1,230 - 2,650	NA
Vanadium	7.8	26	6	136 - 188	6
Zinc	2,300	26	0	NA	0

Note:

¹ Lead action level

² For inorganics, it is number of detects above background, range of concentrations above background, and number of detects above screening values and background.

³ There is no background for hexavalent chromium; therefore, all detections are counted.

TABLE 8-3
Groundwater Summary Statistics
AOC 1 Remedial Investigation Report
Vieques, Puerto Rico

Chemical Name	Human Health Screening Value	Maximum Contaminant Level (MCL)	2004					2006				
			Number of Analyses	Number of Detects ²	Range of Concentrations ²	Number of Detects Above Human Health Screening Value ²	Number of Detects Above MCL ²	Number of Analyses	Number of Detects ²	Range of Concentrations ²	Number of Detects Above Human Health Screening Value ²	Number of Detects Above MCL ²
Volatile Organic Compounds (µg/L)												
1,1-Dichloroethane	81	--	6	0	NA	0	NA	5	1	0.26	0	NA
1,2-Dichloroethane	0.12	5	6	0	NA	0	NA	5	1	1.6	0	NA
1,3-Dichloropropane	0.16	5	6	0	NA	0	NA	5	0	NA	0	NA
1,3-Dichlorobenzene	0.16	5	6	0	NA	0	NA	5	1	0.52	0	NA
1,4-Dichlorobenzene	0.5	75	6	0	NA	0	NA	5	1	0.52	1	0
4-Methyl-2-pentanone	200	--	6	1	14.9	0	NA	5	0	NA	0	NA
Benzene	0.35	5	6	4	0.62 - 59.3	4	2	5	2	4.6 - 28	2	1
Bromofom	8.5	80	6	0	NA	0	NA	5	1	0.13	0	NA
Chloromethane	16	--	6	1	0.51	0	NA	5	0	NA	0	NA
Cyclohexane	1,000	--	6	4	1 - 41.6	0	NA	5	2	13 - 66	0	NA
Toluene	230	--	6	2	1.4 - 1.9	0	NA	5	2	0.3 - 1.9	0	NA
Ethylbenzene	130	700	6	3	0.45 - 14.4	0	NA	5	2	0.41 - 7.9	0	NA
Isopropylbenzene	66	--	6	4	2.6 - 42.4	0	NA	5	2	7.1 - 47	0	NA
Methylcyclohexane	520	--	6	3	1.2 - 29.7	0	NA	5	2	3.7 - 34	0	NA
Xylene, total	0.028	5	6	2	1.4 - 1.9	0	NA	5	2	0.17 - 1.9	0	NA
Xylene, total	--	10,000	6	3	0.42 - 11.2	NA	0	5	2	0.5 - 10	NA	0
Semi-volatile Organic Compounds (µg/L)												
2-Methylnaphthalene	2.4	--	6	3	9.5 - 82.1	3	NA	5	2	3.8 - 110	2	NA
Acenaphthene	37	--	6	0	NA	0	NA	5	1	2.5	0	NA
Acetophenone	61	--	6	2	6.4 - 15.3	0	NA	5	0	NA	0	NA
Dibenzofuran	1.2	--	6	2	3.8 - 4.1	2	NA	5	2	1.2 - 5.5	1	NA
Fluorene	24	--	6	1	6.9	0	NA	5	2	1.7 - 8.3	0	NA
Naphthalene	0.62	--	6	2	46.2 - 81.4	2	NA	5	2	5.5 - 96	2	NA
Phenanthrene	18	--	6	2	4.8 - 5.9	0	NA	5	1	0.7	0	NA
bis(2-Ethylhexyl)phthalate	4.8	6	6	1	9.6	1	1	5	0	NA	0	NA
Total Inorganics (µg/L)												
Aluminum	3,600	--	6	2	39 - 774	0	NA	5	2	276 - 461	0	NA
Antimony	1.5	6	6	0	NA	0	NA	5	0	NA	0	NA
Arsenic	0.045	10	6	2	17 - 18.7	2	2	5	2	4.3 - 4.5	2	0
Barium	730	2,000	6	6	19.2 - 104	0	0	5	5	23.9 - 89.6	0	0
Cadmium	1.8	5	6	1	8.72	1	1	5	0	NA	0	NA
Calcium	--	--	6	1	93,400	NA	NA	5	0	NA	NA	NA
Chromium	11	100	6	4	1.6 - 3.1	0	0	5	0	NA	0	NA
Cobalt	73	--	6	3	7.07 - 8.78	0	NA	5	0	NA	0	NA
Copper	150	1,300	6	2	8.54 - 8.64	0	0	5	1	3.4	0	0
Cyanide	73	200	6	1	11.5	0	0	5	0	NA	0	NA
Iron	1,100	--	6	4	295 - 974	0	0	5	3	280 - 1,840	1	NA
Lead	151	--	6	2	6.66 - 8.38	0	NA	5	0	NA	0	NA
Magnesium	--	--	6	4	47,500 - 59,300	NA	NA	5	0	NA	NA	NA
Manganese	88	--	6	6	57.2 - 1,930	5	NA	5	4	145 - 1,900	4	NA
Mercury	1.1	2	6	2	0.0462 - 0.0478	0	0	5	0	NA	0	NA
Nickel	73	--	6	3	1.8 - 2.51	0	NA	5	1	2.5	0	NA
Potassium	--	--	6	1	1,290	NA	NA	5	1	1,240	NA	NA
Selenium	18	50	6	0	NA	0	0	5	4	1.8 - 3.8	0	0
Sodium	--	--	6	5	111,000 - 382,000	NA	NA	5	5	143,000 - 418,000	NA	NA
Vanadium	3.6	--	6	1	46.9	1	NA	5	0	NA	0	NA
Zinc	1,100	--	6	1	2.14	0	NA	5	2	10.3 - 12	0	NA
Dissolved Inorganics (µg/L)												
Aluminum	3,600	--	6	0	NA	0	NA	5	2	38.9 - 128	0	NA
Antimony	1.5	6	6	0	NA	0	NA	5	0	NA	0	NA
Arsenic	0.045	10	6	5	15.4 - 20	5	5	5	1	6.2	0	0
Barium	730	2,000	6	6	19 - 103	0	0	5	5	25.4 - 94.4	0	0
Cadmium	1.8	5	6	1	8.23	1	1	5	0	NA	0	0
Calcium	--	--	6	1	92,600	NA	NA	5	0	NA	NA	NA
Chromium	11	100	6	2	1.46 - 1.65	0	0	5	3	1.1 - 7	0	0
Cobalt	73	--	6	1	8.61	0	NA	5	4	0.49 - 0.94	0	NA
Copper	150	1,300	6	0	NA	0	0	5	0	NA	0	NA
Iron	1,100	--	6	2	99.8 - 188	0	NA	5	3	117 - 1,470	1	NA
Lead	151	--	6	2	7.83 - 7.95	0	NA	5	0	NA	0	NA
Magnesium	--	--	6	4	46,700 - 58,400	NA	NA	5	0	NA	NA	NA
Manganese	88	--	6	6	44.9 - 1,920	5	NA	5	5	12.1 - 1,960	4	NA
Nickel	73	--	6	1	2.07	0	NA	5	5	0.65 - 1.6	0	NA
Potassium	--	--	6	1	1,340	NA	NA	5	1	1,270	NA	NA
Selenium	18	50	6	0	NA	0	0	5	1	2.2	0	0
Sodium	--	--	6	5	112,000 - 404,000	NA	NA	5	5	147,000 - 430,000	NA	NA
Vanadium	3.6	--	6	1	45.3	1	NA	5	0	NA	0	NA
Zinc	1,100	--	6	2	2.32 - 3.24	0	NA	5	2	10.7 - 12.4	0	NA

NA - Not Applicable
¹ Lead action level
² Detects and Range of Concentrations - above screening values and background

SECTION 9

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