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TRANSMITTAL

TO: Ms. Eva Chu
Alameda County Health Care Services
Department of Environmental Health
80 Swan Way, Room 200
Oakland, CA 94621

DATE: September 3, 1993
PROJECT NUMBER: 60006.04
SUBJECT: ARCO Station No. 6041

FROM: Erin Krueger

WE ARE SENDING YOU:

COPIES	DATED	DESCRIPTION
1	9/3/93	Work Plan for Evaluation of Interim Remediation Alternatives at ARCO Station No. 6041, 7249 Village Parkway, Dublin, California.
1	9/3/93	Preliminary Results of Additional Onsite Subsurface Investigation at ARCO Station No.6041, 7249 Village Parkway, Dublin, California.

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REMARKS:
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Erin Krueger, Staff Geologist

cc: Mr. Mike Whelan, ARCO
Mr. Richard Hiett, CRWQCB

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WORK PLAN FOR EVALUATION OF INTERIM REMEDIATION ALTERNATIVES

at
ARCO Station 6041
7249 Village Parkway
Dublin, California

60006.04

Prepared by
RESNA Industries Inc.

Prepared for

ARCO Products Company
P.O. Box 5811
San Mateo, California 94402

Erin D. Krueger
Staff Geologist

or John Young

Valli Voruganti
Project Engineer

REGISTERED GEOLOGIST
JAMES LEWIS NELSON
No. 1463
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

James L. Nelson
C.E.G. 1463

September 3, 1993

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WORK PLAN FOR EVALUATION OF INTERIM REMEDIATION ALTERNATIVES
at
ARCO Station 6041
7249 Village Parkway
Dublin, California

for
ARCO Products Company

INTRODUCTION

As requested by ARCO Products Company (ARCO), RESNA Industries Inc. (RESNA) has prepared this Work Plan for Evaluation of Interim Remediation Alternatives for review and approval by the California Regional Water Quality Control Board (CRWQCB), and the Alameda County Health Care Services Agency (ACHCSA). This work plan summarizes work previously performed by RESNA and others, and describes the project steps proposed to evaluate interim soil and groundwater interim remediation alternatives.

The proposed work includes: obtaining well construction permits from the Alameda County Flood Control and Water Conservation District (ACFCWCD); drilling and installing two air-sparging wells (AS-1 and AS-2); drilling and installing one vapor-extraction well (VW-5); performing a one day air-sparging test; performing a one day combined air-sparging and vapor extraction test; and preparing a report summarizing the methods, results, and conclusions of this evaluation.

SITE DESCRIPTION AND BACKGROUND

General

ARCO Station 6041 is located at the northeastern corner of the intersection of Village Parkway and Amador Valley Boulevard in Dublin, California. The location is shown on Plate 1, Site Vicinity Map. The site is situated on a relatively flat, predominantly asphalt- and concrete-covered lot at an elevation of approximately 335 feet above mean sea level. Pertinent site features include four service islands (two located in the western portion of the site and two located in the southeastern portion of the site), a station building, four underground gasoline-storage tanks (USTs) in the southern portion of the site, and the former waste-oil tank pit adjacent to the northern wall of the station building in the northern portion of the site. Pertinent site features are shown on Plate 2, Generalized Site Plan.

Regional and Local Hydrogeology

ARCO Station 6041 is located in the northwestern end of the Livermore Valley, within the Coast Ranges Geomorphic Province of Northern California. The Livermore Valley is approximately 13 miles long and 4 miles wide elongated east-west and surrounded by foothills of the Diablo Range. In the vicinity of the site, the valley floor slopes gently to the south-southeast. Soil in the vicinity of the subject site is mapped as Holocene alluvium that consists of unconsolidated, moderately to poorly sorted silt and clay rich in organic material, interfingered with, and graded into, coarser grained stream deposits toward higher elevations (Helley and others, 1979). Holocene alluvium (estimated to be 10 to 50 feet thick) overlies Pleistocene alluvium, which consists of weakly consolidated, poorly sorted, irregularly interbedded clay, silt, sand and gravel, and older sedimentary deposits. The Calaveras Fault is situated approximately 1/2-mile west of the site.

The Livermore Valley groundwater basin is divided into subbasins on the basis of fault traces or other hydrogeologic discontinuities (California Department of Water Resources, 1974). The groundwater system in Livermore Valley is a multi-layered system with an unconfined aquifer overlying a sequence of leaky or semi-confined aquifers. The subject site is located within the Dublin groundwater subbasin. The groundwater in this subbasin has been reported to be at depths ranging from 10 to 60 feet below ground surface (Alameda County Flood Control and Water Conservation District [ACFCWCD]), January 16, 1991). The local groundwater flow direction is generally toward the south-southeast (ACFCWCD, January 16, 1991). The principal streams in the vicinity of the site are Alamo Canal situated about 2/3 of a mile southeast of the site, and Dublin Creek which joins Alamo Canal about 2/3 of a mile south of the site.

PREVIOUS WORK

Previous environmental work performed at the site is summarized Appendix A.

PROPOSED WORK

RESNA proposes performing project Steps 1 through 5, listed below, to evaluate interim soil and groundwater remediation alternatives beneath the subject site. Field work involved with the following project steps will be performed in accordance with RESNA's Field Protocol included in Appendix B, and a site specific safety plan.

Step 1 Obtain well construction permits from the ACFCWCD to install two air-sparging wells and one vapor-extraction well.

Step 2 Drill two soil borings (B-17 and B-18) to depths of approximately 20 (near the anticipated bottom of the shallowest water-bearing unit) and construct two 2-inch-diameter PVC air-sparging wells (AS-1 and AS-2) in the borings. Drill one soil boring to a depth of approximately 10 to 15 feet (near the anticipated top of the water-bearing unit) and construct a 4-inch-diameter vapor extraction well (VW-5) in the boring. The borings will be logged and soil samples collected by a RESNA geologist. Air-sparging well AS-1 will be located in the southwestern portion of the site and vapor well VW-5 will be located next to it. Air-sparging well AS-2 will be located in southern portion of the site near vapor extraction well VW-4, as shown on Plate 3, Proposed Well Locations. The air-sparging wells will be constructed using 2-inch-diameter schedule 40, polyvinyl chloride (PVC) blank and 0.020 inch, machine slotted PVC screen. The slotted section of the pipe will be limited to the bottom 2-½ feet of the well. The vapor extraction well will be constructed using 4-inch-diameter PVC blank and 0.1 inch, machine slotted PVC screen.

Step 3 Conduct a one-day air-sparging test to evaluate the feasibility of air-sparging as an interim soil and groundwater remedial alternative. Using an air compressor, the aquifer will be sparged by introducing air or a mixture of helium (He) and air (25% He) into air-sparging well AS-2 at different air flow rates and air pressures. At each air-sparging flow rate, induced soil-gas pressures at air-sparging well AS-2 and at observation wells VW-1, VW-2, VW-3, VW-4 and VW-5 will be recorded every 10 minutes to evaluate the radius of influence in the vicinity of the air-sparging well. Depth to water levels (DTW) in air-sparging well AS-1 and observation wells MW-1, MW-2 and MW-3 will also be recorded prior to the start of the test and during the test to measure changes in water levels as a result of sparging. If a mixture of He and air is used for sparging, piezometers constructed using 3/4-inch-diameter PVC casing with one foot of 0.020-inch machine slotted screen at the bottom will be installed in each monitoring well. Using an air sampling pump, a vacuum will be applied on each piezometer to extract sparge-off gas from the piezometer. The sparge-off gas will be monitored for He using a field He detector and/or air samples will be collected for laboratory analyses. Air sparging will continue on AS-2 for at least two hours at the air flow rate and pressure at which the highest responses are seen in air pressure in the vapor extraction wells, water levels in the monitoring wells, and He concentrations in the piezometers. Water samples will also be collected from AS-1, MW-1, MW-2, and MW-3 prior to sparging and after two hours of operation at the optimal air-sparging flow rate. These water samples will be analyzed for BTEX, TPHg, and dissolved oxygen (DO) to evaluate any observed changes as a result of sparging. BTEX and TPHg will be laboratory analyzed and DO will be measured using a field DO meter. Air samples will also be collected from vapor-extraction wells VW-1, VW-2 and VW-3 prior to sparging and after two hours of operation at each air-sparging flow rate. Air samples collected will be analyzed for BTEX and TPHg to evaluate changes in soil-gas hydrocarbon concentrations as a result of air-sparging. The test procedures detailed above will be repeated on air-sparge AS-1. Vapor wells VW-1 through VW-5 and monitoring wells MW-1 through MW-3 will be used as observations wells. Appendix A includes a more detailed description of field procedures performed during the air-sparge test.

Data from the air-sparging test will be used to evaluate optimal air flow rates necessary to perform a combined air-sparging/vapor-extraction test and the air-sparge capture zone associated with the selected flow rate. Air and groundwater samples collected during the test will be submitted with Chain of Custody Records to a State certified laboratory and analyzed for BTEX and TPHg using EPA Methods 5030/8020/8015.

Step 4 Conduct a one-day combined air-sparging and vapor-extraction test to evaluate whether vapor extraction is capable of capturing the air-sparge off-gas that is transmitted to the vadose zone. The combined test will be conducted using an internal combustion (I.C.) engine to generate the necessary vapor-extraction air flow rate from VW-4 (at least two times the optimal air-sparge flow rate), and abate extracted vapor. An air compressor will be used to introduce air or a mixture of 25% He in air into the aquifer through sparge well AS-2 at the optimal air-sparge flow rate measured during the air-sparging test described in Step 4 above. The combined test will be conducted for a period of four to five hours. Initially, only the vapor-extraction well VW-4 will be opened and a vacuum will be applied on VW-4 to create an expected air flow rate at least two times greater than the optimal sparge flow rate. Induced vacuum response readings will be recorded at observation wells VW-1, VW-2, and VW-3. Soil-gas samples from the vapor-extraction well and the observation wells will be collected for BTEX and TPHg analysis to measure initial extracted hydrocarbon vapor concentrations prior to air-sparging. Sparging will then be initiated at AS-2 at the optimum air-sparge flow rate for a period of four hours. All measurements including soil-gas pressure/vacuum, and DTW will be recorded from the air-sparging and observation wells. Air and water samples will be collected as described in the Step 4 above and evaluated for changes in BTEX, TPHg, and DO concentrations as a result of air-sparging and vapor-extraction. Monitoring wells MW-1, MW-2, and MW-3, will be used as observation wells to record changes in DTW, DO, BTEX, and TPHg concentrations. Vapor-extraction well VW-1, and observation wells VW-2, VW-3, and VW-5 will be used to record changes in soil-gas pressure/vacuum, and BTEX and TPHg concentrations in extracted soil-gas. If an air and He mixture is used for sparging, the presence of He will observed through piezometers using either a field He detector or by collecting samples for laboratory analyses. Appendix B includes a more detailed description of field procedures performed during the combined air-sparging and vapor-extraction test.

Step 5 Prepare a report summarizing field and laboratory procedures, findings, and conclusions.

SCHEDULE OF OPERATIONS

A preliminary time schedule to perform steps 1 through 5 is included as Plate 4, Preliminary Time Schedule. This time schedule is an estimate in weeks and is subject to change should circumstances dictate. ARCO and the appropriate regulatory agencies will be informed should there be delays and the Preliminary Time Schedule cannot be met. Initiation of this evaluation is dependent on gaining regulatory approval of the Work Plan and incorporation of any changes in this Work Plan requested by regulatory agencies. RESNA can initiate work at the site within 1 to 2 weeks after receiving authorization to proceed. **If ARCO has not received regulatory approval of this work plan within 60 days, they will proceed as stated in Title 23, Article 11, Chapter 16, Sections 2722 (b)(5) and 2726 (c).**

PROJECT STAFF

Mr. Mark E. Detterman or Mr. James L. Nelson, Certified Engineering Geologists in the State of California, will be in overall charge of hydrogeologic facets, and Mr. Richard Walls, Registered Civil Engineer, and/or Mr. Bruce Maeda, Registered Chemical Engineer, will be in overall charge of engineering facets of this project. Mr. John C. Young, Project Manager, will provide supervision of field and office operations of the project. RESNA employs a staff of geologists, engineers, and technicians who will assist with the project.

DISTRIBUTION

Copies of this Work Plan should be forwarded to:

Ms. Eva Chu
Alameda County Health Care Services Agency
Department of Environmental Health
80 Swan Way, Room 200
Oakland, California 94621

Mr. Richard Hiett
California Regional Water Quality Control Board
San Francisco Bay Region
2101 Webster Street, Suite 500
Oakland, California 94612

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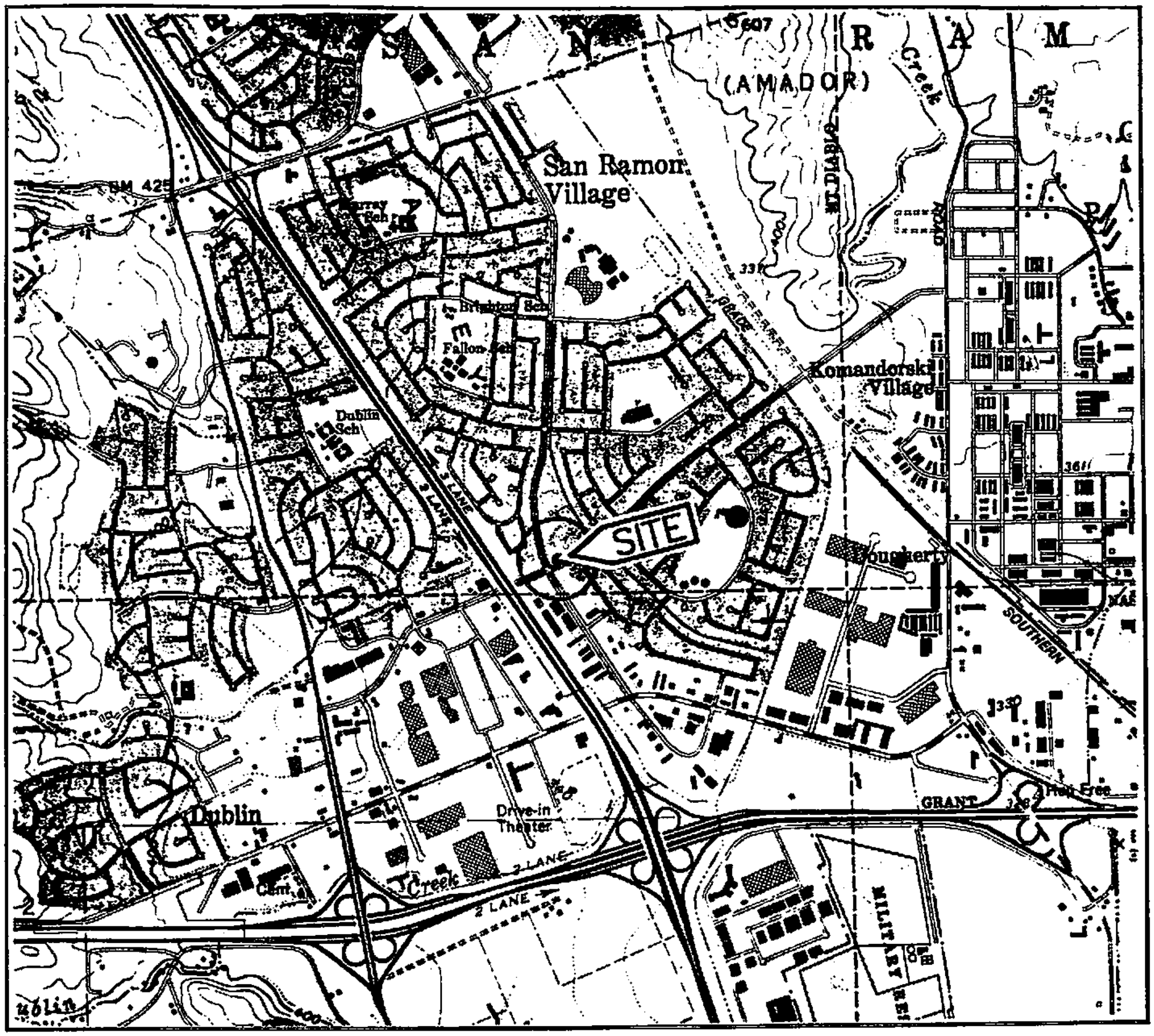

Base: U.S. Geological Survey
7.5-Minute Quadrangle
Dublin, California.
Photorevised 1980

LEGEND

(•) = Site Location

N

Approximate Scale

2000 1000 0 2000 4000

feet

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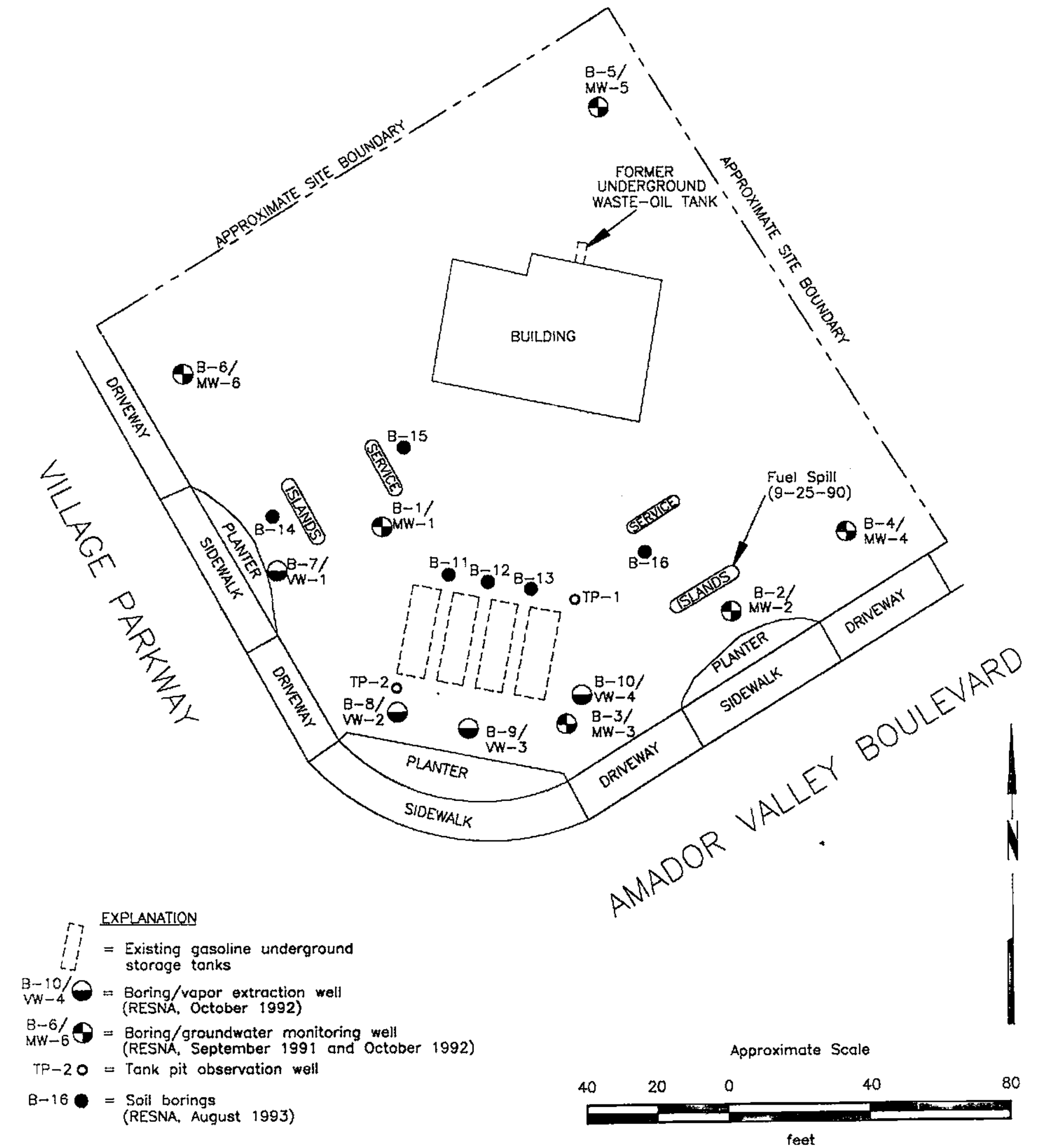
SITE VICINITY MAP
ARCO Service Station 6041
7249 Village Parkway
Dublin, California

PLATE
1



Source: Modified from plan supplied by ARCO.

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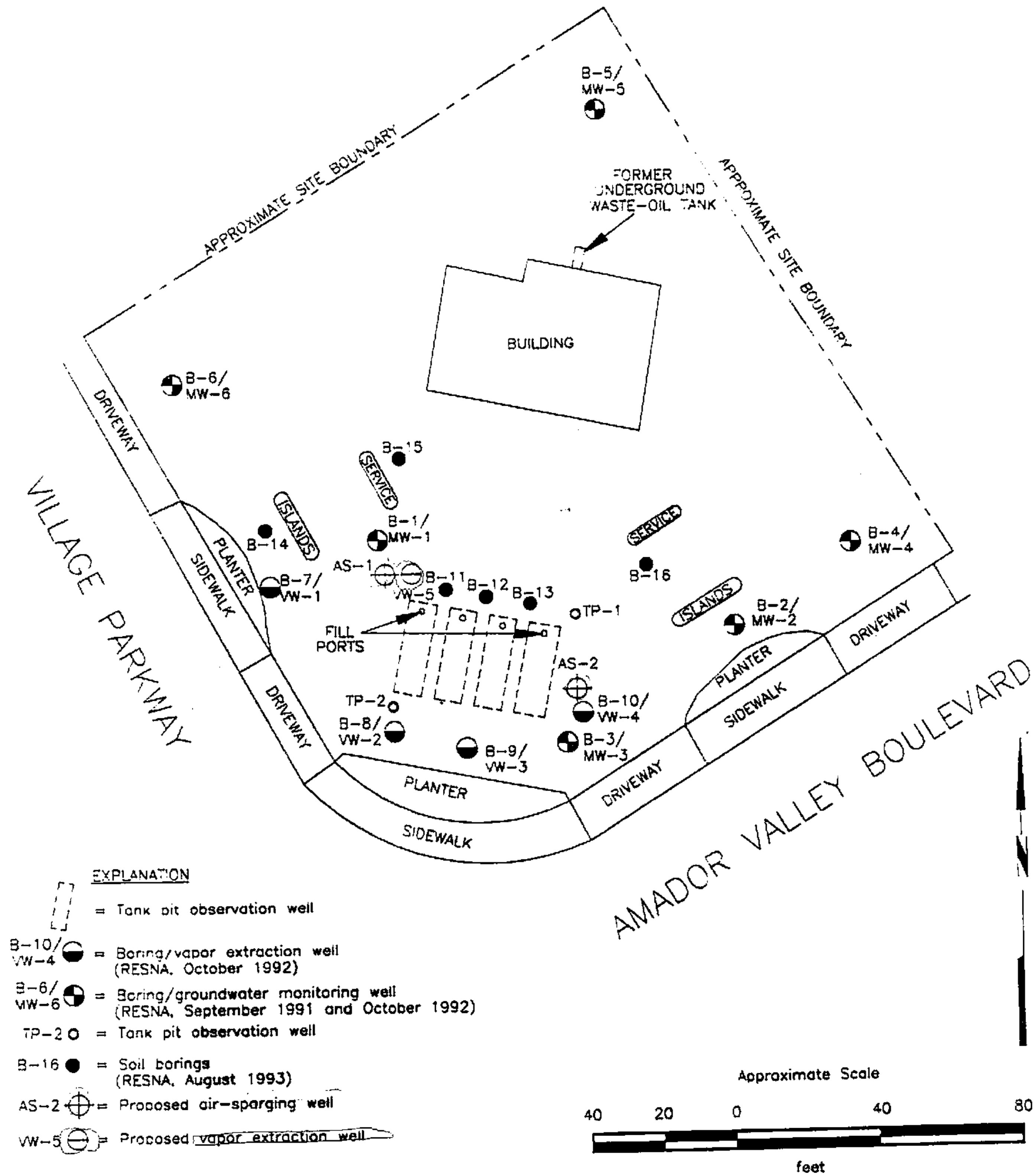
PROJECT 60006.04 60006-4G

GENERALIZED SITE PLAN
ARCO Service Station 6041
7249 Village Parkway
Dublin, California

PLATE 2



Source: Modified from plan supplied by ARCO.

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PROJECT 60006.04 600064-A

PROPOSED WELL LOCATIONS
ARCO Service Station 6041
7249 Village Parkway
Dublin, California

PLATE

3

STEP 1:
Obtain permits to install air-sparging wells and a vapor extraction well.

STEP 2:
Drill borings and install air-sparging wells and a vapor extraction well.

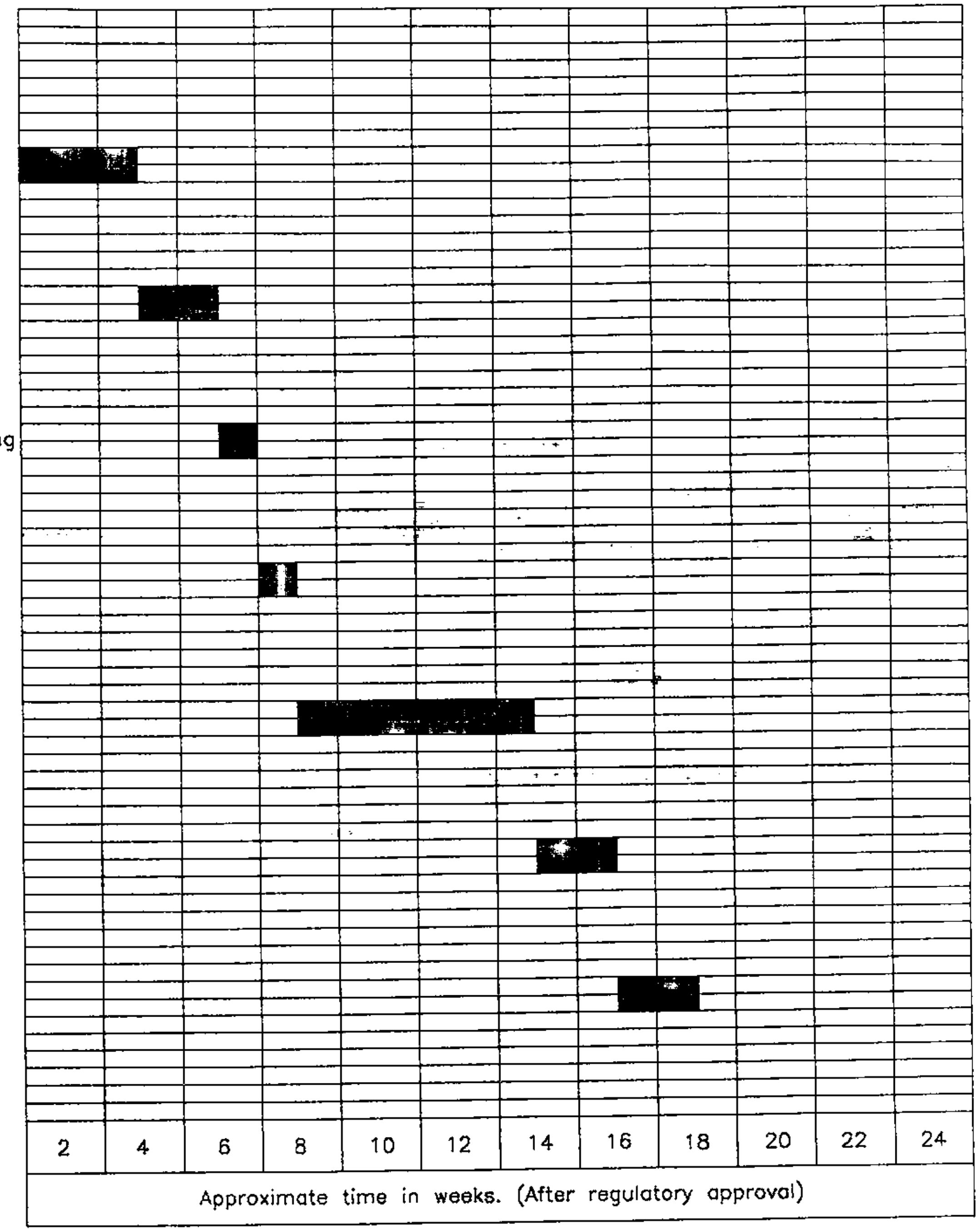
STEP 3:
Conduct a one-day air-sparging test.

STEP 4:
Conduct a one-day combined air-sparging vapor extraction test.

STEP 5a:
Receive analytical results and prepare draft report.

STEP 5b:
ARCO review of draft report.

STEP 5c:
Issue final report.



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PROJECT 60006.04

PRELIMINARY TIME SCHEDULE
ARCO Station 6041
7249 Village Parkway
Dublin, California

PLATE 4

APPENDIX A

PREVIOUS ENVIRONMENTAL WORK

PREVIOUS ENVIRONMENTAL WORK

Waste-Oil Tank Removal

On June 6 and 7, 1990, one 550-gallon waste-oil tank of single wall steel construction was excavated and removed from its location adjacent to the northern wall of the station building at the site. A RESNA geologist examined the outer surface of the tank for signs of leakage, holes, pitting, and areas of weakness. The tank appeared to be in good condition; the geologist observed light localized rusting on the surface of the tank, but no pitting, holes or cracks were observed. No signs of overfill staining were observed on the top and sides of the tank (Applied GeoSystems, September 19, 1990). Information supplied by the station manager indicated that the tank was at least 13 years old.

Soil excavated from the tank pit was screened for evidence of volatile hydrocarbon compounds, both visually and with a portable Organic Vapor Meter (OVM). Initial random screening of backfill material excavated from around the tank yielded OVM readings ranging from nondetectable to 0.8 parts per million (ppm). Excavation proceeded beneath the former tank location to a final depth of approximately 10-1/2 feet. At the limits of the excavation, random grab samples yielded nondetectable readings from the north, south, east and west walls and an OVM reading of 3.25 ppm from the center of the tank pit. No subjective evidence of hydrocarbons such as product odor or soil discoloration was noted in the backfill material or native soil during the excavation process.

Ten soil samples were collected from the tank pit excavation. Two samples were collected from each of the four sidewalls of the tank pit, and two samples were collected from the center of the tank pit floor at the limits of the excavation. The samples were divided into two sets, A and B, with each set consisting of five samples: one from each of the sidewalls, and one from the floor of the tank pit. The samples in set A were analyzed for total oil and grease (TOG) and halogenated volatile organic compounds (HVOCs). The samples in set B were analyzed for total petroleum hydrocarbons as gasoline (TPHg) and TPH as diesel (TPHd), and the gasoline constituents benzene, toluene, ethylbenzene, and total xylenes (BTEX). Four soil samples for compositing and laboratory analyses were collected from the soil stockpile. Analyses of the soil samples collected from the waste-oil tank pit indicated nondetectable levels of TOG, HVOCs, TPHg, TPHd, and BTEX. Approximately 15 to 20 cubic yards of soil were excavated from the tank pit. According to information obtained from ARCO, the soil stockpile was removed from the site by Dillard Trucking, Inc. of Hayward, California and admitted to Chem-Waste Management's facility in Kettleman City on June 12, 1990. On the basis of field observations and the results of analyses of tank pit soil samples, RESNA concluded that no further excavation in the vicinity of the former waste-oil tank was necessary.

Fuel Spill Sampling

On September 25, 1990, a RESNA geologist attempted to collect a soil sample at a reported fuel spill beneath a dispenser pump in the southeastern portion of the site We understand that the spill occurred when a station customer failed to remove the hose from the vehicle after use. The vehicle drove off pulling the hose from the pump. This in turn caused a filter in the pump to fail resulting in a relatively small release of gasoline from the pump. The dispenser pump made collection of a soil sample impractical; however, pea gravel beneath the pump was removed. The OVM reading for the pea gravel sample collected from the depth of ½-foot beneath the pump where the spillage occurred was 750 ppm. Mr. Tom Hathcox of the Dogherty Regional Fire Department estimated that approximately 10 gallons of fuel spilled on the ground. We understand from the station manager that the pump was turned off shortly after the hose was pulled off the pump.

Subsurface Environmental Investigation

In September 1991, RESNA performed a subsurface environmental investigation to evaluate the impact of hydrocarbons released during the fuel spill, which occurred in September 1990, on the soil and groundwater beneath the subject site (RESNA, February 12, 1992). Work performed for this investigation included drilling three soil borings (B-1 through B-3), collecting and describing soil samples from the borings, installing and developing three 4-inch-diameter groundwater monitoring wells (MW-1 through MW-3) in the borings, sampling groundwater from the monitoring wells, performing laboratory analyses on selected soil and groundwater samples, measuring groundwater levels, surveying wellhead elevations, and preparing the report presenting field procedures, results, and conclusions.

Results of the investigation indicated that the soil beneath the site has been impacted by gasoline hydrocarbons, however TPHg concentrations over 100 ppm were not reported in the soil samples collected from the borings, with the exception of one sample from a depth of 9-1/2 feet in B-1 (150 ppm) located near the southwestern service islands. The soil in the vicinity of the southeastern service islands, where the unauthorized fuel spill reportedly occurred in September 1990, has been impacted by low levels of gasoline hydrocarbons (less than 10 ppm of TPHg). Based on the findings of this investigation, the lateral extent of gasoline hydrocarbons in the soil at the site had not been delineated below 10 ppm except in the southeastern part of the site. However, the vertical extent of gasoline hydrocarbons in the soil appeared to have been delineated to nondetectable levels (less than 1 ppm) at the depth of approximately 14-1/2 to 19-1/2 feet below ground surface.

Shallow groundwater was encountered at the site in a relatively thin (2 to 3 feet thick) clayey sand layer at a depth of approximately 10-1/2 to 15 feet and stabilized in the wells at depths of approximately 9 to 11 feet. Groundwater gradient direction was interpreted to be toward the southwest.

Results of the investigation indicated that the first encountered groundwater beneath the site has been impacted by gasoline hydrocarbons at concentrations up to 990 ppb TPHg and up to 50 ppb benzene. The benzene concentrations in all three wells exceeded the State of California Maximum Contaminant Level (MCL). Ethylbenzene and total xylene concentrations were below MCLs in the wells, and toluene concentrations were below the recommended Drinking Water Action Level (DWAL) in wells MW-1 and MW-2 and at the DWAL in well MW-3. The extent of gasoline hydrocarbons in the groundwater was not delineated.

Based on the results of the investigation, RESNA concluded that the fuel spill which occurred on September 25, 1990, did not appear to be the sole source of gasoline hydrocarbons detected beneath the site.

<u>Additional Onsite Subsurface Investigation and Vapor Extraction Test</u>

On October 26 and 27, 1992, RESNA performed a subsurface investigation to further delineate the extent of gasoline hydrocarbons in the soil and groundwater at the subject site, and to prepare for a vapor extraction test (VET) to be performed on November 10, 1992 (RESNA, January 29, 1993). Work performed for this investigation included drilling seven soil borings (B-4 through B-10), collecting and describing soil samples from the borings, installing and developing three 4-inch-diameter groundwater monitoring wells (MW-4 through MW-6) in borings B-3 through B-6, installing four 4-inch-diameter vapor extraction wells (VW-1 through VW-4) in borings B-7 through B-10, sampling groundwater from the monitoring wells, performing laboratory analyses on selected soil and groundwater samples, measuring groundwater levels, surveying wellhead elevations, and preparing the report presenting field procedures, results, and conclusions of the subsurface investigation and the VET.

Laboratory analytical results of soil samples from borings B-3 through B-7, located in the northern, northwestern and southeastern portions of the site indicated concentrations less than the laboratory method detection limits (MDLs) for TPHg (1.0) and BTEX (0.0050).

Results for soil samples collected from borings B-8 through B-10, located in the southern portion of the site, indicated concentrations of TPHg ranging from less than the laboratory MDL to 3,200 ppm, and concentrations of BTEX ranging from less than the laboratory MDL to 390 ppm.

Shallow groundwater was encountered at the site at depths of approximately 10 to 15 feet and appeared to be partially confined. Laboratory analytical results from the groundwater samples collected from monitoring wells MW-4 through MW-6 indicated concentrations of TPHg and BTEX to be less than the laboratory MDLs (50 ppb and 0.5 ppb, respectively).

Laboratory analytical results of air samples from vapor wells VW-1 through VW-4 indicated concentrations of TPHg ranged from 6,600 to 110,000 mg/m^3, with the greatest concentrations present in the vicinity of VW-4. Effective radius of influence's (ROI's) ranged from approximately 10 to 40 feet during the VET at an applied vacuum of 50 inches water column (WC) and an air flow ranging from about 60 to 81 standard cubic feet per minute (scfm) at each vapor well.

Results of the soil borings and groundwater monitoring wells indicated that the soil and groundwater beneath the northern, northwestern, and southeastern portions of the site had not been impacted by gasoline hydrocarbons. Results of the VET indicated that vapor extraction could be a viable soil remediation alternative for the remediation of gasoline hydrocarbons from onsite soils.

Groundwater Monitoring and Sampling

RESNA began monthly groundwater monitoring in October 1991 and quarterly sampling in December 1992 at the site. Data from these and subsequent groundwater monitoring and sampling episodes are summarized in the reports listed in the References section. Groundwater monitoring wells MW-1 through MW-3 continued to contain significant concentrations of TPHg (up to 6,400 ppb), however concentrations of TPHg in wells MW-4 through MW-6 have remained nondetectable since the wells were installed in November of 1992. The interpreted local groundwater gradient remains relatively flat with a variable flow direction. RESNA is involved in a joint monitoring program in conjunction with the consultants for British Petroleum (BP), UNOCAL, and Shell, which are also located at the intersection of Village Parkway and Amador Valley Boulevard in Dublin, California.

APPENDIX B

FIELD PROTOCOL

FIELD PROTOCOL

The following presents RESNA protocol for a typical site investigation involving gasoline hydrocarbon-impacted soil and/or groundwater.

Site Safety Plan

The Site Safety Plan describes the safety requirements for the evaluation of gasoline hydrocarbons in soil and groundwater at the site. The site Safety Plan is applicable to personnel of RESNA and its subcontractors. RESNA personnel and subcontractors of RESNA scheduled to perform the work at the site are to be briefed on the contents of the Site Safety Plan before work begins. A copy of the Site Safety Plan is available for reference by appropriate parties during the work. A site Safety Officer is assigned to the project.

Sampling of Stockpiled Soil

One composite soil sample is collected for each 50 cubic yards of stockpiled soil, and for each individual stockpile composed of less than 50 cubic yards. Composite soil samples are obtained by first evaluating relatively high, average, and low areas of hydrocarbon concentration by digging approximately one to two feet into the stockpile and placing the intake probe of a field calibrated OVM against the surface of the soil; and then collecting one sample from the "high" reading area, and three samples from the "average" areas. Samples are collected by removing the top one to two feet of soil, then driving laboratory-cleaned brass sleeves into the soil. The samples are sealed in the sleeves using aluminum foil, plastic caps, and aluminized duct tape; labeled; and promptly placed in iced storage for transport to the laboratory, where compositing will be performed.

Soil Borings

Prior to the drilling of borings and construction of monitoring wells, permits are acquired from the appropriate regulatory agency. In addition to the above-mentioned permits, encroachment permits from the City or State are acquired if drilling of borings offsite in the City or State streets is necessary. Copies of the permits are included in the appendix of the project report. Prior to drilling, Underground Services Alert is notified of our intent to drill, and known underground utility lines and structures are approximately marked.

The borings are drilled by a truck-mounted drill rig equipped with 8- or 10-inch-diameter, hollow-stem augers. The augers are steam-cleaned prior to drilling each boring to minimize the possibility of cross-contamination. After drilling the borings, monitoring wells are constructed in the borings, or neat-cement grout with bentonite is used to backfill the borings to the ground surface.

Borings for groundwater monitoring wells are drilled to a depth of no more than 20 feet below the depth at which a saturated zone is first encountered, or a short distance into a stratum beneath the saturated zone which is of sufficient moisture and consistency to be judged as a perching layer by the field geologist, whichever is shallower. Drilling into a deeper aquifer below the shallowest aquifer can begin only after a conductor casing is properly installed and allowed to set, to seal the shallow aquifer.

Drill Cuttings

Drill cuttings subjectively evaluated as having hydrocarbon contamination at levels greater than 100 parts per million (ppm) are separated from those subjectively evaluated as having hydrocarbon contamination levels less than 100 ppm. Evaluation is based either on subjective evidence of soil discoloration, or on measurements made using a field calibrated OVM. Readings are taken by placing a soil sample into a ziplock type plastic bag and allowing volatilization to occur. The intake probe of the OVM is then inserted into the headspace created in the plastic bag immediately after opening it. The drill cuttings from the borings are placed in labeled 55-gallon drums approved by the Department of Transportation; or on plastic at the site, and covered with plastic. The cuttings remain the responsibility of the client.

Soil Sampling in Borings

Soil samples are collected at no greater than 5-foot intervals from the ground surface to the total depth of the borings. The soil samples are collected by advancing the boring to a point immediately above the sampling depth, and then driving a California-modified, split-spoon sampler containing brass sleeves through the hollow center of the auger into the soil. The sampler and brass sleeves are laboratory-cleaned, steam-cleaned, or washed thoroughly with Alconox® and water, prior to each use. The sampler is driven with a standard 140-pound hammer repeatedly dropped 30 inches. The number of blows to drive the sampler each successive six inches are counted and recorded to evaluate the relative consistency of the soil.

The samples selected for laboratory analysis are removed from the sampler and quickly sealed in their brass sleeves with aluminum soil and plastic caps. The samples are then labeled, promptly placed in iced storage, and delivered to a laboratory certified by the State of California to perform the analyses requested.

One of the samples in brass sleeves not selected for laboratory analysis at each sampling interval is tested in the field using an OVM that is field calibrated at the beginning of each day it is used. This testing is performed by inserting the intake probe of the OVM into the headspace created in the plastic bag containing the soil sample as described in the Drill Cuttings section above. The OVM readings are presented in Logs of Borings included in the project report.

Logging of Borings

A geologist is present to log the soil cuttings and samples using the Unified Soil Classification System. Samples not selected for chemical analysis, and the soil in the sampler shoe, are extruded in the field for inspection. Logs include texture, color, moisture, plasticity, consistency, blow counts, and any other characteristics noted. Logs also include subjective evidence for the presence of hydrocarbons, such as soil staining, noticeable or obvious product odor, and OVM readings.

Vapor Extraction Well Construction

Vapor Extraction wells are constructed in selected borings using clean 4-inch-diameter, thread-jointed, Schedule 40 polyvinyl chloride (PVC) casing. No chemical cements, glues, or solvents are used in well construction. Each casing bottom is sealed with a threaded end-plug, and each casing top with a locking plug. The screened portions of the wells are constructed of machine-slotted PVC casing with 0.020-inch-wide (typical) slots for initial site wells. Slot size for subsequent wells may be based on sieve analysis and/or well development data.

The annular space of each well is backfilled with No. 2 by 12 sand, or similar sorted sand, to approximately two feet above the top of the screened casing for initial site wells. The sand pack grain size for subsequent wells may be based on sieve analysis and/or well development data. A 1- to 2-foot-thick bentonite plug is placed above the sand as a seal against cement entering the filter pack. The remaining annulus is then backfilled with a slurry of water, neat cement, and bentonite to approximately one foot below the ground surface.

An aluminum utility box with a PVC apron is placed over each wellhead and set in concrete placed flush with the surrounding ground surface. Each wellhead cover has a seal to protect the well against surface-water infiltration and requires a special wrench to open. The design discourages vandalism and reduces the possibility of accidental disturbance of the well.

Sample Labeling and Handling

Sample containers are labeled in the field with the job number, sample location and depth, and date, and promptly placed in iced storage for transport to the laboratory. A Chain of Custody Record is initiated by the field geologist and updated throughout handling of the samples, and accompanies the samples to a laboratory certified by the State of California for the analyses requested. Samples are transported to the laboratory promptly to help ensure that recommended sample holding times are not exceeded. Samples are properly disposed of after their useful life has expired.

Air-Sparge Testing

Air-sparging involves the injection of air below the water table surface so that dissolved hydrocarbons and adsorbed hydrocarbons are stripped from the groundwater and saturated soils and moved upward into the vadose zone. Vapors transmitted to the vadose zone are captured by applying a vacuum to the vapor extraction wells. The capture zone of an air-sparging well and the number of air-sparging wells necessary to provide site coverage is highly influenced by the permeability of the sediments below and above the groundwater surface. A field air-sparging test is necessary to evaluate a site specific capture zone for air-sparging, the number of air-sparging wells required to provide site coverage, optimal air-sparge flow rates, and hydrocarbon removal rates.

The air-sparging well(s) typically consist of a 2-inch-diameter polyvinyl chloride (PVC) pipes with 0.020 inch, machine slotted PVC screen. The slotted sections of the pipes are limited to the bottom 2.5 feet of the pipe. The 2-inch diameter PVC pipe is installed to the bottom of the aquifer that is to be air-sparged. Sparge monitoring points typically consist of existing groundwater monitoring wells (2-inch Schedule 40 PVC pipe with 0.020 inch slots) that are screened at least 5 feet into the groundwater table, and existing vapor-extraction wells (4-inch Schedule 40 PVC pipe with 0.020 inch) that are screened above the water table. The groundwater monitoring wells are used to evaluate changes in water levels and dissolved hydrocarbon and oxygen concentrations during sparging, and the vapor extraction wells are used to measure changes in soil-gas pressure and soil-gas hydrocarbon concentrations as a result of air-sparging.

To obtain baseline data, prior to performing the air-sparge test, static water levels and ambient soil-gas pressures are recorded from the air-sparging well(s), and vapor extraction and groundwater monitoring wells. Other base-line data collected prior to the start of the air-sparging test include: soil-gas hydrocarbon concentrations in all vapor extraction wells based on analytical results of air samples collected from these wells using an air sampling pump; and initial dissolved hydrocarbon and dissolved oxygen (DO) concentrations based on analytical results of water samples collected from all air-sparging and groundwater monitoring wells. Air and groundwater samples are analyzed for BTEX and TPHg in a laboratory while dissolved oxygen is measured using a field DO meter.

Using an oil-less air compressor, air-sparging in performed by introducing air, or a mixture of 25% Helium in air, is initiated at an air flow rate of 25 cubic feet per minute (cfm) into the air-sparging well. The test procedure is repeated at different air-sparge flow rates at each air-sparge well to evaluate the optimal sparge flow rate at which the greatest responses in water levels and dissolved hydrocarbon and oxygen concentrations are observed in monitoring and vapor extraction wells. Tests are run for ½-hour at each sparge flow rate. A long-term test is run for two hours at the optimal air-sparge flow rate. The results from the air-sparging test are used to evaluate optimum air-sparge flow rates that will be used during the combined air-sparging and vapor-extraction test and to evaluate the air-sparge capture zone associated with the selected air-sparging flow rate for each air-sparging well. To evaluate the radius of influence (capture zone) of the air-sparging well, soil-gas pressure at the air-sparge well and the vapor monitoring wells is recorded periodically (typically every 10 minutes) throughout each ½-hour test on each well using magnehelic gauges.

Depth to water levels (DTW) are measured in the air-sparging well and groundwater monitoring wells during each test (every half hour) to evaluate changes in water levels as a result of air-sparging. Water samples are collected from the air-sparge well and groundwater monitoring wells after one and a half hours of operation at each air-sparging flow rate. These water samples are analyzed for BTEX and TPHg and dissolved oxygen (DO) to evaluate changes that may occur as a result of air-sparging. Air samples are also collected from the vapor monitoring points typically after one-half hour of operation at each air-sparging flow rate. Air samples collected are analyzed for BTEX and TPHg to evaluate any changes in soil-gas hydrocarbon concentrations as a result of air-sparging. Soil-gas concentrations in the vapor-monitoring wells before and during the air-sparging tests are also measured using a field organic-vapor measuring instrument, such as a PID or a flame-ionization detector (FID). Air and groundwater samples collected during the test are submitted with Chain of Custody Records to a State certified laboratory and analyzed for BTEX and TPHg using EPA Methods 5030/8020/8015.

Combined Air-Sparging and Vapor-Extraction Test

The combined air-sparging and vapor-extraction test is conducted to evaluate whether vapor extraction is capable of capturing the air-sparge off-gas that is transmitted from the aquifer to the vadose zone as a result of air-sparging. The combined test is conducted using an internal combustion (I.C.) engine and/or a vacuum blower with activated carbon to generate the necessary vapor-extraction air flow rates from the vapor extraction well(s) and abate extracted vapor. An oil-less air compressor is used to sparge the aquifer by introducing air into the air-sparge well (s) at the optimum air-sparge flow rates measured during the air-sparging-only tests. The combined test is conducted for a period of four hours on each vapor-extraction well. To create a vacuum zone that extends beyond the radius of influence of the air-sparge well, a vacuum is applied on the vapor extraction well closest to the air-sparge well to generate a vapor-extraction flow rate of at least two times the optimal air-sparge flow rate.

To obtain baseline data prior to performing the combined test, DTW levels and DO concentrations are measured and recorded using a water-level indicator and a DO meter in the air-sparge well(s) and groundwater monitoring wells. Initially, only the vapor-extraction well is opened and induced vacuum readings at the extraction well and at the vapor monitoring points are recorded. Soil-gas samples from vapor-extraction and the vapor monitoring wells are collected for BTEX and TPHg to evaluate extracted hydrocarbon vapor concentrations prior to the start of sparging. Soil-gas concentrations are also monitored using an FID or a PID. Sparging is then initiated in an air-sparge well located close to the vapor-extraction well using the optimum air-sparge flow rate measured during the air-sparging-only test for a period of four hours. The following measurements are recorded every half hour during the combined test; induced soil-gas pressure/vacuum readings in vapor-monitoring wells using magnehelic gauges, and DTW levels in air-sparging well(s) and groundwater monitoring wells. Air and water samples, as described in the air-sparging-only test, are collected after three hours of operation from air-sparging well(s), vapor-extraction well(s), vapor monitoring wells and groundwater monitoring wells and evaluated for changes in BTEX, TPHg, and DO concentrations as a result of air-sparging and vapor-extraction.

Data collected from the combined air-sparging and vapor-extraction test will be used to evaluate the following: the number of air-sparge and vapor-extraction wells necessary to affect areas of concern at the site; the optimum sparge and vapor-extraction flow rates necessary for vapor-extraction to effectively capture the air-sparge off-gas and limit offsite migration of dissolved hydrocarbons; the changes in extracted hydrocarbon vapor concentrations observed as a result of air-sparging; estimated initial hydrocarbon removal rates; and the sizes and types of blower and air compressors and vapor abatement devices necessary to extract and abate extracted hydrocarbon vapors.