RESNA
Working To Restore Nature

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San Jose, CA 95118
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TRANSMITTAL

TO: Mr. Eddy So
Regional Water Quality Control Board
San Francisco Bay Region
2101 Webster Street, Suite 500
Oakland, CA 94612

DATE: July 15, 1993
PROJECT NUMBER: 69028.11
SUBJECT: ARCO Station No. 6113

FROM: Valli Voruganti

WE ARE SENDING YOU:

COPIES	DATED	DESCRIPTION
1	7/15/93	Final Addendum Three to Work Plan for Installation of Air Sparge Wells and Performance of an Air Sparge Test at ARCO Station No. 6113, 785 East Stanley Boulevard, Livermore, California.

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REMARKS:
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Keith McVail for
Valli Voruganti, Project Engineer

RESNA
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ADDENDUM THREE TO WORK PLAN
for
INSTALLATION OF AIR SPARGE WELLS AND PERFORMANCE OF AN AIR SPARGE TEST
at
ARCO Station 6113
785 E. Stanley Boulevard
Livermore, California

Jul 93   01-0119

69028.11

Prepared by
RESNA Industries Inc.

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

B. Maeda for
Valli Voruganti
Project Engineer

Keith McVicker
Keith Mc Vicker
Project Geologist

Bruce Maeda
Bruce Maeda, P.E.
Project Engineer

July 15, 1993

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ADDENDUM THREE TO WORK PLAN for INSTALLATION OF AIR SPARGE WELLS AND PERFORMANCE OF AN AIR SPRAGE TEST at ARCO Station 6113 785 E. Stanley Boulevard Livermore, California

for
ARCO Products Company

INTRODUCTION

As requested by ARCO Products Company (ARCO), RESNA Industries Inc. (RESNA) has prepared this Addendum Three to RESNA's previous Work Plan (RESNA, October 17, 1991) to install air sparge wells and perform an air sparge test at the subject site. The location of the subject site is shown on the Site Vicinity Map, Plate 1. This Addendum Three to Work Plan will be submitted for review and approval to the Regional Water Quality Control Board (RWQCB), and the Alameda County Health Care Servcies Agency (ACHCSA).

This work plan was initiated at the request of Ms. Susan Hugo of ACHCSA in the May 19, 1993, meeting with RESNA and ARCO personnel (RESNA June 7, 1993) in lieu of an aquifer pump and recovery test previously proposed under Addendum Two to Work Plan (RESNA, December 29, 1992). A revised time schedule of July 15, 1993, was established during the May 19, 1993 meeting, for submission of this Addendum Three to Work Plan. **No time deadlines were established at the May 19, 1993, meeting for installation of the air sparge wells and performance of an air sparge test at the subject site.** No deadlines were established since the middle and deeper zones have been flooded since January 1993 as a result of rising water table elevations (from 62 feet below ground surface [bgs] to 20 feet bgs) rendering the wells incapable of capturing sparge off-gas generated as a result of sparging the deeper water bearing zone (43 feet bgs and below).

This work plan and the reports listed in the references section of this work plan summarize previous work performed at the subject site and RESNA's approach, field methods, and project steps recommended to install one air-sparge well and perform an air-sparge test to evaluate if sparging is a feasible interim soil and groundwater remediation alternative at the above referenced site. The proposed work includes: performing monthly groundwater to determine if water table elevations have decreased enough to allow for capture of the sparge off-gas by vapor extraction wells; obtaining well construction permits from the City of Livermore; drilling and installing one air-sparge well (AS-1); performing a one day air sparge test; performing a one day combined air sparge and vapor extraction test (VET); and preparing a report summarizing the methods, results, and conclusions of the investigation.

SITE DESCRIPTION AND BACKGROUND

General

ARCO Service Station 6113 is an operating retail gasoline service station and AM/PM mini-mart located at the southwestern corner of E. Stanley Boulevard and Mureitta Boulevard in Livermore, California, as shown on Plate 1, Site Vicinity Map. The site is located in an area of commercial and residential development, and is a predominantly asphalt- and concrete-covered lot at an elevation of approximately 457 feet above mean sea level. The site is bounded by E. Stanley Boulevard to the north, Murrieta Boulevard to the east, and the Arroyo Mocho Creek to the south and west. An operating Shell Service Station is located on the southeastern corner of E. Stanley Boulevard and Mureitta Boulevard.

Underground Storage Tanks (USTs)

Two double-wall and one single wall 12,000-gallon gasoline USTs are present on the site. On January 26, 1989, a 280 gallon waste-oil storage tank was excavated and removed from the site (Pacific Environmental Group, April 25, 1989). The former waste-oil tank location is covered by a large concrete utility-pad. From December 1992 through March 1993, Wilkey's

Engineering (Wilkey) of Pleasant Grove, California, under the supervision of Roux Associates, removed and replaced existing product, vapor return and vent lines. In conjunction with this work, the abandoned pump island facing Murietta Boulevard was placed back into operation, and subgrade remediation piping for the interim VES and groundwater remediation system was installed (Roux Associates, May 7, 1993). The approximate locations of the existing USTs, former waste-oil tank, and pertinent station facilities are shown on Plate 2, Generalized Site Plan.

Regional Geology and Hydrogeology

The site is located in the Livermore Valley, which is an intermontane valley in the Coast Ranges geomorphic province. The valley is approximately 13 miles long in an east-west direction and is four miles wide. The valley is surrounded by hills of the Diablo Range (California Department of Water Resources, 1974). The valley floor slopes gently toward the west. The principal streams in the area are the Arroyo Valley and Arroyo Mocho, which flow toward the western end of the valley. Arroyo Mocho is approximately 50 feet south-southwest of the site.

Livermore Valley is underlain by non-water-bearing rocks, water-bearing units, and sediments. The water-bearing units and sediments comprise the Livermore Valley groundwater basin. Water-bearing units include the Tassajara Formation, the Livermore Formation, and valley-fill materials (California Department of Water Resources, 1966, 1974). The Livermore Valley groundwater basin is divided into sub-basins on the basis of fault traces or other hydrologic discontinuities (California Department of Water Resources, 1974). The groundwater system in Livermore Valley is a multilayered system with an unconfined aquifer overlying a sequence of leaky or semiconfined aquifers. Groundwater in the basin flows downslope toward the east-west-trending axis of the valley and then flows generally to the west (Alameda County Flood Control and Water Conservation District - Zone 7, 1991).

PREVIOUS WORK

Previous work performed at the site prior to the ongoing additional onsite and initial offsite subsurface investigation is presented in Appendix A of the Additional Offsite Subsurface Investigation Report (RESNA, December 21, 1992) and in the reports listed in the References section of this Addendum Three to Work Plan. A summary of the ongoing additional onsite and initial offsite subsurface investigation is presented below.

Ongoing Additional Subsurface Investigation

In accordance with proposed work steps outlined in Addendum Two to Work Plan submitted to ACHCSA, RESNA has installed the proposed onsite monitoring well MW-10 and the offsite monitoring wells MW-11 and MW-12 in March 1993 (RESNA, December 29, 1992). Plate 2 depicts the location of these wells. Proposed onsite vapor extraction wells VW-3 and VW-4 screened 15 to 24 feet bgs and 17 to 30 feet bgs, respectively, were installed in June 1993. Proposed vapor extraction well VW-5 was not installed in boring B-15 due to the lack of any visual evidence of permeable soils in the boring and the lack of measurable organic vapor concentrations in the soils as monitored with a photo-ionization detector (PID). A report on the initial offsite and additional onsite investigation detailed above is currently in progress and will be submitted for review and approval to ARCO, RWQCB and ACHCSA by August 15, 1993.

As agreed to in the May 19, 1993, meeting between ARCO, RESNA and ACHCSA personnel, the earlier proposed aquifer pump and recovery test presented in Addendum Two to Work Plan (RESNA, December 29, 1993) will no longer be performed. In lieu of the aquifer test, air sparge wells will be installed and an air sparge test will be performed (RESNA, June 7, 1993).

SUMMARY OF SOIL AND GROUNDWATER CONTAMINATION

Site Geology

Results of previous investigations have indicated that subsurface materials encountered at this site consist primarily of silty clay to gravelly silt interbedded with discontinuous layers of clayey to sandy gravel and clayey sand. These discontinuous layers extend across the site and divide the subsurface soils in the vicinity of the USTs into three approximate zones: a shallow zone occurring at approximate depths of 16 to 28 feet bgs; a middle zone at depths of 26 to 45 feet bgs; and a deeper zone occurring at approximate depths of 43 to 70 feet bgs.

Groundwater Gradient

The interpreted groundwater gradient from the March 30, 1993 monitoring event is shown on Plate 3, Groundwater Gradient Map. The average local groundwater gradient interpreted for the most recent quarter was approximately 0.1 ft/ft, with flow directions toward the northwest in January and February, and toward the north in March 1993.

The groundwater elevation in monitoring well MW-4 (in the shallow zone) increased an average of 7 feet since the fourth quarter 1992 (DTW levels rose from 27 ft bgs to 20 ft bgs). Groundwater elevations in monitoring wells MW-1, MW-2, and MW-3 screened in the middle zone soils (26 to 45 ft bgs) increased an average of 9 feet since the fourth quarter 1992 (DTW levels rose from 30 ft bgs to 20 ft bgs). Groundwater elevations in monitoring wells MW-5 through MW-9 screened in the deeper zone soils (43 ft bgs and below) increased an average of 40 feet since the fourth quarter 1992 (DTW levels rose from 62 ft bgs to 20 ft bgs). Observed increases in groundwater elevations since fourth quarter 1992 appear to be the result of heavy precipitation during first quarter 1993.

Rise in DTW levels (to 20 feet bgs) was observed in all onsite monitoring wells, irrespective of the screened interval. These rises in DTW indicate that the interbedded discontinuous layers of clayey to sandy gravel and clayey sands across the site at different depths may now be interconnected and in hydraulic communication.

Extent of Hydrocarbon Impacted Soil

The majority of gasoline hydrocarbons in the soil appear to be concentrated in the northeastern portion of the site in the immediate vicinity of the active gasoline UST pit at depths of 20 to 50 feet bgs. The highest concentrations in soils have been encountered at a depth of 20 feet during installation of monitoring well MW-5 in the clayey to sandy gravel shallow vadoze zone. Low but measurable concentrations of total petroleum hydrocarbons as gasoline (TPHg, $\geq$ 100 parts per million [ppm]) have been encountered in middle zone at an approximate depth of 40 feet bgs. The lateral extent of gasoline hydrocarbons in the soil at the site has been delineated to less than 1 ppm except west and northwest of the active gasoline-UST pit. The vertical extent of gasoline hydrocarbons in the soil at the site has been delineated to concentrations below 1 ppm TPHg at depths of approximately 50 feet bgs.

Extent of Hydrocarbon Impacted Groundwater

The lateral extent of gasoline hydrocarbons in the groundwater has been delineated to nondetectable concentrations of TPHg (less than 50 ppb), except in the northeastern and northwestern vicinity of the site. The lateral extent of benzene in the groundwater has been delineated to nondetectable concentrations (less than 5 ppb) in the southern, eastern, northwest and southeast portions of the site. Plates 4 and 5, respectively, depict TPHg and benzene concentrations in groundwater based upon the most recent quarterly sampling event conducted on March 30, 1993. The highest TPHg and BTEX concentrations in groundwater appear to be west and north of the active gasoline-storage tank pit (northeastern portion of the site). A sheen of free product has been observed intermittently in monitoring well MW-6 since September 1992, although no floating product was observed in the sample collected from this well for the subjective analyses during the March monitoring event. No visual evidence of floating product or product sheen has been observed in other wells during first quarter 1993. The groundwater beneath the site does not appears to be impacted by waste-oil related hydrocarbons, based on the nondetectable total oil and grease concentrations reported from monitoring well MW-8, located next to the former waste oil tank.

PROPOSED WORK

RESNA proposes performing project Steps 1 through 6, listed below, to evaluate interim groundwater remediation alternatives beneath the subject site. Field work involved with the following project steps will be performed in accordance with the attached RESNA Field Protocol in Appendix A of this Work Plan, and a site specific safety plan.

Step 1 Continue monthly groundwater monitoring data to determine if the current high water table has decreased enough to allow for capture of the sparge off-gas by the deeper zone vapor extraction well (MW-5).

Step 2 Obtain well construction permits from the Alameda Flood Control and Water Conservation District - Zone 7 to install one air- sparging well, if water table elevations have decreased.

Step 3 Drill one soil boring (B-16) to depths of approximately 70 feet (bottom of the aquifer) and construct one 2-inch diameter air-sparge well (AS-1) in boring B-16.

Air-sparge wells AS-1 will be located in the vicinity of the existing USTs, as shown on Plate 6, Proposed Boring/Well Location Map. This location for the air-sparge well will allow for observation wells (MW-5, MW-6 and MW-7) to be located approximately 15, 25, and 55 feet, respectively from the well.

The air-sparge well, AS-1 will consist of one 2-inch-diameter stainless steel pipe with 0.020 inch, machine slotted screen. The slotted section of the pipe will be limited to the bottom 3 feet of each pipe (to a depth of about 70 feet) and will be used to sparge the aquifer (65 to 68 feet below grade surface [bgs]). The well may be installed to deeper depths if natural barriers such as a silty clay aquitard are not encountered.

Step 4 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 into the sparging well AS-1 at three different air flow rates (2, 5, 10 cfm). At each air-sparging flowrate, the induced soil-gas pressure at the sparge well and at observation wells MW-5, MW-6 and MW-7 will be recorded periodically throughout the test. Air sparging will then be continued for an additional 60 to 90 minutes at the optimal sparge flow rate (i.e., when greatest soil-gas pressures are reported in the observation wells). Depth to water levels (DTW) in air-sparging well AS-1 and observation wells MW-5, MW-6 and MW-7 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. Water samples will be collected from AS-1, MW-5, MW-6, and MW-7 prior to sparging and after the 60 to 90 minute test at the optimal air sparging flowrate. These water samples will be analyzed for benzene, toluene, ethylbenzene and xylene (BTEX) BTEX, TPHg and dissolved oxygen (DO) to evaluate any observed changes as a result of sparging. Air samples will also be collected from observation wells MW-5, MW-6 and MW-7 prior to sparging and after two hours of operation at each air-sparging flowrate. Air samples collected will be analyzed for BTEX/TPHg to evaluate changes in soil-gas hydrocarbon concentrations as a result of air sparging. Please refer to Appendix A for a more detailed description of field procedures performed during the air-sparge test. Before and during the test, a flame-ionization detector (FID) and an air sampling pump will be used to monitor soil-gas concentrations in extracted vapor from MW-5 through MW-7.

Data from the air-sparging test will be used to evaluate optimal air flow rates necessary to perform a combination air-sparging/vapor-extraction test and the air-sparge capture zone associated with the selected air-sparging 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 5 Conduct a one-day combined air-sparge 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 MW-5 (two times the air-sparge flow rate) and abate extracted vapor. An air compressor will be used to sparge the aquifer by introducing air into AS-1 at the optimum sparge flow rate determined from the sparge-only test described above. The combined test will be conducted for a period of four hours. Initially, only the vapor-extraction well will be opened and induced vacuum readings at the extraction well MW-5 and at the observation wells VW-1, VW-2, MW-6 and MW-7 will be recorded. Soil-gas samples from the vapor-extraction well and the observation wells will be collected for BTEX/TPHg analysis to measure initial extracted hydrocarbon vapor concentrations prior to sparging.

Sparging will then be initiated at AS-1 at the optimum air sparge flow rate for a period of four hours. All measurements including soil-gas pressure/vacuum, DTW in sparge and observation wells will be recorded periodically. As described in the sparge-only test air and water samples will be collected and analyzed for changes in BTEX/TPHg and DO as a result of sparging and vapor-extraction. Observation wells MW-5, MW-6, MW-7 and sparge well AS-1 will be used to record changes in DTW, DO, and dissolved hydrocarbon concentrations. Observation wells VW-1, VW-2 MW-5, MW-6, and MW-7 will be used to record changes in soil-gas pressure/vacuum, and in BTEX/TPHg concentrations in extracted soil-gas. Please refer to Appendix A for a more detailed description of field procedures performed during the combination vapor-extraction/air-sparge test.

Step 6 Prepare a report summarizing field and laboratory procedures, findings, and conclusions.

SCHEDULE OF OPERATIONS

A preliminary time schedule to perform the steps described above is included as Plate 7, Preliminary Time Schedule. **This time schedule is an estimate and is contingent upon current water table elevations having decreased enough (to 50 feet bgs) to allow for capture of the sparge off-gas by the deeper zone vapor extraction well (MW-5).** ARCO and the appropriate regulatory agencies will be informed should the estimated time for completion of the work proposed in this Work Plan be delayed beyond the timelines depicted in Plate 7. Time is estimated in weeks after review of monthly monitoring data indicate that water table elevations have decreased enough to allow for installation of air sparge wells and performance of an air sparge test.

This preliminary time schedule will be delayed additionally: if regulatory review of the Addendum Three to Work Plan is delayed or, if after review, the regulatory agencies involved have comments and require a submittal of a revised addendum; if delays due to inclement weather are encountered in the installation of onsite air sparging wells and performance of the air sparge test; and if delays are encountered with the City of Livermore in permitting the installation of sparge wells.

PROJECT STAFF

Mr. Mark Detterman or Mr. James L. Nelson, Registered Geologists in the State of California, will be in overall charge of hydrogeologic facets. Mr. Bill Miller, Registered Civil Engineer and Mr. Bruce Maeda, Registered Chemical Engineer in the State of California will be in overall charge of engineering facets of this project. Mr. John Young, Client Manager, will provide supervision of field and office operations of the project. Mr. Keith Mc Vicker, Project Geologist and Ms. Valli Voruganti, Project Engineer, will be responsible for the day-to-day field and office operations of the project. RESNA employs a staff of geologists, engineers, and technicians who will assist with the project.

DISTRIBUTION

It is recommended that copies of this Work Plan be forwarded to:

Ms. Danielle Stefani
City of Livermore Fire Department
4550 East Avenue
Livermore, California 94550

Ms. Susan Hugo
Alameda County Health Care Services Agency
80 Swan Way, Room 200
Oakland, California 94621

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

REFERENCES

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RESNA. December 21, 1992. Report on Additional Subsurface Investigation and Vapor Extraction Test at ARCO Station 6113, 785 East Stanley Boulevard, Livermore, California. 69028.07

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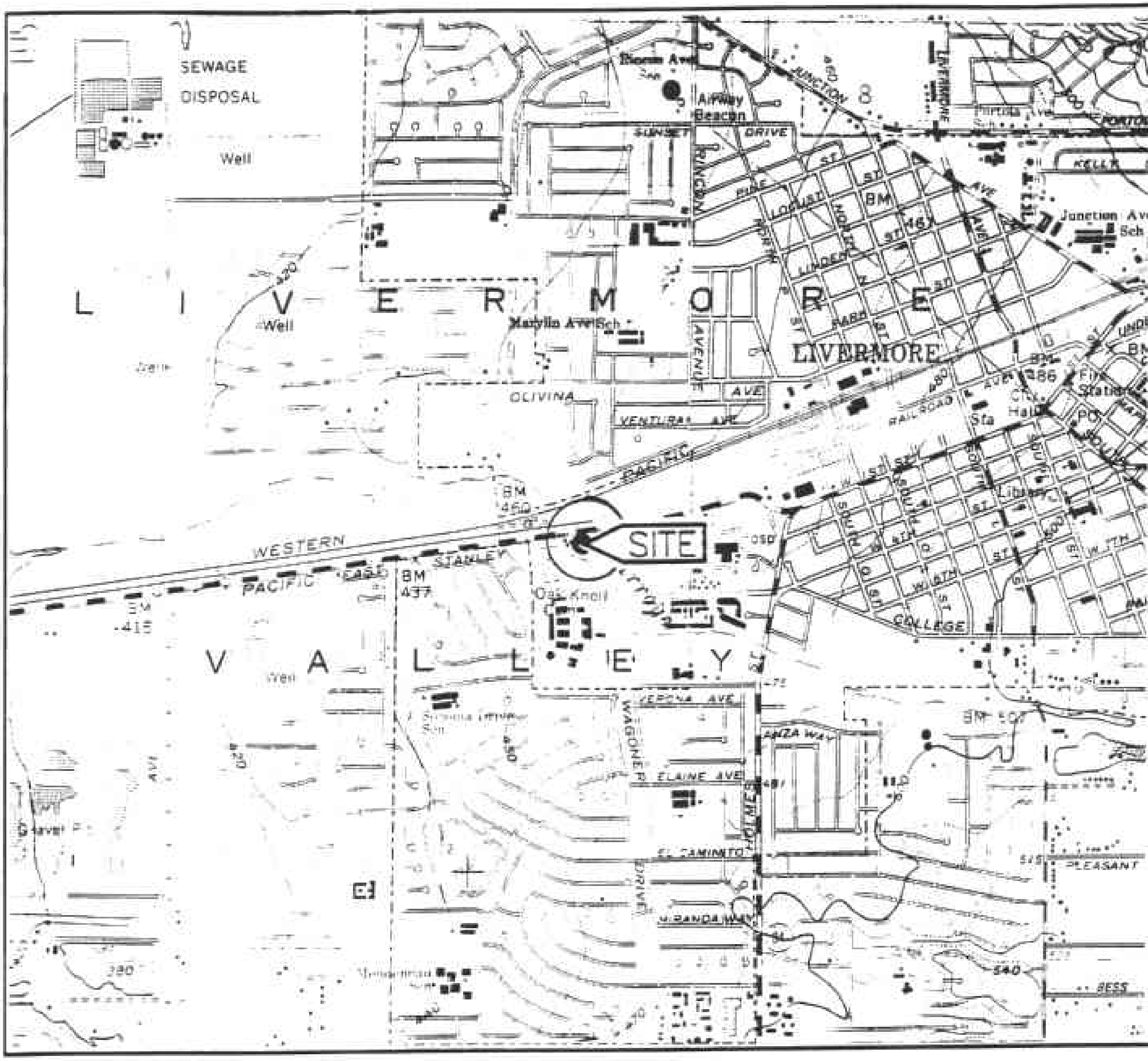
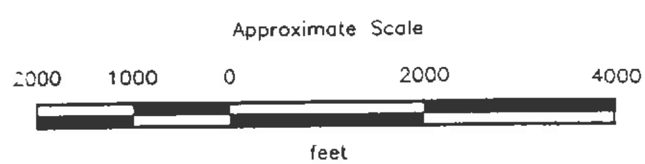


Base: U.S. Geological Survey
7.5-Minute Quadrangles
Livermore, California
Photorevised 1980

LEGEND

(•) = Site Location



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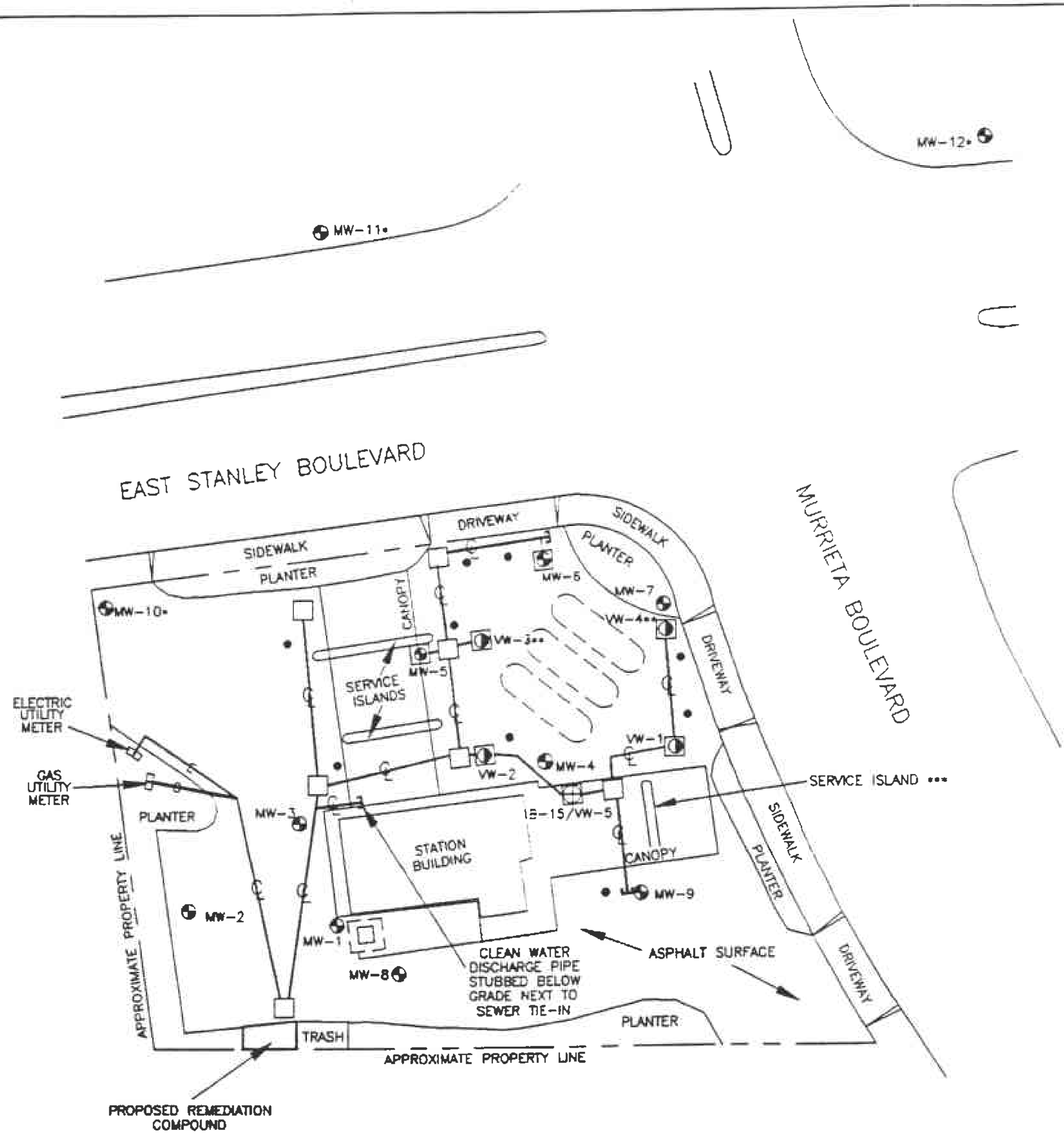
PROJECT 69028.11

SITE VICINITY MAP
ARCO Service Station 6113
785 East Stanley Boulevard
Livermore, California

PLATE
1



EXPLANATION

- ● = Brass monument markers for location of 1" sparge pipe stub-outs below grade
- MW-12 = Boring/monitoring well (RESNA, 09/89, 02/91, 06/92 and 03/93)
- VW-4 = Boring/vapor extraction well (RESNA, 06/92 and 08/92)
- • = MW-10, 11, and 12 installed in March 1993
- •• = VW-3 and VW-4 installed in June 1993
- ••• = Service island in operation since April 1993
- = Existing underground gasoline storage tanks
- = Vault/junction box
- = Center line of subgrade remediation piping trench
- = Pipes stubbed below grade and capped
- B-15/VW-5 = Soil boring/vapor extraction well drilled but not installed in June 1993 since no hydrocarbon-impacted soil was encountered to a depth of 30 feet below grade.

Approximate Scale

40 20 0 40 80

feet

Source: Modified from plan supplied by Ron Archer, Civil Engineer Inc., Feb. 1991; and John Koch Land Surveyor, June 1992 and April 1993.

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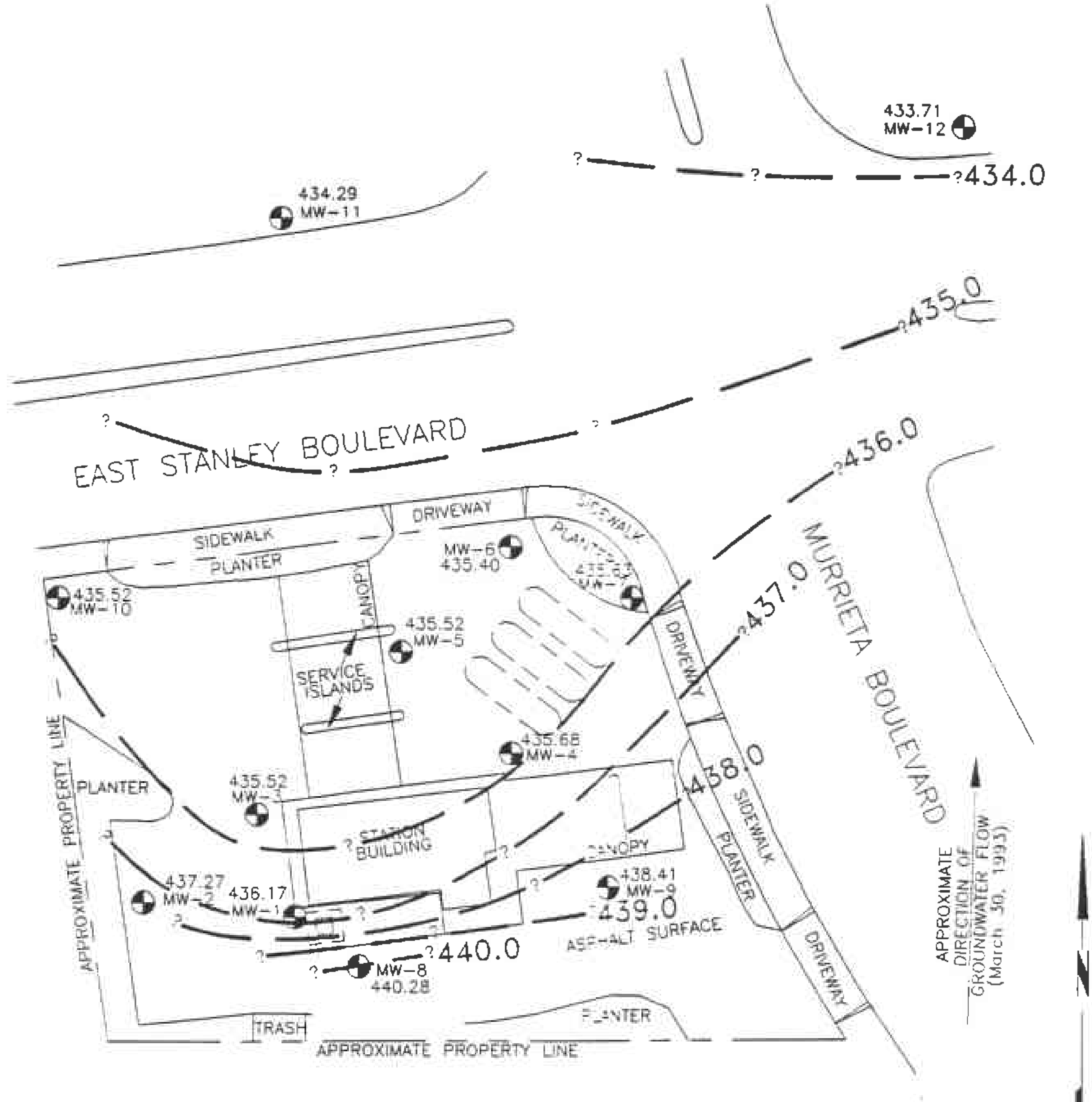
GENERALIZED SITE PLAN
ARCO Station 6113
785 East Stanley Boulevard
Livermore, California

PLATE 2



EXPLANATION

MW-12 = Monitoring well (RESNA, 09/89, 02/91, 06/92 and 03/93)

440.0 = Line of equal elevation of groundwater in feet above mean sea level (MSL)

440.28 = Elevation of groundwater in feet above MSL, March 30, 1993

= Existing underground gasoline storage tanks

Approximate Scale

50 25 0 50 100

feet

Source: Modified from plan supplied by Ron Archer, Civil Engineer Inc., Feb. 1991; and John Koch Land Surveyor, June 1992 and April 1993.

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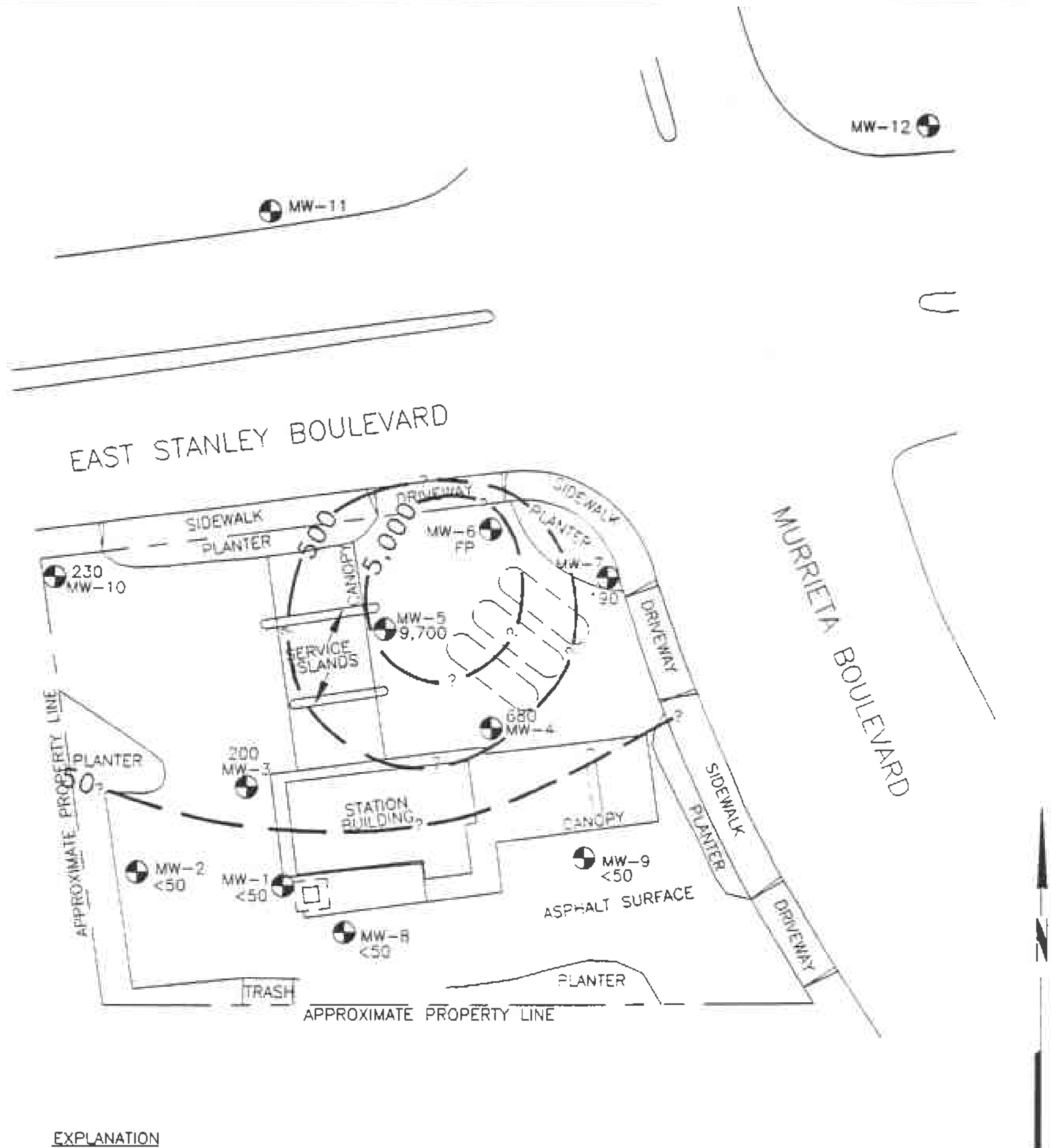
PROJECT: 69028.11

GROUNDWATER GRADIENT MAP
ARCO Station 6113
785 East Stanley Boulevard
Livermore, California

PLATE 3



EXPLANATION

MW-12 = Monitoring well (RESNA, 03/93)

5,000 = Line of equal concentration of TPHg in groundwater in parts per billion (ppb)

9,700 = Concentration of TPHg in groundwater in ppb, March 30 and 31, 1993

FP = Not sampled – floating product present

= Existing underground gasoline storage tanks

Approximate Scale

50 25 0 50 100

feet

Source: Modified from plan supplied by Ron Archer, Civil Engineer Inc., Feb. 1991; and John Koch Land Surveyor, June 1992 and April 1993.

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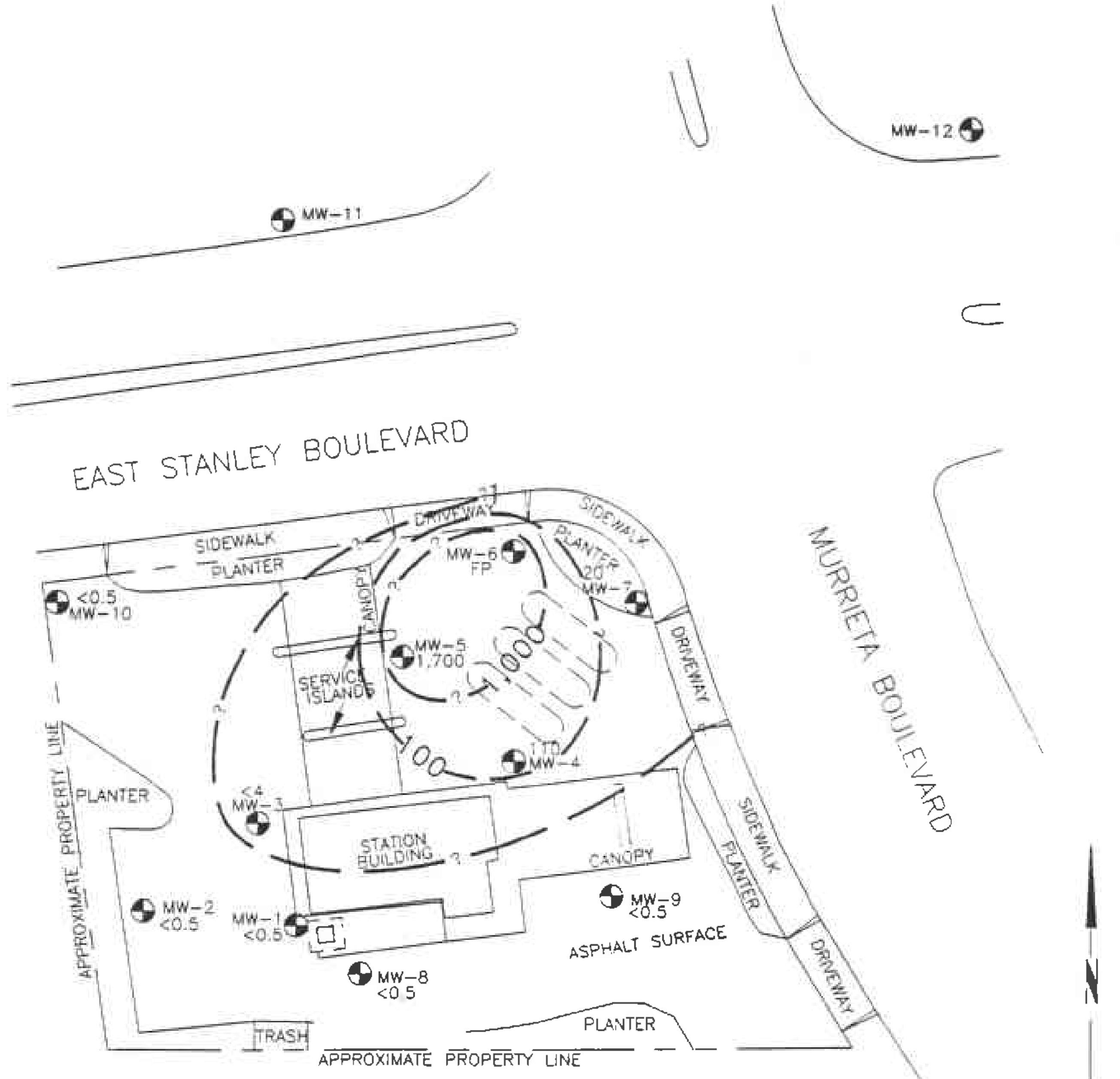
PROJECT: 69028.11

TPHg CONCENTRATIONS IN GROUNDWATER
ARCO Station 6113
785 East Stanley Boulevard
Livermore, California

PLATE 4



EXPLANATION

MW-12 = Monitoring well (RESNA, 09/89, 02/91, 06/92 and 03/93)

1,000 = Line of equal concentration of benzene in groundwater in parts per billion (ppb)

1,700 = Concentration of benzene in groundwater in ppb, March 30 and 31, 1993

FP = Not sampled – floating product present

= Existing underground gasoline storage tanks

Approximate Scale

50 25 0 50 100

feet

Source: Modified from plan supplied by Ron Archer, Civil Engineer Inc., Feb. 1991; and John Koch Land Surveyor, June 1992 and April 1993.

RESNA
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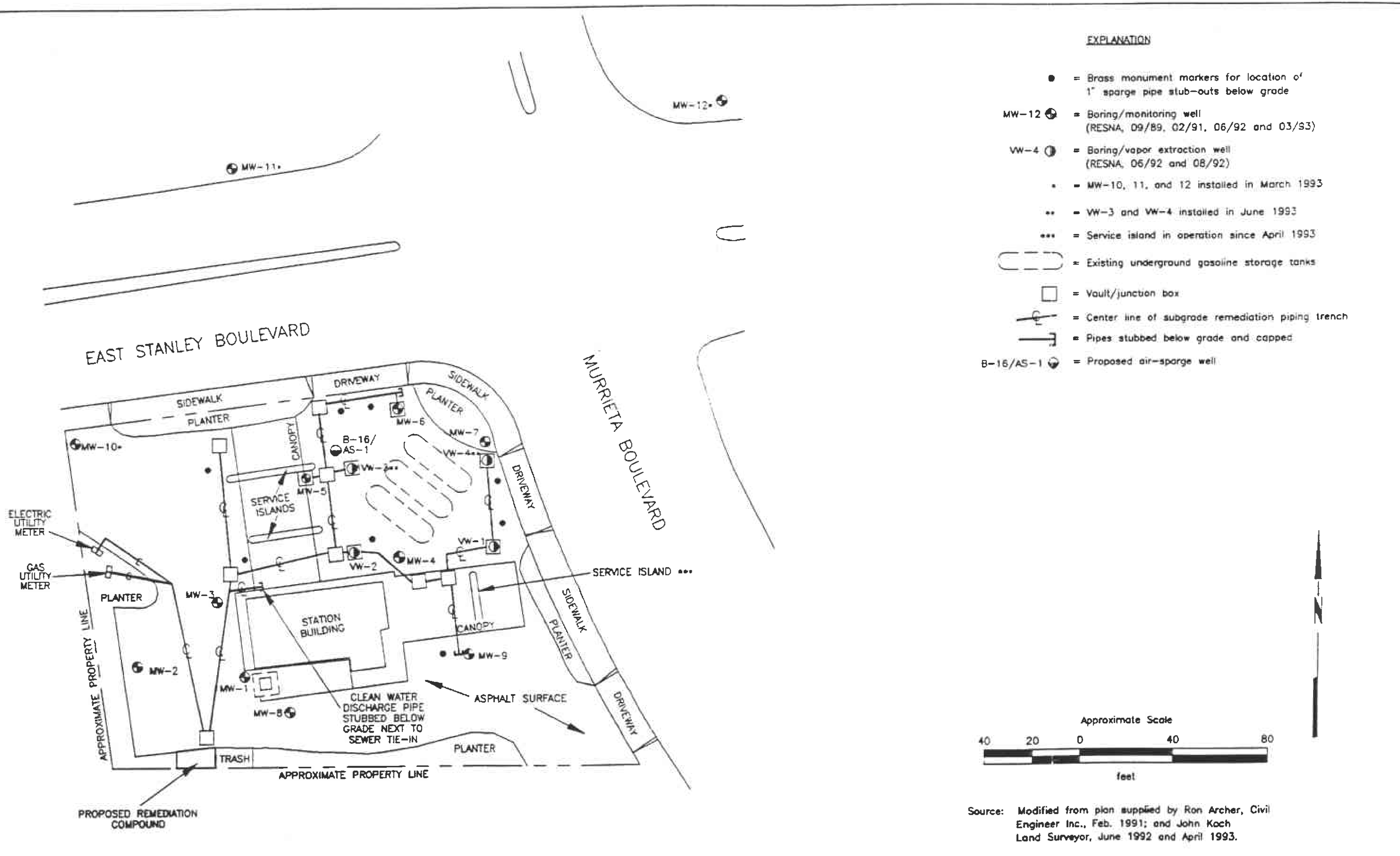
PROJECT: 69028.11

BENZENE CONCENTRATIONS IN GROUNDWATER
ARCO Station 6113
785 East Stanley Boulevard
Livermore, California

PLATE 5

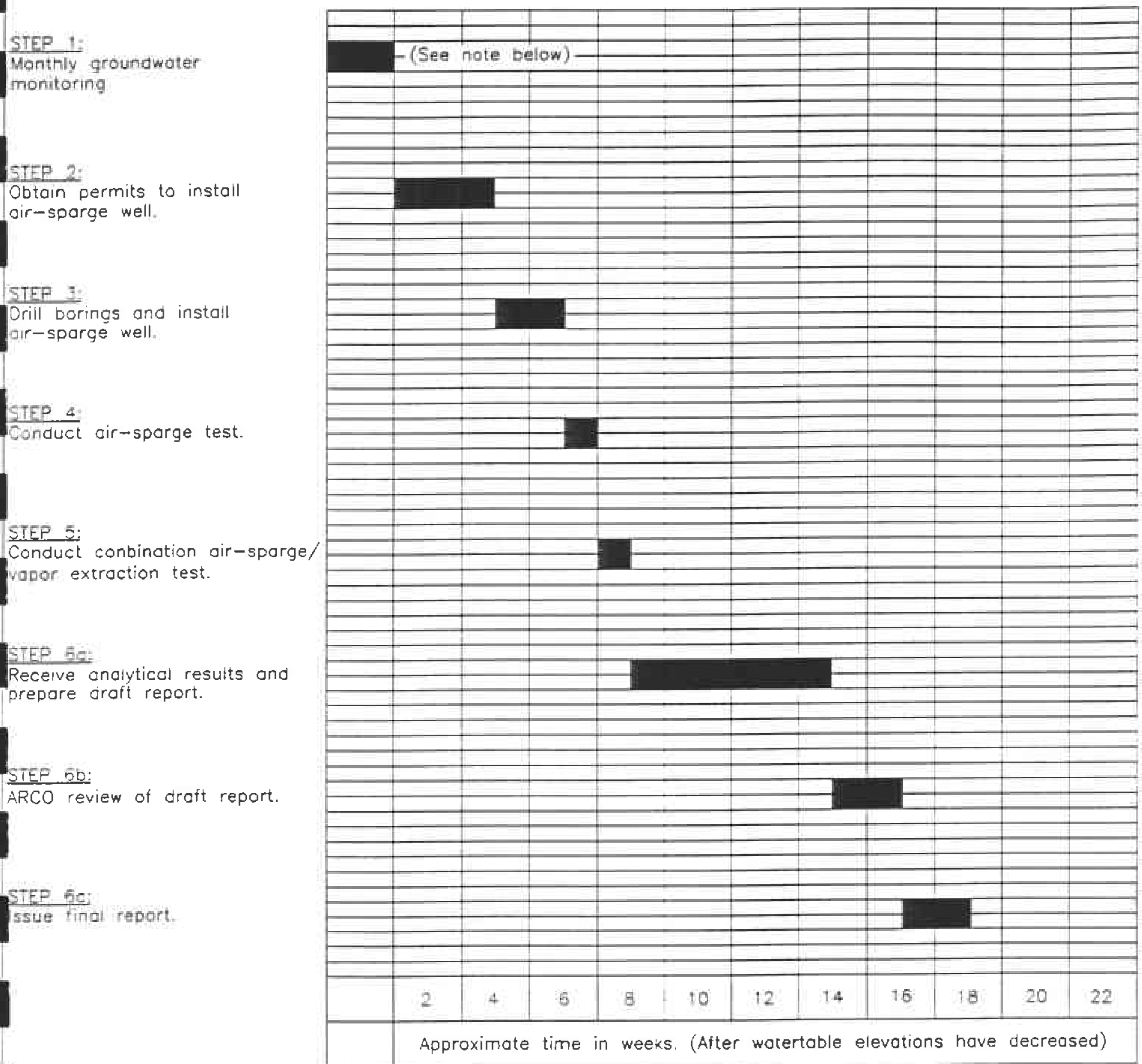


RESNA
Working to Restore Nature

PROJECT 69028.11

PROPOSED BORING/WELL LOCATION
ARCO Station 6113
785 East Stanley Boulevard
Livermore, California

PLATE 6



NOTE: Monthly groundwater monitoring of onsite monitoring wells will continue indefinitely until water levels decreased sufficiently (to 50 feet below grade surface) to allow for installation of air sparge well, and performance of an air sparge test.

RESNA
Working to Restore Nature

PROJECT 69028.11

PRELIMINARY TIME SCHEDULE
ARCO Station 6113
785 East Stanley Boulevard
Livermore, California

PLATE
7

Working to Restore Nature

APPENDIX A

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.

Soil Excavation

Permits are acquired prior to the commencement of work at the site. Excavated soil is evaluated using a field calibrated (using isobutylene) Thermo-Environmental Instruments Model 580 Organic Vapor Meter (OVM). This evaluation is done upon arrival of the soil at the ground surface in the excavator bucket by removing the top portion of soil from the bucket, and then placing the intake probe of the OVM against the surface of the soil in the bucket. Field instruments such as the OVM are useful for measuring relative concentrations of vapor content, but cannot be used to measure levels of hydrocarbons with the accuracy of laboratory analysis. Samples are taken from the soil in the bucket by 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. If field subjective analyses suggest the presence of hydrocarbons in the soil, additional excavation and soil sampling is performed, using similar methods. If ground water is encountered in the excavation, ground water samples are collected from the excavation using a clean Teflon® bailer. The ground water samples are collected as described below under "Ground-Water Sampling". The excavation is backfilled or fenced prior to departure from the site.

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 ground-water 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, plastic caps, and aluminized duct tape. 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.

Monitoring Well Construction

Monitoring wells are constructed in selected borings using clean 2- or 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 screened sections in groundwater monitoring wells are placed to allow monitoring during seasonal fluctuations of groundwater levels.

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 monitoring 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.

Groundwater Monitoring Well Development

The monitoring wells are developed by bailing or over-pumping and surge-block techniques. The wells are either bailed or pumped, allowed to recharge, and bailed or pumped again until the water removed from the wells is determined to be clear. Turbidity measurements (in NTUs) are recorded during well development and are used in evaluating well development. The development method used, initial turbidity measurement, volume of water removed, final turbidity measurement, and other pertinent field data and observations are included in reports. The wells are allowed to equilibrate for at least 48 hours after development prior to sampling. Water generated by well development will be stored in 17E Department of Transportation (DOT) 55-gallon drums on site and will remain the responsibility of the client.

Groundwater Sampling

The static water level in each well is measured to the nearest 0.01-foot using a Solinst® electric water-level sounder or oil/water interface probe (if the wells contain floating product) cleaned with Alconox® and water before use in each well. The liquid in the onsite wells is examined for visual evidence of hydrocarbons by gently lowering approximately half the length of a Teflon® bailer (cleaned with Alconox® and water) past the air/water interface. The sample is then retrieved and inspected for floating product, sheen, emulsion, color, and clarity. The thickness of floating product detected is recorded to the nearest 1/8-inch.

Wells which do not contain floating product are purged using a submersible pump. The pump, cables, and hoses are cleaned with Alconox® and water prior to use in each well. The wells are purged until withdrawal is of sufficient duration to result in stabilized Ph, temperature, and electrical conductivity of the water, as measured using portable meters calibrated to a standard buffer and conductivity standard. If the well becomes dewatered, the water level is allowed to recover to at least 80 percent of the initial water level. Prior to the collection of each ground water sample, the Teflon® bailer is cleaned with Alconox® and rinsed with tap water and deionized water, and the latex gloves worn by the sampler changed. Hydrochloric acid is added to the sample vials as a preservative (when applicable). A sample method blank is collected by pouring distilled water into the bailer and then into sample vials. A sample of the formation water is then collected from the surface of the water in each of the wells using the Teflon® bailer. The water samples are then gently poured into laboratory-cleaned, 40-milliliter (ml) glass vials, 500 ml plastic bottles or 1-liter glass bottles (as required for specific laboratory analysis) and sealed with Teflon®-lined caps, and inspected for air bubbles to check for headspace, which would allow volatilization to occur. The samples are then labeled and promptly placed in iced storage. A field log of well evacuation procedures and parameter monitoring is maintained. Water generated by the purging of wells is stored in 17E DOT 55-gallon drums onsite and remains the responsibility of the client.

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 (4-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 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 monitoring 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 is initiated at an air flow rate of 2 to 10 cubic feet per minute (cfm) into the air-sparging well. The test procedure is repeated applying at different air-sparge flow rates on each air-sparge well to evaluate an optimum air-sparge flow rate 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 throughout the tests on each well using magnehelic gauges. Based on the air sparge flow rate at which the greatest induced soil pressures are observed in the observation wells, a long-term sparge only test (60 to 90 minute duration) is performed on the sprage well at this optimal sparge air flow rate.

Depth to water levels (DTW) are measured in the air-sparging well and groundwater monitoring wells during the long-term test 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. 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. 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-Sparge 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 and induced vacuum readings at the extraction well and at the vapor monitoring points are be 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 be 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.