REMEDIAL INVESTIGATION/FEASIBILITY STUDY AT THE MARINER SQUARE FACILITY
2415 MARINER SQUARE DRIVE
ALAMEDA, CALIFORNIA

Prepared For: Prof Lisa Alvarez-Cohen
Department of Civil Engineering
University of California, Berkeley

By: Andy James
Sandrine Vesque
De-Ling Liu
Dennis Colby
Corinne DeVoe

MAY 1997

CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)

EXECUTIVE SUMMARY

As partial requirements for completion of the Civil Engineering 216, Hazardous and Industrial Waste Management course at University of California, Berkeley, students were to complete group projects in which they inspect field sites and evaluate solutions to a range of hazardous waste releases. As such, a group of students, herein referred to as Cheap Solutions, was assigned to perform a remedial investigation/feasibility study (RI/FS) at the Mariner Square facility in Alameda, California.

In accordance with 40 CFR 300.430(F)(2) the purpose of the RI/FS is "to assess site conditions and evaluate alternatives to the extent necessary to select a remedy." Performance of the RI/FS normally includes: data collection, risk assessment, treatability studies, and analysis of alternatives. With these goals in mind, Cheap Solutions completed the assigned RI/FS and documented the results and findings herein.

The six-acre Mariner Square facility lies along the south shore of the Oakland Inner Harbor and is bordered on the West by a United States Naval industrial facility and to the East by an underground tunnel that leads into the harbor. The asphalt-covered site had been used for storage of over sixty-thousand gallons of fuel as well as boat construction related activities, such as painting, which requires the use of a moderate amount of solvents.

Although concentration of fuel and oil constituents in and around the site are very high (in the part-per thousand range) a human health risk assessment has determined that very little risk has been imposed by these contaminants. This may largely be due to the possibility that the spills are probably over twenty years old and health-related compounds such as Benzene have been degraded over time to within tolerable limits. However, a risk assessment for Lead, in which we used extremely conservative values for reference dose, determined that the potential human health risks may be substantial.

Several possible routes for contaminant migration to the bay exist due to various site-specific factors such as: proximity to the bay, undetermined integrity of the sheet-pile wall to the north, hundreds of feet of on-site storm drains that can possibly be leaking, and specifically the area to the south-east where the groundwater gradient indicates the majority of the flow is moving towards. Because of the large amounts of hydrocarbon and Lead contaminants in the area and the various potential pathways to the bay an accurate Environmental Risk Assessment is required to ensure that nearby aquatic life is not adversely effected and that the beneficial uses of the bay are not disrupted.

Because of similar circumstances between this site and portions of the San Francisco International Airport it was determined that SFRWQB Order 95-136 is an appropriate and reasonable policy for the implementation of remediation goals for the Mariner Square site.

Since groundwater contaminant levels, such as TPHg, are on the order of 10 to 50 times greater than the limits set in this Order for Tier I standards, a more in-depth Environmental Risk Assessment is required if a complete, and possibly unnecessary, remediation of the site is to be avoided.

The increasing presence of free-phase hydrocarbons in one monitoring well is of substantial concern. This may require direct remediation of this source regardless of the outcome of any further Environmental Risk Assessments. This is in-line with the guidelines of Order 95-136 as well as the San Fransisco Bay Basin Water Quality Control Plan which urges that "Immediate removal of the source, to the extent practicable, is required to prevent further spread of pollution."

At the end of this document Cheaper Solutions has made various other recommendations regarding solvents, possible abandoned underground fuel pipes, and methane gas concentrations as well as the possibility that fuel and other contaminants may be migrating from the adjacent Navy site into the Mariner Square facility.

CONTENTS

1. Area and Site Description

2. Site Investigation

3. Risk Assessment

4. Regulatory Overview

5. Preliminary Remediation Alternative Screening

6. Comparison of Remediation Alternatives

1. Area and Site Description

This section provides an overview of the Mariner Square Facility in Alameda, California as well as the surrounding area. This includes the location, site history, and current and future land use. An environmental description includes the geology, ecology and climate of the area.

1.1. Site Location and Description

The Mariner Square Facility is approximately 5.8 acres and is located at 2415 Mariner Square Drive in Alameda, California. The property lies along the south shore of the Oakland Inner Harbor and is bordered on the West by the United States Naval Supply Center. The eastern border is above the southern end of the Webster Street Tube. A vicinity map is presented in Figure 1.1.

The site is located within an area of historic marshland that was traversed by meandering tidal channels. Reclamation of the area began in the late 1800s by filling the area with soils from various areas in the region including Bay material from dredging operations. The filling of the Mariner Square area was completed in the early 1900s.

The north boundary of the property was separated from the Oakland Inner Harbor by the construction of an interlocking concrete sheetpile wall. The wall rises approximately 8 feet above the mean sea level of the Inner Harbor and is reported to extended well into the Bay Mud that made up the historic surface before the filling began.

The construction of the Webster Street Tube occurred in 1957 along the eastern edge of the site. During that time at least 50 feet of material were removed and a sheetpile wall, with a 10-foot deep continuous sheet pile cap, was constructed along the property line. The construction area was backfilled with sand (State of California, Department of Transportation).

Bulk fuel storage and distribution activities of refined oils, lubricants and fuel oils occurred on the site from the 1920s and continued through 1972. During this time at least fourteen storage tanks were located on the site. Several of these facilities, including a 30,000 gallon above ground storage tank, an oil warehouse, part of a firewall and the wharf remain. Since 1972 the area has been used for various commercial purposes such as offices, boat sales, sail manufacturing, automobile repair, stripping and painting and a restaurant. Several rail cars were installed on the site and rest on concrete slab for use as offices and the 30,000 gallon storage tank was converted into garage space. A site map is shown in Figure 1.2.

Currently the site is occupied by several offices, a marine repair and painting facility, a sail manufacturer and a restaurant. There are public and private docks located on the Inner Harbor along the concrete wall. There are no on site residents and are no ground water wells in use for any known purpose. The area is almost completely paved with the exception of a small park in the north-east corner of the property and the areas around several trees.

1.2. Land Use

According to the City of Alameda Planning office (personal communication, April 8, 1997) the property at 2415 Mariner Square Drive is zoned as MU-2 in the city general plan. This is a special use package which avoids the displacement of marine related activities, such as boat repairs and painting, by limiting the residential and office space on each site. The total office space is limited to 5000 square feet and there are a maximum of 2 live/work residents per building on the property. Currently there is only one building that could be suitable for live/work use but future permitted construction could increase this number. Furthermore, all property within 100 feet of the shoreline on the island of Alameda falls under the jurisdiction of the Bay Conservation and Development Commission. They have regulated that it is illegal to limit public access to the shoreline. This insures public access to the site in the foreseeable future.

1.3. Regional Geology

The regional geology of the San Francisco Bay Area is defined largely by the lateral plate interactions of the Pacific and North American tectonic plates. The movements of these systems have caused much warping and faulting and resulted in the formation of a structural depression known as the San Francisco Trough. It is theorized that glacial melting caused the sea level to rise, forming the Bay approximately 10,000 years ago.

The local East Bay Hills consist of mixed bands of Franciscan Complex Cretaceous and Jurassic sandstone, Tertiary intrusive volcanic plugs and dikes and Mesozoic serpentine rock within larger areas of Pliocene sandstone. Erosion has resulted in semi-consolidated alluvial deposits with intermixed marine deposits in most areas immediately surrounding the Bay.

1.4. Site Geology

The entire site is covered with 7 to 17 feet of clayey to silty sands that were used as "hydraulic fill" during the marshland recovery operations done during the late 1800s. The depth varies depending on the location of the pre-existing tidal channels. The location of these channels was described by Radbruch as shown in Figure 1.3. The fill lies on a relatively homogeneous, plastic soil of high clay content known as "Bay Mud." These soils are relatively soft and compressible and are interspersed with very small amounts of sand, shells and organic material.

Boreholes of depths greater than 100 feet were drilled during the construction of the Webster Tube. They indicated that the Bay Mud is above lenses of sand, silts and clayey silts. Although the borings went to depths of 180 feet, no bedrock was encountered (State of California, Department of Public Works, 1959).

1.5. Ecology

This is a highly disturbed site and is far from what previously existed as a natural ecosystem. The original marshland has been filled for nearly 100 years and there has been continuous industrial activity on the site, and on the area surrounding the site, since that time. Currently there are no species of wildlife, endangered or otherwise, living in the area. A small number of mussels are attached to the concrete sheetpile wall that makes the northern border of the property and also on selected pier footings.

1.6. Climate

The Bay Area is within a mild, Mediterranean climactic zone that is tempered by currents from the Pacific Ocean. The area receives approximately 20 inches of rain a year which falls almost exclusively between the months of November and April. During the summer months a stable, off shore high pressure zone directs most of the rain to the north. Temperatures are mild throughout the year and rarely fall below freezing. The coastal zone suffers periods of morning and evening fog from April through August. Although this is most frequent along the Pacific Coast it often travels east across the Bay onto Alameda. The periods without fog are characterized by a steady and nearly continuous westerly wind that averages 5 knots.

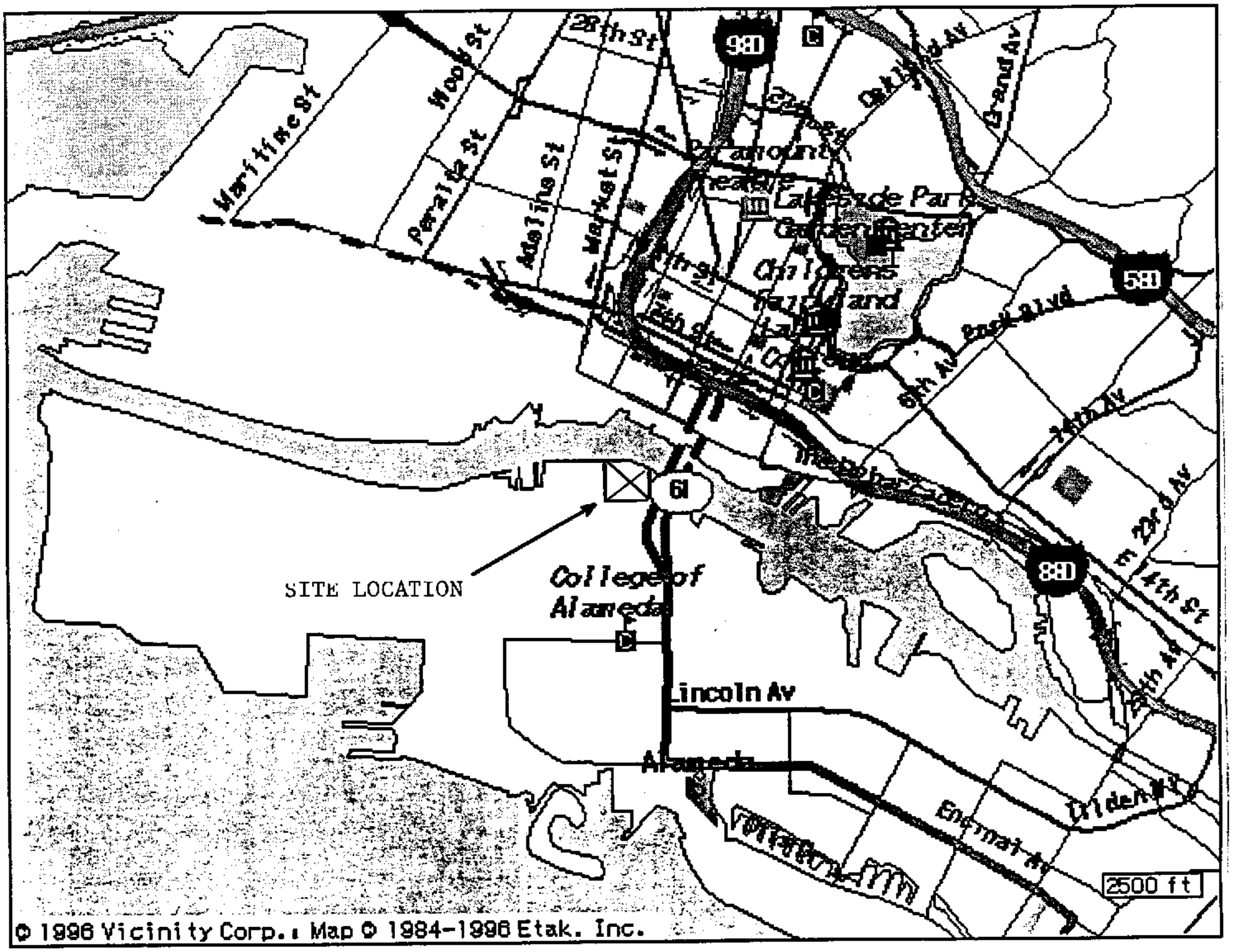


Figure 1.1 - Vicinity Map

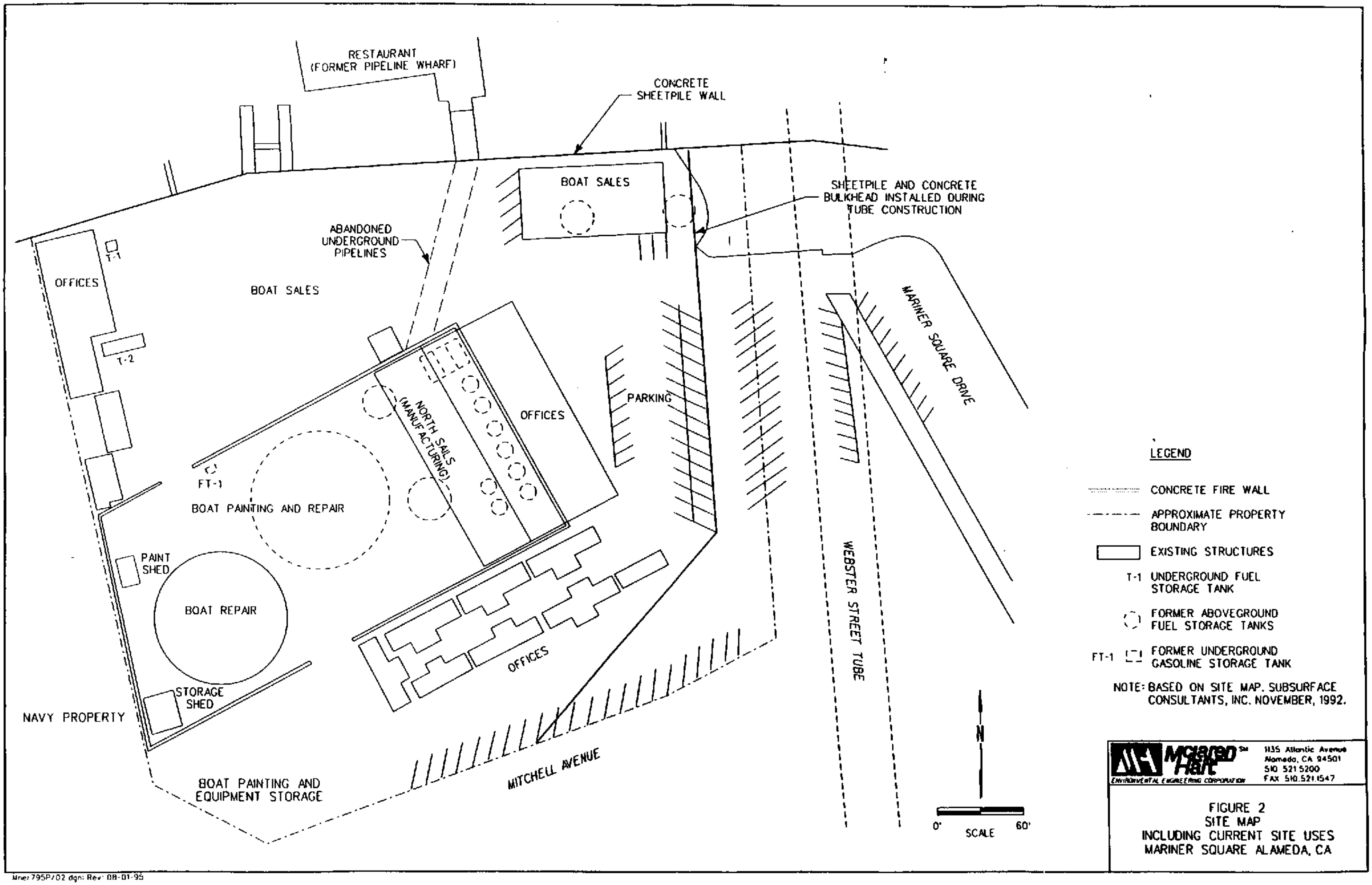


FIGURE 1.2 - SITE MAP

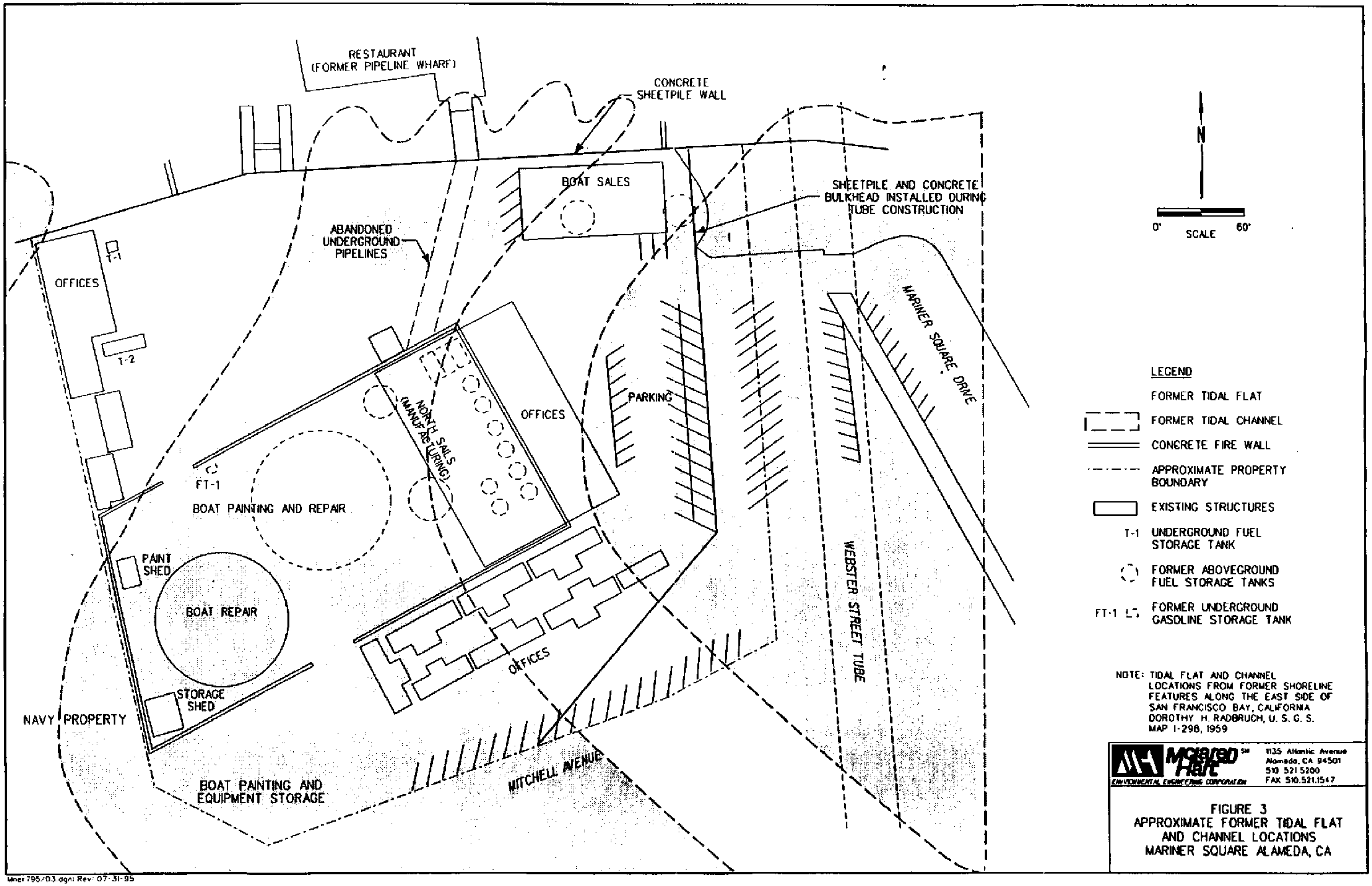


FIGURE 1.3 - HISTORIC TIDAL CHANNELS

2. Site Investigation

2.1. Analytical activities and findings

2.1.1. Introduction

The information relative to all analytical activities on the site are gathered below, in chronological order. The data were found in reports written by several consultants who worked on the site : All West (from 1992 to 1992), Subsurface Consultants (from 1991 to 1994), Mac Laren Hart (in 1994). Corresponding references are listed at the end of the present chapter (References (1) to (7)).

The location of all soil borings and monitoring wells is given in Figure 2-1.

2.1.2. 1990

Activities :

A gasoline UST was excavated. From within or around the excavation, samples were taken as follows : T-1 and T-2 at 5'bgs

- 2 soil samples and 1 composite soil sample, analyzed for TVH, BTEX and total lead ;
- 1 water sample , analyzed for TPHg, BTEX, kerosene, diesel, total oil and grease and total lead.

Findings : (see Table 2-1) in T-2 @ 5'bgs

Xylenes and lead (up to 150ppm) were detected in all soil samples. Only diesel (6900ppb) and oil and grease (160ppm) were found at a detectable level in the water sample.

→ X = .02ppm

2.1.3. 1992

April :

Activities :

The following samples were taken throughout the site :

- 22 soil samples, analyzed for TRPHs and BTEX MS-1 through MS-23
- 4 groundwater samples , analyzed for the same groups of compounds.
  MW-1, MW-7, WS-13, WS-18

The sampling strategy was to verify the presence or absence of petroleum hydrocarbons in the site subsurface, so the sampling points were scattered around the location of the former oil facility. No vertical distribution analysis of pollutants was undertaken.

Findings :(see Figures 2-2 and 2-3, Tables 2-2 to 2-4)
Elevated concentrations of TRPHs were found in 20 out of the 22 soil samples and 2 out of the 4 groundwater samples. The highest concentration level in soil and groundwater sample was 13,000 ppm and 1,200 ppm respectively.

No groundwater sample had detectable concentrations of volatile organics. Only 4 soil samples tested had detectable concentrations of volatile organics, the highest concentration found being 8,400 ppb for xylene.

June :

Activities :
Five monitoring wells were installed at the site (MW1 to 5 on maps).

- 5 soil samples from different depths (4 to 7') were analyzed for : TEH, BTEX, oil and grease and Volatile Hydrocarbons.
- 5 groundwater samples were analyzed for the same set of chemicals.

MW6 was also installed the same month.

Findings :(see Table 2-5)
For the groundwater samples, two volatile hydrocarbons, freon 113 (4ug/l) and vinyl chloride (9ug/l) were this time detected, from MW2 and MW6 respectively. Petroleum hydrocarbons were found in all samples, the highest concentrations being 16ppb for benzene, 6.5 ppb for toluene, 49 for ethylbenzene and 11 ppb for xylenes. No oil and grease was detected in the water.

For the soil samples, no volatile hydrocarbon was detected. Petroleum hydrocarbons were present in 2 of the 4 soil samples, with concentrations up to MW-5 500 ppb for toluene, 21,000 MW- ppb for ethylbenzene and 10,000 for xylenes. Oil and grease were detected once, at 66ppm. MW-2

July / December :

Activities :
Soil samples from MW1 through 5 were collected for a waste extraction test (soluble lead analysis), at a depth of 1.5 ft.

Findings :(see Table 2-6)
2 of the 5 samples contained soluble lead at a concentration higher than the **Soluble Threshold Limit Concentration of 5,000 ppb (20,000ppb at MW5 and 28,000 ppb at MW2)**. The lateral and vertical extent of the contamination could not be assessed with the analysis performed.

Soil Smpl

2.1.4. 1993

May/June :

Activities :
Water samples from MW 5 and 6 , were collected and analyzed for : priority pollutants metals and organic lead (MW5), TEH, Volatile Organics, Volatile Hydrocarbons, PCBs and priority pollutant metals (MW6).

Findings :(see Tables 2-7 to 2-10)
Metals were detected or above the reporting limit for both samples : arsenic, chromium, copper, lead and zinc for MW5, chromium, copper, nickel and zinc for MW6.
Petroleum hydrocarbons were well above the reporting limits, not surprisingly. No volatile organics or PCB was detected. A **0.02 ft thick free oil phase was found in MW6.**

2.1.5. 1994

March/september :

NAVY INVESTIGATION

west ?

Activities :
The Navy is performing an ongoing investigation of the Navy Supply Center, which is located immediately to the east of the Mariner Square site. They supplied information for 1994 on 13 soil borings and 6 groundwater monitoring wells which were located within 120 feet of the property boundary. Figure 2-4 shows the test locations.

11,000 ppm TPH A93.

Findings :(see Figure 2-5 and Tables 2-11 and 2-12)
The soil samples (location on Figure 2-4) indicated that there were significant concentrations of TPH. Boring A93 (5.5ft depth) had **TPHg of** 1,300 **1,100 ppm and** boring **S31 had TPHmo of 6,500** ppm. The highest concentrations were along the property line between 3.5 to 5.5 ft in depth. There were no detectable concentrations of benzene or vinyl chloride from the soil samples on the Navy site.

The water samples revealed moderate to low concentrations of TPH. The highest concentrations of TPHg (740 ppb) and TPHd (3,200 ppb) were obtained from well S27 which is several feet from the Mariner Square site. The highest concentration of TPHmo (630 ppb) was found in well S22. Benzene and vinyl chloride were also identified in the groundwater. Well S22, which is located approximately 120 ft up-gradient of Mariner Square well MW4, had a benzene concentration of 40 ppb and 9 ppb vinyl chloride.

September :

Activities :
Soil borings SB-A through K were drilled at the site, some of them within the area of previous gasoline storage activities or present USTs. MW7 and MW8 were also installed, to assess down-gradient contamination. Soil boring SB-C was renamed MW9 after completion.

Water samples were taken from each monitoring well (MW 1-9) and analyzed for : priority pollutant metals, TPHg, TPHd, TPHmo, BTEX and vinyl chloride. Total dissolved solids were measured for 3 samples only.

Soil samples were also collected at different depths for the same analysis and TOC.

Findings :(see Tables 2-13 to 2-16)
Concentrations of diesel and motor oil petroleum hydrocarbons, toluene, ethylbenzene and xylenes were found in some soil samples, the highest concentrations being where gasoline storage activities occurred in the past. These highest concentrations were : TPHd of 810 ppm (SB-D, 4.5ft) ; TPHmo of 9,200 ppm (SB-C, 1.5 ft) ; 13 ppm toluene and 5.8 ppm ethylbenzene (SB-C, 1.5 ft) ; 1.4 ppm xylenes (SB-D, 4.5ft). Higher concentrations of TOC were found at shallow depths than at higher depths : from 4,000 to 9,000 ppm versus up to 960 ppm. Metals were detected at concentrations above the TTLC or above 10 times the STLC in shallow soil samples (< 2ft), but not at higher depths. The metals found were antimony, copper, lead and zinc. No vinyl chloride was detected in the soil samples.

In the groundwater samples, as in soil samples, petroleum hydrocarbons, toluene, ethylbenzene and xylenes were detected. Furthermore, benzene (in MW4 and MW5) and vinyl chloride (in MW4) were detected. The higher concentrations detected were : in MW4 sample, 12 ppb for benzene and 8 ppb for vinyl chloride ; in MW5 sample, 3.1 ppm for TPHg, 11 ppb for toluene, 8.7 ppb for ethylbenzene, 14 ppb for xylenes ; in MW6 sample, 9.9 ppm for TPHd and 3.2 ppm for TPHmo. Among the metals tested for, only arsenic was detected in water (3 samples), well below the MCL of 50 ppb. Total dissolved solids level exceeded 500 ppm in the 3 samples tested. A separate phase of hydrocarbons was found in one of the well, of a maximum thickness of 0.03 ft. It was pumped out and not found at a measurable thickness in subsequent analysis.

2.1.6. 1996

Between October 1994 and June 1996, no analytical activities were conducted on the site, partly due to litigation problems.

June :

Activities :
Water samples were collected from monitoring well MW 1 through 9 (except MW6) and analyzed for : TPHg, TPHd, TPHmo, BTEX, vinyl chloride (as in 1994) and also PAHs.

Findings :(see Tables 2-16 and 2-17)
In MW6, a separate phase of hydrocarbons was found and no sample was collected. Vinyl chloride was only found in MW4, as in 1994, at 2.5 ppb. The highest concentrations for TPH were : 610 ppm for TPHd, 790 ppb for TPHmo, 5,000 ppm for TPHg in MW5. Benzene was found in more wells than in 1994, with the highest concentrations still in MW4, at 4 ppb. Toluene, ethylbenzene and xylenes were at maximum concentrations in MW5 again, at 6.8 ppb, 21 ppb and 14 ppb respectively. PAH were detected in MW2, MW4, MW5 and MW9. Fluoranthene was the most commonly found PAH (4 samples), followed by pyrene (3 samples), acenaphtalene (2 samples) and acenaphthene (2 samples). The maximum concentrations for these PAH were : 8.6 ug/l, 8.4 ug/l, 96 ug/l (uncertain) and 3 ug/l respectively, all found in MW5 sample. 11 different PAH were found in the same sample.

2.1.7. Recapitulation

The following table summarizes which chemicals were found on the site and in which medium. As no gas phase measurements were done on the site, only soil and groundwater media are shown. Chemicals reported have been found in the soil or in groundwater above critical levels. It should be noted that these reporting levels depend on the chemical, on the medium, and the way data were analyzed in the different documents reviewed.

Table 2-18 Summary of Contaminant Findings

Chemicals	In groundwater	In soil
Petroleum hydrocarbons (TPHg, TPHd, TPHmo)	+ (including free phase)	+
BTEX	+	+
Volatile hydrocarbons :		
Freon		+
Vinyl chloride		+
Metals :		
Arsenic	+	
Chromium	+	
Nickel	+	
Lead	+	+
Zinc	+	+
Copper	+	+
Antimony		+
PAH	+	
Oil and grease	+ (free phase)	+

Figures 2-5 through 2-12 serve as a graphical summary of the majority of the findings previously described.

2.2. Lithology

Subsurface soil characterization was investigated by Subsurface Consultants in 1992 and by McLaren Hart in 1994. Subsurface Consultants drilled 5 test borings about 15 feet deep. They concluded that the area was covered with about 7 to 13 feet of hydraulic fill that consists of clean, clayey and silty sands. Below the fill is a layer of Bay Mud that extends to an undetermined depth. McLaren Hart took a total of 13 soil borings and reinforced the previous conclusions. Figure 2-13 shows the geological cross-section in the direction of groundwater flow and Figure 2-14 shows a cross-section perpendicular to groundwater flow. In addition they reported that the soil sample taken from the boring at MW-8 was made up entirely of Webster Tube backfill material to a depth of 15 feet. They also performed tests on samples from SB-A and SB-C to measure certain physical parameters of the soil. These are shown in Table 2-19.

Table 2-19 Lithology Data

Boring Number	Bulk Density (g/cm^3)	Total Porosity (%)	Fluid Saturation (%)
SB-A	1.77	38.4	30.0
SB-C	1.84	30.2	50.0

2.3. Groundwater Investigation

The groundwater flow of the area was measured by Subsurface Consultants in 1992 and later by McLaren Hart in 1994. Both groups utilized groundwater elevations in the monitoring wells to establish a general gradient of flow. Their conclusions were consistent in stating the flow of water is to the southeast with a fairly small gradient. The water is shown to originate on the Navy property and crosses over in the northwest corner of the Mariner Square property. The water around MW-1 is depressed, possibly due to local infiltration into a storm drain and/or sanitary sewer. Figure 2-15 shows the groundwater gradient. McLaren Hart hypothesized that the Webster Tube backfill may partially explain the lower groundwater elevations to the southeast.

A tidal influence study was performed in 1992 to check the effect of the tide on the ground water level. This was done by measuring the groundwater levels in Monitoring Wells 2 and 3, which are located closest to the concrete sheet pile wall, during several tidal cycles. These showed that there was less than 0.08 feet change in groundwater elevation during a 4.5 foot tidal change. It was thereby concluded that the wall is an effective hydraulic barrier. Furthermore, Subsurface Consultants indicated that the wall built during the construction of the Webster Tube "most probably represents a hydraulic barrier to the east" (Subsurface Consultants, Inc., 1992).

2.4. Site visit

In April 1997 two site visits were performed by Cheap Solutions with the intention of qualitatively assessing the probable routes of contaminant from the groundwater to the bay. Several photographs were taken and are displayed in Appendix B, along with a rough map of surface storm drains. Observations are summarized as follows:

- Approximately 90% of the site is covered with asphalt or buildings. There are a few isolated areas which contain trees. In Plate-1 the largest office is pictured. The possible underground abandoned pipelines run along the asphalt-covered area in the vicinity of the elongated shadow towards the right of the picture.

- One of the large above ground storage tanks has been removed, with the remaining tank currently being used as a carpenter's garage. In Plate-2 the Concrete Fire Wall can be seen to the right as well as to the center and left.

- The area along the piers was examined visually. Several possible means of transport of contaminant into the bay were noted. Storm drainage is pumped from the region of the Webster Street Tube directly into the bay, with the effluent as seen in Plate-3. Since groundwater is migrating towards the Webster Street Tube this may be an area of concern.

- A few surface drains are shown on the map in Appendix B. These drain directly into the Bay as seen in Plate-4. Both of these drain pipes seem extremely rusty. On the first visit to the site the lower pipe (not pictured here), which is at a level lower than the top of the groundwater, had a flow to the bay of maybe a half-liter per minute. On the second visit this same drain was completely submerged under the tide.

- Also noted was a strange smell from one area of the wall which, upon further examination, was seen to be coming from the same general location as a leaking near the bay water surface. Roughly 50 ml per minute flow was observed to be coming from this split in the sheetpile wall. Also, within the vicinity of the end of the underground abandoned pipes (the head of the pier shown on the map) the sheetpile wall was seen to be bulging outwards and a half-inch wide vertical crack that was approximately four feet long had developed.

- Another aspect of this site investigation was with respect to the past solvent use in the south-west corner of the site. About a dozen 55-gallon drums were stored in this area of which two were labeled for solvents. Both of these were rusty and one had about an inch of liquid in it. Plate-5 was taken of the nearby corner where paint stains, rubber gloves, old solvent cans and an abandoned car battery were found. It seems that the majority of this soil is resting on *top* of the asphalt.

2.5. References

(1) Subsurface Consultants Inc, Results of environmental engineering performed by Subsurface Consultants Inc, February 1990 (letter)

(2) Subsurface Consultants Inc, Results of lead analysis in soil, December 1992

(3) Subsurface Consultants Inc, Results of supplemental sampling and analytical testing services performed by Subsurface Consultants Inc, November 1993

(4) All West Environmental Inc, Subsurface investigation report, Mariner Square, December 1993

(5) MBT Environmental Laboratories, results for 23 soil samples submitted by Mac Laren Hart to MBT on September 17, 1994 (letter)

(6) Mac Laren Hart, Supplemental site investigation at the Mariner Square Facility 2415 Mariner Square Drive Alameda, California, August 1995

(7) Alameda County Environmental Health Services, Environmental Protection Division, 1996 groundwater elevations and sample analytical results, April 1997 (fax)

Table 1

Table 1. Contaminants in Soil and Water From Gasoline Tank and Dispenser Area

Tank Excavation	Gasoline (ppm)[1]	Benzene (ppb)[2]	Toluene (ppb)	Ethyl-benzene (ppb)	Total Xylenes (ppb)	Lead (ppm)
T1 @ 5'	ND[3]	ND	ND	ND	6.3	11
T2 @ 5'	ND	ND	17	ND	20	150
Dispenser						
D1 @ 1'	ND	ND	ND	ND	ND	12
Stockpile Composite						
SP-A,B,C & D	1.3	ND	15	ND	24	29

Tank Excavation	Gasoline (ppb)	BTEX[4] (ppb)	Kerosene (ppb)	Diesel (ppb)	TOG[5] (ppm)	Lead (ppm)
* Water Sample	ND	ND	ND	6,900	160	ND

[1] ppm = parts per million
[2] ppb = parts per billion
[3] ND = Not detected, chemicals not present at concentrations above detection limits
[4] BTEX = Benzene, Toluene, Ethylbenzene, and Xylene
[5] TOG = Total Oil and Grease

Samples of the soil and water from within the excavation were individually analyzed. A composited sample of the excavated materials containing 4 individual soil samples was obtained from the soil stockpile. The stockpile contained less than 10 cubic yards of soil.

TABLE - 2.1

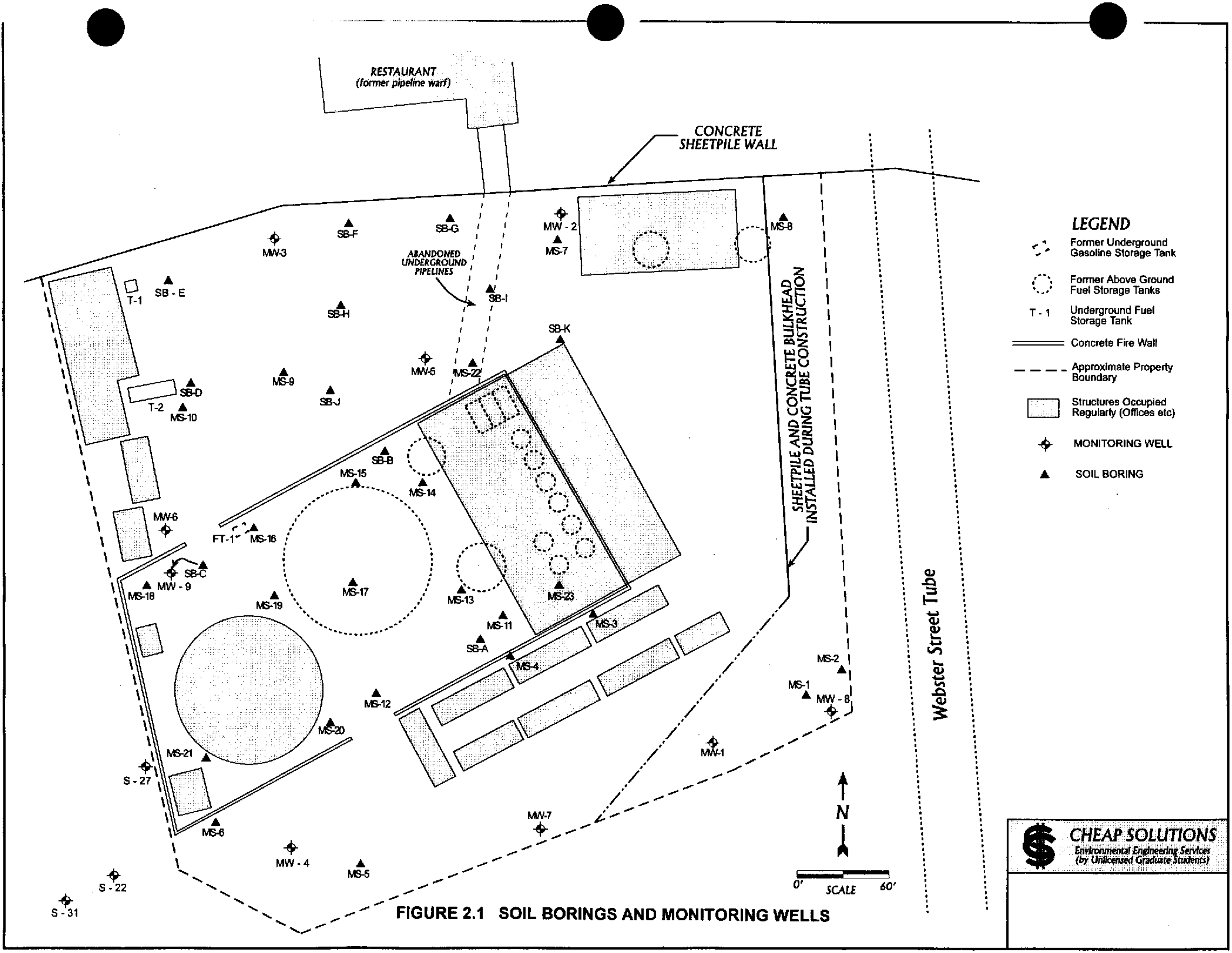
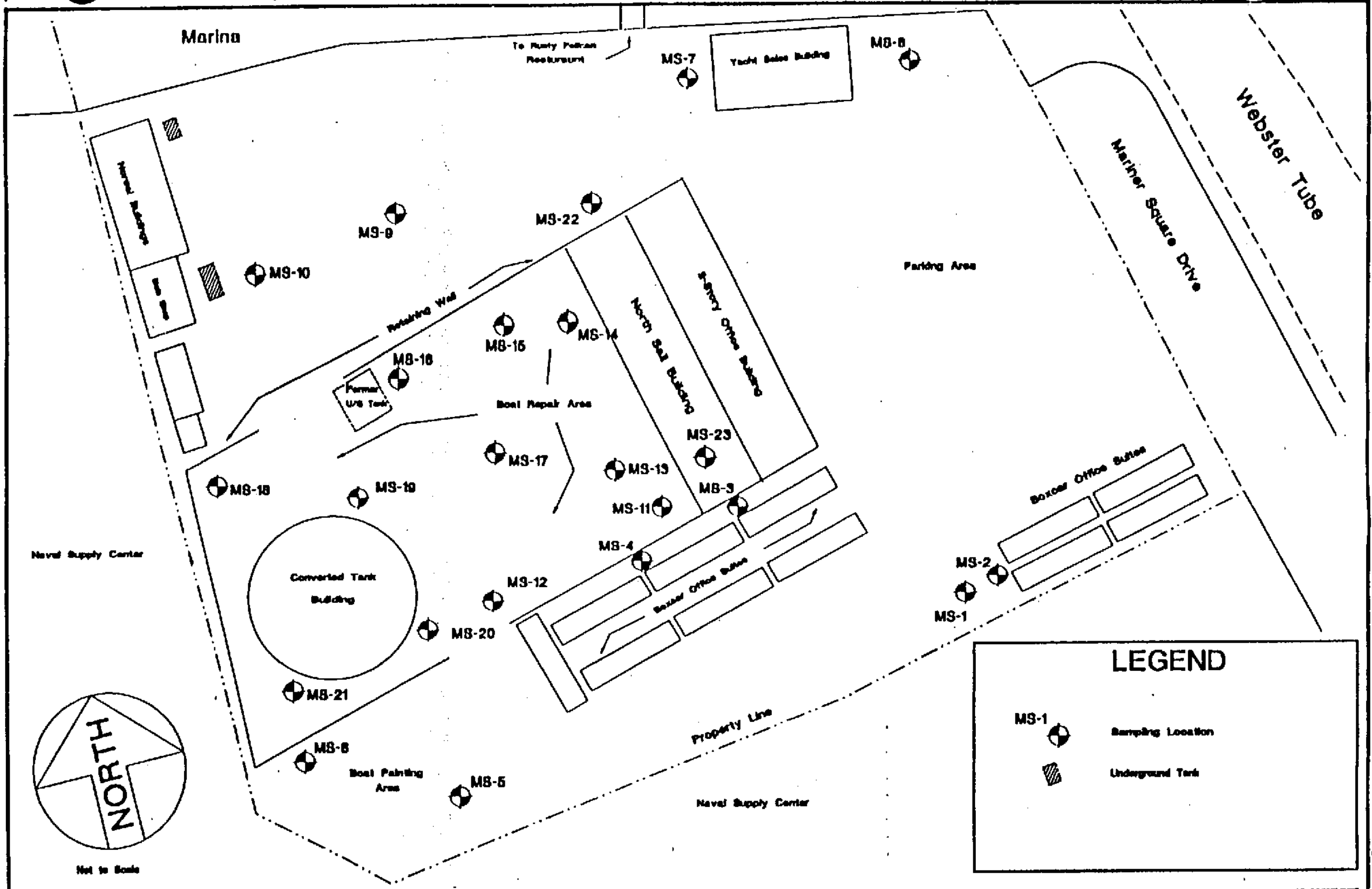


FIGURE 2.1 SOIL BORINGS AND MONITORING WELLS



ALLWEST
Environmental, Inc.

April 1992

Site Plan

Project 91278.23

Figure 3

Mariner Square, City Of Alameda, California

AllWest

FIGURE - 2.2

Figure 2

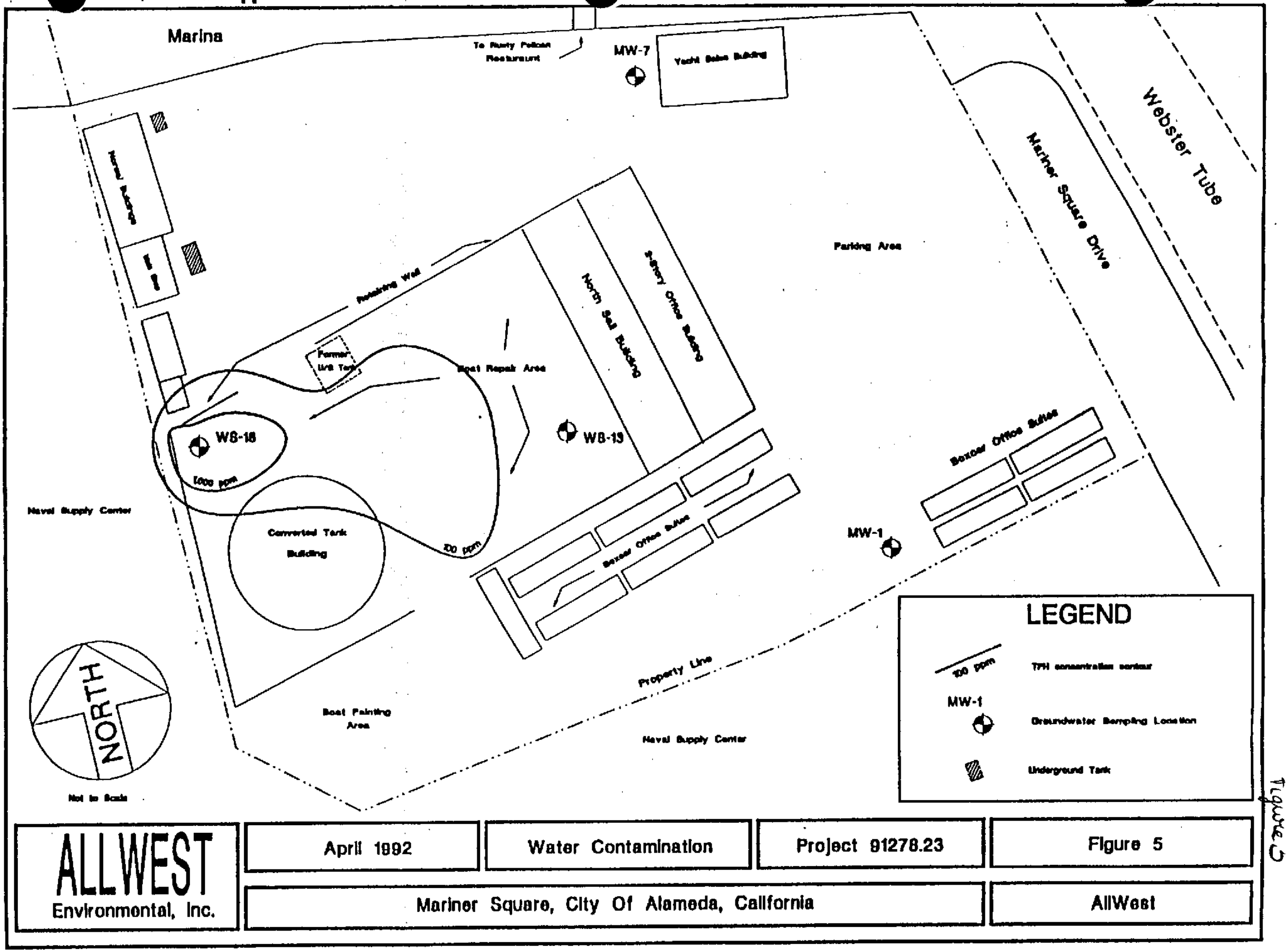


Figure 5

FIGURE 2.3

Table 2

TABLE B-1

PHASE I
Results Of Analyses Of Soil Samples[a]
Mariner Square
City of Alameda, California
AllWest Project No. 91287.23

Samples Obtained April 7,8, & 9, 1992

SAMPLE	DEPTH (feet)	TRPH (PPM)	B (ppb)	T (ppb)	E (ppb)	X (ppb)
MS-1	3-4	ND	ND	ND	ND	ND
MS-2	3-4	NA	NA	NA	NA	NA
MS-3	3-4	870	ND	ND	27	54
MS-4	3-4	13,000	ND	ND	1,000	1,200
MS-5	3-4	170	ND	ND	ND	ND
MS-6	3-4	520	ND	ND	ND	ND
MS-7	3-4	290	ND	ND	ND	ND
MS-8	3-4	46	ND	ND	ND	ND
MS-9	3-4	12	ND	ND	ND	ND
MS-10	3-4	37	ND	ND	ND	ND
MS-11	3-4	3,000	ND	ND	ND	ND
MS-12	3-4	3,200	ND	ND	140	270
MS-13	3-4	4,900	ND	ND	ND	ND
MS-14	3-4	6,300	ND	ND	ND	ND
MS-15	3-4	6,400	ND	ND	ND	ND
MS-16	3-4	27	ND	ND	ND	ND

TABLE 2.2

Table 3

TABLE B-1

SAMPLE	DEPTH (feet)	TRPH (PPM)	B (ppb)	T (ppb)	E (ppb)	X (ppb)
MS-17	1-2	3,300	ND	ND	1,600	8,400
MS-18	3-4	11,000	ND	ND	ND	ND
MS-19	3-4	3,900	ND	ND	ND	ND
MS-20	3-4	970	ND	ND	ND	ND
MS-21	3-4	39	ND	ND	ND	ND
MS-22	3-4	ND	ND	ND	ND	ND
MS-23	2-3	6,200	ND	ND	ND	ND
Reporting Limit	-	10	5	5	5	10

TRPH - Total Recoverable Petroleum Hydrocarbons (EPA Method 418.1).
B - Benzene
T - Toluene
E - Ethylbenzene
X - Total Xylenes
ND - Not detected above laboratory reporting limits.
NA - Not analyzed.
a - Locations for these samples are shown in Figure 4.

Table 4

TABLE B-2

PHASE I
Results Of Analyses Of Groundwater Samples[a]
Mariner Square
City of Alameda, California
AllWest Project No. 91287.23

Samples Obtained April 7,8, & 9, 1992

SAMPLE	TRPH (ppm)	B (ppb)	T (ppb)	E (ppb)	X (ppb)
MW-1	ND	ND	ND	ND	ND
MW-7	ND	ND	ND	ND	ND
WS-13	23	ND	ND	ND	ND
WS-18	1,200	ND	ND	ND	ND
Reporting Limit	10	5	5	5	10

TRPH	-	Total Recoverable Petroleum Hydrocarbons (EPA Method 418.1).
B	-	Benzene
T	-	Toluene
E	-	Ethylbenzene
X	-	Total Xylenes
ND	-	Not detected above laboratory reporting limits.
a	-	Locations for these samples are shown in Figure 5.

TABLE 2.4

Table 5 .

Table 4.
Contaminant Concentrations in Soil

Sample ID	Oil and Grease mg/kg	TEH mg/kg	Benzene ug/kg	Toluene ug/kg	Ethyl-Benzene ug/kg	Xylenes ug/kg	Volatile Halocarbons ug/kg
1 @ 7.0'	ND (50)	ND(1)	ND (5)	ND (5)	ND (5)	ND (5)	ND (10)
2 @ 6.0'	66	40	ND (800)	ND (800)	21,000	10,000	ND (10)
3 @ 4.5'	ND (50)	ND(1)	ND (5)	ND (5)	ND (5)	ND(5)	ND (10)
4 @ 4.0'	ND (50)	ND(1)	ND (5)	ND (5)	ND (5)	ND (5)	ND (10)
5 @ 4.5'	ND (50)	220	ND (400)	500	1600	1400	ND (10)

Table 5.
Contaminant Concentrations in Groundwater

Sample ID	Oil and Grease mg/l	TEH ug/l	Benzene ug/l	Toluene ug/l	Ethyl-Benzene ug/l	Xylenes ug/l	Volatile Halocarbons ug/L
MW-1	ND (5)	580	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (5-20)
MW-2	ND (5)	2200	ND (0.5)	6.5	3.2	5.3	4-Freon 113
MW-3	ND (5)	1000	ND (0.5)	1.0	ND (0.5)	2.4	ND
MW-4	ND (5)	1300	16	2.6	0.6	2.7	9-Vinyl Chloride
MW-5	ND (5)	2200	9	6	49	11	ND (5-20)

TEH = total extractable hydrocarbons, EPA 8015/3550
mg/kg = milligrams per kilogram or parts per million (ppm)
ug/kg = micrograms per kilogram or parts per billion (ppb)
mg/l = milligrams per liter or parts per billion (ppb)
ug/l = micrograms per liter or parts per billion (ppb)
ND = None detected above reporting limits indicated in parentheses.

TABLE 2.5

Curtis & Tompkins, Ltd.

Table 6

LABORATORY NUMBER: 109403
CLIENT: SUBSURFACE CONSULTANTS
PROJECT ID: 554.005
LOCATION: MARINER SQUARE

DATE SAMPLED: 07/22/92
DATE RECEIVED: 12/02/92
DATE EXTRACTED: 12/04/92
DATE ANALYZED: 12/07/92
DATE REPORTED: 12/09/92

ANALYSIS: STLC LEAD
EXTRACTION BY WASTE EXTRACTION TEST: CCR TITLE 26 SECTION 22-66700
ANALYSIS METHOD: EPA 7420

LAB ID	CLIENT ID	RESULT	UNITS	REPORTING LIMIT
109403-1	1@4'	100	ug/L	60
109403-2	2@1.5'	28,000	ug/L	200
109403-3	3@4.5'	790	ug/L	60
109403-4	4@4.5'	90	ug/L	60
109403-5	5@1.5'	20,000	ug/L	60

TABLE 2.6

QA/QC SUMMARY

RPD, %	<1
RECOVERY, %	100

Table 7

Curtis & Tompkins, Ltd.

ABORATORY NUMBER: 111019-1
LIENT: SUBSURFACE CONSULTANTS
ROJECT ID: 554.009
LOCATION: MARINER SQUARE
SAMPLE ID: MW 5

X DATE SAMPLED: 05/25/93
DATE RECEIVED: 05/25/93
DATE ANALYZED: 05/26-06/01/93
DATE REPORTED: 06/03/93

EPA Priority Pollutant Metals in Aqueous Solutions

METAL	RESULT ug/L	REPORTING LIMIT ug/L	METHOD
Antimony	ND	60	EPA 6010
Arsenic	10	5	EPA 7060
Beryllium	ND	2	EPA 6010
Cadmium	ND	5	EPA 6010
Chromium (total)	10	10	EPA 6010
Copper	30	10	EPA 6010
Lead	82	3	EPA 7421
Mercury	ND	0.2	EPA 7470
Nickel	ND	30	EPA 6010
Selenium	ND	5	EPA 7740
Silver	ND	10	EPA 6010
Thallium	ND	5	EPA 7841
Zinc	60	20	EPA 6010

ND = Not detected at or above reporting limit.

QA/QC SUMMARY

	RPD, %	RECOVERY, %
Antimony	2	101
Arsenic	15	96
Beryllium	2	100
Cadmium	4	105
Chromium	3	103
Copper	3	104
Lead	7	91

	RPD, %	RECOVERY, %
Mercury	<1	101
Nickel	6	102
Selenium	9	100
Silver	1	97
Thallium	4	96
Zinc	3	101

TABLE 2.7

Table 8

ABORATORY NUMBER: 111019-2
LIENT: SUBSURFACE CONSULTANTS
ROJECT ID: 554.009
LOCATION: MARINER SQUARE
SAMPLE ID: MW 6

X DATE SAMPLED: 05/25/93
DATE RECEIVED: 05/25/93
DATE ANALYZED: 05/26-06/01/93
DATE REPORTED: 06/03/93

EPA Priority Pollutant Metals in Aqueous Solutions

METAL	RESULT ug/L	REPORTING LIMIT ug/L	METHOD
Antimony	ND	60	EPA 6010
Arsenic	ND	5	EPA 7060
Beryllium	ND	2	EPA 6010
Cadmium	ND	5	EPA 6010
Chromium (total)	30	10	EPA 6010
Copper	30	10	EPA 6010
Lead	ND	3	EPA 7421
Mercury	ND	0.2	EPA 7470
Nickel	50	30	EPA 6010
Selenium	ND	5	EPA 7740
Silver	ND	10	EPA 6010
Thallium	ND	5	EPA 7841
Zinc	40	20	EPA 6010

ND = Not detected at or above reporting limit.

QA/QC SUMMARY

	RPD, %	RECOVERY, %		RPD, %	RECOVERY, %
Antimony	2	101	Mercury	<1	101
Arsenic	15	96	Nickel	6	102
Beryllium	2	100	Selenium	9	100
Cadmium	4	105	Silver	1	97
Chromium	3	103	Thallium	4	96
Copper	3	104	Zinc	3	101
Lead	7	91			

TABLE 2.8

Table 9

Curtis & Tompkins, Ltd.

ABORATORY NUMBER: 111019
LIENT: SUBSURFACE CONSULTANTS
ROJECT ID: 554.009
LOCATION: MARINER SQUARE

DATE SAMPLED: 05/25/93
DATE RECEIVED: 05/25/93
DATE EXTRACTED: 05/26/93
DATE ANALYZED: 05/28/93
DATE REPORTED: 06/03/93

Extractable Petroleum Hydrocarbons in Aqueous Solutions
California DOHS Method
LUFT Manual October 1989

LAB ID	CLIENT ID	KEROSENE RANGE (ug/L)	DIESEL RANGE (ug/L)	REPORTING LIMIT* (ug/L)
111019-2	MW6	**	2,700,000	50,000

* Reporting limit applies to all analytes.

** Kerosene range not reported due to overlap of hydrocarbon ranges.

QA/QC SUMMARY

RPD, %	11
RECOVERY, %	89

TABLE 2.9

Table 10

Curtis & Tompkins, Ltd.

LABORATORY NUMBER: 111019
CLIENT: SUBSURFACE CONSULTANTS
PROJECT ID: 554.009
LOCATION: MARINER SQUARE

✓ DATE SAMPLED: 05/25/93
DATE RECEIVED: 05/25/93
DATE ANALYZED: 05/28/93
DATE REPORTED: 06/03/93

TABLE 2.10

Total Volatile Hydrocarbons as Gasoline in Aqueous Solutions
California DOHS Method
LUFT Manual October 1989

LAB ID	CLIENT ID	TVH AS GASOLINE (ug/L)	REPORTING LIMIT (ug/L)
111019-2	MW6	460	50

QA/QC SUMMARY

RPD, %	<1
RECOVERY, %	96

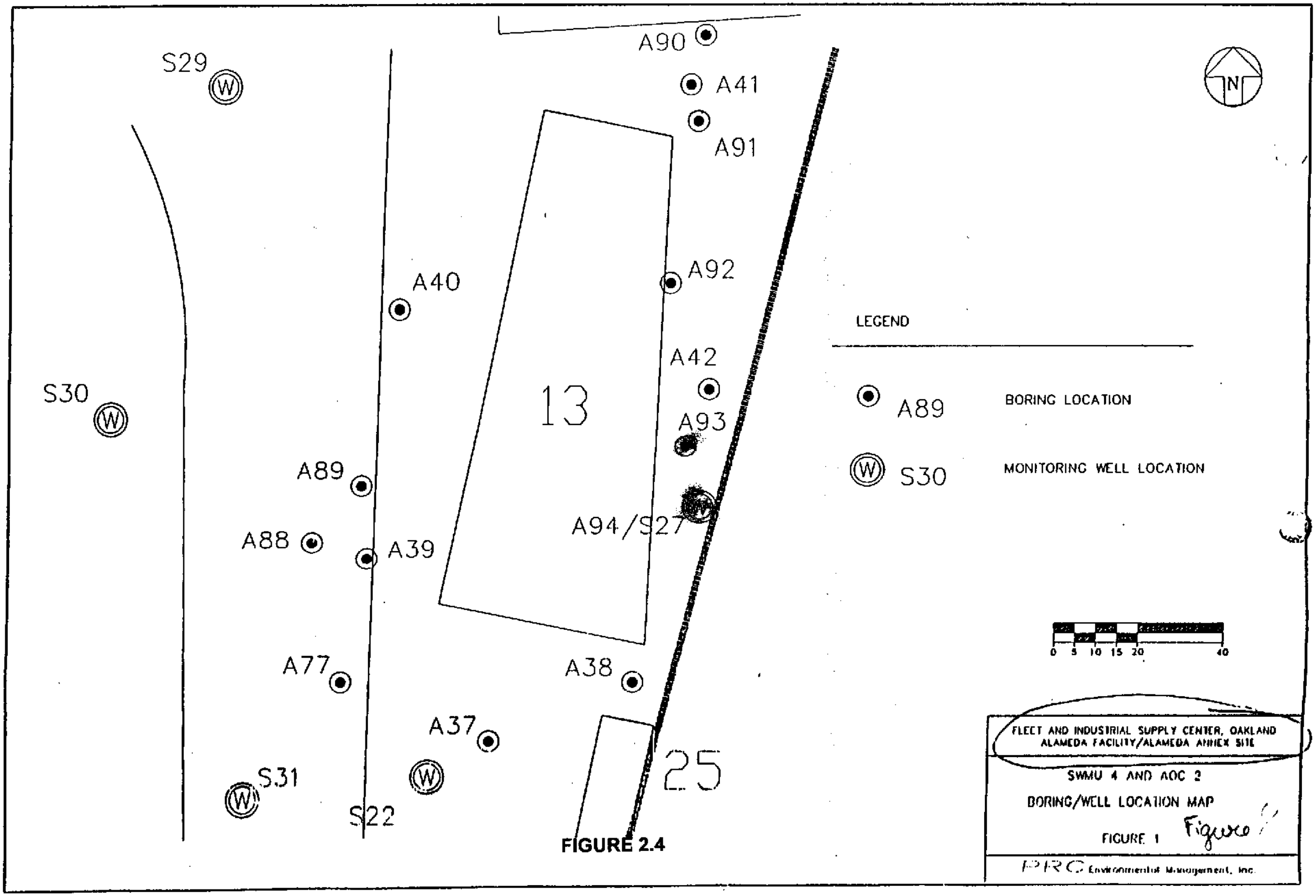

A90
S29
A41
A91
N
A40
A92
LEGEND
A42
S30
13
A93
A89
BORING LOCATION
S30
MONITORING WELL LOCATION
A89
A94/S27
A88
A39
0 5 10 15 20 40
A77
A38
A37
FLEET AND INDUSTRIAL SUPPLY CENTER, OAKLAND
ALAMEDA FACILITY/ALAMEDA ANNEX SITE
25
SWMU 4 AND AOC 2
BORING/WELL LOCATION MAP
S31
S22
FIGURE 1
Figure ?
PRC Environmental Management, Inc.

FIGURE 2.4

Table 11

[redacted]PROPERTY

[redacted]Sample Results (above detection limits [redacted]):

A37: 14,000 TPHmo(2');

A38: 380,000 TPHmo(1.5'); 1,300,000 TPHmo(4');

A39: 1,000,000 TPHmo(2'); 860 anthracene(4'); 420 benzo(a)anthracene(2'); 1500 benzo(a)anthracene(4'); 1,000 benzo(a)pyrene(2'); 2,400 benzo(a)pyrene(4'); 690 benzo(a)fluoranthene(2'); 1300 benzo(a)fluoranthene(4'); 1400 benzo(k)fluoranthene(4'); 640 chrysene(2'); 1700 chrysene(4'); 830 indeno(1,2,3-CD)pyrene(2'); 1400 indeno(1,2,3-CD)pyrene(4'); 1300 pyrene(2');

A40: 30,000 TPHmo(3');

A41: 160,000 TPHmo(2'); 530,000 TPHmo(2.5'); 20 chloroform (2.5'); 400 pyrene(2.5'); 108ppm lead(2.5');

A42: 260,000 TPHmo(1.5'); 29,000 TPHmo(4.5'); 690 fluoranthene(4.5'); 510 phenanthrene(4.5'); 720 pyrene(4.5');

A77: 170,000 TPHmo(1.5'); 56 acetone(5')

A88: 2,800,000 TPHmo(1'); 11,000 TPHmo(4.5'); 15 acetone(1'); 64 acetone(4.5'); 15 methylene chloride(1'); 12 methylene chloride(4.5'); 24 total xylenes(1'); 4300 bis(2-ethylhexyl)phthalate(1'); 440 fluoranthene(4.5'); 620 pyrene(4.5'); 52ppm chromium(4.5');

A89: 2,100,000 TPHmo(0.5'); 76,000 TPHmo(3.5'); 600,000 TPHmo(5'); 14 acetone(0.5'); 34 acetone (3.5'); 32 acetone(5'); 14 methylene chloride(0.5'); 17 methylene chloride(3.5'); 13 methylene chloride(5'); 82ppm chromium(3.5');

A90: 1,900,000 TPHmo(1'); 330,000 TPHmo(4'); 24 acetone(1'); 14 acetone(4'); 24 acetone(6.5'); 22 methylene chloride(1'); 33 methylene chloride(4'); 27 methylene chloride(6.5'); 7500 bis(2-ethylhexl)phthalate(1');

A91: 1,600,000 TPHmo(1'); 70,000 TPHmo(4'); 31,000 TPHmo(5.5'); 140 acetone(1'); 22 acetone (5.5'); 13 methylene chloride(1'); 13 methylene chloride(4'); 620 benzo(a)anthracene(5.5'); 860 benzo(a)pyrene(5.5'); 820 benzo(B)fluoranthene(5.5'); 770 benzo(g,h,i)perylene(5.5'); 650 chrysene(5.5'); 1400 fluoranthene(5.5'); 540 indeno(1,2,3-CD)pyrene(5.5'); 690 phenanthrene(4'); 1100 phenanthrene(5.5'); 440 pyrene(4'); 1700 pyrene(5.5');

TABLE 2.11

A92: 1,700,000 TPHmo(1'); 470,000 TPHmo(3'); 37 acetone(1'); 53 acetone(3'); 18 acetone(5'); 22 acetone(5.5'); 22 methylene chloride(1'); 19 methylene chloride(3'); 20 methylene chloride(5'); 24 methylene chloride(5.5'); 4100 bis(2-ethylhexyl)phthalate(1'); 89ppm lead(3'); 96ppm lead(5.5');

A93: **11,000,000 TPHd(5.5')**; 970 TPHg(1'); 72,000 TPHg(3.5'); **1,300,000 TPHg(5.5')**; 1,100,000 TPHmo(1'); 1,600,000 TPHmo(3.5'); 2,000,000 TPHmo(5.5'); 200 acetone(3.5'); 16 methylene chloride(1');

A94: **2,000,000 TPHmo**(1.5'); 35 acetone(1.5'); 26 methylene chloride(1.5'); 3100 bis(2-ethylhexl)phthalate(1.5');

S22: 800,000 TPHmo(3'); 43 acetone(3'); 410 benzo(a)pyrene(3'); 900 benzo(g,h,i)perylene(3'); 440 indeno(1,2,3-cd)pyrene(3'); 640 pyrene(3');

S29: 130,000 TPHd(6'); 1,500,000 TPHmo(1.5'); 810,000 TPHmo(4'); 170,000 TPHmo(6'); 44 acetone(4'); 28 acetone(6'); 13 methylene chloride(1.5'); 12 methylene chloride(4'); 16 methylene chloride(6'); 420 anthracene(6'); 2400 benzo(a)anthracene(6'); 3800 benzo(a)pyrene(6'); 4100 benzo(b)fluoranthene(6'); 1300 benzo(k)fluoranthene(6'); 2900 chrysene(6'); 410 fluoranthene(4'); 6200 fluoranthene(6'); 2500 indeno(1,2,3-cd)pyrene(6'); 370 phenanthrene(4'); 2400 phenanthrene(6'); 580 pyrene(4'); 8100 pyrene(6');

S30: 2,800,000 TPHmo(0.5'); 300,000 TPHmo(2.5'); 23 2-butanone(2.5'); 150 acetone(2.5'); 47 acetone(5.5'); 15 methylene chloride(0.5'); 16 methylene chloride(2.5'); 14 methylene chloride(5.5'); 13 xylenes(0.5'); 610 2-methylnaphthalene(2.5'); 460 benzo(a)anthracene(2.5'); 440 chrysene(2.5'); 750 fluoranthene(2.5'); 4100 napthalene(2.5'); 940 phenanthrene(2.5'); 970 pyrene(2.5'); 86 ppm lead(2.5');

S31: 5,000,000 TPHd(2.5'); 1,200,000 TPHmo(0.5'); 6,500,000 TPHmo(2.5'); 15 2-butanone(2.5'); 26 acetone(0.5'); 100 acetone(2.5'); 29 acetone(4.5'); 13 methylene chloride(0.5'); 28 methylene chloride(4.5'); 498ppm lead(2.5');

Table 12

NAVY PROPERTY

Water Samples (with conc. above detection limits (in ppb)):

S22: 11 acetone; 40 benzene; 9 vinyl chloride; 4300 TPHd; 260 TPHg; 630 TPHmo; 1.8 antimony; 9.1 arsenic; 390 barium; 0.11 beryllium; 3.2 copper; 1.3 lead; 23,900 magnesium; 1590 manganese; 0.03 mercury; 1.4 molybdenum; 2.3 thallium; 2.8 vanadium; 6.1 zinc

S27: 21 benzene; 3,200 TPHd; 740 TPHg; 43.8 aluminum; 2.8 antimony; 1.7 arsenic; 128 barium; 0.16 beryllium; 1.7 cobalt; 85,300 magnesium; 1340 manganese; 0.05 mercury; 3.1 nickel; 2.6 selenium; 3.3 vanadium; 7.2 zinc; 14.6 antimony; 134 barium; 0.71 cobalt; 1.4 lead; 0.041 mercury; 0.6 molybdenum

S29: 170 TPHd; 130 TPHmo; 3.5 selenium; 1.6 vanadium; 4.9 zinc

S30: 12 acenaphthene; 170 TPHd; 120 TPHmo; 35.6 aluminum; 4.7 antimony; 2.5 arsenic; 0.15 beryllium; 0.91 cobalt; 0.044 mercury; 3.2 selenium; 1.1 vanadium; 4.8 zinc

S31: 200 TPHd, 160 TPHmo; 40 aluminum; 6.6 antimony; 2.3 arsenic; 0.16 beryllium; 1.3 cobalt; 0.043 mercury; 2.7 nickel; 3.6 selenium; 2.4 vanadium; 6.1 zinc

TABLE 2.12

TABLE 6

SOIL SAMPLE ANALYTICAL RESULTS-ORGANICS
SUPPLEMENTAL SITE INVESTIGATION
MARINER SQUARE, ALAMEDA, CALIFORNIA

BORING/ WELL NUMBER	DEPTH (feet)	DATE	TOTAL PETROLEUM HYDROCARBONS			BENZENE (ppm)	TOLUENE (ppm)	ETHYLBENZENE (ppm)	XYLENES (ppm)	VINYL CHLORIDE (ppb)	TOTAL ORGANIC CARBON (ppm)
			GAS (ppm)	DIESEL (ppm)	MOTOR OIL (ppm)						
SB-A	1.5	9/15/94	NQ	NQ	NQ	NA	NA	NA	NA	NA	6,700
SB-A	5.5	9/15/94	NQ	NQ	NQ	<0.005	<0.0063	<0.005	<0.046	<10	960
SB-B	1.5	9/16/94	NQ	NQ	NQ	NA	NA	NA	NA	NA	19,000
SB-B	4.5	9/16/94	NQ	NQ	NQ	NA	NA	NA	NA	NA	<500
SB-C	1.5	9/16/94	NQ	NQ	9,200	<0.005	13	5.8	<0.005	<20	4,000
SB-C	5.5	9/16/94	NQ	NQ	NQ	NA	NA	NA	NA	NA	<500
SB-D	4.5	9/16/94	<50	810	140	<0.050	<0.073	<0.050	1.380	NA	NA
SB-E	4.5	9/16/94	<10	<10	60	<0.005	0.019	<0.005	<0.005	NA	NA
MW-7	4.0	9/15/94	<30	<30	200	<0.005	0.014	<0.005	<0.005	<10	NA

ppm = Parts per million
ppb = Parts per billion
< = Compound not detected at or above the specified laboratory reporting limit
NA = Not analyzed
NQ = Not quantified-fuel fingerprint to determine nature of hydrocarbons performed.

Table 13

TABLE 2.13

Antimony

TABLE 7
SOIL SAMPLE ANALYTICAL RESULTS - INORGANICS
SUPPLEMENTAL SITE INVESTIGATION
MARINER SQUARE, ALAMEDA, CALIFORNIA

BORING NUMBER	DEPTH (feet)	DATE	TTLC METALS (ppm)																	STLC (ppm)
			Sb	As	Ba	Be	Cd	Cr	Co	Cu	Pb	Hg	Mo	Ni	Se	Ag	Tl	V	Zn	Pb
SB-A	1.5 3.0	9/15/94 9/15/94	29 NA	7.2 NA	410 NA	0.32 NA	<0.50 NA	44 NA	6.7 NA	28 NA	250 4.2	0.33 NA	1.7 NA	26 NA	<0.25 NA	<1.0 NA	<0.50 NA	33 NA	370 NA	NA NA
SB-B	1.5 3.0	9/16/94 9/16/94	<2.5 NA	1.8 NA	88 NA	<0.25 NA	1.2 NA	40 NA	7.3 NA	17 NA	250 14	0.20 NA	<1.0 NA	36 NA	<0.25 NA	<1.0 NA	<0.50 NA	28 NA	580 NA	NA NA
SB-C	1.5 3.0	9/16/94 9/16/94	<2.5 NA	3.4 NA	120 NA	<0.25 NA	<0.50 NA	52 NA	8.5 NA	25 NA	1000 5.7	0.26 NA	1.4 NA	47 NA	<0.25 NA	<1.0 NA	<0.50 NA	38 NA	210 NA	NA NA
SB-D	1.5	9/16/94	<2.5	3.3	36	<0.25	<0.50	35	3.8	18	8.0	<0.10	<1.0	25	<0.25	<1.0	<0.50	20	18	NA
SB-E	1.5	9/16/94	<2.5	1.4	82	<0.25	<0.50	35	4.3	14	38	<0.10	<1.0	28	<0.25	<1.0	<0.50	25	51	NA
SB-F	1.5	9/16/94	<2.5	1.2	31	<0.25	<0.50	31	3.1	6.2	12	<0.10	<1.0	20	<0.25	<1.0	<0.50	18	34	NA
SB-G	1.5 3.0	9/16/94 9/16/94	<2.5 NA	2.2 NA	69 NA	<0.25 NA	<0.50 NA	39 NA	4.9 NA	13 NA	59 25	<0.10 NA	<1.0 NA	31 NA	<0.25 NA	<1.0 NA	<0.50 NA	25 NA	150 NA	2.7 NA
SB-H	1.5 3.0	9/16/94 9/16/94	<2.5 NA	3.0 NA	76 NA	<0.25 NA	<0.50 NA	46 NA	5.1 NA	47 NA	68 26	<0.10 NA	<1.0 NA	35 NA	<0.25 NA	<1.0 NA	<0.50 NA	28 NA	160 NA	2.8 NA
SB-I	1.5	9/16/94	<2.5	<5.0	48	<0.25	<0.50	36	10	90	38	<0.10	1.1	29	<0.25	<1.0	<0.50	24	100	NA
SB-J	1.5 3.0	9/16/94 9/16/94	170 <2.5	11 NA	570 NA	<0.25 NA	1.9 NA	54 NA	11 NA	300 5.4	5700 4.6	0.16 NA	2.0 NA	43 NA	<0.25 NA	<1.0 NA	<0.50 NA	31 NA	2700 16	NA NA
SB-K	1.5 3.0	9/16/94 9/16/94	<2.5 NA	5.0 NA	96 NA	<0.25 NA	<0.50 NA	44 NA	5.6 NA	4200 6.5	30 NA	<0.10 NA	1.3 NA	33 NA	<0.25 NA	1.0 NA	<0.50 NA	28 NA	150 NA	21 NA
TTLC (ppm)	–	–	500	500	10,000	75	100	2500	8000	2500	1000	20	3500	2000	100	500	700	2400	5000	–
STLC (ppm)	–	–	15	5.0	100	0.75	1.0	560	80	25	5.0	0.2	350	20	1.0	5.0	7.0	24	250	–

ppm = Parts per million
< = Compound not detected at or above specified reporting limit
TTLC = Total threshold limit concentration (CCR Title 22)
STLC = Soluble threshold limit concentration (CCR Title 22)
ppm = Parts per million
NA = Not analyzed
Sb = Antimony

As = Arsenic
Ba = Barium
Be = Beryllium
Cd = Cadmium
Co = Cobalt

Cu = Copper
Pb = Lead
Hg = Mercury
Mo = Molybdenum
Ni = Nickel

Se = Selenium
Ag = Silver
Tl = Thallium
V = Vanadium
Zn = Zinc

101TLSI.TBL

04.0601316.000

Table 14

TABLE 10
GROUNDWATER SAMPLE ANALYTICAL RESULTS - INORGANICS
SUPPLEMENTAL SITE INVESTIGATION
MARINER SQUARE, ALAMEDA, CALIFORNIA

WELL NUMBER	DATE	PRIORITY POLLUTANT METALS (ppb)												
		Sb	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Tl	Zn
MW-1	9/27/94	<50	22 / stet	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-2	9/26/94	<50	<10	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-3	9/27/94	<50	<10	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-4	9/27/94	<50	<10	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-5	9/26/94	<50	<10	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-6	9/27/94	<50	<10	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-7	9/27/94	<50	20 / stet	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-8	9/27/94	<50	13/stet	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MW-9	9/26/94	<50	<10	<5	<10	<10	<20	<3	<0.2	<20	<5	<10	<10	<20
MCL	–	NE	50	NE	10	50	NE	15	2	NE	10	50	NE	5000

ppb = Parts per billion
Sb = Antimony
As = Arsenic
Be = Beryllium
Ca = Cadmium
Cr = Chromium (total)
Cu = Copper
Pb = Lead
Hg = Mercury
Ni = Nickel
Se = Selenium
Ag = Silver
Tl = Thallium
Zn = Zinc
MCL = Maximum Contaminant Level, California Department of Health Services, Drinking Water Standards, Primary MCL
NE = Not established

Table 15

TABLE 2.15

GROUND WATER ELEVATONS AND SAMPLE ANALYTICAL RESULTS

Mariner Square
2415 Mariner Square Drive
Alameda, CA

Table 16

Well I.D. #	Sample Date	TOC (feet)	DTW (feet)	GWE (feet)	TPHd (µg/L)	TPHmo (µg/L)	TPHg (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	Vinyl Cl (µg/L)
MW-1	6/13/94	11.99	5.69	6.30	--	--	--	--	--	--	--	--
	9/27/94	11.99	5.64	6.35	530	ND<50	ND<50	ND<0.3	ND<0.3	ND<0.3	ND<0.3	--
	10/25/94	11.99	5.86	6.13	--	--	--	--	--	--	--	--
	6/28/96	11.99	5.34	6.65	ND<50	ND<200 (1)	ND<100	ND<0.5	ND<1.0	ND<1.0	ND<2.0	ND<0.5
MW-2	6/13/94	15.21	5.92	9.29	--	--	--	--	--	--	--	--
	9/26/94	15.21	6.51	8.70	ND<50	240	320	ND<3.0	ND<3.0	ND<3.0	ND<3.0	--
	10/25/94	15.21	6.67	8.54	--	--	--	--	--	--	--	--
	6/28/96 (2)	15.21	5.68	9.53	100 (3,4)	ND<200 (1)	980	0.5	ND<1.0	2.3	3.1	ND<0.5
MW-3	6/13/94	14.19	4.91	9.28	--	--	--	--	--	--	--	--
	9/27/94	14.19	5.29	8.90	720	ND<50	ND<50	ND<3.0	ND<0.3	ND<0.3	ND<0.3	--
	10/25/94	14.19	5.42	8.77	--	--	--	--	--	--	--	--
	6/28/96	14.19	4.69	9.50	120 (3)	ND<200 (1)	ND<100	ND<0.5	ND<1.0	ND<1.0	ND<2.0	ND<0.5
MW-4	6/13/94	13.95	4.50	9.45	--	--	--	--	--	--	--	--
	9/27/94	13.95	5.39	8.56	890	ND<50	ND<50	12	0.43	ND<0.3	ND<0.3	--
	10/25/94	13.95	5.55	8.40	--	--	--	--	--	--	--	--
	6/28/96	13.95	4.25	9.70	170 (3,4)	ND<200 (1)	180	4	ND<1.0	ND<1.0	ND<2.0	2.5
MW-5	6/13/94	14.60	5.30	9.30	--	--	--	--	--	--	--	--
	9/26/94	14.60	5.82	8.78	780	ND<500	3,100	7.9	11	8.7	14	--
	10/25/94	14.60	5.95	8.65	--	--	--	--	--	--	--	--
	6/28/96	14.60	5.04	9.56	610 (3,4)	790 (1)	5,000	1.2	6.8	21	14	ND<0.5

2-29

TABLE 2.16

GROUND WATER ELEVATONS AND SAMPLE ANALYTICAL RESULTS

Mariner Square
2415 Mariner Square Drive
Alameda, CA

Well I.D. #	Sample Date	TOC (feet)	DTW (feet)	GWE (feet)	TPHd (µg/L)	TPHmo (µg/L)	TPHg (µg/L)	B (µg/L)	T (µg/L)	E (µg/L)	X (µg/L)	Vinyl Cl (µg/L)
MW-6	6/13/94	14.81	5.96	8.85	--	--	--	--	--	--	--	--
	9/27/94	14.81	5.90	8.91	9,900	3,200	1,100	ND<3.0	ND<3.0	ND<3.0	ND<3.0	--
	10/7/94	14.81	5.82	8.99	--	--	--	--	--	--	--	--
	10/14/94	14.81	5.89	8.92	--	--	--	--	--	--	--	--
	10/21/94	14.81	5.90	8.91	--	--	--	--	--	--	--	--
	10/25/94	14.81	5.99	8.82	--	--	--	--	--	--	--	--
	6/28/96	14.81	5.33	9.48	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH
MW-7	9/27/94	13.61	5.95	7.66	1,800	ND<250	ND<250	ND<0.3	ND<0.3	ND<0.3	ND<0.3	--
	10/25/94	13.61	6.09	7.52	--	--	--	--	--	--	--	--
	6/28/96	13.61	5.42	8.19	490 (3,4)	ND<200 (1)	560	0.6	ND<1.0	ND<1.0	2.7	ND<0.5
MW-8	9/27/94	12.64	6.06	6.58	320	ND<50	ND<50	ND<0.3	ND<0.3	ND<0.3	ND<0.3	--
	10/25/94	12.64	6.26	6.38	--	--	--	--	--	--	--	--
	6/28/96	12.64	6.00	6.64	58 (3)	ND<200 (1)	ND<100	ND<0.5	ND<1.0	ND<1.0	ND<2.0	ND<0.5
MW-9	9/26/94	14.92	5.88	9.04	2,200	ND<500	ND<500	ND<0.3	ND<0.3	ND<0.3	ND<0.3	--
	10/25/94	14.92	6.04	8.88	--	--	--	--	--	--	--	--
	6/28/96	14.92	5.14	9.78	550 (3,4)	ND<200 (1)	390	5.2	ND<1.0	ND<1.0	ND<2.0	ND<0.5

CA Primary MCL (5)					--	--	--	1	100 (7)	680	1,750	0.5
Federal Primary MCL (6)					--	--	--	5	1,000	700	10,000	2

TABLE 2.16 (CONT)

Page 2 of 3

GROUND WATER ELEVATONS AND SAMPLE ANALYTICAL RESULTS

Mariner Square
2415 Mariner Square Drive
Alameda, CA

Notes:

TOC : Top of well casing referenced to mean sea level. Survey conducted by a state-licensed surveyor.
DTW : Depth to water.
GWE : Ground water elevation.
TPHg : Total petroleum hydrocarbons as gasoline by EPA Method 8015 (modified).
BTEX : Benzene, toluene, ethylbenzene and total xylenes by EPA Method 8020.
TPHd : Total petroleum hydrocarbons as diesel by EPA Method 8015 (modified).
TRPH : Total Recoverable Petroleum Hydrocarbons by EPA Method 418.1.
Vinyl Cl : Vinyl chloride by EPA Method 524.2.
µg/L : Micrograms per Liter.
— : Not analyzed/sampled.
ND : Not detected above the indicated laboratory method detection limit.
(SPH) : Separate phase hydrocarbons - No sample collected.
(1) : Lubricating oil can not be qualitatively identified by type of oil because of chromatographic likeness of different oil types. Due to non-volatility of certain oils, much of the oil present may never be quantified by this gas chromatographic method. Quantitation obtained for lubricating oil by this method should, therefore, be treated as an estimate. This method quantifies lubricating oil against 10-W-40 standards. For the most accurate analysis of lubricating oil, an infrared method is recommended.
(2) : Water sample collected from MW-2 was analyzed for Freon 113 by EPA Method 8010A. Results were below the detection limit of 1.0 µg/L.
(3) : Qualitative identification is uncertain because the material present does not match laboratory standards.
(4) : Quantitation uncertain due to matrix interferences.
(5) : Drinking Water Standards, California Department of Health Services, Primary Maximum Contaminant Level (MCL).
(6) : Drinking Water Standards, U.S. Environmental Protection Agency, Primary Maximum Contaminant Level (MCL).
(7) : California State Action Level, Department of Health Services.

TABLE 2.16 (CONT)

Table 2

Table 17

POLYNUCLEAR AROMATICS SAMPLE ANALYTICAL RESULTS

Mariner Development
2415 Mariner Square Drive
Alameda, CA

Well No.	Sample Date	Naphthalene µg/L	Acenaphthalene µg/L	Acenaphthene µg/L	Fluorene µg/L	Phenanthrene µg/L	Anthracene µg/L	Fluoranthene µg/L	Pyrene µg/L
MW-1	6/28/96	ND<2.0	ND<2.0	ND<2.0	ND<2.0	ND<1.0	ND<1.0	ND<0.5	ND<0.5
MW-2	6/28/96	ND<2.0	ND<2.0	ND<2.0	ND<2.0	ND<1.0	ND<1.0	0.82	0.77
MW-3	6/28/96	ND<2.0	ND<2.0	ND<2.0	ND<2.0	ND<1.0	ND<1.0	ND<0.5	ND<0.5
MW-4	6/28/96	ND<2.0	2.5	2.3	ND<2.0	ND<1.0	ND<1.0	1.8	2.1
MW-5	6/28/96	2.0	96 (1)	3.0	ND<2.0	9.5	2.3	8.6	8.4
MW-6	6/28/96	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH
MW-7	6/28/96	ND<2.0	ND<2.0	ND<2.0	ND<2.0	ND<1.0	ND<1.0	ND<0.5	ND<0.5
MW-8	6/28/96	ND<2.0	ND<2.0	ND<2.0	ND<2.0	ND<1.0	ND<1.0	ND<0.5	ND<0.5
MW-9	6/28/96	ND<2.0	ND<2.0	ND<2.0	ND<2.0	ND<1.0	ND<1.0	0.73	ND<0.5
CA Primary MCLs (2)		--	--	--	--	--	--	--	--
EPA Primary MCLs (3)		--	--	--	--	--	--	--	--

TABLE 2.17

Table 2

POLYNUCLEAR AROMATICS SAMPLE ANALYTICAL RESULTS

Mariner Development
2415 Mariner Square Drive
Alameda, CA

Well No.	Sample Date	Benzo[a]-anthracene µg/L	Chrysene µg/L	Benzo[b]fluor-anthene µg/L	Benzo[k]fluor-anthene µg/L	Benzo[a]-pyrene µg/L	Dibenzo[a,h]-anthracene µg/L	Benzo[g,h,i]-perylene µg/L	Indeno[1,2,3-cd pyrene µg/L
MW-1	6/28/96	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5
MW-2	6/28/96	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5
MW-3	6/28/96	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5
MW-4	6/28/96	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5
MW-5	6/28/96	1.0	0.68	ND<0.5	ND<0.5	0.78	ND<0.5	0.57	ND<0.5
MW-6	6/28/96	SPH	SPH	SPH	SPH	SPH	SPH	SPH	SPH
MW-7	6/28/96	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5
MW-8	6/28/96	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5
MW-9	6/28/96	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5	ND<0.5
CA Primary MCLs (2)		–	–	–	–	–	--	–	--
EPA Primary MCLs (3)		0.1	0.2	0.2	0.2	0.2	0.3	--	0.4

TABLE 2.17 (CONT)

Table 2

POLYNUCLEAR AROMATICS SAMPLE ANALYTICAL RESULTS

Mariner Development
2415 Mariner Square Drive
Alameda, CA

Notes:

Polynuclear Aromatics:	Polynuclear Aromatics by EPA Method 8310.
Well No. :	Well identification number used by HETI.
Date:	Date ground water sample was collected.
µg/L :	Micrograms per liter (ppb).
ND :	Not detected in concentrations exceeding the laboratory method detection limit.
(1) :	The qualitative identification for Acenaphthylene is uncertain due to matrix interferences.
(2) :	Drinking Water Standards, California Department of Health Services, Primary Maximum Contaminant Level (MCL).
(3) :	Drinking Water Standards, U.S. Environmental Protection Agency, Primary Maximum Contaminant Level (MCL).
SPH :	Separate phase hydrocarbons - No sample collected.

TABLE 2.17 (CONT)

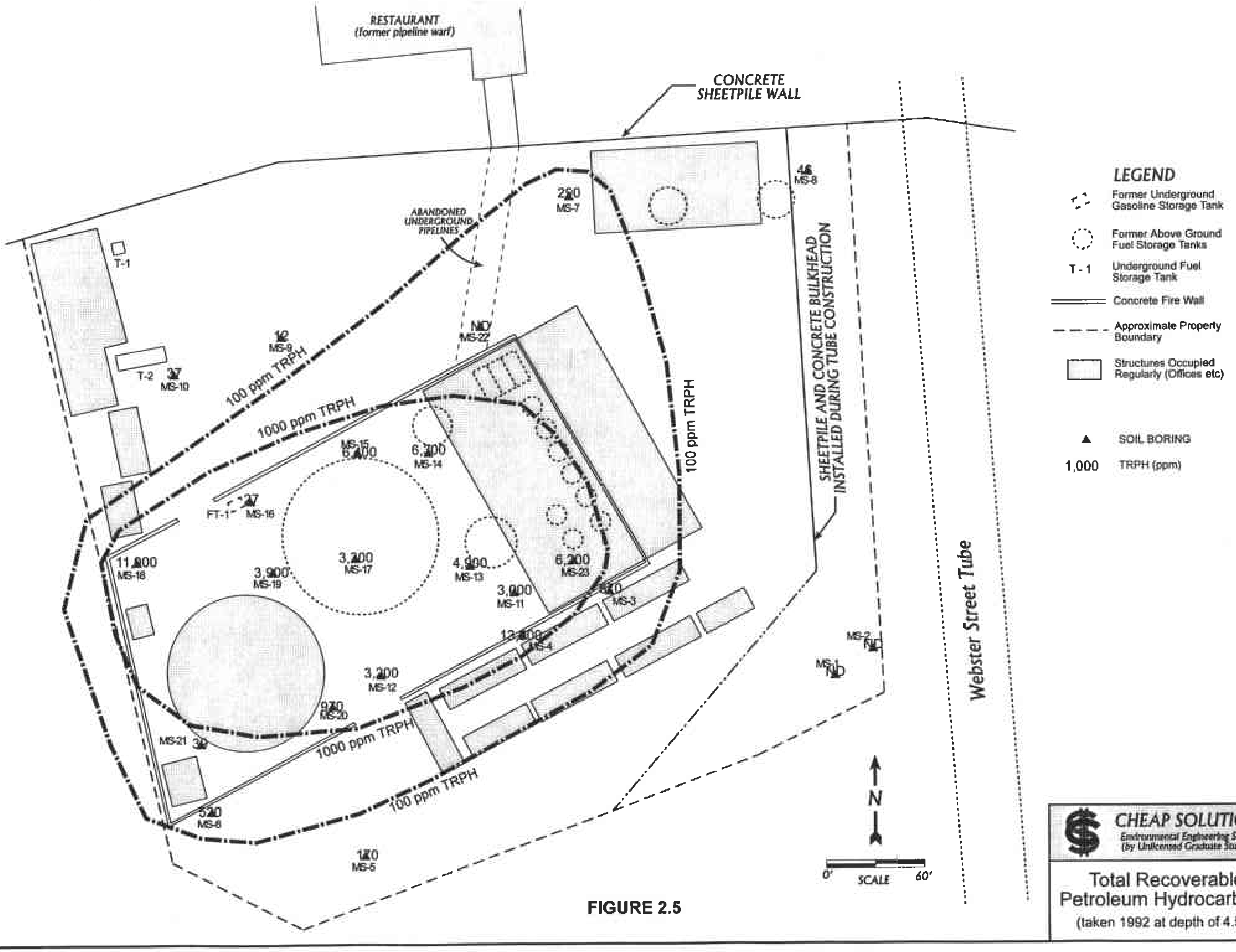


FIGURE 2.5

CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)

Total Recoverable
Petroleum Hydrocarbons
(taken 1992 at depth of 4.5 ft)

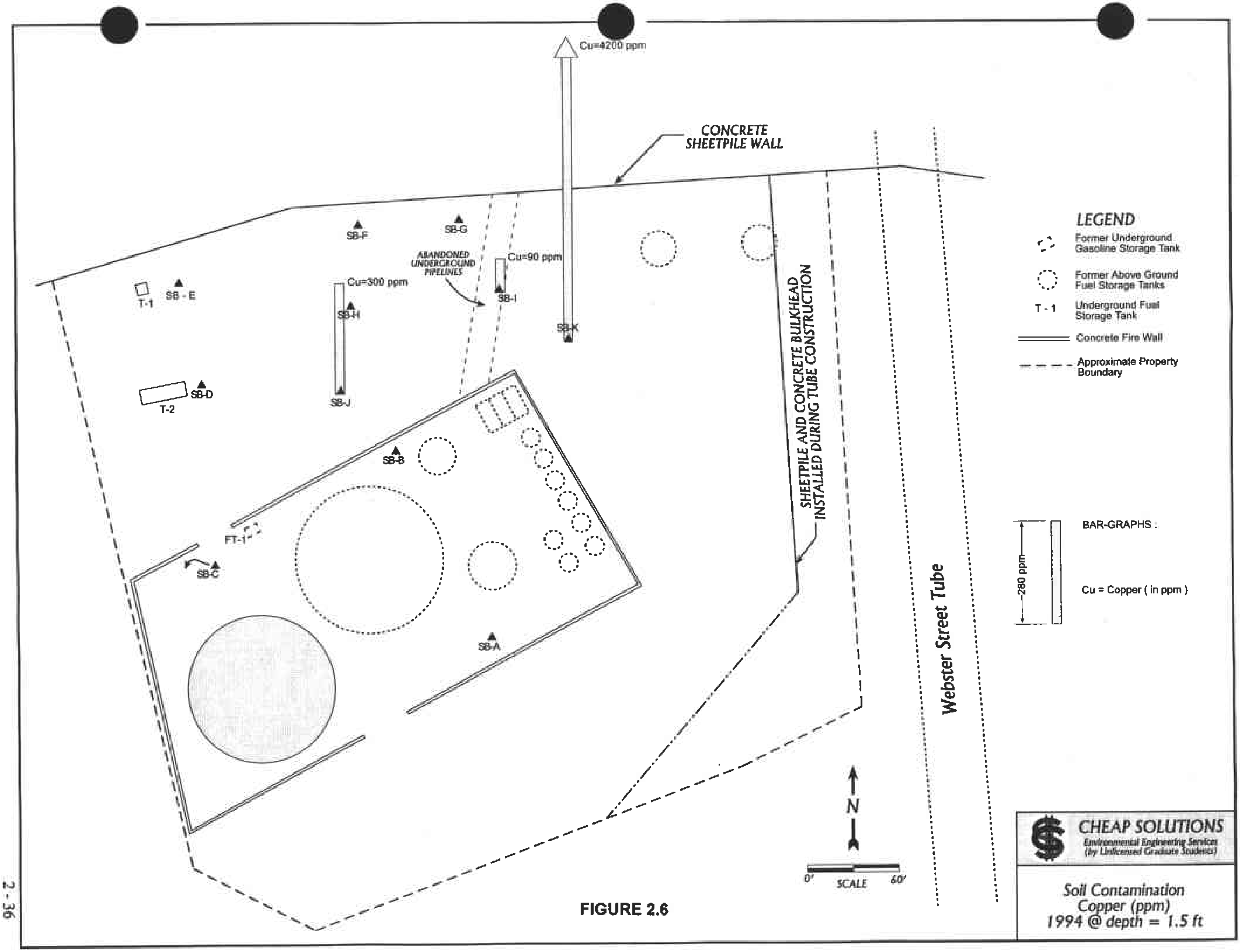

Cu=4200 ppm
CONCRETE SHEETPILE WALL
LEGEND
Former Underground Gasoline Storage Tank
Former Above Ground Fuel Storage Tanks
T - 1
Underground Fuel Storage Tank
Concrete Fire Wall
Approximate Property Boundary
SB-F
SB-G
ABANDONED UNDERGROUND PIPELINES
Cu=90 ppm
Cu=300 ppm
T-1
SB - E
SB-H
SB-I
SB-K
T-2
SB-D
SB-J
SHEETPILE AND CONCRETE BULKHEAD INSTALLED DURING TUBE CONSTRUCTION
SB-B
FT-1
SB-C
SB-A
BAR-GRAPHS :
280 ppm
Cu = Copper (in ppm)
Webster Street Tube
N
0'
SCALE
60'
CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)
Soil Contamination
Copper (ppm)
1994 @ depth = 1.5 ft

FIGURE 2.6

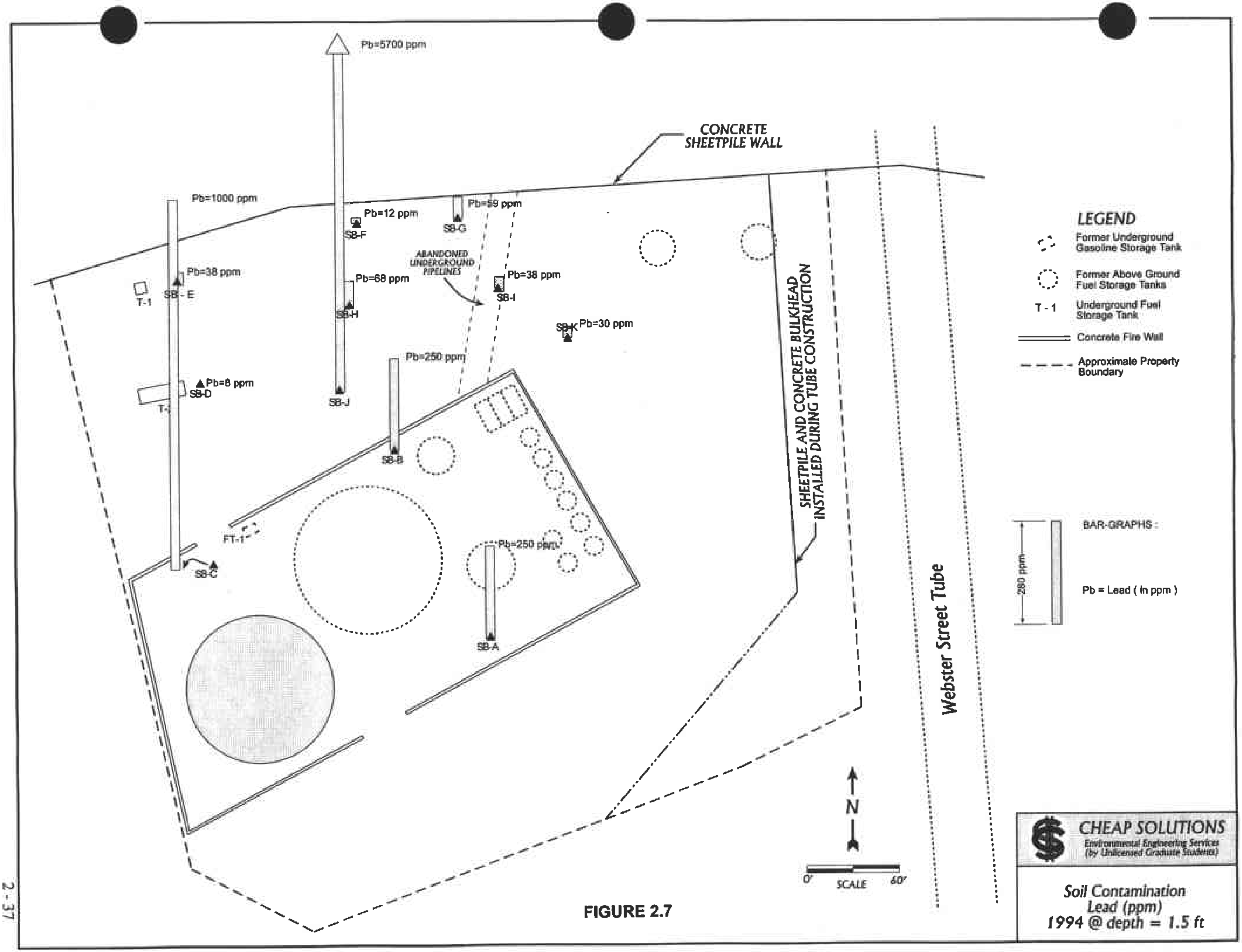


FIGURE 2.7

Soil Contamination
Lead (ppm)
1994 @ depth = 1.5 ft

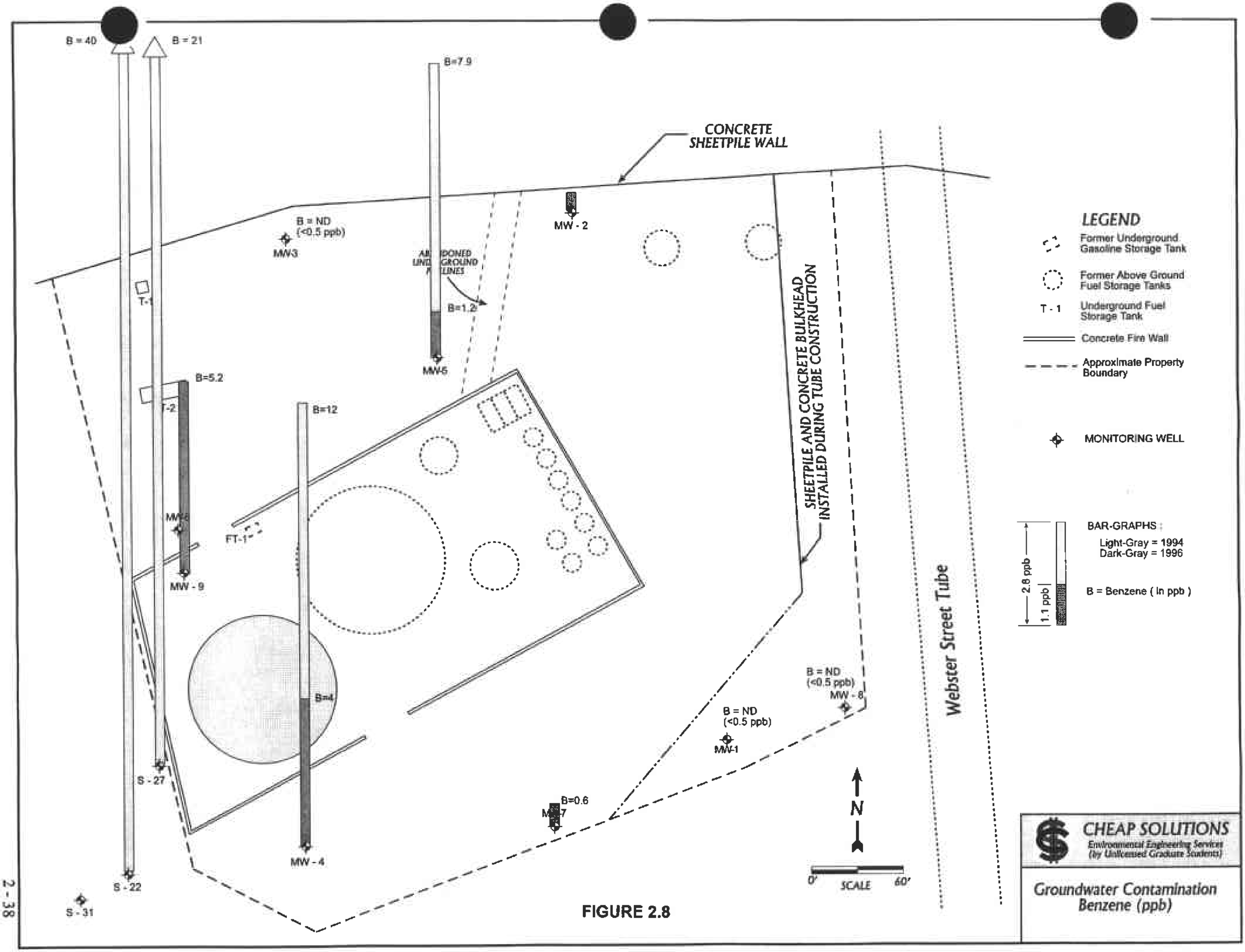

B = 40
B = 21
B=7.9
CONCRETE SHEETPILE WALL
B = ND (<0.5 ppb)
MW3
MW - 2
ABANDONED UNDERGROUND PIPELINES
B=1.2
MW-5
T-1
T-2
B=5.2
B=12
MW-6
MW - 9
FT-1
SHEETPILE AND CONCRETE BULKHEAD INSTALLED DURING TUBE CONSTRUCTION
Webster Street Tube
B=4
S - 27
S - 22
S - 31
MW - 4
B=0.6
MW-7
B = ND (<0.5 ppb)
MW-1
B = ND (<0.5 ppb)
MW - 8
N
0'
SCALE
60'
LEGEND
Former Underground Gasoline Storage Tank
Former Above Ground Fuel Storage Tanks
T - 1
Underground Fuel Storage Tank
Concrete Fire Wall
Approximate Property Boundary
MONITORING WELL
BAR-GRAPHS :
Light-Gray = 1994
Dark-Gray = 1996
2.8 ppb
1.1 ppb
B = Benzene (in ppb)
CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)
Groundwater Contamination
Benzene (ppb)

FIGURE 2.8

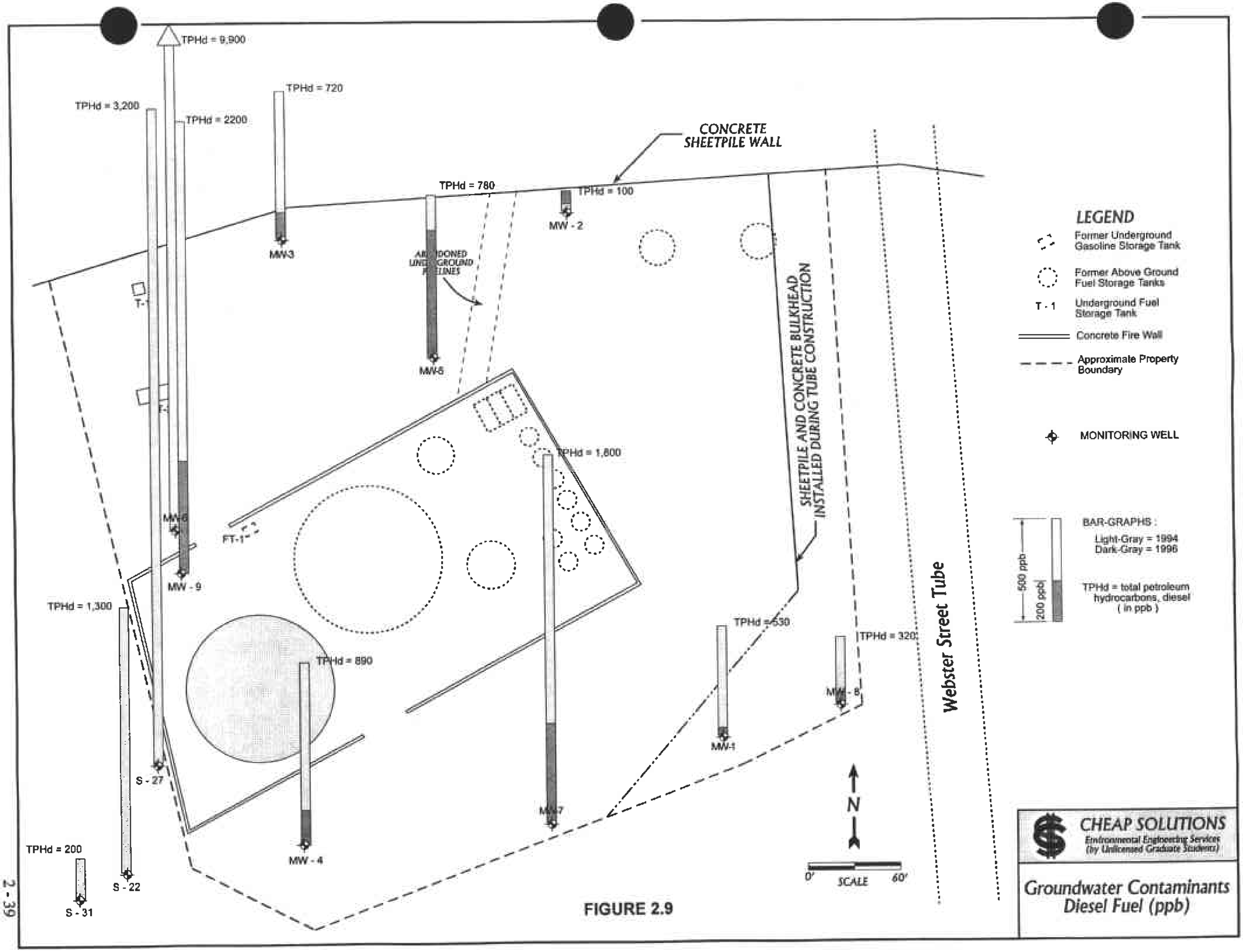
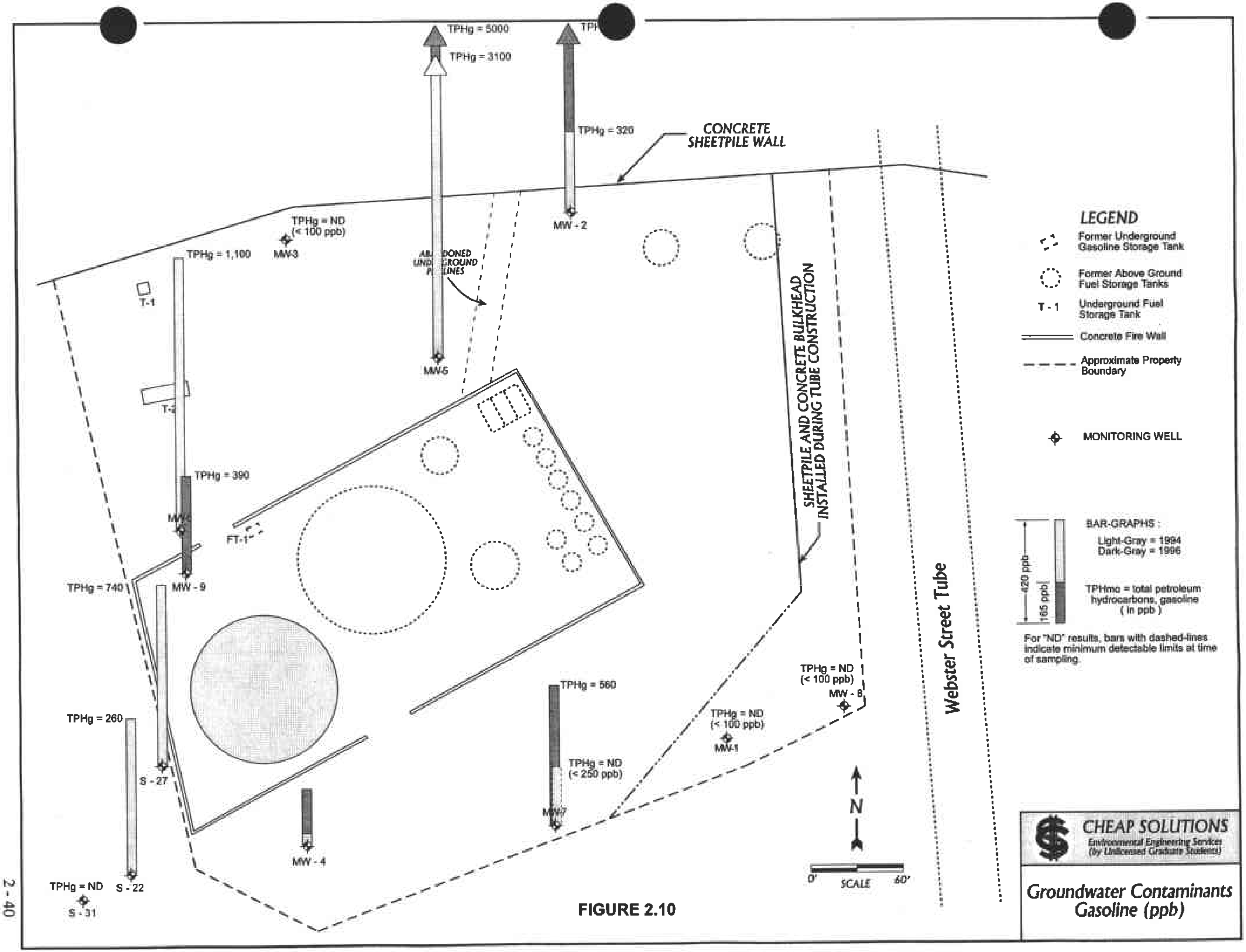

TPHd = 9,900
TPHd = 720
TPHd = 3,200
TPHd = 2200
CONCRETE SHEETPILE WALL
TPHd = 780
TPHd = 100
MW - 2
MW-3
ABANDONED UNDERGROUND PIPELINES
MW-5
T-1
T-
LEGEND
Former Underground Gasoline Storage Tank
Former Above Ground Fuel Storage Tanks
T - 1
Underground Fuel Storage Tank
Concrete Fire Wall
Approximate Property Boundary
MONITORING WELL
SHEETPILE AND CONCRETE BULKHEAD INSTALLED DURING TUBE CONSTRUCTION
TPHd = 1,800
MW-6
FT-1
MW - 9
BAR-GRAPHS :
Light-Gray = 1994
Dark-Gray = 1996
500 ppb
200 ppb
TPHd = total petroleum hydrocarbons, diesel (in ppb)
TPHd = 1,300
TPHd = 530
TPHd = 320
Webster Street Tube
TPHd = 890
MW - 8
MW-1
S - 27
MW-7
N
CHEAP SOLUTIONS
Environmental Engineering Services (by Unlicensed Graduate Students)
Groundwater Contaminants Diesel Fuel (ppb)
TPHd = 200
MW - 4
0'
SCALE
60'
S - 22
S - 31

FIGURE 2.9



Groundwater Contaminants Gasoline (ppb)

FIGURE 2.10

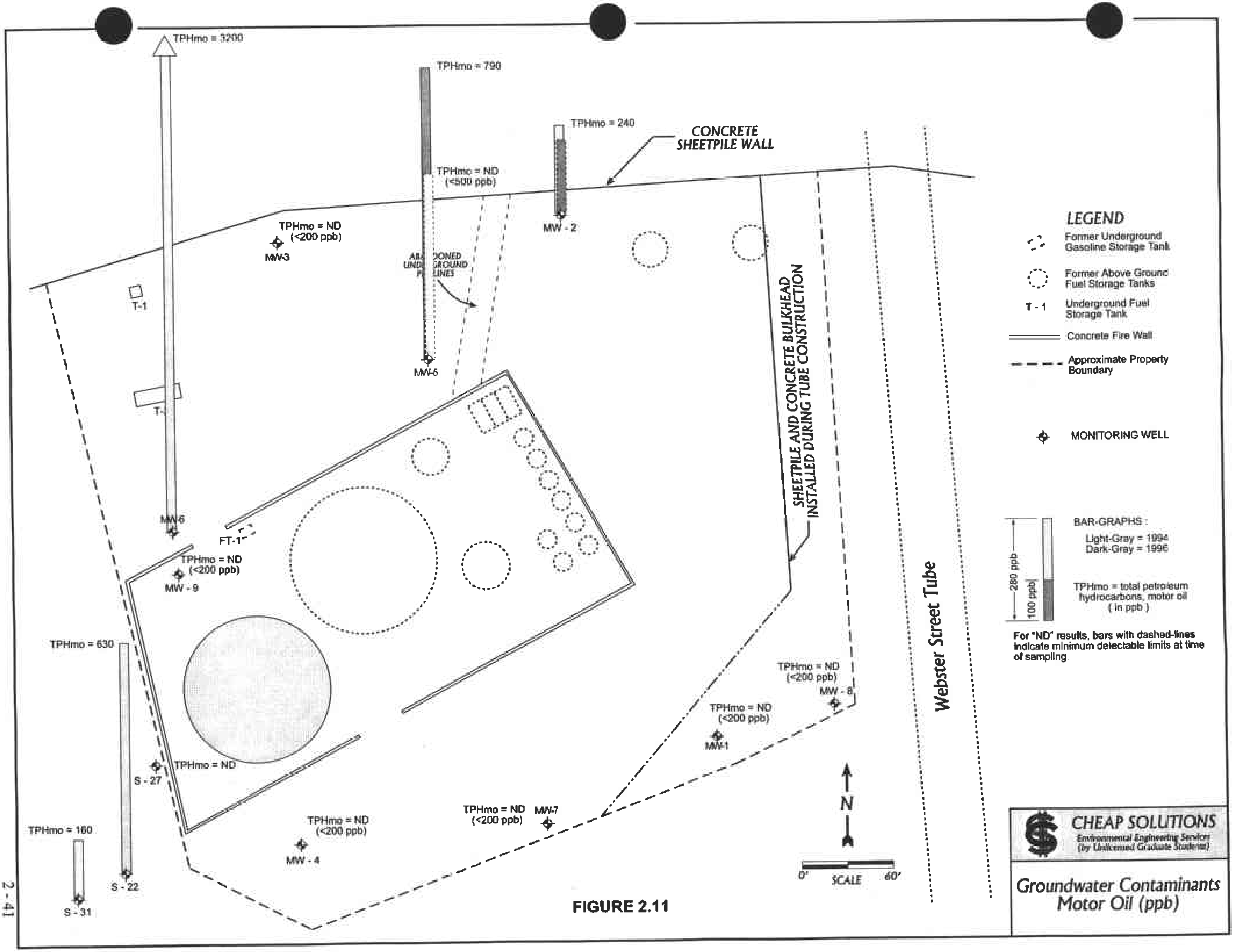

TPHmo = 3200
TPHmo = 790
TPHmo = ND
(<500 ppb)
TPHmo = 240
CONCRETE
SHEETPILE WALL
TPHmo = ND
(<200 ppb)
MW-3
MW - 2
ABA DONED
UND GROUND
P LINES
T-1
MW-5
T-
SHEETPILE AND CONCRETE BULKHEAD
INSTALLED DURING TUBE CONSTRUCTION
MW-6
FT-1
TPHmo = ND
(<200 ppb)
MW - 9
TPHmo = 630
TPHmo = ND
S - 27
TPHmo = 160
S - 22
S - 31
TPHmo = ND
(<200 ppb)
MW - 4
TPHmo = ND
(<200 ppb)
MW-7
TPHmo = ND
(<200 ppb)
MW-1
TPHmo = ND
(<200 ppb)
MW - 8
Webster Street Tube
N
0'
SCALE
60'
LEGEND
Former Underground Gasoline Storage Tank
Former Above Ground Fuel Storage Tanks
T - 1
Underground Fuel Storage Tank
Concrete Fire Wall
Approximate Property Boundary
MONITORING WELL
BAR-GRAPHS :
Light-Gray = 1994
Dark-Gray = 1996
280 ppb
100 ppb
TPHmo = total petroleum hydrocarbons, motor oil (in ppb)
For "ND" results, bars with dashed-lines indicate minimum detectable limits at time of sampling
CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)
Groundwater Contaminants
Motor Oil (ppb)

FIGURE 2.11

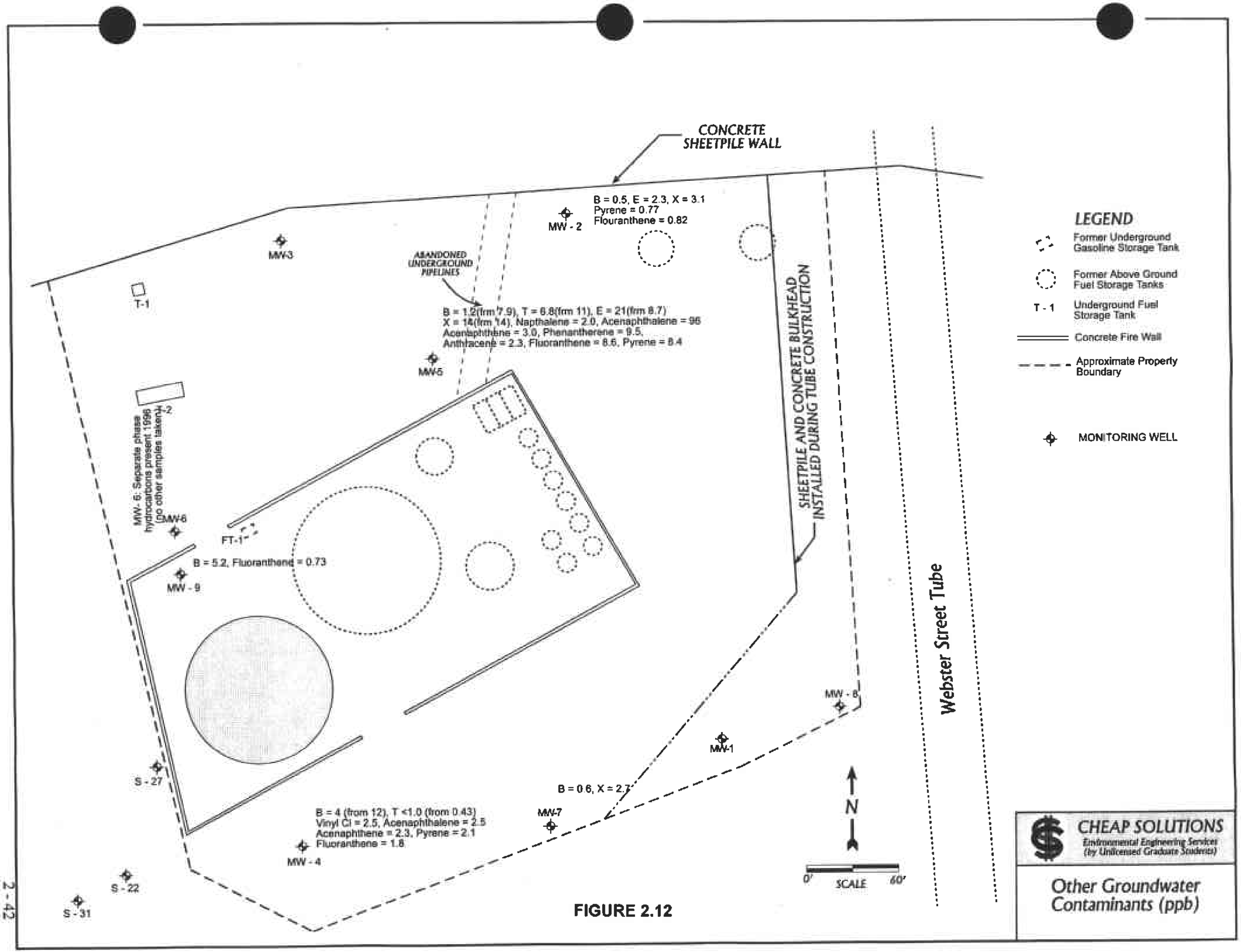

CONCRETE SHEETPILE WALL
B = 0.5, E = 2.3, X = 3.1
Pyrene = 0.77
Flouranthene = 0.82
MW - 2
MW-3
T-1
ABANDONED UNDERGROUND PIPELINES
B = 1.2(frm 7.9), T = 6.8(frm 11), E = 21(frm 8.7)
X = 14(frm 14), Napthalene = 2.0, Acenaphthalene = 96
Acenaphthene = 3.0, Phenantherene = 9.5,
Anthracene = 2.3, Fluoranthene = 8.6, Pyrene = 8.4
MW-5
T-2
MW- 6: Separate phase hydrocarbons present 1996 (no other samples taken)
MW-6
FT-1
B = 5.2, Fluoranthene = 0.73
MW - 9
SHEETPILE AND CONCRETE BULKHEAD INSTALLED DURING TUBE CONSTRUCTION
Webster Street Tube
MW - 8
MW-1
B = 0.6, X = 2.7
MW-7
B = 4 (from 12), T <1.0 (from 0.43)
Vinyl Cl = 2.5, Acenaphthalene = 2.5
Acenaphthene = 2.3, Pyrene = 2.1
Fluoranthene = 1.8
MW - 4
S - 27
S - 22
S - 31
N
0'
SCALE
60'
LEGEND
Former Underground Gasoline Storage Tank
Former Above Ground Fuel Storage Tanks
T - 1
Underground Fuel Storage Tank
Concrete Fire Wall
Approximate Property Boundary
MONITORING WELL
CHEAP SOLUTIONS
Environmental Engineering Services (by Unlicensed Graduate Students)
Other Groundwater Contaminants (ppb)

FIGURE 2.12

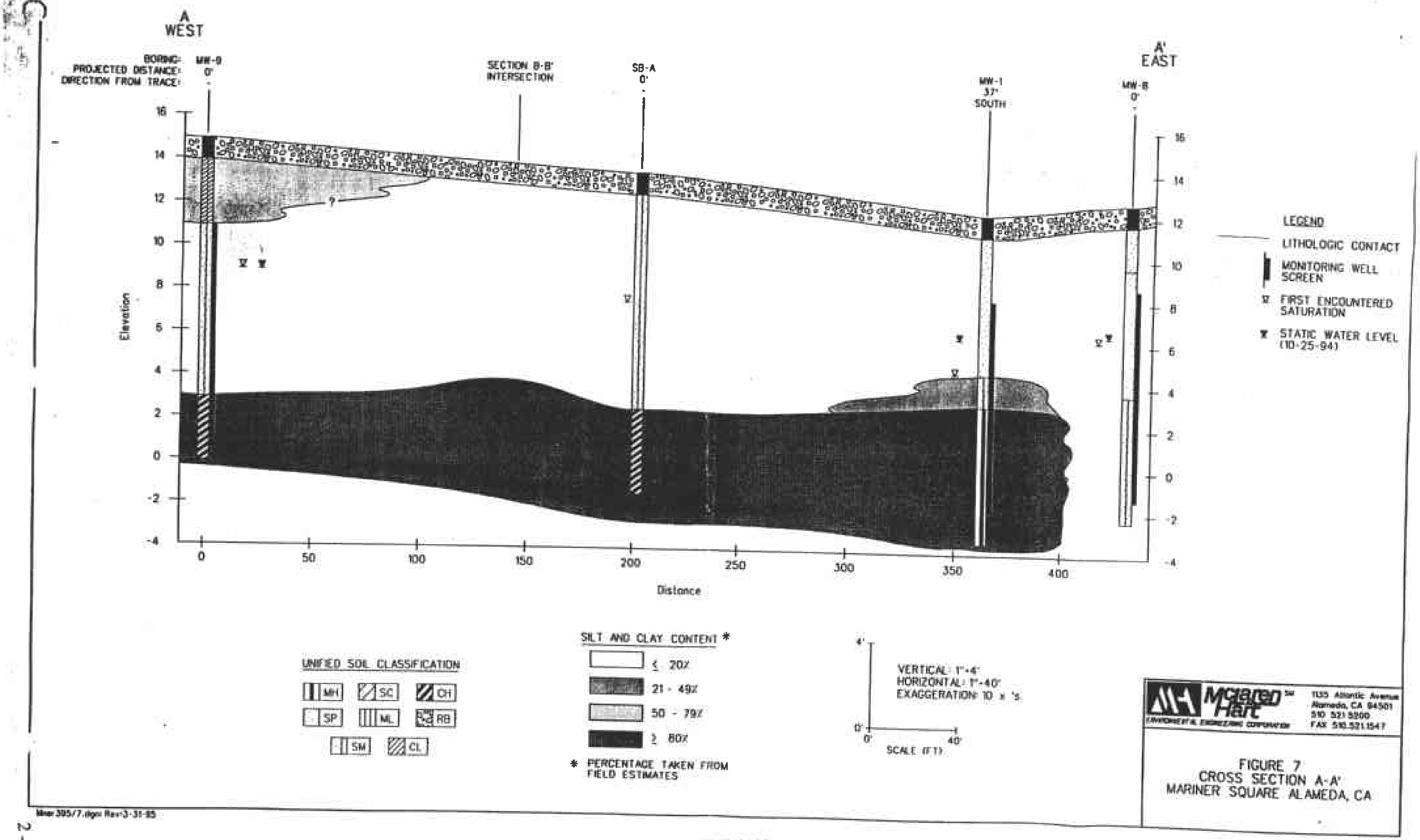
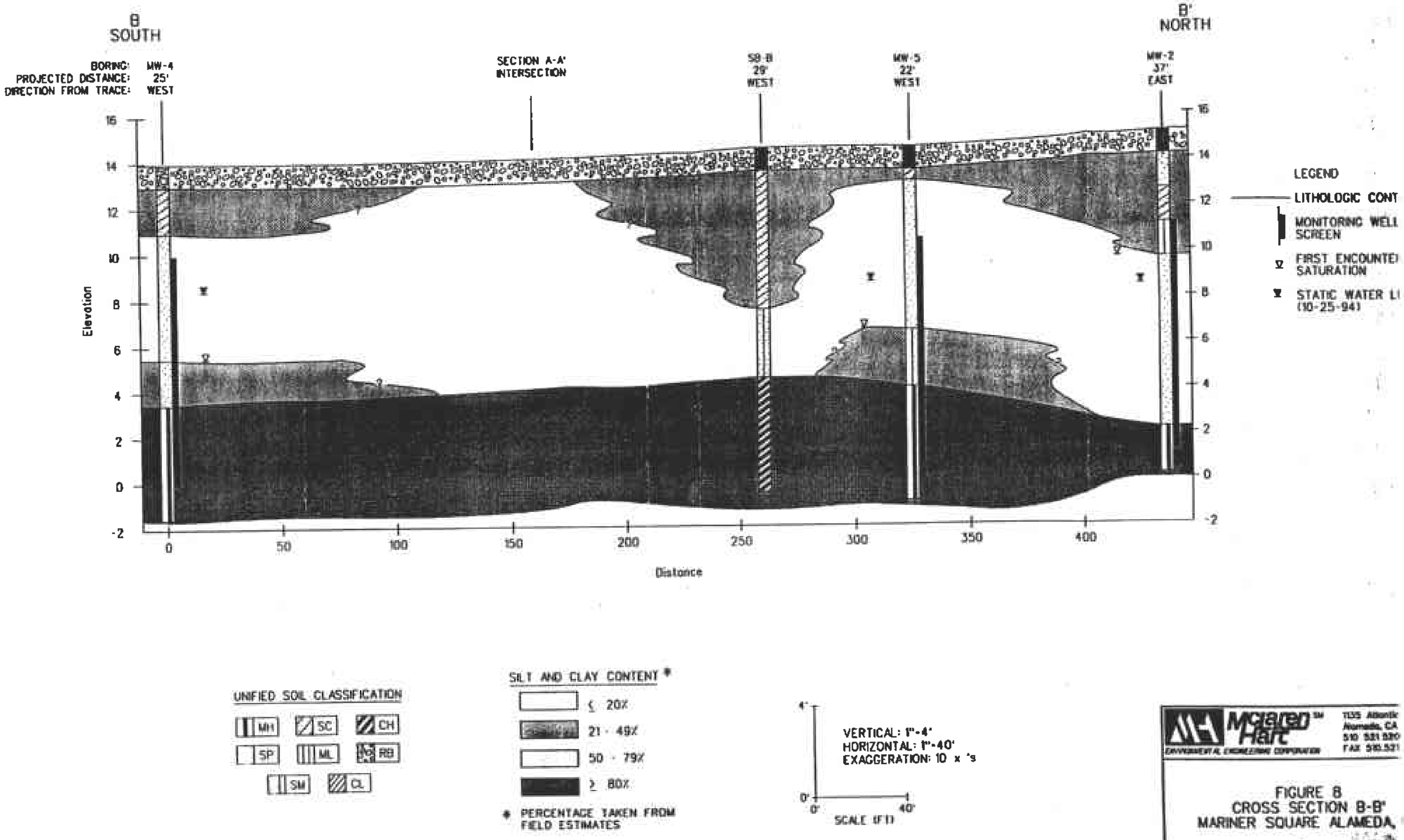

A
WEST
BORING:
PROJECTED DISTANCE:
DIRECTION FROM TRACE:
MW-9
0'
SECTION B-B' INTERSECTION
SB-A
0'
MW-1
37'
SOUTH
A'
EAST
MW-8
0'
Elevation
16
14
12
10
8
6
4
2
0
-2
-4
0
50
100
150
200
250
300
350
400
Distance
?
LEGEND
LITHOLOGIC CONTACT
MONITORING WELL SCREEN
FIRST ENCOUNTERED SATURATION
STATIC WATER LEVEL (10-25-94)
UNIFIED SOIL CLASSIFICATION
MH
SC
CH
SP
ML
RB
SM
CL
SILT AND CLAY CONTENT *
≤ 20%
21 - 49%
50 - 79%
≥ 80%
* PERCENTAGE TAKEN FROM FIELD ESTIMATES
4'
0'
0'
40'
SCALE (FT)
VERTICAL: 1"=4'
HORIZONTAL: 1"=40'
EXAGGERATION: 10 x 's
McLaren Hart
ENVIRONMENTAL ENGINEERING CORPORATION
1135 Atlantic Avenue
Alameda, CA 94501
510 521 5200
FAX 510.521.1547
FIGURE 7
CROSS SECTION A-A'
MARINER SQUARE ALAMEDA, CA
Mner 395/7.dgn Rev=3-31-95

FIGURE 2.13



McLaren Hart
ENVIRONMENTAL ENGINEERING CORPORATION
1135 Atlantic
Alameda, CA
510 521 520
FAX 510.521

FIGURE 8
CROSS SECTION B-B'
MARINER SQUARE ALAMEDA,

liner795/08.dgn Rev: 07-31-95

FIGURE 2.14

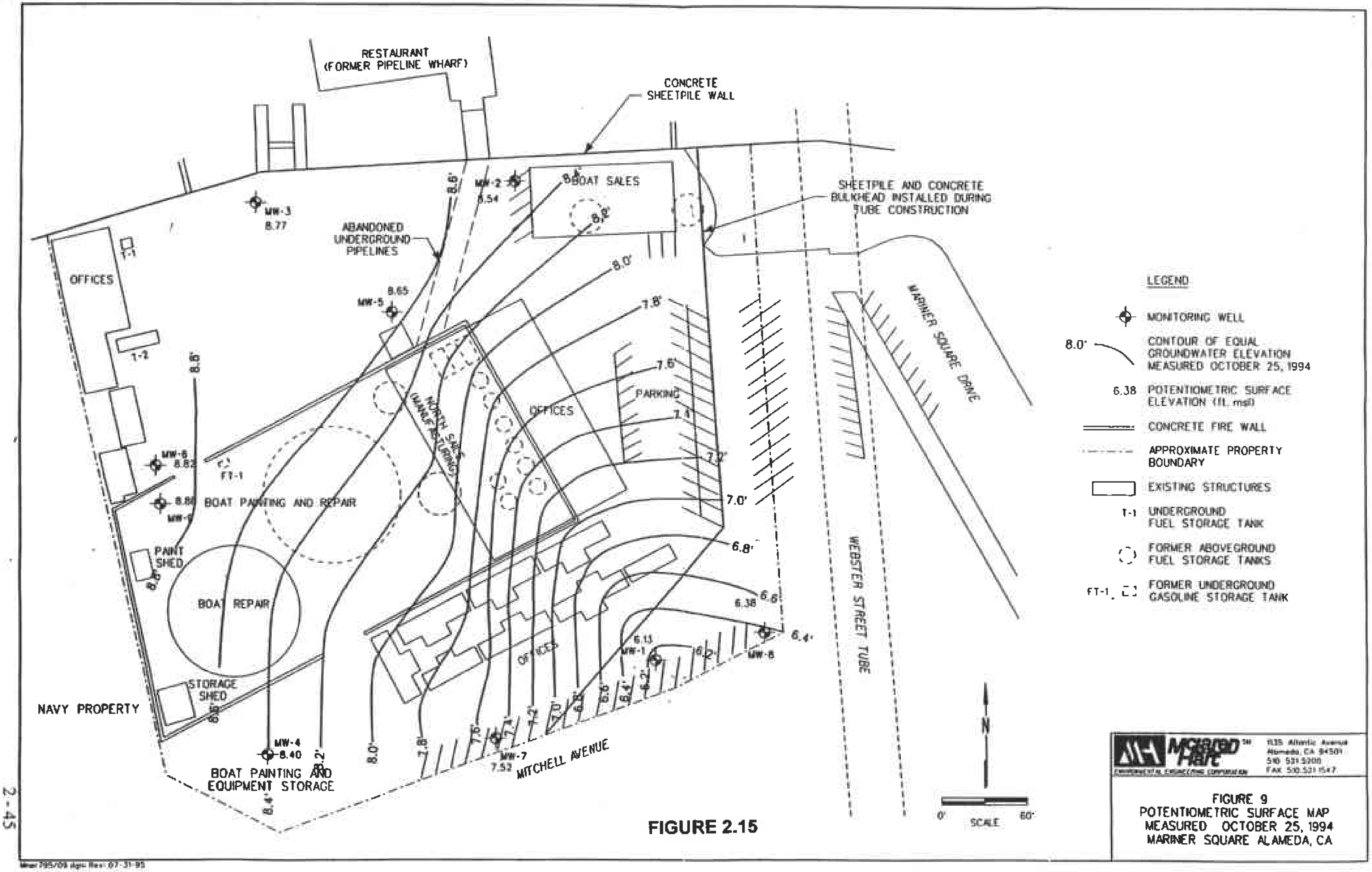

RESTAURANT
(FORMER PIPELINE WHARF)
CONCRETE SHEETPILE WALL
SHEETPILE AND CONCRETE BULKHEAD INSTALLED DURING TUBE CONSTRUCTION
ABANDONED UNDERGROUND PIPELINES
BOAT SALES
OFFICES
T-1
T-2
MW-3
8.77
MW-2
8.54
MW-5
8.65
MW-6
8.82
MW-9
8.86
FT-1
BOAT PAINTING AND REPAIR
PAINT SHED
BOAT REPAIR
STORAGE SHED
NAVY PROPERTY
MW-4
8.40
BOAT PAINTING AND EQUIPMENT STORAGE
NORTH SALES (MANUFACTURING)
OFFICES
PARKING
OFFICES
MW-7
7.52
MITCHELL AVENUE
MW-1
6.13
MW-8
6.38
WEBSTER STREET TUBE
MARINER SQUARE DRIVE
8.6'
8.4'
8.2'
8.0'
7.8'
7.6'
7.4'
7.2'
7.0'
6.8'
6.6'
6.4'
6.2'
N
0'
SCALE
60'
LEGEND
MONITORING WELL
8.0'
CONTOUR OF EQUAL GROUNDWATER ELEVATION MEASURED OCTOBER 25, 1994
6.38
POTENTIOMETRIC SURFACE ELEVATION (ft. msl)
CONCRETE FIRE WALL
APPROXIMATE PROPERTY BOUNDARY
EXISTING STRUCTURES
T-1
UNDERGROUND FUEL STORAGE TANK
FORMER ABOVEGROUND FUEL STORAGE TANKS
FT-1
FORMER UNDERGROUND GASOLINE STORAGE TANK
McLaren Hart
ENVIRONMENTAL ENGINEERING CORPORATION
1135 Atlantic Avenue
Alameda, CA 94501
510 521 5200
FAX 510 521 1547
FIGURE 9
POTENTIOMETRIC SURFACE MAP
MEASURED OCTOBER 25, 1994
MARINER SQUARE ALAMEDA, CA

FIGURE 2.15

3. Risk Assessment

3.1 Human Risk Assessment[1]

The primary objective of risk assessment is to facilitate the decision making for the remediation of contaminated sites. In addition, risk assessment can be utilized as the basis for selecting remediation alternatives as well as to establish the cleanup standards via back calculations. The following describes the four stages of the risk assessment: (1) hazard identification; (2) exposure assessment; (3) toxicity assessment; (4) risk characterization.

3.1.1 Hazard Identification

Hazard identification examines the evidence that associates exposure to an agent with its toxicity.

3.1.1.1 Media of Concern

The potential contaminated media at the site of Mariner Square include soil, groundwater, air, and bay waters. The human health risk caused from contaminated bay waters is not considered because the contaminant concentration in groundwater is of ppb to ppm levels and it will be diluted in seawater. Furthermore the sea water is not a drinking water source.

3.1.1.2 Areas of Concern

Areas of concern are classified as on-site and off-site. The on-site populations are the direct receptors of the contamination. Although the sources of contamination are located on-site, it is very likely that people off site would breathe the air containing the contaminants. In addition, people off site could use groundwater as a drinking water source.

3.1.1.3 Contaminates of Concern

The primary chemicals found on the Mariner Square site can be classified into the following categories:

(1) VOC and SVOCs:
TPHg, TPHMo, TPHd, benzene, ethylbenzene, toluene, xylene, vinyl chloride, and PAHs such as naphthalene, pyrene, bezo[a]pyrene, etc.
(2) Metals:
Copper, zinc, chromium, nickel, lead, etc.

The chemicals of interest with potential adverse health effect are shown in Table 3.1. Benzene and vinyl chloride have been confirmed as human carcinogens. The toxicity concerning each contaminants is summarized in Table 3.2. **Total petroleum-gasoline, diesel, and mobile oils are not considered, since there is not sufficient toxicity information for risk assessment.**

Table 3.1 Chemicals of concern

VOCs	PAHs	Metal
Benzene Ethylbenzene Toluene Xylene Vinyl Chloride	Acenaphthene Anthracene Benzo[a]pyrene Fluoranthene Naphthalene	Antimony Arsenic Chromium Copper Lead Zinc

Table 3.2 Toxicity effects regarding the contaminates of concern[1-4]

Metals	Arsenic	nausea, vomiting, and diarrhea; decreased production of red and white blood cells; abnormal heart rhythm, blood vessel damage; "pins and needles" sensation in hands and feet
	Antimony	liver damage and blood changes reported in animal studies, exact effects not well-known
	Chromium	toxic to respiratory, gastrointestinal system
	Nickel	kidney damage., skin allergy
	Lead	toxic to central nervous system, particularly in children; also damages kidneys and the immune system; may cause anemia, causes abortion and damages the male reproductive system
	Copper	causes an allergic skin rash
VOCs	Benzene	confirmed human carcinogen; harmful to blood cells, bone marrow and immune system.
	Toluene	brain and kidney damage; neurotoxicity
	Ethylbenzene	eyes, nose, throat , and skin irritation; high exposure may damage the liver
	Xylene	repeated exposure may damage bone marrow causing low blood cell count, may also damage the eyes, and cause stomach problems.
	Vinyl Chloride	damage to the liver, nerves, and immune system; known human carcinogen
PAHs		not sufficient data to determine carcinogenicity contribution from the individual PAH; oral exposure accounts for adverse health effect, especially for benzo[a]pyrene.

3.1.2 Exposure Assessment

The purpose of exposure assessment is to estimate the uptake of a chemical by current and potential future receptors of concern through all relevant routes of exposure. This includes the magnitude, frequency, and duration of such exposure. Given the release and identification of contaminants, it is possible to analyze the transport and transfer behavior and in turn estimate the potential risk to the receptors.

3.1.2.1 Population of Concern

Table 3.3 is a summary of receptors that might be exposed to the contaminants pertaining to the Site:

Table 3.3 Population of concern

Current Scenario	**Future Scenario**
On-site	*On-site*
worker	worker
visitor (adult)	visitor (adult)
visitor (child)	visitor (child)
maintenance worker	maintenance worker
	construction worker
	resident
Off-site	*Off-site*
worker	worker
visitor (adult)	visitor (adult)
visitor (child)	visitor (child)
resident	resident

On-site workers spend most of their time working in offices (yacht rental and sales), and off-site workers are mainly working in restaurants. It is expected that the receptors include on-site and off-site visitors since there is an adjacent recreational area. Maintenance workers are also potential on-site exposure receptors. In the future scenario, on-site residents and construction workers could be target receptors because it is possible that the Site will become a residential area. Furthermore, it is necessary to pay special attention to children since they receive higher risk burden due to their higher susceptibility as well as the adverse health effects regarding developmental toxicity.

3.1.2.2 Potential Exposure Pathway

Exposure results from a collective chain of events called pathways. A pathway is the environmental route from the contaminant source to the receptors. The potential routes of contaminants exposure are summarized in figure 3.1 and figure 3.2 (Site Conceptual Exposure Model, SCEM), for the current and future scenario, respectively.

3.1.2.3 Receptor Dose Calculation[*]

The general formula regarding contaminant intake dose is:

---

[*] Dose calculation is justified in Appendix A.

SITE CONCEPTUAL EXPOSURE MODEL

Volatile and Semi-Volatile Organic Carbons

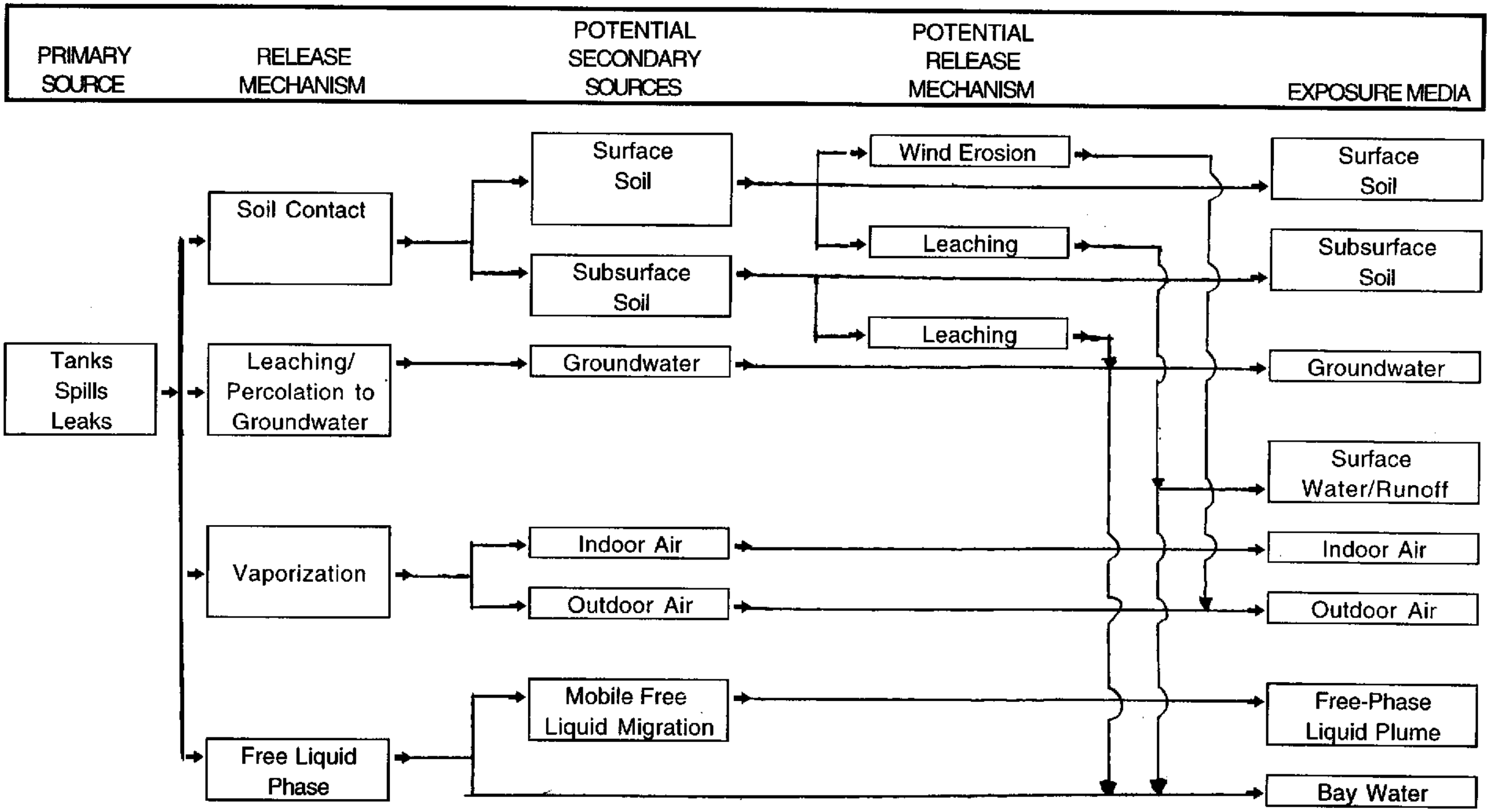


FIGURE 3.1

SITE CONCEPTUAL MODEL - ORGANIC CARBONS
PAGE 1 of 3

SITE CONCEPTUAL EXPOSURE MODEL

	EXPOSURE	HUMAN RECEPTOR					
		CURRENT SCENARIO					
EXPOSURE MEDIA	ROUTE	On-Site Worker	Off-Site Worker	On-Site Visitor	Off-Site Visitor	On-Site Maintenance Worker	Off-Site Resident
Surface Soil	Ingestion	●		●		●	
	Dermal	●		●		●	
Subsurface Soil	Ingestion						
	Dermal						
Groundwater	Ingestion						
	Dermal						
Surface Water/Runoff	Ingestion					●	
	Dermal					●	
Indoor Air	Inhalation	●		●		●	
Outdoor Air	Inhalation	●	●	●	●	●	●
Free-Phase Liquid Plume	Ingestion						
	Dermal						
Bay Water	Ingestion						
	Dermal						

SITE CONCEPTUAL MODEL - ORGANIC CARBONS
PAGE 2 of 3

FIGURE 3.1

SITE CONCEPTUAL EXPOSURE MODEL

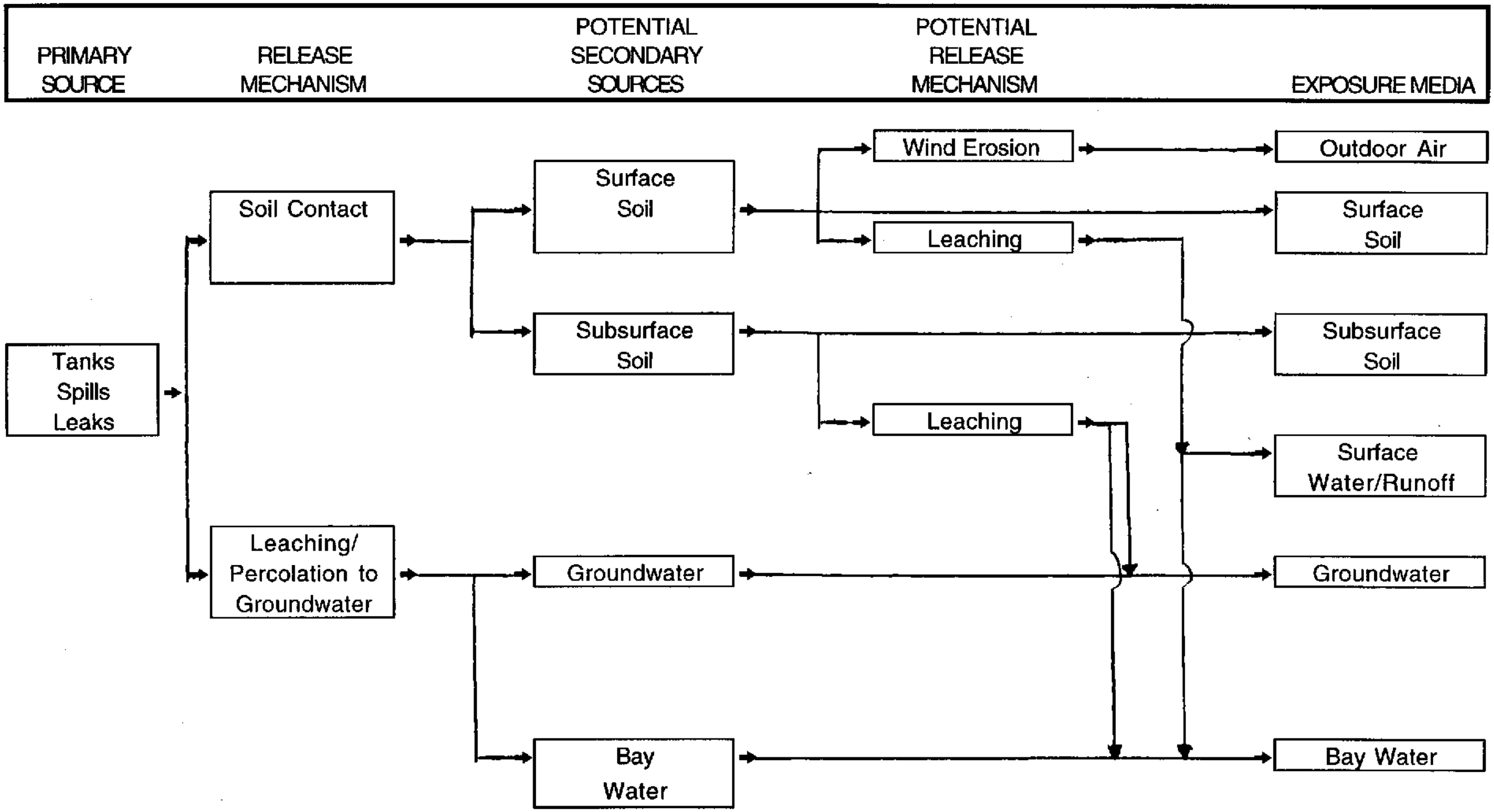
EXPOSURE MEDIA	EXPOSURE ROUTE	HUMAN RECEPTOR								ECOLOGICAL RECEPTOR
		FUTURE SCENARIO								
		On-Site Construction Worker	On-Site Worker	Off-Site Worker	On-Site Visitor	Off-Site Visitor	On-Site Maintenance Worker	On-Site Resident	Off-Site Resident	
Surface Soil	Ingestion	●	●		●		●	●		
	Dermal	●	●		●		●	●		
Subsurface Soil	Ingestion	●								
	Dermal	●								
Groundwater	Ingestion	●								
	Dermal	●								
Surface Water/Runoff	Ingestion	●					●			
	Dermal	●					●			
Indoor Air	Inhalation		●		●		●	●		
Outdoor Air	Inhalation	●	●	●	●	●	●	●	●	
Free-Phase Liquid Plume	Ingestion	●								
	Dermal	●								
Bay Water	Ingestion									●
	Dermal									

FIGURE 3.1

SITE CONCEPTUAL MODEL - ORGANIC CARBONS
PAGE 3 of 3

SITE CONCEPTUAL EXPOSURE MODEL

Metals and Grease



SITE CONCEPTUAL MODEL - METALS
PAGE 1 of 3

FIGURE 3.2

SITE CONCEPTUAL EXPOSURE MODEL

EXPOSURE MEDIA	EXPOSURE ROUTE	HUMAN RECEPTOR					
		CURRENT SCENARIO					
		On-Site Worker	Off-Site Worker	On-Site Visitor	Off-Site Visitor	On-Site Maintenance Worker	Off-Site Resident
Outdoor Air	Inhalation	●	●	●	●	●	●
Surface Soil	Ingestion	●		●		●	
	Dermal	●		●		●	
Subsurface Soil	Ingestion						
	Dermal						
Surface Water/Runoff	Ingestion					●	
	Dermal					●	
Groundwater	Ingestion						
	Dermal						
Bay Water	Ingestion						
	Dermal						

SITE CONCEPTUAL MODEL - METALS
PAGE 2 of 3

FIGURE 3.2

SITE CONCEPTUAL EXPOSURE MODEL

EXPOSURE MEDIA	EXPOSURE ROUTE	HUMAN RECEPTOR								ECOLOGICAL RECEPTOR
		FUTURE SCENARIO								
		On-Site Construction Worker	On-Site Worker	Off-Site Worker	On-Site Visitor	Off-Site Visitor	On-Site Maintenance Worker	On-Site Resident	Off-Site Resident	
Outdoor Air	Inhalation	●	●	●	●	●	●	●		
Surface Soil	Ingestion	●	●		●		●	●		
	Dermal	●	●		●		●	●		
Subsurface Soil	Ingestion	●								
	Dermal	●								
Surface Water/Runoff	Ingestion	●					●			
	Dermal	●					●			
Groundwater	Ingestion	●								
	Dermal	●								
Bay Water	Ingestion									●
	Dermal									

FIGURE 3.2

SITE CONCEPTUAL MODEL - METALS
PAGE 3 of 3

$$Dose = C \cdot \frac{CR \cdot EF \cdot ED}{BW \cdot AT} \qquad (3.1)$$

where:

Dose : chemical intake (mg/kg body weight/day)
C : average chemical concentration contacted over the exposure period
CR : contact rate; the amount of contaminated medium contacted per unit time or event, such as inhalation and ingestion rate (IR).
EF : exposure frequency
ED : exposure duration
BW : body weight
AT : average time; period over which exposure is averaged.

The exposure factors used for above scenarios are summarized in Table 3.4:

Table 3.4 Exposure factors applied in the human risk assessment for current and future scenarios

Exposure Parameters	EF [d/year]	ED [years]	BW [kg]	AT for Cancer Risk [a] [days]	AT for Hazard Quotient [b] [days]
Current Scenario					
On-site					
worker	250	25	70	25550	9125
visitor (adult)	10	25	70	25550	9125
visitor (child)	10	15	15	25550	5475
maintenance worker	20	25	70	25550	9125
Off-site					
worker	250	25	70	25550	9125
visitor (adult)	10	25	70	25550	9125
visitor (child)	10	15	15	25550	5475
resident	365	70	70	25550	25500
Future Scenario					
On-site					
worker	250	25	70	25550	9125
visitor (adult)	10	25	70	25550	9125
visitor (child)	10	15	15	25550	5475
maintenance worker	20	25	70	25550	9125
construction worker	250	1	70	25550	365
resident	365	70	70	25550	25550
Off-site					
worker	250	25	70	25550	9125
visitor (adult)	10	25	70	25550	9125
visitor (child)	10	15	15	25550	5475
resident	365	70	70	25550	25550

[a] 365 d/yr x 70 yrs
[b] 365 d/yr x ED yrs

The contaminant intake calculations for inhalation, ingestion of water and soil, as well as dermal contact of soil and water are described as the following.

3.1.2.3.1 *Inhalation*[6-9]

In order to estimate the contaminant intake via inhalation, the atmospheric contaminant concentration must be determined. The metal concentrations in air are ignored here because metals have little tendency to vaporize, and the erosion of metals from soil is negligible since Mariner Square is mostly paved. The VOCs and PAHs concentrations in air are determined by assuming the contaminants are in equilibrium among soil, water and air phases. Detailed calculation are shown in Appendix A.

Table 3.5 Inhalation rate, activity pattern, and exposure frequency of potentially exposed populations.

	IR [m3/d]	T_{out} [hr/day]	T_{in} [hr/day]	EF [d/year]
Current Scenario				
On-site				
worker	20	1	8	250
visitor (adult)	20	4	4	10
visitor (child)	10	4	4	10
maintenance worker	30	8	2	20
Off-site				
worker	20	1	8	250
visitor (adult)	20	4	4	10
visitor (child)	10	4	4	10
resident	20	3	21	365
Future Scenario				
On-site				
worker	20	1	8	250
visitor (adult)	20	4	4	10
visitor (child)	10	4	4	10
maintenance worker	30	8	2	20
construction worker	30	10	0	250
resident	20	3	21	365
Off-site				
worker	20	1	8	250
visitor (adult)	20	4	4	10
visitor (child)	10	4	4	10
resident	20	3	21	365

T_{out} : time of staying outdoors
T_{in} : time of staying indoors

Therefore, the contaminant intake can be calculated as:

$$Dose_{air} = \frac{\left(T_{out} \cdot C_{out} + T_{in} \cdot C_{in}\right) / 24 \cdot IR \cdot EF \cdot ED}{BW \cdot AT} \tag{3.2}$$

where:

C_{out} : outdoor contaminant concentration, mg/m^3
C_{in} : indoor contaminant concentration, mg/m^3.

C_{in} is calculated by assuming the indoor environment is a well-mixed chamber (see Appendix A for details):

It should be noted that the atmospheric contaminant concentration estimated in this way is highly conservative because:

1. The highest soil gas concentration is selected, and the total amount of contaminants into atmosphere is maximized by utilizing a much broader area than the actual sampling point area.
2. The off-site air contaminant concentration is assumed to be the same as on site. Thus the risk would be overestimated for off-site receptors.

3.1.2.3.2 Water Ingestion

Since there is no well on site or off site, the groundwater can not be used as drinking water source. On-site maintenance workers have the possibility of ingesting groundwater. Groundwater ingestion is considered for on-site exposure setting in the future, in case a drinking water well is developed.

Thus, the contaminant intake dose via water ingestion by receptors can be expressed as:

$$Dose = C_w \cdot \frac{IR \cdot FI \cdot EF \cdot ED}{BW \cdot AT} \tag{3.3}$$

where C_w is contaminant concentration in groundwater, IR is the water ingestion rate, FI is the fraction of groundwater intake within one day, and other parameters are the same as in equation (3.1).

Table 3.6 Water ingestion rate, fraction of ingestion, and exposure frequency of potential on-site exposed populations.

	IR [L/d]	FI [-]	EF [d/yr]
Current Scenario			
maintenance worker	0.05	0.04	20
Future Scenario			
Construction worker	2	0.75	250
worker	2	0.75	250
visitor (child)	2	0.25	10
maintenance worker	2	0.75	20
resident	2	1	365

3.1.2.3.3 Soil Ingestion

The contaminant intake from soil ingestion can be obtained by the following:

$$Dose = C_s \cdot \frac{IR \cdot FI \cdot EF \cdot ED}{BW \cdot AT} \tag{3.4}$$

In the future scenario it is assumed the asphalt has been removed, so the population has a possibility of being exposed to the contaminated soil.

Table 3.7 Water ingestion rate, fraction of ingestion, and exposure frequency of potential on-site exposed populations.

	IR [mg soil/d]	FI [-]	EF [d/yr]
Current Scenario			
worker	100	0.04	250
visitor (child)	200	0.08	20
maintenance worker	100	0.04	50
Future Scenario			
Construction worker	100	0.12	5
worker	100	0.04	250
visitor (child)	200	0.08	20
maintenance worker	100	0.04	50
resident	100	0.02	350

3.1.2.3.4 Soil Dermal Contact

The daily contaminant intake via soil dermal contact is calculated as:

$$Dose = C_s \cdot \frac{SA \cdot AF \cdot ABS \cdot EF \cdot ED}{BW \cdot AT} \qquad (3.5)$$

where SA is exposed skin surface area, AF is soil to skin adherence factor, and ABS is absorption factor.

Table 3.8 Soil dermal contact rate, exposed skin surface area, soil to skin adherence factor, and exposure frequency of potential on-site exposed populations.

	SA [m^2/event]	AF [mg/cm^2]	ABS [-]	EF [event/yr]
Current Scenario				
worker	0.312	2.77	0.1	20
visitor (child)	0.312	2.77	0.1	2
maintenance worker	0.312	2.77	0.1	50
Future Scenario				
Construction worker	0.312	2.77	0.1	10
worker	0.312	2.77	0.1	40
visitor (child)	0.312	2.77	0.1	2
maintenance worker	0.312	2.77	0.1	100
resident	0.312	2.77	0.1	100

3.1.2.3.4 Water Dermal Contact

The daily contaminant intake via soil dermal contact can be calculated as:

$$Dose = C_w \cdot \frac{SA \cdot PERM \cdot ET \cdot EF \cdot ED}{BW \cdot AT} \qquad (3.6)$$

where PERM is skin permeability and ET is exposure time per event, assuming groundwater is used for drinking water supply in the future.

Table 3.9 Water dermal contact rate, exposed skin surface area, contaminant permeability, and exposure frequency of potential on-site exposed populations.

	Surface Area [m^2/event]	Permeability [cm/h]	ET [hr/event]	Exposure Frequency [event/yr]
Current Scenario				
maintenance worker	0.312	0.04	8	5
Future Scenario				
Construction worker	0.312	0.04	8	10
worker	0.312	0.04	8	5
visitor (child)	1.5	0.04	6	2
maintenance worker	0.312	0.04	8	3
resident	0.312	0.04	10	20

3.1.3 Toxicity Assessment

The objective of toxicity assessment is to determine the quantitative relation between the magnitude of dose and the potential adverse health effects.

3.1.3.1 Carcinogens vs. Noncarcinogens

Chemicals are categorized in terms of carcinogens and noncarcinogens. For carcinogens, there is no threshold effect, and the dose-response relationships are reported as incidence of lifetime cancer versus dose. The slope is called cancer potency, or slope factor (SF). Noncarcinogens, on the other hand, have threshold effects, indicating the chemicals would not cause adverse health effects below a threshold. This is known as the Reference Dose (RfD).

3.1.3.2 Source of Toxicity Information

In this risk assessment study the applied toxicity parameters, such as slope factor for carcinogens and Reference Dose for noncarcinogens, are based upon California EPA recommended values, which are more stringent than Federal standards*. The toxicity parameters for contaminants of concern are listed below.

---

* For example, IRIS, Integrated Risk Information System of USEPA, is a toxicity resource commonly used in risk assessment

Table 3.10 Slope factors and Reference Dose for the contaminants of concern

Chemicals	Slope Factor $(mg/kg/d)^{-1}$			Reference Dose (mg/kg/d)		
	Inhalation	Oral	Dermal	Inhalation	Oral	Dermal
Benzene	0.1	0.1	0.1	0.0017	0.0007	0.0007
Vinyl Chloride	0.27	0.27	0.27	0	0	0
Ethylbenzene	na	na	na	0.3	0.1	0.1
Toluene	na	na	na	0.03	0.2	0.2
Xylene	na	na	na	2.0	2.0	2.0
Acenaphthene	na	na	na	0.06	0.06	0.06
Anthracene	na	na	na	0.3	0.3	0.3
Benzo[a]pyrene	na	na	na	0.03	0.03	0.03
Fluoranthene	na	na	na	0.04	0.04	0.04
Naphthalene	na	na	na	0.003	0.04	0.04
Antimony	na	na	na	nd	0.0004	0.0004
Arsenic	na	na	na	nd	0.00003	0.00003
Chromium	na	na	na	nd	0.005	0.005
Copper	na	na	na	nd	0.037	0.037
Lead	na	na	na	nd	10^{-7}	nd
Nickel	na	na	na	nd	0.02	0.02
Zinc	na	na	na	nd	0.3	0.3

na: not applicable
nd: no data available

It should be mentioned that, although lead is a well-recognized toxic substance, there is no slope factor or RfD associated with it. This is because either there is no strong evidence suggesting it can cause cancer, or it is inappropriate to develop an RfD for inorganic lead due to its essentially low threshold. However, we adopted a very conservative approach, and thus assumed the lead in the soil matrix is entirely organic (tetraethyl lead with the RfD for oral exposure 10^{-7}) in the risk calculation.

3.1.3.3 Carcinogenic Risk

The carcinogenic risk is defined as the value of chemical intake dose multiplied by the carcinogenic slope factor. The product indicates the possibility of excess lifetime cancer from exposure to this contaminant.

$$\text{Risk} = \text{Dose} \times \text{SF} \qquad (3.7)$$

where:

Dose: chronic daily intake, mg/kg/day
SF: chemical-specific slope factor $(mg/kg/day)^{-1}$

If the carcinogenic risk exceeds acceptable risk (usually 10^{-4} to 10^{-6}, depending on residential, occupational settings, etc.), risk management and further remediation action of the contaminants are required. If the estimated cancer risk is less than the acceptable level, no action is required from the human health risk perspective.

3.1.3.4 Noncarcinogenic Risk

The carcinogenic risk is characterized by a hazard index (HI) ,or hazard quotient (HQ), which is the ratio of chemical intake dose divided by the Reference Dose. The ratio provides a criterion to determine the hazard level. Hazard quotient is computed as:

$$HQ = \frac{\text{Dose}}{\text{RfD}} \qquad (3.8)$$

There are no strict criteria to relate actual hazard with HQ values beacuseHQ is a protective level rather a predictive value. Generally, an HQ smaller than one is regarded as an acceptable level. HQ can be applied to provide insights to decision-makers for risk management.

3.1.3.5 Risks Associated with the Site

Based on the procedure of cancer and noncancer risk assessment, the calculated risks and hazard quotients are summarized in Appendix Table A.1-8

Of particular note is that the exposure parameters used in the risk assessment are highly conservative. For example, the contaminated groundwater is assumed to be used as a direct drinking water source; highest contaminants sampling concentrations are applied; a high exposure frequency and long exposure duration are selected; as well as the worst lead exposure scenario.

3.1.4 Risk Characterization

The objective of risk characterization is to identify the nature and magnitude of human risk associated with contaminants exposure, and evaluate the uncertainties and major assumptions involved.

3.1.4.1 Interpretation of Calculated Risks

3.1.4.1.1 Carcinogenic Risk

Table 3.11 is a summary of total cancer risks from the exposure to all contaminants from all potential pathways. The total cancer risks suggest there is no carcinogenic threat in the current scenario. However, the future on-site worker and resident might receive a higher cancer risk if Mariner Square is developed as a residential area because more soil matrix and contaminants might be exposed to the atmosphere. Nevertheless, it is clear that the estimated cancer risks are acceptable (the highest one is in the order of magnitude 10^{-5}). It should be noted that a significant portion of the cancer risk results from direct drinking of groundwater which is contaminated with vinyl chloride. This is the worst case scenario.

Table 3.11 Total cancer risks for exposure to all contaminants from all potential pathways

	Total Cancer Risk		Total Cancer Risk
Current Scenario		**Future Scenario**	
On-site		*On-site*	
worker	3.0E-09	worker	2.6E-05
visitor (adult)	1.1E-10	visitor (adult)	7.4E-09
visitor (child)	1.5E-10	visitor (child)	7.5E-06
maintenance worker	9.9E-07	maintenance worker	5.6E-06
Off-site		construction worker	1.9E-06
worker	2.7E-09	resident	6.3E-05
visitor (adult)	1.1E-10	*Off-site*	
visitor (child)	2.3E-10	worker	1.3E-07
resident	3.3E-08	visitor (adult)	5.2E-09
		visitor (child)	1.4E-08
		resident	4.3E-07

3.4.1.2 Noncarcinogenic Risk

With the exception of Lead, the calculated hazard quotients for each contaminant are within acceptable levels in the current scenario. In a future scenario with the asphalt removed the highest non-Lead HQ is determined to be 1.1 due to ingestion of Arsenic (page A-28). Hence all noncarcinogenic risk associated with the chemicals of concern (with the exception of Lead) are minimal, especially with the asphalt cap retained.

However, *initial risk assessment of acute Lead exposure indicates a significant threat to human health in almost all scenarios*, with HQ values in excess of 10 (page A-25). It must be emphasized that this assessment was performed using *a highly conservative estimate that all Lead measured on the site is in the form of Tetraethyl Lead*, as explained in section 3.1.3.2. *This is an unlikely assumption. Further investigation into the exact forms of Lead within the site must be completed before these high HQ values can be meaningful.*

The high values for on-site Total HQ in Table 3.12 are due solely to exposure to Lead.

Table 3.12 Total hazard quotients when exposed to all contaminants from all potential pathways

	Total Hazard Quotient		Total Hazard Quotient
Current Scenario		**Future Scenario**	
On-site		*On-site*	
worker	1.4E+01	worker	1.9E+02
visitor (adult)	1.3E-04	visitor (adult)	8.3E-04
visitor (child)	2.2E+01	visitor (child)	1.4E+03
maintenance worker	2.9E+00	maintenance worker	3.8E+01
Off-site		construction worker	5.4E+00
worker	3.2E-03	resident	1.6E+02
visitor (adult)	1.3E-04	*Off-site*	
visitor (child)	3.0E-04	worker	1.4E-02
resident	1.4E-02	visitor (adult)	5.7E-04
		visitor (child)	1.3E-03
		resident	6.3E-02

3.1.4.2 Uncertainty Analysis

3.1.4.2.1 Sources of Uncertainty

Risk assessment involves estimation from various factors, such as contaminant concentration, intake rate, exposure frequency, etc. Each factor, as well as each step, introduce variability, thus it is essential to examine the inherent uncertainty. The uncertainties associated with the site of Mariner Square might result from:

1. Atmospheric contaminant concentration: since there is no air sampling data, the estimation of atmospheric contaminate concentration is based upon the calculation of the CalTOX* program.
2. Contaminant concentration: it is assumed the contaminant concentration is constant during the entire exposure duration. However, it cannot be in this way in a highly fluctuating natural environment.
3. Exposure pattern: contaminant contact rate, exposure frequency, and durations are presumed to be identical during the whole life time in the current conventional risk assessment arena.
4. Individual variability: the susceptibility to chemical hazard varies with individual. Body weight is a distribution among population and nobody maintains body weight through their lifetime.
5. Slope factor/Reference Dose: those parameters are obtained by animal studies, therefore there are inherent uncertainties. For example, the extrapolations (from animals to human being, and the from high dose to low dose exposure in bioassays) would inevitably bring uncertainty.

3.1.4.4.2 Monte Carlo Simulation

Many of the data in risk estimation are statistical point estimates (90th or 95th percentile values). Therefore, a stochastic model can be used to utilize the full range of information. The Monte Carlo simulation is a well-established procedure that replaces point data with random variables from certain known distributions. In order to compare the risks obtained from Monte Carlo simulation and the conventional risk assessment approach, the cancer risk caused by vinyl chloride inhalation was modeled with a Monte Carlo simulation. The commercial software used was Crystal Ball®. Since there was not sufficient information to determine the mean and standard deviation of every parameter, we pluged in different reasonable values in order to estimate the distribution spread. After five simulations, the resulting forecast data point for the 90th percentile falls in the same order of magnitude of 10^{-6}. (Table 3.13) Figure 3.3 is an example of the output of the simulation

---

* CalTOX was developed by CalEPA and Lawrence Livermore National Laboratory and has been used to assist in health-risk assessment. Only the atmospheric contaminant concentration in representative California landscape properties is taken from the output. Other data is not used because further information can not be obtained regarding the appropriate use of CalTOX.

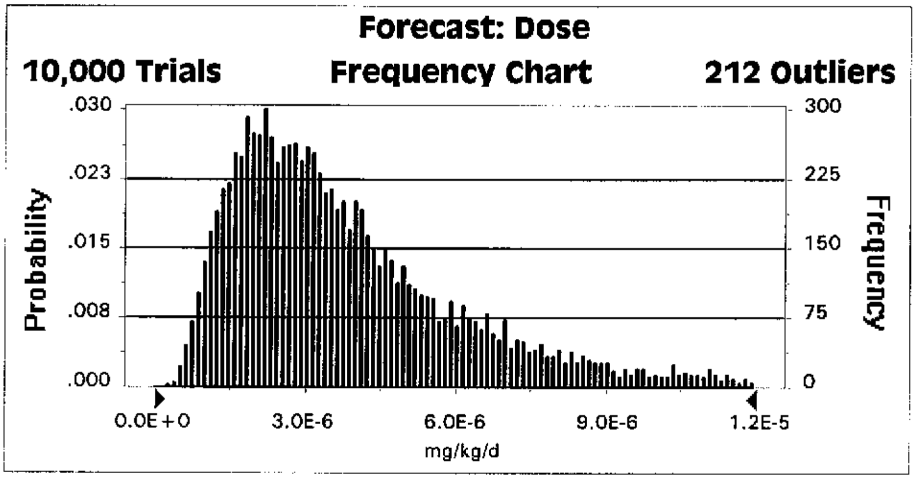
Crystal Ball Report

Simulation started on 4/25/97 at 0:01:57
Simulation stopped on 4/25/97 at 0:03:50

Forecast: Dose

Summary:

Display Range is from 0.0E+0 to 1.2E-5 mg/kg/d
Entire Range is from 3.0E-7 to 3.4E-5 mg/kg/d
After 10,000 Trials, the Std. Error of the Mean is 2.8E-8



Percentiles:

Percentile	mg/kg/d
0%	3.0E-07
10%	1.5E-06
20%	1.9E-06
30%	2.4E-06
40%	2.8E-06
50%	3.3E-06
60%	3.9E-06
70%	4.6E-06
80%	5.7E-06
90%	7.6E-06
100%	3.4E-05

End of Forecast

Fig 3-3 Output Example of Monte Carlo Simulation

Table 3.13 Four different simulation situations and results for estimation of vinyl chloride intake via inhalation exposure in the future residential scenario.

Options	**Distribution**		**Run 1**	**Run 2**	**Run 3**	**Run 4**
Vinyl chloride air concentration, mg/m^3	lognormal	Mean	$1.5x10^{-5}$	$1.5x10^{-5}$	$1.5x10^{-5}$	$1.5x10^{-5}$
		Stdev.	$1.0x10^{-5}$	$1.0x10^{-6}$	$1.5x10^{-5}$	$2.0x10^{-5}$
Inhalation Rate, m^3/day	lognormal	Mean	20	20	21	22
		Stdev.	2.0	3	4	5
Time staying outdoors, hrs	Normal	Mean	3	4	5	5
		Stdev.	0.3	0.8	1	2
Time staying indoors, hrs	Normal	Mean	21	20	19	19
		Stdev.	2.1	2	4	4
Exposure Frequency, d/yr	Normal	Mean	342	300	250	250
		Stdev.	20	20	60	70
Exposure Duration, yrs	Normal	Mean	60	50	40	40
		Stdev.	10	20	20	10
Body weight, kg	Normal	Mean	70	65	65	62
		Stdev.	10	15	13	12
Dose at 90th percentile			$7.6x10^{-6}$	$4.1x10^{-6}$	$4.2x10^{-6}$	$4.2x10^{-6}$

1. Stdev. : Standard deviation
2. The result is obtained from 10,000 trials of simulation.

From figure 3.3, the 90th percentile value falls at $7.6x10^{-6}$, which is multiplied by a slope factor[*] of 0.27, and thus yields a cancer risk of $2.0x10^{-6}$. This indicates the vinyl chloride induced cancer risk via inhalation in residential setting for future scenario is at the borderline of the acceptable criteria. The point data estimation is $6.3x10^{-6}$. The point data estimation and the 90th percentile value from the Monte Carlo simulation are very close.

3.1.4.2.3 The Worst Exposure Scenario Analysis

The worst exposure scenario is defined as the residential setting, where the population will be exposed for 24 hours a day, during the entire lifetime of 70 years. The uncovered surface leads to higher vinyl chloride concentration in the atmosphere. Both methods assume inhalation as the exposure pathway.

$$Dose = \frac{C_{vc,air} \cdot IR \cdot EF \cdot ED}{BW \cdot AT}$$

$$= \frac{2.4 \cdot 10^{-5} mg/m^3 \cdot 20m^3 \cdot 365d/yr \cdot 70 years}{70kg \cdot 365d/yr \cdot 70 years}$$

$$\approx 6.9 \cdot 10^{-6} mg/kg/d$$

$$CancerRisk = Dose \cdot SlopeFactor$$

$$= 6.9 \cdot 10^{-6} mg/kg/d \cdot 0.27 (mg/kg/d)^{-1}$$

$$\approx 1.9 \cdot 10^{-6}$$

---

[*] The slope factor, a data point, is drawn from a probability distribution function. However, like other exposure factors, the mean and standard deviation can not be correctly obtained due to insufficient information.

The above calculation adopts the most conservative approach:

1. the highest vinyl chloride concentration;
2. the highest exposure frequency and the longest exposure duration.

The resulting cancer risk is still in the order of magnitude of 10^{-6*}.

3.1.4.3 Summary

Based on the conventional risk assessment procedures, the calculated cancer risk and noncancer risk indicate there is no significant human health risk existing currently at the site of Mariner Square. This is because the asphalt cover retards the diffusion of contaminants (mostly VOCs) to the atmosphere, and also reduces the soil dermal contact opportunity. In the future scenario, however, a higher risk would result if the cover is removed. The highest cancer risk is approximately 6.3×10^{-5} and the hazard quotient can be as high as 1400.

3.2 Ecological Risk Assessment

According to the EPA's Proposed Guidelines for Ecological Risk Assessment an ecological risk assessment provides a "tool for considering available scientific information when selecting a course of action, in addition to other factors that may affect the decision (e.g., social, legal, political or economic)."[10] The procedure includes three phases, with several steps for each phase, as outlined below.

I. Problem Formation
    A. Identify goals and assessment endpoints
    B. Prepare a conceptual model
    C. Develop an analysis plan

II. Analysis
    A. Evaluate exposure levels
    B. Evaluate effects of stressors

III. Risk Characterization
    A. Estimate risk
    B. Determine ecological adversity

The nature of the existing data available for the Mariner Square site on Alameda makes it problematic to complete the suggested phases through the Risk Characterization. The information was collected strictly on site and excludes any baseline characterization of the potentially affected ecological receptors. Following is a summary of the justifiable risk assessment along with recommendations to enable completion.

---

[*] The inhalation rate and body weight vary with individual growth, and individual susceptibility is difficult to determine.

3.2.1 Problem Formation

3.2.1.1 Identify Goals and Assessment Endpoints

An appropriate goal for the ecological risk resulting from the contamination at the site is:

Avoid further environmental degradation due to the migration of anthropogenic substances.

This would include the local area as well as all environmental receptors affected by this site. A more ambitious goal would be to restore the local ecosystem to an undisturbed state. This is thought to be unrealistic due to the high level of industrial activity on, and surrounding, the Mariner Square site that has been continuous since the beginning of the century. The huge amount of resources required to attain and maintain this condition makes it, effectively, impossible.

There are several possible assessment endpoints available from scientific studies including: acute toxicity, chronic toxicity, Lowest Observable Effect Level (LOEL), No Observable Effect Level (NOEL), carcinogenic effects, mutagenic effects and others. Considering the stated goal is reasonable to limit the ecological receptors to exposure less than the NOEL. Exact limits, however, are difficult to set. Often times the compound in question has not been sufficiently studied or it may behave differently depending on the environment in which its found.

3.2.1.2 Conceptual Model

An analysis of the potential exposure pathways has been done. Table 3.14 shows the pathways that lead to ecological receptors.

Table 3.14 Potential Ecological Pathways

	Pathway	Receptor
Metals	Surface Soil	Limited under current scenario
	Subsurface Soil	Limited under current and future scenario
	Groundwater - Bay	Aquatic life and Marine fowl
VOCs	Surface Soil	Limited - due to degradation and volatilization
	Subsurface Soil	Limited under current and future scenario
	Groundwater - Bay	Aquatic life and Marine fowl

3.2.1.3 Develop an analysis plan

To the present date there has been little attention to the potential ecological risk posed due to the contamination on site. The following are some recommended steps that would allow a more complete analysis of the ecological hazard.

1. Verify or discount the exposure pathways.
2. Determine the baseline characteristics of the receptor locations.
3. Evaluate the stressor concentrations at the receptor.
4. Evaluate the effects of the stressors on the biological receptors.
5. Determine the risk.
6. Evaluate the uncertainty.

This is, of course, a very brief outline and may not be completely applicable. It is critical to reevaluate the plan upon obtaining more information.

3.2.2 Analysis

3.2.2.1 Evaluate exposure levels

Assuming that the San Francisco Bay is the major ecological receptor system, it has been assumed that the majority of the exposure will result from groundwater migration. There are still many uncertainties about the groundwater flow so a list of maximum groundwater concentrations has been developed and is shown in Table 3.15.

Table3.15 Mariner Square Groundwater Contamination

Pollutant	Maximum Groundwater Concentration (ppb)
Arsenic	10
Chromium	30
Copper	30
Lead	82
Nickel	50
Zinc	60
TPHg[11]	5000
TPHd[11]	610
TPHMo[11]	790
Benzene	5.2
Toluene	11
Ethylbenzene	21
Xylene	14
Vinyl Chloride	2.5
Acenapthalene	96

Although it is not likely that these levels will reach the Bay, it is suspected that an exposure pathway exists that could transport the pollutants as shown in figure 3.4. There is a drain system

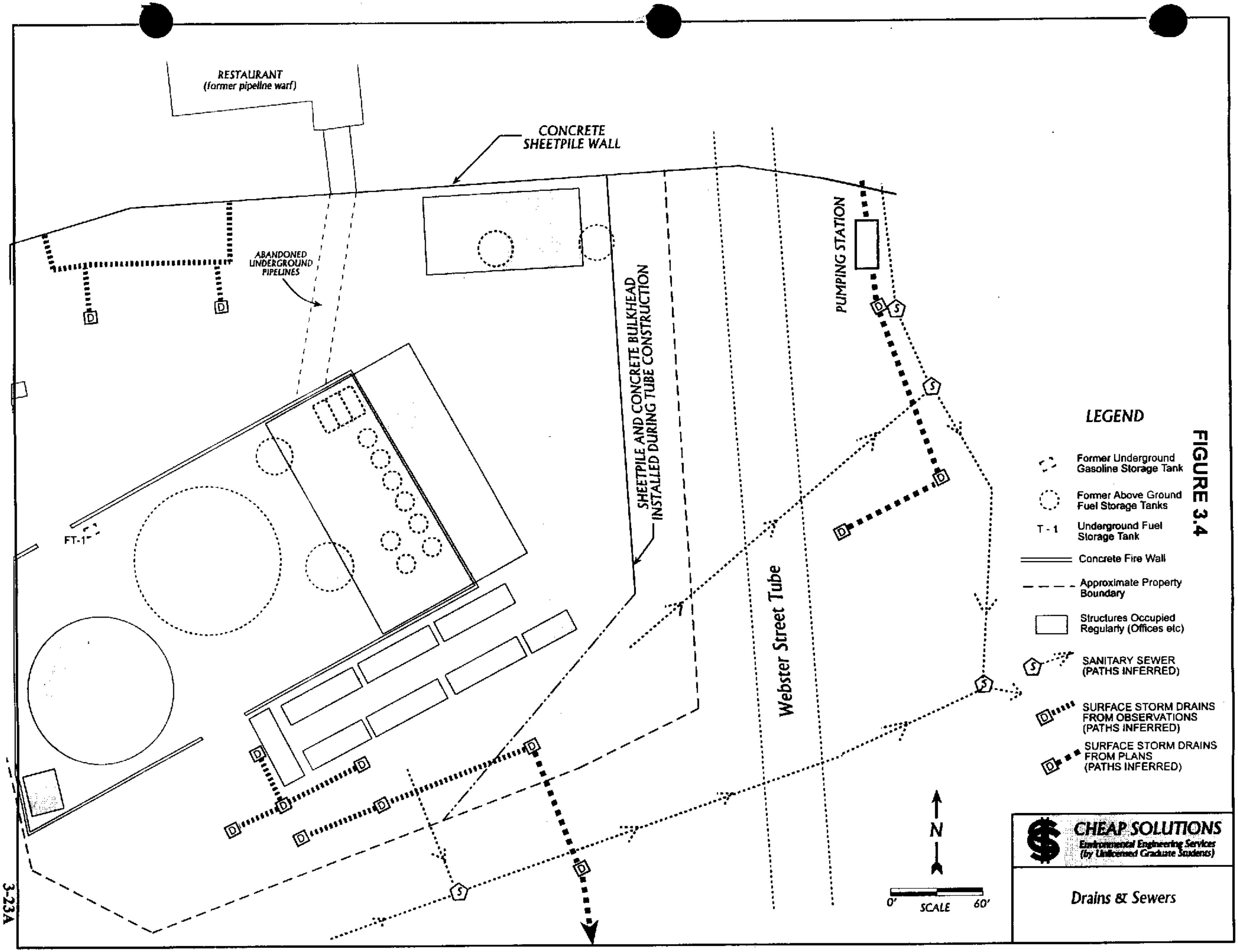


FIGURE 3.4

Drains & Sewers

on site; it is likely that it connects to the City of Alameda storm sewer system. The local connections are routed into the Bay[12]. At the time of writing, however, the is no evidence to support or invalidate this theory so no conclusions can be made.

3.2.2.2 Evaluate effects of stressors

A review of the available literature reveals many uncertainties on the affects of the chemicals on a generalized ecological receptor such as the Bay. Not only threshold levels vary for individual species (sometimes up to two orders of magnitude), but the interactions of the chemicals is not well understood. Some pollutants have yet to be sufficiently studied. The EPA has generated information sheets on many of the chemicals. The available information is summarized below[13].

Arsenic
Arsenic metabolism and effects are significantly influenced by the animal/plant tested, the route of administration, the physical and chemical form of the arsenic, and the dose. Inorganic arsenic compounds are more toxic than organic arsenic compounds.
Arsenic has high acute toxicity to aquatic life, birds, and land animals. Except where soil arsenic content is high (around smelters and where arsenic-based pesticides have been used heavily), arsenic does not accumulate in plants to toxic levels. Where soil arsenic content is high, growth and crop yields can be decreased.
Arsenic has high chronic toxicity to aquatic life, and moderate chronic toxicity to birds and land animals.

Chromium
Chromium exists mainly in the 3+ (III) or 6+ (VI) oxidation states in natural bodies of water, and each form can be converted to the other form under appropriate environmental conditions. Chromium is more toxic in soft water than in hard water.
Chromium (VI) has high acute toxicity to aquatic life, and chromium (III) has moderate acute toxicity to aquatic life.
Chromium (III) and chromium (VI) both have high chronic toxicity to aquatic life. No data are available on the short-term or long-term effects of chromium to plants, birds, or land animals.

Copper
At low concentrations it is an essential element for both plants and animals. At slightly higher concentrations it is toxic to aquatic life. The toxicity of copper and its compounds to aquatic life varies with the physical and chemical conditions of the water. Factors such as water hardness, alkalinity and pH influence copper toxicity.
Copper and its compounds have high acute and chronic toxicity to aquatic life. No data are available on the short-term or long-term effects of copper to plants, birds, or land animals.

Lead
Toxicity to aquatic life is affected by water hardness - the softer the water, the greater the toxicity. Lead and its compounds have high acute toxicity to aquatic life. Insufficient data are available to evaluate or predict the short-term effects of lead and its compounds to plants, birds,

or land animals. Lead causes nerve and behavioral effects in humans and could cause similar long-term effects in birds and land animals exposed to lead and its compounds.

Nickel

Water hardness affects nickel toxicity to aquatic organisms -the softer the water, the higher the toxicity.

Nickel and its compounds have high acute and chronic toxicity to aquatic life. Insufficient data are available to evaluate or predict the short-term or long-term effects of nickel and its compounds to plants, birds, or land animals.

Zinc

The toxicity of zinc to aquatic life is related to water hardness, with increased toxicity occurring in softer waters. Zinc and its salts have high acute and chronic toxicity to aquatic life. Insufficient data are available to evaluate or predict the short-term or long-term effects of zinc and its compounds to plants, birds, or land animals.

Benzene

Benzene has high acute toxicity to aquatic life. It can cause death in plants and roots and membrane damage in leaves of various agricultural crops. No data are available on the short-term effects of benzene on birds or land animals. Benzene has high chronic toxicity to aquatic life. No data are available on the long-term effects of benzene on plants, birds, or land animals. Benzene is slightly persistent in water, with a half-life of between 2 to 20 days.

Toluene

Toluene has moderate acute and chronic toxicity to aquatic life. Toluene has caused leaf membrane damage in plants. Insufficient data are available to evaluate or predict the short-term or long-term effects of toluene to birds or land animals or the long-term effects to plants. Toluene is non-persistent in water, with a half-life less than 2 days.

Ethyl Benzene

Ethyl Benzene has high acute and chronic toxicity to aquatic life. It has caused injury to various agricultural crops. Insufficient data are available to evaluate or predict the short-term or long-term effects of Ethyl Benzene to birds or land animals or long-term effects to plants. Ethyl Benzene is non-persistent in water, with a half-life -due to volatilization - of less than 2 days.

Xylene

Xylene is a mixture of the three isomers of xylene (ortho, meta, and para).Since comparative data on the toxicity of the several forms are limited and inconclusive, all forms are considered equal in toxicity for purposes of these ecological fact sheets. Xylene has high acute and chronic toxicity to aquatic life. Xylene causes injury to various agricultural and ornamental crops. Insufficient data are available to evaluate or predict the short-term or long-term effects of xylene to birds or land animals or long-term effects to plants. Xylene is non-persistent in water, with a half-life less than 2 days.

Vinyl Chloride

Vinyl chloride is a highly flammable chemical which exists as a gas at room temperature. Data are insufficient to determine if vinyl chloride poses any acute or chronic toxicity hazards to aquatic life. No data are available on the short-term or long-term effects of vinyl chloride on plant, birds, or land animals. Vinyl Chloride is non-persistent in water.

3.2.3.3 Risk Characterization

3.2.3.3.1 Evaluate Risk

Due to the uncertain nature of the fate and transport of the chemicals on this site it is not possible to determine an absolute risk imposed by the site contamination. A reasonable guideline would be to utilize the EPA's Ambient Water Quality Guidelines as well as applicable guidelines produced by the San Francisco Regional Water Quality Control Board (SFRWQCB) and assume any concentrations below these levels would have a negligible ecological risk. Table 3.16 shows the current standards for a marine environment, the bioaccumulation factor (BCF) for fish and the regional guidelines. The toxicity of certain metals is dependent on the water hardness. A value of 4000 mg/L as $CaCO_3$ was used as representative of the water in the Bay[14].

Table 3.16 Ambient Water Quality Standards

Chemical	Marine Acute Toxicity[15] (ppb)	Marine Chronic Toxicity[15] (ppb)	BCF[16] (L/kg)	Max. Groundwater Concentration (ppb)
Arsenic	69	36	44	
Chrome (III)[17]	1100	50	16	50[18]
Copper[17]	2.9	2.9	200	-
Lead[17]	140	5.6	49	5.6[19]
Nickel[17]	75	8.3	47	7.1[18]
Zinc[17]	95	86	47	58[18]
TPHg	-	-	-	100[20]
TPHd	-	-	-	100[20]
TPHMo	-	-	-	-
Benzene	5100	700	5.2	-
Toluene	6300	5000	10.7	-
Ethylbenzene	430	-	37.5	-
Xylene	-	-	-	-
Vinyl Chloride	-	-	-	
Acenapthalene	970	710	-	-

The groundwater concentrations for lead, nickel, TPHg and TPHd exceed the maximum groundwater concentrations as stated by the SFRWQCB suggesting that there is an associated

ecological risk. Assuming that there is an active groundwater-to-Bay exposure route there would be an additional risk due to the copper contamination. It is possible that the groundwater flow characteristics at this specific site make it beginning with respect to the surrounding ecosystem.

3.2.3.2 Determine Ecological Adversity

It is difficult to estimate the ecological adversity experienced due to the contamination on this site for the following reasons:

1) A baseline survey of potentially affected organisms does not exist.
2) The magnitude of pollution migration is uncertain.
3) The Bay is an open system and receives influent from many sources.
4) The Bay is a complex system and chemical interactions, and the resulting toxicological characteristics are not well understood.

It is necessary to obtain the information for 1) and 2) before estimating the ecological adversity.

3.2.4 Conclusion

Due to the limitations mentioned above it is not possible to complete an ecological risk assessment. There exist several guidelines from the SFRWQCB, the San Francisco Basin Plan and the State that were applied to the San Francisco International Airport project due to ecological risk. It is believed this site is sufficiently similar to Mariner Square to warrant further investigation.

3.3. References and Notes

1) Risk Assessment and Risk Management: A Definable Approach to Problem Solving, Ravi Arulanantham, Ph.D., CalEPA/S.F. Bay RWQCB

2) gopher://ecosys.drdr.Virginia.EDU:70/00/library/gen/toxics

3) http://chemfinder.camsoft.com/

4) http://www.epa.gov/ngispgm3/iris/Substance_List.html

5) Toxicological Profile for Polyaromatic Hydrocarbons (PAHs), Agency for Toxic Substance and Disease Registery, US Department of Health and Human Services, 1995

6) CEE216 Reader, Hazardous and Industrial Waste Management, Professor Lisa Alverez-Cohen

7) CEE219 Reader, Contaminat Transport Processes, Professor Jim Hunt

8) http://www.cwo.com/~herd1/downset.htm

9) CalTOX™, A Multimedia Total Exposure Model For Hazardous-Waste Sites, Spreadsheet User's Guide, Version 1.5. The Office of Scientific Affairs, Department of Toxic Substances Control, California Environmental Protection Agency, Sacramento, California, August 1994

10) EPA/630/R-95/002B, Sept. 1996

11) Separate Phase Hydrocarbon was found in MW-6 on 29 June, 1996. Values listed are otherwise highest concentrations.

12) Interview of CalTrans Employee Tom Thomas by McLaren Hart Consultants, 1995

13) EPA FACTSHEETS, http://mail.odisnet.com/TRIFacts

14) Brent, Aaron, Hardness Measurements Performed on 24 April 1997

15) Suspect Chemicals Sourcebook, CWA Section 307, Roytech Publications, Inc.

16) LaGrega, Buckingham, Evans, Hazardous Waste Management, pg. 1040-1051

17) For Th>1ppt use maximum freshwater or marine toxicity value. Federal Register, Vol 56, No. 223, pg. 58444, 1991

18) SFRWQCB Order 95-136, San Francisco Bay Region Basin Plan Shallow Water Effluent Limit

19) SFRWQCB Order 95-136, California Water Quality Criteria

20) SFRWQCB Order 95-136, EC_{10} bivalves and Sea Urchins Bioassay, United Airlines

21) Shin, Juliet, Mariner Square Case Letter, Alameda County Health Care Services, 21 February 1997

4. Regulatory Overview

4.1 Definition of ARARs

The 1986 Superfund Amendments and Reauthorization Act require remedial actions to meet Applicable or Relevant and Appropriate Requirements (ARARs).

According to the NCP (40 CFR § 300.5), *applicable requirements* are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial actions, location, or other circumstance found at a CERCLA site."

Under 40 CFR § 300.400(g)(2), even if a regulatory "requirement is not directly applicable to a specific release the requirement may still be relevant and appropriate to the circumstances of the release." Hence, the requirement in question may be utilized in making remediation decisions.

Specific guidance is given in evaluating relevance and appropriateness in sections (g)(2)(i) through (g)(2)(vii) of 40 CFR § 300.400. These guidelines shall be used to "determine whether a requirement addresses problems or situations sufficiently similar to the circumstances of the release or remedial action contemplated, and whether the requirement is well-suited to the site, and therefore is both relevant and appropriate. The pertinence of each of the following factors will depend, in part, on whether a requirement addresses a chemical, location, or action."

4.2 Identification of potential ARARs

A review of applicable regulations and guidance materials, as well as past remedial investigations, was used by Cheap Solutions to determine potential ARARs for the Mariner Square site.

In accordance with 40 CFR § 300.400(g)(5) "The lead agency and support agency shall identify their specific requirements that are applicable or relevant and appropriate for a particular site" and within the specific timeframes specified in § 300.515 (d)(2) and (h)(2). Therefore, for a more rigorous listing of potential ARARs it would be appropriate to contact relevant regulatory agencies such as California EPA and SFRWQCB.

4.2.1 Chemical Specific ARARs

Chemical Specific ARARs are those requirements that are directly related to the pollutants or chemicals of concern. Table 4-1 contains a summary of contaminant level limitations associated with the chemical specific ARARs for the Mariner Square site.

Table 4 - 1 Chemical specific ARAR limitations for Mariner Square

	SOIL CONCENTRATIONS [ppm]		GROUNDWATER CONCENTRATIONS [ppb]		
		ARAR		ARARs	
CONTAMINANT	Maximum Level On-Site	TTLC (1)	Maximum Level On-Site	Resolution 95-136 groundwater limits (2)	Federal Water Quality Criteria (3)
TRPH	13000	-		-	-
TPHg	1300*	-	5000	100	-
TPHd	5000*	-	9900	100	-
TPHmo	2800*	-	3200	-	-
Benzene	nd	-	12	71	-
Toluene	nd	-	11	5000	-
Ethylbenzene	21	-	49	43	29000
Total Xylenes	10	-	14	2200	-
Vinyl Chloride	nd	-	2.5	17	525
Freon 113	nd	-	4	-	-
Napthalene	nd	-	2	100	-
Lead	5700**	1000	82	5.6	-
Copper	4200**	2500	30	-	-
Arsenic	7.2**	500	22	-	-
Chromium	1.9**	100	10	50	-
Zinc	2700**	5000	60	58	-
Nickel	47**	2000	50	7.1	-

* Values determined from adjacent Navy Site

** Metals measured using TTLC method

(1) Total Threshold Limit Concentration (CCR title 22, Hazardous waste landfill disposal)

(2) SFRWQCB Resolution 95-136, cleanup values for groundwater adjacent to surface waters for San Francisco Intl. Airport

(3) 40 CFR 131 - Water Quality Standards

4.2.1.a SWRCB Resolution No. 88-63

Resolution 88-63, adoption of policy entitled "Sources of Drinking Water," states that all ground waters of the State are to be designated as potentially suitable for domestic water supply with the exception of ground waters where:

- The TDS exceed 3,000 mg/L and it is not reasonably expected by Regional Boards to supply a public water system, or
- There is contamination unrelated to the specific pollution incident that cannot reasonably be treated for domestic use, or
- The water source does not provide a sustained yield of 200 gpd.

TDS values greater than 500 mg/L throughout the site are above the California Department of Health Services recommended secondary drinking water standards. Also, a TDS sample from MW-8 was found to be greater than 3,000 mg/l. Because of these high TDS levels, the on-site groundwater does not qualify as a potential drinking water supply. Therefore, all State and Federal regulations that only apply to drinking water supplies are not ARARs. This excludes National Primary Drinking Water Standards (40 CFR § 141) and California DHS MCL standards for drinking water supplies from the list of ARARs for the Mariner Square site.

4.2.1.b San Francisco Bay Basin Water Quality Control Plan

The Basin Plan applies to all waters within the larger San Francisco Bay Estuary, and smaller segments within the Estuary as well as any watersheds draining into the larger system. It incorporates other state regulations and policies, providing a comprehensive plan for maintaining water quality within the region. The Mariner Square site is within this region and hence the basin plan contains applicable regulations and guidance for this site. Relevant excerpts from the Basin Plan are included in Appendix C.

4.2.1.c SFRWQCB Resolution No. 95-136

Resolution 95-136 is specifically designed for remeditation of fuels and other contaminants within the area of the San Francisco International Airport. This resolution is not applicable to the Mariner Square site.

However, the Resolution does establish remediation goals and guidance for areas within approximately 400 feet of the bay, known in the Resolution as the "Saltwater Ecological Protection Zone". The guidance given in sections (g)(2)(i) through (g)(2)(vii) of 40 CFR § 300.400 is used herein for evaluating relevance and appropriateness of Resolution 95-136 to the Mariner Square site.

The site conditions are similar in the following ways: they are located equidistant from bay, both are covered by an asphalt cap, the main contaminants of concern areTPHd and TPHg with metals, they share a similar subsurface geology and have the same regional climate. Because of these reasons it is believed that the conditions for relevance and appropriateness are met and that

Resolution No. 95-136 is an ARAR for the Mariner Square site. Tier I groundwater and soil contamination levels were established for some contaminants of concern such as TPHd, TPHg and Lead. These clean-up levels are included in table 4-1. Relevant excerpts from this resolution are included in Appendix C.

4.2.1.d 40 CFR § 131

Federal Water Quality Criteria (FWQC) establishes values based on effect on human health and aquatic life. These standards are relevant and appropriate. MCLs for the San Francisco Bay are specified in section § 131.36 and are included in table 4-1.

4.2.1.e 22 CCR

This regulation is actually a potential action specific ARAR and is included here due to the fact that it contains chemical specific concentration limits. Total Threshold Limit Concentration (TTLC) limits are applied to potential waste streams to determine if the waste is to be considered hazardous for disposal.

4.2.2 Location Specific ARARs

Location specific ARARs restrict activities or pollutant concentrations within certain areas due to an increased sensitivity or other non-typical characteristics. Types of locations that may be of interest include: unstable ground (earthquake faults), flood plains, critical habitats or areas of increased public concern such as scenic rivers.

Location specific ARARs applicable to the Mariner Square site are:

- The San Francisco Bay Basin Water Quality Control Plan.

- California Coastal Act of 1976 [14 CCR § 13001-13600] and Coastal Zone Management Act [16 USC § 1451 et seq.] are applicable to any activities that effect the coastal zone.

4.2.3 Action Specific ARARs

Action specific ARARs are those requirements that are applicable to the undertaking of any future activities of the site in question. These should be considered when comparing remediation strategies.

Appendix C contains a comprehensive listing of potential action specific ARARs for the Mariner Square site.

4.2.3.a 40 CFR 268

Land disposal restrictions require pre-treatment of high concentrations of hazardous wastes prior to placement in a hazardous waste landfill. For Lead the limit is 5.0 mg/L TCLP. Some soil samples from the Mariner Square site have been measured in excess of 28 ppm by STLC method. This could mean that much of the soil would have to be pre-treated prior to disposal in a hazardous waste site. Also, a RCRA Policy statement from Elliott P. Laws, Assistant Administrator addresses incineration techniques for metal-contaminated wastes. This policy statement holds that improper incineration of metal-based contaminants is considered "dilution" and therefore, in many cases, is not an acceptable means of pre-treating this type of waste. This may make excavation, incineration and burial of lead and copper laden soil extremely expensive.

4.3 Remediation Goals

The goal of any remediation activity is to protect human health and to retain or improve the beneficial uses of the environment. SFRWQCB Resolution 95-136, which has been established as an ARAR for the Mariner Square site, states the following:

"The cleanup objectives for the soil and groundwater are such that when the groundwater reaches the bay it is protective of the beneficial uses and does not pose a significant risk to either the aquatic species or the people using the Bay."

Upon examining the possible exposure risk scenarios for the San Francisco International Airport the following two major objectives were established:

- the protection of the aquatic and other species such that there is no acute or significant chronic toxicity affecting the species inhabiting the bay
- the protection of humans who may come in contact with or eat the organisms exposed to the contaminated water

4.3.1 Protection of Human Health

In completing our preliminary risk assessment for human health all current scenarios (with the exception of Lead) yielded Hazard Quotients less than 1 and cancer risks less than 1×10^{-6}. These are well within the EPA's guidelines for remediation goals.

With the exception of Lead, for future scenarios the highest total lifetime carcinogenic risk was determined to be 5.6×10^{-4}. The maximum Hazard Quotient for non-Lead contaminants was determined to be 1.0 from Arsenic. However these values came from the assumption that the groundwater was being used as a primary drinking water source for on-site residents. Since the groundwater at the Mariner Square site has been determined to not be a potential drinking water source, the level of risk to human health is once again within the EPA's guidelines for remediation goals.

The hazard quotients for Lead were determined to be greater than 20 for the current scenario. Therefore a primary remediation goal will be to address this health issue.

4.3.2 Protection of the Environment

As seen in Table 4-1, SFRWQCB Resolution 95-136 has established Tier I groundwater cleanup goals adjacent to the Bay for TPHg and TPHd to less than 100 ppb each. Soluble Lead concentrations within groundwater are to be limited to 5.6 ppb. These levels were determined as a result of the goals mentioned in section 4.3 above.

Because groundwater contamination levels for these pollutants have been found to be greater than 10 to 50 times these limits, another primary goal for remediation of the Mariner Square site will be to address the effects of pollutants on the Bay Environment.

Because the risk assessment on the Bay Environment is currently beyond the scope of Cheaper Solutions, the information in the Basin Plan and Resolution 95-136 will be utilized for further guidance.

The Basin Plan states that "Immediate removal of the source, to the extent practicable, is required to prevent further spread of pollution." And resolution 95-136 states that "This Order requires that all free-phase product reasonably accessible will be removed." Therefore removal of possible sources of contaminant will be a secondary goal in considering remediation alternatives.

Resolution 95-136 further states that:

"In the event it is proposed by the Discharger that the Tier 1 standards are not applicable to a given site for reasons that may include specific conditions… then the discharger may request to determine site specific clean-up standards through the application of a Tier 2 risk assessment methodology."

The Resolution gives further information for conducting a more in-depth Risk Assessment than has been performed herein. This includes such things as: submittal of a plan to conduct a site-specific risk assessment and recommendation of the use of ASTM RBCA guidelines for a tiered approach. Further guidelines from both the Basin Plan and Resolution 95-136 have been included in Appendix C.

5 Preliminary Remediation Alternative Screening

5.1 Screening Methodology

There are numerous remediation alternatives which are theoretically applicable to the contaminated site at Mariner Square. It is necessary to utilize a standardized screening process in order to rank and select the most appropriate method for the given site characteristics. The EPA suggests the following factors be applied when comparing alternatives.

1) Applicability
2) Short-Term Effectiveness
3) Long-Term Effectiveness
4) Commercial Availability
5) Awareness of, and experience with, given technology
6) Additional Treatment for Off Gasses or Fluids
7) System Reliability
8) Regulatory Acceptability
9) Community Acceptability
10) Cost

Due to the nature of the contamination at Mariner Square it was decided to break down the potential treatment alternatives with respect to: metals contamination, free-phase hydrocarbon contamination and the hydrocarbon plume. Factors 1) and 2) were then used in a preliminary screening. Processes that were not applicable or effective were not given further consideration and are not presented here. This section discusses the potential alternatives in more detail excluding factors 8), 9) and 10). Due to the dissimilar nature of the contaminants some alternatives which were only applicable for hydrocarbon remediation were retained for further analysis. A final screening is included in chapter 6. A more detailed description, including the information needed to complete the screening analysis will be discussed.

5.2 Remediation Screening

5.2.1 No Action

No action is considered a control option and will be used as a basis of comparison for all alternatives. In this option, it is assumed that intrinsic bioremediation will be sufficient to minimize the spread of the hydrocarbon contamination and that the transport of the metal is sufficiently slow to avoid harming the surrounding environment. It is contingent upon approval by the appropriate regulatory bodies.

5.2.2 Solidification/Stabilization

In a stabilization process, additives are mixed with waste to minimize the rate of contaminant migration and reduce the toxicity of the waste. In solidification, which is one kind of stabilization, the contaminants are enclosed within a stabilized mass of solidifying material.

Effectiveness
Metals seem well adapted to this method because precipitation of metals occurs naturally and the process chosen for remediation can mimic nature (La Grega, 1994). If well applied, the method can be a permanent solution, as a good long term physical and chemical stability was demonstrated. For organics, the method may also be used, as opposed to excavation, where all the organic pollution would be brought to the air and have to be handled (transport, landfilling or incineration). Problems with the inorganic-based method is the volatilization of organics during the process and the unknown long-term stability.

Implementability
The method is well adapted to metals as we have seen. 8 out of 11 sites presented by La Grega, where stabilization was used on full scale, involved metals, the others organics. The problem for the site is that there is, in the soil, a mixture of organic compounds and metals. Inorganic and organic based stabilization techniques are different. Metals could be stabilized first independently but then the handling of inorganics, and the groundwater remediation, would be hindered. The method might therefore only be applied to metals as a last step in the remediation of the site.

Screening
Not retained

5.2.3 Containment

Vertical barriers are used to contain contaminants and to redirect the groundwater flow. Different containment techniques are available : slurry trench cutoff walls, grout curtains and steel sheet piling (La Grega, 1994). These techniques are commonly used in association with a pump-and-treat system, to prevent clean groundwater to flow through the contaminated site during pumping. They can also be used when excavation is chosen for the site.

Effectiveness
It is necessary to use groundwater and contaminant transport modeling to predict the effectiveness of any kind of wall in preventing spreading of pollution (LaGrega, 1994). In the case of permeable reactive walls, an accelerated rate of contaminant degradation is possible.

Implementability
For our site, the petroleum hydrocarbons plume is not well defined and probably extends on a large surface, as hydrocarbons have been spilled in the subsurface for decades. To optimize the pumping of the known free phase hydrocarbons, a containment wall may be used. The extent of the free phase has to be determined first.

Screening
Not retained

5.2.4 In Situ Bioremediation

In Situ bioremediation enhances the degradation of organic contaminants by naturally occurring microbial communities by supplying nutrients and oxygen to the subsurface. This is done by injecting water, enriched in nutrients and oxygen, into the contaminated zone. This stimulates microbial growth which speeds the contaminant degradation. Water is usually withdrawn downgradient to maintain the desired flow direction and avoid spreading the plume. Hydrogeologic factors such as ground heterogeneaties and hydraulic conductivity are critical in the process (LaGrega, 1994).

Variations
Several methods of supplying oxygen are utilized including air saturation, pure oxygen saturation and hydrogen peroxide feed. In area with significant concentrations, hydrogen peroxide is often the most efficient method of supplying the necessary oxygen. The recovered groundwater can be treated and re-injected or discharged (if permitted by regulation.) An extraction trench can be used in locations with shallow groundwater conditions.

Effectiveness
This technology has been used to remediate contamination plumes containing hydrocarbons, phenols and aromatic compounds. Its application is highly dependent on hydrogeologic conditions. It can be applied to soil and groundwater contamination, as well as free phase hydrocarbons.

Implementability
The major contaminants on site are petroleum hydrocarbons and metals. In situ bioremediation is appropriate to the former and inappropriate to the later. The subsurface consists of a relatively shallow aquifer with a sand content of near 80% overlying Bay Mud. The extensive tidal flow channels may be problematic in creating and maintaining the desired groundwater gradient.

Screening
Retained for the treatment of hydrocarbons.

5.2.5 In Situ Vitrification

Vitrification is a solidification technique in which a high current is applied to a contaminated area, raising temperatures sufficiently high to melt the soil into a molten mass. In the process nearly all of the organics are broken down into their elemental components and inorganics are encompassed into the mass.

Effectiveness
This method is suitable for reducing contaminant concentrations to a safe level.

Implementability
Pilot studies would be needed to verify applicability. It is believed that the high TDS may cause problems with electrical current application.

Screening
Not retained

5.2.6 Pumping before ex-situ treatment (free phase and hydrocarbons in groundwater)

Groundwater is first extracted using various recovery methods: wells, well points, or drain tile collection systems. Then the water is treated using available methods: air stripping, carbon adsorption, biological treatment for organics and physical-chemical processes for inorganics. The final step is to discharge the water back into the aquifer or dispose of off-site.

Effectiveness
The effectiveness of the method can only be assessed site by site and is not perfectly predictable. There is an uncertainty concerning the duration of operation if the method is applied to the whole aquifer. If a source of contaminants is still leaching into the aquifer, or if the hydraulic conductivity in the subsurface is very low, or the extent of the plume to be pumped out is very large, the process can last during decades also. For a free phase, the extent of the contamination is rather limited and most of it can be pumped out with this process.

Implementability
Today, the site is used by offices, workshops, a restaurant, and in the future, it may be used for residential purposes. A long term treatment unit on the site is therefore not desirable. We know that free phase hydrocarbons are a source of contaminants but also all the contaminated soil above the aquifer. This has to be cleaned up before any pumping and treat option can be implimented. Even in this case, residual contaminants may still sit in pores or lenses in the soil, causing the pump and treat option to last years. Furthermore, the site is close to the Bay and pumping is likely to cause Bay water to intrude. As for the free phase hydrocarbons, pumping is one of the few methods that can be used though it is undesirable.

Screening
Not Retained..

5.2.7 Soil Flushing

In situ soil flushing is the extraction of contaminants from the soil with water or other suitable aqueous solutions. Soil flushing is accomplished by passing the extraction fluid through soils using an injection or infiltration process. Extraction fluids are recovered from the underlying aquifer and, when possible, they are recycled.

The target contaminant group for soil flushing is inorganic (including radioactive) contaminants. The technology can be used to treat VOCs, SVOCs, fuels, and pesticides with the addition of compatible surfactants. However, it may be less cost-effective than alternative technologies for these contaminant groups. Soil flushing offers the potential for recovery of metals and can mobilize a wide range of organic and inorganic contaminants from coarse-grained soils.

Effectiveness
Soil flushing with an acid or base solution can extract inorganic metals, and flushing solvent with surfactant is applicable to non-aqueous phase liquids (NAPL) contaminants present at high concentrations.

Implementability
The soil properties would be altered after flushing, possibly requiring additional evaluations leading to further need of remediation. There has been very little commercial success with this technology.

Screening
Not retained.

5.2.8 Soil Vapor Extraction (SVE)

SVE is an in-situ physical process that extracts volatile and semi-volatile contaminants from the unsaturated zone. By applying a vacuum through a system of wells, contaminants are pulled to the surface as off-gas which is then further treated by various methods such as activated carbon adsorption or incineration. Air Sparging is the use of air injection wells into the unsaturated zone to improve overall removal rates. These injection wells may also be placed within the saturated zone to allow removal of contaminants from that area as well.

Effectiveness
SVE alone is only effective at removing volatile substances such as fuels, BTEX and other VOCs from within the unsaturated zone. Conditions such as homogeneous, porous, high permeability soils with low amounts of organic carbon and low soil moisture increase the efficiency of this method. Other factors such as soil caps or a shallow water table must also be taken into account. Air Sparging can extend the capability of SVE by allowing removal of VOC from within the saturated zone and may also increase the intrinsic biodegradation of the contaminants.

Implementability
This site has generally high permeable, relatively homogeneous sandy soils at the 2 to 5 foot depths which contain the majority of TPHd and TPHg. In addition over 90% of the contamination zone is capped with concrete and asphalt which can be used to direct air flows to maximize efficiency of SVE. The high permeability areas extend into the saturated zone which makes Air Sparging a valid option. Also, high levels of microbial activity throughout the site indicate that addition of oxygen to the contaminant zones could increase aerobic bacterial growth, further enhancing VOC removal. SVE and Air Sparging would have no appreciable effect in remediation of metals.

Screening
Not retained for removal of metals or free-phase hydrocarbons. Retained for removal of VOCs in unsaturated zone and contaminant plume.

5.2.9 Thermally Enhanced Soil Vapor Extraction

Thermally enhanced SVE is a full-scale technology that uses steam/hot-air injection or electric/radio frequency heating to increase the mobility of semivolatiles and facilitate extraction.

Effectiveness
1. It is effective on VOC and SVOCs in vadose zone
2. Thermal enhanced SVE it can be more effective than SVE by up to fifty times..
3. The technology does not work with metals.

Furthermore, the following factors may limit the applicability and effectiveness of the process:
1. Soil that has a high organic content has a high sorption capacity of VOCs, which results in reduced removal rates.
2. Soil with high moisture content has a reduced permeability to air, thus hindering the operation of thermally enhanced SVE and requiring more energy input to increase vacuum and temperature.
3. Soil with highly variable permeability may result in uneven delivery of gas flow to the contaminated regions.
4. Air treatment and permitting will increase project costs, and residual liquids and spent activated carbon may require further treatment.

Implementability
The system is effective in treating SVOCs (PAHs) and VOCs (BTEX and vinyl chloride). In addition, it is applicable for the Site due to the relatively high permeability and the 30-50% fluid saturation of the soil. After application of this process, subsurface conditions may be excellent for biodegradation of residual contaminants.

Screening
Retained.

5.2.10 Excavation

Surface soils containing contaminants are removed and transported to a hazardous waste treatment storage and disposal facility.

Effectiveness
Removes contaminant of concern directly and may be suitable if depth to contaminant is not too great. May be undesirable due to possible further exposure from dust and volatile contaminant exposure during excavation. High concentrations of lead may have to be pre-treated prior to placement in a hazardous waste site in accordance with the Land Ban (40 CFR 268). This

method is relatively expensive but ensures direct and rapid removal of the contaminant of concern.

Implementability
Soil contaminants contain a mixture of Lead, Fuel and PAHs. The majority of this site is paved adding additional expenses for disposal of wastes. It is an unrealistic remediation technique for wide application throughout the site, especially for areas under offices, the large tank/garage and the thick concrete section within the firewall due to extra expenses incurred and unreasonable impact on these businesses. However, this may be the only possible choice for removal of Lead contaminants and it may be applicable for use in removal of the relatively small area contaminated by liquid-phase hydrocarbons.

Screening
Retained for removal of metals or free-phase hydrocarbons. Not retained for removal of VOCs in unsaturated zone and contaminant plume.

5.2.11 Alchemy

In this process, a practitioner of the Science of Alchemy will be contracted to change all contaminants in the local subsurface into gold. This will eliminate the toxicity of the contaminant and will have the additional value of increasing the property value.

Effectiveness
This technology is 100% effective and is applicable to any and all contaminants, regardless of subsurface conditions. It is an in situ process further reducing costs.

Implementability
Reliability of practitioners has been a historic problem.

Screening
Regretfully, not retained.

5.3 Summary of Selected Alternatives

The following is a list of selected technologies as applied to the specific waste.

Table 5.1 Selected Remediation Alternatives

Metals	Free Phase Hydrocarbons	Other Hydrocarbons
No Action	No Action	No Action
Excavation	Excavation	In Situ Bioremediation
	In Situ Bioremediation	Thermally Enhanced SVE
	Thermally Enhanced SVE	SVE

6. Comparision of Remediation Alternatives

6.1 Purpose

In this chapter, remediation options retained during the previous screening are examined for consideration as possible actions to be taken at the Mariner Square site.

For each remediation technique, the following characteristics are assessed, as a basis for future choice of an adequate solution:

- purpose
- effectiveness
- short-term liability
- long-term liability
- public perception
- demonstration of technology effectiveness
- cost.

6.2 Characteristics of remediation alternatives

On the following pages, the summarized results of the analysis described are gathered for each remediation technique:

Bioremediation
Thermally enhanced soil-vapor extraction
Soil-vapor extraction - venting
Soil-vapor extraction - air sparging
Excavation (of the free phase hydrocarbons or of the metals)

Elements of design and cost estimates for each remediation technique, as applied to the Mariner Square site, are gathered in Appendix D.

6.2.1. In Situ Bioremediation

Purpose: In situ enhanced bioremediation can lead to the degradation of organics on site. It is generally ineffective against inorganics.

Effectiveness: Potential to completely remove contaminant plume. Ineffective on inorganics.

Short-Term Liability: The short term liability is highly dependent on soil conditions. The degradation may not be extremely rapid under all conditions.

Long-Term Liability: An effective bioremediation action will completely remove organic contaminants eliminating the possibility of contaminant desorbtion.

Public Perception: Considered good as there are no off gasses or wastes produced. The passive system suggested in the appendix should have high acceptability due to "natural" operation.

Demonstration Of Technology:
There are no known units in existence.

Cost: Capital and O&M costs are low.

6.2.2. Thermally Enhanced Soil Vapor Extraction

Purpose: Thermally enhanced soil vapor extraction can mobilize both VOCs and SVOCs, which in turn are removed by vacuum extraction.

Effectiveness: It had been demonstrated to be highly effective to remove VOCs and SVOCs. However, it is nor applicable to metals.

Short-Term Liability: The short-term liability is dependent in aquifer conditions. The more porous the soil matrix, the better performance will be achieved. In addition, the study of TESVE has been shown being able to get rid of organic contaminates pretty quickly. Concerns with operation of steam equipment must be addressed.

Long-Term Liability: This technology can clean up organic contaminates to a very low concentrations, and also provide a great environment for further bioremediation.

Public Perception: It might not be good since there are wastes (waste water, noise, etc,) produced, plus the steam generation and delivery system might be dangerous if no appropriate operation and maintenance.

Demonstration Of Technology: Field studies indicate it is workable, but this technique is not yet commercialized.

Cost: Available data indicates the overall cost for thermally enhanced SVE system is approximately $30 to $130 per cubic meter ($25 to $100 per cubic yard).

6.2.3. Soil Vapor Extraction & Passive Venting

Purpose: Primarily to remove contaminants of VOCs in the unsaturated zone.

Effectiveness: This procedure is likely to yield virtually complete removal of VOCs in the unsaturated zone within three to four years of implementation.

Short-Term Liability: Several short-term liability considerations must be taken into account when utilizing SVE. Air treatment must be monitored regularly during removal process to ensure compliance with air pollution regulations. Initial pumping extractions are expected to contain high concentrations of methane gasses due to anaerobic biological activity that has been present under the capped soil for many years. This can very easily lead to explosive conditions within the vacuum blowers during the first couple weeks of operations. Neither of these liabilities are limiting effects, but they must be taken into consideration when designing the SVE system.

Long-Term Liability: Wastes generated from this process can easily be destroyed by incineration techniques due to high organic content and inherent heating value of the off-gas products once recovered by an applicable treatment system such as activated carbon or resin filters. Waste condensate could possibly be reused in combustion engines or heating. Since complete destruction of contaminant is likely, long-term liability is very low.

Public Perception: This process does not release any visible off-gasses. One nuisance may be the sound of air blowers at night. However, since the site is not in a residential area this should not be a problem. Since SVE results in virtually complete destruction of COC, it is generally well adapted by the public. At one innovative site the SVE system was used as a training facility for volunteers from the community to learn about collecting laboratory samples which helped increase acceptance of the cleanup efforts.

Demonstration Of Technology: According to the EPA, SVE is the most frequently selected innovative treatment at Superfund sites. The method is "so widely used that the term 'innovative' may seem inapropriate." Because innovative variations on SVE are still being considered, EPA continues to track this technology, keeping it on the innovative technology list.

Cost: Expected total cost is over $2.0 million due to high volume of hydrocarbons to be removed and treated.

6.2.4. Soil Vapor Extraction & Air Sparging

Purpose: Primarily to remove contaminants of VOCs in the unsaturated zone. Secondarily to remove contaminants from groundwater.

Effectiveness: This procedure is likely to yield virtually complete removal of VOCs in the unsaturated zone within one to two years of implementation. Extensive removal of VOCs in groundwater saturated zone is also expected.

Short-Term Liability: Similar to 6.2.3. Additional considerations include the possibility of "ejecting" some methane and other gases from cracks and other defects of the soil cap. Because enhanced biodegredation rates are expected to greatly reduce amount of VOCs needed to be extracted, overall liability of air-treatment of off-gasses should be reduced.

Long-Term Liability: Similar to 3.2.3. Air sparging techniques should also increase aerobic degradation within the soil, greatly reducing overall amount of contaminants that will need to be incinerated or otherwise disposed of. Therefore this alternative is a preferred long-term liability option.

Public Perception: Perception is similar to 6.2.3. However, even greater destruction of VOCs is performed with less overall air-treatment required, this alternative is a preferred public perception option.

Demonstration Of Technology: Similar to 6.2.3.

Cost: Expected total cost is over $1.5 million due to high volume of hydrocarbons to be removed and treated.

6.2.5. Excavation

Purpose: Excavation can be used to remove from the site either the lead-contaminated soil that causes the aquifer to be contaminated or the free phase hydrocarbons sitting at monitoring well 6 location (and the contaminated soil above)

Effectiveness: Excavation can remove all the free phase in a relatively short time. The extent of the free phase has to be determined first. For the metals, the contaminated zone to remove has to be delineated after further investigation at the water table level. Once this determined, the method insures the total removal of the contaminated soil in a short time.

Short-Term Liability: Exposure of the engineers/workers during excavation is a major health and safety issue concerning excavation. The on-site workers also have to be protected against both inhalation of hydrocarbons and contact with metals.

Long-Term Liability: If the landfilling option is chosen, a lifelong responsibility will be held by the owner of the site for the wastes.

Public Perception: The method does not get rid of the pollutants, which will be sitting elsewhere, but is cleaning up the site effectively. Public perception can therefore be positive or negative. For such a site, with no residents, no publicity, it is not critical anyway.

Demonstration Of Technology: Excavation has been demonstrated to be effective and has been commonly used for decades.

Cost: For the lead removal, the total cost of excavating and landfilling is about $1,800,000. For the free phase hydrocarbons removal, it would be approximately $700,000.

6.3 Cost-effectiveness analysis

6.3.1 Remediation options

For the Mariner Square site it is recognized that the optimal solution for meeting remediation goals may require a combination of remediation techniques. Therefore a cost-effectiveness analysis was performed on various likely combinations of remediation techniques.

Given the individual remediation alternatives retained, the probable combinations of remediation techniques for hydrocarbons were found to be:

0. Do nothing
1. Bioremediation (entire site)
2. Thermally enhanced soil-vapor extraction (entire site)
3. Excavation of the free phase and soil-vapor extraction - venting
4. Excavation of the free phase and soil-vapor extraction - air sparging
5. Excavation of the free phase and bioremediation
6. Thermally enhanced soil-vapor extraction (free phase) and soil-vapor extraction - venting
7. Thermally enhanced soil-vapor extraction (free phase) and soil-vapor extraction - air sparging
8. Thermally enhanced soil-vapor extraction (free phase) and bioremediation

For lead, the remediation options considered are:

0. Do nothing
1. Excavation

6.3.2 Criteria

Seven criteria have been chosen and weighed (with a number between 1 and 5) according to their importance for the site :

- Protection of human health
- Protection of Bay water
- Regulatory compliance
- Short-term liability
- Long-term liability
- Public perception
- Demonstration of effectiveness

6.3.3 Construction of Table 1 and Figure 1

Table 1 and Figure 1 present the cost-effectiveness analysis of remediation options. Lead and hydrocarbons were addressed separately.

The cost-effectiveness analysis follows La Grega presentation (1994). Each remediation option has been assigned a number between -2 and +2 for each criterion based on the effectiveness of that option to meet that criterion. The *raw score* of each remediation option is the sum of all points weighted by the criterion importance. The *effectiveness* of each option was calculated as follows: effectiveness = raw score - raw score of do nothing option

The *cost* was roughly evaluated for each individual remediation technique, outlined in Appendix D. When a combination of remediation techniques is used in a single remediation option, the cost of the two separate techniques was simply added together. A cost-effectiveness graph (Figure 6.1) was then plotted to determine the most viable solutions.

For Lead, the cost-effectiveness analysis only involves two probable outcomes and, hence, a graph was not utilized.

Table 6.1 Remediation Options Cost-Effectiveness

Criteria		Metals		Hydrocarbons								
	Weight	**L0**	**L1**	**HC0**	**HC1**	**HC2**	**HC3**	**HC4**	**HC5**	**HC6**	**HC7**	**HC8**
Protection of human health	5	0	-1	0	0	0	-1	-1	-1	0	0	0
Protection of Bay water	3	-2	1	-1	-1	0	1	1	1	0	0	0
Regulatory compliance	4	-1	2	-1	0	2	2	2	0	2	2	2
Short-term liability	2	1	-2	0	-1	-1	-1	-1	-1	-1	-1	-1
Long-term liability	3	0	-1	-1	0	1	0	1	1	2	2	2
Public perception	2	0	-1	-1	2	0	-1	-1	-1	0	0	1
Demonstration of effectiveness	3	0	2	0	-1	0	1	1	0	1	1	0
Raw score		-8	3	-12	-4	9	5	8	-3	15	15	14
Effectiveness		0	11	0	8	21	17	20	9	27	27	26
Cost (in million dollars)		0	1.9	0	1	1.4	3	2.5	1.7	3	2.5	1.8

LEGEND FOR REMEDIATION OPTIONS

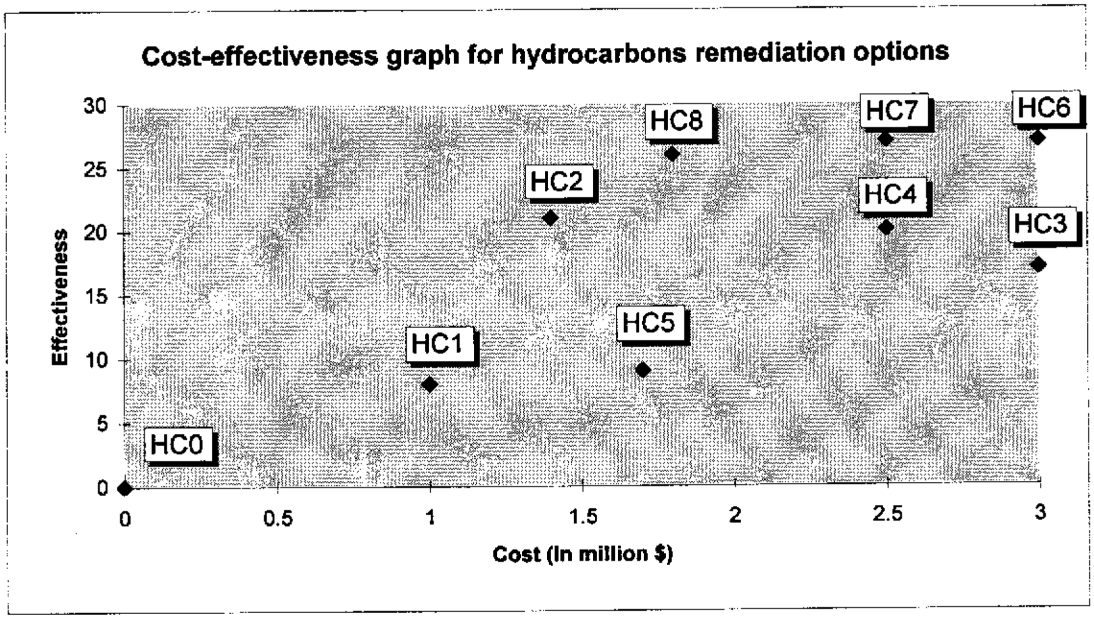
For metals (lead) :

L0. Do nothing
L1. Excavation

For hydrocarbons :

HC0. Do nothing
HC1. Bioremediation
HC2. Thermally enhanced soil-vapor extraction (plume)
HC3. Excavation of the free phase and soil-vapor extraction - venting
HC4. Excavation of the free phase and soil-vapor extraction - air sparging
HC5. Excavation of the free phase and bioremediation
HC6. Thermally enhanced soil-vapor extraction (free phase) and soil-vapor extraction - venting
HC7. Thermally enhanced soil-vapor extraction (free phase) and soil-vapor extraction - air sparging
HC8. Thermally enhanced soil-vapor extraction (free phase) and bioremediation

Figure 6.1



Legend for remediation options :

HC0. Do nothing
HC1. Bioremediation
HC2. Thermally enhanced soil-vapor extraction (plume)
HC3. Excavation of the free phase and soil-vapor extraction - venting
HC4. Excavation of the free phase and soil-vapor extraction - air sparging
HC5. Excavation of the free phase and bioremediation
HC6. Thermally enhanced soil-vapor extraction (free phase) and soil-vapor extraction - venting
HC7. Thermally enhanced soil-vapor extraction (free phase) and soil-vapor extraction - air sparging
HC8. Thermally enhanced soil-vapor extraction (free phase) and bioremediation

Conclusions

After reviewing all available information regarding the contamination, human risk, ecological risk, regulation and potential remediation alternatives we have concluded the following:

1) The site at Mariner Square does not meet the standards that would allow no further action. There is soil and groundwater contamination to the extent that it must be addressed either with remedial action or study.

2) It is not practical or economically feasible to remediate the pollution to levels set by the San Francisco Region Water Quality Control Board (SFRWQCB) that would allow complete and permanent closure.

3) Under current conditions there is no discernible risk posed to human health by the contamination on the site, with the exception of 3a).

3.a) There is a potential risk due to ingesting lead in the soil. See recommendation 1.a.ii).

4) There are potential future scenarios (i.e., a resident living on site being exposed to the maximum groundwater contamination) that produce a risk that would necessitate further investigation.

5) There is a potentially large, albeit uncertain, ecological risk to receptors in the San Francisco Bay due to the contamination on site.

6) There are Appropriate and Applicable Regulations set by the SFRWQCB that require remedial action be taken.

Recommendations

We recommend two general lines of action based on the risk analysis, regulation and cost analysis. It is necessary to determine the extent of risk posed to the environment. Once this is determined then the extent of cleanup, especially with regard to the metals, will be more completely understood. We also feel that it is necessary to remove the free phase hydrocarbons as soon as possible due to the evidence of its migration. The following is a summary list of recommendations for further action pertaining to the contamination on site:

1) Recommendations for Study

1.a) Ecological Risk Assessment - We feel it necessary to verify the risk posed to the receptors in the Bay due to contamination on site. At the minimum this would include the following:

1.a.i) Identifying the exposure pathways that link the groundwater contamination to the Bay. This should be done by verifying flow patterns and locating the storm and sanitary sewer drains that are on or near the site. There are also storm drains and outlets on the north side of the site that should be investigated. These may lead to direct Bay contamination.

1.a.ii) It is necessary to differentiate between forms of lead, specifically between tetraethyl and inorganic lead, found on the site because of the potential risk to human health due to soil ingestion. It is also necessary to determine the extent of the lead "plume" with respect to the soil depth and groundwater.

1.a.iii) Determine the extent to which the metals (Pb, Cu and Zn) must be remediated to prevent ecological risk.

1.b) Determine the extent of, and interactions with, the contamination on the adjacent Naval Supply Center with that found at Mariner Square. It would be unreasonable to undertake remedial action before the extent of contaminant migration, either onto or off of Mariner Square, was determined.

1.c) Undertake soil gas sampling to investigate the possibility of methane gas production (through anaerobic degradation) on the site. It is possible that dangerous concentrations could be collecting below the asphalt surface that covers the site.

1.d) Identify the source of the TPHg contamination that is increasing in monitoring wells MW-2 and MW-5 in the north-center section of the site. We believe that there may be abandoned underground pipelines that were used to transport fuel from ship docked in the harbor to the storage tanks on site.

1.e) Observation suggests that there may be solvent contamination in the south west corner of the site. There is the possibility that the upper layers of the soil may be contaminated and available for human exposure. Sampling of the shallow soil should be performed and careful groundwater monitoring should continue.

2) Recommendations for Action

2.a) Free Phase Removal - Groundwater sampling has shown that there is significant free phase hydrocarbon contamination near and around MW-6. Due to the fact that there is apparent migration of TPHd, as well as localized increases in TPHg concentrations, we feel it is necessary to remove the free produce to the extent practicable.

2.a.i) A preliminary cost analysis has shown that excavation or Thermally Enhanced Soil Vapor Extraction are the most economically feasible remediation alternatives. This final decision is contingent upon: the extent of metals remediation required (see 1.a.iii), the extent of excavation required to remove existing underground storage tanks and possible TPHg sources (see 1.d) and the nature of the exposure pathways (see 1.a.i).

2.a.ii) After free phase remediation it will be necessary to continue a monitoring regime to determine whether action needs to be taken with respect to the hydrocarbon plume. Evidence suggests that there is significant microbial activity in the subsurface which may control any future hydrocarbon migration.

2b) Metals Remediation - This is contingent on the ecological risk assessment. A preliminary cost analysis has shown that excavation is the most probable course of action, if deemed necessary.

APPENDIX A

RISK ASSESSMENT ADDENDUMS

A1. Determination of Atmospheric Contaminant Concentration of VOCs

The following equations are used to calculate the generic contaminant concentration in these phases:

$$C_a = H_c \cdot C_w \quad \text{(A.1)}$$

$$C_s = 0.6 f_{oc} \cdot K_{ow} \cdot C_w \quad \text{(A.2)}$$

where:

C_a : contaminant concentration in soil gas
C_W : contaminant concentration in water
C_s : contaminant concentration in soil
H_c : Henry's Constant, specific to chemicals
f_{oc} : fraction of organic carbon in soil
K_{ow} : octanol-water partition coefficient, specific to chemicals

Therefore, the contaminant concentration in soil gas can be obtained under two situations:
a. For groundwater samples, a contaminant is partitioned between soil gas (C_a) and groundwater (C_w); use equation (A.1)
b. For soil samples, a contaminant is partitioned among soil (C_{As}), the water film (C_w) on the soil surface, and soil gas (C_a); use both equation (A.2) and (A.1).

To be conservative, the highest contaminant concentration in soil gas C_a is selected from the results of both approaches.

The mass transfer rate from subsurface to atmosphere can be calculated via Fick's diffusion law:

$$Flux = D_{eff} \frac{C_a}{d} \quad \text{(A.3)}$$

where:

Flux : contaminant mass transfer rate [mass/time/area]
D_{eff} : effective diffusion coefficient in air
d : depth of contaminant sample in soil or groundwater

In equation (A.3), the effective coefficient of contaminants can be expressed as (Millington and Quirk, 1961):

$$D_{eff} = D_{mol} \frac{n_a^{3.3}}{n_T^{2}} \quad \text{(A.4)}$$

where:

D_{mol} : chemical-specific diffusion coefficient in air
n_a : air-filled porosity in soil
n_T : total soil porosity

The product of contaminant flux and the available site surface area is the moles of contaminant released from subsurface per unit time. The emission rate can be an input into CalTOX (based upon multimedia transport model) to obtain atmospheric contaminant concentration, which is crucial for receptor dose estimation.

Therefore, the contaminant intake can be calculated as:

$$Dose_{air} = \frac{\left(T_{out} \cdot C_{out} + T_{in} \cdot C_{in}\right) / 24 \cdot IR \cdot EF \cdot ED}{BW \cdot AT} \qquad \text{(A.5)}$$

where:

C_{out} : outdoor contaminant concentration, mg/m^3

C_{in} : indoor contaminant concentration, mg/m^3.

C_{in} is calculated by assuming the indoor environment is a well-mixed chamber (see below for details):

$$C_{in} = C_{out} + \frac{Flux}{ACH \cdot H} \qquad \text{(A.6)}$$

where Flux is the contaminant flux through the floor cracks, ACH is the air exchange rate (hr^{-1}) and H is the height of ceiling.

A.2 Model of Well-mixed Chamber

(Mass in from outdoor air)
= (Mass out from well-mixed chamber)
+ (Mass flux)(floor area)(time)

$$C_{out} \cdot Q \cdot dt + Flux \cdot A \cdot dt = C_{in} \cdot Q \cdot dt \tag{A.7}$$

$$\begin{aligned} C_{in} &= \frac{C_{out} \cdot Q + Flux \cdot A}{Q} \\ &= C_{out} + \frac{Flux \cdot A \cdot H}{Q \cdot H} \\ &= C_{out} + \frac{Flux \cdot V}{Q \cdot H} \\ &= C_{out} + \frac{Flux}{ACH \cdot H} \end{aligned} \tag{A.8}$$

where:

C_{out} : outdoor contaminant concentration, mg/m^3
C_{in} : indoor contaminant concentration, mg/m^3.
Q : air flow rate, m^3/d
dt: time step
Flux : contaminant flux through the cracks of floor
A : floor surface area, m^2
ACH : the air exchange rate (hr^{-1})
H : the height of ceiling, m

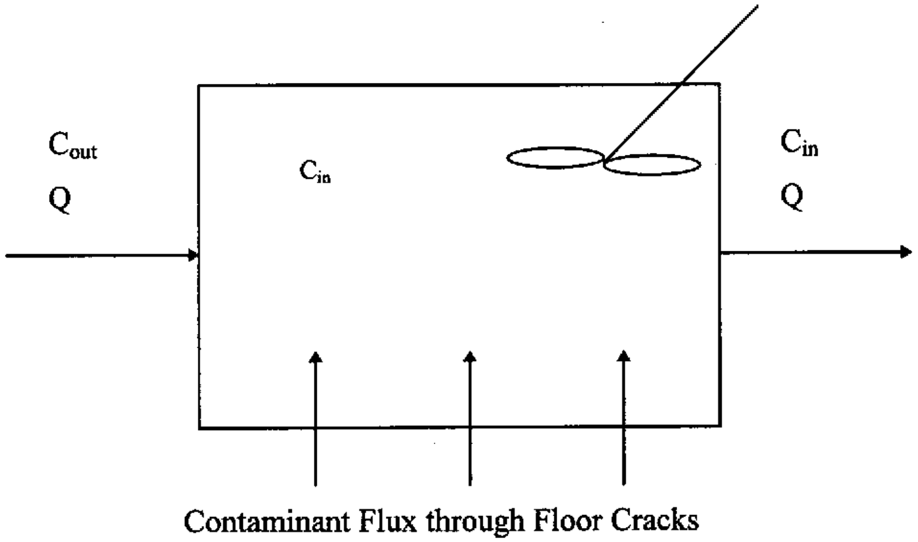


Figure A.1 Model of well-mixed chamber

A3. Risk Assessment Assumptions For Metals

A3.1. Formulas used

The formulas used for risk assessment calculations for metals are gathered in the following table. The metals considered have not be proven to be carcinogenic so the risk is measured by a hazard quotient HQ.

Route	Risk formula
Ingestion of chemicals in soil	HQ = (CS*IR*CF*FI*EF*ED/BW*AT) / RfD
Ingestion of chemicals in water	HQ = (CW*IR*EF*ED/BW*AT) / RfD
Dermal contact with chemicals in soil	HQ = (CS*CF*SA*AF*ABS*EF*ED/BW*AT) / RfD

where :

ABS : absorption factor (unitless)
AF : soil to skin adherence factor in mg/cm2
AT : averaging time in days
BW : body weight in kg
CF : conversion factor
CS: concentration in soil mg/kg soil or ppm
CW : concentration in water
ED : exposure duration in years
EF : exposure frequency in days
FI: fraction from contaminated sources
HQ : hazard quotient
IR : ingestion rate in mg soil/day or l water/d
SA : skin surface area available for contact in cm2/event

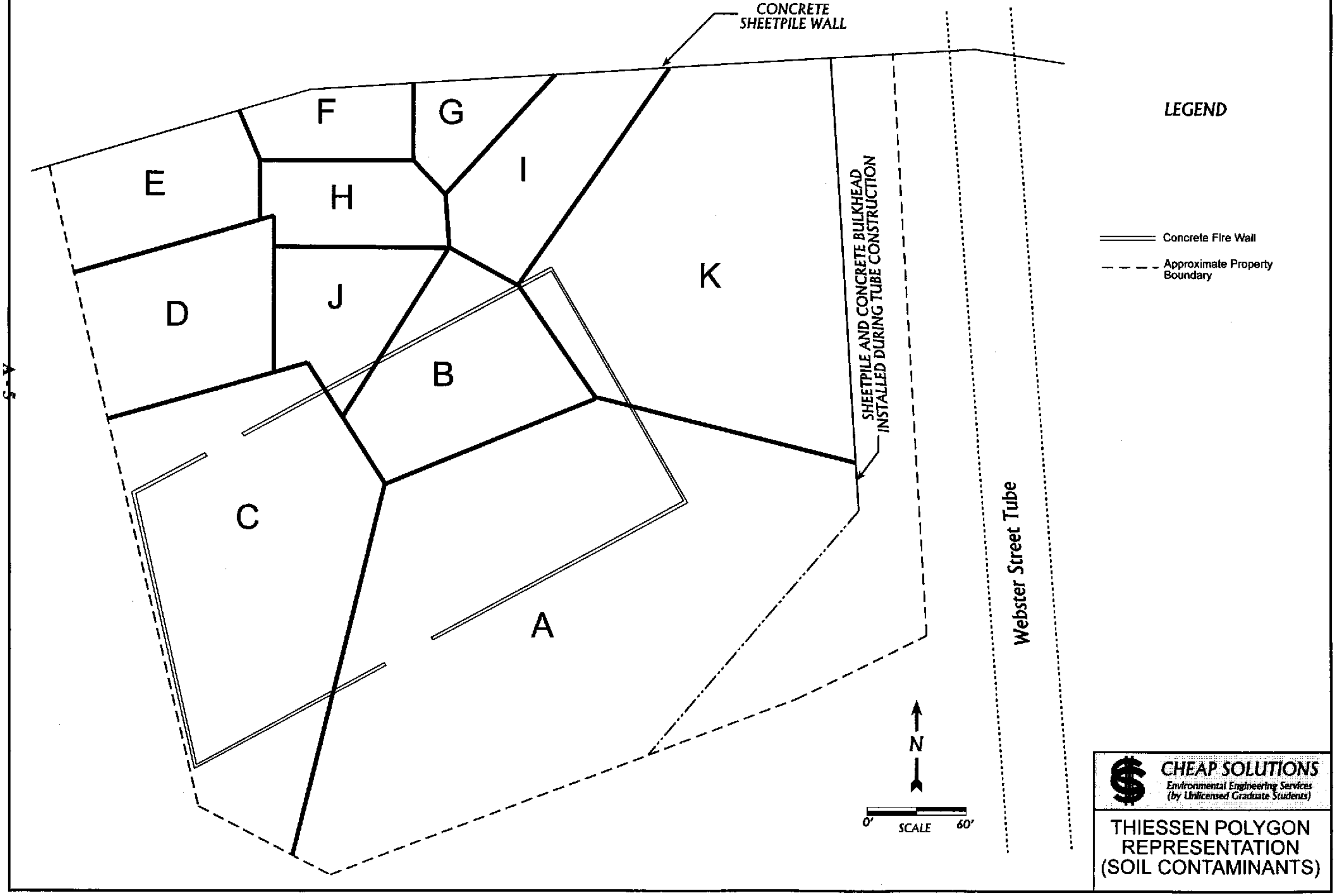
A3.2. Assumptions

The following are assumptions made in the calculations for site-specific values of several factors or when no value was recommended by EPA.

A3.2.1. Assumptions for ingestion of soil

Concentrations

For current scenario, trees and surrounding non-covered areas are only around soil borings F,G,I and K. The area-weighted average for this zone is thus taken as the concentration to which people are exposed (except the construction worker, for which the highest concentration is considered, as he could dig anywhere on the site). The enclosed figure details the shape and size of the polygons used for these area-weighted averages.



CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)

THIESSEN POLYGON
REPRESENTATION
(SOIL CONTAMINANTS)

For the future scenario, the whole area-weighted average is considered as people can be in contact with any part of the soil.

Fraction from contaminated sources

We assumed the maximum time in the non-covered areas could be, for the current scenario :
1 hour for a worker eating his lunch (1/24)
2 hour for a visiting child playing around the trees (2/24)
In the future scenario, the resident is assumed to spend more time off-site than the workers (0.5 hour per day = 1/48) and the construction worker spends by definition more time on the site (3 hours per day = 3/24).

Exposure factors

On site worker spends 5 days a week during the year on the site and takes vacation or is sick during 10 days (250 days).
The visitor goes to the site twice a week.
The maintenance worker works on the site 1 day per week, whereas the construction worker may spend 5 days in a row on the site.

A3.2.2. Assumptions for dermal contact

Introduction

EPA lacks verified toxicity values for the dermal route (soil or water). We extrapolated these values from oral values, as suggested by EPA.
Chemical specific absorption values for skin contact have been recommended by EPA only for five chemicals. For inorganics, the default absorption value suggested and used in our calculations is 1%.
Furthermore, formulas are given to calculate the risk presented by dermal contact with chemicals in soil but not in water. EPA has not yet found an adequate method to describe the potential risk posed by dermal contact with contaminated water.

Exposure factors

The construction and maintenance workers are assumed to have their hands dirty with soil each time they work on the site (5 and 50 events/year respectively). An on-site worker can be in accidental contact with the soil. This is assumed to happen once a month (12 events/year). The on-site visitor is assumed to be a child, as he is more likely to touch dirt on the site. We assumed the child played with the dirt during each of his visit (20 days a year). The on-site resident is also assumed to be a child, as the contamination most likely to occur is through playing with dirt every day (350 days/year).

A3.2.3. Assumptions for ingestion of water

As the groundwater is not used as a source of drinking water, no current risk has been calculated. The future scenario considered is that the groundwater is used for that purpose.

Concentrations
The concentrations of metals taken are the highest found in the groundwater under the site (historical maximum, corresponding to 1994 measurements).

Ingestion factors
For a future scenario where the water is used, the ingestion rate taken is 2 l/d but we added a FI (fraction ingested) term to account for the fact that we were not in a residential scenario for all receptors. Therefore, all the water drunk does not come from the contaminated area. FI are rather conservative :
1 for the resident using mainly tap water at home,
3/4 for the workers, on their workplace the whole day,
1/4 for the visitor who can drink tap water on site during his visit.

Exposure factors
Exposure frequencies, exposure durations, body weight and averaging times are consistent with previous calculations for ingestion of soil.

A3.3. Notes on metals risk assessment

1)No RfD was available for metals for inhalation of particles contaminated with metals. This seems a plausible way of being contaminated by metals. Given the small areas represented by soil as opposed to concrete on the site, the risk associated with inhalation is likely to be very low anyway.
2)No RfD was available for any route concerning inorganic lead.

A4. Risk Assessment Assumptions For Liquid and Soil Routes of Exposure for VOCs

To be consistent the assumptions and methods for VOC contaminant exposures followed the same assumptions as those used for metals in regards to exposure times and amounts of soil ingested, etc.

Because of the difficulty involved in accurately determining exposure routes an extremely conservative approach was taken by using a dilution factor of 1.0 in most cases. That is, exposure was assessed as if it were occurring at the highest observed concentrations on the Mariner Square site. By using these extreme assumptions even calculating the risk of a person drinking 2 liters of water per day straight from the Vinyl Chloride "hot spot" yields a lifetime additional cancer risk of only 5.6×10^{-5}.

Table A.1 Cancer risk and hazard quotient from benzene exposure through all potential pathways

Benzene	Inhalation Cancer Risk	Water Ingestion Cancer Risk	Water Ingestion Hazard Quotient	Soil Ingestion Cancer Risk	Soil Ingestion Hazard Quotient	Soil Dermal Contact Cancer Risk	Soil Dermal Contact Hazard Quotient	Water Dermal Contact Cancer Risk	Water Dermal Contact Hazard Quotient
Current Scenario									
On-site									
worker	4.5E-10			2.0E-12	1.2E-07		2.0E-06		
visitor (adult)	1.6E-11								
visitor (child)	2.2E-11			7.3E-13	1.7E-07		4.6E-06		
maintenance worker	5.9E-11	4.9E-13	4.8E-13	4.1E-13	2.3E-08	2.9E-08	5.0E-06	3.0E-08	6.0E-04
Off-site									
worker	4.0E-10								
visitor (adult)	1.6E-11								
visitor (child)	1.0E-10								
resident	4.9E-09								
Future Scenario									
On-site									
worker	3.9E-08	4.6E-08	4.5E-08	2.0E-12	1.2E-07	2.9E-08	4.6E-06	3.0E-08	6.0E-04
visitor (adult)	1.4E-09								
visitor (child)	9.2E-09	1.5E-09	1.4E-09	3.6E-12	8.6E-07	2.0E-07	4.6E-06	2.0E-07	6.7E-03
maintenance worker	5.2E-09	9.3E-09	9.0E-09	4.1E-13	2.3E-08	1.8E-08	1.0E-05	1.8E-08	3.6E-04
construction worker	2.6E-09	3.7E-11	3.6E-11	4.7E-15	2.8E-10	5.9E-08	4.0E-08	5.9E-08	1.2E-03
resident	4.3E-07	1.0E-07	1.0E-07	1.7E-12	9.7E-08	1.5E-07	1.2E-05	1.5E-07	6.7E-02
Off-site									
worker	3.5E-08								
visitor (adult)	1.4E-09								
visitor (child)	9.1E-09								
resident	4.3E-07								

Table A.2 Cancer risk from vinyl chloride exposure through all potential pathways

Vinyl Chloride	Inhalation Cancer Risk	Water Ingestion Cancer Risk	Water Dermal Contact Cancer Risk
Current Scenario			
On-site			
worker	2.6E-09		
visitor (adult)	9.1E-11		
visitor (child)	1.3E-10		
maintenance worker	3.4E-10	2.6E-10	9.3E-07
Off-site			
worker	2.3E-09		
visitor (adult)	9.1E-11		
visitor (child)	1.3E-10		
resident	2.8E-08		
Future Scenario			
On-site			
worker	1.7E-07	2.5E-05	9.3E-07
visitor (adult)	6.0E-09		
visitor (child)	8.5E-09	8.0E-07	6.3E-06
maintenance worker	2.3E-08	5.0E-06	5.6E-07
construction worker	1.1E-08	2.0E-08	1.7E-06
resident	1.2E-06	5.6E-05	4.6E-06
Off-site			
worker	9.4E-08		
visitor (adult)	3.8E-09		
visitor (child)	5.3E-09		
resident	1.2E-06		

Table A.3 Hazard quotient from toluene exposure through all potential pathways

Toluene	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient	Soil Ingestion Hazard Quotient	Soil Dermal Contact Hazard Quotient	Water Dermal Contact Hazard Quotient
Current Scenario					
On-site					
worker	2.3E-03	5.3E-09	1.6E-07	6.8E-07	
visitor (adult)	8.2E-05				
visitor (child)	1.9E-04		2.5E-07	1.6E-06	
maintenance worker	3.1E-04		3.3E-08	1.7E-06	2.1E-05
Off-site					
worker	2.0E-03				
visitor (adult)	8.2E-05				
visitor (child)	1.9E-04				
resident	9.0E-03				
Future Scenario					
On-site					
worker	1.4E-02	5.0E-04	1.6E-07	1.4E-06	2.1E-05
visitor (adult)	5.0E-04				
visitor (child)	1.2E-03	1.6E-05	1.2E-06	1.6E-06	2.3E-04
maintenance worker	1.9E-03	1.0E-04	3.3E-08	3.4E-06	1.2E-05
construction worker	2.3E-02	4.0E-07	4.0E-10	1.4E-08	4.1E-05
resident	5.2E-02	1.1E-03	1.4E-07	4.1E-06	2.3E-03
Off-site					
worker	1.2E-02				
visitor (adult)	4.8E-04				
visitor (child)	1.1E-03				
resident	5.2E-02				

Table A.4 Hazard quotient from ethylbenzene exposure through all potential pathways

Ethylbenzene	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient	Soil Ingestion Hazard Quotient	Soil Dermal Contact Hazard Quotient	Water Dermal Contact Hazard Quotient
Current Scenario					
On-site					
worker	1.3E-03	3.3E-08	2.3E-06	3.9E-05	
visitor (adult)	4.8E-05				
visitor (child)	1.1E-04		3.4E-06	9.2E-05	
maintenance worker	1.8E-04		4.5E-07	9.8E-05	2.1E-05
Off-site					
worker	1.2E-03				
visitor (adult)	4.8E-05				
visitor (child)	1.1E-04				
resident	5.2E-03				
Future Scenario					
On-site					
worker	8.1E-03	3.1E-03	2.3E-06	7.9E-05	2.1E-05
visitor (adult)	2.9E-04				
visitor (child)	6.7E-04	9.9E-05	1.7E-05	9.2E-05	2.3E-04
maintenance worker	1.1E-03	6.2E-04	4.5E-07	2.0E-04	1.2E-05
construction worker	1.3E-02	2.5E-06	5.5E-09	7.9E-07	4.1E-05
resident	5.2E-03	6.9E-03	1.9E-06	2.4E-04	2.3E-03
Off-site					
worker	1.2E-03				
visitor (adult)	4.8E-05				
visitor (child)	1.1E-04				
resident	5.2E-03				

Table A.5 Hazard quotient from xylene exposure through all potential pathways

Xylene	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient	Soil Ingestion Hazard Quotient	Soil Dermal Contact Hazard Quotient	Water Dermal Contact Hazard Quotient
Current Scenario					
On-site					
worker	3.2E-07	1.1E-09	1.6E-07	2.8E-06	
visitor (adult)	1.2E-08				
visitor (child)	2.7E-08		2.5E-07	6.6E-06	
maintenance worker	4.3E-08		3.3E-08	7.1E-06	1.4E-06
Off-site					
worker	2.9E-07				
visitor (adult)	1.1E-08				
visitor (child)	2.7E-08				
resident	1.3E-06				
Future Scenario					
On-site					
worker	9.5E-04	1.0E-04	1.6E-07	5.7E-06	1.6E-06
visitor (adult)	3.4E-05				
visitor (child)	7.9E-05	3.3E-06	1.2E-06	6.6E-06	1.5E-05
maintenance worker	1.3E-04	2.1E-05	3.3E-08	1.4E-05	8.2E-07
construction worker	1.6E-03	8.2E-08	4.0E-10	5.7E-08	2.7E-06
resident	3.7E-03	2.3E-04	1.4E-07	1.7E-05	1.5E-04
Off-site					
worker	8.5E-04				
visitor (adult)	3.4E-05				
visitor (child)	7.9E-05				
resident	3.7E-03				

Table A.6 Hazard quotient from acenaphthalene, anthracene benzo[a]pyrene exposure through all potential pathways

Acenaphthalene	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient	**Anthracene**	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient	**Benzo[a]pyrene**	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient
Current Scenario			**Current Scenario**			**Current Scenario**		
On-site			*On-site*			*On-site*		
worker	3.1E-06		worker	3.9E-10		worker	7.6E-12	
visitor (adult)	1.1E-07		visitor (adult)	1.4E-11		visitor (adult)	2.7E-13	
visitor (child)	2.5E-07		visitor (child)	3.2E-11		visitor (child)	6.3E-13	
maintenance worker	4.1E-07	2.5E-13	maintenance worker	5.2E-11	1.2E-15	maintenance worker	1.0E-12	4.1E-15
Off-site			*Off-site*	0.0E+00		*Off-site*		
worker	2.7E-06		worker	3.5E-10		worker	6.7E-12	
visitor (adult)	1.1E-07		visitor (adult)	1.4E-11		visitor (adult)	2.7E-13	
visitor (child)	2.5E-07		visitor (child)	3.2E-11		visitor (child)	6.3E-13	
resident	1.2E-05		resident	1.5E-09		resident	3.0E-11	
Future Scenario			**Future Scenario**			**Future Scenario**		
On-site			*On-site*			*On-site*		
worker	1.8E-04	2.4E-08	worker	2.4E-08	1.1E-10	worker	4.6E-10	3.8E-10
visitor (adult)	6.5E-06		visitor (adult)	8.7E-10		visitor (adult)	1.7E-11	
visitor (child)	1.5E-05	7.5E-10	visitor (child)	2.0E-09	3.6E-12	visitor (child)	3.9E-11	1.2E-11
maintenance worker	2.4E-05	4.7E-09	maintenance worker	3.3E-09	2.3E-11	maintenance worker	6.2E-11	7.6E-11
construction worker	3.1E-04	1.9E-11	construction worker	4.1E-08	9.0E-14	construction worker	7.7E-10	3.1E-13
resident	7.1E-04	5.3E-08	resident	9.5E-08	2.5E-10	resident	1.8E-09	8.6E-10
Off-site	0.0E+00		*Off-site*			*Off-site*		
worker	1.6E-04		worker	2.2E-08		worker	4.1E-10	
visitor (adult)	6.5E-06		visitor (adult)	8.7E-10		visitor (adult)	1.7E-11	
visitor (child)	1.5E-05		visitor (child)	2.0E-09		visitor (child)	3.9E-11	
resident	7.1E-04		resident	9.5E-08		resident	1.8E-09	

Table A.7 Hazard quotient from fluoranthene and naphthalene exposure through all potential pathways

Fluoranthene	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient	**Naphthalene**	Inhalation Hazard Quotient	Water Ingestion Hazard Quotient
Current Scenario			**Current Scenario**		
On-site			*On-site*		
worker	1.2E-09		worker	2.1E-06	
visitor (adult)	4.3E-11		visitor (adult)	7.3E-08	
visitor (child)	1.0E-10		visitor (child)	1.7E-07	
maintenance worker	1.6E-10	3.4E-14	maintenance worker	2.7E-07	7.8E-15
Off-site			*Off-site*		
worker	1.1E-09		worker	1.8E-06	
visitor (adult)	4.3E-11		visitor (adult)	7.3E-08	
visitor (child)	1.0E-10		visitor (child)	1.7E-07	
resident	4.7E-09		resident	8.0E-06	
Future Scenario			**Future Scenario**		
On-site			*On-site*		
worker	7.3E-08	3.2E-09	worker	1.2E-04	7.3E-10
visitor (adult)	2.6E-09		visitor (adult)	4.3E-06	
visitor (child)	6.1E-09	1.0E-10	visitor (child)	1.0E-05	2.4E-11
maintenance worker	9.8E-09	6.3E-10	maintenance worker	1.6E-05	1.5E-10
construction worker	1.2E-07	2.5E-12	construction worker	2.0E-04	5.9E-13
resident	2.9E-07	7.1E-09	resident	4.8E-04	1.6E-09
Off-site			*Off-site*		
worker	6.5E-08		worker	1.1E-04	
visitor (adult)	2.6E-09		visitor (adult)	4.3E-06	
visitor (child)	6.1E-09		visitor (child)	1.0E-05	
resident	2.9E-07		resident	4.8E-04	

Table A.8 Hazard quotient from antimony, arsenic, chromium, copper exposure through all potential pathways

Antimony	Soil Ingestion Hazard Quotient	**Arsenic**	Water Ingestion Hazard Quotient	**Chromium**	Water Ingestion Hazard Quotient	Soil Ingestion Hazard Quotient	**Copper**	Water Ingestion Hazard Quotient	Soil Ingestion Hazard Quotient
Current Scenario		**Current Scenario**		**Current Scenario**			**Current Scenario**		
On-site		*On-site*		*On-site*			*On-site*		
worker	0.0E+00	worker		worker		1.8E-05	worker		3.0E-03
visitor (adult)		visitor (adult)		visitor (adult)			visitor (adult)		
visitor (child)	0.0E+00	visitor (child)		visitor (child)		2.7E-05	visitor (child)		4.5E-03
maintenance worker	0.0E+00	maintenance worker	5.2E-06	maintenance worker	9.4E-07	3.6E-06	maintenance worker	1.3E-07	6.1E-04
Off-site		*Off-site*		*Off-site*			*Off-site*		
worker		worker		worker			worker		
visitor (adult)		visitor (adult)		visitor (adult)			visitor (adult)		
visitor (child)		visitor (child)		visitor (child)			visitor (child)		
resident		resident		resident			resident		
Future Scenario		**Future Scenario**		**Future Scenario**			**Future Scenario**		
On-site		*On-site*		*On-site*			*On-site*		
worker	1.5E-03	worker	4.9E-01	worker	8.8E-02	4.3E-05	worker	1.2E-02	8.9E-04
visitor (adult)		visitor (adult)		visitor (adult)			visitor (adult)		
visitor (child)	1.1E-02	visitor (child)	1.6E-02	visitor (child)	2.8E-03	3.2E-04	visitor (child)	3.8E-04	6.7E-03
maintenance worker	2.9E-04	maintenance worker	9.8E-02	maintenance worker	1.7E-02	8.6E-06	maintenance worker	2.4E-03	1.8E-04
construction worker	4.0E-05	construction worker	3.9E-04	construction worker	7.1E-05	8.5E-07	construction worker	9.5E-06	1.1E-05
resident	1.2E-03	resident	1.1E+00	resident	2.0E-01	3.6E-05	resident	2.7E-02	7.5E-04
Off-site		*Off-site*		*Off-site*			*Off-site*		
worker		worker		worker			worker		
visitor (adult)		visitor (adult)		visitor (adult)			visitor (adult)		
visitor (child)		visitor (child)		visitor (child)			visitor (child)		
resident		resident		resident			resident		

Table A.9 Hazard quotient from lead, nickel, zinc exposure through all potential pathways

Lead	Soil Ingestion Hazard Quotient	**Nickel**	Water Ingestion Hazard Quotient	**Zinc**	Water Ingestion Hazard Quotient	Soil Ingestion Hazard Quotient
Current Scenario		**Current Scenario**		**Current Scenario**		
On-site		*On-site*		*On-site*		
worker	1.45E+01	worker		worker		1.8E-05
visitor (adult)		visitor (adult)		visitor (adult)		
visitor (child)	2.16E+01	visitor (child)		visitor (child)		2.7E-05
maintenance worker	2.16E+01	maintenance worker	1.6E-07	maintenance worke	3.1E-08	3.6E-06
Off-site		*Off-site*		*Off-site*		
worker		worker		worker		
visitor (adult)		visitor (adult)		visitor (adult)		
visitor (child)		visitor (child)		visitor (child)		
resident		resident		resident		
Future Scenario		**Future Scenario**		**Future Scenario**		
On-site		*On-site*		*On-site*		
worker	1.87E+02	worker	1.5E-02	worker	2.9E-03	4.3E-05
visitor (adult)		visitor (adult)		visitor (adult)		
visitor (child)	1.40E+03	visitor (child)	4.7E-04	visitor (child)	9.4E-05	3.2E-04
maintenance worker	3.74E+01	maintenance worker	2.9E-03	maintenance worke	5.9E-04	8.6E-06
construction worker	5.35E+00	construction worker	1.2E-05	construction worker	2.4E-06	8.5E-07
resident	1.57E+02	resident	3.3E-02	resident	6.6E-03	3.6E-05
Off-site		*Off-site*		*Off-site*		
worker		worker		worker		
visitor (adult)		visitor (adult)		visitor (adult)		
visitor (child)		visitor (child)		visitor (child)		
resident		resident		resident		

Table A.10a Chemical and toxicological properties of contaminates of concern

Chemical and toxicological parameters		Benzene	Vinyl Chloride	Ethylbenzene	Toluene	Xylene
Molecular weight (g/mol)	MW	78.1	62.5	106.2	92.1	106.2
Octanol-water partition coefficient	Kow	1.51E+02	1.52 E+01	1.33 E+03	4.82 E+02	1.30 E+03
Melting point (K)	Tm	279	119	178	178	248
Vapor Pressure in (Pa)	VP	1.27E+04	3.67 E+05	1.28 E+03	3.77 E+03	1.07 E+03
Solubility in mol/m3	S	2.25E+01	3.94 E+01	1.64 E+00	6.22 E+00	1.78 E+00
Henry's law constant (Pa-m^3/mol)	H -	5.7E+02	2.6E+03	8.3E+02	6.6E+02	6.9E+02
Diffusion coefficient in pure air (m2/d)	Dair	7.56E-01	9.14 E-01	6.48 E-01	7.52 E-01	6.22 E-01
Diffusion coefficient; pure water (m2/d)	Dwater	9.63E-05	1.21 E-04	7.66 E-05	8.51 E-05	7.66 E-05
Organic carbon partition coefficient Koc	Koc -	5.51E+01	2.92E+01	2.28E+02	1.39E+02	2.71E+02
Slpoe factor - inhalation	SFi	0.1	0.27	-	-	-
Slpoe factor - oral	SFo	0.1	0.27	-	-	-
Slpoe factor - dermal	SFd	0.1	0.27	-	-	-
Reference Dose - inhalation	RfDi	0.0017	-	0.3	0.03	2
Reference Dose - oral	RfDo	0.0007	-	0.1	0.2	2
Reference Dose - dermal	RfDd	0.0007	-	0.1	0.2	2

Table A.10b Chemical and toxicological properties of contaminates of concern

Chemical and toxicological parameters		Acenaphthalene	Anthracene	Benzo[a]pyrene	Fluoranthene	Naphthalene
Molecular weight (g/mol)	MW	154.2	178.2	252.3	202.3	128.2
Octanol-water partition coefficient	Kow	9.26 E+03	3.03 E+04	2.20 E+06	1.27 E+05	2.39 E+03
Melting point (K)	Tm	368	488	451	384	354
Vapor Pressure in (Pa)	VP	9.47 E-01	1.18 E-02	7.13 E-07	1.19 E-03	1.29 E+01
Solubility in mol/m3	S	2.75 E-02	3.16 E-04	1.03 E-05	1.16 E-03	2.43 E-01
Henry's law constant (Pa-m^3/mol)	H -	4.0E+01	4.3E+00	9.2E-02	-9.9E+01	4.7E+01
Diffusion coefficient in pure air (m2/d)	Dair	3.64 E-01	2.80 E-01	4.36 E-01	2.61 E-01	5.10 E-01
Diffusion coefficient; pure water (m2/d)	Dwater	6.76 E-05	6.25 E-05	5.26 E-05	5.90 E-05	7.44 E-05
Organic carbon partition coefficient Koc	Koc -	5.03E+03	2.22E+04	2.49E+06	4.94E+04	1.07E+03
Slpoe factor - inhalation	SFi	-	-	-	-	-
Slpoe factor - oral	SFo	-	-	-	-	-
Slpoe factor - dermal	SFd	-	-	-	-	-
Reference Dose - inhalation	RfDi	0.06	0.3	0.03	0.04	0.003
Reference Dose - oral	RfDo	0.06	0.3	0.03	0.04	0.04
Reference Dose - dermal	RfDd	0.06	0.3	0.03	0.04	0.04

Table A.11 Relevant parameters used in risk assessment

Landscape chracteristics		
Total on-site area	A	18147 m^2
Percentage of cracks in curent scenario		1%
Percentage of uncovered area in future scenario		60%
Soil sample depth	d_s	1.5 ft
Groundwater sample depth	d_w	4 ft
Soil property		
Total porosity	n_T	0.35
Air-filled porosity	n_a	0.25
Fraction of organic carbon	f_{oc}	0.10
Indoor environment characteristics		
Air Exahange rate	ACH	5 hr^{-1}
Floor Area	A_{floor}	55 m^2
Ceiling Height	H	3 m

Table A.12 Cancer risks caused via inhalation

Benzene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Cancer Risk
Current											
On-site											
worker	1.7E-07	1.7E-07	20	1	8	250	25	70	25550	4.5E-09	4.5E-10
visitor (adult)	1.7E-07	1.7E-07	20	4	4	10	25	70	25550	1.6E-10	1.6E-11
visitor (child)	1.7E-07	1.7E-07	10	4	4	10	15	15	25550	2.2E-10	2.2E-11
mainteinance worker	1.7E-07	1.7E-07	30	8	2	20	25	70	25550	5.9E-10	5.9E-11
Off-site											
worker	1.7E-07		20	1	8	250	25	70	25550	4.0E-09	4.0E-10
visitor (adult)	1.7E-07		20	4	4	10	25	70	25550	1.6E-10	1.6E-11
visitor (child)	1.7E-07		10	4	4	10	15	15	5475	1.0E-09	1.0E-10
resident	1.7E-07		20	3	21	365	70	70	25550	4.9E-08	4.9E-09
Future											
On-site											
worker	1.5E-05	1.5E-05	20	1	8	250	25	70	25550	3.9E-07	3.9E-08
visitor (adult)	1.5E-05	1.5E-05	20	4	4	10	25	70	25550	1.4E-08	1.4E-09
visitor (child)	1.5E-05	1.5E-05	10	4	4	10	15	15	5475	9.1E-08	9.1E-09
mainteinance worker	1.5E-05	1.5E-05	30	8	2	20	25	70	25550	5.2E-08	5.2E-09
construction worker	1.5E-05	1.5E-05	30	10	0	250	1	70	25550	2.6E-08	2.6E-09
resident	1.5E-05	1.5E-05	20	3	21	365	70	70	25550	4.3E-06	4.3E-07
Off-site											
worker	1.5E-05		20	1	8	250	25	70	25550	3.5E-07	3.5E-08
visitor (adult)	1.5E-05		20	4	4	10	25	70	25550	1.4E-08	1.4E-09
visitor (child)	1.5E-05		10	4	4	10	15	15	5475	9.1E-08	9.1E-09
resident	1.5E-05		20	3	21	365	70	70	25550	4.3E-06	4.3E-07

Vinyl Chloride	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Cancer Risk
Current											
On-site											
worker	3.6E-07	3.6E-07	20	1	8	250	25	70	25550	9.5E-09	2.6E-09
visitor (adult)	3.6E-07	3.6E-07	20	4	4	10	25	70	25550	3.4E-10	9.1E-11
visitor (child)	3.6E-07	3.6E-07	10	4	4	10	15	15	25550	4.7E-10	1.3E-10
mainteinance worker	3.6E-07	3.6E-07	30	8	2	20	25	70	25550	1.3E-09	3.4E-10
Off-site											
worker	3.6E-07		20	1	8	250	25	70	25550	8.4E-09	2.3E-09
visitor (adult)	3.6E-07		20	4	4	10	25	70	25550	3.4E-10	9.1E-11
visitor (child)	3.6E-07		10	4	4	10	15	15	5475	2.2E-09	5.9E-10
resident	3.6E-07		20	3	21	365	70	70	25550	1.0E-07	2.8E-08
Future											
On-site											
worker	2.4E-05	2.4E-05	20	1	8	250	25	70	25550	6.3E-07	1.7E-07
visitor (adult)	2.4E-05	2.4E-05	20	4	4	10	25	70	25550	2.2E-08	6.0E-09
visitor (child)	2.4E-05	2.4E-05	10	4	4	10	15	15	5475	1.5E-07	3.9E-08
mainteinance worker	2.4E-05	2.4E-05	30	8	2	20	25	70	25550	8.4E-08	2.3E-08
construction worker	2.4E-05	2.4E-05	30	10	0	250	1	70	25550	4.2E-08	1.1E-08
resident	2.4E-05	2.4E-05	20	3	21	365	70	70	25550	6.9E-06	1.9E-06
Off-site											
worker	1.5E-05		20	1	8	250	25	70	25550	3.5E-07	9.4E-08
visitor (adult)	1.5E-05		20	4	4	10	25	70	25550	1.4E-08	3.8E-09
visitor (child)	1.5E-05		10	4	4	10	15	15	5475	9.1E-08	2.5E-08
resident	1.5E-05		20	3	21	365	70	70	25550	4.3E-06	1.2E-06

1. For off-site scenario, outdoor concentration and indoor concentration are set identical.

Table A.13 Noncancer risks caused via inhalation

Ethyl Benzene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	5.5E-03	5.5E-03	20	1	8	250	25	70	9125	4.0E-04	1.3E-03
visitor (adult)	5.5E-03	5.5E-03	20	4	4	10	25	70	9125	1.4E-05	4.8E-05
visitor (child)	5.5E-03	5.5E-03	10	4	4	10	15	15	5475	3.3E-05	1.1E-04
mainteinance worker	5.5E-03	5.5E-03	30	8	2	20	25	70	9125	5.4E-05	1.8E-04
Off-site											
worker	5.5E-03		20	1	8	250	25	70	9125	3.6E-04	1.2E-03
visitor (adult)	5.5E-03		20	4	4	10	25	70	9125	1.4E-05	4.8E-05
visitor (child)	5.5E-03		10	4	4	10	15	15	5475	3.3E-05	1.1E-04
resident	5.5E-03		20	3	21	365	70	70	25550	1.6E-03	5.2E-03
Future											
On-site											
worker	3.3E-02	3.3E-02	20	1	8	250	25	70	9125	2.4E-03	8.1E-03
visitor (adult)	3.3E-02	3.3E-02	20	4	4	10	25	70	9125	8.6E-05	2.9E-04
visitor (child)	3.3E-02	3.3E-02	10	4	4	10	15	15	5475	2.0E-04	6.7E-04
mainteinance worker	3.3E-02	3.3E-02	30	8	2	20	25	70	9125	3.2E-04	1.1E-03
construction worker	3.3E-02	3.3E-02	30	10	0	250	1	70	365	4.0E-03	1.3E-02
resident	3.3E-02	3.3E-02	20	3	21	365	70	70	25550	9.4E-03	3.1E-02
Off-site											
worker	5.5E-03		20	1	8	250	25	70	9125	3.6E-04	1.2E-03
visitor (adult)	5.5E-03		20	4	4	10	25	70	9125	1.4E-05	4.8E-05
visitor (child)	5.5E-03		10	4	4	10	15	15	5475	3.3E-05	1.1E-04
resident	5.5E-03		20	3	21	365	70	70	25550	1.6E-03	5.2E-03

Toluene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	9.4E-04	9.4E-04	20	1	8	250	25	70	9125	6.9E-05	2.3E-03
visitor (adult)	9.4E-04	9.4E-04	20	4	4	10	25	70	9125	2.5E-06	8.2E-05
visitor (child)	9.4E-04	9.4E-04	10	4	4	10	15	15	5475	5.7E-06	1.9E-04
mainteinance worker	9.4E-04	9.4E-04	30	8	2	20	25	70	9125	9.2E-06	3.1E-04
Off-site											
worker	9.4E-04		20	1	8	250	25	70	9125	6.1E-05	2.0E-03
visitor (adult)	9.4E-04		20	4	4	10	25	70	9125	2.5E-06	8.2E-05
visitor (child)	9.4E-04		10	4	4	10	15	15	5475	5.7E-06	1.9E-04
resident	9.4E-04		20	3	21	365	70	70	25550	2.7E-04	9.0E-03
Future											
On-site											
worker	5.7E-03	5.7E-03	20	1	8	250	25	70	9125	4.2E-04	1.4E-02
visitor (adult)	5.7E-03	5.7E-03	20	4	4	10	25	70	9125	1.5E-05	5.0E-04
visitor (child)	5.7E-03	5.7E-03	10	4	4	10	15	15	5475	3.5E-05	1.2E-03
mainteinance worker	5.7E-03	5.7E-03	30	8	2	20	25	70	9125	5.6E-05	1.9E-03
construction worker	5.7E-03	5.7E-03	30	10	0	250	1	70	365	7.0E-04	2.3E-02
resident	5.7E-03	5.7E-03	20	3	21	365	70	70	25550	1.6E-03	5.4E-02
Off-site											
worker	5.5E-03		20	1	8	250	25	70	9125	3.6E-04	1.2E-02
visitor (adult)	5.5E-03		20	4	4	10	25	70	9125	1.4E-05	4.8E-04
visitor (child)	5.5E-03		10	4	4	10	15	15	5475	3.3E-05	1.1E-03
resident	5.5E-03		20	3	21	365	70	70	25550	1.6E-03	5.2E-02

Xylene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	8.8E-06	8.9E-06	20	1	8	250	25	70	9125	6.5E-07	3.2E-07
visitor (adult)	8.8E-06	8.9E-06	20	4	4	10	25	70	9125	2.3E-08	1.2E-08
visitor (child)	8.8E-06	8.9E-06	10	4	4	10	15	15	5475	5.4E-08	2.7E-08
mainteinance worker	8.8E-06	8.9E-06	30	8	2	20	25	70	9125	8.6E-08	4.3E-08
Off-site											
worker	8.8E-06		20	1	8	250	25	70	9125	5.7E-07	2.9E-07
visitor (adult)	8.8E-06		20	4	4	10	25	70	9125	2.3E-08	1.1E-08
visitor (child)	8.8E-06		10	4	4	10	15	15	5475	5.4E-08	2.7E-08
resident	8.8E-06		20	3	21	365	70	70	25550	2.5E-06	1.3E-06
Future											
On-site											
worker	2.6E-02	2.6E-02	20	1	8	250	25	70	9125	1.9E-03	9.5E-04
visitor (adult)	2.6E-02	2.6E-02	20	4	4	10	25	70	9125	6.8E-05	3.4E-05
visitor (child)	2.6E-02	2.6E-02	10	4	4	10	15	15	5475	1.6E-04	7.9E-05
mainteinance worker	2.6E-02	2.6E-02	30	8	2	20	25	70	9125	2.5E-04	1.3E-04
construction worker	2.6E-02	2.6E-02	30	10	0	250	1	70	365	3.2E-03	1.6E-03
resident	2.6E-02	2.6E-02	20	3	21	365	70	70	25550	7.4E-03	3.7E-03
Off-site											
worker	2.6E-02		20	1	8	250	25	70	9125	1.7E-03	8.5E-04
visitor (adult)	2.6E-02		20	4	4	10	25	70	9125	6.8E-05	3.4E-05
visitor (child)	2.6E-02		10	4	4	10	15	15	5475	1.6E-04	7.9E-05
resident	2.6E-02		20	3	21	365	70	70	25550	7.4E-03	3.7E-03

1. For off-site scenario, outdoor concentration and indoor concentration are set identical.

Table A.13 (cont.)

Acenaphthene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	2.5E-07	2.5E-07	20	1	8	250	25	70	9125	1.8E-08	3.1E-06
visitor (adult)	2.5E-07	2.5E-07	20	4	4	10	25	70	9125	6.5E-10	1.1E-07
visitor (child)	2.5E-07	2.5E-07	10	4	4	10	15	15	5475	1.5E-09	2.5E-07
mainteinance worker	2.5E-07	2.5E-07	30	8	2	20	25	70	9125	2.4E-09	4.1E-07
Off-site											
worker	2.5E-07		20	1	8	250	25	70	9125	1.6E-08	2.7E-06
visitor (adult)	2.5E-07		20	4	4	10	25	70	9125	6.5E-10	1.1E-07
visitor (child)	2.5E-07		10	4	4	10	15	15	5475	1.5E-09	2.5E-07
resident	2.5E-07		20	3	21	365	70	70	25550	7.1E-08	1.2E-05
Future											
On-site											
worker	1.5E-05	1.5E-05	20	1	8	250	25	70	9125	1.1E-06	1.8E-04
visitor (adult)	1.5E-05	1.5E-05	20	4	4	10	25	70	9125	3.9E-08	6.5E-06
visitor (child)	1.5E-05	1.5E-05	10	4	4	10	15	15	5475	9.1E-08	1.5E-05
mainteinance worker	1.5E-05	1.5E-05	30	8	2	20	25	70	9125	1.5E-07	2.4E-05
construction worker	1.5E-05	1.5E-05	30	10	0	250	1	70	365	1.8E-06	3.1E-04
resident	1.5E-05	1.5E-05	20	3	21	365	70	70	25550	4.3E-06	7.1E-04
Off-site											
worker	1.5E-05		20	1	8	250	25	70	9125	9.8E-07	1.6E-04
visitor (adult)	1.5E-05		20	4	4	10	25	70	9125	3.9E-08	6.5E-06
visitor (child)	1.5E-05		10	4	4	10	15	15	5475	9.1E-08	1.5E-05
resident	1.5E-05		20	3	21	365	70	70	25550	4.3E-06	7.1E-04

Anthracene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	1.6E-09	1.6E-09	20	1	8	250	25	70	9125	1.2E-10	3.9E-10
visitor (adult)	1.6E-09	1.6E-09	20	4	4	10	25	70	9125	4.2E-12	1.4E-11
visitor (child)	1.6E-09	1.6E-09	10	4	4	10	15	15	5475	9.7E-12	3.2E-11
mainteinance worker	1.6E-09	1.6E-09	30	8	2	20	25	70	9125	1.6E-11	5.2E-11
Off-site											0.0E+00
worker	1.6E-09		20	1	8	250	25	70	9125	1.0E-10	3.5E-10
visitor (adult)	1.6E-09		20	4	4	10	25	70	9125	4.2E-12	1.4E-11
visitor (child)	1.6E-09		10	4	4	10	15	15	5475	9.7E-12	3.2E-11
resident	1.6E-09		20	3	21	365	70	70	25550	4.6E-10	1.5E-09
Future											
On-site											
worker	1.0E-07	1.0E-07	20	1	8	250	25	70	9125	7.3E-09	2.4E-08
visitor (adult)	1.0E-07	1.0E-07	20	4	4	10	25	70	9125	2.6E-10	8.7E-10
visitor (child)	1.0E-07	1.0E-07	10	4	4	10	15	15	5475	6.1E-10	2.0E-09
mainteinance worker	1.0E-07	1.0E-07	30	8	2	20	25	70	9125	9.8E-10	3.3E-09
construction worker	1.0E-07	1.0E-07	30	10	0	250	1	70	365	1.2E-08	4.1E-08
resident	1.0E-07	1.0E-07	20	3	21	365	70	70	25550	2.9E-08	9.5E-08
Off-site											
worker	1.0E-07		20	1	8	250	25	70	9125	6.5E-09	2.2E-08
visitor (adult)	1.0E-07		20	4	4	10	25	70	9125	2.6E-10	8.7E-10
visitor (child)	1.0E-07		10	4	4	10	15	15	5475	6.1E-10	2.0E-09
resident	1.0E-07		20	3	21	365	70	70	25550	2.9E-08	9.5E-08

Bezo[a]pyrene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	3.1E-12	3.1E-12	20	1	8	250	25	70	9125	2.3E-13	7.6E-12
visitor (adult)	3.1E-12	3.1E-12	20	4	4	10	25	70	9125	8.1E-15	2.7E-13
visitor (child)	3.1E-12	3.1E-12	10	4	4	10	15	15	5475	1.9E-14	6.3E-13
mainteinance worker	3.1E-12	3.1E-12	30	8	2	20	25	70	9125	3.0E-14	1.0E-12
Off-site											
worker	3.1E-12		20	1	8	250	25	70	9125	2.0E-13	6.7E-12
visitor (adult)	3.1E-12		20	4	4	10	25	70	9125	8.1E-15	2.7E-13
visitor (child)	3.1E-12		10	4	4	10	15	15	5475	1.9E-14	6.3E-13
resident	3.1E-12		20	3	21	365	70	70	25550	8.9E-13	3.0E-11
Future											
On-site											
worker	1.9E-10	1.9E-10	20	1	8	250	25	70	9125	1.4E-11	4.6E-10
visitor (adult)	1.9E-10	1.9E-10	20	4	4	10	25	70	9125	5.0E-13	1.7E-11
visitor (child)	1.9E-10	1.9E-10	10	4	4	10	15	15	5475	1.2E-12	3.9E-11
mainteinance worker	1.9E-10	1.9E-10	30	8	2	20	25	70	9125	1.9E-12	6.2E-11
construction worker	1.9E-10	1.9E-10	30	10	0	250	1	70	365	2.3E-11	7.7E-10
resident	1.9E-10	1.9E-10	20	3	21	365	70	70	25550	5.4E-11	1.8E-09
Off-site											
worker	1.9E-10		20	1	8	250	25	70	9125	1.2E-11	4.1E-10
visitor (adult)	1.9E-10		20	4	4	10	25	70	9125	5.0E-13	1.7E-11
visitor (child)	1.9E-10		10	4	4	10	15	15	5475	1.2E-12	3.9E-11
resident	1.9E-10		20	3	21	365	70	70	25550	5.4E-11	1.8E-09

1. For off-site scenario, outdoor concentration and indoor concentration are set identical.

Table A.13 (cont.)

Fluoranthene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	6.6E-10	6.6E-10	20	1	8	250	25	70	9125	4.8E-11	1.2E-09
visitor (adult)	6.6E-10	6.6E-10	20	4	4	10	25	70	9125	1.7E-12	4.3E-11
visitor (child)	6.6E-10	6.6E-10	10	4	4	10	15	15	5475	4.0E-12	1.0E-10
mainteinance worker	6.6E-10	6.6E-10	30	8	2	20	25	70	9125	6.5E-12	1.6E-10
Off-site											
worker	6.6E-10		20	1	8	250	25	70	9125	4.3E-11	1.1E-09
visitor (adult)	6.6E-10		20	4	4	10	25	70	9125	1.7E-12	4.3E-11
visitor (child)	6.6E-10		10	4	4	10	15	15	5475	4.0E-12	1.0E-10
resident	6.6E-10		20	3	21	365	70	70	25550	1.9E-10	4.7E-09
Future											
On-site											
worker	4.0E-08	4.0E-08	20	1	8	250	25	70	9125	2.9E-09	7.3E-08
visitor (adult)	4.0E-08	4.0E-08	20	4	4	10	25	70	9125	1.0E-10	2.6E-09
visitor (child)	4.0E-08	4.0E-08	10	4	4	10	15	15	5475	2.4E-10	6.1E-09
mainteinance worker	4.0E-08	4.0E-08	30	8	2	20	25	70	9125	3.9E-10	9.8E-09
construction worker	4.0E-08	4.0E-08	30	10	0	250	1	70	365	4.9E-09	1.2E-07
resident	4.0E-08	4.0E-08	20	3	21	365	70	70	25550	1.1E-08	2.9E-07
Off-site	4.0E-08										
worker	4.0E-08		20	1	8	250	25	70	9125	2.6E-09	6.5E-08
visitor (adult)	4.0E-08		20	4	4	10	25	70	9125	1.0E-10	2.6E-09
visitor (child)	4.0E-08		10	4	4	10	15	15	5475	2.4E-10	6.1E-09
resident	4.0E-08		20	3	21	365	70	70	25550	1.1E-08	2.9E-07

Naphthalene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	8.4E-08	8.4E-08	20	1	8	250	25	70	9125	6.2E-09	2.1E-06
visitor (adult)	8.4E-08	8.4E-08	20	4	4	10	25	70	9125	2.2E-10	7.3E-08
visitor (child)	8.4E-08	8.4E-08	10	4	4	10	15	15	5475	5.1E-10	1.7E-07
mainteinance worker	8.4E-08	8.4E-08	30	8	2	20	25	70	9125	8.2E-10	2.7E-07
Off-site											
worker	8.4E-08		20	1	8	250	25	70	9125	5.5E-09	1.8E-06
visitor (adult)	8.4E-08		20	4	4	10	25	70	9125	2.2E-10	7.3E-08
visitor (child)	8.4E-08		10	4	4	10	15	15	5475	5.1E-10	1.7E-07
resident	8.4E-08		20	3	21	365	70	70	25550	2.4E-08	8.0E-06
Future											
On-site											
worker	5.0E-06	5.0E-06	20	1	8	250	25	70	9125	3.7E-07	1.2E-04
visitor (adult)	5.0E-06	5.0E-06	20	4	4	10	25	70	9125	1.3E-08	4.3E-06
visitor (child)	5.0E-06	5.0E-06	10	4	4	10	15	15	5475	3.0E-08	1.0E-05
mainteinance worker	5.0E-06	5.0E-06	30	8	2	20	25	70	9125	4.9E-08	1.6E-05
construction worker	5.0E-06	5.0E-06	30	10	0	250	1	70	365	6.1E-07	2.0E-04
resident	5.0E-06	5.0E-06	20	3	21	365	70	70	25550	1.4E-06	4.8E-04
Off-site											
worker	5.0E-06		20	1	8	250	25	70	9125	3.3E-07	1.1E-04
visitor (adult)	5.0E-06		20	4	4	10	25	70	9125	1.3E-08	4.3E-06
visitor (child)	5.0E-06		10	4	4	10	15	15	5475	3.0E-08	1.0E-05
resident	5.0E-06		20	3	21	365	70	70	25550	1.4E-06	4.8E-04

1. For off-site scenario, outdoor concentration and indoor concentration are set identical.

Pyrene	Outdoor Conc. mg/m3	Indoor Conc. mg/m3	Inhalation Rate m3/d	Time staying outdoors hr/day	Time staying indoors hr/day	Exposure Frequency d/year	Exposure Duration years	Body Weight kg	Average Time days	Dose mg/kg/d	Hazard Quotient
Current											
On-site											
worker	1.9E-09	1.9E-09	20	1	8	250	25	70	9125	1.4E-10	4.6E-09
visitor (adult)	1.9E-09	1.9E-09	20	4	4	10	25	70	9125	5.0E-12	1.7E-10
visitor (child)	1.9E-09	1.9E-09	10	4	4	10	15	15	5475	1.2E-11	3.9E-10
mainteinance worker	1.9E-09	1.9E-09	30	8	2	20	25	70	9125	1.9E-11	6.2E-10
Off-site											
worker	1.9E-09		20	1	8	250	25	70	9125	1.2E-10	4.1E-09
visitor (adult)	1.9E-09		20	4	4	10	25	70	9125	5.0E-12	1.7E-10
visitor (child)	1.9E-09		10	4	4	10	15	15	5475	1.2E-11	3.9E-10
resident	1.9E-09		20	3	21	365	70	70	25550	5.4E-10	1.8E-08
Future											
On-site											
worker	1.1E-07	1.1E-07	20	1	8	250	25	70	9125	8.1E-09	2.7E-07
visitor (adult)	1.1E-07	1.1E-07	20	4	4	10	25	70	9125	2.9E-10	9.6E-09
visitor (child)	1.1E-07	1.1E-07	10	4	4	10	15	15	5475	6.7E-10	2.2E-08
mainteinance worker	1.1E-07	1.1E-07	30	8	2	20	25	70	9125	1.1E-09	3.6E-08
construction worker	1.1E-07	1.1E-07	30	10	0	250	1	70	365	1.3E-08	4.5E-07
resident	1.1E-07	1.1E-07	20	3	21	365	70	70	25550	3.1E-08	1.0E-06
Off-site											
worker	1.1E-07		20	1	8	250	25	70	9125	7.2E-09	2.4E-07
visitor (adult)	1.1E-07		20	4	4	10	25	70	9125	2.9E-10	9.6E-09
visitor (child)	1.1E-07		10	4	4	10	15	15	5475	6.7E-10	2.2E-08
resident	1.1E-07		20	3	21	365	70	70	25550	3.1E-08	1.0E-06

1. For off-site scenario, outdoor concentration and indoor concentration are set identical.

Table A.14 Cancer risks caused via soil ingestion

BENZENE

Sfo = 2.90E-02 [kg.d/mg]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario								
On-site worker	0.005	100	0.04	250	25	70	25550	2.027E-12
On-site visitor (child)	0.005	200	0.08	20	6	15	25550	7.264E-13
On-site maintenance worker	0.005	100	0.04	50	25	70	25550	4.054E-13
Future Scenario (removal of concrete cover)								
Construction worker	0.005	100	0.12	5	1	70	25550	4.864E-15
On-site worker	0.005	100	0.04	250	25	70	25550	2.027E-12
On-site visitor (child)	0.005	200	0.08	20	30	15	25550	3.632E-12
On-site maintenance worker	0.005	100	0.04	50	25	70	25550	4.054E-13
On-site resident	0.005	100	0.02	350	30	70	25550	1.703E-12

VINYL CHLORINE

Sfo = 1.90E+00 [kg.d/mg]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario								
On-site worker	0.02	100	0.04	250	25	70	25550	5.312E-10
On-site visitor (child)	0.02	200	0.08	20	6	15	25550	1.904E-10
On-site maintenance worker	0.02	100	0.04	50	25	70	25550	1.062E-10
Future Scenario (removal of concrete cover)								
Construction worker	0.02	100	0.12	5	1	70	25550	1.275E-12
On-site worker	0.02	100	0.04	250	25	70	25550	5.312E-10
On-site visitor (child)	0.02	200	0.08	20	30	15	25550	9.519E-10
On-site maintenance worker	0.02	100	0.04	50	25	70	25550	1.062E-10
On-site resident	0.02	100	0.02	350	30	70	25550	4.462E-10

Table A.15 Noncancer risks caused via soil ingestion

BENZENE

RfDo = 1.70E-03 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	0.005	100	0.04	250	25	70	9125	1.151E-07
On-site visitor (child)	0.005	200	0.08	20	6	15	2190	1.719E-07
On-site maintenance worker	0.005	100	0.04	50	25	70	9125	2.302E-08
Future Scenario (removal of concrete cover)								
Construction worker	0.005	100	0.12	5	1	70	9125	2.763E-10
On-site worker	0.005	100	0.04	250	25	70	9125	1.151E-07
On-site visitor (child)	0.005	200	0.08	20	30	15	2190	8.595E-07
On-site maintenance worker	0.005	100	0.04	50	25	70	9125	2.302E-08
On-site resident	0.005	100	0.02	350	30	70	9125	9.67E-08

TOLUENE

RfDo = 0.2 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	0.2	100	0.04	250	25	70	9125	3.914E-08
On-site visitor (child)	0.2	200	0.08	20	6	15	2190	5.845E-08
On-site maintenance worker	0.2	100	0.04	50	25	70	9125	7.828E-09
Future Scenario (removal of concrete cover)								
Construction worker	0.2	100	0.12	5	1	70	9125	9.393E-11
On-site worker	0.2	100	0.04	250	25	70	9125	3.914E-08
On-site visitor (child)	0.2	200	0.08	20	30	15	2190	2.922E-07
On-site maintenance worker	0.2	100	0.04	50	25	70	9125	7.828E-09
On-site resident	0.2	100	0.02	350	30	70	9125	3.288E-08

ETHYLBENZENE

RfDo = 0.1 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	5.8	100	0.04	250	25	70	9125	2.27E-06
On-site visitor (child)	5.8	200	0.08	20	6	15	2190	3.39E-06
On-site maintenance worker	5.8	100	0.04	50	25	70	9125	4.54E-07
Future Scenario (removal of concrete cover)								
Construction worker	5.8	100	0.12	5	1	70	9125	5.448E-09
On-site worker	5.8	100	0.04	250	25	70	9125	2.27E-06
On-site visitor (child)	5.8	200	0.08	20	30	15	2190	1.695E-05
On-site maintenance worker	5.8	100	0.04	50	25	70	9125	4.54E-07
On-site resident	5.8	100	0.02	350	30	70	9125	1.907E-06

XYLENES

RfDo = 2 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	8.4	100	0.04	250	25	70	9125	1.644E-07
On-site visitor (child)	8.4	200	0.08	20	6	15	2190	2.455E-07
On-site maintenance worker	8.4	100	0.04	50	25	70	9125	3.288E-08
Future Scenario (removal of concrete cover)								
Construction worker	8.4	100	0.12	5	1	70	9125	3.945E-10
On-site worker	8.4	100	0.04	250	25	70	9125	1.644E-07
On-site visitor (child)	8.4	200	0.08	20	30	15	2190	1.227E-06
On-site maintenance worker	8.4	100	0.04	50	25	70	9125	3.288E-08
On-site resident	8.4	100	0.02	350	30	70	9125	1.381E-07

Table A.15 (cont.)

COPPER

RfDo = 3.70E-02 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	2877	100	0.04	250	25	70	9125	3.04E-03
On-site visitor (child)	2877	200	0.08	20	6	15	2190	4.54E-03
On-site maintenance worker	2877	100	0.04	50	25	70	9125	6.09E-04
Future Scenario (removal of concrete cover)								
Construction worker	4200	100	0.12	5	1	70	9125	1.07E-05
On-site worker	842	100	0.04	250	25	70	9125	8.91E-04
On-site visitor (child)	842	200	0.08	20	30	15	2190	6.65E-03
On-site maintenance worker	842	100	0.04	50	25	70	9125	1.78E-04
On-site resident	842	100	0.02	350	30	70	9125	7.48E-04

ZINC

RfDo = 3.00E-01 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	137	100	0.04	250	25	70	9125	1.79E-05
On-site visitor (child)	137	200	0.08	20	6	15	2190	2.67E-05
On-site maintenance worker	137	100	0.04	50	25	70	9125	3.57E-06
Future Scenario (removal of concrete cover)								
Construction worker	2700	100	0.12	5	1	70	9125	8.45E-07
On-site worker	328	100	0.04	250	25	70	9125	4.28E-05
On-site visitor (child)	328	200	0.08	20	30	15	2190	3.20E-04
On-site maintenance worker	328	100	0.04	50	25	70	9125	8.56E-06
On-site resident	328	100	0.02	350	30	70	9125	3.59E-05

Lead

RfDo = 1.00E-07 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	37	100	0.04	250	25	70	9125	1.45E+01
On-site visitor (child)	37	200	0.08	20	6	15	2190	2.16E+01
On-site maintenance worker	37	100	0.04	50	25	70	9125	2.90E+00
Future Scenario (removal of concrete cover)								
Construction worker	5700	100	0.12	5	1	70	9125	5.35E+00
On-site worker	478	100	0.04	250	25	70	9125	1.87E+02
On-site visitor (child)	478	200	0.08	20	30	15	2190	1.40E+03
On-site maintenance worker	478	100	0.04	50	25	70	9125	3.74E+01
On-site resident	478	100	0.02	350	30	70	9125	1.57E+02

ANTIMONY

RfDo = 4.00E-04 [mg/kg.d]	CS [mg/kg soil]	IR [mg soil/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site worker	0	100	0.04	250	25	70	9125	0.00E+00
On-site visitor (child)	0	200	0.08	20	6	15	2190	0.00E+00
On-site maintenance worker	0	100	0.04	50	25	70	9125	0.00E+00
Future Scenario (removal of concrete cover)								
Construction worker	170	100	0.12	5	1	70	9125	3.99E-05
On-site worker	15	100	0.04	250	25	70	9125	1.47E-03
On-site visitor (child)	15	200	0.08	20	30	15	2190	1.10E-02
On-site maintenance worker	15	100	0.04	50	25	70	9125	2.94E-04
On-site resident	15	100	0.02	350	30	70	9125	1.23E-03

Table A.16 Cancer risks caused via groundwater ingestion

BENZENE

Sfo = 1.70E-03 [kg.d/mg]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario								
On-site maintenance worker	0.0052	0.05	0.04	2	25	70	25550	4.943E-13
Future Scenario (groundwater used for supply)								
Construction worker	0.0052	2	0.75	5	1	70	25550	3.707E-11
On-site worker	0.0052	2	0.75	250	25	70	25550	4.634E-08
On-site visitor (child)	0.0052	2	0.25	20	30	70	25550	1.483E-09
On-site maintenance worker	0.0052	2	0.75	50	25	70	25550	9.268E-09
On-site resident	0.0052	2	1	350	30	70	25550	1.038E-07

VINYL CHLORIDE

Sfo = 1.9 [kg.d/mg]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario								
On-site maintenance worker	0.0025	0.05	0.04	2	25	70	25550	2.656E-10
Future Scenario (groundwater used for supply)								
Construction worker	0.0025	2	0.75	5	1	70	25550	1.992E-08
On-site worker	0.0025	2	0.75	250	25	70	25550	2.49E-05
On-site visitor (child)	0.0025	2	0.25	20	30	70	25550	7.968E-07
On-site maintenance worker	0.0025	2	0.75	50	25	70	25550	4.98E-06
On-site resident	0.0025	2	1	350	30	70	25550	5.577E-05

Table A.17 Noncancer risks caused via groundwater ingestion

BENZENE

RfDo = 1.70E-03 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.0052	0.05	0.04	2	25	70	9125	4.789E-13
Future Scenario (groundwater used for supply)								
Construction worker	0.0052	2	0.75	5	1	70	9125	3.592E-11
On-site worker	0.0052	2	0.75	250	25	70	9125	4.489E-08
On-site visitor (child)	0.0052	2	0.25	20	30	70	9125	1.437E-09
On-site maintenance worker	0.0052	2	0.75	50	25	70	9125	8.979E-09
On-site resident	0.0052	2	1	350	30	70	9125	1.006E-07

TOLUENE

RfDo = 2.00E-01 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.0068	0.05	0.04	2	25	70	9125	5.32E-09
Future Scenario (groundwater used for supply)								
Construction worker	0.0068	2	0.75	5	1	70	9125	3.99E-07
On-site worker	0.0068	2	0.75	250	25	70	9125	4.99E-04
On-site visitor (child)	0.0068	2	0.25	20	30	70	9125	1.60E-05
On-site maintenance worker	0.0068	2	0.75	50	25	70	9125	9.98E-05
On-site resident	0.0068	2	1	350	30	70	9125	1.12E-03

ETHYLBENZENE

RfDo = 1.00E-01 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.021	0.05	0.04	2	25	70	9125	3.29E-08
Future Scenario (groundwater used for supply)								
Construction worker	0.021	2	0.75	5	1	70	9125	2.47E-06
On-site worker	0.021	2	0.75	250	25	70	9125	3.08E-03
On-site visitor (child)	0.021	2	0.25	20	30	70	9125	9.86E-05
On-site maintenance worker	0.021	2	0.75	50	25	70	9125	6.16E-04
On-site resident	0.021	2	1	350	30	70	9125	6.90E-03

XYLENES

RfDo = 2.00E+00 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.014	0.05	0.04	2	25	70	9125	1.10E-09
Future Scenario (groundwater used for supply)								
Construction worker	0.014	2	0.75	5	1	70	9125	8.22E-08
On-site worker	0.014	2	0.75	250	25	70	9125	1.03E-04
On-site visitor (child)	0.014	2	0.25	20	30	70	9125	3.29E-06
On-site maintenance worker	0.014	2	0.75	50	25	70	9125	2.05E-05
On-site resident	0.014	2	1	350	30	70	9125	2.30E-04

Table A.17 (cont.)

COPPER

RfDo = 3.70E-02 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.03	0.05	0.04	2	25	70	9125	1.27E-07
Future Scenario (groundwater used for supply)								
Construction worker	0.03	2	0.75	5	1	70	9125	9.52E-06
On-site worker	0.03	2	0.75	250	25	70	9125	1.19E-02
On-site visitor (child)	0.03	2	0.25	20	30	70	9125	3.81E-04
On-site maintenance worker	0.03	2	0.75	50	25	70	9125	2.38E-03
On-site resident	0.03	2	1	350	30	70	9125	2.67E-02

ZINC

RfDo = 3.00E-01 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.06	0.05	0.04	2	25	70	9125	3.13E-08
Future Scenario (groundwater used for supply)								
Construction worker	0.06	2	0.75	5	1	70	9125	2.35E-06
On-site worker	0.06	2	0.75	250	25	70	9125	2.94E-03
On-site visitor (child)	0.06	2	0.25	20	30	70	9125	9.39E-05
On-site maintenance worker	0.06	2	0.75	50	25	70	9125	5.87E-04
On-site resident	0.06	2	1	350	30	70	9125	6.58E-03

CHROMIUM

RfDo = 5.00E-03 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.03	0.05	0.04	2	25	70	9125	9.39E-07
Future Scenario (groundwater used for supply)								
Construction worker	0.03	2	0.75	5	1	70	9125	7.05E-05
On-site worker	0.03	2	0.75	250	25	70	9125	8.81E-02
On-site visitor (child)	0.03	2	0.25	20	30	70	9125	2.82E-03
On-site maintenance worker	0.03	2	0.75	50	25	70	9125	1.76E-02
On-site resident	0.03	2	1	350	30	70	9125	1.97E-01

ARSENIC

RfDo = 3.00E-04 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.01	0.05	0.04	2	25	70	9125	5.22E-06
Future Scenario (groundwater used for supply)								
Construction worker	0.01	2	0.75	5	1	70	9125	3.91E-04
On-site worker	0.01	2	0.75	250	25	70	9125	4.89E-01
On-site visitor (child)	0.01	2	0.25	20	30	70	9125	1.57E-02
On-site maintenance worker	0.01	2	0.75	50	25	70	9125	9.78E-02
On-site resident	0.01	2	1	350	30	70	9125	1.10E+00

NICKEL

RfDo = 2.00E-02 [mg/kg.d]	CW [mg/L]	IR [L/d]	FI	EF [d/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario								
On-site maintenance worker	0.02	0.05	0.04	2	25	70	9125	1.57E-07
Future Scenario (groundwater used for supply)								
Construction worker	0.02	2	0.75	5	1	70	9125	1.17E-05
On-site worker	0.02	2	0.75	250	25	70	9125	1.47E-02
On-site visitor (child)	0.02	2	0.25	20	30	70	9125	4.70E-04
On-site maintenance worker	0.02	2	0.75	50	25	70	9125	2.94E-03
On-site resident	0.02	2	1	350	30	70	9125	3.29E-02

Table A.18 Cancer risks caused by soil dermal contact

BENZENE

RfDo = 2.90E-02 [mg/kg.d]	CS [mg/kg soil]	SA [m^2/event]	AF [mg/cm^2]	ABS -	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario									
On-site worker	0.005	0.312	2.77	0.1	20	25	70	25550	4.166E-08
On-site visitor (child)	0.005	0.312	2.77	0.1	2	30	15	25550	2.333E-08
On-site maintenance worker	0.005	0.312	2.77	0.1	50	25	70	25550	1.041E-07
Future Scenario (removal of concrete cover)									
Construction worker	0.005	0.312	2.77	0.1	10	1	70	25550	8.331E-10
On-site worker	0.005	0.312	2.77	0.1	40	25	70	25550	8.331E-08
On-site visitor (child)	0.005	0.312	2.77	0.1	2	30	15	25550	2.333E-08
On-site maintenance worker	0.005	0.312	2.77	0.1	100	25	70	25550	2.083E-07
On-site resident	0.005	0.312	2.77	0.1	100	30	70	25550	2.499E-07

VINYL CHLORINE

RfDo = 1.90E+00 [mg/kg.d]	CS [mg/kg soil]	SA [m^2/event]	AF [mg/cm^2]	ABS -	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario									
On-site worker	0.02	0.312	2.77	0.1	20	25	70	25550	1.666E-07
On-site visitor (child)	0.02	0.312	2.77	0.1	2	30	15	25550	9.331E-08
On-site maintenance worker	0.02	0.312	2.77	0.1	50	25	70	25550	4.166E-07
Future Scenario (removal of concrete cover)									
Construction worker	0.02	0.312	2.77	0.1	10	1	70	25550	3.333E-09
On-site worker	0.02	0.312	2.77	0.1	40	25	70	25550	3.333E-07
On-site visitor (child)	0.02	0.312	2.77	0.1	2	30	15	25550	9.331E-08
On-site maintenance worker	0.02	0.312	2.77	0.1	100	25	70	25550	8.331E-07
On-site resident	0.02	0.312	2.77	0.1	100	30	70	25550	9.998E-07

Table A.19 Noncancer risks caused by soil dermal contact

BENZENE

RfDo = 1.70E-03 [mg/kg.d]	CS [mg/kg soil]	SA [m^2/event]	AF [mg/cm^2]	ABS -	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario									
On-site worker	0.005	0.312	2.77	0.1	20	25	70	9125	1.99E-06
On-site visitor (child)	0.005	0.312	2.77	0.1	2	30	15	2190	4.643E-06
On-site maintenance worker	0.005	0.312	2.77	0.1	50	25	70	9125	4.974E-06
Future Scenario (removal of concrete cover)									
Construction worker	0.005	0.312	2.77	0.1	10	1	70	9125	3.979E-08
On-site worker	0.005	0.312	2.77	0.1	40	25	70	9125	3.979E-06
On-site visitor (child)	0.005	0.312	2.77	0.1	2	30	15	2190	4.643E-06
On-site maintenance worker	0.005	0.312	2.77	0.1	100	25	70	9125	9.949E-06
On-site resident	0.005	0.312	2.77	0.1	100	30	70	9125	1.194E-05

TOLUENE

RfDo = 0.2 [mg/kg.d]	CS [mg/kg soil]	SA [m^2/event]	AF [mg/cm^2]	ABS -	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario									
On-site worker	0.2	0.312	2.77	0.1	20	25	70	9125	6.765E-07
On-site visitor (child)	0.2	0.312	2.77	0.1	2	30	15	2190	1.579E-06
On-site maintenance worker	0.2	0.312	2.77	0.1	50	25	70	9125	1.691E-06
Future Scenario (removal of concrete cover)									
Construction worker	0.2	0.312	2.77	0.1	10	1	70	9125	1.353E-08
On-site worker	0.2	0.312	2.77	0.1	40	25	70	9125	1.353E-06
On-site visitor (child)	0.2	0.312	2.77	0.1	2	30	15	2190	1.579E-06
On-site maintenance worker	0.2	0.312	2.77	0.1	100	25	70	9125	3.383E-06
On-site resident	0.2	0.312	2.77	0.1	100	30	70	9125	4.059E-06

ETHYLBENZENE

RfDo = 0.1 [mg/kg.d]	CS [mg/kg soil]	SA [m^2/event]	AF [mg/cm^2]	ABS -	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario									
On-site worker	5.8	0.312	2.77	0.1	20	25	70	9125	3.924E-05
On-site visitor (child)	5.8	0.312	2.77	0.1	2	30	15	2190	9.155E-05
On-site maintenance worker	5.8	0.312	2.77	0.1	50	25	70	9125	9.809E-05
Future Scenario (removal of concrete cover)									
Construction worker	5.8	0.312	2.77	0.1	10	1	70	9125	7.848E-07
On-site worker	5.8	0.312	2.77	0.1	40	25	70	9125	7.848E-05
On-site visitor (child)	5.8	0.312	2.77	0.1	2	30	15	2190	9.155E-05
On-site maintenance worker	5.8	0.312	2.77	0.1	100	25	70	9125	0.0001962
On-site resident	5.8	0.312	2.77	0.1	100	30	70	9125	0.0002354

XYLENES

RfDo = 2 [mg/kg.d]	CS [mg/kg soil]	SA [m^2/event]	AF [mg/cm^2]	ABS -	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	HAZARD QUOTIENT
Current Scenario									
On-site worker	8.4	0.312	2.77	0.1	20	25	70	9125	2.841E-06
On-site visitor (child)	8.4	0.312	2.77	0.1	2	30	15	2190	6.63E-06
On-site maintenance worker	8.4	0.312	2.77	0.1	50	25	70	9125	7.103E-06
Future Scenario (removal of concrete cover)									
Construction worker	8.4	0.312	2.77	0.1	10	1	70	9125	5.683E-08
On-site worker	8.4	0.312	2.77	0.1	40	25	70	9125	5.683E-06
On-site visitor (child)	8.4	0.312	2.77	0.1	2	30	15	2190	6.63E-06
On-site maintenance worker	8.4	0.312	2.77	0.1	100	25	70	9125	1.421E-05
On-site resident	8.4	0.312	2.77	0.1	100	30	70	9125	1.705E-05

Table A.20 Cancer risks caused by groundwater dermal contact

BENZENE

Sfo = 2.90E-02 [kg.d/mg]	CW [mg/L]	SA [m2/event]	PERM [cm/h]	TI [hr/event]	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario									
On-site maintenance worker	0.0052	0.312	0.04	8	5	25	70	9125	2.95E-08
Future Scenario (groundwater used for supply)									
Construction worker	0.0052	0.312	0.04	8	10	1	70	365	5.89E-08
On-site worker	0.0052	0.312	0.04	8	5	25	70	9125	2.95E-08
On-site visitor (child)	0.0052	1.5	0.04	6	2	30	15	10950	1.98E-07
On-site maintenance worker	0.0052	0.312	0.04	8	3	25	70	9125	1.77E-08
On-site resident	0.0052	0.312	0.04	10	20	30	70	10950	1.47E-07

VINYL CHLORIDE

Sfo = 1.90E+00 [kg.d/mg]	CW [mg/L]	SA [m2/event]	PERM [cm/h]	TI [hr/event]	EF [event/yr]	ED [yrs]	BW [kg]	AT [d]	CANCER RISK
Current Scenario									
On-site maintenance worker	0.0025	0.312	0.04	8	5	25	70	9125	9.28E-07
Future Scenario (groundwater used for supply)									
Construction worker	0.0025	0.312	0.04	8	10	1	70	365	1.86E-06
On-site worker	0.0025	0.312	0.04	8	5	25	70	9125	9.28E-07
On-site visitor (child)	0.0025	1.5	0.04	6	2	30	15	10950	6.25E-06
On-site maintenance worker	0.0025	0.312	0.04	8	3	25	70	9125	5.57E-07
On-site resident	0.0025	0.312	0.04	10	20	30	70	10950	4.64E-06

Table A.21 Noncancer risks caused by groundwater dermal contact

BENZENE

RfDo = 1.70E-03 [mg/kg.d]	CW	SA	PERM	TI	EF	ED	BW	AT	HAZARD
	[mg/L]	[m2/event]	[cm/h]	[hr/event]	[event/yr]	[yrs]	[kg]	[d]	QUOTIENT
Current Scenario									
On-site maintenance worker	0.0052	0.312	0.04	8	5	25	70	9125	5.98E-04
Future Scenario (groundwater used for supply)									
Construction worker	0.0052	0.312	0.04	8	10	1	70	365	1.20E-03
On-site worker	0.0052	0.312	0.04	8	5	25	70	9125	5.98E-04
On-site visitor (child)	0.0052	1.5	0.04	10	2	30	15	10950	6.70E-03
On-site maintenance worker	0.0052	0.312	0.04	8	3	25	70	9125	3.59E-04
On-site resident (child)	0.0052	1.5	0.04	10	20	30	15	10950	6.70E-02

TOLUENE

RfDo = 2.00E-01 [mg/kg.d]	CW	SA	PERM	TI	EF	ED	BW	AT	HAZARD
	[mg/L]	[m2/event]	[cm/h]	[hr/event]	[event/yr]	[yrs]	[kg]	[d]	QUOTIENT
Current Scenario									
On-site maintenance worker	0.021	0.312	0.04	8	5	25	70	9125	2.05E-05
Future Scenario (groundwater used for supply)									
Construction worker	0.021	0.312	0.04	8	10	1	70	365	4.10E-05
On-site worker	0.021	0.312	0.04	8	5	25	70	9125	2.05E-05
On-site visitor (child)	0.021	1.5	0.04	10	2	30	15	10950	2.30E-04
On-site maintenance worker	0.021	0.312	0.04	8	3	25	70	9125	1.23E-05
On-site resident (child)	0.021	1.5	0.04	10	20	30	15	10950	2.30E-03

ETHYLBENZENE

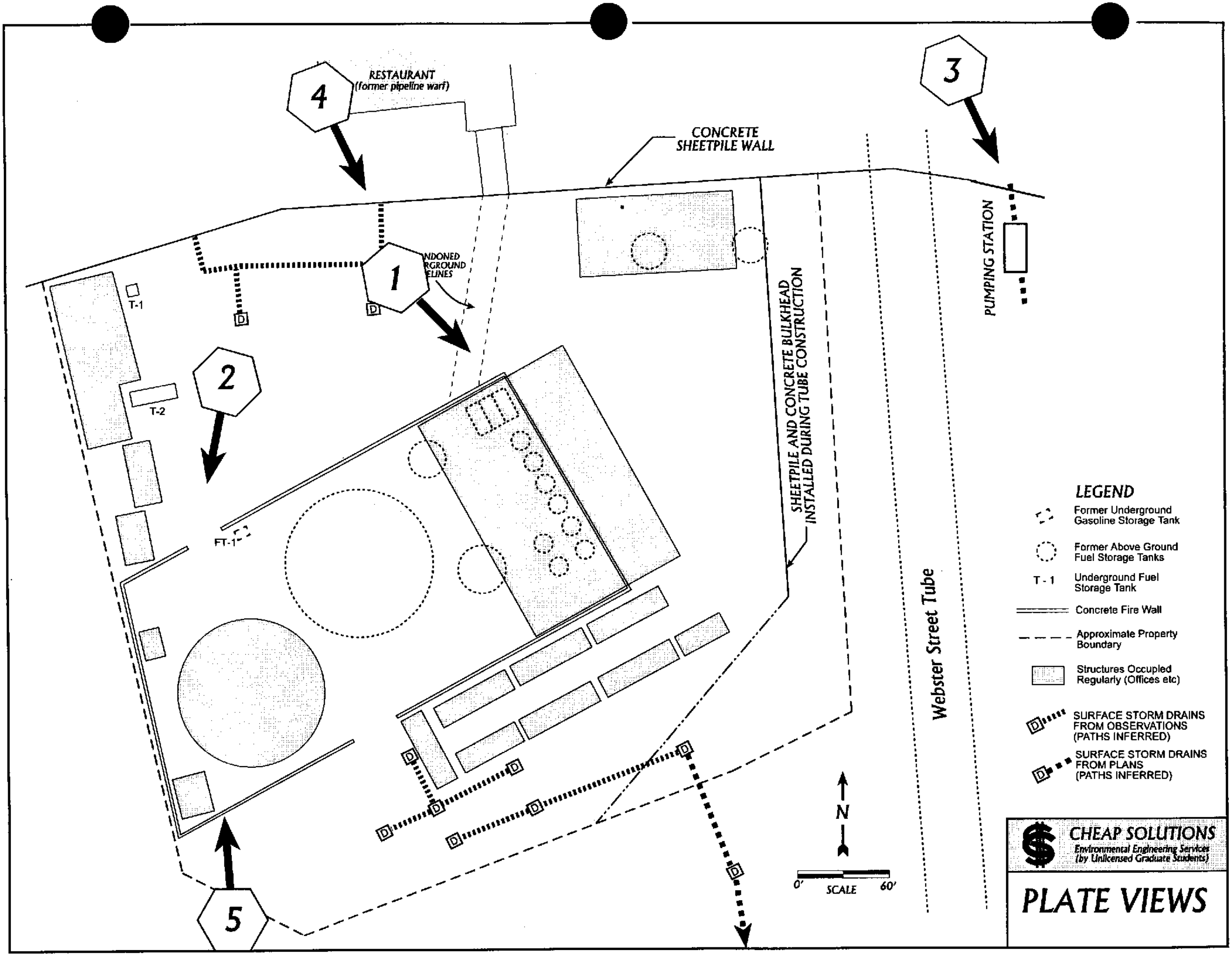
RfDo = 1.00E-01 [mg/kg.d]	CW	SA	PERM	TI	EF	ED	BW	AT	HAZARD
	[mg/L]	[m2/event]	[cm/h]	[hr/event]	[event/yr]	[yrs]	[kg]	[d]	QUOTIENT
Current Scenario									
On-site maintenance worker	0.0068	0.312	0.04	8	5	25	70	9125	1.33E-05
Future Scenario (groundwater used for supply)									
Construction worker	0.0068	0.312	0.04	8	10	1	70	365	2.66E-05
On-site worker	0.0068	0.312	0.04	8	5	25	70	9125	1.33E-05
On-site visitor (child)	0.0068	1.5	0.04	10	2	30	15	10950	1.49E-04
On-site maintenance worker	0.0068	0.312	0.04	8	3	25	70	9125	7.97E-06
On-site resident (child)	0.0068	1.5	0.04	10	20	30	15	10950	1.49E-03

XYLENES

RfDo = 2.00E+00 [mg/kg.d]	CW	SA	PERM	TI	EF	ED	BW	AT	HAZARD
	[mg/L]	[m2/event]	[cm/h]	[hr/event]	[event/yr]	[yrs]	[kg]	[d]	QUOTIENT
Current Scenario									
On-site maintenance worker	0.014	0.312	0.04	8	5	25	70	9125	1.37E-06
Future Scenario (groundwater used for supply)									
Construction worker	0.014	0.312	0.04	8	10	1	70	365	2.74E-06
On-site worker	0.014	0.312	0.04	8	5	25	70	9125	1.37E-06
On-site visitor (child)	0.014	1.5	0.04	10	2	30	15	10950	1.53E-05
On-site maintenance worker	0.014	0.312	0.04	8	3	25	70	9125	8.21E-07
On-site resident (child)	0.014	1.5	0.04	10	20	30	15	10950	1.53E-04

APPENDIX B

PLATES



CHEAP SOLUTIONS
Environmental Engineering Services (by Unlicensed Graduate Students)

PLATE VIEWS

PLATE - 1

PLATE - 2

PLATE - 3

PLATE - 4

PLATE - 5

APPENDIX C

REGULATORY OVERVIEW ADDENDUMS

APPENDIX C TABLE OF ACTION SPECIFIC ARARs

WASTE MANAGEMENT	
CITATION	REQUIREMENTS
RCRA 40 CFR 262, 264	RCRA contains requirements fo rthe transportation, storage, and disposal of hazardous wastes.
58 FR 8658	This Fedral Register promulgates standards to accommodate treatment of hazardous wastes.
Hazardous Waste Control Act 22 CCR, Division 4.5	Regulates hazardous waste from the point of generation to it's ultimate disposal
23 State Water Resources Control Board [CCR Division 3, Chapter 15]	Waste management requirments, including groundwater monitoring at landfills and waste piles.

SURFACE WATER DISCHARGES	
CITATION	REQUIREMENTS
40 CFR 122.44(a), 122.44(e), 122.41(l)	National Pollutant Discharge Elimination System (NPDES) stipulates requirements for permits, BAT and effluent limitations
San Francisco Bay Basin Water Quality Control Plan	As all ready mentioned
California State Board Resolution No. 68-16	California non-degradation policy regarding discharges to high qualtiy waters.
California State Board Resolution No. 92-49	Policies and procedures for oversight of RI and cleanup of waste that effect or threaten water quality. Includes actions for Non Attainment Areas when cleanup goals can not be met.

GROUNDWATER DISCHARGES	
CITATION	REQUIREMENTS
Safe Drinking Water Act 40 CFR 144 through 147	Underground injection control standards for subsurface injections. Designed to protect drinking water supplies
San Francisco Bay Basin Water Quality Control Plan	As all ready mentioned
California State Board Resolution No. 68-16	California non-degradation policy regarding discharges to high qualtiy waters.
California State Board Resolution No. 92-49	Policies and procedures for oversight of RI and cleanup of waste that effect or threaten water quality. Includes actions for Non Attainment Areas when cleanup goals can not be met.

APPENDIX C TABLE OF ACTION SPECIFIC ARARs (con't)

AIR EMMISSIONS	
CITATION	REQUIREMENTS
40 CFR 52	Requires filing of an air pollution emmision notice (ASPEN) with the state that includes estimation of emission rates for each pollutant expected
40 CFR 60 California Statute 1568	Standards of performance for differnet types of sources
San Francisco Bay Area Air Quality Management District Rules and Regulations	Pertain to stationary sources of air emissions. Addresses visible emissions prohibition, incinerator standards, nuisance and ambient air emission standards.
40 CFR 61	Emission verifications of: mercury, vinyl chloride and benzene

TREATMENT SPECIFIC	
CITATION	REQUIREMENTS
RCRA 40 CFR 264, Subpart M; 22 CCR, Chapter 30, Article 28	LAND TREATMENT
RCRA 40 CFR 264, Subpart O; 22 CCR, Chapter 30, Art 15.5 & 30	INCINERATION of hazardous waste
RCRA 40 CFR 264, Subpart I,J; 22 CCR, Chapter 30, Articles 24.25	Storage or Treatment within Tanks
RCRA 40 CFR 265, Subpart P; 22 CCR, Chapter 30, Art 31	THERMAL TREATMENT of hazardous waste
RCRA 40 CFR 265, Subpart Q; 22 CCR, Chapter 30, Article 32	CHEMICAL, PHYSICAL or BIOLOGICAL TREATMENT of hazardous waste
RCRA 40 CFR 280; 23 CCR DIV3, CH 16; 20 HSC 25280-25299; Alameda County Fire Code, Section 79.114(e)	UNDERGROUND STORAGE TANKS

LANDFILLS	
CITATION	REQUIREMENTS
40 CFR 246	Guidelines for source separation for material recovery for federal agencies
RCRA 40 CFR 257	Classification of solid waste disposal facilities and practices for use in determining when they pose a reasonable probability of adverse affect to human health or the environment
RCRA 40 CFR 264, Subpart N; 40 CFR 268; Hazardous Waste Control Act 22 CCR 66900-66935; 22 CCR 67700-67780	Standards for landfills and land disposal restrictions on hazardous wastes that are restricted from land disposal. Circumstances where treated wastes may be disposed of on land.

implemented long-term remediation projects. At the remaining sites, the Regional Board is requiring completion of Remedial Investigation/Feasibility Studies and proposed Remedial Action Plans (RAPs). After public review and comments on these studies and plans, the Regional Board will adopt the RAPs in individual Site Clean-up Orders. When U.S. EPA approves of the Regional Board's actions, it will administratively adopt a Record of Decision.

ABOVEGROUND PETROLEUM STORAGE ACT

The state's Aboveground Petroleum Storage Act was enacted in 1989 and amended in 1991. The act became effective on January 1, 1990.

The purpose of this act is to protect the public and the environment from the serious threat of spillage of millions of gallons of petroleum-derived chemicals stored in thousands of aboveground storage tanks. The act requires that the Regional Board inspect aboveground petroleum storage tanks used for crude oil and its fractions for their compliance with the federally required Spill Prevention, Control, and Countermeasure Plan. In the event that a release occurs that threatens surface or groundwater, the act allows the state to recover reasonable costs incurred in the oversight and regulation of the cleanup.

"Storage Statements" are required from the facilities describing the location, nature, and size of their tanks. Filing fees are required, which are intended to fund inspections, training, and research. There are approximately 225 facilities within the region that have filed their storage statements.

REQUIREMENTS FOR SITE INVESTIGATION AND REMEDIATION

The State Board adopted Resolution No. 92-49, "Policies and Procedures for Investigation, Cleanup and Abatement of Discharges Under Water Code Section 13304." This resolution contains the policies and procedures that all Regional Boards shall follow to oversee and regulate investigations and cleanup and abatement activities resulting from all types of discharge or threat of discharge subject to Section 13304 of the Water Code. Therefore, the five program areas listed above (i.e., UST, SLIC, DoD/DoE, Superfund, and Aboveground Storage) now follow the same policies and procedures outlined in Resolution No. 92-49 for determining:

- When an investigation is required;
- The scope of phased investigations necessary to define the nature and extent of contamination or pollution;
- Cost-effective procedures to detect, clean up or abate contamination; and
- Reasonable schedules for investigation, cleanup, abatement, or any other remedial action at a site.

State Water Board Resolution No. 92-49 outlines the five basic elements of a site investigation. Any or all elements of an investigation may proceed concurrently, rather than sequentially, in order to expedite cleanup and abatement of a discharge, provided that the overall clean-up goals and abatement are not compromised. State Water Board Resolution No. 92-49 investigation components are as follows:

a. Preliminary site assessment to confirm the discharge and the identity of the dischargers; to identify affected or threatened waters of the state and their beneficial uses; and to develop preliminary information on the nature and vertical and horizontal extent of the discharge;

b. Soil and water investigation to determine the source, nature, and extent of the discharge with sufficient detail to provide the basis for decisions regarding subsequent clean-up and abatement actions, if any are determined by the Regional Board to be necessary;

c. Proposal and selection of clean-up action to evaluate feasible and effective clean-up and abatement actions and to develop preferred clean-up and abatement alternatives;

d. Implementation of clean-up and abatement action to implement the selected alternative and to monitor in order to verify progress; and

e. Monitoring to confirm short- and long-term effectiveness of cleanup and abatement.

State Board Resolution No. 92-49 requires that the Regional Board ensure that the discharger is aware of and considers minimum clean-up and abatement methods. The minimum methods that the discharger should be aware of and consider, to the extent that they may be applicable to the discharge or threat thereof, are:

1. Source removal and/or isolation;

2. In-place treatment of soil or water, including bioremediation, aeration, and fixation;

3. Excavation or extraction of soil, water, or gas for on-site or off-site treatment techniques, including bioremediation; thermal destruction; aeration; sorption; precipitation, flocculation and sedimentation; filtration; fixation; and evaporation; and

4. Excavation or extraction of soil, water, or gas for appropriate recycling, reuse, or disposal.

PROGRESS OF THE REGIONAL BOARD'S PROGRAM

The Regional Water Board has over 12 years of experience in the cleanup of polluted sites. The following findings are drawn from this regulatory experience.

INVESTIGATION

þ A complete on- and off-site investigation of soil and groundwater to determine full horizontal and vertical extent of pollution is necessary to ensure that adequate clean-up plans are proposed.

REMEDIATION

þ Immediate removal of the source, to the extent practicable, is required to prevent further spread of pollution as well as its being among the most cost-effective remediation actions.

þ Pump-and-treat groundwater remediation, in some instances, is effective in hydraulically containing pollution and removing pollutants.

þ Vacuum extraction of pollutants in the vadose zone can be a cost-effective method to remove pollution sources.

þ Bioremediation of petroleum pollution can be a cost-effective soil and groundwater treatment alternative.

LIMITS OF EXISTING TECHNOLOGY

þ Available options for removing or treating in-situ polluted groundwater are limited.

þ Recent research, much of which is being confirmed at sites within the region, demonstrates that using pump-and-treat technology removes and controls pollutant mass migration. However, pump-and-treat technology is not adequate technology, in some situations, to meet low concentration groundwater objectives because the costs and time-frames may be prohibitive.

þ Groundwater pollution cleanup is lengthy and requires significant resources of both the discharger and the regulator.

SETTING CLEAN-UP LEVELS

The Regional Board approves soil and groundwater clean-up levels for polluted sites. State Board Resolution No. 92-49 requires conformance with the provisions of State Board Resolution No. 68-16 and applicable provisions of CCR Title 23, Chapter 15.

State Board Resolution No. 92-49 directs the Regional Board to ensure that dischargers are required to clean up and abate the effect of discharges. This cleanup and abatement shall be done in a manner that promotes attainment of either background water quality, or the best water quality that is reasonable if background levels of water quality cannot be restored, considering all demands being made and to be made on those waters and the total values involved: beneficial and detrimental, economic and social, tangible and intangible. In approving any alternative clean-up levels less stringent than background, apply Section 2550.4 of Chapter 15, or, for cleanup and abatement associated with underground storage tanks, apply Section 2725 of Chapter 16, while considering the factors in Section 2550.4 of Chapter 15. Any such alternative clean-up levels shall:

þ Be consistent with maximum benefit to the people of the state;

þ Not unreasonably affect present and anticipated beneficial uses of such water; and

þ Not result in water quality less than that prescribed in the Water Quality Control Plans and Policies adopted by the State and Regional Boards.

GROUNDWATER CLEAN-UP LEVELS

The overall clean-up level established for a waterbody is based upon the most sensitive beneficial use identified. In all cases, the Regional Board first considers high quality or naturally occurring "background" concentration objectives as the clean-up levels for polluted groundwater and the factors listed above under "Setting Clean-up Levels." For groundwaters with a beneficial use of municipal and domestic supply, clean-up levels are set no higher than:

þ Maximum Contaminant Levels (MCLs) or Secondary MCLs incorporated by reference in Chapter 3, whichever is more restrictive, or þ A more stringent level (i.e., below MCLs) based upon a site-specific risk assessment. Clean-up levels must be set to maintain the excess upperbound lifetime cancer risk to an individual of less than 1 in 10,000 (10^{-4}) or a cumulative toxicological effect as measured by the Hazard Index of less than one. For all sites performing risk assessments, an alternative with an excess cancer risk of 1 in 1,000,000 (10^{-6}) or less must also be considered.

The Regional Board determines excess cancer risks and the Hazard Index following U.S. EPA procedures (U.S. EPA's Risk Assessment Guidance for Superfund, Volume I, Parts A, dated August, 1989, B, dated December, 1991, and C, dated December, 1991, which are incorporated by reference into this plan). The Regional Board may modify U.S. EPA's approach outlined in these publications based on consultation with Cal/EPA's Office of Environmental Health Hazard Assessment or more current site- or pollutant-specific information.

Groundwater clean-up levels are approved on a case-by-case basis by the Regional Board. The Executive Officer or a local agency may approve clean-up levels as appropriately established by the Regional Board. Proposed final clean-up levels are based on a discharger-developed feasibility study of clean-up alternatives that compares effectiveness, cost, time to achieve clean-up standards, and a risk assessment to determine impacts on beneficial uses, human health, and the environment. Clean-up levels must also take into account the mobility, toxicity, and volume of pollutants. Feasibility studies of clean-up alternatives may include the guidance provided by Subpart E of the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300); Section 25356.1(c) of the California Health and Safety Code; U.S. EPA's Comprehensive Environmental Response, Compensation, and Liability Act; the State Board's Resolutions Nos. 68-16 and 92-49; and the Regional Board Resolution No. 88-160.

SOIL CLEAN-UP LEVELS

Soil pollution can present a health risk and a threat to water quality. The Regional Board sets soil clean-up levels for the unsaturated zone based upon threat to water quality. Guidance from U.S. EPA, California Department of Toxics Substances Control, and Cal/EPA's Office of Health Hazard Assessment is also considered on health risks. In addition, if it is unreasonable to clean up soils to background concentration levels, the Regional Board may:

þ Allow residual pollutants to remain in soil at concentrations such that:

  a) Any residual mobile constituents generated would not cause groundwater to exceed applicable groundwater quality objectives, and

  b) Health risks from surface or subsurface exposure are within acceptable guidelines.

þ Require follow-up groundwater monitoring to verify that groundwater is not polluted by chemicals remaining in the soil. Follow-up groundwater monitoring may not be required where residual soil pollutants are not expected to impact groundwater.

þ Require measures to ensure that soils with residual pollutants are covered and managed to minimize pollution of surface waters and/or exposure to the public.

þ Implement applicable provisions of Chapter 15 where significant amounts of wastes remain on-site. This may include, but is not limited to, subsurface barriers, pollutant immobilization, toxicity reduction, and financial assurances.

In order for a discharger to make site-specific recommendations for soil clean-up levels above background, the fate and transport of leachate can be modeled by the discharger using site-specific factors and appropriate models. Assumptions for minimal leachate dilution, as proposed by the discharger, may be considered by the Regional Board if deemed reasonable.

Clean-up levels are approved by the Regional Board. The Executive Officer or a local agency may approve clean-up levels as established by the Regional Board. Due to the tremendous number of sites with soil pollution, the Regional Board has considered developing "generic" clean-up levels for common soil pollutants. However, given the extreme variability of hydrogeologic conditions in the region, the Regional Board is presently unable to recommend levels that would be protective of groundwater at every site. One exception to this are clean-up standards for volatile organic chemicals (VOCs) and semi-volatile organic chemicals.

Several Regional Board orders, adopted primarily for Superfund sites, include clean-up standards of 1 mg/kg (ppm) for total VOCs, and 10 ppm for total semi-VOCs (as defined by EPA Methods 8240 and 8270, respectively, of the U.S. EPA Testing Methods for Evaluating Solid Waste, SW-846, 1986, which is incorporated by reference into this plan).

These standards apply to unsaturated soils only and are based on the modeling results at a Superfund site in the region and the professional judgement of Regional Board staff. As these are clean-up standards for total VOCs and total semi-VOCs, levels for individual constituents at polluted sites commonly are significantly lower than 1 ppm and 10 ppm, respectively. In particular, some constituents of concern have water quality standards of less than 5 ppb (e.g., benzene, vinyl chloride, ethylene dibromide). Individual clean-up levels well below the 1 ppm VOC and 10 ppm semi-volatile standards may be established for these constituents.

At this time, the Regional Board finds that these are appropriate clean-up levels for total VOCs and total semi-VOCs in the unsaturated zone at sites where groundwater is being monitored and where cleanup to background is unreasonable. At sites where it is determined that the 1 ppm clean-up level for total VOCs and 10 ppm clean-up level for total semi-VOCs may be inappropriate, the Executive Officer may modify these clean-up levels to whatever level is considered adequately protective of water quality, human health, and the environment.

A common misconception is that the Regional Board has developed "generic" clean-up levels for petroleum hydrocarbons (gasoline, gasoline by-products, and diesel). One source of the misconception is a misreading of Recommendations for Preliminary Evaluation and Investigation of Underground Tank Sites, written by the staffs of the North Coast, Central Valley, and San Francisco Bay Regional Boards. This document is commonly referred to as the Tri-Regional Guidelines. The Guidelines use 100 ppm total petroleum hydrocarbons in soil as one screening tool for prioritization. The 100 ppm level is not a "generic" clean-up level.

NON-ATTAINMENT OF GROUNDWATER CLEAN-UP LEVELS

The Regional Board has been developing policy, through the basin planning process, to address various situations when groundwater clean-up levels cannot be attained. After consideration of the Regional Board's proposed Basin Plan Amendment (Regional Board Resolution 94-101) to address non-attainment, the State Board adopted Resolution 94-117. Resolution 94-117 directs the State Board Executive Director to develop a statewide policy on groundwater and soil cleanup. In response to this, the State Board staff plans to amend State Board Resolution 92-49 to address non-attainment of groundwater clean-up levels. When Resolution 92-49 is formally approved, the Regional Board will implement the new sections on non-attainment.

FUTURE REGULATORY MANAGEMENT STRATEGIES

The following findings are drawn from the Regional Board's current regulatory experience:

- Risk assessment and management techniques can provide the Regional Board with a quantitative estimate of risks to assist in decision making.
- An inflexible, resource-intensive approach is not the most cost-effective, considering the multitude of existing and potential sources of groundwater pollution requiring cleanup.
- Institutional controls, such as deed restrictions, are an additional mechanism to protect beneficial uses and public health and safety. Guidance from U.S. EPA and the California Department of Toxic Substances Control is considered in setting institutional controls.

As a result of these findings regarding regulatory management strategy, the Regional Board will also review its overall approach to managing site cleanups. Table 4-19 lists options that the Regional Board plans to consider. Additional input regarding these and other options will be sought from all interested and affected parties during the triennial review of the Basin Plan.

GROUNDWATER PROTECTION PROGRAMS

The intimate ties between the land, surface water, groundwater, the Estuary, and human activity must be acknowledged in order to promote wise, balanced, and sustainable use of water resources. In this regard, the Regional Board will encourage planning and management by supplying tools and information that will provide an integrated environmental management approach to problem solving. It also must be recognized that groundwater quality and quantity are inextricably linked. Because an informed and involved citizenry is crucial to realizing groundwater protection, policies and plans should encourage and promote research, education, and public involvement as integral parts of any protection program.

EXCERPTS FROM SFRWQCB ORDER 95-136
REMEDIATION ACTIONS FOR SAN FRANCISCO INTERNATIONAL AIRPORT

a. Cleanup Levels : This Order requires that all free-phase product reasonably accessible will be removed; remaining chemical constituents of concern/product must be remediated or managed. This Order also establishes a Tier 0 cleanup standard for those dischargers who elect to remediate contamination (to "Non-detect levels") and Tier 1 cleanup standards for soil and groundwater remediation for each of the five RMZs and Westside Basin Protection Areas. The Tier 0 level is for those dischargers who may wish not to be burdened by any consequential risk management requirements. For those using Tier 1 or Tier 2 approaches which involve implementing the NAA concept, the cleanup goals for on-site polluted soils and groundwater have been based in part on consideration of criteria outlined in the two Task 3 submittals prepared by the Dischargers pursuant to the January 18, 1995, Board Order. The clean-up levels specified for each of the defined zones are contingent upon the discharger preparing and complying with a remedial action plan and a residual contamination risk management plan to manage and monitor remaining COCs in the soil and/or groundwater, and meeting specified water quality objectives at containment monitoring points.

TIER O CLEANUP STANDARDS

Removal of contamination to Tier 0 levels. For the purpose of defining the Tier 0 levels for TPH-g,j,d, Oil and Grease, and BTEX, Tier 0 soil and groundwater cleanup are as follows:

SOIL	
TPH - g	10 mg/kg
TPH - j,d	50 mg/kg
Oil and Grease	50 mg/kg
BTEX	.005 mg/kg
GROUNDWATER	
TPH - g, j, d	50 ppb
Oil and Grease	5 ppm
BTEX	MCLs

TIER 1 CLEANUP STANDARDS:

The methodology used to derive the Tier 1 cleanup standards for each RMZ is presented below. The cleanup standards are listed in the Specification Section, Item 4 and Attachment 1 of this Order. The exposure scenarios and input parameters for Tier 1 Standards and DAF input parameters used to determine Tier 1 Cleanup Standards are listed on Attachment 3.

1. Saltwater Ecological Protection Zone

Due to the close proximity of the Airport to San Francisco Bay, and the likelihood of polluted groundwater discharging into the bay, protection of the beneficial uses of the adjacent surface water receptor is the objective of the Saltwater Ecological Protection Zone. The cleanup objectives for the soil and groundwater are such that when the groundwater reaches the bay it is protective of the beneficial uses and does not pose a significant risk to either the aquatic species or the people using the Bay. Upon examining the possible exposure risk scenarios, two major objectives were identified; 1) the protection of the aquatic and other species such that there is no acute or significant chronic toxicity affecting the species inhabiting the bay and wetlands adjacent to the Airport and 2) the protection of humans who may come in contact with or eat the organisms exposed to the contaminated water.

To evaluate the level protective of saltwater aquatic species, an extensive data search was performed for each of the chemicals of concern identified. The following applicable criteria documents were reviewed: USEPA ambient water quality criteria marine chronic criteria, California Water Quality Objectives for Saltwater Aquatic Life, San Francisco Bay Region Basin Plan's Shallow Water Effluent Limitations for Marine Water, USEPA Integrated Risk Information System (IRIS), and the National Toxics Rule. The values from each of the documents were compared and the lowest value was selected for each of the COCs. The most current information available was used when comparing values. In those instances where no chronic criteria were available, 10% of the acute value was used. These values are considered to be protective of the aquatic species.

Since adopted aquatic standards do not currently exist for total petroleum hydrocarbons (TPH), the EC_{10} (the level at which 90% of the organisms developed normally) was calculated using the bivalve and sea urchin development tests performed by United Airlines. The EC_{10} value is the basis for the cleanup standard for both Ecological Protection Zones and is similar to toxicity requirements adopted by the Board in other shallow water effluent discharges. To verify the results of the studies conducted, additional bioassay testing will be required as a condition of this Order.

Several possible human receptors were identified who may come into contact with the contaminated groundwater upon discharge to surface water. They include recreational users (i.e. windsurfers, swimmers, etc.), recreational fisherman, and subsistence fisherman. A risk evaluation was performed for each category of human receptors and a set of values were calculated for each of the COCs. The values calculated for each scenario were compared and the most sensitive receptor group was identified and the lowest value was selected for each COC.

Finally, the human health levels were compared to the aquatic species levels and the limiting or lowest value was chosen for each COC. These Tier 1 standards are listed in Attachment 1, Table 2 and are considered cleanup standards for the Saltwater Ecological Protection Zone. Dischargers identified within this zone must meet the Tier 1 standards for soil and groundwater. Dischargers may perform a Tier 2 evaluation as specified in the Tier 2 methodology for the Ecological Protection Zone for consideration and approval by the Executive Officer. (See Attachment 2). Election to perform a Tier 2 evaluation must take into account the Master Plan and other construction, maintenance, and operation schedule requirements.

Tier 2 Evaluation : In the event it is proposed by the Discharger that the Tier 1 standards are not applicable to a given site for reasons that may include site specific conditions such as: unique conditions relating to contaminant types, levels and/or extent; unique conditions relating to human or ecological receptors; subsurface conditions unique to the site such as insufficient thickness of the Bay Mud; changes in current or future land-use scenarios, that necessitate application of alternate standards; etc, then the discharger may request to determine site specific clean-up standards through the application of a Tier 2 risk assessment methodology. The Discharger shall prepare a description of the methods by which they shall determine Tier 2 cleanup levels for their site. A copy of the Discharger's proposal shall be sent to the Executive Officer for review and approval. At the same time the proposal is submitted to the Executive Officer, a copy of the proposal shall also be sent to the Airport's staff and the adjacent tenants or potentially affected parties. Comments on the proposed Tier 2 analysis shall be submitted to the Executive Officer and to the Discharger within 30 days. The resulting Tier 2 evaluation and cleanup standards must be approved by the Executive Officer prior to implementation. Attachment 2 outlines the general procedures to be employed for the Tier 2 analysis.

Dischargers will remain responsible for any future source removal, containment, management and monitoring of existing and/or remaining polluted soil and groundwater that may be required as a result of changes in land use, applicable requirements or new information.

In addition, a long term airport wide monitoring program (surface, ground water, sediment) will be required as part of this Order to determine compliance with the non-attainment containment monitoring points as well as when to implement contingency measures to assure that the containment monitoring points are not violated. An airport wide monitoring network for both interior and along the airport boundary is required under Task 6 of this Order. The monitoring program will focus on the preferential pathways including but not limited to utility and storm drain conduits.

b. Subsequent Order(s) This order will be followed by subsequent Order(s) which will revise, as necessary, the boundaries of the Human Health, Ecological, and Migration Management Zones, as well as revise any of the associated cleanup standards specified for Tier 1. Revisions or modifications to the RMZ boundaries and associated cleanup standards may be made by the Executive Officer. Board staff anticipate that the subsequent Order or revision of this Order will occur in approximately a two year period or may occur sooner at Discharger's request or as necessary to reflect the results of the Task 1C or other required studies.

TIER II SITE-SPECIFIC RISK ASSESSMENTS

This document, in conjunction with the corresponding flowchart, outlines the items and procedures required for the completion of site-specific risk assessments (Tier 2 and 3). To ensure protection for both ecological and human receptors and the Westside Basin, the gathering of adequate site-specific data and subsequent analysis is required. The Board strongly encourages the dischargers to utilize the framework provided in the American Society for Testing and Materials (ASTM) ES 38-94 "Emergency Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites" [RBCA] (May 27, 1994) or its successor when developing Tier II cleanup levels. The tiered approach, and the methodology to perform the tiered analyses in the ASTM RBCA provides a consistent decision-making tool, especially where multiple parties are involved. In addition, ASTM-RBCA was developed as a consensus procedure, has been peer-reviewed, received wide-spread input and acceptance, is internally consistent, was developed subsequent to and consistent with EPA's (CERCLA) RAGS, and fully utilizes the tiered-approach as the basis of the guide.

Details on site-specific risk assessments will be based on procedures outlined in Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities (DTSC 1992), Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) (USEPA 1989), Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities (DTSC 1994), and Guidance for Data Useability in Risk Assessment (USEPA 1992).

Prior to initiating Tier II risk assessments, a workplan must be submitted to the Regional Board for approval. The Tier II Assessment should include Sections regarding data evaluation, conceptual site models, exposure and toxicity assessment, risk characterization and uncertainty analysis. The risk goals and toxicity values selected for inclusion in this document were chosen to be consistent with values selected by the SFBRWQCB staff at the May 4, 1995, meeting.

Samples from each applicable medium (e.g. soil, ground water, surface water, sediment, etc.) will be collected and analyzed for appropriate analysis as determined by historical contamination and established sampling procedures. At a minimum, compounds of concern (COCs) listed in the SFBRWQCB Order must be considered as compounds of potential concern (COPCs) for the Tier II risk assessments, or an explanation must be provided for their exclusion. Statistical significance, data evaluation, detection limits, and COC selection will be determined as outlined in Guidance for Data Useability in Risk Assessment (USEPA 1992).

A site-specific conceptual site model (CSM) consistent with the CSM developed for Task 3 under the Regional Board Order dated January 18, 1995, will be presented for both human and ecological receptors. At a minimum, the CSM will include: primary sources, primary release mechanisms, secondary sources, secondary release mechanisms, pathways, and receptors.

Dose equations will be developed for all complete human exposure pathways, as determined by the conceptual site model discussed above. Exposure concentrations will be determined based on a statistical analysis of the data (e.g. calculating the 95% upper confidence level of the mean). Equations and variables used to describe exposure point concentrations and intake will be selected from the most current DTSC and USEPA guidance documents on risk assessment.

Quantitative toxicity information, carcinogenic slope factors and non-carcinogenic reference doses, will be obtained, in descending order, from the most recent updates of USEPA Database: Integrated Risk Information System (IRIS), Health Effects Assessment Summary Tables (HEAST), and other applicable federal and state values.

Acceptable risk and hazard will be determined based on the following criteria: the risk for individual Class A, B, and C carcinogens shall not exceed 1×10^{-5}, the cumulative risk for all carcinogens shall not exceed 1×10^{-4}. In addition, consistent with US EPA RAGS, the risk for non-carcinogenic chemicals must be summed for the COCs which either operate through a similar mechanism or affect the same target organ and the cumulative hazard from non-carcinogenic constituents shall not exceed 1.0. For sites where day care centers are proposed, the cumulative risk for all carcinogens shall not exceed 1×10^{-6}.

A qualitative uncertainty analysis will be performed on the assumptions, models, and variables used to quantify risk and develop RBLs.

Attachment 3 provides the exposure scenarios and input parameters used by the Regional Board to establish Tier 1 Standards and DAF Parameters for this Order. The Discharger may use the same models that were used to establish the Tier 1 Standards and DAF Parameters to develop Tier 2 Standards by modifying the input parameters and exposure scenarios provided in Attachment 3 with site specific information.

Implementation Procedure: The Discharger shall prepare a description of the methods by which they shall determine Tier 2 cleanup levels for their site. A copy of the Discharger's proposal shall be sent to the Executive Officer for review and approval. At the same time the proposal is submitted to the Executive Officer, a copy of the proposal shall also be sent to the Airport's staff and the adjacent tenants or potentially affected parties. Comments on the proposed Tier 2 analysis shall be submitted to the Executive Officer within 30 days and to the Discharger. The resulting Tier 2 evaluation and levels must be approved by the Executive Officer following the comment period.

TIER II ECOLOGICAL ASSESSMENT

This section outlines the items and procedures required for the completion of site-specific, Tier II ecological risk assessments. The Tier II assessments will be based on procedures outlined in Guidance for Ecological Risk Assessment at Hazardous Wastes Sites and Permitted Facilities (DTSC 1994). Prior to initiating a Tier II assessment, a workplan must be submitted to the SFBRWQCB and the Airport for approval. The workplan will include: habitat and species identification for both terrestrial and aquatic flora and fauna, with particular emphasis on rare, threatened, and endangered species within one mile of the site, pathway assessment for all applicable medium, including potential movement of contaminants to higher trophic levels, data evaluation, including COPC identification, development of a conceptual site model, and a toxicity evaluation. Both qualitative and quantitative information will be required. Examples of possible quantitative information include: chemical analysis of surface water, and sediment of the near shore saltwater and fresh water of the adjacent estuarine and wetlands, species diversity, community structure and contaminant concentrations in the adjacent benthic populations, wetland delineation, and bioassay studies.

TABLE 2: SALTWATER ECOLOGICAL PROTECTION ZONE TIER 1 STANDARDS

Chemical Constituent	Maximum Soil Concentration	Maximum Groundwater Concentration	Basis for Standard (Limiting Factor)
ORGANIC COMPOUNDS	mg/kg	µg/L	
1. Benzene (B)	2.7	71	Water: Basin Plan Shallow Water Effluent Soil: USEPA OLM Model
2. Benzo(a)pyrene	0.04	0.031	Water: Basin Plan Shallow Water Effluent Soil: USEPA OLM Model
3. Chloroform	17	470	Water: US EPA Water Quality Criteria Soil: USEPA OLM Model
4. 1,1-Dichloroethane (1,1-DCA)	2.3	99	Water: US EPA Water Quality Criteria Soil: USEPA OLM Model
5. 1,2-Dichloroethane (1,2-DCA)	1.8	99	Water: US EPA Water Quality Criteria Soil: USEPA OLM Model
6. 1,1-Dichloroethene (1,1-DCE)	0.09	3.2	Water: US EPA Water Quality Criteria Soil: USEPA OLM Model
7. 1,2-Dichloroethene (1,2-DCE)	0.02	3.2	Water: Based Upon USEPA Water Quality Criteria for 1,1-DCE Soil: USEPA OLM Model
8. Ethylbenzene (E)	5	43	Water: 10% US EPA Marine Accute Criteria Soil: USEPA OLM Model
9. Methylene Chloride (MC)	42	1,060	Water: Protection Subsistence Fisherman Soil: USEPA OLM Model
10. Methyl Tertiary Butyl Ether (MTBE)	------	------	Monitoring Only
11. Naphthalene	41	100	Water: Based on TPH-j EC10 Soil: USEPA OLM Model
12. Oil & Grease (TOG)	------	------	Site Specific Value to be Recommended by Discharger for Executive Officer approval
13. Poly-Aromatic Hydrocarbons (Total PNAs)	0.04	0.031	Water: USEPA Water Quality Criteria Soil: USEPA OLM Model
14. Poly-chlorinated Biphynols/Aroclor (Total PCBs)	8×10^{-7}	0.000045	Water: US EPA Water Quality Criteria Soil: USEPA OLM Model
15. Tetrachloroethylene (PCE)	0.3	6.9	Water: California water quality objective Soil: USEPA OLM Model
16. Toluene (T)	2,700	5,000	Water: US EPA marine chronic criteria Soil: USEPA OLM Model
17. Total Petroleum Hydrocarbons as Gasoline (TPH-g)[4]	16	100	Water: EC_{10} -bivalves and sea urchin bioassay Soil: $K_{sw} = 160$
18. Total Petroleum Hydrocarbons as Jet Fuel (TPH-j)[4]	68	100	Water: EC_{10} -bivalves and sea urchin bioassay Soil: $K_{sw} = 686$
19. Total Petroleum Hydrocarbons as Diesel	68	100	Water: EC_{10} -bivalves and sea urchin bioassay

TABLE 2: SALTWATER ECOLOGICAL PROTECTION ZONE TIER 1 STANDARDS

Chemical Constituent	Maximum Soil Concentration	Maximum Groundwater Concentration	Basis for Standard (Limiting Factor)
ORGANIC COMPOUNDS	**mg/kg**	**µg/L**	
(TPH-d)[4]			Soil: K_{sw} = 686
20. 1,1,2-Trichloroethane (1,2-TCA)	0.7	42	Water: US EPA Water Quality Criteria Soil: USEPA OLM Model
21. Trichloroethylene (TCE)	4.3	81	Water: US EPA Water Quality Criteria Soil: USEPA OLM Model
22. Vinyl Chloride (VC)	0.4	17	Water: Protection Subsistence Fisherman Soil: USEPA OLM Model
23. Xylene (X)	>Saturation[5] =990 (1,440)	2,200	Water: US EPA Water Quality Criteria Soil: =Saturation concentration
INORGANICS	mg/kg	µg/L	
24. Cadmium	See Foot Note #3	9.3	Water: US EPA Marine Chronic Criteria Limit Soil: USEPA OLM Model
25. Chromium[1]	See Foot Note #3	50	Water: Basin Plan Shallow Water Effluent Limit Soil: USEPA OLM Model
26. Lead[2]	See Foot Note #3	5.6	Water: California Water Quality Criteria Limit Soil: USEPA OLM Model
27. Mercury (inorganic)	See Foot Note #3	0.025	Water: US EPA Marine Chronic Criteria Limit Soil: USEPA OLM Model
28. Nickel	See Foot Note #3	7.1	Water: Basin Plan Shallow Water Effluent Limit Soil: USEPA OLM Model
29. Zinc	See Foot Note #3	58	Water: Basin Plan Shallow Water Effluent Limit Soil: USEPA OLM Model

1. Chromium is the value for total chromium assuming all is hexavalent chromium. If dischargers opt to speciate between hexavalent and trivalent, an alternate level will be considered.

2. This concentration is for total lead. If lead is detected above the screening level for an area identified with TPH-g, then an analysis for tetra-ethyl lead shall be done.

3. Soil standards for metals will be determined on a site specific basis and must be protective of the water quality standards listed above.

4. An EC_{10} value of approximately 200 ppb was calculated for TPH for gasoline and diesel fractions. It was assumed that each made up 50 % of the mixture and therefore this concentration was divided in half to calculate Tier 1 standards for the TPH-g and TPH-d fractions. Therefore, up to twice the concentration may be used as a Tier 1 cleanup criteria if the Discharger has only TPH-g, TPH-j, or TPH-d at their particular site with approval from the Executive officer.

5. Risk based levels for the zone exceeded the saturation or solubility concentrations. Therefore, since no free product is acceptable as part of the conditions of this Order, the saturation or solubility concentration will be used as the Tier 1 standard. The risk based level calculated is shown in parenthesis within the table.

APPENDIX D

REMEDIATION TECHNIQUES

6.2 In Situ Bioremediation

Nearly the entire area at Mariner Square is covered with asphalt and concrete making In Situ processes advantageous in that soil can be treated without being excavated or transported. In Situ bioremediation can treat contaminated groundwater, soil and free phase simultaneously, providing additional cost advantages.[1] These factors, along with the fact that In Situ bioremediation is a treatment process and not simply a mass transfer process, make it desirable for application on site. The major disadvantages include ineffectiveness against inorganic contaminants[*] and uncertainty of application to the specific site.

The large amount of petroleum hydrocarbons would create a heavy oxygen demand. It was estimated that there are approximately 40,000 kg of TPH in the subsurface (appendix). This would require 100,000 kg of Oxygen for degradation[4]. Although it would be possible to meet this demand with aerated or oxygenated water, given enough time, this is considered impractical. The high DO concentrations attainable through hydrogen peroxide make it the desired method. Other oxygen supply considerations include:
1) Several studies have shown that hydrogen peroxide may react with the soil and release the oxygen making the microbial utilization less efficient.
2) Hydrogen Peroxide and/or excessive DO concentrations may be toxic to microorganisms.
3) Air may be injected into the vadose zone to biodegrade plumes above the water table.
4) Chemical competition for oxygen may affect performance. Redox potential should be measured.
There are several factors that may affect biological treatment methods including[3]:

- Moisture
- Temperature
- pH
- Total Dissolved Solids
- Nutrient Availability
- Toxins and Inhibition

Moisture

In general soil moisture content should be near 40% of saturation to support microbial growth. The contamination at Mariner Square is found in saturated soil and soil of sufficient saturation to accommodate microorganisms.

Temperature

The optimum temperature for microbial growth is generally between 20° C and 40°C and is strongly dependent on the type of microorganism present. The site at Mariner Square has ground temperatures near 12°C which is below optimum but still suitable.

pH

Most bacteria grow best between pH of 5-9. The groundwater was found to be near neutral by McLaren Hart..

Total Dissolved Solids

---

[*] Crusberg et al.[2] have shown that heavy metals, including Pb, Cu and Zn, can be bound by biological organisms such as algae and fungus under certain pH conditions. This effectively removes the metals from the waste stream.

D - 1

LaGrega suggests that TDS should be less than 40,000 mg/L and should not vary by more than a factor of 2.0 over a period of a few days. McLaren-Hart measured the TDS level to be near 3000 mg/L on site. Haines et al. found that salinity will also affect degradation rates. Water with 1% salinity was shown to reduce maximum growth rate by 5-10%. The proximity of the Bay may lead to groundwater with high salinity.

Nutrients

In addition to carbon, microbes require nitrogen and phosphorous, among other micronutrients, to maintain growth. Further testing is required to determine whether these need to be supplied in the in situ process.

Toxins and Inhibition

The presence of copper, lead and zinc may adversely affect microbial populations. Further, the presence of free phase hydrocarbons may be inhibitive to growth reducing effectiveness.

Soil assays performed by McLaren Hart have found strong microbial populations. Three soil samples within the oil storage containment wall (SB-A, SB-B and SB-C) found 20,000 CFU/mg soil, 85,000 CFU/mg soil and 850,000 CFU/mg soil, respectively. The highest value was found nearest the well where free-phase hydrocarbons were found, suggesting that there is significant degradation occurring. It also suggests that there are sufficient nutrients and limited toxic effects in the subsurface.

There are other process limitations which must be considered before implementation. Cleanup goals may not be attained if the soil matrix prohibits contaminant-microorganism contact.[**] Preferential flow paths may severely decrease contact between injected fluids and contaminants. It is not uncommon for microbial growth to reduce the hydraulic conductivity of soils and retard injected water flow.

Field testing should be performed to determine the radius of influence and well spacing.

It may also be necessary to remove and treat the excess groundwater injected for treatment. This could be done by active and/or passive means where the existing sheetpile walls are used to direct the flow. Depending on the metals concentration is may be possible to discharge the treated effluent.[7]

The appendix contains a preliminary well design. Specific soil characteristics would need to be determined to verify the model.

Cost: Typical costs for in situ bioremediation range from \$30 to \$100 per cubic meter (\$20 to \$80 per cubic yard) of soil. Variables affecting the cost are the nature and depth of the contaminants, use of bioaugmentation and/or hydrogen peroxide addition, and groundwater pumping rates.

Sources:

1) httm//:clu-in.com/techindx.htm

[**] Drake et al.[6] studied the effects of age on degradability of a substance based on the theory that aged spills may be less available to degradation due to adsorption onto soil surfaces and possible diffusion into micropores. They concluded that aged TPH had significant potential for degradation.

2) Crusberg, Weathers and Baker, Biotraps for Heavy Metal Removal and Recovery from Industrial Wastewater, Biological Processes, Innovative Hazardous Waste Treatment Technology, 1991

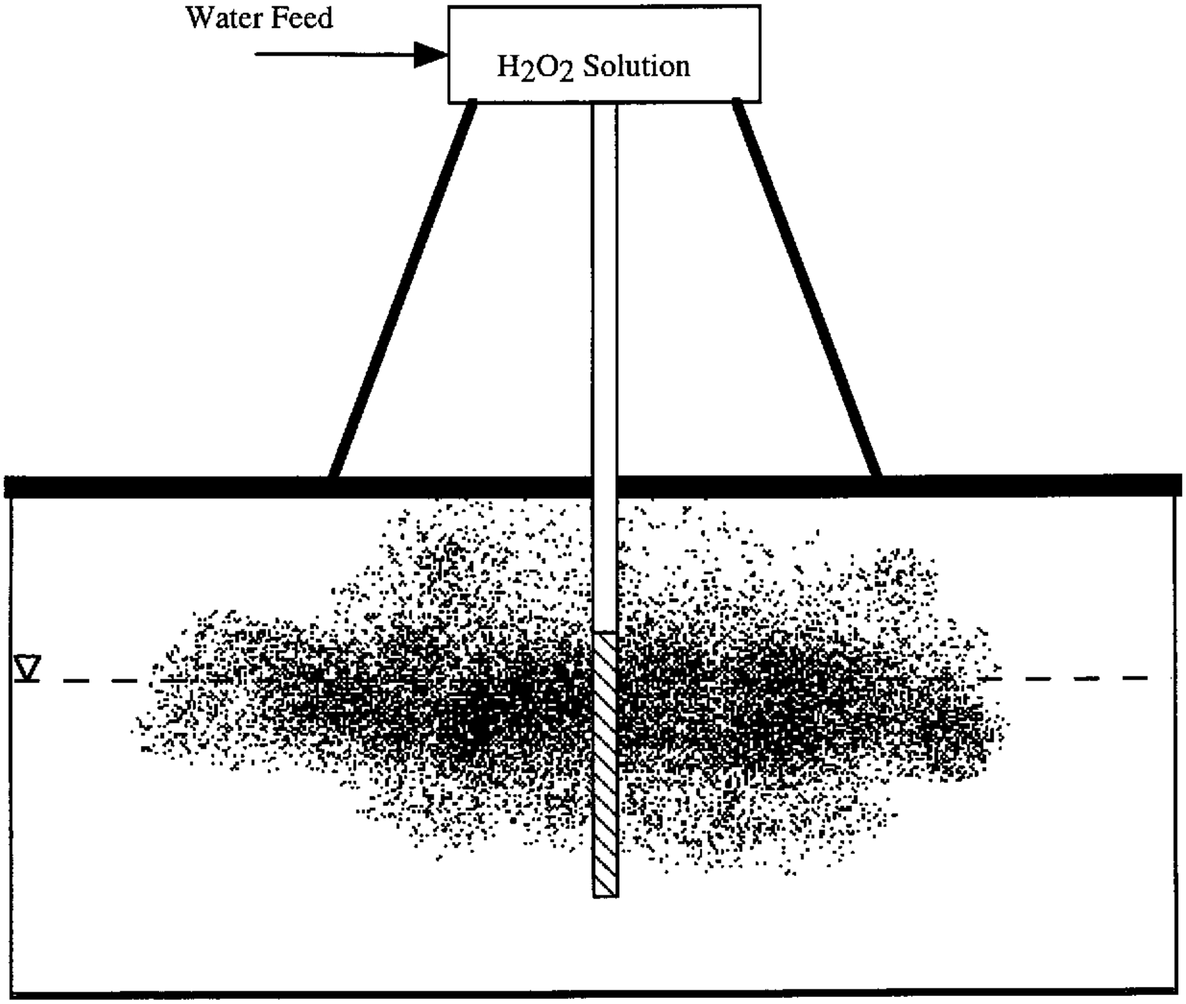
3) LaGrega, Buckingham and Evans, Hazardous Waste Management, pg. 563

4) Ibid., pg. 599

5) Haines, Kadkhadayan, Mocsny, Jones, Islam and Venosa, Effect of Salinity, Oil Type and Incubation Temperature on Oil Degradation. Applied Biotechnology for Site Remediation, 1994

6) Drake, Stokely, Calcavecchio, Bare, Rothenburger, Douglas and Prince, Nutrient Stimulated Biodegradation of Aged Refinery Hydrocarbons in Soil, Monitoring and Verification of Bioremediation, 1995

7) SFRWQCB General Discharge Permit described in personal communication with SFRWQCB information officer, 25 April 1997



Proposed Enhanced Bioremediation System

Thermally Enhanced Soil Vapor Extraction

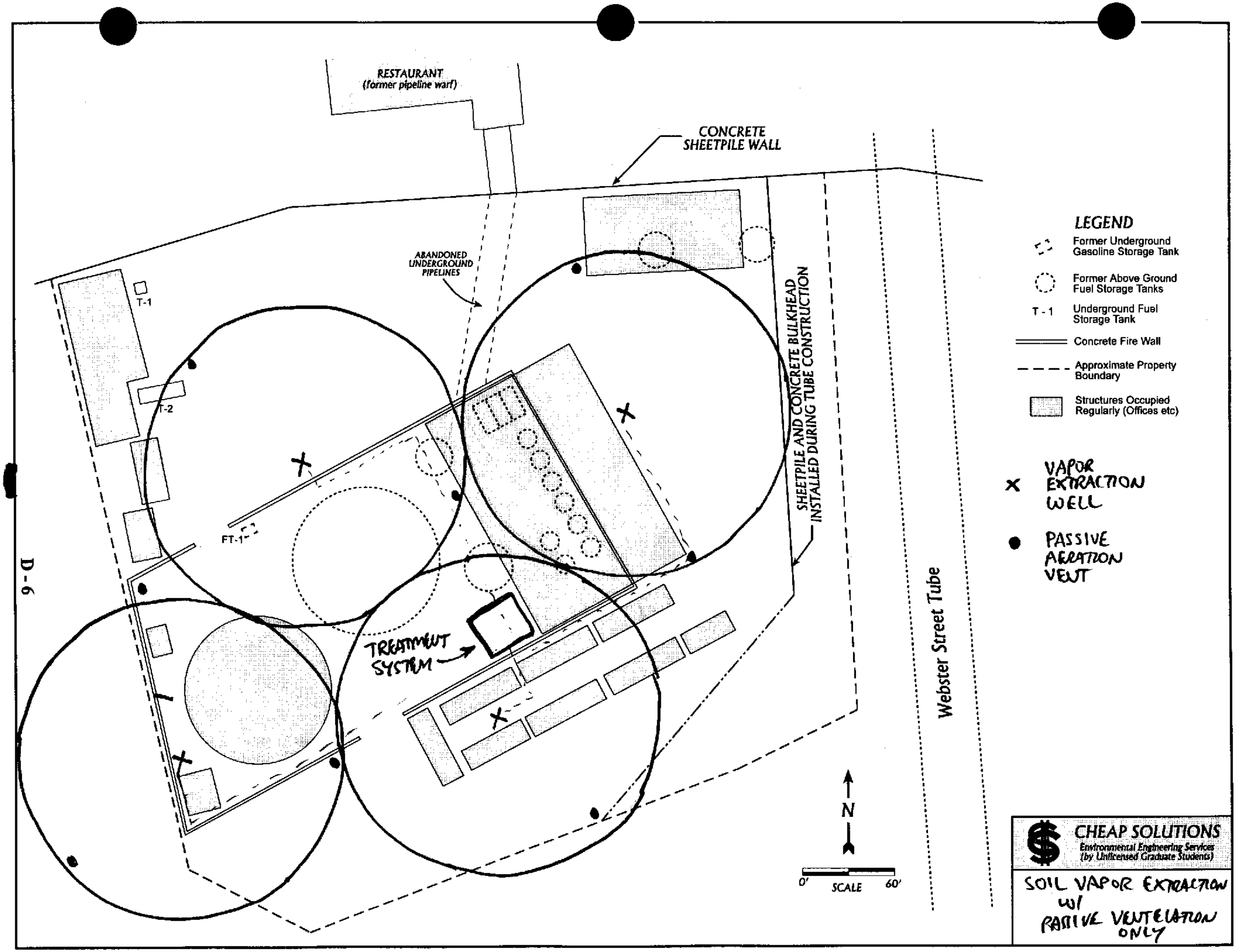
Steam injection wells well be located in the periphery of the plume and free product area. Soil vapor extraction wells will be centrally developed around the contaminanted region. High-pressure steam is injected into the soil surrounding the contaminated area. The resulting dynamic steam pressure front drives groundwater with aqueous phase and separate phase hydrocarbons toward the extraction well. In addition, the dynamic underground steam heats and strips soil of organics by volatization (mass transfer of contaminants into the vapor state). The resulting soil behind the moving steam front is dry with a significantly reduced contaminant concentration. The asphalt cover at the Mariner Square can prevent short-circuiting of the injected steam to the atmosphere, and can also prevent atmospheric air from entering aquifer matrix. The relatively high permeability of the soil matrix at the Mariner Square facilitates steam/air movement, no electrical resistance heating needed, thus the cost is reduced. Intermittent steam injection and extraction achieve better performance than continuous operation.

Surface equipment includes:
1.The steam generation and delivery system consists of standard steam heating equipment, related steam piping, and monitoring equipment.
2. The extraction system is a solvent recovery system that includes a vacuum blower, steam condenser, other cooling and dehumidifier equipment, and activated carbon filter, which requires further treatment or off-site disposal.

This energy-demanding technique is effective for high concentration of organic contaminates removal at the Mariner Square, however, it might result in lower public compliance due to the noise during operation, and the steam generation system might be dangerous if there is no proper operation and maintenance.

[redacted]

[redacted]



CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)

SOIL VAPOR EXTRACTION
w/
PASSIVE VENTELATION
ONLY

SOIL VAPOR EXTRACTION W/ PASSIVE AERATION VENTS

EXTRACTION WELLS NUMBER = 4 DEPTH 3 ft DIA 3" PIPING

TOTAL LENGTH OF PIPE = 4 × 3 ft = 12 ft

VOLUME WASTE CUTTINGS = $\left(\frac{6''\text{dia}}{2}\right)^2 \pi \times 12\text{ft} \times \left(\frac{\text{ft}}{12\text{in}}\right)^2 = 2.4\text{ft}^3 = 0.09 \text{ CY YD}$

DENSITY OF SOIL = $\underset{\gamma}{\underset{(\text{sand/clay})}{(2.7)}}\underset{\rho}{\underset{(\text{WATER})}{\left(\frac{1000\text{ kg}}{\text{m}^3}\right)}}\underset{(1-n)}{(0.7)}\left(\frac{.765\text{m}^3}{\text{yd}^3}\right) = 1450 \frac{\text{kg}}{\text{yd}^3} = 3{,}200 \text{ lb/CY}$

DISPOSAL OF $\overset{\text{CUTTINGS}}{\text{WASTE}}$ = $(0.09 \text{ CY})(3{,}200 \text{ lb/CY})\left(\frac{\text{TON}}{2000 \text{ lb}}\right) = 0.15 \text{ TONS}$

PIPING 850 feet × $\overset{\text{SAFETY F.}}{1.25}$ = 1000 feet 3" dia PVC 80

VACUUM PUMP 1 PUMP, 100 CFM

ACTIVATED CARBON USED

TOTAL MASS TRPH IS ABOUT 33,000 kg
ASSUME ~ 6¢/g FOR GAC REMOVAL

INSALLATION OF CARBON TREATMENT FACILITY

BASE 10' × 20' = 200 SF = 22.5 YD²
TREATMENT PLANT = 1 @ 1000 CFM

DAILY MONITORING AND UPKEEP

ASSUME 2 YEARS OF OPERATION, WEEKLY VISIT FOR 5 HOURS @ $25/HR

PASSIVE VENTS NUMBER = 8 DEPTH = 4 ft DIA = 2"

TOTAL LENGTH OF PIPE = 8 × 4 ft = 32 feet

VOLUME CUTTINGS = $\left(\frac{4''\text{dia}}{2}\right)^2 \pi \times 32\text{ft} \times \left(\frac{\text{ft}}{12\text{in}}\right)^2 = 2.8\text{ft}^3 = 0.1 \text{ CY YD}$

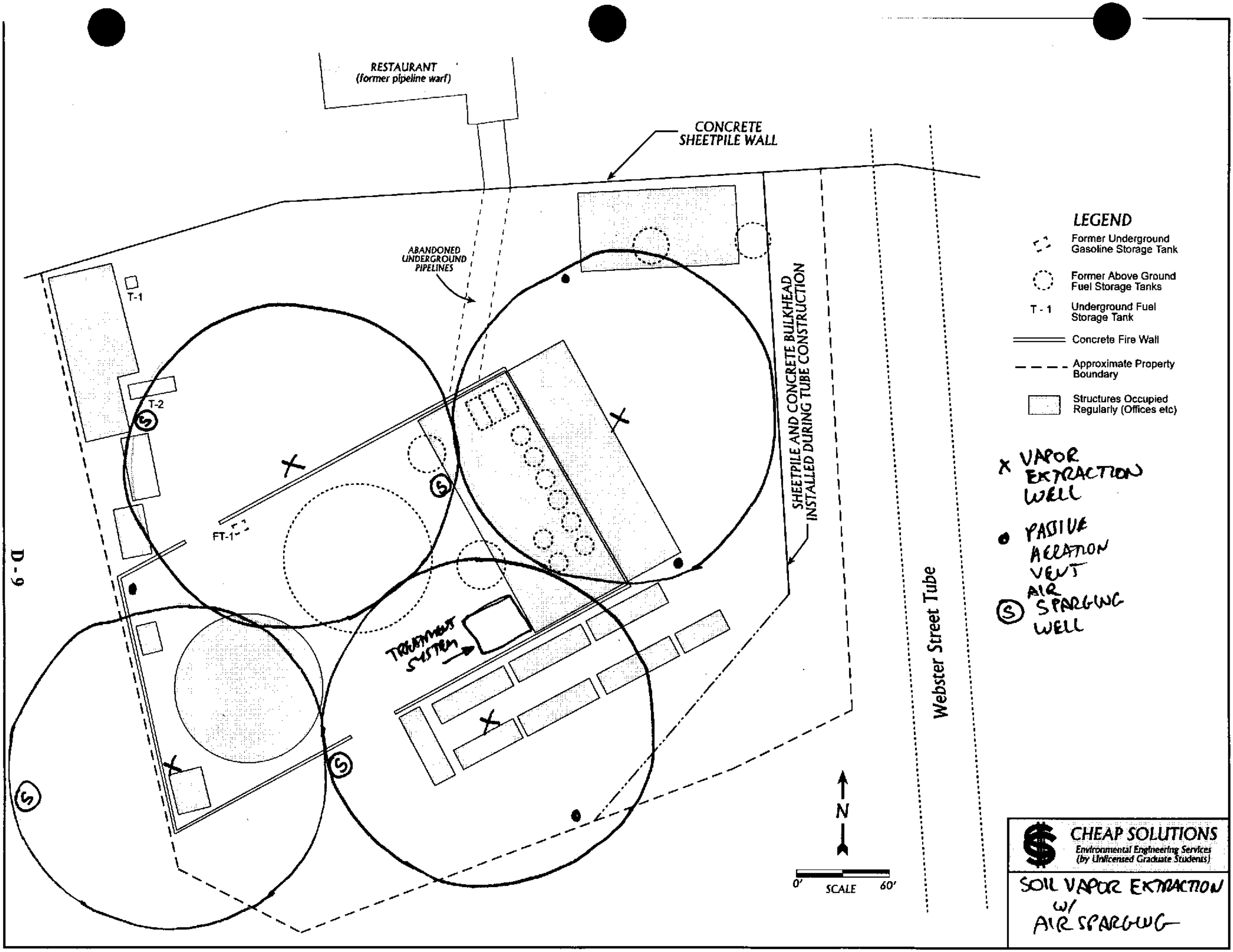
WASTE CUTTINGS TO DISPOSE = $(0.1 \text{ CY})(3200 \text{ lb/CY})\left(\frac{\text{TON}}{2000 \text{ lb}}\right) = 0.16 \text{ TONS}$

SOIL VAPOR EXTRACTION WITH PASSIVE VENTALATION ONLY

ACTION	ATTRIBUTE	UNIT	UNITS REQUIRED	DAILY OUTPUT (1)	DAYS REQUIRED	DAILY COST (2)	UNIT COST	TOTAL COST
surveying		ACRE	2	0.6	3.33	$ 800		$ 2,667
activated carbon treatment facilities	concrete	SY	22.5	300	0.08	$ 2,137	$ 15	$ 498
	treatment plant	PLANT	1				$ 1,000	$ 1,000
extraction well installations	3" piping & casing	LF	12				$ 30	$ 360
	installation	LF	12	0.25	48.00	$ 1,400		$ 67,200
	removal of waste cuttings	CY	0.09	99	0.001	$ 252		$ 0
	disposal of waste cuttings	TON	0.15				$ 350	$ 53
aeration vent installations	2" piping & casing	LF	32				$ 25	$ 800
	installation	LF	32	0.25	128.00	$ 1,400		$ 179,200
	removal of waste cuttings	CY	0.1	99	0.001	$ 252		$ 0
	disposal of waste cuttings	TON	0.16				$ 350	$ 56
piping installations	Sch. 80 PVC piping, 3" dia	LF	1000				$ 5	$ 5,000
	fittings & supports						*10%*	$ 500
	installation	LF	1000	53	18.87	$ 422		$ 7,962
vacuum pump installation	100 CFM pump	PUMP	1				$ 1,000	$ 1,000
	installation	PUMP	1	1.6	0.63	$ 1,004		$ 628
periodic upkeep		WEEK	104	0.14	728.00	$ 18		$ 12,958
							SUBTOTAL	$ 279,882
permitting							*20%*	$ 55,976
overhead							*10%*	$ 27,988
mobilization/demobilization							*10%*	$ 27,988
Treatment of VOC in GAC (3)		Kg VOC	33000				$ 57	$ 1,881,000
							TOTAL	$ 2,272,834

Notes:

1. Daily number of units produced per day for a typical field crew (Means Cost Data, 1995 and other)
2. Daily cost includes labor and equipment (Means Cost Data, 1995 and other)
3. Based on rough estimates of $0.06 per gram of VOC removed from waste stream



CHEAP SOLUTIONS

Environmental Engineering Services (by Unlicensed Graduate Students)

SOIL VAPOR EXTRACTION
w/
AIR SPARGING

SOIL VAPOR EXTRACTION w/ AIR SPARGING

EXTRACTION WELLS (SAME AS SVE w/VENTS)

PIPING 1000 ft FOR EXTRACTION WELLS
765 ft × 1.25 = 950 ft FOR AIR SPARGING
SF

VACUUM/BLOWER 100 CFM

ACTIVATED CARBON USED
ASSUME IMPROVED BIOREMEDIATION DEGRADES 1/3RD OF TRPH IN 1.5 YEARS → TOTAL TRPH REMOVED BY SVE = (33,000 kg) 2/3 = 22,000 kg
= 22,000,000 g

INSTALL CARBON TREATMENT FACILITY
BASE = 22.5 YD²
TREATMENT PLANT ?

PERIODIC MONITORING + UPKEEP
ASSUME 1.5 years, WEEKLY VISIT FOR 5 HOURS @ $25/HR

AIR SPARGING WELLS NUMBER = 4, 3" DIA, 7.5 feet deep
TOTAL LENGTH = (7.5)(4) = 30 feet
VOLUME WASTE CUTTINGS = $\left(\frac{0.09\text{ CY}}{12\text{ ft}}\right)(30\text{ ft}) = 0.225\text{ CY}$
DISPOSAL OF CUTTINGS = $\left(\frac{0.15\text{ TONS}}{12\text{ ft}}\right)(30\text{ ft}) = 0.375\text{ TONS}$

SURVEY AREA = 2 ACRES

AERATION VENTS NUMBER = 4
TOTAL LENGTH = 16 feet, 0.05 CY CUTTINGS
0.08 TONS

SOIL VAPOR EXTRACTION WITH AIR SPARGING

ACTION	ATTRIBUTE	UNIT	UNITS REQUIRED	DAILY OUTPUT (1)	DAYS REQUIRED	DAILY COST (2)	UNIT COST	TOTAL COST
surveying		ACRE	2	0.6	3.33	$ 800		$ 2,667
activated carbon treatment facilities	concrete	SY	22.5	300	0.08	$ 2,137	$ 15	$ 498
	treatment plant	PLANT	1				$ 1,000	$ 1,000
extraction well installations	3" piping & casing	LF	12				$ 30	$ 360
	installation	LF	12	0.25	48.00	$ 1,400		$ 67,200
	removal of waste cuttings	CY	0.09	99	0.001	$ 252		$ 0
	disposal of waste cuttings	TON	0.15				$ 350	$ 53
sparging well installations	3" piping & casing	LF	30				$ 30	$ 900
	installation	LF	30	0.25	120.00	$ 1,400		$ 168,000
	removal of waste cuttings	CY	0.225	99	0.002	$ 252		$ 1
	disposal of waste cuttings	TON	0.375				$ 350	$ 131
aeration vent installations	2" piping & casing	LF	16				$ 25	$ 400
	installation	LF	16	0.25	64.00	$ 1,400		$ 89,600
	removal of waste cuttings	CY	0.05	99	0.001	$ 252		$ 0
	disposal of waste cuttings	TON	0.08				$ 350	$ 28
piping installations	Sch. 80 PVC piping, 3" dia	LF	1950				$ 5	$ 9,750
	fittings & supports						*10%*	$ 975
	installation	LF	1950	53	36.79	$ 422		$ 15,526
vacuum/blower installation	100 CFM vacuum/blower	v/b	2				$ 1,000	$ 2,000
	installation	v/b	2	1.6	1.25	$ 1,004		$ 1,255
periodic upkeep		WEEK	78	0.14	546.00	$ 18		$ 9,719
							SUBTOTAL	$ 370,062
permitting							*20%*	$ 74,012
overhead							*10%*	$ 37,006
mobilization/demobilization							*10%*	$ 37,006
Treatment of VOC in GAC (3)		Kg VOC	22000				$ 57	$ 1,254,000
							TOTAL	$ 1,772,087

Notes:

1. Daily number of units produced per day for a typical field crew (Means Cost Data, 1995 and other)
2. Daily cost includes labor and equipment (Means Cost Data, 1995 and other)
3. Based on rough estimates of $0.06 per gram of VOC removed from waste stream

For chapter 6

Remediation option : excavation

1. Excavation of metals

1.1. Excavation location and volume : discussion

Among the metals, only lead has been shown to be at unacceptable concentrations regarding biological risk. The target concentration in groundwater is 5 ppb, as discussed in the regulatory part. No direct relationship between the concentration in the soil and the concentration in the aquifer can be found. Therefore, the target level of 5 ppb for the water does not naturally yield into a target clean-up level for soil.

Lead has mainly been found at a depth of 1.5 feet below the surface. But the water table is about 6 to 7 feet below the surface. As the site is almost totally covered, metals are probably not entrained into the groundwater by infiltration. Probable sources of lead in the groundwater are :

- uncovered areas underneath which water infiltrates during storms, entraining lead into the aquifer
- contaminated soil from which lead is washed out when the level of the water table fluctuates

With these assumptions, there are two excavation complementary options :

- excavation of the highest concentrations of lead in the soil, down to around 1.5 feet, when they are close to uncovered areas;
- excavation down to the deepest portion of soil, supposedly acting as a source of contamination for the groundwater.

For the second option to be valid, one still needs to determine where the highest concentrations of lead are near the water table. Without further investigation, all the site would have to be excavated to eliminate the risk of lead contamination !

That is all that can be concluded with the results of the investigations. Other sources of lead may exist that we are not aware of. Another unknown is the composition of lead in the soil that is to say the proportion of inorganic and organic lead. Probably all the lead that is left in the soil, decades after the spills, is only inorganic and can not be naturally degraded by bacteria in the soil, but it has not been proven. It is assumed here that all the lead left in the soil is inorganic and has to be removed during the excavation.

1.2. Excavation volume and mass : calculations

Uncovered areas do not correspond to high concentrations of lead in the soil around. To have a rough estimate of what mass of soil has to be removed due to the second option, let us assume that 1/6 of the site surface area is the major source of lead in water (presence of lead near the water table). The depth of the water table being at an average of 7 ft on the site, and the total surface area of the site being around 190,000 ft^2, the total volume of soil to be removed would be : $7ft * (190{,}000ft^2 / 6) = 220{,}000\ ft^3 = 6240\ m^3$.

With a wet soil density of 2g/cm^3 (typical value assumed), this yield a total mass of 12500 tons to excavate.

1.3. Estimation of the cost of excavation

In the course reader, a value of $50 per ton is given as typical. Hence, the excavation would cost : $625,000. Landfilling of the contaminated soil would cost about : $100 / ton * 12500 tons = $1,250,000, transportation cost included. Landban does not apply for this kind of waste (no chlorinated organic compounds, not a liquid waste with metals). There is no maintenance cost associated with excavation, as it can be done in a few days with nothing left on the site. Therefore a rough estimate of the total associated with excavation and landfilling of lead contaminated soil is : $ 1,875,000.

2. Excavation of free phase hydrocarbons

2.1. Excavation location and volume

The free phase hydrocarbons were found in MW 6 only, at a depth of around 5.3 feet = 1.6 m. The horizontal extent of the free phase has not been determined. It should be before excavation begins (this is not a requirement for the pumping option).
For the sake of our calculations, we considered the extent of the free phase to correspond to the polygon delineated around MW6. Therefore, the total surface area to be excavated is around : 1515 m^2.
The total volume of soil and free phase to be excavated would therefore be about :
1515 m^2 * 1.6 m = 2400 m^3.
Assuming a density of 2g/cm^3 for the sludge excavated, the total mass to excavate will be : 2400 m^3 * 2 ton/ m^3= 4800 tons.

2.2 Excavation cost

With $50 per ton, the excavation would cost : $240,000. Landfilling of the contaminated soil would cost about : $100 / ton * 4800 tons = $480,000, transportation cost included. There is no maintenance cost associated with the operation, as before. Therefore, a rough estimate of the total cost associated with the excavation and landfilling of the free phase and contaminated soil above is : $720,000.

3. Equipment

Excavation and transport for disposal or treatment uses conventional earth-moving equipment such as draglines, backhoes, clamshells, bulldozers and loaders. Transportation has to be in containerized vehicles with adequate protection against spillage and leakage (La Grega, 1994). For our site, the concrete cover would probably require heavier equipment, depending on the thickness and the resistance of the cover.

4. Safety and health issues

The safety of workers excavating the metal-rich and hydrocarbons-rich soil is a major concern.Workers will be directly exposed to inhalation of hydrocarbons if they are not protected. Contact with metals in the soil also presents a risk.

The on-site workers have to be kept out of the excavation zone during operation. The free phase zone is partly under offices, which will complicate the operation.

5. Disposal or treatment

The concrete removed can be reused after treatment to cover the excavated zones.

Another option is to put some clean soil back into the excavated zone and keep the area uncovered. This would allow a better oxygen penetration in the subsurface and a better degradation of hydrocarbons. A major disadvantage is the infiltration of rain, with higher leakage of the exposed contaminants into the groundwater. The site is also used as a commercial area so it is not desirable to keep it uncovered (parking places, walkways, etc needed).

MASS OF HYDROCARBON

Assume Depth of Groundwater = 2.5 meters

Porosity ≈ 30%

GASOLINE

Ave Concentration = 1645 $\frac{mg}{L}$

DIESEL

Ave Conc. = 320 $\frac{mg}{L}$

Motor Oil

Ave Conc. - 220 $\frac{mg}{L}$

Volume of water

$$33.7 \times 522.5 \frac{M^2}{Unit} \times 2.5\,M \times 0.30 \approx 13200\,M^3$$
$$= 13.2 \times 10^6\,L$$

MASS OF CONTAMINANT

$$\left[(1645 \times 10^{-6}) + (320 \times 10^{-6}) + (220 \times 10^{-6})\right] \times 13.2 \times 10^6\,L$$

$\boxed{\sim 29 \text{ kg of TPH in water}}$

FREE PHASE

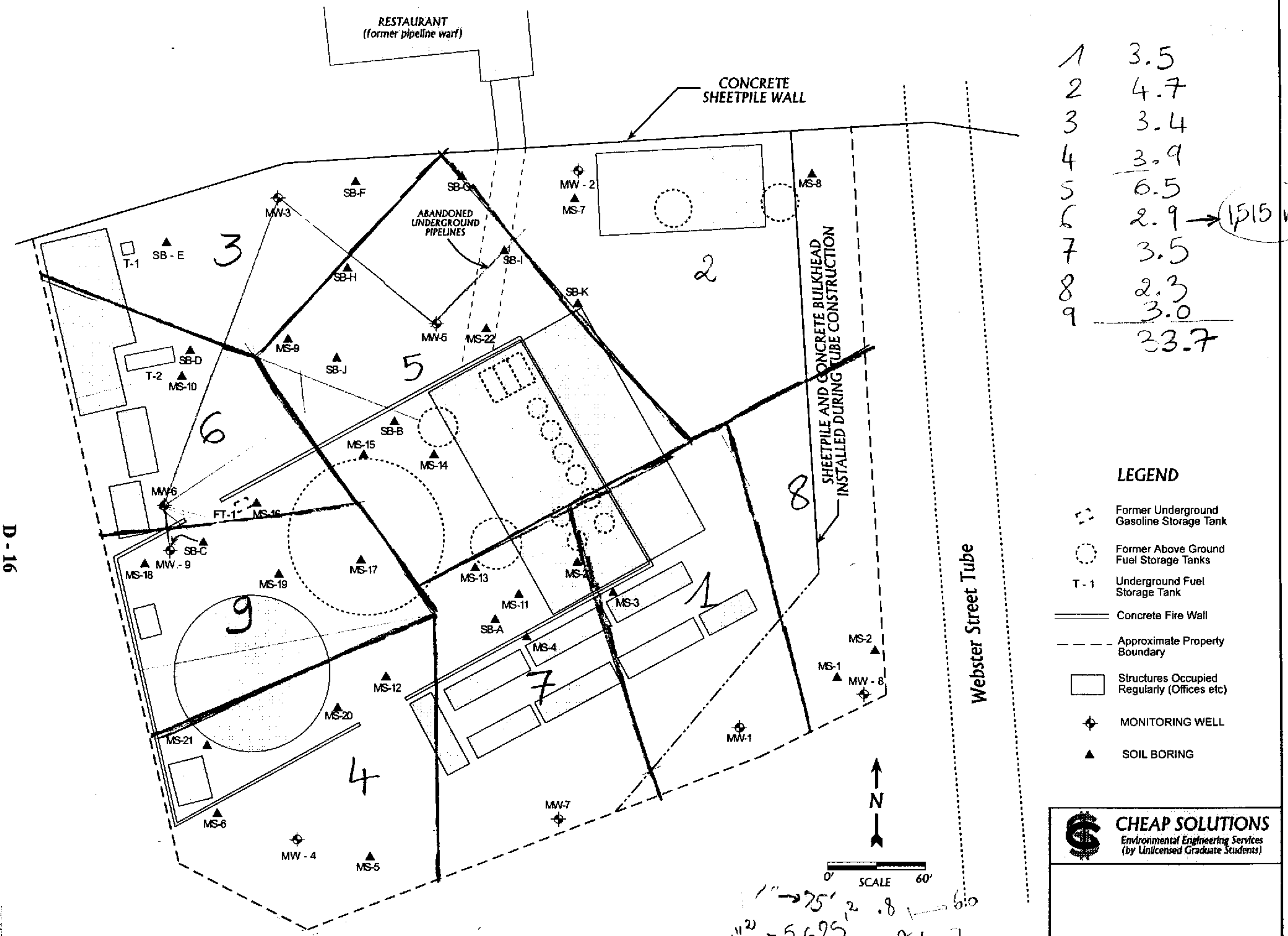
$$(0.03\text{ feet})\left(0.3048\frac{M}{ft}\right)\left(1515\,M^2\right)\left(0.8\frac{kg}{L}\right)\left(\frac{1000\,L}{M^3}\right)$$

$\boxed{11000 \text{ of TPH in Free Phase}}$

MASS OF TRPH IN SOIL (MAINLY TPH_d + TPH_g)

$\boxed{\sim 33{,}000\text{ Kg}}$ @ ABOUT 3.5 → 5.5 feet depth

D - 16



1	3.5
2	4.7
3	3.4
4	3.9
5	6.5
6	2.9 → 1515 m²
7	3.5
8	2.3
9	3.0
	33.7

1" → 75'

.8 → 60

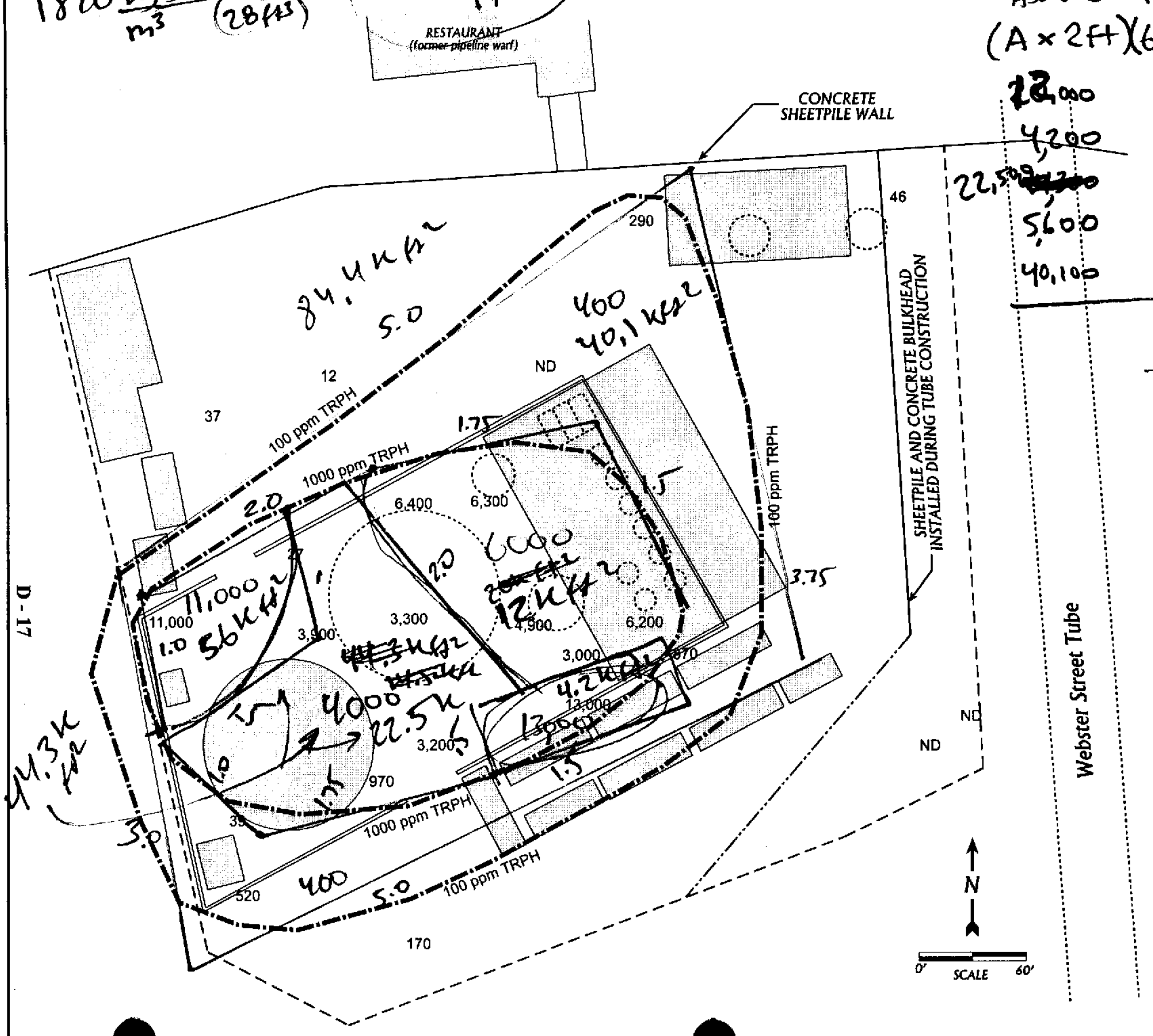
1"² → 5625'²

(522.5 m²) 33.7

$1890 \frac{kg\ soil}{m^3} \left(\frac{}{28 ft^3}\right) = 67.5 \frac{kg\ soil}{ft^3}$

ASSUME 2ft HIGH

$(A \times 2ft)(67.5 \frac{kg\ soil}{ft^3})(C \frac{mg}{kg}) = \frac{mg}{cont}$



~~12,000~~ 12,000
4,200
22,500 ~~[illegible]~~
5,600
40,100

6000 10^10 mg
13000 7.5^8
4000 1.2^10
11000 8.4^9
400 2.2^9

3.33 × 10^10 mg
→ 33,300 kg

LEGEND

1,000 TRPH (ppm)

◌ Former Above Ground Fuel Storage Tanks

═ Concrete Fire Wall

- - - Approximate Property Boundary

▨ Structures Occupied Regularly (Offices etc)

CHEAP SOLUTIONS
Environmental Engineering Services
(by Unlicensed Graduate Students)

Total Recoverable
Petroleum Hydrocarbons
(taken 1992 [illegible]th ~~[illegible]~~ 4.5 ft)