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Underground storage tank regulations: A critical assessment of the Federal, California and San Jose regulations

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Underground Storage Tank Regulations:
A Critical Assessment
of the Federal, California and San Jose Regulations

A final report submitted in partial satisfaction of the requirements for the degree

Doctor of Environmental Science and Engineering

by

Joseph Malulani Chun Afong

1989

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DEDICATION

In Mermory of My Father

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LIST OF ABBREVIATIONS

CAC	California Administrative Code
DCA	Dichloroethane
DCE	Dichloroethylene
DHS	Department of Health Services
EAK	Ethyl Amyl Ketone
EPA	Environmental Protection Agency
gal	gallons
gph	gallons per hour
Hg	mercury
HMP	Hazardous Materials Program
HMSO	Hazardous Materials Storage Ordinance
HSC	Health and Safety Code
IBM	Internal Business Machine Corporation
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MEK	Methyl Ethyl Ketone
MVF	Motor Vehicle Fuel
NFPA	National Fire Protection Agency
NMP	N-Methyl-2-Pyrrolidone
PCE	Perchloroethylene
RWQCB	Regional Water Quality Control Board
SCVWD	Santa Clara Valley Water District
SVTC	Silicon Valley Toxic Coalition
TCA	Trichloroethane
TCE	Trichloroethylene
TPH	Total Petroleum Hydrocarbon
UFC	Uniform Fire Code
USC	United States Code
UST	Underground Storage Tank

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ABSTRACT OF THE FINAL REPORT

Underground Storage Tank Regulations:

A Critical Assessment

of the Federal, California and San Jose Regulations

by

Joseph Malulani Chun Afong

Doctor of Environmental Science and Engineering

University of California, Los Angeles, 1989

Professor Michael K. Stenstrom, Chair

The underground storage tank (UST) is being used ubiquitously in the United States. In recent years, leakages from USTs have been recognized as a major cause of groundwater contamination. Once a material leaks from its storage container into the environment, the clean-up of the spilled material involves a tremendous amount of time and resources. Some case studies of solvent and motor vehicle fuel leaks are presented in this paper to illustrate the magnitude of impacts from leaky USTs. Other case studies describe gasoline leaks, which contain highly water soluble toxic components, such as benzene, toluene, xylenes, and ethyl benzene.

In 1983, cities in the Santa Clara County drafted a model ordinance to regulate USTs. San Jose adopted the Hazardous Materials Storage Ordinance and became one of the first jurisdictions in the country to have local UST regulations. In the same year, using the Santa Clara County Model Ordinance as a guide, California drafted similar UST legislation. The U.S. Congress did not pass legislation requiring EPA to promulgate federal UST regulations until 1987.

The federal, California, and San Jose UST regulations contain many common elements; however, there are also substantial differences in the regulations, especially with respect to the philosophy and the approach to regulation. Differences between the regulations provide an opportunity to evaluate the effectiveness of the different approaches.

This report provides an assessment on some of the major elements essential to an UST program. Recommendations are formulated based on insights gained in the assessment process, and they can be used to amend existing UST regulations to provide more effective UST program implementation. Recommendations discussed in this report include: 1) Improve coordination between governmental agencies; 2) establish a uniform set of federal regulations which can adequately address the needs of the majority of USTs in the country; 3) simplify UST regulations; 4) modify the definition of an UST; 5) require secondary containment for all new USTs and piping; 6) establish a tank replacement program; 7) provide a national technical review panel to evaluate and approve new leak detection devices; and 8) establish performance-based regulations utilizing best available technology.

EXECUTIVE SUMMARY

The underground storage tank (UST) is being used ubiquitously in the United States for the storage of solvents, waste solvents, motor vehicle fuels, waste oils, and a variety of other chemicals and wastes. In recent years, leakages from USTs have been recognized as a major cause of groundwater contamination. The groundwater is being used as a source of drinking water for approximately half of the population in the United States, and in the Santa Clara subbasin, it contributes to about half of the non-agricultural consumption.

Once a solvent or a motor vehicle fuel leaks from its storage container into the environment, the clean-up of the spilled material involves a tremendous amount of time and money. Some case studies of UST leaks are presented in this paper to illustrate the magnitude of impacts from leaky USTs. As a result of a leaky waste solvent UST, the Fairchild Camera and Instrument Corporation in San Jose was declared a State Superfund site; a public drinking water well has been shut down; more than 3,000 cubic yards of contaminated soil were excavated and disposed at a hazardous waste disposal site; millions of gallons of the groundwater have been extracted; and Fairchild was sued by its neighbors for birth defects and miscarriages. Despite more than seven years of extensive effort, the clean-up work is not finished. It is estimated that additional

clean-up will cost approximately $11 million and take at least five more years.

Leakages of waste solvents from USTs and piping at the International Business Machine Corporation (IBM) in San Jose led to the closure of four public drinking water supply wells, and plumes of the contaminants up to five miles long were found in three groundwater aquifers. IBM has spend $42 million in its mitigation effort, and further clean-up is estimated to cost an additional $42 million to $58 million for the next 20 years. The groundwater will be extracted initially at a rate of 2.4 million gallons per day. The Fairchild and IBM leaks provided the main thrust for the drafting of the Santa Clara Model Hazardous Materials Storage Ordinance.

In addition to solvent leaks, leakages from USTs used for motor vehicle fuel storage also have created severe impacts. Fuel leaks generally do not generate as much publicity and public outcries as solvent leaks; however, gasoline contains toxic components such as benzene, toluene, xylenes, and ethyl benzene, which have substantial solubilities in the water at levels exceeding the federal and California action levels. In a 1986 national survey on motor fuel USTs, the Environmental Protection Agency (EPA) estimated that 189,000 or 35% of the nation's non-farm USTs are potentially leaking. There are more than 130,000 fuel USTs in California; more than 6,000, in

Santa Clara County; and more than 1,000, in San Jose. There are currently over 850 cases of leaky fuel USTs reported in the Santa Clara County.

Leaks in underground gasoline distribution lines at a San Jose J.C. Penney service station and a Santa Clara County transit yard resulted in losses of approximately 15,000 gallons of gasoline and 300,000 gallons of diesel fuel, respectively. At the J.C. Penney service station, gasoline in excess of seven feet in thickness was detected on top of the groundwater, and benzene and xylenes were found in the groundwater in concentrations which exceeded the Department of Health Services' action levels. At the County transit yard, the floating product on the groundwater was found to cover an area of about one acre; while, dissolved contaminates extended to an area of approximately 2.4 acres. Despite spending millions of dollars in the clean-up efforts, which include the installation of interception trenches and groundwater extractions, the mitigation work at these two sites is still not complete.

The case history of a leak at a neighborhood service station presents the clean-up scenario for a small leak caused by holes in two USTs. As a result, some contaminated soil were excavated and removed; a soil vapor survey was conducted; and five soil borings and three groundwater monitoring wells were installed. The cost of investigation and limited soil removed is about $59,000. For final clean-up of the site, if vapor extraction can be used without any groundwater work, then additional clean-up may cost another $20,000; however, if the clean-up work involves the groundwater, then the cost will be much higher. Most fuel leak cases are not as extensive as the ones at the J.C. Penney service station or the County transit yard; however, the large number of fuel USTs and the prevalence of leakage from these USTs make leaky fuel USTs a concern and an important aspect of any UST regulations.

Due to the recognition of potential public health and environmental concerns associated with leaky USTs in the early 1980s and the lack of existing regulations for USTs, there was an urgent need to draft UST regulations at all levels of governments. In 1983, cities in the Santa Clara County participated in a county-wide effort to draft a model ordinance to regulate USTs. San Jose adopted its Hazardous Material Storage Ordinance (HMSO) in May of 1983, and it became one of the earliest local jurisdictions in the country to have its local UST regulations. In the same year, using the Santa Clara County Model Ordinance as a guide, California drafted similar UST legislation. The state statute required the State Water Resource Board (State Board) to draft detailed regulations for new and existing USTs. In 1987, the U.S. Congress passed legislation which required EPA to promulgate federal UST regulations.

The main components of the San Jose HMSO consist of new UST construction, leak detection, and closure requirements, as well as sections on permits, fees, compliance dates, and penalties. The HMSO requires secondary containment for new USTs and leak detection for both new and existing USTs. The HMSO is performance-orientated that it does not contain approval for specific secondary containment or leak detection devices. Instead, the staff of the Hazardous Materials Program (HMP) has to work with UST owners and operators, leak detection manufacturers and vendors, and other regulators to formulate acceptable installation and leak detection methods under the HMSO. Initially, the flexible membrane liner was the only available method for secondary containment of USTs and piping, but the double-wall UST and the fiberglass piping trench are now the more advanced methods for secondary containment. The groundwater monitoring well was originally the only leak detection method available to USTs, but now other options such as vadose zone monitoring and internal tank level sensors are preferred over groundwater monitoring. New leak detection devices such as piping pressure loss sensors are being developed specifically to address leak detection for piping.

The California UST statute was modeled after the Santa Clara County Model Ordinance, and it contains similar elements as the San Jose HMSO. However, it deviates from the performance-oriented approach of the Model Ordinance and contains specific approvals for certain leak detection systems and a special exemption for complete secondary containment of new fuel USTs. It retains some performance-oriented features that it requires the State Board to promulgate some technical standards. The state statute places responsibility for UST program administration at the county level, but it exempts local jurisdictions from the state regulations if a local HMSO meets some minimal state requirements. A distinctive feature of the state regulations is its approach to leak detection for existing USTs. The California Administrative Code lists eleven leak detection alternatives for existing USTs, which consist of different combinations of tank testing, inventory reconciliation, groundwater monitoring, vadose zone monitoring, soil testing, pipeline leak detector, and internal tank level monitoring. A variance has to be obtained from the State Board if an UST owner, operator, or a local administering agency wishes to deviate from the state requirements. The estimated fee for a variance ranges from $3,000 to $11,000.

The U.S. Congress passed federal UST regulations by attaching a new subtitle in the Hazardous and Solid Waste

Amendment of 1984. The new Subtitle I provides a detailed framework for a national UST program and requires EPA to promulgate regulations to supplement the legislation with technical standards. It instituted an interim prohibition on the installation of new USTs unless corrosion protection and leak detection are provided. Subtitle I also established the framework where UST owners and operators have to demonstrate that they have financial mechanisms to cover damages caused by leaky USTs. States are allowed to develop their own UST programs in place of the federal program. Since many elements of the federal UST program have already been specified in detail in Subtitle I, EPA only had to make interpretive rulings in these areas; however, EPA had to draft new rules in technical areas such as leak detection and new tank standards. One of the most distinctive features of the EPA regulations is the absence of secondary containment requirement for new petroleum USTs and piping; new USTs storing other regulated substances are required to have secondary containment. All existing USTs and piping must meet new UST standards which consist of cathotic protection; mean while, there is a phase-in schedule for the installation of leak detection systems which varies from one to five years, depending on the age of an UST. EPA has invested a substantial amount of effort in an attempt to quantify the accuracy and the detection limit of tank integrity tests and internal tank level sensors.

The federal, California, and San Jose UST regulations contain many common components. There are similarities within some of the components between the different regulations; however, there are also substantial differences between other components of the regulations, especially with respect to the philosophy and approach to regulation. Differences between the regulations can provide an opportunity to evaluate the effectiveness of the different approaches. This report provides an assessment on some of the major elements essential to an UST program, including:

* The adequacy of an UST regulation to regulate newly synthesized chemicals, which may be stored in USTs and are potential threats to public health and the environment;

* the adequacy of an UST definition to encompass partially buried tanks and those placed above ground and have direct contact with the ground surface;

* the use, advantages, and disadvantages of performance- and technologically-based standards;

* the adequacy of corrosion protection in the UST regulations;

* the regulatory approach to leak detection and the acceptance of various leak detection methods;

* new UST and piping construction requirements;

* the use of best available technology;

* consideration of resources available for program implementation;

* the need for technological assessment and information transfer;

* the advantages, disadvantages, and balance between flexibility and uniformity of regulations; and

* the need for improved coordination between leak detection and clean-up activities.

At the time when the San Jose, California and federal UST statutes and regulations were enacted or promulgated, there was limited knowledge regarding UST management within all levels of governments, UST owners and operators, equipment manufacturers and vendors, as well as the scientific community. Today, after acquiring experience through UST program implementation, it is desirable to review and improve the regulations. After six years of administering its pioneering UST program, the basic HMSO in San Jose remains largely unchanged. San Jose appears to be entrenched in its own regulations without much awareness of the state and federal regulations and without any vision for change. California has amended some technical aspects of its regulations, but its general regulatory approach remains unchanged. EPA acknowledges its lack of experience in many aspects of UST management and has requested state and local agencies for assistance.

After having considered the strengths and weaknesses of the different UST regulations, recommendations are formulated based on insights gained in the assessment process. Recommendations derived in this report can be used to amend the existing UST regulations to provide more effective UST programs and program implementation. Recommendations discussed in this report include:

* Improve coordination between governmental agencies to minimize duplication and to streamline the regulatory process for USTs;

* establish a uniform set of federal regulations which can adequately address the need of the majority of USTs across the nation without the need for excessive modification by local administering agencies;

* simplify UST regulations in order to make them more feasible for local administering agencies to implement;

* modify the definition of an UST to include a tank which has one or more surfaces in contact with the ground such that visual monitoring of the tank is not possible;

* require secondary containments for all new UST and piping constructions;

* establish a tank replacement requirement which shifts the emphasis of UST regulations from leak detection and clean-up to prevention;

* provide a national technical review panel to evaluate and approve new leak detection devices; and

* establish performance-based regulations using best available technology.

1.0 INTRODUCTION

The underground storage tank (UST) is being used ubiquitously in the United States for the storage of organic solvents, petroleum fuels, heating oils, waste oils, waste solvents, and a variety of other chemicals and wastes. In recent years, leakage from USTs, along with leakage from industrial and municipal landfills and lagoons, and spills of chemical, oil and brine, have been recognized as major causes of groundwater contamination. Groundwater contamination is an important public health and environmental concern because half of the population (117 million people) in the United States uses groundwater for drinking. Approximately 48,000 public water systems and 12 million individual wells are used to extract groundwater for drinking purposes (EPA, 1984a). During 1981 to 1982, in the Santa Clara sub-basin, groundwater also contributed to about half (140,000 acre feet) of the non-agricultural consumption. Several thousand private wells and about 300 groundwater wells were used by 16 large public water systems (EPA, 1984b).

Public awareness of the problems associated with UST is reflected in the news media coverage of the UST. In July of 1983, the San Jose Mercury newspaper published a three-day series titled "Clean Industry, Dirty Water" regarding contamination of groundwater in the Santa Clara County, as well as the rest of the country, with special emphasis on leakages from USTs used by the semiconductor industry. Also, in July of 1983, Times magazine published an article on pollution problems of the high-tech industries subtitled, "Chemical Pollution Tarnishes an Industry's Clean Image". In August of the same year, ABC Television presented on national television an one-hour documentary on contaminated water focusing on the Silicon Valley and three other cities in the country. Several families living in the South San Jose area were interviewed concerning the impact that contaminated groundwater has had on their lives.

The problems of leaky USTs and the deficiency in regulations for USTs were recognized by legislators at the local, state, and federal levels. In recent years, legislations have been enacted to address the issue of leaky USTs. In 1983, cities in the Santa Clara County drafted a model ordinance to regulate the storage of hazardous materials. The ordinance consists of requirements relating to the installation, closure, and leak detection of USTs for motor vehicle fuels, solvents, and other hazardous chemicals and wastes. In the same year, the state of California passed legislations requiring registration of USTs. In addition, the state legislations required the State Water Resources Control Board to draft regulations for new and existing USTs. The U.S. Congress followed suit and passed legislation in 1987, which required the U.S. Environmental Protection Agency (EPA) to draft regulations for USTs. The passage of these laws led to the drafting of administrative regulations and guidelines by regulatory agencies, and the development of UST programs at all levels of government.

In this report, an assessment will be performed on the existing federal, California, and San Jose UST regulations to evaluate the strengths and weaknesses of these regulations. The objective of this report is to help design a better set of UST regulations, which can be of value to the federal, state and local UST administering agencies. Because the leaky UST was not recognized as a major threat to public health and the environment until recently, regulatory agencies, UST owners and operators, and the scientific community have generally lacked the knowledge and experience on UST management. Due to an urgent need to address the concerns for leaky USTs, statutes and regulations for UST were adopted or promulgated without the benefit of previous experience. But now, with experience gained after six years of implementing the San Jose UST program, an assessment of these different UST regulations may reveal insights which were not apparent at the time the regulations were adopted.

Chapter 1 of this report presents the demographics of UST and an overview of typical UST installations for motor vehicle fuel, waste oil, solvent and waste solvent storage. In order to illustrate the consequences of leaky USTs and the magnitude of clean-up effort involved at contaminated sites, Chapter 2 presents case histories of some motor vehicle fuel leaks and waste solvent leaks in San Jose, including the two cases which provided the thrust for the drafting of the Santa Clara County Model Hazardous Materials Storage Ordinance. Chapter 3.1 gives a description of the San Jose Hazardous Materials Storage Ordinance and the implementation process of the ordinance. Chapters 3.2 and 3.3 provide similar descriptions of the federal and California regulatory processes, respectively. Chapter 4 provides an assessment of the regulations based on elements common to these three and any other UST regulations. Chapter 5 presents a list of recommendations which can be used to improve current regulations to make them more effective. Finally, Chapter 6 presents an outline of an ideal set of UST regulations based on a synthesis of the list of recommendations formulated in Chapter 5.

1.1 Demographics of Underground Storage Tanks

At the present time, the precise number of USTs in the United States, California or San Jose is unknown due mainly to the lack of a systematic registration and accounting system. In July of 1983, in accordance to its Hazardous Materials Storage Ordinance (HMSO), the City of San Jose initiated its Hazardous Materials Program (HMP) and required facilities with UST to submit inventories of hazardous materials at their facilities. Although the exact number of USTs in San Jose is not yet available, it is estimated that, in 1987, there were 1,056 fuel USTs, 289 waste oil USTs, and about 30 chemical and waste chemical USTs. Based on data from the Bay Area Air Quality Management District, it has been estimated that there are 6,453 fuel tanks in the San Clara County (Hinman, 1985). In 1984, the state of California also initiated a program to register all USTs in the state. As of January 1, 1988, 134,359 fuel USTs and 27,654 waste oil and chemical USTs have been registered (Moreno, 1989). In a 1986 survey funded by the EPA, it was estimated that there were 796,000 motor fuel storage tanks in the United States (EPA, 1986); however, there is much uncertainty in this estimate because of its wide 95% confidence limits of 503,000 to 1,090,000. Non-fuel tanks were not included in the survey.

1.2 Overview of Underground Storage Tank Facilities

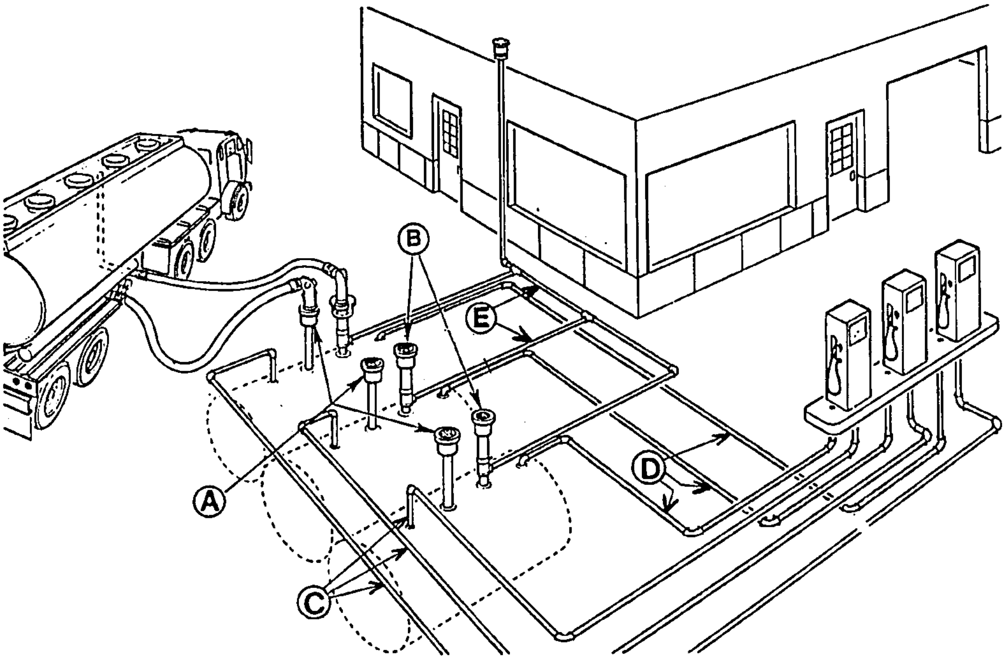
In almost all installations, an underground storage tank facility consists of one or more UST(s), dispenser(s), and buried piping connecting the tank(s) and dispenser(s). Since underground pipes have been a common source of leakage in an UST facility, underground piping has been included as an integral part of an UST as defined by federal, state and local regulations. In this report, an UST will be used to describe a buried storage tank as well as any buried piping associated with the tank.

1.2.1 Motor Vehicle Fuel Underground Storage Tanks

Most automobile service stations have three to four USTs for the storage of different kinds of motor vehicle fuel, such as regular and unleaded gasoline and diesel fuel. Sometimes, there are additional USTs for waste oil storage at stations that perform oil changes. Steel or fiberglass USTs with 10,000 gallon capacity are commonly used in service stations for motor vehicle fuels, and 500 gallon steel USTs are common for waste oil storage. In companies which are not in the motor vehicle fueling business but maintain fuel USTs for convenience item (for example, trucking firms), it is common to find smaller USTs in the size range of 500 to 2,000 gallons.

In a service station, there is a large array of piping associated with its fuel storage tanks. A product line delivers fuel product from an UST to the fuel dispenser, and a vapor return line transports vapor from vehicles being fueled back to the UST. Usually, a submerged centrifugal pump is placed inside an UST to pressurize all the delivery piping associated with that tank. Typically, a pair of main product and vapor return pipes come from the submergible pump to a service island, which come from the submergible pump to a service island, which is 50 to 100 feet from the UST, then branches off to different dispensers at the service island. Steel and fiberglass pipes (two inch diameter) are commonly used for fuel and vapor return lines. Air and vapor inside an UST expand and contract as the temperature changes; thus, a vent pipe is needed on each UST for pressure relieve and compensation. A vent pipe is usually a 1-1/2 or 2 inch diameter steel or fiberglass pipe, which is typically 50 to 100 feet in length and runs from the top of an UST to a high point above the roof of a service building. Also, there is a fill pipe at each UST for the delivery of fuel product and a tanker vapor return pipe to allow vapor inside an UST to escape back to a delivery tanker during fueling operations. Fill and tanker vapor return pipes are usually four inch diameter steel pipes with a typical length of four to five feet connecting the top of an UST to a service box just beneath the ground surface. Figure 1-1 presents a typical configuration of piping normally found in a service station. For a station that sells three types of fuel product and have three service islands with two sets of dispensers at each island, there may be as many as 45 pieces or segments of piping for product delivery, vapor return, vent, and tank filling operation.

Waste oil tanks are normally small, consisting of 500 gallons USTs placed next to service buildings. The piping



A. Fill Pipe with Over-fill Containment Box
B. Tanker Vapor Return
C. Product Delivery Pipe
D. Vapor Return Pipe
E. Vent Pipe

Figure 1-1. A typical configuration of piping layout at a service station.

Source: SWRCB, 1985

associated with waste oil tanks is usually much less extensive than those used for motor vehicle fuel delivery. There is usually only one straight four inch pipe that runs from the top of a waste oil tank to the ground surface. Waste oil may be deposited and removed from the same opening, or sometimes, a separate 1-1/2 or 2 inch diameter pipe is connected to the tank from an opening in the floor of the adjacent service building for more convenient drop-offs. Typical piping length in such instances are 10 to 15 feet. A vent pipe such as those for fuel UST is used for air pressure compensation.

1.2.2 <u>Solvent and Waste Solvent Underground Storage Tanks</u>

Solvent and waste solvent USTs are either steel or fiberglass tanks, and their sizes vary widely depending on the need of an individual facility . Like the waste oil UST, the waste solvent UST has a short four inch diameter pipe for solvent input and removal, and a vent pipe for air pressure compensation. For the waste solvent UST, there is usually one or more pipes from interior work areas for the direct input of waste solvent into the UST. Piping lengths can vary from 20 feet for a small facility to several hundred feet for a large complex facility.

In comparison to USTs for waste solvents, USTs for solvents have additional piping for tanker delivery and vapor return, and perhaps product delivery to end users.

Such systems are similar to a fuel UST but usually simpler because there is only one dispenser for each solvent UST as oppose to the multi-dispensing system at a service station. Furthermore, vapor return line is not necessary for the solvent UST.

2.0 CASE HISTORY OF UNDERGROUND STORAGE TANK LEAKS

2.1 Solvent and Waste Solvent Tanks

Although the number of waste solvent underground storage tanks (USTs) and the volume of their content is small in comparison to fuel USTs, the damaging effect on the environment created by a solvent leak is generally more severe than that of a motor vehicle fuel leak. Halogenated alkanes, chlorinated alkenes, ketones, esters and alcohols are solvents commonly used by the semiconductor industry. They are highly soluble in water; thus, contamination that arises from leakage of these solvents spread rapidly as contaminants mix and migrate with the groundwater. Water quality criteria, standards, and action levels for some of these compounds are presented in Table 2-1.

Two of the earliest and most severe incidents involving leaks of solvents from UST in Santa Clara County occurred in San Jose at the Fairchild Camera and Instrument Corporation and the International Business Machines Corporation. These two incidents generated much public interest and concern and became catalysts to the drafting of UST regulations in Santa Clara County.

Table 2-1. Water Quality Criteria, standards and action levels for some solvents commonly found in soil and groundwater in the Santa Clara County.

Compounds	DHS Action Levels[a] (ppb)	EPA's Drinking Water Regulations MCLs[b] (ppb)	EPA's Drinking Water Regulations MCLGs[c] (ppb)	EPA's Water Quality Criteria[d] (ppb)
Acetone	-	-	-	-
Benzene	0.7	5	0	66[i]
Chloroform	100[e]	-	-	0.19[i]
1,1-Dichloro-ethane (DCA)	20	-	-	-
1,1-Dichloro-ethylene (DCE)	6	7	7	0.033[i]
1,2-Dicloro-ethylene (DCE)	16	-	70	-
Freon 11[f]	3,400	-	-	-
Freon 12[g]	-	-	-	-
Freon 113[h]	18,000	-	-	-
Isopropanol	-	-	-	-
Methylene Chloride	40	-	-	0.19[i]
Perchloroethylene	4	-	0	0.80[i]
Toluene	100	-	2,000	14,300
1,1,1-Trichloro-ethane (TCA)	200	200	200	18,400
Trichloro-ethylene (TCE)	5	5	0	2.7[i]
Xylene	620	-	440	-

Footnotes:

a. DHS Drinking Water State Action Level (RWQCD, 1988).
b. EPA Maximum Contaminate Level (EPA 1985).
c. EPA Proposed or Final Maximum Contaminant Level Goals (EPA, 1985).
d. EPA Ambient Water Quality Criteria (EPA, 1980).
e. Based on MCL of 100 ppb for total trihalomethanes (THMs).
f. Trichlorofluoromethane (Freon 11).
g. Dichlorodifluromethane (Freon 12).
h. 1,1,1-Trichloro-1,2,2-trifluroethane (Freon 113).
i. Based on a lifetime cancer risk of 1 in 1,000,000.

2.1.1 Case History 1 - Fairchild Camera and Instruments Corporation

On November 25, 1981, the Fairchild Camera and Instruments Corporation (Fairchild) detected the presence of chemical residues in the groundwater at its South San Jose facility (Canonie, 1988). After an initial investigation, it was determined that there had been leakage from a fiberglass waste solvent UST. Contaminants found in the soil and groundwater consisted primarily of 1,1,1-trichloroethane (TCA) and 1,1-dichloroethene (DCE); while xylenes, acetone, isopropyl alcohol, 1,1,2-trichloro-1,2,2-tri-fluoroethane, (Freon 113) and tetrachloroethene (PCE) were also detected but in lesser amounts. Soil contamination was limited to the plant site; however, contaminants have migrated off-site to three groundwater aquifers (A, B and C). Groundwater aquifers are named alphabetically in increasing depth; A-aquifer is the shallowest, B-aquifer is deeper, and C-aquifer is deeper than both A- and B-aquifers. A public drinking water supply well (#13) which is located approximately 2,000 feet away and operated by the Great Oaks Water Company was shut-down when it was found to be contaminated. TCA was detected in the groundwater at levels as high as 8,800 ppb in the winter of 1981, and DCE was detected at 8.8 ppb in March of 1982 (DHS, 1985). Both chemicals exceeded EPA's drinking water standards or Maximum Contaminants Levels (MCLs) of

200 ppb for 1,1,1-TCA and seven ppb for 1,2-DCE. At the maximum extend, contaminants in the groundwater were found almost a mile from the leaky UST and reached a depth of up to 190 feet (RWQCB, 1988b).

Immediately after the discovery of the leak in December of 1981, the faulty UST was removed. A total of 3,389 yards of contaminated soil with an estimated 38,000 pounds of chemical residues was excavated in 1982 and disposed at a hazardous waste disposal site. During the process of defining the extent of the contamination, 275 soil borings were drilled. To control the spread of solvents in the groundwater, 136 groundwater observation and/or recovery wells were installed. Between 1982 and 1988, an estimated 75,000 pounds of solvents have been extracted from on-site recovery wells with an additional 15,000 pounds recovered from off-site wells. The groundwater has been extracted and discharged into the San Francisco Bay both with and without treatment since 1982. A pilot in-situ soil venting study removed over 400 pounds of solvents in 1987.

In an effort to prevent further migration of contaminants from the contaminated soil, Fairchild constructed a three-foot wide underground slurry wall in 1986 consisting of bentonite grout mixed with sand and gravel to encapsulate the site to a depth of 80 to 140 feet. The slurry wall completely surrounds the site on four sides, while the bottom is sealed naturally by a clay aquitard. An inward gradient is maintained across the wall through groundwater removal inside the site.

Since notification of the contamination, residents that lived near the leaky tank and were serviced by the Great Oak Water Company expressed concern that the contaminated water supply may be the cause of an apparent large number of birth defects and miscarriages in the near by areas. The Epidemiological Studies and Surveillance Section of California Department of Health Services, in collaboration with the Santa Clara county Health Department, conducted two epidemiological studies to examine a possible relationship. In both studies (DHS, 1985), the rate of spontaneous abortions for women resided in the area served by the contaminated water was compared to that of two control areas in the county. There was a 2.6-fold increase in the rate of major cardiac malformations among children of mothers residing in the affected area. The 95% confidence interval was 1.3 to 4.9. The magnitude of correlation between contaminated water and spontaneous abortions and birth defects seems convincing; however, the temporal distribution of cases did not support a conclusion that the Fairchild leak was the cause of the observed excesses. To clarify some of the possible confounding factors, the Department of Health Services (DHS) conducted further epidemiological studies.

In one study, the rate of spontaneous abortions for women in the study area who drank bottle water was compared to those who did not drink bottle water (DHS, 1988a). The results show the odds ratio to range from 0.3 to 0.8, and there was a significant negative correlation between the risk of spontaneous abortion and the amount of bottle water usage. Prevalence of birth defects was slightly, but not significantly, lower in women who drank bottle water. Despite these findings, once again, there was a lack of temporal correlation. Furthermore, DHS could not find animal data in its literature review to support a causal relationship. It concluded that "data presented in this report are perplexing" and "bias recall of exposure is the most likely candidate among those possible explanations" (DHS, 1988a).

In another study, DHS found that the prevalence of cardiac defects returned to normal after the study period, but this decrease did not coincide with the closing of the Great Oaks water supply well (DHS, 1988b). Thus, the leak seems to be an unlikely explanation for the cluster of birth defects found in 1981. In conclusion, DHS stated that "on balance it appears unlikely that the excess of cardiac defects seen in 1981 was due to waterborne exposure to TCA from Well #13, although it probably will never be possible to determine conclusively what role the leak played in this observed cluster" (DHS, 1988b).

Although there is no support from epidemiological studies for a causal relationship between Fairchild's leak and spontaneous abortion and birth defects, Fairchild was sued by neighbors with reported cases of spontaneous abortion and birth defects. The case was settled out of court in 1988 for an undisclosed amount of money.

In 1984, the Fairchild site was ranked 17th on the state's list of the 93 most hazardous chemical sites, and subsequently, it was declared to be a state Superfund site (SJMN, 1984a). As of October of 1988, Fairchild has spent $28 million on its site investigation and remedial efforts. The extensive mitigation effort by Fairchild seems to have an effect in decreasing the amount of contaminants in the groundwater. Due to the continuous pumping of groundwater, A-aquifer is now essentially dry (Canonie, 1988). TCA in off-site B-aquifer wells has decreased from greater than 1,000 ppb in 1982 to 100 ppb in June of 1988. In off-site C-aquifer wells, TCA has declined from more than 1,000 ppb in October of 1982 to less than 5 ppb at the present time, while DCE has declined form 3.0 ppb to non-detectable levels. However, despite all of Fairchild's efforts for the past seven years, mitigation work at the site is not finished.

In March of 1987, the San Francisco Regional Water Quality Control Board (RWQCB) ordered Fairchild to submit a report or a Remedial Action Plan (RAP) to evaluate the effectiveness of interim clean-up measures and propose alternatives for final clean-up of the site. Fairchild submitted a draft in September of 1987 and a revised version in October of 1988. In the revised RAP, Fairchild presented seven clean-up alternatives, ranging from no further action to extensive continue clean-up with a cost estimate ranging from $1.3 million to $21.9 million (RWQCB, 1988c).

The RWQCB's staff reviewed Fairchild's RAP and recommended the Board to adopt, with some modifications, a combination of two different alternatives proposed by Fairchild (RWQCB, 1988d). For on-site clean-up, groundwater pumping would continue until drinking water action levels are achieved for all chemicals, and in-situ aeration of soil would be used to decrease the TCA level to 1 ppm. The duration of these on-site clean-up operations remains uncertain due to the lack of sufficient knowledge on soil aeration. For off-site clean-up, groundwater extraction in the B-aquifer would continue until chemical concentrations are reduced enough to achieve a Hazard Index[2-1] of 0.25. Pumping is estimated to continue for five years with an initial pumping rate of about 984 acre-feet per year or 878,000 gallons per day. Estimated costs for on- and off-site clean-up are $6.5 million and $4.4 million, respectively. This translates to an estimated total cost of $10.9 million. The final RAP has been approved by the

RWQCB on January 18, 1989 (RWQCB, 1989).

The fiberglass UST in Fairchild's leak was a fairly new tank, which had been in use for less than four years prior to the discovery of the leak. The accurate date when the leak began is unknown because the tank was not routinely monitored; however, Fairchild estimated that the leakage probably occurred sometime after the middle of 1980 (Fairchild, 1982). A probable explanation for the leak is that the resin material used in the construction of the tank was incompatible with the kind of wastes deposited in the tank. The waste mixture reacted with the resin and deteriorated the tank.

The exact quantity of leakage was unknown because there was no inventory control to indicate the volume of waste solvents deposited in the tank. Measurements using a dip stick were the only method used to measure the level of waste in the tank, and it was used only to test whether the tank was full and needed to be emptied. In a reconstruction effort using material balancing, Fairchild estimated that about 60,000 gallons of a variety of waste chemicals had leaked from the tank (Fairchild, 1982).

2.1.2 Case History 2 - International Business Machines Corporation

Leakages from USTs and pipes at the International Business Machines Corporation (IBM) in San Jose presented a similar situation as the Fairchild case. IBM discovered the presence of chemical contaminants in its groundwater in September of 1980 (SJMN, 1983). Four public drinking water supply wells and several private wells in South San Jose were shut down in 1984, and more than a dozen public and private wells were threatened (SJMN, 1984b). According to one environmental organization, the Silicon Valley Toxics Coalition, the leak is the largest discovered in the Santa Clara Valley (SVTC, 1989). Contamination was found in three groundwater aquifers with plumes of up to five miles long. The site was listed 21st on the state's list of 93 most hazardous chemical sites in 1984 (SJMN, 1984a). Contaminants found at the site in soil and/or groundwater included (Kennedy and Jenks, 1987):

Halogenated Alkanes:
1,1,1-Trichloro-1,2,2-trifluorethane (Freon 113)
Dichlorodiflurомethane (Freon 112)
Trichlorofluoromethane (Freon 11)
1,1,1-Trichloroethane (1,1,1-TCA)
1,1-Dichloroethane (1,1-DCA)
Chloroform
Methylene Chloride

Chlorinated Alkenes:
Perchloroethylene (PCE)
Trichloroethylene (TCE)
1,1-Dichloroethylene (1,1-DCE)
1,2-Dichloroethylene (1,2-DCE)

Hydrocarbons:
Toluene
Xylene
Diesel Fuel
Kerosene
Shall Sol 140
Petroleum Naphtha

Ketones/Esters/Alcohols:
Acetone
Methyl Ethyl Ketone (MEK)
Ethyl Amyl Ketone (EAK)
Isophorone
N-Butyl Acetate (NBA)
Isopropanol (IPA)
N-Methyl-2-Pyrrolidone (NMP)

Most of these chemicals have been found only within the IBM site; however, four have been found off-site with Freon 113 being the most prominent, followed by TCA, and 1,1-DCE and TCE in lower concentrations.

As of June, 1987, mitigation measures used to clean-up the site included the following:

1. Sixty five USTs have been removed or replaced with above grade tanks with secondary containment and monitoring systems.

2. Approximately 23,000 cubic yards of contaminated soil have been excavated and disposed at Class I landfills.

3. Over 1,000 soil borings have been drilled in the attempt to define the extend of the contamination.

4. Over 350 new monitoring wells have been installed in addition to the 40 existing ones. Figures 2-1, 2-2 and 2-3 depict the location of monitoring and extraction wells in A- and B-aquifers.

5. Approximately 25,000 groundwater samples have been collected and analyzed.

6. About 9 million gallons of groundwater have been extracted.

IBM has thus far spend $42 million in its mitigation effort (SVTC, 1989). During June of 1987, the groundwater was extracted at the rate of about 8.8 million gallons

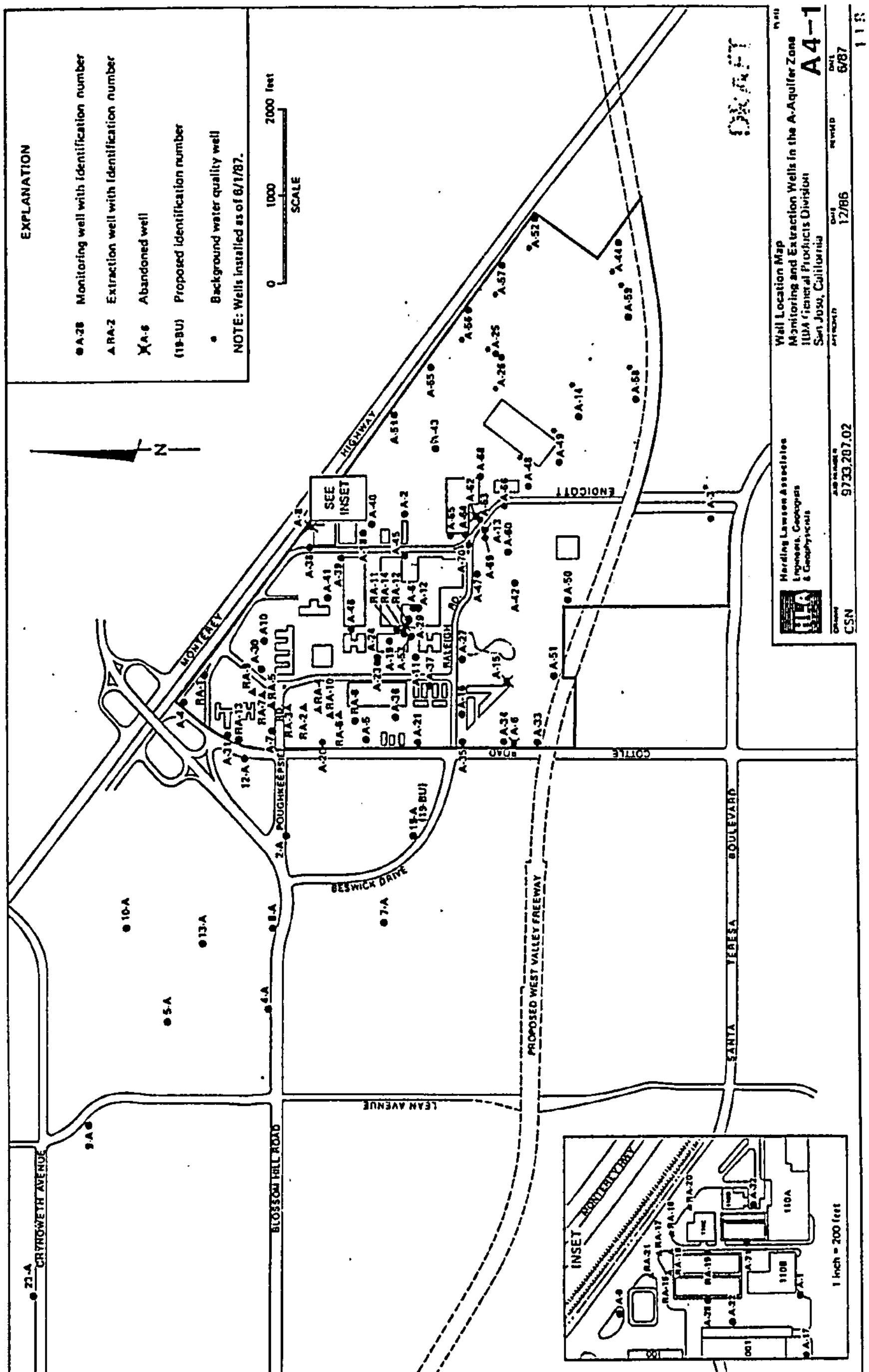


Figure 2-1. Location of monitoring and extraction wells in the A-Aquifer at the IBM site in San Jose. Source: Kennedy and Jenks, 1987.

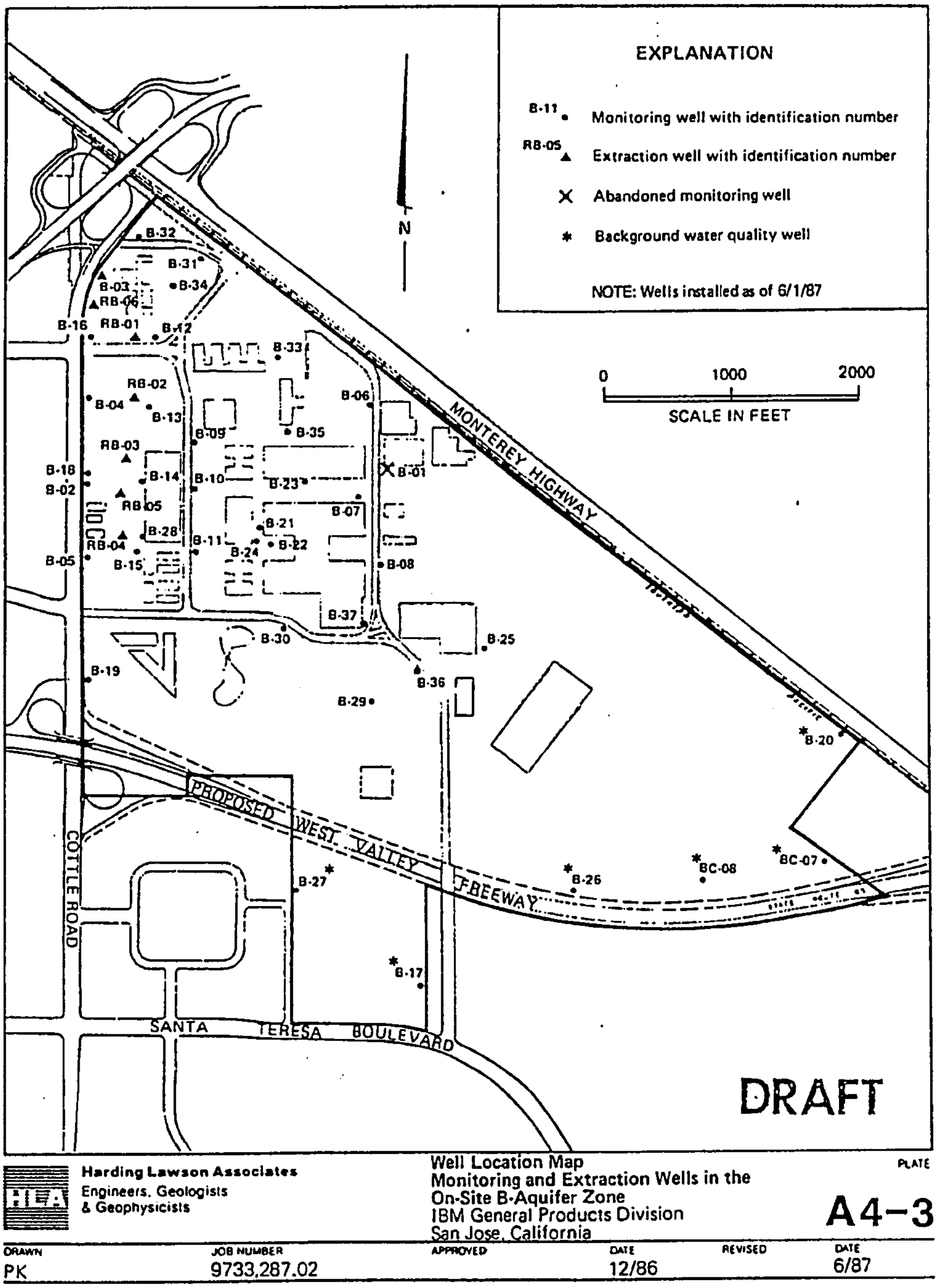


Figure 2-2. Location of monitoring and extraction wells in the B-Aquifer at the IBM site in San Jose. Source: Kennedy and Jenks, 1987.

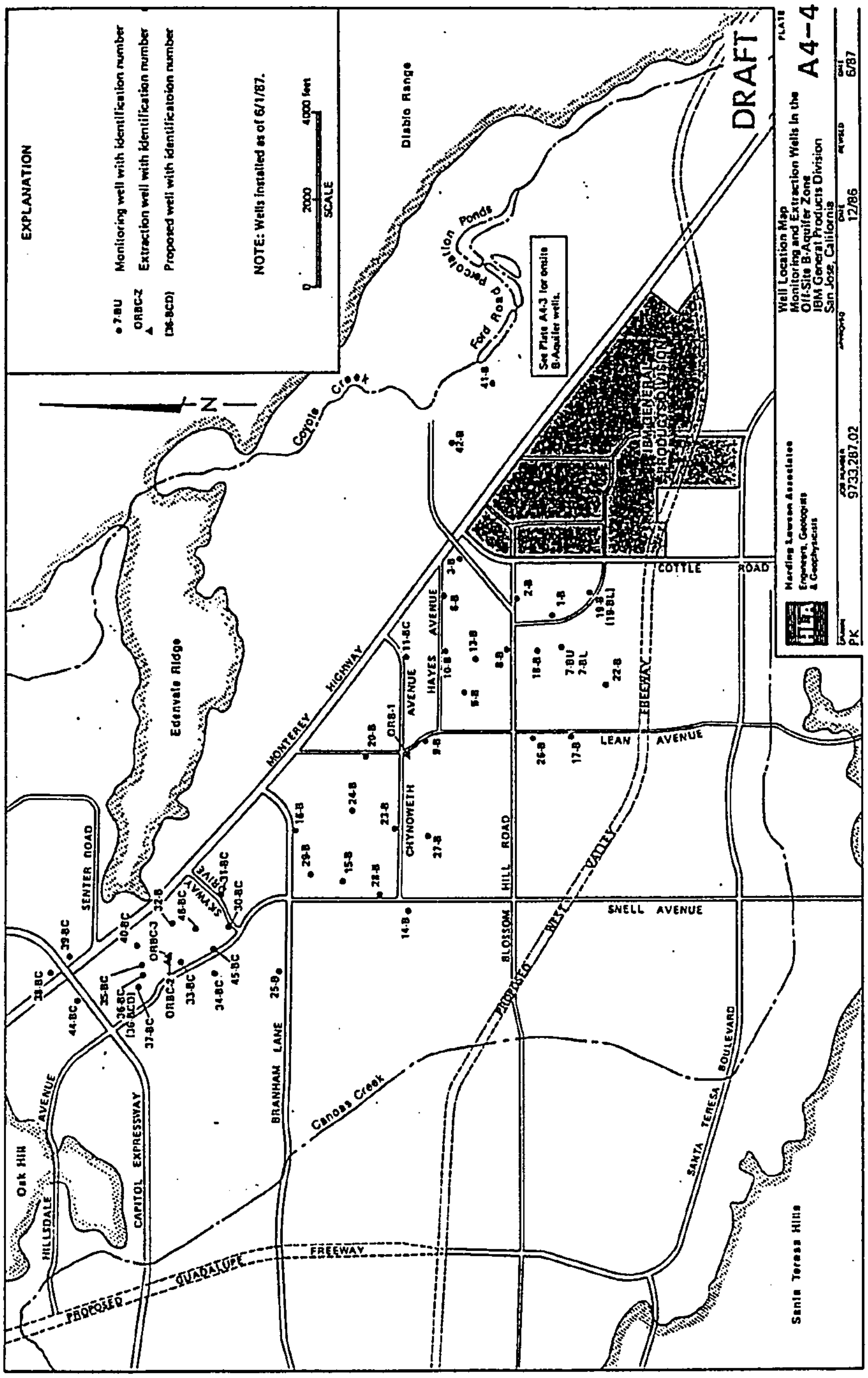


Figure 2-3. Location of monitoring and extraction wells in the B-Aquifer off-site from the IBM site in San Jose. Source: Kennedy and Jenks, 1987.

per day, which is approximately the amount of water 11,700 families of four typically use each day. The use of extraction wells to control migration of chemicals in the groundwater has caused groundwater levels to decline. By June of 1987, only one of the 13 extraction wells in the A-aquifer remained in operation (Kennedy and Jenks, 1987).

In June of 1987, IBM submitted a comprehensive plan to RWQCB with six options for the continued clean-up of its site. In October of 1988, RWQCB adopted a plan which required IBM to clean the groundwater in the B- and C- aquifers to more than four times the present Safe Drinking Water Levels for each non-cancer causing chemicals, with the exception of TCE. The Hazard Index for the mixture of chemicals has to be less than or equal to 0.25. At the same time, the cancer risk from groundwater consumption should not exceed one in a million above the background level. The Safe Drinking Water Levels are used as clean-up goals for chemicals in the A-aquifer. Less stringent clean-up goals were adopted for the shallowest A-aquifer because the groundwater in this aquifer is not used directly for drinking water supplies. Furthermore, attenuation occurs as contaminants migrate from the shallower to the deeper aquifers. The adopted clean-up levels for individual chemicals for the different aquifers are presented in Table 2-2.

Table 2-2. Groundwater cleanup levels for IBM in different water aquifer and regulated drinking water levels (RWQCB, 1988d).

Proposed Groundwater Cleanup Levels in the Aquifer and Regulated Drinking Water Levels.

Location of Chemicals	Cleanup Levels (ppb)*		Regulated Drinking Water Levels (ppb)	
	A-Aquifer	B- & Deeper	SAL or Guideline	EPA MCL
Chemicals found Off IBM Site				
Freon 113	18,000	4,500	18,000(SAL)	NA
1,1,1-Trichloroethane (TCA)	200	50	200(SAL)	200
1,1-Dichloroethylene(DCE)	6	1.5	6(SAL)	7
Trichloroethylene(TCE)	5	3.1	5(SAL)	5
Chemicals Found On IBM Site				
Benzene	0.7	N.P.	0.7(SAL)	5
1,2-Dichloroethylene	16	N.P.	16(SAL)	NA
1,1-Dichloroethane	20	5	20(SAL)	NA
Acetone	700	N.P.	700(ARC)	NA
Chloroform	4.3	0.43	4.3(AAL)	NA
Ethyl Amyl Ketone	123	N.P.	123(ARC)	NA
Freon 11	3,400	850	3,400(SAL)	NA
Freon 12	750	N.P.	750(ARC)	NA
Isopropanol	450	N.P.	450(ARC)	NA
Methylene Chloride	40	4.8	40(SAL)	NA
N-Methyl-Pyrrolidone	700	N.P.	700(ARC)	NA
Perchloroethylene	4	N.P.	4(SAL)	NA
Shell Sol 140	1,000	N.P.	1,000(ARC)	NA
Toluene	100	N.P.	100(SAL)	NA
Xylene	440	N.P.	620(SAL)	NA

NOTES:
ppb* .. Parts per billion of chemical concentration
SAL .. Dept. of Health Services Drinking Water State Action Level
AAL .. Dept. of Health Services Applied Action Level for Cleanup
ARC .. Dept. of Health Services Aquifer Remediation (cleanup) Criterion
MCL .. Environmental Protection Agency, Maximun Contaminent Level
NA .. No applicable guidelines for chemical
NP .. Not Present

To carry out the proposed clean-up, it is estimated that the groundwater will have to be extracted for 20 years at on-site wells and for 10 years at off-site wells with an initial combined extraction rate of more than 2.4 million gallons per day (RWQCB, 1988d). The rate of clean-up may be limited by the amount of water present in the aquifers. In order to conserve water, the treated groundwater will be used in IBM's cooling towers, irrigation systems and groundwater recharge wells on site; while the untreated groundwater will be used for irrigation. The initial cost to install and build the necessary clean-up apparatus is estimated to range from $8.1 million to $13.7 million, and the operating cost is anticipated to range from $1.7 million to $2.2 million each year. The operating cost for 20 years is estimated to range from $42.1 million to $57.7 million at present value.

2.1.3 Other Solvent Leak Cases

The discovery of groundwater contaminations at IBM in September of 1980 was the first documented case of chemical contamination of groundwater by an electronics firm in the Santa Clara County. Subsequently, in the next 15 months, a series of leaks were discovered at other sites including Fairchild in San Jose, another IBM site in San Jose, Intel Corporation in Mountain View, and two of Hewlett-Packard Company's plants in Palo Alto. In March of

1982, after the discovery of several solvent UST leaks, RWQCB required subsurface chemical contamination investigations for companies in the Santa Clara County, South Alameda County and Livermore Valley which had a solvent or waste solvent UST that did not have corrosion protection and was placed in operation prior to January 1, 1975. Out of eighty companies which performed and completed investigations, 64 (80%) found contaminations in the ground beneath their plants, and 57 (71%) appeared to have hazardous materials leaked from underground facilities which have caused, or threaten to cause, contamination of the groundwater (RWQCB, 1983).

Not all solvent contamination cases are as severe as the Fairchild and IBM cases; however, almost all leaks which involve the clean-up of the groundwater are a costly endeavor. For example, when a solvent contamination was discovered in a $120 million high-rise project in San Jose, the developer had to spend more than $1.5 million on its clean-up (SJBJ, 1986). Perchloroethylene was found in the groundwater at concentrations as high as 5,400 ppb. The solvent probably came from an old laundry operation which had previously occupied the site. The clean-up effort involved extracting the groundwater and stripping the volatile organics through three sprinklers installed at a water fountain.

2.2 Motor Vehicle Fuel Storage Tanks

Leakages from USTs used for motor vehicle fuel storage generally do not generate as much publicity and public outcries as those of chemical storage tanks. This is because gasoline was thought to be rather innocuous, and spilled fuel would float on the groundwater surface in the shallow aquifer without too much danger of migration to deeper aquifers where water producing wells are located. However, gasoline contains toxic components including benzene (2-3%), toluene (5-18%), and xylenes and ethyl benzene (9-23%) (Guard, 1983), and these constituents have substantial solubilities in the water at levels exceeding the federal and California action levels (Table 2-3). Octanol/water partition coefficients for benzene and toluene have been determined to be 135 and 490, respectively (Buikema and Hendricks, 1980). Once toxic constituents are partitioned into the groundwater, they can migrate with the groundwater and are capable of moving from shallow aquifers to deep drinking water aquifers.

2.2.1 Case History 1 - J.C. Penney Company, Eastridge Mall

On February 20 of 1979, two explosions occurred almost simultaneously in a water pump station at the Eastridge Shopping Mall when its automatic pumps were turned on. The pump station is a 24-foot by 12-foot structure

Table 2-3. Comparison of solubility and federal and California action levels for toxic components found in gasoline.

Compound	Solubility[a]	DHS Action Levels[b] (ppb)	EPA MCL[c] (ppb)	EPA MCLG[d] (ppb)
Benzene	19,100 - 42,500	0.7	5	-
Toluene	17,300 - 61,400	100	-	2,000
Xylenes	9,500 - 27,700[e]	620	-	440
Ethyl benzene	-[e]	-	-	680

Footnotes:

a. Solubility in 18°C water (Guard et.al., 1983)

b. Department of Health Services Drinking Water State Action Level (RWQCB, 1988).

c. EPA Maximum Contaminant Level (EPA, 1985).

d. EPA Proposed Maximum Contaminant Level Goal (EPA, 1985).

e. Solubility for xylenes and ethyl benzene was determined together as C_2-benzene (Guard et.al., 1983).

located 16 feet below the ground level and is used to collect storm water runoffs from the low lying part of the mall. The cause of the explosions was attributed to leaks in the gasoline distribution lines of a J.C. Penney Company automobile service center approximately 100 feet from the pump station (Dames and Moore, 1979). Gasoline and gasoline vapor from the leak migrated through the groundwater and soil and accumulated in the pump station. An inventory audit subsequent to the explosions revealed a loss of approximately 15,000 gallons of unleaded gasoline in a period of 15 months prior to the explosions (Dames and Moore, 1988b).

The J.C. Penney store was a relatively new store constructed around 1970, and there were three 10,000 gallon USTs at the service station. After the explosion, on March 2 of 1979, gasoline odor was detected in the basement of the service station (Dames and Moore, 1979). An investigation led to the discovery of gasoline in an oil interceptor sump in the basement, which is located 225 feet from the leaky lines. The oil interceptor measures four feet by eight feet and is buried eight feet below the basement. It was used to separate the oil and grease from the service station's waste water stream before the waste water is discharged to the sanitary sewer. As a part of the clean-up effort, approximately 20,000 gallons of waste water and gasoline mixture with about 5,400 gallons of fuel were pumped out from the sump in the course of several days and hauled to a Class I hazardous waste disposal site. Subsequently, pumping continued for several weeks by a Roto-Rooter unit which drew 2,600 gallons of water and gasoline mixture once or twice a week. It was not clear where the Roto-Rooter unit disposed the waste mixture.

Between 1979 and 1980, in an effort to determine the extent of contamination, 18 monitoring wells were installed at the site. In 1979, gasoline in excess of seven feet in thickness was detected on top of the groundwater in two monitoring wells. As the gasoline plume migrated in a northwestern direction, it became flattened and thinner. Figure 2-4 shows the contour of the gasoline thickness found in May of 1979, where the thickest level (6.3 feet) was found in well number 17.

A 450-foot long interceptor trench was installed late in 1979 to stop the further migration of the contaminants and to recover some of the gasoline. With the interceptor trench in operation, the gasoline plume can be seen migrating in a northern direction toward the trench. Figure 2-5 shows the gasoline plume configuration on October 29, 1979 where the gasoline lens on top of the groundwater was found to be as thick as five feet. By February of 1982, there was a further decrease in the plume thickness as it continued to migrate toward the interceptor trench.

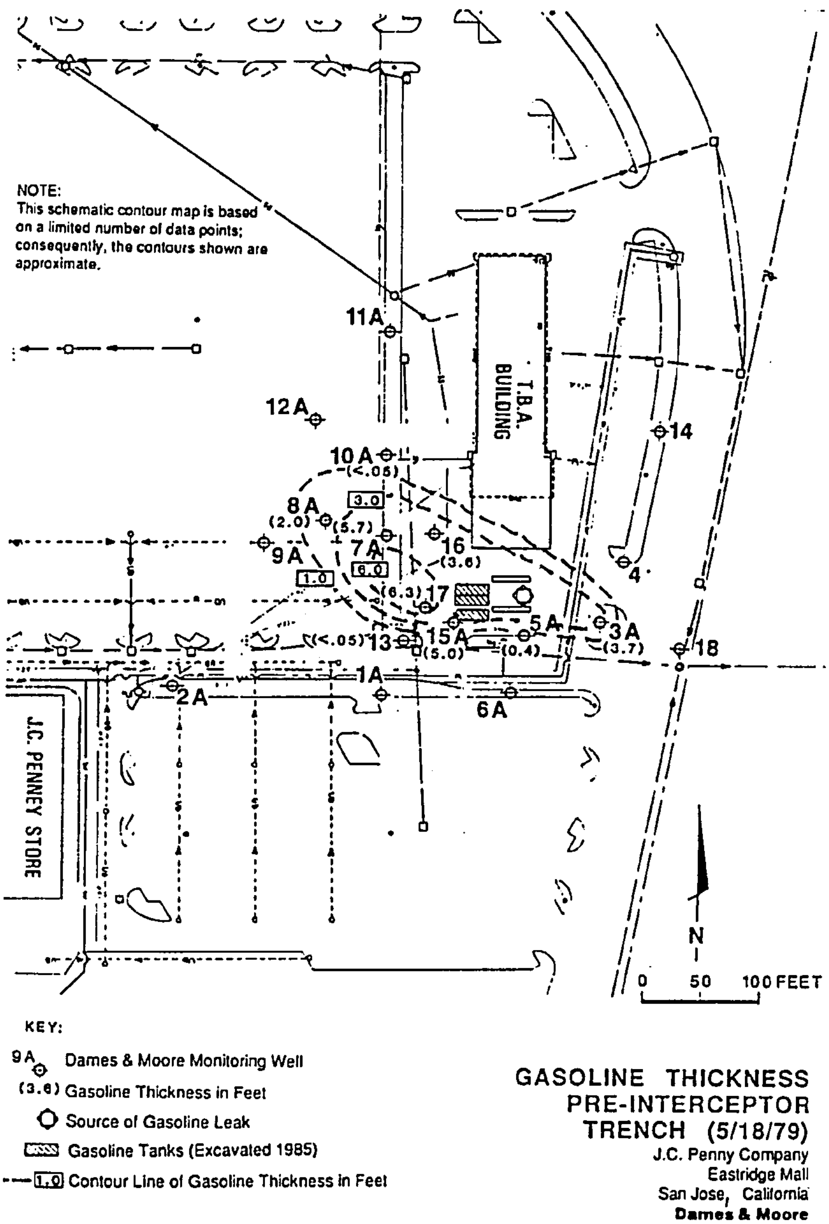


Figure 2-4. Thickness of gasoline found in monitoring wells on May 18, 1979 before the installation of the interceptor trench at the J.C. Penney service station in San Jose. Source: Dames & Moore, 1979.

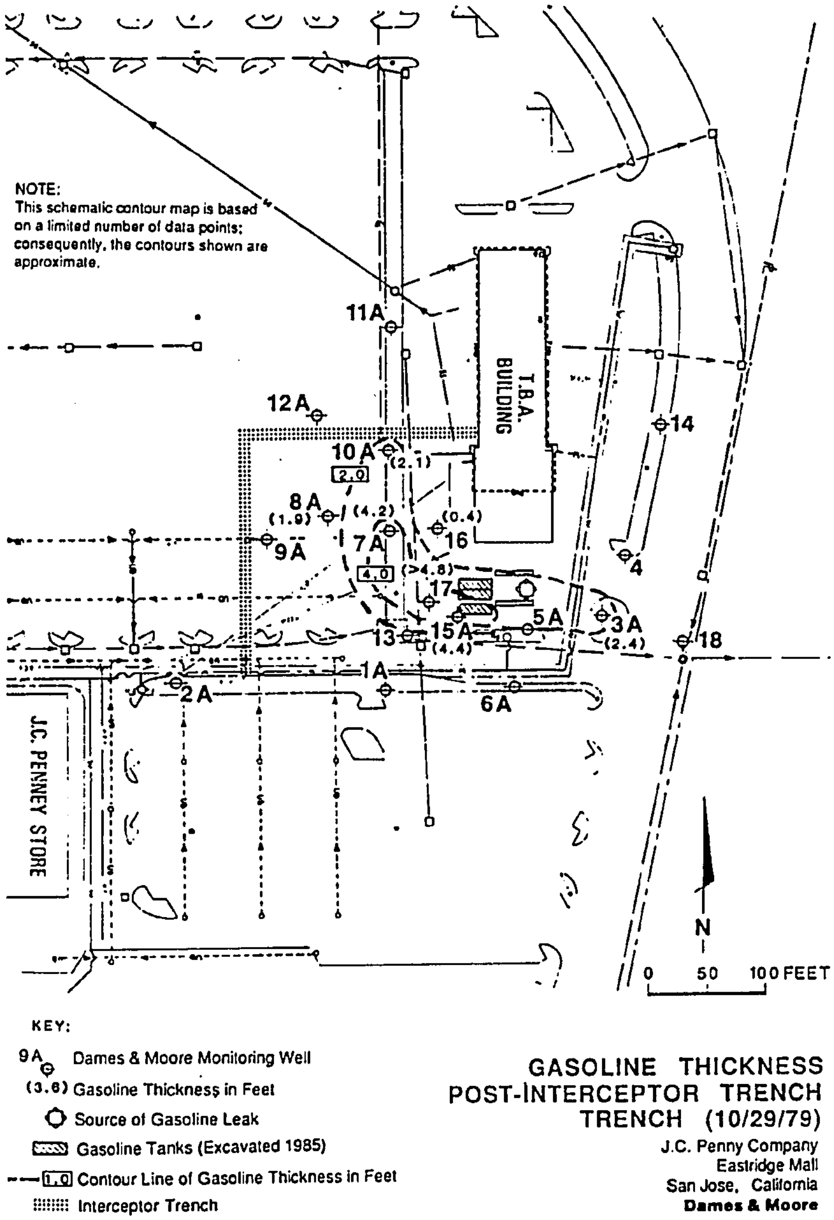


Figure 2-5. Thickness of gasoline found in monitoring well on October 29, 1979 after the installation of the interceptor trench at the J.C. Penney service station in San Jose. Source: Dames & Moore, 1979.

In July of 1984, the San Jose Fire Department ordered the removal of the three inactive USTs at the site. The tanks were removed in October of 1985, and soil samples obtained beneath the USTs were found to contain hydrocarbon concentrations ranging from 1.8 to 11.7 mg/kg, which were below RWQCB action level of 100 mg/kg. However, analysis of a groundwater sample showed benzene and xylenes concentrations of 1,200 and 2,000 ug/l, respectively (Safety Specialist, 1985). They exceeded the Department of Health Services action levels of 0.7 ug/l for benzene and 620 ug/l for xylenes.

When a new site investigation was performed in February of 1986, the interceptor trench was found to be inoperative, and apparently it has not been in operation for some time (Dames and Moore, 1988b). Furthermore, only four of the 18 monitoring wells installed in 1979 could be located. The other 14 were either buried by dirt and vegetation, paved over with asphalt, or destroyed during the excavation of the fuel tanks. It was not clear when the remedial effort stopped and who authorized the termination. In a letter to the site occupant on December of 1985, the RWQCB required the groundwater wells to be monitored every six months which included a measurement of the water level and the depth of fuel product, and a groundwater analysis for the dissolved constituents

(RWQCB, 1985). There was no mention of water or petroleum product extractions.

In the 1986 investigation, 3/8 and 2-1/4 inches of floating gasoline were observed in two of the four remaining wells. A soil gas study was conducted in April of 1987, where 40 probes were driven into the soil in an attempt to obtain volatile hydrocarbon readings and to correlate them to the presence of gasoline in the groundwater underneath. The gasoline vapor was found to be confined to an area of about 100 feet by 400 feet in approximately the same location where gasoline was found on the water table in the past (Figure 2-6). A second area with a high level of soil hydrocarbons was detected northwest of the main plume. The chemical composition of this plume was different from a gasoline plume since it was composed mainly of methane and did not have the common composition of gasoline such as benzene, toluene, and xylenes (Figure 2-7). It is likely that the methane came from a nearby sanitary sewer. In 1987, six new monitoring wells were installed, and groundwater samples from these and two additional existing wells were obtained and analyzed. Concentrations of benzene, toluene, and xylenes were found to exceed the Department of Health Services' recommended action levels and the EPA's drinking water standards. Table 2-4 presents the results of the analysis and compares them to the state and federal standards.

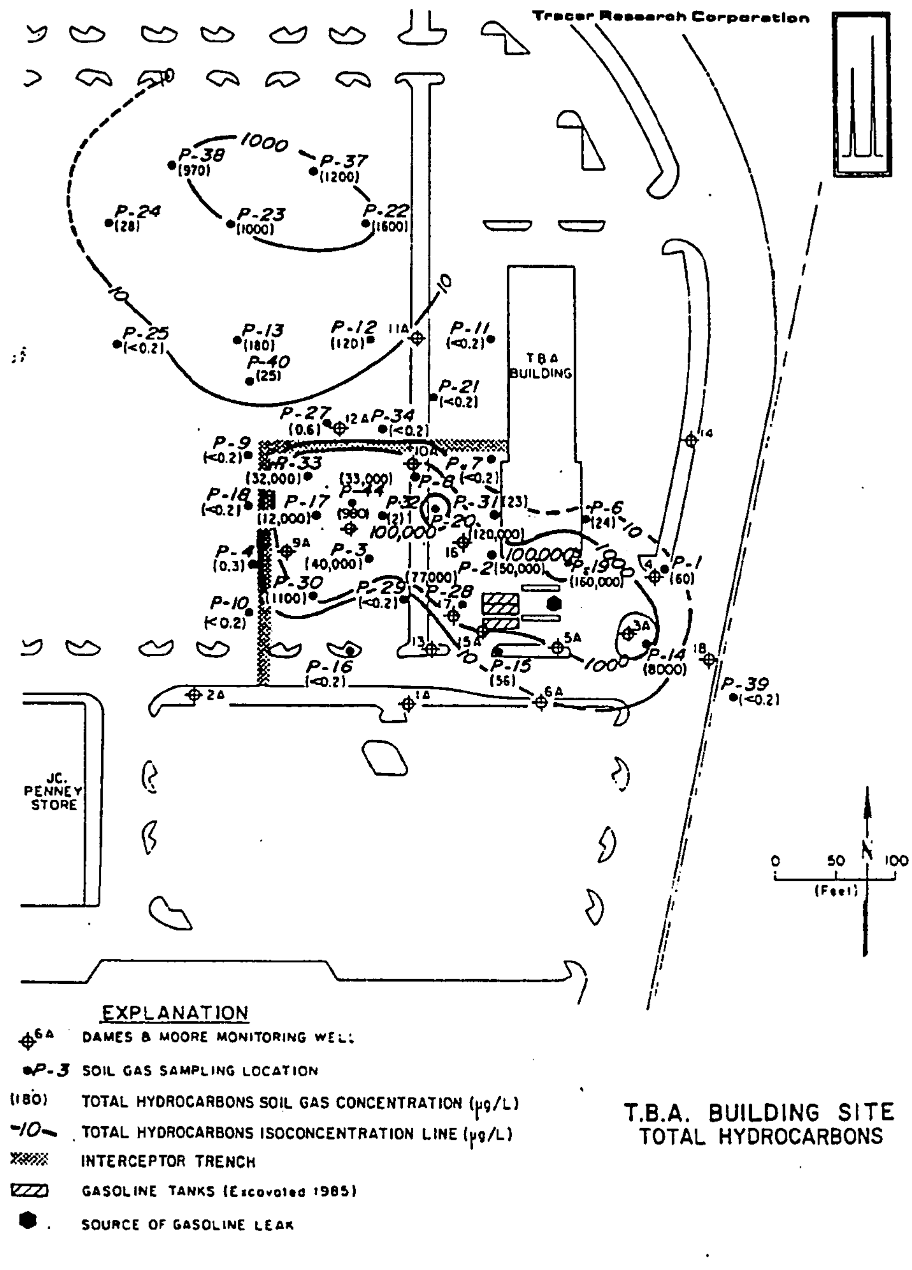
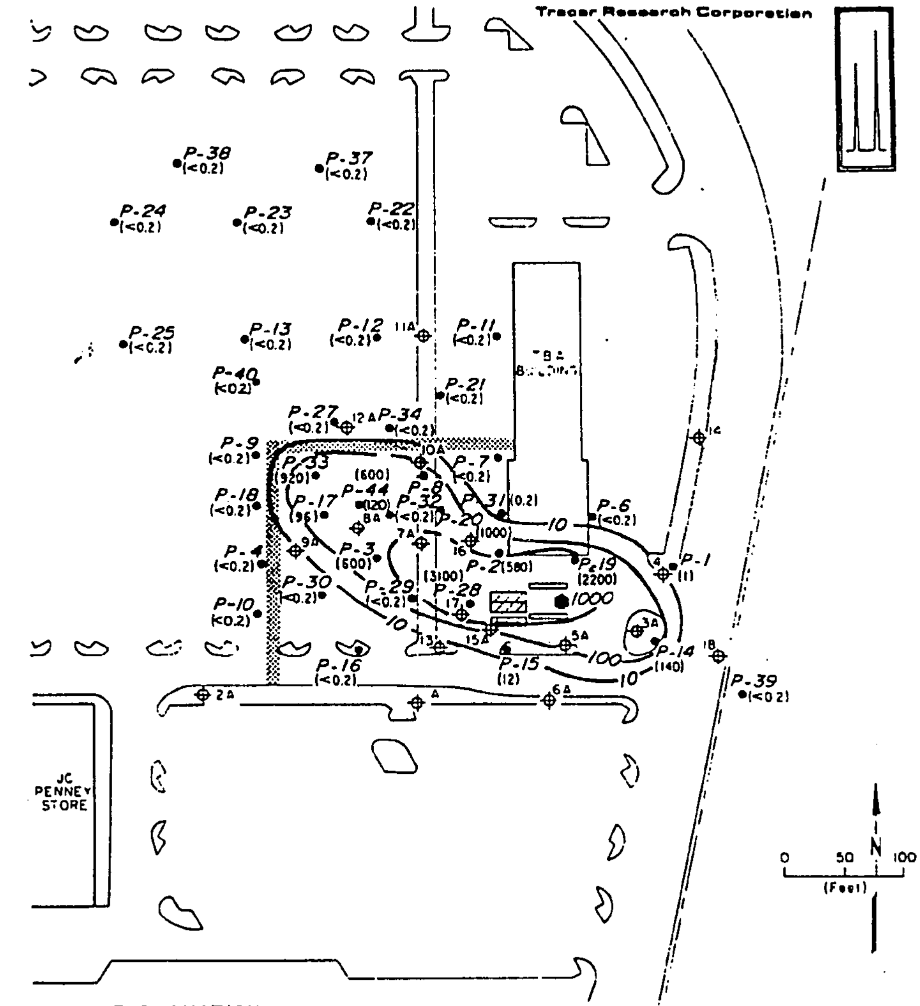


Figure 2-6. Soil gas concentration of total hydrocarbons at the J.C. Penney service station on April of 1987. Source: Tracer Research, 1987.



EXPLANATION

- 6A DAMES & MOORE MONITORING WELL
- P-3 SOIL GAS SAMPLING LOCATION
- (180) TOTAL HYDROCARBONS SOIL GAS CONCENTRATION (µg/L)
- —10— TOTAL HYDROCARBONS ISOCONCENTRATION LINE (µg/L)
- INTERCEPTOR TRENCH
- GASOLINE TANKS (Excavated 1985)
- SOURCE OF GASOLINE LEAK

T.B.A. BUILDING SITE
TOLUENE

Figure 2-7. Soil gas concentration of toluene at the J.C. Penney service station on April of 1987. Source: Tracer Research, 1987.

Table 2-4. Results of groundwater sample obtained on June 1, 1987 at the J.C. Penney Company is compared to the federal and California drinking water action levels (Dames and Moore, 1988b).

Well Number	TPH (ug/l)	Benzene (ug/l)	Toluene (ug/l)	Xylene (ug/l)	Ethyl Benzene (ug/l)
(Up-gradient)					
4	*[a]	*	*	*	*
(Central)					
23	700	780	120	1,400	*
21	21,500	3,600	*	800	*
22	47,000	1,200	2,800	8,900	*
9A	*	*	*	*	*
(Down gradient of interceptor trench)					
19	*	*	*	*	*
20	*	*	*	*	*
Detection Limit	50	0.6	1	1	1
DHS Action Levels[b]	-	0.7	100	620	-
EPA MCLs[c]	-	5	-	-	-
EPA MCLGs[d]	-	-	2,000	440	680

Footnotes:

a. Less than detection limit.

b. Department of Health Services Drinking Water State Action Level (RWQCB, 1988).

c. EPA Maximum Contaminant Levels (EPA, 1985).

d. EPA Proposed Maximum Contaminant Level Goals (EPA, 1985).

In February of 1988, the Santa Clara Valley Water District (SCVWD) assumed clean-up oversight responsibility for the site from RWQCB. J.C. Penney was ordered to remove all floating products and to clean-up the soil contamination and dissolved constituents in the groundwater (SCVWD, 1988a). In July of 1988, the consultants for J.C. Penney proposed further studies to characterize the horizontal and vertical extend of the dissolved constituent plume and to investigate appropriate remedial clean-up actions, including reactivation of the interceptor trench (Dames and Moore, 1988a). SCVWD accepted the proposal and ordered J.C. Penney to proceed immediately with the plan (SCVWD, 1988b).

2.2.2 Case History 2 - Rotten Robbie Service Station

On February 22 of 1988, Rotten Robbie Service Station reported a possible petroleum release at its 650 S. White Road site in San Jose. USTs at the service station were being monitored with internal tank level sensors which provided the initial warning that there may be a problem with the UST used to store regular gasoline. The suspected UST was then tested using an internal tank test. It failed the test twice and was removed from service.

The leaky UST and another UST (10,000 and 12,000 gallons capacities) were removed from the site on March 9, 1988. They were single wall, unwrapped steel tanks estimated to be approximately 27 years old (Robinson, 1989). On the 10,000 gallon tank, several holes about the size of a dime were found after the clay and corrosion on the tank surface were removed (Geonomics, 1988). There was one hole at the fill end of the 12,000 gallon tank which was 1/8 inch in diameter initially; however, it was easily enlarged to 1/2 inch after the removal of the corroded materials. Some contaminated soil were removed at the time of the tank excavation.

Four soil samples were obtained from the bottom of the tank pit after the USTs were removed. Results of the soil analysis revealed contaminations at levels which required further investigation. Two soil borings and a groundwater monitoring well were constructed in September of 1988. A soil vapor survey was performed in October of 1988 where a total of 17 soil vapor samples were taken in an attempt to estimate the distribution of volatile hydrocarbons in the soil and the groundwater, and to obtain an outline of the gasoline plume (On-Site Technologies, 1988). To further define the plume, three additional soil borings and two monitoring wells were installed in November of 1988. A summary of the soil and water sampling and analytical results is presented in Table 2-5 where maximum concentrations found for various contaminants are compared

Table 2-5. Highest contaminant levels found at 605 S. White Road on different sampling date. Regulatory criteria for drinking water include California Department of Health Services (DHS) recommended action level for drinking water, EPA's Maximum Contaminant Level or drinking water limit and EPA's Maximum Contaminant Goal, a proposed standard scheduled to be finalized in June 1988.

Soil Samples

Sample Date	# of Borings	TPH (mg/kg)	Benzene (mg/kg)	Toulene (mg/kg)	Xylene (mg/kg)	Ethyl Benzene (mg/kg)
3/09/88	4	1,200	130	73	110	25
8/31/88	4	2,800	50	140	200	67
1/28/88	5	640	10	17	47	17

Groundwater Samples

Sample Date	# of Borings	TPH (ug/l)	Benzene (ug/l)	Toulene (ug/l)	Xylene (ug/l)	Ethyl Benzene (ug/l)
9/13/88	1	9,000	1,000	1,300	700	100
12/1/88	3	9,000	1,300	1,400	1,300	160
DHS Action Levels[a]		-	0.7	100	620	-
EPA MCLs[b]		-	5	-	-	-
EPA MCLGs[c]		-	-	2,000	440	680

Footnotes:

a. Department of Health Services Drinking Water State Action Level (RWQCB, 1988).

b. EPA Maximum Contaminant Levels (EPA, 1985).

c. EPA Proposed Maximum Contaminant Level Goals (EPA, 1985).

to the state action levels and the EPA drinking water limits.

As of today, the cost of investigating the extend of contamination and limited soil removal is about $59,000 (Robinson, 1989). The full mitigation cost is unknown at this time because a mitigation method has not been selected. If vapor extractions can be used to clean-up the site without any groundwater work, then it may cost another $20,000; however, if the clean-up effort involves groundwater extraction, then the cost will be much higher.

2.2.3 Case History 3 - Santa Clara County Don Pedro Chaboya Station

One of the most severe case of fuel leaks occurred in a relatively new fuel storage complex at a San Clara County's transit yard. The Don Pedro Chaboya Station serves to fuel and maintain buses in the county transit system, and it began operation on May 1, 1981. On February 2, 1982, it was discovered that all the underground diesel storage tanks were essentially empty (Maniaci, 1982). Additional fuel was delivered to the site the next day, and an inspection revealed evidence of diesel contamination on the ground surface next to a service island. During a subsequent investigation, a break in a product line was found at a fuel island. A review of the fuel purchase and consumption records for the time period from

May 1, 1981 to February 2, 1982 showed an inventory shortage of approximately 300,000 gallons of the diesel fuel. Thus, during the 293 days when the service center was in operation, an average of over 1,000 gallons of the fuel leaked out per day.

The construction of Don Pedro Chaboya Station began in 1980, and product lines were tested in September of that year. The transit yard's eight diesel USTs (40,000 gallon capacity each) were filled to their full capacity of 320,000 gallons in October of 1980 to insure adequate settlement of the back-fill and soil material surrounding the tanks before a concrete cover was installed. Underground pipes were buried 18 inches below the ground surface and were covered with sand. During the week of October 6, there were six separate contractors working in the piping area preparing forms for the concrete cover. It was speculated that a sharp object, a pick axe or a concrete form stake, used during this period had caused the damage to the product line.

A consultant was hired in June of 1982 to conduct a subsurface investigation to determine the extent of the contamination. Recovery of the floating product began that same year. Approximately 50,000 gallons or 17 percent of the leaked fuel were recovered by July of 1984 (Applied Soil Mechanics, 1984). In February of 1986, after 3-1/2 years of operating the recovery program, an estimated 20,000 to 30,000 gallons of fuel still remains at the site (Applied Soil Mechanics, 1986). Much of the floating product in the sandy subsurface had been recovered, and the remaining product was in a clay area which has very low permeability; thus, the consultant was pessimistic about the ability to recover much of the remaining spilled fuel in the form of free product.

In 1986, the main body of the floating product covered an area of about one acre; while, the dissolved contaminates extended to an area of approximately 2.4 acres (Applied Soil Mechanics, 1986). The dissolved constituent plume extended approximately 35 feet in depth and up to 800 feet laterally from the source. In 1987, the diesel fuel and benzene were found in the groundwater at concentrations as high as 2,900 ug/l and 15 ug/l, respectively (RWQCB, 1987).

A groundwater extraction and treatment system was installed in November of 1987 (Santa Clara County, 1987). Two extraction trenches of 260 and 390 feet in length and of 44 to 46 feet in deepth were constructed. The groundwater extracted from the trenches first passed through an oil and water separator, then an aeration unit, and finally two carbon absorbers before it was discharged to the storm water system.

The original projected extraction rate from the trenches was 15,000 gallons per day (gpd) at start-up and decreased to 600 gpd during subsequent maintenance operation (RWQCB, 1987); however, the actual extraction rate had been substantially less. During the month of January in 1989, approximately 1,120 gallons (36 gpd) of the groundwater were extracted (Brencis, 1989). As of September of 1988, more than 50 monitoring wells had been constructed, and the floating product plume was found to have a thickness of greater than five feet.

The total cost of the investigation and clean-up is unknown, but it is probably in the millions of dollars. Construction, investigation, and management costs for the extraction trenches alone were more than $1.6 million (Bruce, 1987). The annual operating cost of the extraction system is estimated at $80,000 per year, with an estimated 10 to 15 years of operation time.

2.2.4 Other Fuel Leak Cases

In a 1986 national survey on motor fuel USTs, EPA estimated that 35% (95% confidence interval of 30-40%) of the nation's non-farm UST systems (including tanks and piping) could not pass a tank integrity test, which has a 5% probability of a false alarm of a tight tank (false positive) and a 5% probability of failing to detect a leak of 0.10 gallon per hour or greater (false negative) (EPA, 1986). When these results are extrapolated to the estimated number of non-farm fuel USTs in the United States, the number of potentially leaking tanks in the U.S. is estimated to be 189,000 with a 95% confidence interval of 153,000 to 226,000. Non-farm UST represents approximately 80% of all USTs. A tank testing company which has tested more than 22,000 USTs reported that 30% of the UST systems it had tested failed the test (Tainter, 1985).

As of November of 1988, there were 864 reported cases of leaky fuel USTs in the Santa Clara County (SCVWD, 1988c). Out of all the cases, 300 of them (35%) were classified as confirmed groundwater contamination cases, where either floating products were present at monitoring wells, or analytical laboratory results indicated the presence of dissolved constituents. Soil contaminations were found in 466 cases (54%), which required further investigations to determine the extent of their contamination and their impact on the groundwater. Only 98 cases (11%) had contamination at low enough levels that no immediate further action was required. As of today, among the fuel cases which required some form of clean-up measures, only one had been completed to the satisfaction of RWQCB and SCVWD (Goldie, 1989).

2.3 Summary

In summary, several case studies involving leaky USTs have been discussed in this chapter. The USTs in these cases were used for the storage of motor vehicle fuels, solvents, or waste solvents. The amount of materials leaked from the USTs and the specific detail relating to the leaks may vary; however, the leaks share some common characteristics. First of all, the leaky USTs (with one exception) were not being monitored routinely, and secondly, extensive investigation and clean-up measures were needed to mitigate the damages caused by the leaks. The Fairchild and IBM leaks are among the most severe in the Santa Clara County, and they gave rise to the drafting of the Santa Clara County Model Hazardous Materials Storage Ordinance.

Footnote

2-1. Hazard Index (HI) is a method proposed by the RWQCB (RWQCB, 1988c) for assessing the health risk associated with exposure to multiple chemicals. It is the sum of the fractions of each chemical found in the groundwater divided by its corresponding Drinking Water Standard. In other words,

$$HI = \sum_{i=1}^{n} Ch_i/Std_i$$

where n = Number of chemicals found in groundwater.
Ch_i = Concentration of chemical-i in groundwater.
Std_i = Drinking Water Standard for chemical-i.

3.0 REGULATORY APPROACH

The efforts to regulate the underground storage tank (UST) began at the local level, and proceeded to the state level, then finally to the federal level of government. Cities in the Santa Clara County were among the earliest local jurisdictions to enact ordinances to address the problem of leaky USTs. They drafted the Santa Clara County Model Hazardous Materials Storage Ordinance (Model Ordinance), which was adopted by most cities in the county and used as a model for many other jurisdictions in the state and across the nation. San Jose was an active participant in the drafting of the Model Ordinance. Other local jurisdictions in the nation which have developed distinctive UST ordinances in the early days of UST regulations include Suffolk County in New York and Dade County in Florida.

Soon after the development of the Model Ordinance in the Santa Clara County, the State of California used it as a guide and enacted UST legislation for the state. Concerns for leaky USTs then reached the federal level, and the U.S. Congress enacted UST legislation for the entire country.

3.1 Local Approach - City of San Jose

Shortly after the discovery of groundwater contaminations from solvent leaks at the IBM site in 1980 and the

Fairchild site in 1981, the city and elected officials in San Jose realized that there was insufficient regulation on USTs to provide adequate protection for the city's drinking water aquifers. Although the Department of Health Services (DHS) has jurisdiction over the storage of hazardous wastes, it did not address the specific hazards associated with USTs. Inadequacies in DHS' regulations were demonstrated by the solvent leaks in San Jose and other parts of the state. Furthermore, DHS' regulations were limited to hazardous wastes and did not extend to the storage of solvents and motor vehicle fuels. City officials in San Jose recognized that, besides solvent and waste solvent USTs, the motor vehicle fuel UST is also a potential source of groundwater contamination (Delgado, 1983).

Prior to the adoption of the UST regulations in San Jose, the Buildings and the Fire Departments were the local departments involved in the issuing of permits to underground gasoline and solvent tanks. The Buildings Department's involvement was limited to the issuance of permits for electrical wiring of fuel dispensers; while, the Fire Department's involvement was more extensive. It specified minimum separation (five feet) between an UST and building or property line, and minimal burial depth (18 to 24 inches) for USTs and pipes. It required tanks and piping to be tested either pneumatically or hydrostatically at the time of installation. It also required daily liquid level measurement with a dip stick; however, there was no requirement for secondary containment or any other form of leak detection.

The Fire Department regulates the storage and usage of gasoline, diesel fuel, and other solvents because of the fire hazards associated with these liquids. Gasoline has a flash point[3-1] range of -50°F to -45°F and is classified as a flammable liquid[3-2], while diesel fuel is classified as a combustible (class IIb) liquid[3-3] with a flash point range of 126°F to 204°F. Storage of flammable liquid in above ground tank is prohibited under San Jose's fire regulations, both the 1970 edition of the Fire Prevention Code which was in effect up to 1987 and the 1985 edition of the Uniform Fire Code which is currently in use. In essence, under the Fire Department's regulations, for reasons of public safety, the only possible location for gasoline or solvent storage tank is underground. The Uniform Fire Code is a model fire code developed by the Western Fire Chiefs Association and used by most cities in the western states, including those in the Santa Clara County. Thus, many cities have the same restriction as San Jose's on the placement of flammable liquid tank. Under the fire regulations, combustible liquids may be stored in above ground tanks, but the San Jose Fire Department normally does not allow large combustible liquid storage tank to be placed above ground. Most service stations probably preferred diesel tanks to be placed underground because they do not occupy the precious and limited surface area in service stations.

Problems with leaky USTs are not limited to the City of San Jose, but common throughout the Santa Clara County. In 1982, fire chiefs from the major cities in the county initiated a process to draft an ordinance to address the problems associated with USTs. Soon after the process began, it was recognized that the ordinance could be expanded to provide fire departments with chemical inventories at facilities which store hazardous materials. Such information could be vital for fire department personnels when they respond to emergencies at these facilities. Thus, the fire chiefs expanded the original focus of the ordinance beyond USTs to include hazardous materials stored above ground. Furthermore, a community right-to-know provision was added to the ordinance.

In the drafting of the ordinance, there was active participation from representatives of the semiconductor industry, the Department of Health Services, the San Francisco Bay Regional Water Quality Control Board, the governor's office, and the labor organizations, as well as the environmental advocates. The final product of this effort became the Santa Clara County Model Hazardous Material Storage Ordinance (Model Ordinance). It had the support of all the sectors of the community, with the exception of the oil industry (Gallo, 1983). The Model Ordinance has been adopted by most cities in the Santa Clara County including Campbell, Gilroy, Milpitas, Morgan Hill, Mountain View, Palo Alto, San Jose, Santa Clara, and Sunnyvale, as well as the unincorporated area of the county. Today, after separate modifications by individual cities and revisions mandated by subsequent state legislations, the ordinances in various cities in the Santa Clara County are still quite similar.

3.1.1 San Jose's Hazardous Materials Storage Ordinance

The San Jose City Council adopted the Model Ordinance on May 15, 1983 and incorporated it as Chapter 17.68 of the San Jose Municipal Code (SJMC). The effective date of the San Jose UST regulations was July 1, 1983. Instead of referring to its code section, most people still refer to the regulation as the Hazardous Materials Storage Ordinance (HMSO). In this paper, discussion of local regulations in this paper is limited to the San Jose's HMSO; however, because of its similarity to HMSOs in other cities in the Santa Clara County, the San Jose's HMSO is a good representative of other HMSOs. Also, discussion of the HMSO is limited to USTs; other aspects of the HMSO such as above ground storage and the community right-to-know provision will not be discussed.

Materials Regulated

The San Jose HMSO refers to several lists of chemicals for materials regulated under the HMSO. The lists include:

1. List of Common Names and Chemical Names in California's hazardous waste regulations (Sections 66680 and 66685, Title 22, CAC).
2. Director's List of Chemicals California Occupational Safety and Health Administration (Section 339, Title 8, CAC).
3. EPA's list of priority pollutants (Section 401.15, 40 CFR).

The first two lists are very comprehensive and include most of the chemicals produced and used by industries. In addition to the use of the chemical lists, the HMSO regulates flammable and combustible Class II and IIIa liquids with flash points less than 200°F.

New USTs

New USTs are required under the HMSO to have secondary containment and leak detection systems. The HMSO defines secondary containment as having the capability to contain a leak from a primary container for the period of time necessary to clean up the leak. It does not specify the type of construction for achieving secondary containment. The HMSO requires a new UST to have a leak detection system capable of detecting leakage from the primary containment. It also does not specify the type of leak detection system except that visual inspection is the preferred method.

Existing USTs

The HMSO requires existing USTs to have leak detection systems, but there is no specification as to the type of devices which is acceptable. Abandoned USTs which are out of service must either be closed properly within 90 days of the discovery or be fitted with acceptable leak detection systems. In the closure process, a facility owner must "minimize the need for further maintenance and controls to the extent that a threat to public health or safety or to the environment from residual hazardous materials in the storage facility is minimized or eliminated" (Section 17.680.670, SJMC).

Permits and Fees

A hazardous materials storage permit is required for a facility storing hazardous materials. The HMSO allows the City to assess permit fees to recover 100% of the cost associated with the administration of the HMSO. A provisional hazardous materials storage permit may be issued for a six-month duration to a facility that has complied with the main components of the HMSO but does not met all of its requirements. A provisional permit can be extended by the City for a period of up to six months.

Compliance Dates and Penalties

The operator of a facility which stores regulated materials is required to submit a Hazardous Materials Inventory Statement to the City by January 1 of 1984, listing the regulated materials and the maximum quantities of these materials at the facility at any time during the year. Within a year of the HMSO's effective date, by July 1 of 1984, the HMSO requires the operator to submit a Hazardous Materials Management Plan (HMMP) with a description of the storage facility and the method of leak detection used at the facility. For a facility without any leak detection systems, a proposal to monitor leaks is required to be included in the HMMP for a review by the City. There is no time limit for the City to review the proposal and the HMMP; thus, there is no deadline for the installation of leak detection systems at these facilities. Operators of facilities which are not in compliance with the HMSO are subjected to civil penalties of up to $500 per day of violation, but there is no provision for administrative penalties or criminal prosecutions.

3.1.2 Program Implementation

Implementation of the HMSO in the City of San Jose is delegated to the Fire Department, because it is the most logical department to assume the responsibility. First of all, the Fire Department is the agency in the City most familiar with the HMSO since it participated in the drafting of the Model Ordinance. Secondly, above ground hazardous material storage information required by the HMSO will be used by the Fire Department when its personnel responds to emergencies at the storage facilities. Lastly, there is already a group of fire inspectors within the Fire Prevention Bureau of the Fire Department whose job is to conduct annual fire safety inspections at existing facilities. It was thought that, the fire safety inspectors could conduct hazardous material inspections along with their regular fire safety inspections.

In 1983, the Hazardous Materials Program (HMP) was formed within the Fire Prevention Bureau of the San Jose Fire Department. A program manager and an environmental scientist were hired to administer and provide technical support for the program, and a fire safety inspector who had been involved in UST installation and removal activities was assigned to the program. An additional environmental scientist was added to the staff in 1984. In the early days of the HMSO implementation, the UST was an important issue and the staff devoted approximately 75% of their time to projects relating to the UST and spent the remaining 25% on issues relating to above ground storages.

At the end of 1985, the HMP staff has increased to include a program manager, two environmental scientists and three fire inspectors. However, despite the increase in staffing, the HMP was still gravely understaffed and was plagued by a high turn over rate among its fire inspectors. At the same time, administrators within the Fire Department and the City were reluctant to approve additional personnel. In early 1987, conditions of the HMP were brought to the attention of the city council who immediately took steps to correct the situation. As of today, staffing in the HMP includes a program manager, a supervisor, six civilian hazardous materials inspectors (formerly classified as environmental scientists), three fire inspectors, and several clerical support personnel. Most of the staff's time is involved in above ground storage of hazardous materials. It is estimated that a total of four full-time equivalent staff persons (excluding clerical staff) are involved in UST-related work. The HMP intends to hire two additional civilian inspectors in the middle of 1989, which will increase the total number of staff (excluding clerical) to 13. The two new people are not expected to have much involvement with UST.

Secondary Containment Standard

The HMSO is performance-oriented rather then technologically-based. During the first three years of the HMSO implementation, the HMP spent much of its effort in reviewing available technologies and compliance options. For example, with regard to secondary containment, the

HMSO specified that new UST (tank and piping) must have secondary containments capable of containing a spill until the spill can be cleaned-up. In 1983, the flexible membrane liner was the only available and feasible method of secondary containment for large, 10,000 gallon USTs used at service stations. The installation of flexible membrane liners is a labor intensive operation that requires welding together several pieces of fabrics in the field and sizing the final fabric to fit a tank excavation. A finished liner is required to be tested by its ability to hold water. The water level is monitored over a 24-hour period, and almost all installations were found to leak initially. It is difficult to locate leaky seams and holes in a tank liner which may measure 40 feet by 50 feet, and it normally takes several repairs in order to pass the required water test. Since there is no requirement for further testing, should a liner become damaged during the installation of tank and piping, the damage may remain undetected.

The flexible membrane liner industry recognized the problems associated with its product, and in 1984, devised prefabricated (one piece, factory welded) liners for an entire tank excavation. However, despite this improvement, the inherent difficulties with the installation of flexible membrane liners still remains.

At the time of the HMSO adoption in 1983, the double-wall UST was not available. City officials recognized the desirability of double-wall UST, especially in view of the difficulties with flexible membrane liners, and they began working with UST manufacturers on the design of double-wall USTs. By the end of 1984, two steel tank manufacturers were able to supply double-wall steel USTs, and by 1986 the fiber glass tank industry was also making double-wall fiberglass USTs. A double-wall UST consists of a tank within another tank which is capable of containing leakage from the primary tank. An interstitial space exists between the tanks to allow for monitoring. Since double-wall USTs became available, there has not been any further installations of flexible membrane liners for secondary containment of USTs in the City of San Jose.

Secondary containment for piping faces similar problems as those for USTs. Despite the flexible membrane liner industry's attempts to improve its product and its limited success to eliminate the necessity for field welding, inherent problems of flexible membrane liners led installers and facility owners to explore other means of secondary containment.

Double-wall piping has been tried and had limited success. Contractors, were able to install in some instances, two inch fiberglass product or vapor pipes within four inch PVC pipes. However, installations have usually been limited to simple facilities with short or straight lengths of pipes. There had been only one or two attempts to install double-wall piping in complex facilities such as service stations. Recently, a fiberglass piping manufacturer introduced a double-wall piping system using four inch fiberglass outer pipe with prefabricated joints. Installers found the piping too difficult to install and often encountered problems with leakages; thus, the system has not been widely used.

The most widely used method of secondary containment for piping is a fiberglass trench system which has been available since late 1985. It is a simple trenching system similar to flexible membrane liners. It comes in ten-foot sections with prefabricated fiber glass elbows and tees for changes in piping directions and connections, and sections can be joined in the field with fiberglass. It has a width of approximately three feet which is large enough to accommodate several piping runs normally found in a service station installation. The fiberglass trench is more resilient to damages than flexible membrane liners and is comparable in cost to flexible membrane liners. It is easy to install, and almost all installations are able to pass the water test in the first attempt. Since its introduction in 1985, the fiberglass trench has become the choice of secondary containment for piping among oil companies and contractors, and there has not been any piping installation with flexible membrane liners in the City of San Jose since 1987.

There have been a few attempts to use concrete or gunnite trenches for secondary containment of piping. Gunnite is a form of concrete which can be sprayed in an earth trench to form a hard concrete structure. Also, it is widely used in the construction of swimming pool. The use of gunnite and concrete trenches in most underground piping installations is discouraged due to their high costs.

Leak Detection

The HMSO requires all USTs to be monitored monthly, at a minimum. It does not specify the type of leak detection systems acceptable for new or existing USTs; thus, the HMP staff has to review available leak detection devices and formulate guidelines to address the different situations. Monitoring of new USTs is relatively simple in comparison to existing USTs. Since the beginning of the HMSO implementation in 1983, a significant portion of the staff's time is spent on issues concerning monitoring of existing USTs.

In the beginning of the HMP, the groundwater monitoring well was essentially the only form of monitoring available. The HMP staff had little or no experience with groundwater monitoring; therefore, it relied on the Santa

Clara Valley Water District (SCVWD) for its expertise. The SCVWD is a local water wholesaler who has experience with water well installation and oversees all water well installations. This process ensures that they are sealed properly at the ground surface and between water aquifers. Contamination of groundwater from surface run-off and from an overlying aquifer to a lower aquifer can be the result of improperly installed wells. In 1983, the SCVWD published a set of guidelines for the installation of monitoring wells, which is widely used in all the cities in the Santa Clara County that have adopted the HMSO. In the guidelines, the SCVWD recommended one groundwater well down gradient from an UST or a cluster of USTs for every 35 feet of the longest tank or tank cluster dimension (SCVWD, 1983). For a service station with three USTs placed side-by-side, the tank cluster usually measures approximately 30 feet by 30 feet; therefore, under this guideline, only one monitoring well is required. If groundwater is more than 20 feet deep, then an additional vadose zone[3-4] monitoring well is necessary. If groundwater is not encountered within 45 feet from the surface, then a vadose zone monitoring well by itself is adequate without the groundwater well (Table 3-1). The SCVWD also specified construction requirements for groundwater and vadose zone monitoring wells such as slot depth, screen size, and well sealing requirements (Figure 3-1). It

Table 3-1. Santa Clara Water District's 1983 guidelines on the installation of groundwater and vadose zone monitoring wells as a function of groundwater depth (SCVWD, 1983).

Depth of Groundwater (Feet)	Groundwater Monitoring Well	Vadose Zone Monitoring Well
0 - 20	Required	Not Required
20 - 45	Required	Required
Over 45	Not Required	Required

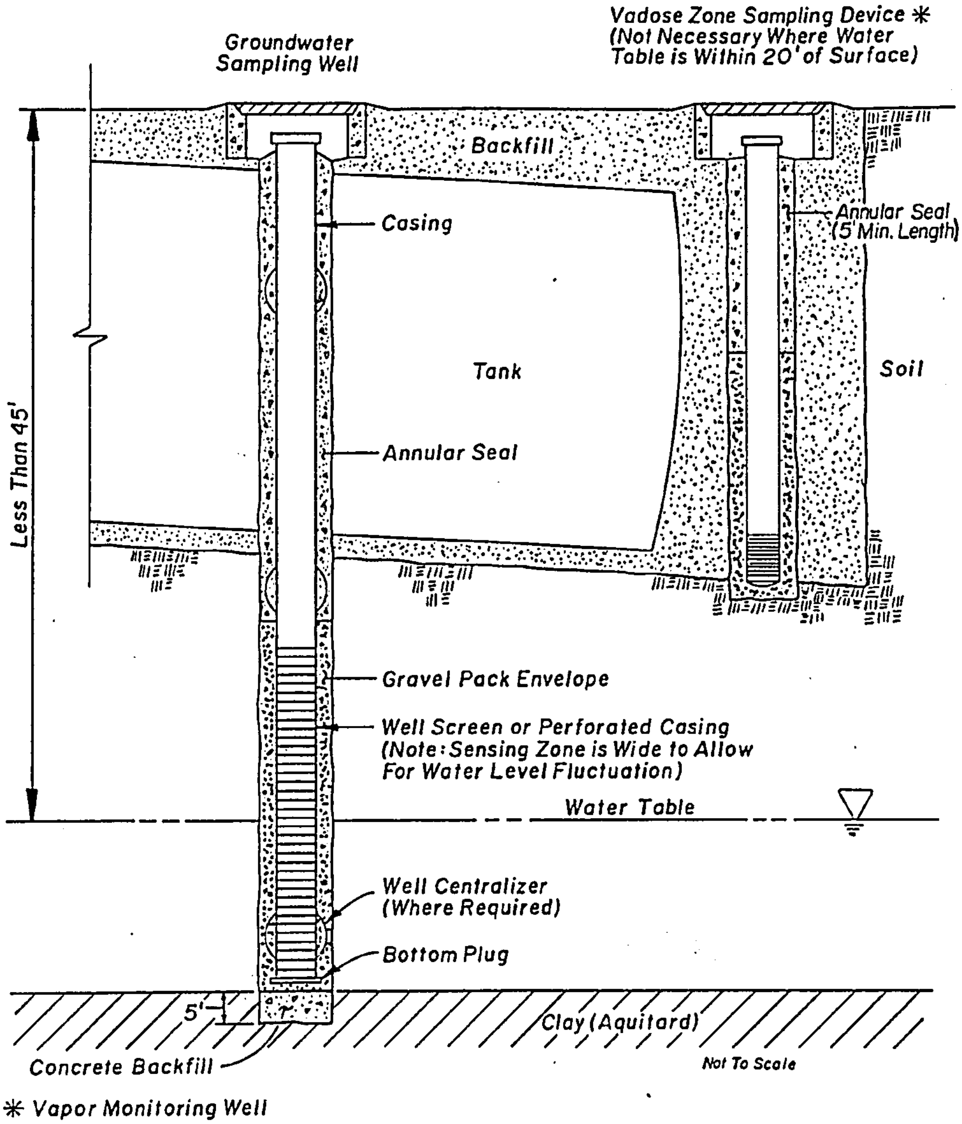


Figure 3-1. San Clara Valley Water District's construction guidelines for groundwater and vadose monitoring wells. Source: SCVWD, 1983.

recommended a monthly monitoring schedule. Monitoring of groundwater wells can be accomplished by obtaining a water sample from the surface of the water table with a bailer and examining it for sheen and odor; while, vadose well monitoring involves field analysis of vapors with combustible gas detectors or vapor absorption on charcoal tubes for subsequent laboratory analysis. If both kinds of wells are present, then the vadose well can be monitored at a semi-annual frequency. Currently, the cost of installing a groundwater or vadose well is about $1,000 to $2,000.

The SCVWD guidelines satisfied the most immediate needs of local HMPs after the HMSO adoption; however, it did not address the issue concerning monitoring of piping. Furthermore, the effectiveness of groundwater wells for monitoring USTs has not been thoroughly substantiated. There have been many documented cases where the detection of floating hydrocarbons on the groundwater in a monitoring well had led to tank removals and visual confirmations of holes in the tanks; however, there have also been cases where groundwater wells failed to detect hydrocarbons on the groundwater even after the confirmation of leaks by inventory shortages and the evidence of holes in the USTs the time of removal. Despite these potential problems, the groundwater monitoring well was the only method available for monitoring existing USTs immediately after the adoption of the HMSO. As other monitoring methods became available, San Jose imposed restrictions on the use of groundwater monitoring wells, and in 1986, it no longer approves groundwater monitoring wells, unless the groundwater table is higher than the invert of an UST at all times of the year. There is no upgrade requirements of groundwater wells which were previously approved.

Recognizing the potential problems with groundwater monitoring wells, city officials in San Jose and other cities in the Santa Clara County worked with manufacturers of vadose zone monitoring devices in an attempt device better monitoring methods. The Santa Clara County became the testing ground of different vadose zone monitoring devices. Most areas in the Santa Clara County have groundwater tables deeper than 20 feet, and in some cities, groundwater is deeper than 45 feet. In contrast, groundwater tables are much closer to the surface in other parts of the country such as Dada County, Florida and Suffolk County, New York, and vadose zone monitoring may not be as appropriate in these locations as groundwater monitoring.

Vadose zone monitoring is only effective for a chemical with a high vapor pressure. Vadose zone monitoring is generally thought to be capable of detecting a small gasoline leak quicker than the groundwater monitoring well. The time it takes a small amount of gasoline to produce enough vapor to migrate to vadose wells is less than that for the gasoline to migrate down to the groundwater. Scientific data on the migration rate of fuel vapors in the soil is limited. In laboratory tests, diffusion rates for gasoline vapor were found to be about 0.7 foot/hour; while, diffusion rates for diesel were approximately 70% slower than that of gasoline (Young, 1986). In a laboratory test using an aspirated vapor detector at the rate of two liters per minute, the migration rate of gasoline was found to vary from 0.35 to 0.7 foot/hour (Genelco, ____). In a field study in Palo Alto, the same aspirated vadose monitoring device was able to detect a leak of approximately one to two gallons of gasoline in a sandy back-filled piping trench nine feet away in 20 minutes (Clark, 1984).

Currently, there are several types of vadose zone monitoring systems available on the market. Some of them aspirate air from vadose wells to the detectors; while, others have sensors in the bottom of monitoring wells and wait for vapors to migrate to the sensors. Aspirated devices can operate intermittently or on a continuous bases, and most static sensors operate continuously. Table 3-2 illustrates the different categories of vapor sensors and lists some available devices in each category.

Table 3-2. Examples of different aspirated or static and intermittence or continuous vadose zone monitors.

Mode of Operation	Aspirated Monitors	Static Monitors
Inter-mittence	Chemical Tubes, Combustible Gas Detector	Not Available
Continuous	Soil Sentry or Azonic	Leak Alert, U.S.Industrial Products

The simplest vapor sensing device is a glass (Drager) tube with two open ends and the center filled with a chemical which is designed to react and change color when it is in contact with a specific vapor. When a specific volume of air passes through the tube, the amount of chemical which changes color depends on the concentration of the specific vapor in the test sample. The chemical tube is calibrated along its length to allow for concentration readings in parts per million. Several companies manufacture chemical tubes which can detect gasoline vapors, and at least one makes a tube sensitive to diesel fuel. The chemical tube is the lowest price vadose zone device available on the market. Each chemical tube costs approximately \$3 to \$5, and a hand pump costs about \$100. If there is no vadose zone monitoring wells at a site, then the initial set-up cost will have to include the construction cost of vadose zone wells.

With the exception of chemical glass tubes, most of the other vadose zone monitoring devices for motor vehicle fuels depend on a solid state semiconductor sensor which is capable of detecting the presence of hydrocarbon molecules. The sensor uses a semiconductor material with a metal oxide surface which changes resistance when hydrocarbons adsorb to its surface. Resistance can be correlated to the concentration of specific hydrocarbons. Sensitivity of the sensor depends on the molecular size of hydrocarbons. The sensor has poor sensitivity for small molecules such as methane and ethane. It can effectively detect the mixture of compounds in gasoline, but its sensitivity decreases with the large molecules found in diesel fuel. Most manufacturers claimed that their sensor is capable of detecting diesel vapor; however, testings are usually done in laboratories instead of the actual environment. One leading manufacturer recently sent out a disclaimer on the capability of its equipment to detect diesel in the actual field environment (Azonic, 1989).

The combustible gas detector is an example of an intermittence, aspirated detector. It is a portable instrument with a pump to draw air from a vadose well to the gas sensor in the instrument. It is used intermittently when a well is sampled, and one instrument can service several vadose zone wells and facilities. The instrument requires periodic calibrations, and it costs about $500 to $1,000 per instrument.

A more sophisticated form of the portable, aspirated combustible gas detector is an instrument which can continuously monitor as many as 16 vadose wells at a facility. Air is drawn from the vadose wells at a rate of two liters per minute to a sensor inside the instrument which is usually mounted inside a service station. A computer chip in the instrument directs the instrument to sample a vadose well for a 30-minute duration, then it is rotated to sample another well. When all the wells have been sampled, the instrument returns to the first well to repeat the cycle. There is a paper printer to document high vapor readings and other unusual circumstances such as a clogged line, water in the line, or a breakage in the line. The instrument costs about $7,000 which does not include the costs of the vadose well installation, the trenching for air hose and wires, and the set up cost of the system.

The passive, continuous monitor is similar to the continuous aspirated device that several monitoring locations are linked to a central computer controlled unit, but this system places a gas sensor at the bottom of each vadose well and relies on vapors from a leaky UST or line to diffuse to the sensors. The unit operates on a continuous bases, where status of each sensor is continuously fed back to the central control unit, and the instrument can be equipped with a paper printout, visual and audible alarms, and an internal memory to record past events. the cost of this system is comparable to a continuous, aspirated system.

In order for a vadose zone monitoring system to be approved in San Jose, it must have a minimum sensitivity of 100 ppm for the material being monitored. The chemical tube and semiconductor sensors can easily meet this standard for gasoline. San Jose requires vadose zone monitoring wells to be monitored as least at a weekly frequency. Self monitoring is acceptable, and a facility operator is required to keep a monitoring log on site to record routine monitoring results. Vapor concentrations exceeding 1,000 ppm have to be reported to the City. A minimum of one vadose well is required per gasoline tank, and two vadose wells are required for each diesel tank. Vadose wells must be installed in sand or pea gravel back-fills because the porosity of these back-fill materials allows for rapid vapor migration. If vadose wells are installed outside of porous back-fills, then some conductivity test must be performed to demonstrate that the vapor is capable of traveling from the back-fill of a leaky tank or pipe to the vadose wells. Criteria for performing such tests have not been established; however, it is likely to involve the injection of a predetermined amount of a tracer gas into the back-fill, and a duration of time is allowed for the vapor to migrate to the vapor wells.

The tank integrity test is capable of detecting and quantifying small leaks in USTs and in pipes. It can be used at a monthly frequency to satisfy the monitoring requirement of USTs. The precision tank test is a tank integrity test which has a detection limit of 0.05 gallon per hour (gph); however, the name has generally been used interchangeable with tank integrity tests. The precision tank test is defined by the National Fire Prevention Association as a tank test which "takes into consideration the temperature coefficient of expansion of the product being tested as related to any temperature change during the test, and is capable of detecting a loss of 0.05 gph" (NFPA, 1987). The Uniform Fire Code requires that tank testing devices be capable of meeting the 0.05 gph detection limit in the precision tank test definition (UFC, 1985). Detection limits of different tank integrity tests were unknown at the time when the precision tank test definition was formulated, and it was not until 1988 before they were systematically tested under a program funded by the EPA. Results of the EPA study (EPA, 1989) indicated that none of the 25 existing tank integrity tests can meet the 0.05 gph detection limit at the present time due to a number of problems associated with tank testing.

An UST is tested by filling it with the substance stored in the tank, and the leak rate is determined by observing the amount of fluid lost from the tank over a period of time. Temperature changes of the liquid during the test period can interfere with the accuracy and sensitivity of the test. With a coefficient of expansion of 0.0006 for gasoline, a change of 0.01°F in 10,000 gallons of gasoline corresponds to a change of 0.06 gallons. Generally an UST is filled to capacity just before the tank test, and the temperature of the newly delivered fuel is different from the temperature of the existing fuel in the

UST and that of the underground environment. Thus, the temperature of the delivered fuel will increase or decrease to equilibrate with the existing fuel and the UST surrounding. In a survey of typical tank testing conditions (MRI, 1988), initial and ending temperatures of 60% of USTs tested differ by more than 1.5°F which correlates to a change of 90 gallons. It is necessary for a tank test to separate the confounding effects of a volume change which is due to a temperature change from one which is the result of a leaky UST or pipe. Generally, a test method will use high sensitive thermistors in the range of 0.001°F to measure temperature change, in an attempt to account for the volume change which is caused by a temperature change.

To further complicate the tank test procedure, temperature not only changes during a tank test, but there is also temperature stratification of gasoline in the tank. Warm gasoline has a greater buoyancy than cooler gasoline and it has a tendency to rise to the top of a tank. For fuels which are closer to the tank walls, the temperature will change faster than those in the interior of a tank. In an attempt to account for temperature stratification, one testing device uses a pump to continuously mix and circulate fuel during the testing process; while, others use several thermistors to obtain temperature readings at different levels inside an UST.

Vapor pockets inside an UST can also interfere with the accuracy of a tank test. Usually, an UST is placed in the ground at a slope with the gas dispensing end higher than the fuel delivery end. This allows water to accumulate at the low end of the tank and avoid pumping the water to vehicles being fueled, but vapor pockets can be trapped in the high end and other locations of an UST. Vapor expands and contracts in response to a temperature change according to the following formula (MRI, 1988):

$$dV = V_i(T_f/T_i - 1),$$

where V_i is the initial vapor pocket volume, T_i and T_f are the initial and final temperatures in degrees Kelvin, and the pressure is assumed to remain constant. For a vapor pocket with a volume of two cubic feet, a change from 70°F to 72°F results in an increase of 0.0075 cubic feet or 0.056 gallons. In other words, a small vapor pocket inside a tank mimics a large change in the fuel volume. The number and volume of vapor pockets are unknown in a tank test, so there is no feasible method to quantify the effects of vapor pockets in a tank test.

Changes in the barometric pressure can also cause expansion and contraction of vapor pockets; however, it is unlikely to be a major factor at most testing conditions unless a large vapor pocket is present or there is a large change in barometric pressure. If a vapor pocket has an initial volume of 10 gallons (1.3 cubic feet), a change of

0.1 inch Hg from an initial pressure of 30 inches Hg would result in a change of volume of about 0.03 gallons (MRI, 1988). Approximately 10% of testing conditions in a recent survey showed a barometric pressure change of more than 0.1 inch Hg between the beginning and the end of the test (MRI, 1988).

The tank end deflection is another confounding factor in a tank test. When a 10,000 gallon UST is filled with liquid, the weight of the liquid creates enough head pressure on the tank such that ends of the tank deflects outward (Figure 3-2). The amount of deflection an UST exhibits and the rate the deflection occurs are unpredictable. During a tank test, tank end deflection causes the liquid level to decrease and can be mistaken as a leak. To correct this phenomenon, one test method fills a stand pipe with fluid to 42 inches above the top of an UST before a test in an attempt to induce an UST to deflect to its maximum extend, then it lowers the fluid level to 12 inches during the actual testing process.

A summary of the major factors which can influence the liquid level in an UST and affect the result of an internal tank test is depicted in Figure 3-3. A number of other factors can also interfere with the tank test to a varying degree. They include water inside a tank, fluctuations in the water table, tidal movement, and vehicle traffic. Some of these factors may individually have min-

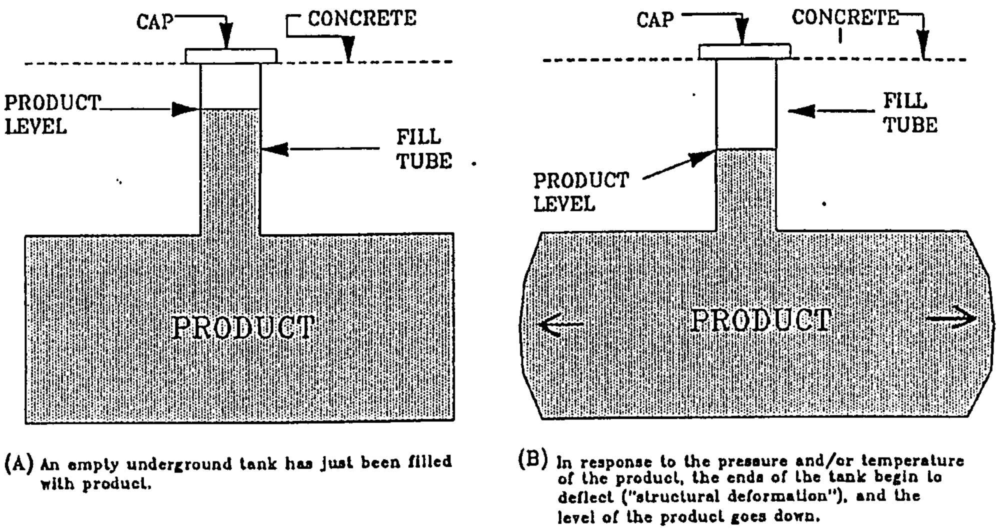
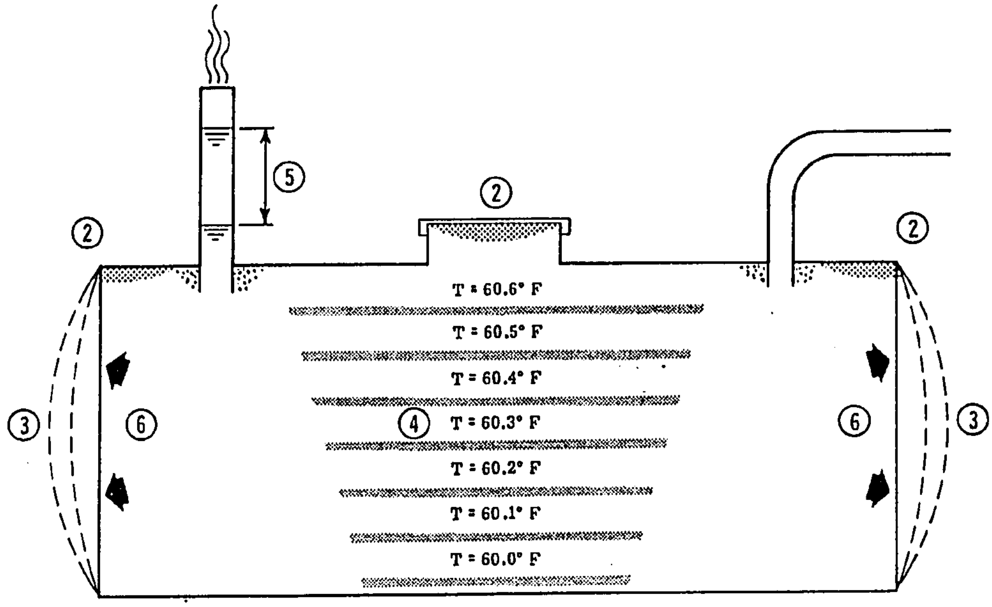


Figure 3-2. Schematic illustrating the effect of tank end deflection on the liquid level of an UST which has been filled in the preparation for a tank integrity test.

Source: EPA, 1988.



1. EVAPORATION
2. VAPOR POCKETS
3. TANK END DEFLECTION
4. TEMPERATURE STRATIFICATION
5. THERMAL CONTRACTION OR EXPANSION
6. PRESSURE VARIATIONS

Figure 3-3. Factors which can influence liquid level in an UST and accuracy of tank integrity test.

Source: EPA, 1988.

imal effect on a tank test; however as a group, they can significantly decrease the accuracy of a tank test, and in instances when their biases occur in the same direction, they may affect the outcome of a tank test.

There are several companies offering a variety of tank testing methods. The different tank testing methodologies all measure leak rates by examining the rate of change in the liquid level when a tank is full, and they attempt to account for the various confounding factors with different means which have been discussed in the previous paragraphs. The main factor which distinguishes the different tank testing methods is the way in which the change in the liquid level is measured.

In one testing method, the liquid level is maintained at a fixed level in a stand-pipe with the addition or removal of fuel. The amount of fuel added or withdrew over a certain time period then translates to a leak rate. A second method utilizes the Arcamedies principle to measure level changes. A rod is immersed partially in the liquid in a fill pipe, and its weight is determined by the use of a sensitive scale. A change in the liquid level is reflected in a corresponding change in the weight of the rod (Figure 3-4). Another testing method bubbles air into the fuel just a few inches below the surface inside the fill pipe, and the liquid level can be determined by measuring the back pressure of the gas. One test method

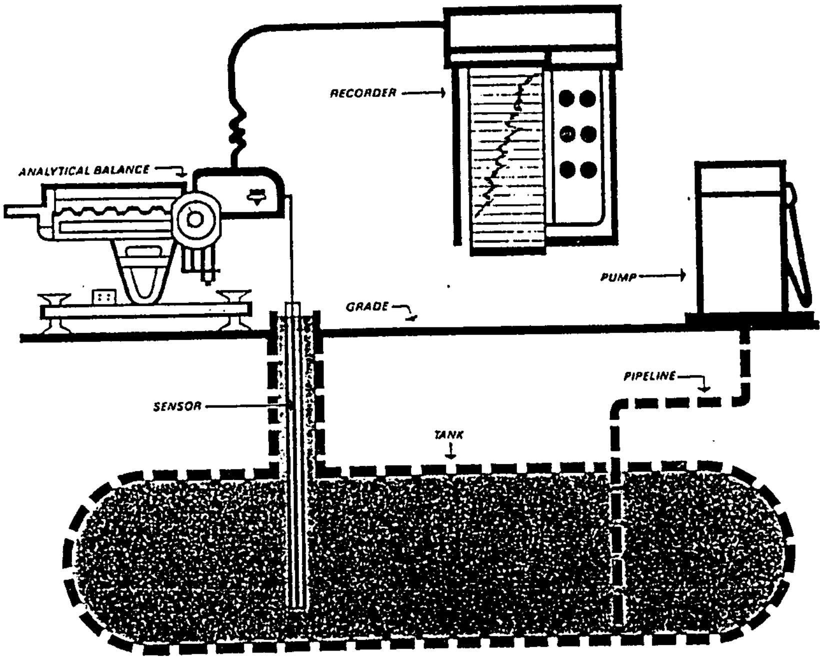


Figure 3-4. Schematic of a tank integrity testing method where changes in liquid level is measured by changes in the weight of a rod partially immersed in the liquid.

Source: Hunter, ____.

places a pressure sensor at the bottom of an UST. The height of the liquid inside the tank creates a head pressure on the sensor, thus enable the sensor to indirectly measure the liquid level. Another testing method measures the time it takes an ultrasound signal to travel from the bottom of an UST to the liquid surface and derives the distance or the liquid level from the travel time.

All tank testing systems require trained technicians to operate the testing instruments and to interpret the data. therefore, unlike other monitoring devices which are purchased by an UST facility operator, a tank integrity test is usually performed by trained consultants or contractors. San Jose requires a tank integrity test to be performed at least once a month in order for it to be considered as an acceptable form of monitoring for UST. The cost of a tank test is about $500 to $600 per tank; thus, it costs about $1,500 to 1,800 to test three USTs at a service station. When the test is repeated 12 times in a year, the annual cost for a services station comes to about $20,000. Because of its high cost, the tank integrity test has not been used for routine monitoring of USTs; instead, it is generally used as a periodic or a confirmation test when there is a suspected leak in an UST.

The internal tank level sensor is another method to monitor USTs. It is similar to the tank integrity test that it is capable of deriving quantitative leak rates, but it differs from the tank test that a probe is permanently placed in an UST, and the test can be performed at any liquid level at any time without the need for specially trained tank testing operators. The first internal level sensor was developed around 1984, and there are now about three or four systems on the market. Liquid level sensors can generally measure a change in the fuel level with an accuracy of about 0.001 inch, which translates to about 0.14 gallons[3-5] when a tank is half full. The absolute accuracy of these devices is substantially lower; the fuel volume can be measured with a resolution of about 15 gallons. To determine the leakage rate, a level sensor first measures the liquid level inside an UST over a period of time when there is no input and withdrawal activities; converts the liquid level measurements to fuel quantities (gallons); then calculates the change in the fuel volume during the test period to derive a rate of change in terms of gallons per hour. In order to minimize the effect of the background instrument noise, an instrument usually takes a reading several times per second to obtain a statistical average reading. One instrument requires five to six hours of testing time in order to achieve sensitivity of 0.2 gallon per hour.

There are several confounding factors which can interfere with the accuracy of an internal tank monitor.

The internal tank monitoring is similar to the integrity test that both methods rely on measuring the liquid level in an UST; thus factors which affect the liquid level in an UST are common to both methods. A discussion of these factor can be found in the section on tank integrity tests. Of all the possible factors, temperature change and stratification have the greatest impacts on the accuracy of the internal tank monitoring.

There are several manufacturers of internal tank level devices which utilize different methods to measure liquid levels. The earliest device uses a long capacitor probe inserted vertically inside a tank. The capacitance of the probe changes when it is in contact with fuel, and it is possible to correlate the fuel level with the capacitance. Another manufacturer utilizes a pressure transducer placed at the bottom of the UST. The pressure sensor detects the head pressure of the liquid in the tank, and the liquid level can be correlated to the head pressure. Another manufacturer places an ultrasonic transducer at the bottom of the tank. The transducer generates a signal which propagates through the fluid in the tank up to the top of the liquid surface, and the length of time it takes the signal to travel from the bottom to the top is proportional to the depth of the liquid. Recently, two manufacturers have made devices which are based on the magnetostrictive principle. A thin metal probe is inserted in the tank with an insulated wire running inside the probe and a reference point at the top of the probe. Fuel and water magnetic flotation rings which float on top of the fuel and between the fuel and the water interface are inserted on the outside of the probe (Figure 3-5). A current pulse is sent through the wire downward from the reference point, and it is reflected by the magnets in the level flotation rings. The amount of time it takes the current pulse to travel down the probe and return to the reference point can be accurately correlated to the fuel and water levels.

In order for an internal level sensor to be accepted in San Jose, a manufacturer must demonstrate to the satisfaction of the City that its device can detect a leak rate as small as 0.2 gallon per hour. In the past, the City has asked a manufacturer to perform a series of tests to demonstrate the response of its device to simulated leaks at different leak rates. Recently, the City adopted the federal criteria used in its extensive testing of internal tank level sensors (Section 3.3.2). It now requires a manufacturer to demonstrate that a device is capable of detecting a 0.2 gph leak with a 95% probability of detection (true positive), and with no more than a 5% probability of false negatives at a 0.1 gph leak rate. As of today, one device (the capacitor probe) has been accepted

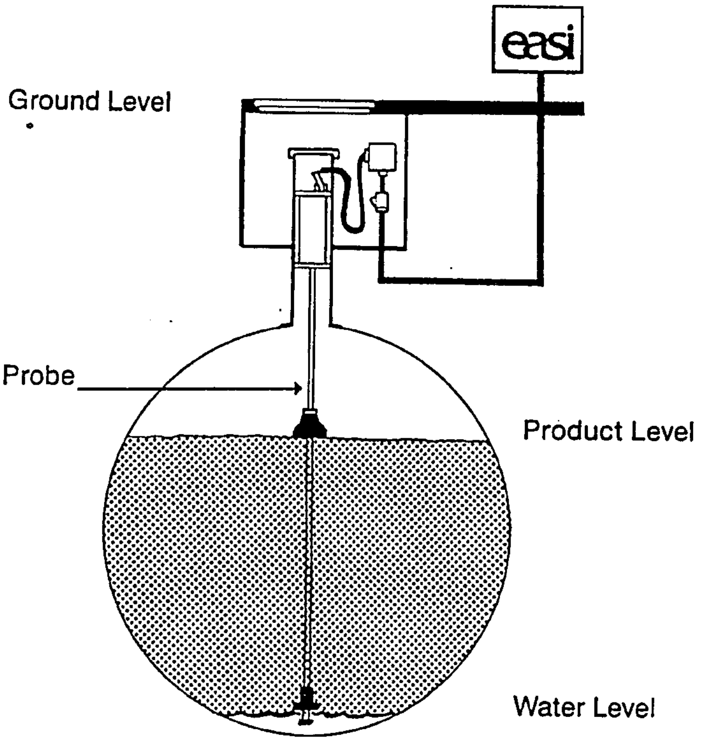


Figure 3-5. Internal tank level sensor based on the magnetostrictive principle.

Source: EASI, ____.

in the City of San Jose, two have been rejected, and two are currently under review.

Besides serving as a leak detector, an internal tank level sensor can provide a service station operator with other benefits, such as an inventory control system which can notify an operator when an UST is low on fuel, verify the quantify of a fuel delivery and alert an operator to incidences of theft. As for the frequency of leak detection, a facility which closes at night usually turns the instrument to the leak detection mode at night, and a 24-hour service station have to shut-down its USTs at least once a week for the five to six hours necessary to perform a leak test.

Piping Monitoring

Underground pipes share some common characteristics with USTs and may be monitored by similar methods; however, they also possess different characteristics which require separate considerations. Most pipes are buried in the same porous back-fill materials as USTs; therefore, they are compatible with vadose zone monitoring systems. They are buried in shallow trenches which make vadose monitoring wells easy to construct, but a large net work of monitoring wells is usually required for long lengths of trenches and pipes. The configuration of piping installations also makes groundwater monitoring wells ineffective for the monitoring of piping. The distance between the shallow trenches and the groundwater increases the time it takes a material to migrate from a leaky pipe to a groundwater monitoring well. This delay in detection can leak to the further migration of contaminants and a more difficult clean-up project. Furthermore, the installation of a large net work of groundwater wells is likely to be much more expensive than the installation of shallow vadose wells.

San Jose requires one vadose zone monitoring well per service island, and additional wells are necessary in the piping trench if a pipe is longer than 60 to 80 feet or if there are bends along the length of the pipe. Similar to monitoring wells for USTs, vadose wells for pipes must also be in porous back-fill materials.

Internal tank level devices may be used for piping monitoring if a pipe is pressurized by turning on the submergible pump when an internal tank level sensor is on the leak detection mode. Any leakage from the pressurized pipe will lead to a drop in the liquid level in the UST, and an internal tank level sensor should be capable of detecting leaks as small as 0.2 gallons per hour.

A unique leak detection system to monitor single wall pipes is the piping pressure loss sensor. A delivery piping system is always primed with fuel in order to enable the pump to function properly. A one-way check valve is normally installed at the tank end of a delivery pipe, which allows fuels to flow from an UST to the dispensers, but does not allow fuels to flow back to the UST. A pressure sensor can be installed in the pipe which can detect the loss of pressure caused by a leak in the pipe when it is not in use. The concept used in this detection method is simple; however, there are problems when the piping pressure sensor system is used in existing UST facilities. In the majority of existing installations, check values are not always able to hold pressure. A faulty check valve can lead to false alarms when a pipe is not actually leaking. Furthermore, contractions of the fuel caused by temperature change can also be mistaken as a leak. As of today, several line pressure sensors have been tested in San Jose, but none has able to demonstrate its effectiveness and accepted by the City.

Installation of New USTs

Prior to the installation of a new UST, installation plans must be submitted to the San Jose Fire Department for review and approval. Plans are checked to determined whether they comply with requirements of the HMSO and the Uniform Fire Code. The majority of new installations use double-wall tanks and fiberglass trenches for secondary containment of piping. Both of these items have been discussed previously in this section. Other noticeable differences between new and existing installations include the requirement for a 15 gallon over-fill containment box around the fill pipe of a new UST. At the end of a fuel delivery, if the delivery hose from a delivery truck to the UST is mistakenly disconnected at the tank prior to its disconnection at the truck, then the fuel in the delivery hose can flow out from the tank end of the hose. The normal length of a delivery hose holds approximately 15 gallons of fuel, and the purpose of the over-fill containment box is to contain this accidental discharge. Another required element in a new UST is a ball float value at the vent outlet inside an UST. The purpose of the ball float value is to prevent over-filling of the UST. When the liquid level reaches near the top of the UST, the ball value floats up to block further displacement of air inside the tank, and at result, additional fuel cannot be dispensed into the tank.

Subsequent to the approval of a plan, the Fire Department conducts inspections through out the installation process to ensure that an UST is being installed properly according to the approved plan. Following are the usual inspections performed by the Fire Department:

1. Pressure test the inner and the outer compartments of a double-wall UST at 3 to 5 psi.

2. Pressure test pipes at 50 to 75 psi, and also pressure test the outer pipe if a double-wall piping system is used.

3. Test the integrity of over-fill containment boxes using 24-hour water test. Piping trenches can also be water tested if they are used to provide secondary containment for piping.

4. Inspect to ensure that monitoring devices are properly installed.

Inspection of Existing Facilities

The goal of the San Jose Fire Department is to perform annual inspections of all existing UST facilities. The purpose of the inspection is to ensure that all Fire Code requirements are met and USTs are being properly monitored. Currently, an inspector checks whether a monitoring log sheet is maintained and whether the routine monitoring is performed at the minimum monitoring interval; however, there is no inspection procedure to determine whether a monitoring device is working properly, and whether it has been properly maintained.

Due to a shortage of personnel in the Hazardous Materials Program, routine inspections for service stations and most of the other existing UST facilities did not start in San Jose until the end of 1988. Out of a total of approximately 600 facilities with existing USTs, less than 40 (7%) have been properly inspected by trained inspectors as of May of 1989.

Tank Closure Procedures

The HMSO requires out of service USTs to be properly closed with 90 days. San Jose requires a closure plan be submitted to the City for approval prior to the initiation of any closure work. The HMSO requires that the closure plan include procedures to control the threat of residual hazardous materials and to minimizes the need for further maintenance. San Jose interprets the HMSO to require a soil investigation at the time of an UST closure in order to demonstrate whether a site requires further maintenance or poses any future environmental threats. This interpretation was not adopted by all the cities in the Santa Clara County at the beginning of the HMSO implementation. However, all the cities have since recognized the value of soil sampling, and now, they all require soil sampling as a part of their tank closure requirements. In San Jose, two soil samples are required for each fuel UST with a capacity greater than 1,000 gallons. A sample is generally taken just beneath the back-fill material at the native soil. It is believed that if a contamination is present at a site, then the surface of the dense native soil, just beneath the porous back-fill material, would have the greatest amount of contaminants. The soil sample is analyzed for total petroleum hydrocarbon, benzene, toluene, xylenes, and ethyl benzene.

The role of San Jose under the HMSO is to check for the existence of contaminations. If a contamination is found through soil sampling and analysis, then San Jose reports the contamination to the San Francisco Regional Water Quality Control Board and defers all clean-up oversights to the state agency.

Fee Schedule

The HMSO authorizes San Jose to assess permit fees to enable its HMP to be 100% cost recovery. The HMP regulates both above ground and underground storage of hazardous materials and uses the same fee schedule for its entire program. A permit fee is based on the chemical hazard category and the quantity of hazardous materials at a storage facility. The quantity of materials is classified into one of five quantity ranges as follows:

Quantity Range	Quantity of Hazardous Material
1	Less than 55 gallons
2	55 to 550 gallons
3	550 to 2,750 gallons
4	2,750 to 5,500 gallons
5	Greater than 5,500 gallons

The annual permit fee is based on the total number of quantity ranges of all the chemical hazard categories at a storage facility. Currently, the annual permit fee is $110 per quantity range. For a service station with motor vehicle fuels and waste oils, the only chemical hazard category for the facility is flammable and combustible liquids. The quantity of materials almost certainly will exceed 5,500 gallons, which corresponds to a quantity range of five with an annual permit fee of $550. In addition to the annual permit fee, San Jose charges an inspection fee. After a first hour of free inspection, additional inspection fee is charged by the half-hour based on an hourly rate of $75. If the total inspection time at a service station is three hours, then the inspection fee for the facility is $150, and the total fee for the annual permit and the inspection adds up to $700.

3.2 California

Shortly after the creation of the Santa Clara County Model Hazardous Materials Storage Ordinance (Model Ordinance), Assembly person Byrn Sher of Palo Alto used the Model Ordinance as a model and introduced similar legislation for California. AB 1362 or the Sher Bill was signed by Governor Dukemajian on September 23, 1983, and it added Sections 25280 to 25299 to Chapter 6.7 of the California Health and Safety Code. It adopted the main components of the underground storage tank (UST) regulations encompassed in the Model Ordinance, but left out the above ground storage regulations and the right-to-know component. In the text of the bill, it declared that "underground tanks used for the storage of hazardous substances and waste are potential sources of contamination of the ground and underlying aquifers, and may pose other dangers to public health and the environment" and "current laws do not specifically govern the construction, maintenance, testing and use of underground tanks used for the storage of hazardous substances, or the short-term storage of hazardous waste prior to disposal, for the purposes of protecting the public health and the environment".

The state statute contains some technical provisions and left the remainder of regulation development to the State Water Resource Control Board (State Board). Regulations developed by the State Board became effective August

11, 1985 and were codified in Section 2610 to 2714, Subchapter 16, Chapter 3 of the California Administrative Code (CAC). The Sher Bill required local governments to assume the responsibility for implementation of the regulations with general oversight from the State Board.

Since the original adoption of the Sher Bill in 1983, Chapter 6.7 of the California Health and Safety Code on Underground Storage of Hazardous Substances has been amended several times, including amendments from the passage of AB 3565, AB 3447 and AB 3781 in 1984; AB 1755 and AB 2239 in 1985; and AB 3570, SB 1818 and AB 2920 in 1986. Some of these amendments necessitate changes in the corresponding California Administrative Code.

3.2.1 California Statute - Health and Safety Code

The Sher Bill and its subsequent amendments, as codified in Chapter 6.7 of the California Health and Safety Code (HSC), contain all the major components found in the Model Ordinance as it relates to USTs. In fact, the original Sher Bill was modeled after the Model Ordinance with requirements for secondary containment, monitoring, spill reporting, and closure of USTs. However, the state statute deviated from the performance orientated approach of the Model Ordinance. It contained specific approvals for certain leak detection systems and a special exception for the installation of motor vehicle fuel USTs. Some portions of the state statute is still performance oriented that it required the State Board to promulgate regulations to implement and achieve the standards established in the statutory requirements.

The state statute places the responsibility for the implementation of the UST regulations, including those adopted by the State Board, at the county level. A city may assume responsibility for USTs within the city if it provides a notice to the county before January 1, 1986. Assembly person Sher recognized the pre-existence of local UST regulations in the Santa Clara County and other parts of the state prior to the passage of state regulations; thus, the state statute exempts local jurisdictions from the state regulations if they had ordinances prior to January 1, 1984, which at a minimum, contained requirements of double containment of new USTs and monitoring of existing USTs. These local ordinances only have to meet the original requirements in Sections 25284 an 25284.1 of the Sher bill prior to any subsequent amendments and renumberings.

In the definition of a hazardous substance, the state statute refers to it as:

1. Any substance on the list prepared by the Director of Industrial Relations (Section 6382 of the Labor Code).

2. A material defined by the National Fire Protection Association as a flammable liquid, or a class II or class III-A combustible liquid.

3. A hazardous substance as defined in Section 25316 of Department of Health Services' regulations on Hazardous Substance Account which include:

   a. Any Substance designated pursuant to Section 1321 (b)(2)(A) of Title 33 of the United States Code.

   b. Any element, compound, mixture, solution, or substance designated pursuant to Section 102 of the federal act (42 U.S.C. 9602).

   c. Any hazardous waste having the characteristics identified under or listed pursuant to Section 6921 of Title 42 of the U.S.C., but not including any waste the regulation of which under the Solid Waste Disposal Act has been suspended by act of Congress.

   d. Any toxic pollutant listed under Section 1317 (a) of Title 33 of the U.S.C.

   e. Any hazardous air pollutant listed under Section 7412 of Title 42 of the U.S.C.

   f. Any imminently hazardous chemical substance or mixture with respect to which the Administrator of the U.S. EPA has taken action pursuant to Section 2606 of Title 15 of the U.S.C.

   G. Any hazardous waste or extremely hazardous waste as defined by Sections 25117 and 25115, respectively, unless expressly excluded.

Under the state statute, a new UST installed after January 1, 1984 must have a secondary containment and a monitoring system. The definition of a secondary containment is similar to the one used in the HMSO that it shall be capable of containing a spilled material for the maximum anticipated period of time necessary for detection and clean-up. However, there is an exception for USTs used for motor vehicle fuels in the state regulations. A special allowance is made for fuel USTs to exempt them from have complete secondary containment if an interceptor system is used. Furthermore, the original Sher Bill exempted a motor vehicle fuel piping system from the secondary containment requirement. This exemption was deleted in a subsequent amendment which requires piping constructed after July 1, 1987 to have secondary containment.

A monitoring system is required on or before July 1, 1985 for an existing UST installed prior to January 1, 1984. The state statute specifically names several monitoring methods as acceptable alternatives, which include tank testing, groundwater monitoring wells, and vadose zone monitoring wells. Furthermore, it allows the combination of daily tank gauging and inventory reconciliation as an acceptable form of monitoring for motor vehicle fuel USTs. The state statute allows local agencies to required alternative monitoring methods if monitoring frequency is at least on a monthly basis.

The state statute prohibits a person to abandon an UST without a proper closure of the facility. An UST may be temporarily taken out of service, but the operator must continue to monitor it. For permanent closure, all residual storage substances must be removed and the tank sealed to minimize future threat to public safety and environment. Furthermore, the operator must demonstrate that there has been no significant soil contamination resulting from discharges from the UST.

The state statute adopted the Model Ordinance's approach to unauthorized releases and classified unauthorized releases into recordable or reportable discharges. It requires reportable discharges to be reported with 24 hours after a release. A full written report is required within five working days. Also, it requires the State Board, in cooperation with the Office of Emergency Services and local implementation agencies, to submit an annual report on all unauthorized releases to the state legislature.

A facility owner or operator may apply to the State Board for either categorical or site-specific variances from the secondary containment and monitoring requirements of the state statute. The series of steps in the variance consideration and approval process include public notifications and a public hearing. The State Board is authorized to charge and collect a fee from the applicant sufficient to recover reasonable costs associated with the variance process. If a local agency wants to deviate from the state regulations, it must also obtain an approval from the State Board, and a public notification and hearing process is also required.

Under the state statute, a local jurisdiction is responsible for the review and issuance of permits for new and existing USTs. It can collect permit fees to cover the operation of its program. Furthermore, a local administering agency is required to conduct site inspections at least once every three years.

An operator or owner of an UST who is in violation of the state statute is liable for a civil penalty of not less than $500 or more than $5,000 per day on each count of a violation. A person convicted of falsifying monitoring records or failing to report an unauthorized release is subject to criminal prosecution and a fine of not less than $5,000 or more than $10,000, and the person may be imprisoned for up to one year.

3.2.2 California Administrative Code

Under California's statutory regulation, Section 25299.3 (a), Division 20, Chapter 6.7 of the California Health and Safety Code, the State Board has to promulgated regulations to implement standards mandated by the state statute. Regulations from the State Board became effective August 11, 1985 and were codified in Section 2610 to 2714, Subchapter 16, Chapter 3 of the California Administrative Code (CAC). These regulations were modified subsequently to reflect changes in the state statute as a result of the numerous amendments to the original Sher Bill.

State Board's regulations are specific and lengthy, and an article was devoted to each of the following topics: New UST construction and monitoring standards, existing UST monitoring standards, release reporting requirements, allowable repairs, closure requirements, categorical and site-specific variance procedures, local agency additional standards request procedures, and permit application, annual report and trade secret requirements. These articles followed the general outline in the state statute and provided detail instructions for local agencies to use in their implementation efforts, and for UST owners and operators to follow in their compliance efforts.

New USTs

The CAC requires a new UST storing any regulated material to have a secondary level of containment. A new UST is an UST installed after January 1, 1984, the effective date of the state statute. The CAC recognizes the double-wall tank, the flexible membrane liner, and the concrete vault as possible devices which can satisfy the secondary containment requirement. It does not preclude other devices not mentioned as long as they meet some structural integrity, volumetric and other design requirements. The CAC relies heavily on independent testing agencies, voluntary industrial standards, and registered engineers for certification of technical items such as the durability of primary and secondary containers and associated piping, the chemical compatibility of these systems with the hazardous material stored, and the adequacy of corrosion protection. For example, the CAC provides a list of specific standards which a membrane liner has to meet for the time period prior to the development of standards for synthetic membrane liners by an independent testing organization. These standards include criteria on the permeability, absorption, solubility, hardness, and strength of the membrane liner.

Under the CAC, an acceptable leak detection system for a new UST include visual inspection, the liquid level indicator, annular space liquid level indicator, vapor monitor, and pressure or vacuum loss detector. Both electronic monitoring and manual monitoring are acceptable; however, a double-wall UST must be monitored with a continuous monitoring device, which is connected to an audible or visible alarm system. Manual monitoring must be performed daily, expect on weekends and legal holidays. A written procedure for routine monitoring and a response plan to address unauthorized release must be included as part of the monitoring program for a storage facility.

Following the state statute, the CAC contains a special construction standards for new motor vehicle fuel USTs which exempt them from full secondary containment. It allows the construction of a leak interception and detection system (Figure 3-6) and recognizes the synthetic membrane liner as an acceptable method to satisfy this requirement. The minimum criterion of the leak interception and detection system is that it has to prevent any stored material from reaching the groundwater in the event of a leak. An applicant who wishes to install a leak interception and detection system has to demonstrate to the satisfaction of a local agency that a proposed system will work after taking into account the containment volume of the leak interception and detection system, the maximum leak rate, frequency and accuracy of monitoring, depth of groundwater, soil characteristics, effects of precipitation, and the anticipated cleanup response.

Under the 1987 version of the CAC, pressurized piping connected to an motor vehicle fuel UST is no longer exempt from the secondary containment requirement. The 1987 amendments also allow a suction delivery pipeline to be excluded from the secondary containment requirement if there is no valve between the pipeline inlet and the check value located next to the suction pump. Other requirements of the CAC include over-fill protection systems which consist of spill catchment basin and audible/visible

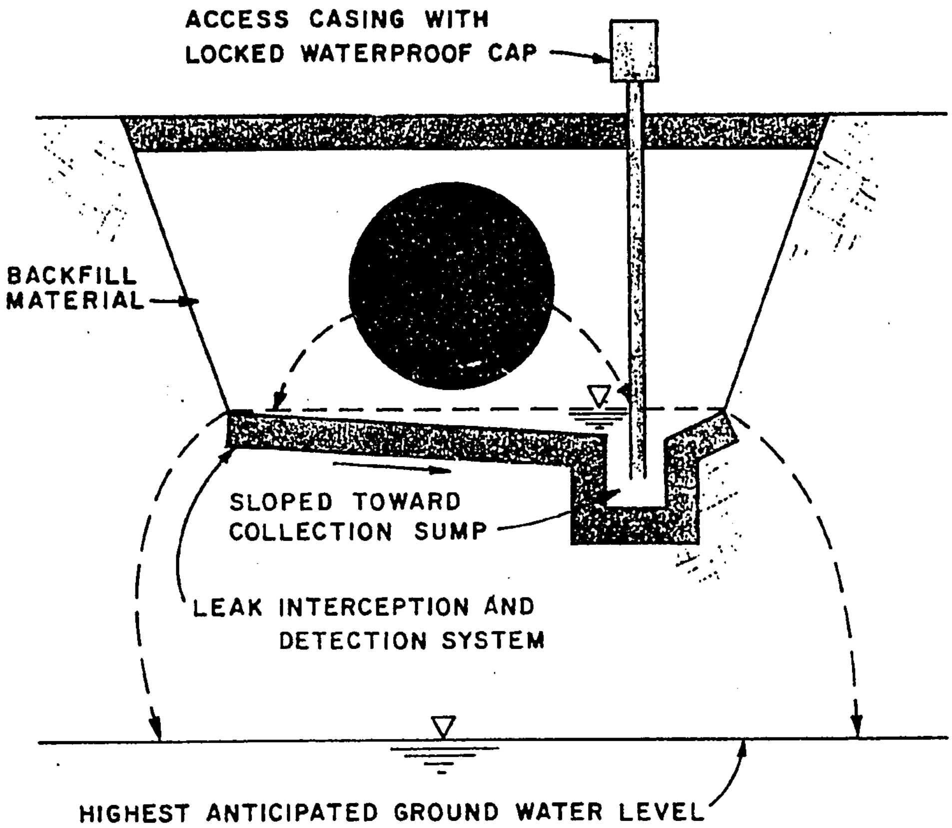


Figure 3-6. Schematic of California's leak interception and detection system for motor vehicle fuel UST.

Source: SWRCB, 1985

alarm system or automatic shut-off devices when an UST is full.

Existing USTs

The CAC provides detail description of various leak detection methods for existing USTs, geological settings in which these methods are acceptable; operational requirements of the system; and alarm response procedures. The article on monitoring of existing USTs is by far the lengthiest article among all CAC articles on USTs. An existing UST is defined as an UST which is not a new UST; in other word, it is an UST installed prior to January 1, 1984.

The CAC stated that the objective of a monitoring program for existing USTs is to detect unauthorized releases before the soil or groundwater is adversely affected. A monitoring system should be capable of detecting any active or future unauthorized releases, but not necessarily historical releases. However, when an external monitoring system is used to detect the presence of stored materials outside an UST, then a test of the external environment has to be conducted to determine the presence of the stored material or any other materials which may interfere with the operation of the monitoring system. Whenever possible, visual monitoring is the preferred method of leak detection.

The CAC listed nine leak detection alternatives for an existing UST when visual monitoring is not possible for the entire UST. They involve different combinations of tank testing, inventory reconciliation, groundwater monitoring, vadose monitoring, soil testing, pipeline leak detector, and internal tank level monitoring. Construction requirements, UST specifications, geological constraints, and monitoring frequencies vary between the different monitoring alternatives. The CAC allows local administering agencies to impose additional requirements and shorter monitoring frequency than those specified in the nine alternatives if they are necessary to achieve the monitoring objectives as stated in the regulations.

Following is a brief description of the eleven monitoring options for existing USTs and the conditions permitting the use of these alternatives:

1. Tank Testing (Monthly). The precision tank test is allowed for all existing USTs.

2. Vadose Zone Monitoring (Continuous/Weekly) and Groundwater Monitoring (Semi-annual). The groundwater must be less than 100 feet deep. For groundwater less than 50 feet deep, a single tank with capacity of 1,000 gallon or more requires a minimum of two wells; two or three tanks require three wells minimum; and four or more tanks require at least four wells. For groundwater greater than 50 feet deep, a single tank requires one well, and multiple tanks require three wells. Pipelines may require additional wells at the discretion of local administering agencies.

3. Vadose Zone Monitoring (Daily/Weekly) and Tank Testing (Annual). The groundwater has to be more than 100 feet deep, has no actual or potential beneficial uses, and is not hydraulically connected to other groundwater which has or potentially has beneficial uses.

4. Groundwater Monitoring (Monthly). The groundwater has to be less than 30 feet deep, has no beneficial uses, and is not hydraulically connected to other groundwater which has or potentially has beneficial uses.

5. Inventory Reconciliation (Daily), Tank Testing (Annual) and Pipeline Leak Detectors. Limited to motor vehicle fuel USTs. Inventory reconciliation which exceeds an allowable measurement error plus 0.15 percent of the throughput at any time during a 30-day period requires further investigation. Allowable measurement error depends on the tank size and is as follows:

Tank Size (Gal)	Allowable Measurement Error (Gal)
Less than 4,000	25
4,000 - 8,000	50
8,000 - 12,000	75
12,000 - 16,000	100
Greater than 16,000	125

6. Inventory Reconciliation (Weekly/Monthly), Tank Testing (Annual), Pipeline Leak Detector, Vadose Monitoring (Variable) and Groundwater Monitoring (Variable). Limited to motor vehicle fuel USTs. The minimum number of groundwater wells is the same as Alternative #2. Inventory reconciliation which exceeds any of the following requires further investigation:

   a. Seven-day variation of five percent of throughput or 100 gallons, whichever is greater but no greater than 350 gallons.

   b. A monthly variation of 0.5 percent of throughput or 100 gallons, whichever is greater.

7. Tank Gauging (Weekly) and Tank Testing (Annual). Limited to USTs which do not have inputs or withdrawals for a period of 36 hours each week and where the liquid level in the USTs can be measured to the accuracy of nine gallons. A liquid

level difference of 17 gallons or more requires further investigation.

8. Inventory Reconciliation (Daily) or Tank Gauging (Daily/Weekly) and Tank Testing (Annual). This is an interim monitoring alternative which can be implemented for up to three years and expire on or before August 13, 1988. An UST must either be closed or replaced with a new UST within the allowable time period. Instead of tank replacement, small businesses or governmental agencies may monitor their USTs with other acceptable alternatives.

9. Inventory Reconciliation (Daily), Internal Tank Level Monitoring (Weekly/Bimonthly), Pipeline Leak Detectors and Tank Testing (3 years). Limited to motor vehicle fuel USTs. The allowable variation in inventory reconciliation is the same as Alternative #5 for bimonthly tank level monitoring; and Alternative #6, for weekly tank level monitoring.

10. Vadose Zone Monitoring (Monthly/Annually) and Groundwater Monitoring (Monthly/Annually). Limited to large USTs over 20,000 gallons and the groundwater is less than 50 feet deep, has no beneficial uses, and is not hydraulically connected to other groundwater which has or potentially has beneficial uses.

11. Continuous Leak Detection in Wells (Continuous). Must be able to do both vadose and groundwater monitoring.

A one-time of soil sampling and analysis is necessary whenever a vadose zone or groundwater monitoring well is constructed. Under some of the monitoring alternatives, a pipeline leak detector is required. The pipeline leak detector has to be capable of sensing a pressure loss in a pipeline, but complete shut-off the dispensing operation is not required. A summary of the state alternatives is presented in Table 3-3.

Table 3-3. Summary of Monitoring Alternatives for Existing Underground Storage Tanks and Their Conditions and Constraints Under the California Administrative Code.

Monitoring Alternatives and Constraints	Tank Integrity Testing	Vadose Zone Monitoring	Groundwater Monitoring	Soil Testing	Pipeline Leak Detector	Inventory Control	Tank Gauging	In-Tank Level Sensor
	Monitoring Requirements							
1. Tank test	x							
2. Groundwater less than 100'		x	x	x				
3. Groundwater less than 100' with no beneficial uses	x	x		x				
4. Groundwater less than 30' with no beneficial uses			x	x				
5. Stringent inventory control Motor vehicle fuel (MVF) UST	x				x	x		
6. Less stringent inventory control, MVF UST	x	x	x	x	x	x		
7. UST with 36 hours quiet period, Gauge +/- 9 Gal.	x						x	
8. Interim alternative with 3 years maximum term	x					x	x	
9. In-Tank level sensor and inventory control, MVF UST	x				x	x		x
10. Large tank over 20,000 gallon capacity		x	x					
11. Continuous leak detection in monitoring wells		x	x	x				

Others

In the articles on unauthorized releases, the CAC adds little to the already comprehensive state statute. The same is true for the article on permanent closure of USTs, except that the CAC specifies the number of soil samples necessary to determine residual contamination at a closure location. It specifies that, at a minimum, an undisturbed soil sample has to be taken for every 100 square-feet of an UST excavation and every 20 lineal-feet of piping trench excavation.

With respect to variances, an applicant, whether it is an UST owner, operator, or local administering agency, is required to pay a fee based on the actual cost incurred by the State Board in the consideration process. All applicants must pay an initial payment at the time when an application is submitted. The initial payment for a categorical variance is $11,000; $2,750 for a site-specific variance of one site; $5,500 for a site-specific variance with more than one site; and $5,500 for a local agency.

3.2.3 Status of the California UST Program

At the present time, summary information on the status of the California UST program is incomplete. Local implementing agencies are required to submit UST information to the State Board, but the State Board does not have complete information on the status of all the local implementing programs. It is in the process of meeting with the local agencies to formulate a mechanism to transfer UST information from the local agencies to the state. About 64% of all USTs in California are located in local jurisdictions which have local ordinances and exempted from parts of the state regulations. These local jurisdictions encompass 41 cities which account for 50 to 60% of the total population in California (Holtry, 1989). In general, cities in the Santa Clara County are more advance in the implementation of their UST programs than the majority of other cities and counties in California.

3.3 The United States

After being made aware of the problems associated with the leaky Underground storage tank (UST), the 1984 U.S. Congress responded quickly by introducing an attachment to an existing bill in the House whose purpose was to amend the Resource Conservation and Recovery Act (RCRA). It added a new subtitle in the Hazardous and Solid Waste Amendment of 1984, and President Reagan signed it into law on November 8, 1984. The new Subtitle I provides for the development and implementation of a national regulatory program on USTs used for the storage of petroleum and other hazardous substances. The hazardous wastes UST is not regulated by the new statute, because it is regulated under the RCRA hazardous waste program. Subtitle I required UST owners to notify and supply the states with demographic information on their USTs and required the Environmental Protection Agency (EPA) to develop regulations to prevent, detect, and correct releases from USTs. It instituted an interim prohibition on the installation of new USTs unless corrosion protection and leak detection are provided. Subtitle I also allows states to develop their own UST program in place of the federal program if their regulations are at least as stringent as the federal regulations.

Subsequent to the passage of Subtitle I, EPA created the Office of Underground Storage Tanks within its Office of Solid Waste and Emergency Response to develop the regulations mandated by the statute. On April 17, 1987, EPA published a proposed set of regulations including technical standards for new and existing USTs, financial responsibility requirements of UST owners, and approval process for state programs. EPA conducted public hearings and workshops and issued its final regulations on technical standards and state program approval procedures on September 8, 1988. Its final financial responsibility requirements were issued on October 26, 1988.

3.3.1 Hazardous and Solid Waste Amendment of 1984, Subtitle I

Subtitle I of the Resource Conservation and Recovery Act (RCRA) was enacted on November 8, 1984 as a part of the Hazardous and Solid Waste Amendments of 1984, which was subsequently codified as Section 6991, Chapter 42 of the United Sates Code (USC). It was amended on October 17, 1986 by the Superfund Amendments and Reauthorization Act of 1986 (SARA Title II amendments). Subtitle I provided a detail framework for a national UST program and required EPA to promulgate regulations to supplement the legislation with technical standards.

Subtitle I defines an UST as "any one or combination of tanks (including underground pipes connected thereto) which is used to contain an accumulation of regulated substances, and the volume of which (including the volume of the underground pipes connected thereto) is 10 percent or more beneath the surface of the ground". The definition specifically exempts a farm or residential tank with a capacity of 1,100 gallons or less used for storing motor vehicle fuel for noncommercial purposes. A regulated substance includes any petroleum product or any of the 701 hazardous substances as defined under Section 101(14) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (Section 9601(14), USC), but it excludes any substance regulated as a hazardous waste.

Within 18 months after its passage, Subtitle I requires owners of existing USTs to notify and supply state or local agencies with information such as the age, size, type, location, and uses of their USTs. Notification is also required for new USTs and those USTs which have been taken out of service after January 1, 1974 but have not been removed from the ground. Furthermore, for an 18 month period, a person who delivers and deposits a regulated substance in an UST is responsible to inform the owner or operator of the UST of the notification requirement. A state is required (under SARA Title II amendments) to compile the notification information it received and submit summary statistics to EPA.

EPA is required to "promulgate release detection, prevention, and correction regulations applicable to all owners and operators of USTs, as may be necessary to protect human health and the environment". In promulgating these regulations, EPA "may distinguish between types, classes, and ages of USTs" (Section 6991b(a), 42 USC). It may consider intrinsic factors to the USTs such as the tank age, size, fabrication material, material stored, through-put quantity, and extrinsic environmental factors such as the tank location, soil and climate conditions, the hydrogeology, and water table. The regulations promulgated must include, but not limited to the following elements:

1. Requirements for a leak detection system, an inventory control system together with tank testing or other acceptable monitoring methods.
2. Requirements for record keeping.
3. Reporting requirements for a release from an UST.
4. Corrective actions in responses to a release.
5. Closure requirements to prevent the future release of regulated substances into the environment.
6. Requirements for maintaining evidence of financial responsibility in the event of a release.

Subtitle I requires EPA to promulgate regulations to ensure that UST owners and operators have financial mechanisms "for taking corrective action and compensating third parties for bodily injury and property damage caused by sudden and non-sudden accidental releases arising from operating an UST" (Section 6991b(c), 42 USC). SARA Title

III amendments established the level of financial responsibility coverage for petroleum USTs at $1 million for each release occurrence. The amount of coverage may be reduced for USTs containing other regulated substances or small amount of petroleum products. Financial responsibility may be provided by mechanisms such as insurance, guarantee, surety bond, letter of credit, self-insurance, or any other methods deemed acceptable to the EPA.

The statute established maximum time allowances between its adoption (November 8, 1984) and the effective date of the EPA's regulations. For regulations on petroleum USTs, the maximum time period is 30 months, which makes May 8, 1987 the deadline for the EPA regulations to go into effect; for regulations on USTs containing other regulated substances, it is 36 months or November 8, 1987; and for regulations on financial responsibility, it is 48 months or November 8, 1988.

Prior to the effective date of the standards promulgated by EPA, the statute established an interim prohibition on the installation of new USTs unless an UST meets some minimal new UST construction standards. The interim Prohibition specifies that no person shall install an UST unless:

1. It can prevent releases due to the corrosion or structure failure for the operation life of the tank.

2. It is cathodically protected against corrosion; constructed of noncorrosive material, steel clad with a noncorrosive material; or designed to prevent the release or threatened release of stored substances. Corrosion protection may be waived if the soil resistivity at the installation location is greater than 12,000 ohm-cm or more.

3. The material used in the construction or lining of the UST is compatible with the substance stored.

Subtitle I allows states, beginning May 8, 1987, to apply to EPA for the authorization to operate an UST program in lieu of the federal program. A state program must include all the regulatory elements of the federal program and provide for adequate enforcement of compliance. After a one- to three-year grace period, state requirements must not be less stringent than the federal requirements.

Violators of the federal statute or regulations are subject to civil penalties of up to $10,000 per tank for each day of violation. Federal government facilities are subject to all federal, state, and local requirements, including the payment of reasonable service charges.

In the event of a release of petroleum product, SARA Title II amendments required an UST owner or operator to take corrective action and allowed EPA or a state, which has a cooperative agreement with the EPA, to take corrective actions if such actions are necessary to protect human health and the environment. SARA Title II also established a $500 million Leaking Underground Storage Tank Trust Fund which is financed from a gasoline tax and allows EPA or a state to use the fund to pay for corrective actions. A site must be in compliance with the financial assurance requirements in order to be eligible for the fund; in other words, the fund cannot be used for the first $100,000 incurred at such a site.

3.3.2 Federal EPA Regulations

Regulations promulgated by EPA to implement the statutory requirements of Subtitle I can be found in 40 CFR Part 280. Since many elements of the federal UST program have already been specified in detail in the statute, EPA only had to make interpretive rulings in many areas to reflect the agency's interpretation of the statute and to announce its intended method of implementation. For example, in the definition and interim prohibition sections, the federal regulations simply mirrored the federal statute and added very little to the statutory requirements. On the other hand, in technical areas such as leak detection and new tank standards, EPA had to draft new rules pursuant to the statutory authority. It sought comments from the industries, state and local UST programs, manufacturers of leak detector devices, and consultants with expertise in the field. As part of its information gathering process, EPA also sponsored several workshops and funded many studies.

New USTs and Piping

In order to prevent releases due to structural failures, corrosion, spills, or overfills, the federal regulations required new USTs and piping to be designed and constructed according to the appropriate code of practice developed by nationally recognized associations or independent testing laboratories. An UST may be constructed of fiberglass, coated steel with cathodic protection, or steel clad with fiberglass. A spill prevention mechanism such as a catchment basin is required to prevent the release of products to the environment when the transfer hose is detached from the fill pipe. Also required is a mechanism for over-fill prevention, such as an automatic shut off device when a tank is 95 percent full, or a flow restrictor or a high-level alarm to alert the transfer operator when the tank is 90 percent full. Owners and operator may use other alternate devices if they have been determined by the local administering agency to offer the same level of protection for public health and the environment. Under the federal regulations, secondary containments are not required for new petroleum USTs and piping, but new USTs and piping storing other regulated substances are required to have secondary containments.

Existing USTs and Piping

No later than December 22 of 1998, all existing USTs and piping must either meet new UST standards, comply with upgrade requirements, or be properly closed. Upgrade requirements for steel tanks can be met by interior lining and/or cathodic protection. An interior lining needs to be inspected 10 years after its installation, and every five year thereafter. The federal regulations specify that a cathodic protection system must meet specific standards by the American Petroleum Institute, the National Leak Prevention Association, and the National Association of Corrosion Engineers. Similar to new petroleum USTs, secondary containment is not required for existing petroleum USTs and piping. Existing USTs storing other regulated substances are required to meet the new tank standards and be retrofitted with secondary containments by December 22, 1998; while, underground piping containing other regulated substances must be retrofitted with secondary containment by December 22, 1990 (40 CFR Section 280,40(c)).

Leak Detection

The section on leak detection is the most technical section of the federal regulations, much more extensive than the sections on new and existing USTs. The federal regulations require a monitoring system:

1. To be able to detect a release from any portion of an UST and piping.

2. To be installed, calibrated, operated and maintained according with the manufacturer's instructions.

3. To meet certain performance standards specified in the federal regulations.

The federal regulations set up compliance dates for the installation of a leak detection system depending on the age of an UST and the type of piping system (pressurized or suction). Following table is the leak detection phase-in schedule for USTs and suction piping:

Year of UST Installation	Year Leak Detection Is Required
Before 1965 or Unknown	December 22, 1989
1965 - 1969	December 22, 1990
1970 - 1974	December 22, 1991
1975 - 1979	December 22, 1992
1980 - 1988	December 22, 1993
After December 22, 1988	At Time of installation

Pressurized pipes are required to have leak detection systems by December 22, 1990. Also under the monitoring requirements, a pressurized pipe used to transfer a regulated substance other than petroleum must be retrofitted with secondary containment.

An UST has to be monitored at least once a month for leaks using one of the following methods:

1. Automatic tank gauging with a minimum detection limit of 0.2 gallon per hour leak rate.

2. Vapor monitoring within the excavation where a back-fill is sufficiently porous. The regulated substance or tracer has to be sufficiently volatile to allow for detection, and the level of

background contaminations must not interfere with the monitoring of new leaks.

3. Groundwater monitoring where the regulated substance is immiscible in water and has a specific gravity of less than one. The groundwater has to be more than 20 feet below the ground surface; the hydraulic conductivity of the soil is not less than 0.01 cm/sec; and a monitoring device has to be able to detect the presence of at least 1/8 inch of the free product on the top of the groundwater.

4. Interstitial monitoring between the UST and the secondary containment.

5. Other methods which can detect a 0.2 gallon per hour leak rate or a release of 150 gallons within a month with a 95% probability of detection and a 5% probability of false alarm. A local implementing agency may approve other methods, if these methods can protect human health and the environment to the same degree as the previous methods.

Owners and operators of new USTs and those USTs that meet the new tank standards can have the monthly monitoring requirement waived until December 22, 1998 (or for ten years after the installation or upgrade of a petroleum UST) provided they perform the following:

1. Monthly inventory control to detect a release of at least one percent of through-put plus 130 gallons. Accuracies of product and water level measurements in an UST must be within 1/8 inch, and product dispensing is metered with an accuracy of six cubic inches for every five gallons of product withdrawn.

2. Tank tightness testing at least once every five years with a testing method capable of detecting a 0.1 gallon per hour leak rate.

The monthly monitoring requirement can be waived for an UST until December 22, 1998 if monthly inventory control or manual tank gauging is performed along with annual tank testing according to the above performance standards. Manual tank gauging is limited to USTs with capacities of 2,000 gallons or less and have a minimum of 36 hours where there is no inputs or withdrawals from the UST. The accuracy of the manual tank gauge must be at least 1/8 inch. USTs with capacities of 550 gallons or less may be monitored by weekly tank gauging without annual tank tests.

Pressurized petroleum pipes must be monitored by one of the following methods:

1. Retrofitted or equipped with an automatic line leak detector which restricts or shuts off the piping flow or links to a visible or audible alarm. The minimum detection limit of a detector is a leak of three gallons per hour at ten psi of line pressure within one hour.

2. Annual line tightness test with detection limit of 0.1 gallon per our leak rate at 1.5 times the operating pressure.

3. Monthly UST monitoring methods, including vapor monitoring, groundwater monitoring, interstitial monitoring, or other methods with performance standards similar to those specified for UST.

Suction piping for petroleum products can be monitored by a line tightness test once every three years or by the same methods used for pressurized piping on a monthly basis. Monitoring is exempted for a suction pipe if the pipe slopes and drains back to the UST, if the underground portion of the pipe operates at less than atmospheric pressure, and if the pipe has only one check valve located directly below the suction pump.

Suction piping for regulated substances other than petroleum must have secondary containment by December 22, 1998 (40 CFR Section 280.42(a)); while, pressurized piping must have secondary containments by December 22, 1990 (40 CFR Section 280.40(c)). Monitoring of the interstitial space is required at a minimum monthly frequency.

Requirement for Financial Responsibility

As required by Subtitle I, EPA promulgated regulations requiring owners or operators of petroleum USTs to demonstrate that they are capable of meeting the financial responsibility for taking corrective action and compensating third parties for bodily injury and property damage as a result of accidental releases from their USTs. Of all the federal regulations, the section of financial responsibility is the most elaborate with many detailed and specific regulations. For example, there are detailed instructions for the calculation of the tangible net worth, specific clauses for insurance policies, and exact wordings for the letters of credit and trust agreements. Financial responsibility regulations for regulated substances other than petroleum has not been promulgated.

Subtitle I established the minimum amount of financial responsibility at $1 million per occurrence for petroleum UST facilities. The federal regulations lower the per-occurrence amount to $500,000 for facilities which are not in the petroleum marketing business and handle an average of no more than 10,000 gallons of petroleum per month. The federal regulations also require an annual aggregate amount of $2 million for owners or operators of 101 or more petroleum USTs; and $1 million for owners or operators of one to 100 petroleum USTs.

The demonstration of financial responsibility can be from one or a combination of the following mechanisms: Self-insurance, a guarantee, an insurance and risk retention group coverage, a surety or performance bond, a letter of credit, a state-required mechanism, a state fund, or other state assurance and trust funds. The regulations provided detail instructions and specific wordings for each of the mechanisms.

Compliance dates for owners of petroleum USTs depend on whether an owner is in the petroleum marketing business and the number of USTs own by a petroleum marketing firm or the net worth of a non-petroleum marketing firm. They are as follows:

Compliance Dates	Petroleum Marketing Firms	Non-Petroleum Marketing Firms
7-24-1989	1,000 or more USTs	Tangible net worth $20 million or more
10-26-1989	100 - 999 USTs	
4-26-1990	13 - 99 USTs	
10-26-1990	1 - 12 USTs	All Others

Federal and state government entities are exempt from the financial responsibility requirements. The compliance deadline for the local government is October 26, 1990.

An owner or operator must submit documentation for evidence of financial responsibility after the installation of a new UST, within 30 days of a release, after a previous coverage is cancelled, or when a state or local implementing agency requires it. An owner or operator is relieved from maintaining the financial responsibility requirement after an UST has been properly closed and all corrective actions have been completed.

Closure Requirement

Under the federal regulations, an UST may be temporarily closed for up to 12 months if its owner and operator continue to operate and maintain the leak detection and corrosion protection systems. However, if an UST is empty, then the leak detection system is not required. Permanent closure requires a notification to the local administering agency and site assessment for the presence of containments. Details regarding sample types, sample locations, and measurement methods are not specified. If an external monitoring system in operation at the time of closure indicates that there has not been any release, then requirements for the site assessment are waived.

Release Response and Corrective Action

Owners and operators of USTs are responsible to immediately investigate and confirm all suspected releases from their UST operation. They must conduct a tank and/or a piping tightness test within seven days. Within 24 hours of the confirmation of a release, they must:

1. Report the leak to the local administering agency.
2. Take immediate action to prevent any further release.
3. Identify and mitigate the fire, explosion and vapor hazards.

An initial site investigation should be conducted, and include informations such as:

1. The nature and the estimated quantity of release.
2. The surrounding population and land use, water quality, subsurface geological conditions, approximate locations and use of wells potentially affected by the release, and location of subsurface sewers.
3. Results of a free product investigation.

An implementing agency may require a corrective action plan for the cleanup of contaminated soil and groundwater. Public notification is required whenever a confirmed release requires a corrective action plan, and an implementing agency may hold a public meeting to gather public comments.

Footnotes:

3-1. The flash point is a measure of the ease in which a liquid burns under laboratory test conditions. A liquid is place in an open spoon, and a flame is applied to it from underneath. The temperature in which the liquid starts to burn is its flash point.

3-2. A flammable liquid in a liquid which has a flash point below 100°F (UFC, 1985).

3-3. A Combustible liquid is a liquid which has a flash point (FP) at or above 100°F. It is subdivided as follows (UFC, 1985):

Class II - FP at or above 100°F and below 140°F
Class IIIA - FP at or above 140°F and below 200°F
Class IIIb - FP at or above 200°F

3-4. The vadose zone is the unsaturated zone of the underground strata between the surface and the groundwater table. A vadose monitoring well is a well installed in the vadose zone to monitor vapors within this zone.

3-5. For an average 10,000 gallon gasoline tank, the volume change which corresponds to a 0.001 inch change of the liquid when the tank is half full is calculated as follows:

Volume Change = 0.001 in x surface area at half capacity x specific weight of gasoline

= 0.001 in x 1 ft/12 in x 28 ft length x 8 ft width x 7.48 gal/cu. ft.

= 0.14 gallonsdb

4.0 ASSESSMENT OF THE DIFFERENT UST REGULATORY SYSTEMS

The federal, the state of California, and the San Jose underground storage tank (UST) regulations contain many common elements such as the definitions for hazardous material and UST, new UST construction standards, leak detection requirements, and spill response procedures. However, the approaches used in the regulations to address these issues are not always the same, and they affect the way the regulations are implemented. A comparative assessment between the three regulations can provide insights as to the strengths and weaknesses of the regulations.

4.1 Materials Regulated

The federal, the state of California,and the San Jose regulations for USTs all reference pre-existing chemical lists in their definition of hazardous materials. Since the lists are not composed of identical chemicals, there are variations in the materials regulated by the different agencies. Some regulations utilize a combination of several chemical lists, which further increase the likelihood that a hazardous material is regulated. However, since most of the chemical lists are quite comprehensive, majority of USTs used for hazardous materials storage are probably regulated under all three regulations. The main difference between the regulations is their ability to designate and regulate a substance which is hazardous but is not on any of the chemical lists.

The federal regulations reference the Hazardous Substances List of 701 chemicals defined under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). The California regulations make reference to several chemical lists including those for hazardous wastes, hazardous air pollutants, and those substances which can cause detrimental effects to fish, shell fish and navigable waters. The hazardous materials referenced in the San Jose Hazardous Materials Storage Ordinance (HMSO) is based primarily on the List of Chemical Names and Common Names (Title 22, CAC), which is used for the identification of hazardous wastes in California, and the Director's List of Hazardous Substances (Title 8, CAC), which is used by the California Occupational Safety and Health Administration. Even though the three levels of regulations reference different chemicals, they are generally being accepted by the regulated communities. One reason may be due to the realization by the regulated communities that most USTs contain hazardous materials should be regulated, and another reason may be because the chemical lists used in the federal, California, and San Jose regulations are not overly stringent, that they do not regulate materials which do not pose potential hazards when they are stored in USTs.

An important element of the regulations is their ability to identify hazardous materials which should be regulated yet not on the lists. Since new chemicals are constantly being manufactured, it is not possible for a chemical list to include new chemicals which are not in production at the time the list was compiled. To address this problem, the California hazardous waste identification system utilizes both a listing process and a hazard criteria review procedure based on the intrinsic toxicity and other physical properties of a waste. The San Jose HMSO adopted the listing portion of the California hazardous waste identification system without the criteria portion; thus, a drawback of the San Jose regulations is that they cannot regulated new hazardous chemicals and other hazardous substances not already on the list. The San Jose HMSO established a criterion for regulating liquid materials based on their flammability, but its usefulness may be limited to cases where substances leak from USTs into basements and vaults. It has little relevance to the environmental hazard of a substance leaked into the soil or the groundwater. The San Jose HMSO does not have any provision to allow the City to regulate a hazardous substance which is not a flammable liquid or is not on its referenced lists.

Another issue which needs to be considered in a hazardous material identification process is the placement of the burden of proof for determining whether a material is hazardous or non-hazardous. Under the California hazardous waste identification system, the burden of proof is on the generator of hazardous wastes. If the Department of Health Services (DHS) suspects a waste is hazardous, it can regulate the waste as a hazardous waste, unless a generator can demonstrate that the waste is non-hazardous under the hazardous waste criteria. On the contrary, San Jose cannot regulate a substance which is not a flammable liquid and not on its chemical lists. The only way to regulate such a material is for a permittee to voluntarily declare it as hazardous. When new hazardous wastes are generated, the California hazardous waste regulations place the burden of proof on the permittee; while, the San Jose HMSO offers a regulator no recourse at all with regard to new hazardous substances.

The California UST regulations adopted the state's descriptive definition of hazardous waste for it hazardous substance definition, but it is not clear whether the toxic and hazardous criteria are also adopted. It is also unclear whether the state or a facility operator has the burden of proof on whether a chemical is regulated. The federal UST regulations include some descriptive definitions of hazardous waste in its hazardous substance definition, but it is also unclear who has the burden of proof.

4.2 Definition of an UST

The definition of an UST is not consistent between the federal, state and San Jose UST regulations. A tank may be identified as an UST by one regulatory agency, but not by another agency. In the federal UST definition, more than 10% of a tank must be underground in order for it to be recognized as an UST. The California regulations refer to an UST as a tank which is "substantially or totally beneath the surface of the ground" (CAC, Ch. 6.7). There is no clarification on the meaning of "substantially"; therefore, there is much ambiguity in California's definition of an UST. The San Jose HMSO adopted the state's definition of an UST due to the state's requirement that local regulations must be as least as stringent as the state regulations.

The distinction between above ground and underground storage tanks should depend on the method in which a tank can be monitored. Due to the lack of readily available monitoring methods to detect leakages, an UST poses public health risks and environmental hazards not ordinarily found in an above ground tank. An above ground tank can usually be monitored effectively by visual inspection of the tanks, but the monitoring of an UST requires the use of special leak detection devices. A tank resting on the ground surface whose bottom surface is in contact with the ground behaves more like an UST, because it cannot be monitored readily by visual inspections and must be monitored by one of the UST monitoring methods. The state and federal definitions of an UST do not include a tank resting on the ground surface, and there is no current federal or state regulations which adequately address the monitoring needs of these partially buried tanks.

4.3 Performance vs. Technological Standards

San Jose's HMSO utilizes performance standards in its approach to regulate the UST; while the California and federal regulations depend heavily on technical standards. Regulations based on performance standards specify the goal of the regulations and allow a regulated facility and an administering agency the freedom to select the means to attain the end. On the other hand, regulations based on technological standard specify the means, usually in terms of specific technologies, one must use to comply with the regulations. One of the advantages of a performance standard is that it allows a regulatory agency the flexibility to require the use of the most appropriate construction or monitoring method for a specific site. It also provides the agency an easy avenue to adjust to technological advances and require more sensitive and effective devices as they become available. One of the disadvantages of a technological standard is that heavy demand is placed on the resources of regulatory agencies which have to constantly review and approve devices as they become available on the market. In comparison to performance standards, regulations based on technological standard are easier to implement because equipments are pre-approved in the regulations. However, technological standards often discourage the development of new technology and the use of the most appropriate technology.

An example of the use of the two different regulatory approaches is in the area of monitoring of existing USTs. The San Jose HMSO requires monitoring for existing USTs, but it does not specify what type of leak detection devices are acceptable. Instead, it allows an UST owner the freedom to select the best available leak detection system. The staff of the HMP was given the responsibility to establish guidelines and to review proposals for leak detection systems to see whether they meet the intend of the HMSO. As the technology changes, the staff has to change the monitoring requirements to reflect the advancement in technology. With the development of vadose zone monitoring devices, vadose zone monitoring is now preferred to groundwater monitoring in most instances. The monitoring frequency has been increased from a minimum of once a month to once a week, due to the availability of continuous monitoring devices. In contrast, the federal and state regulations are specific in the type of leak detection systems allowed. Although it is possible to amend the regulations to reflect the advancement in the technology, such a process is time consuming and can be done only on an infrequent basis. There is a greater time lag between regulatory requirements and technological advancements in technological-based standards than performance standards. The lack of flexibility in standards based on existing technology also discourages the development of new technology.

4.4 Adequacy of Corrosion Protection

The federal regulations require all new and existing USTs to have corrosion protections, but the California and the San Jose regulations do not have such a provision. Both the San Jose HMSO and the California regulations require corrosion protections only for new steel USTs and existing steel USTs which have been repaired and re-lined. Corrosion protection of an UST is important, because in an EPA's survey of release incidents in 50 states involving the release of hazardous materials from USTs (EPA, 1986b), corrosion was found to be the main cause of tank failure, especially for USTs constructed of steel (Figure 4-1) and USTs older than 10 years of age (Figure 4-2). Corrosion of an UST can be the result of external or internal corro-

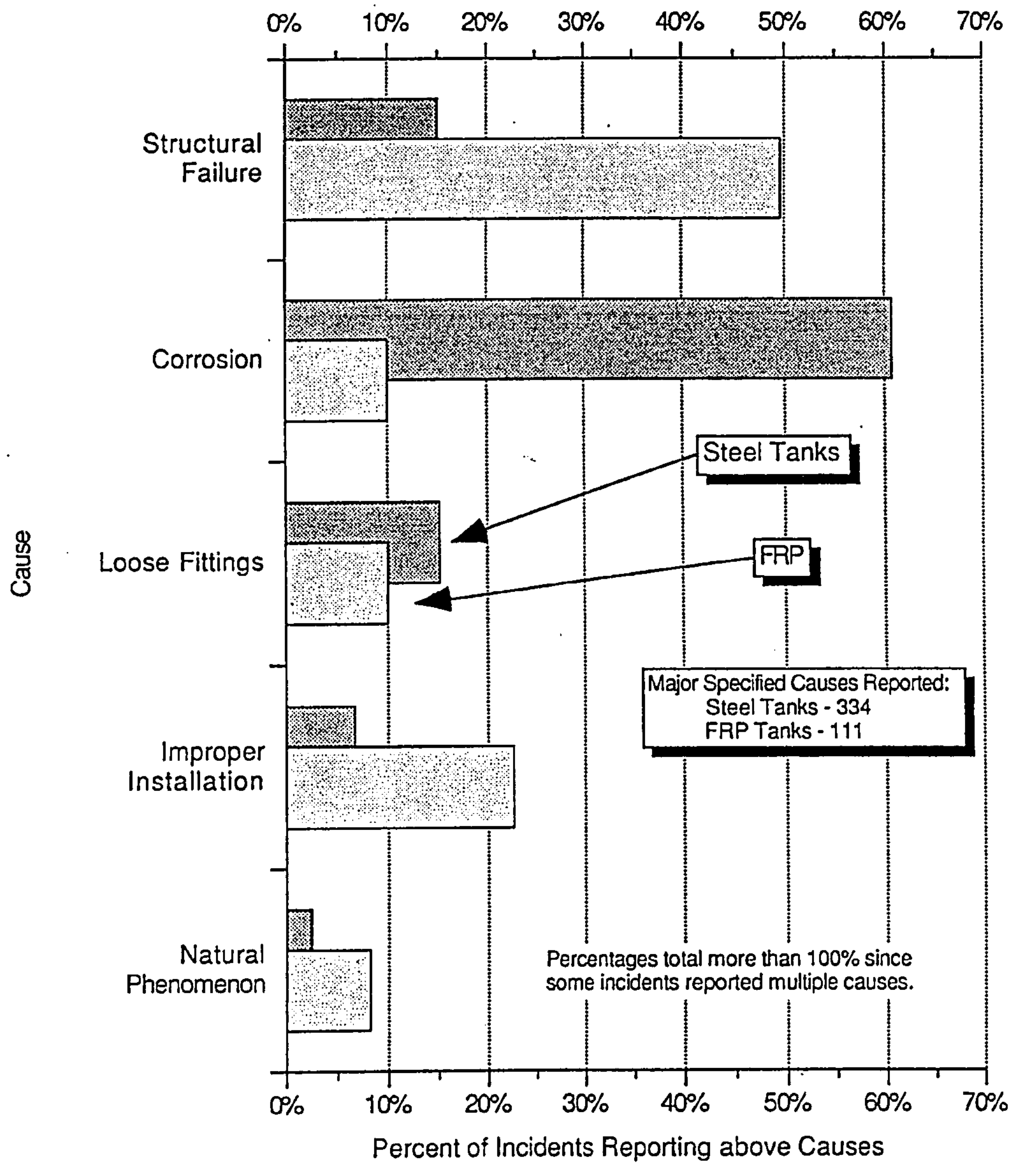


Figure 4-1. Cause of leakages from steel and fiberglass (FRP) USTs.

Source: EPA, 1986b.

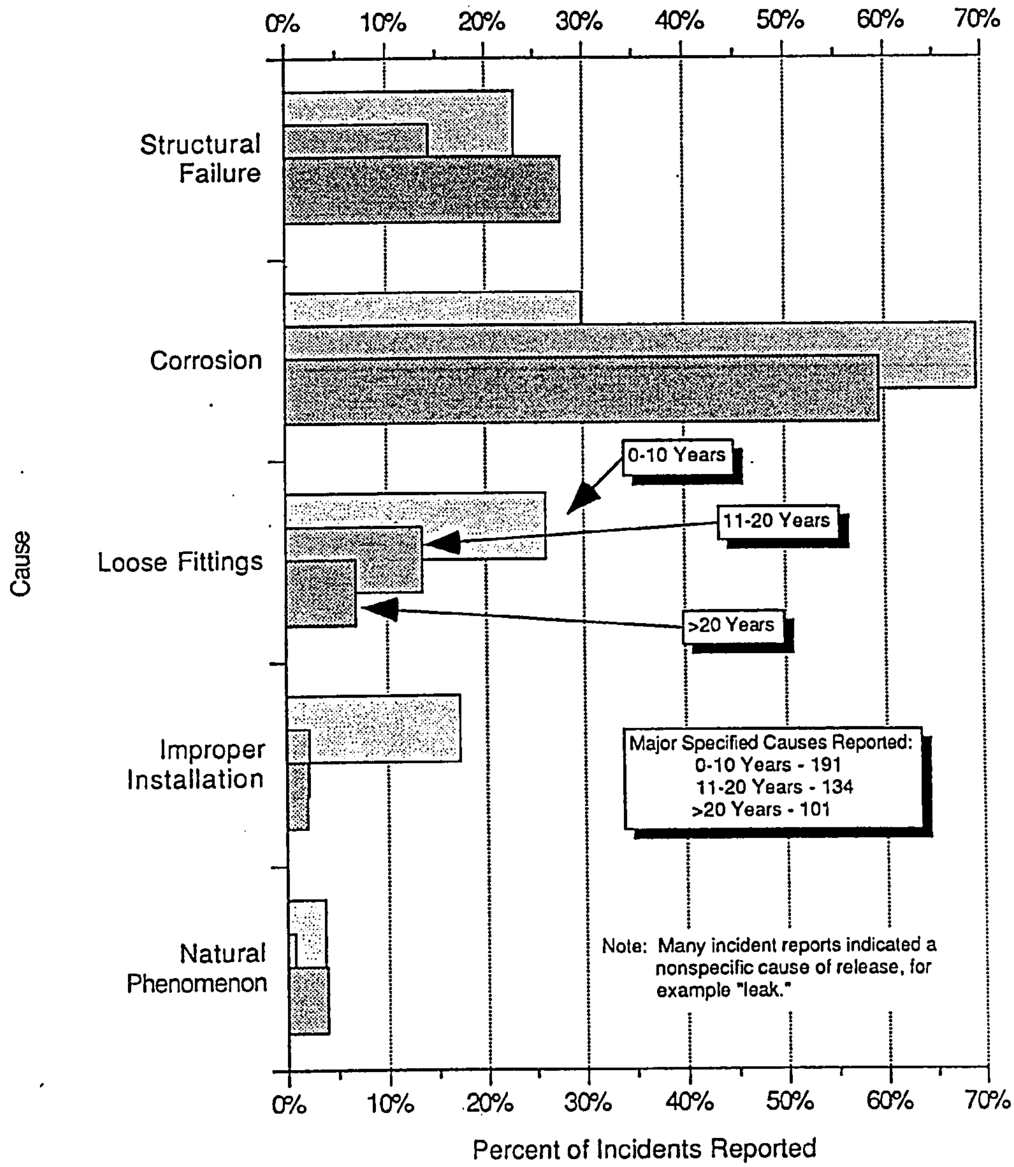


Figure 4-2. Cause of leakages from UST by the age of the USTs.

Source: EPA, 1986b.

sion. External corrosions can be prevented with sacrificial anodes or impressed currents; however, there is no method which can effectively protect against internal corrosions.

4.5 Leak Detection

Leak detection requirements vary greatly between the federal, California, and San Jose UST regulations. Although the different regulations accept similar basic leak detection methods, they differ in the conditions under which the different methods are accepted. In its approach to leak detection, California requires an UST to be monitored by more than one leak detection systems. On the other hand, San Jose imposes more stringent requirement on leak detection systems and relies on the increased accuracy of a single leak detection device to monitor a site.

Inventory Reconciliation

Inventory reconciliation is not recognized as an acceptable monitoring method in San Jose because experience has shown that it is inaccurate and unreliable. However, inventory reconciliation is accepted under the federal regulations for existing USTs on an interim basis until December 22 of 1998, if annual precision tank testing is performed. For ten years after the installation of a new tank, inventory reconciliation is acceptable if a tank test is performed every five years. California also accepts inventory control indefinitely under its monitoring option #5 where annual tank tests and pipeline leak detectors are required along with inventory reconciliation.

California's monitoring option #5 has been in use in many service stations prior to the enactment of UST regulations. Inventory reconciliation which consists of a daily measurement of the fluid level in an UST with a dip stick has been required under the Uniform Fire Code; the Red Jacket line leak detector has been routinely installed by the major oil companies at their service stations; and the annual precision tank test has already be required regularly by most major oil companies. However, the combination of these three methods was unable to provide early leak detection for the many leaky USTs and pipes whose leaks were detected by other leak detection methods or were confirmed at the time the USTs were removed.

Under the Uniform Fire Code, inventory reconciliation is intended to detect gross leaks, but the California regulations attempt to use it to detect much smaller leaks. The state established stringent allowances for discrepancies in inventory reconciliation, and outlined investigation procedures if inventory reconciliation exceeds this allowable amount. Inherent inaccuracies of inventory reconciliation such as the lack of temperature corrections and calibration errors of dispensing meters cast much doubts on whether the degree of accuracy desired by the state is realistic. Furthermore, the state also relies on facility operators to change their old, sloppy dip stick measurement habits. Education and enforcement are needed to change old habits of tank operators, and it is questionable whether administering agencies have adequate resources to perform these functions.

Even if improvements are possible to minimize the inherent problems of inventory reconciliation to the level in which inventory reconciliation produces the level of accuracy prescribed in the California and federal regulations, inventory reconciliation is not sensitive enough to make it an acceptable early leak detection method. For a 10,000 gallon UST with a monthly through-put of 30,000 gallons, the federal and California monitoring methods with inventory reconciliation potentially can allow leaks of 5,160 and 1,440 gallons to occur undetected per year, respectively (Table 4-1). Monthly through-put of 30,000 gallons per UST is a conservative number, even for the low volume service stations.

Tank Testing

Although tank testing is a component of several monitoring options under the federal, state, and San Jose reg-

Table 4-1. Allowable discrepancies in inventory reconciliation under the federal and California monitoring options before investigative action is required.

Regulations	Allowable Discrepancies	
	Monthly	Annually
Federal	1% of Through-put[a] + 130 gal = 0.01 x 30,000 gal + 130 gal = 430 gal	430 gal x 12 =5,160 gal
California Option #5	0.15% of through-put[a] + 75[b] gal = 0.015 x 30,000 gal + 75 gal = 120 gal	120 gal x 12 =1,440 gal

Footnotes:

a. Assume 30,000 gallons of through-put per month.

b. Assume UST capacity of 10,100 gallons.

ulations, it has been demonstrated to be unreliable, and its detection limit is too low for it to be consider as an early leak detection system. There have been documented cases in the Santa Clara County where the results of tank tests showed USTs to be tight, but subsequent removal of USTs revealed that there were holes in the USTs. Almost all testing methods claimed to meet the 0.05 gallon per hour (gph) detection limit specified by the National Fire Protection Agency (NFPA 329); however, a test of 25 commercially available tank testing systems at Edison, New Jersey found that none of them was able to perform better than 0.1 gph with a 99% probability of detection and a 1% probability of a false alarm (Roach, 1988). Detection limits ranged from 0.13 to 3.22 gph for 19 tests where quantitative results were obtained.

The author of the EPA study concluded that performance of the tank testing methods was limited by current test protocols rather than by the testing hardwares. With improvements in their methodologies, over 60% of the tank tests should be able to achieve detection limits within the range of 0.05 and 0.15 gph, and all the tests should be able to obtain a detection limit of 0.02 gph.

In 1987, California passed legislation (AB 1413) in an attempt to assure the competency of the people conduction tank tests. Beginning January 1, 1989, a tank tester has to obtain a license from the State Water Resources

Control Board (State Board). A license is good indefinitely as long as a tester satisfactorily meets the State Board's requirements at the time of application. Tank testings depend greatly on the skill of a tank tester, and it is questionable whether a one-time licensing effort can ensure that a tester will maintain an acceptable quality of performance for the time period after the license is issued.

The federal regulations require that, after December 22, 1990, tank tests must be able to detect a 0.1 gph leak rate with a 95% probability of detection and a 5% probability of a false alarm. Even if this regulatory approach succeed, a 0.1 gph leak rate still translates to a leak of 876 gallons per year. Given the problems of tank tests and their low detection limits at the present time, the tank test is not a dependable leak detection system.

Groundwater Monitoring

Groundwater monitoring is an acceptable form of monitoring at all three levels of regulations, but there is a trend to place restrictions to limit the situations where groundwater monitoring is allowed. A monitoring system should be able to provide early detection of a leak before the environment is impacted by the leak, but groundwater monitoring provides a warning only after the groundwater has been contaminated by contaminants from a leaky UST.

Furthermore, groundwater monitoring wells may serve as conduits for contaminates to migrate from shallow aquifers to deeper aquifers and accelerate the spread of contaminants. There are many differences between the regulations in terms of the geological conditions which groundwater monitoring is accepted; the required number, placement, and monitoring frequency of groundwater wells; and the way in which monitoring is conducted.

San Jose originally allowed groundwater monitoring for sites where the groundwater depth is less than 45 feet, but subsequently, it restricted the use of groundwater monitoring to sites where the groundwater level is not deeper than the invert of an UST (usually 12 to 15 feet) at all times of the year. The federal regulations allow groundwater monitoring in cases where the groundwater is up to 20 feet deep. California allows groundwater monitoring as the sole form of monitoring where the groundwater is of no beneficial use and is less than 30 feet; otherwise, if it is acceptable for a groundwater depth up to 100 feet, when it is used in conjunction with vadose zone monitoring.

The location and the number of monitoring wells are important factors to consider in a groundwater monitoring system, but there is no consensus among current regulations on the number of groundwater monitoring wells necessary to provide adequate leak detection. The federal regulations leave it to the discretion of local administering agencies to determine the number and placement of wells. California's regulations specify the number of groundwater monitoring wells required for different UST configurations. The San Jose HMSO does not specify the number of wells required, but the City's HMP adopted the recommendations of a local water wholesaler, the Santa Clara Valley Water District (SCVWD), and use them as administrative guidelines. Under the SCVWD guidelines, San Jose approved many groundwater monitoring proposals where there is only one groundwater monitoring well for an entire service station with up to three USTs. The number of groundwater monitoring well required by San Jose is much less than that required under California's requirement, and San Jose's requirements are probably grossly inadequate in providing early leak detection.

All three regulations have avoided addressing the issues regarding the use of groundwater monitoring for underground pipes. The groundwater monitoring well is not an effective form of monitoring for underground pipes, but it was the only form of monitoring available at the early days of San Jose's HMP. San Jose has accepted, in the past, monitoring proposals with minimal numbers of groundwater monitoring wells for USTs and without any additional monitoring wells for underground pipes.

Originally, San Jose required groundwater wells to be monitored, at a minimum frequency of once a month, by the visual inspection of sheens on the water surface and the presence of odor in the groundwater. In 1986, it decreased the minimum monitoring frequency to weekly monitoring for new groundwater wells, but at the same time, it still honors the monthly monitoring frequency for those facilities which had been previously approved. At the present time, San Jose is considering imposing an additional requirement on all existing and new groundwater monitoring wells, which consists of a semi-annual laboratory test for dissolved constituents such as benzene, toluene, and xylenes. California requires monthly monitoring if groundwater monitoring is the sole monitoring system. If groundwater monitoring is used in conjunction with vadose monitoring, the semi-annual monitoring is required. The federal regulations require monthly monitoring for all monitoring systems. Both California and federal regulations do not specify how monitoring is to be performed, e.g. visual inspection or chemical analysis.

Vadose Zone Monitoring

Similar to groundwater monitoring, there are many differences between the federal, California, and San Jose UST regulations with respect to vadose zone monitoring. The differences include the conditions in which vadose zone monitoring is accepted, the number and placement of vadose zone wells, and the minimum monitoring frequency of vadose wells. The lack of consistency between the regulations may be the result of difference in monitoring philosophies and a lack of complete understanding of the vadose zone monitoring systems.

Difference in regulatory requirements for vadose zone monitoring systems is summarized in Table 4-2. Vadose zone monitoring is accepted by the federal government and San Jose as a "stand alone" system, but under the California regulations, it is accepted only in conjunction with either tank testing or groundwater monitoring. Similar to groundwater wells, the placement and the number of vadose zone wells are important factors which can influence the effectiveness of a vadose zone monitoring system. In its administrative guidelines, San Jose specifies the minimum number of vadose zone wells for different UST and piping configurations, but the federal and state regulations fail to address this issue. Both the federal and local regulations, required vadose wells to be in porous materials, but California does not have a similar requirement. California and San Jose allow vadose zone wells to be monitored at a weekly frequency; while, the federal regulations allow monthly monitoring. The federal and California regulations rely on local administering agencies to review and approve proposals involving the use of vadose

Table 4-2. Difference in requirements for vadose zone monitoring systems under the federal, California, and San Jose UST regulations.

Requirements	Federal	California	San Jose
Vadose Zone Well as Stand Alone System	Yes	No	Yes
Number and Placement of Vadose Zone Wells	Not Specified	Not Specified	Specified
Requirement for Vadose Wells to be in Porous Back-fill Material	Yes	No	Yes
Minimum Monitoring Frequency	Monthly	Weekly	Weekly

zone monitoring. Vadose zone monitoring is a relatively new form of UST leak detection system which has its origin in the Santa Clara County. Local regulatory agencies outside the Santa Clara County are generally unfamiliar with vadose zone monitoring; therefore, it is necessary for federal and state agencies to provide these local administering agencies guidelines for determining the number and the placement of vadose zone monitoring wells necessary for leak detection under different UST and piping configurations. Furthermore, the different regulatory agencies should attempt to formulate uniform requirements for vadose zone monitoring systems.

Internal Tank Level Sensor

The internal tank level sensor is accepted as the sole monitoring method under both the San Jose and the federal regulations; however it is allowed under the California regulations only if it is used in conjunction with inventory reconciliation, the pipeline leak detector, and tank testing. The San Jose and federal regulations require an internal tank level sensor to be able to detect a leak rate as small as 0.2 gph with a 95% probability of detection and a 5% probability of a false alarm, but the California regulations do not have a similar performance requirement.

Similar to tank tests, the current federal and California regulations rely on individual local administering agencies to review and approve internal tank level sensors in their jurisdictions, and it is questionable whether the local administering agencies all have the necessary resources and ability to determine whether a device meets the specified performance standards. The EPA Edison study concluded that, while it is possible for an internal tank level sensor to detect a leak rate of 0.2 gph leak, not all of the devices were able to achieve such a detection limit at the time of testing. Although manufacturers all claim they can achieve some performance standards; however, they often cannot substantiate their claims with adequate scientific data; but it is necessary for a local administering agency to thoroughly review the performance of an internal tank level monitoring device. San Jose's experience has shown that it takes a tremendous amount of time and effort on the part of an agency to perform such a review, and it often involves additional field testing of a proposed monitoring device. On the manufacturers' point of view, it is a time consuming process to have to obtain approvals for a monitoring device from different local implementing agencies. Requirements may not be uniform among the administering agencies, and most manufacturers prefer to have a centralize review mechanism for their monitoring devices.

Overall Assessment of Leak Detection

An overall comparison between the different leak detection methods is difficult because the distinctive features in many leak detection methods cannot be quantified. Quantitative methods such as the tank integrity test and the internal tank level sensor can be compared quantitatively based on their detection limits in gallons per hour. In addition, they can be compared based on the size of a detectable leak, which is the maximum amount of hazardous materials that can escape an UST before the leak is detected. A method to calculate detectable leak size can be standardized by multiplying the detection limit by the frequency of monitoring, e.g. gallons per hour x hours = gallons. A monitoring method which has a poor detection limit can be used on a more frequent basis to achieve the same sensitivity for the size of a detectable leak as another method which has a better detection limit but is not monitored as frequently. Inventory reconciliation may be able to quantify large leaks, but due to the inherent inaccuracies of the method, it is difficult to accurately quantify a detection limit and a detectable leak size. Table 4-3 compares the detectable leak sizes of different quantitative methods under different monitoring frequencies. It shows a great variability between these different leak detection scenarios.

Table 4-3. Sizes (in gallons) of potentially undetected leak as a function of monitoring frequency and detection limit of different quantitative leak detection methods.

Leak Detection Method	Detection Limit (gph)	Monitoring Frequency Daily	Weekly	Monthly	Yearly
Tank Integrity Test	0.05[a]	1.2	8	37	438
	0.1[b]	2.4	17	73	876
Internal Tank Level Sensor	0.2[c]	4.8	34	146	1752
Daily Tank Level Measurement with Dip Stick	1/8"	37[d]	-	-	-

Footnotes:

a. Detection limits specified by the National Fire Protection Agency (NFPA, 1987) for precision tank test. There is no basis to support this detection limit which is not achievable by the current tank integrity tests.

b. Detection limit required under the federal regulations for tank integrity tests conducted after December 22, 1990.

c. San Jose and federal requirements.

d. Assume the only error for inventory control is the inaccuracy of reading a dip stick and ignore effects of temperature and meter inaccuracies. Assume a dip stick can be read to within 1/8" for a 10,000 gallon UST measuring 30 feet in length and 8 feet in diameter.

$$\text{Detection Limit} = 2 \times 1/8'' \times 1'/12'' \times 30' \times 8' \times 7.48 \text{ gallons/cubic foot} = 37 \text{ gallons}$$

Leak detection methods such as groundwater monitoring and vadose zone monitoring are not capable of yielding a quantitative detection limit. Although it has been suggested that vadose zone monitoring is very effective in porous back-fill materials, and leaks as small as ten gallons have been detected, but it is rare that quantitative detection limits can be established. There is even more uncertainty in groundwater monitoring wells since hydrogeological variables are not as well defined as back-fill materials in the case of vadose zone monitoring. Regulations require the placement of groundwater monitoring wells down gradient of USTs, but it is often difficult to determine the exact groundwater gradient due to variations caused by seasonal changes and adjacent human activities.

In summary, leak detection requirements differ greatly in the federal, California, and San Jose UST regulations in the circumstances under which various leak detection methods are allowed. It is difficult to compare the various monitoring alternatives because quantitative leak rates cannot be derived for many of the methods. California tends to have the least stringent requirements for individual leak detection systems, but the use of redundant leak detection systems may improve its overall effectiveness. The California regulations specified eleven monitoring alternatives which differ greatly in the level of protection they offer. The basic components of alternative number five have been in use for years in service stations, and experience has demonstrated that it is plagued with problems.

4.6 New USTs and Piping

Under the three UST regulations, secondary containment is required for new USTs containing regulated substances, but secondary containment requirement for new petroleum USTs varies between the different regulations. San Jose's HMSO is most stringent among the regulations and requires secondary containment for new petroleum USTs; California accepts the interceptor trench for new motor vehicle fuel USTs; while, the federal regulations are the least restrictive and do not have any secondary containment requirement for any new petroleum USTs. With regard to underground piping, all three regulations require secondary containment for new piping associated with non-petroleum USTs. For new piping associated with petroleum USTs, the federal regulations have no requirement for secondary containment. California had allowed single-wall piping for motor vehicle fuels in the past, but it amended its regulations in 1987 to require secondary containment. San Jose has always required full secondary containment for new piping.

In its regulatory preamble, EPA stated the major advantage of secondary containment for a new UST system (tank and pipe) is that it "provides two complete barriers to prevent releases, and a simpler, more certain system for detecting releases between the barriers" (EPA, 1987). Furthermore, interstitial monitoring "is widely believed to be the most accurate monitoring available ..." Interferences from environmental factors are minimized in the interstitial space, where monitoring can be accurately performed with vapor, liquid, pressure, or vacuum probes. EPA stated that a possible advantage of secondary containment "is the long-term savings from reduced costs for corrective action, insurance, leak detection and maintenance".

Despite all the advantages of secondary containment, EPA requires secondary containment only for new non-petroleum USTs and piping but not for USTs and pipes for petroleum products. Because the initial cost of a secondarily contained system is higher than a single-wall UST and piping system, EPA claimed that the "incremental benefit it provides over the single-wall tank system may not be substantial". This is a contradiction to its earlier statement that secondary containment can provide long-term savings from life time operating and closure costs.

EPA's regulations rely on corrosion protection to prevent the deterioration of new USTs; however, corrosion protection alone will not be able to eliminate all leakages from USTs and pipes because leaks can be the result of other factors such as defective USTs and piping, loose pipe fittings, improper installations, and other physical damages. Secondary containment provides actual physical protection against leakages into the environment and enables leak detection systems to function more effectively in a controlled environment. Furthermore, there are leak detection methods which operate only in secondarily contained systems. Regulations which allow single-wall USTs and piping for new installations limit leak detection alternatives to those used for existing single-wall systems. In other words, as a result of the lack of secondary containment requirement under the federal regulations, there is no improvement in the leak detection capability of new USTs in comparison to existing USTs.

4.7 Requirement of Best Available Technology

Under all of the UST statutes or regulations, there is no requirement for the use of best available technology (BAT). In fact, some regulations only tinker with existing practices and offer no substantial improvement for human health and environmental protection over existing practices. The California statute specifically allows the use of construction and monitoring methods which are not BAT. For example, the state statute specifically allows the interceptor trench in place of full secondary containment for new petroleum USTs. In the area of leak detection for motor vehicle fuel USTs, it accepts existing leak detection methods, inventory reconciliation and tank testing, which have been shown to be ineffective. DHS has to promulgate its administrative regulations within the constraints of the state statute and make allowances accordingly.

The federal statute required EPA to promulgate regulations necessary to protect human health and the environment. It did not specified whether "necessary" means the use of BAT to protect public health and the environment to the best possible extend, or whether $1x10^{-6}$ or some other cancer risk is acceptable. From the regulatory preamble published in the Federal Registrar (EPA, 1987), it seems that EPA tried to draft regulations based on technical availability, economic feasibility, and the ease of administration. However, regulations promulgated by EPA show inconsistency in the application of these guidelines. Examples of inconsistencies include the allowance of new single-wall USTs for new constructions and the use of inventory reconciliation for leak detection. Details regarding the drawbacks of these systems can be found in preceding section.

The San Jose HMSO also did not specify the use of BAT, nor did it provide the HMP any guidelines as to the degree of protection it desires in its new construction and leak detection requirements. However, the performance-oriented nature of the HMSO allows the HMP to select BAT in some applications, although BAT is not consistently used. The federal, California, and San Jose regulations allow new constructions and leak detection systems which do not provide adequate public health and environmental protection. To over come this problem, regulations should required regulatory agencies to mandate the use of BAT when it is economically feasible.

4.8 Resources for Program Implementation

The amount of resources available to implement an UST program is a critical factor directly influencing the success and the failure of the program; however, it has not been thoroughly considered in all the UST regulations. In San Jose's HMP, the level of personnel was not filled to the originally estimated level until three years after the initiation of the program. One reason was due to a lack of experience at the beginning of program implementation, but another was a lack of appreciation on the part of the administration on the degree of complexity of the HMP. It took a crisis and an inquisition from the city council to staff the program with a reasonable number of personnel. The San Jose HMP regulates both above ground and underground storages, and its staff performs functions in both areas. Since the UST activity is not performed by a separate functional group within the HMP, there is no separate personnel and budget accounting for the UST-related activities. The initial focus of the HMP was on USTs, but the focus has since been shifted to above ground storage and other new issues such as toxic gas storage and monitoring. Currently, San Jose is substantially behind in attaining its goal of annual inspection for all regulated facilities. In fact, the majority of UST facilities have not received a proper initial inspection after six years of HMSO implementation.

The state and federal UST programs rely on local governments to implement their programs without adequate consideration for the resources and capabilities of the local governments to carry out such activities. They delegate essential activities such as permit issuance, construction review, monitoring system review, closure over-sight, and periodic inspection to local administering agencies. The federal UST program delegates to the local administering agencies the difficult task of reviewing and approving leak detection systems. Even though the state regulations are more narrowly defined, there are still many areas where technical judgements and decision makings are required. Both state and federal regulations allow local administering agencies to charge permit fees to recover the cost of operating their programs, but local governments are under constant scrutiny from the public to keep permit fees at a low level. Furthermore, the federal and state regulations failed to address the availability of technical personnel on a state- and nation-wide basis. Technical help may be more readily available in the metropolitan areas, many of which already have UST programs; however, this availability is uncertain in rural areas. Availability of adequate resources and personnel at the local government level is out of the hands of the federal and state government; thus, the success of the federal and state UST programs is dependent on factors not under the federal and state control.

4.9 Technological Assessment and Information Transfer

To administer an UST program as required by the San Jose, California, and federal UST regulations, an administering agency will require a substantial amount of technical knowledge. The agency will have to keep up with the development of new monitoring devices and acquire analytical skills to evaluate them. As of today, local administering agencies do not have adequate technical staff, and there lacks a mechanism for the state of federal government to perform the technical assessment and transfer the results to the local agencies.

The San Jose HMP does not have the capability to conduct all the reviews as required by the HMSO. The San Jose HMSO requires existing USTs to be monitored and new USTs to have secondary containment and monitoring. However, it does not specify what constitute acceptable monitoring and leaves all technical aspects of the UST program to the staff of the HMP. Since the beginning of the HMSO implementation in 1983, there has been a constant advancement in the monitoring technology and the methodology for secondary containment. During these six years, technological advancements include the development of vadose zone monitoring devices, internal tank level sensors, new tank integrity testing devices, double-wall USTs, and fiber glass piping trenches. It took substantial time and effort to evaluate the different methodologies and devices which have come through the City for approval. The staff has developed protocols for the review and approval process for some monitoring methods such as vadose zone monitoring and groundwater monitoring, but protocols are still lacking for others such as the tank integrity test and the internal tank level sensor. Performances of precision tank tests and internal tank level sensors are specified in terms of probabilities of detection and false alarm. The review of these methods involve the use of statistics, and it is uncertain that the staff has adequate technical expertise to perform such reviews.

The federal regulations ask administering agencies to use nationally recognized standards as guidelines for construction and monitoring standards; however, there are no available standards for many new technologies and devices used for monitoring. The federal regulations provide an outline of the acceptable methodologies for leak detection, and left it to the discretion of local implementing agencies to approve specific leak detection devices. For example, the determination of the location and the number of vadose zone and groundwater monitoring wells is left to the local administering agencies. The EPA study on tank testing methods and internal tank level sensors at Edison, New Jersey was a one-time, fact finding study on the overall capability of these devices, and its intention was not to give the local administering agencies a list of approved devices.

Although the California regulations are more specific with regard to monitoring methodologies, they face similar problems found in the local and federal regulations, where local administering agencies are left with the responsibility of approving individual monitoring devices. At the present time, there is no protocol from the state on how to perform a proper review.

Technology in UST monitoring is under constant and rapid development. Federal and state regulators do not want to be involved in the approval process of individual devices perhaps for the fear that a centralized state or federal approval process would take longer than a local approval process, and in some instances, it may preclude the installation of a superior device. They defer the approval process to local administering agencies with the hope that the local agencies will have the chance to review the latest technology immediately prior to the installation of these devices. However, they failed to recognize the tremendous demand on technical knowledge when making such evaluations and the lack of such skills at the local level.

4.10 Flexibility vs. Uniformity of Regulations

Regulations should be uniform and stringent enough to provide adequate guidelines for the majority of UST facilities; however, they should be flexible enough to accommodate other UST facilities which have special needs. There should be a balance between flexibility and uniformity in order for regulations to be effective.

Among the three levels of government regulations, the performance-oriented San Jose HMSO allows an administering agency the most flexibility; the HMP was given full authority to determine what constitute adequate monitoring and secondary containment without the need for public reviews or city council's approvals. The federal regulations are more restrictive and specify the performance criteria for different monitoring methods and new UST construction standards (and retrofit requirements). They allow a local administering agency to be more restrictive if the local agency determines that the more restrictive regulation is necessary for the protection of public health and the environment. The least flexible of the regulations is the California regulations, which do not allow the regulated communities and local administering agencies to deviate from the regulations unless a variance is obtained from the state. Public notifications and hearings are necessary in the variance process, and a variance applicant is responsible for the cost incurred by the state in the variance process. The amount of time, effort, and cost associated with the variance process certainly would discourage local agencies and UST owners and operators to undertake such actions.

Excessive flexibility in the regulations can lead to the lack of uniformity. Various cities in the Santa Clara County implement their own HMSOs in a similar way as San Jose. They conduct separate reviews of monitoring devices and grant approvals and disapprovals according to their best judgements. A survey was conducted recently to determine the status of various leak detection devices at the different cities in the Santa Clara County. Results of the survey indicate a high degree of variability in the status of the various monitor devices (Table 4-4). Some monitoring devices have been reviewed by some jurisdictions but not by others; furthermore, among those jurisdictions which have conducted reviews of a monitoring device, the devices may be approved by some jurisdictions

Table 4-4. Results of a survey on the status of various monitoring devices in the different cities in the Santa Clara County.

Cities	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
	Monitoring Systems[1]																					
Campbell	+	+	+	?	-	-	-	?	-	+	+	+	?	?	+	-	?	+	-	+	+	+
Central Fire[2]	.	+	+	?	?	?	?	-	+	+	+	?	?	?	?	?	?	+	-	+	+	+
Gilroy	-	-	-	?	-	-	-	-	+	+	+	+	+	?	-	-	-	-	-	-	-	-
Milpitas	?	?	+	-	?	?	?	?	+	+	+	?	?	?	+	?	?	+	-	+	+	+
Mountain View	+	r	-	-	-	+	+	-	r	+	+	-	+	+	-	-	+	+	-	?	?	?
Palo Alto	+	+	+	?	?	+	?	?	+	+	+	+	?	?	+	+	?	+	+	+	+	+
San Jose	r	?	+	?	+	+	?	?	-	+	+	+	?	?	-	r	r	+	+	+	+	+
Santa Clara	+	+	?	+	+	+	?	+	+	+	+	+	+	?	+	+	?	+	+	+	+	+
Sunnyvale	+	?	+	+	-	+	?	+	-	+	+	+	?	?	+	?	?	.	+	-	+	+

Footnotes:

1. Monitoring Systems a to h are liquid sensors, i to o are vapor sensors, p is a line leak detector, q to s are precision tank testing methods, and t to v are in-tank level sensors. Following are the names of the monitoring systems:
   - a. API/Ronan LS-3 Liquid
   - b. In-Situ RSE Liquid
   - c. Owens-Corning HM
   - d. Petrometer
   - e. Pollulert FD 102
   - f. Pollulert FD 103
   - g. Scully Liquid Sensor
   - h. Trace Tek TT500
   - i. API/Ronan X76HVD
   - j. Azonic Enviro-Ranger
   - k. Genelco Soil Sentry
   - l. Leak Alert
   - m. Leak Sensor Jr.
   - n. Sierra Monitoring
   - o. Red Jacket
   - p. Gilbarco
   - q. Petrosonic III
   - r. Veeder Root TLS 250
   - s. AES System II
   - t. Horner E-ZY Check
   - u. Hunter Leak Lokator
   - v. Petrotite

   Symbols for the status of monitoring systems are as follows:
   - \+ Approved
   - \- Disapproved
   - r Under review
   - ? Unfamiliar with device
   - . Missing data

2. Central Fire Districts enforces HMSO for the cities of Saratoga, Cupertino and Los Gatos.

and disapproved by others. This variability is not limited to a few selective monitoring devices, but it can be found in most devices.

Some variations in the acceptance of monitoring devices by various cities in the Santa Clara County may be due to the different hydrogeological conditions peculiar to the individual cities; however, many are be due to differences in personalities differences and technical competencies within the various UST programs. For example, the City of Campbell does not allow groundwater monitoring wells, because the groundwater aquifer is quite deep through-out the city. The City of Gilroy only accepts aspirated vadose zone monitoring, because it believes that vadose zone monitoring is the best monitoring system available. Mountain View is the only city which disapproved a vadose zone monitoring system, because it is the only city which has conducted thorough testing and found deficiencies in the device. San Jose has not approved two internal tank level sensors because they have not demonstrate their performance claim to the satisfaction of the city.

Various equipment manufacturers, vendors, installers, and facility owners and operators have voiced their desire of a more uniform review process between the various cities in the Santa Clara County. It is a costly and time consuming effort for the different equipment manufacturers and vendors to go through each city in order to gain approval of their systems for that one city, and it is difficult for contractors and facility owners and operators to keep track of the current status of the various devices. In a recent service station association's news article, the author remarked that "inexperience and sometimes the egos of the local approving authorities are getting in the way of good approvals done at that level" and suggested creating a state office to examine, test, and approve equipments (Shields, Harper & Co., 1989). Another disadvantage of an over-flexible implementation system is the need of highly technical staffs at many local administering agencies (See Sections 4.8 and 4.9). It is necessary for regulators to consider the advantages and disadvantages of the various regulatory and implementation approaches and strike a balance between flexibility and uniformity. Cities in the Santa Clara County have formed a committee to review the approval process for monitoring devices and to develop uniform criteria which can be used by all the cities in their review process.

4.11 Coordination Between Leak Detection and Clean-up Activities

Currently, there is a lack of coordination between the governmental agencies responsible for leak detection and site mitigation. The lack of coordination has lad to a long back-log of fuel contamination cases which have been discovered through leak detection programs and UST closures but are awaiting direction for clean-up activities.

Under the HMSO, the San Jose HMP is responsible for the detection of leaky UST cases through its monitoring and UST closure requirements. Under the California codes, once contamination is detected at a site, the San Francisco Regional Water Quality Control Board (RWQCB) has the responsibility to over-see any subsequent remediation work. In March of 1987, the Santa Clara Valley Water District (SCVWD) entered into an informal agreement with RWQCB to provide oversight in the Santa Clara County for contamination cases which involve motor vehicle fuels. In April of 1988, SCVWD entered into a formal agreement with the State Water Resources Control Board to assume RWQCB's oversight function. Responsibility of contamination cases involving other toxic chemicals remains with RWQCB. SCVWD's responsibility in fuel cases is to ensure that mitigation is carried out according to state guidelines; while, final approval for the termination of a mitigation project is still in the hands of RWQCB.

Since the adoption of HMSOs in the Santa Clara County, there has been a tremendous increase in the number of reported contamination cases involving motor vehicle fuels and waste oils. the incidence rate of new fuel cases exceeded RWQCB's capability to handle them and created a long back-log of cases in the Santa Clara County. Reported cases often remained in the files of RWQCB for months and years. This delay has cause problems in many property transactions and may have resulted in further migration of contaminants and more extensive clean-ups. During the time period between 1983 and 1988, not one single fuel case in the Santa Clara County was signed off by RWQCB.

As of October of 1988, SCVWD has taken responsibility for the oversight of 93 fuel cases in the Santa Clara County. There were a total of 847 outstanding fuel cases in the Santa Clara County with 453 suspected cases and confirmed cases involving groundwater contaminations (SCVWD, 1988). SCVWD is currently in the process of hiring additional personnel to handle the fuel cases, and the success of its program remains to be seen.

The credibility of local administering agencies has been damaged as a result of the delay in clean-up oversight. Owners of USTs were asked and given deadlines to install leak detection systems and to conduct soil investigation in order to protect public health and the environment. On the other hand, there is no action taken by government agencies once a contamination is discovered. UST owners are given conflicting messages by different governmental agencies with regard to the urgency of the leaky UST problem. This conflicting signal leads to mistrust of the regulatory agencies. In order for governmental agencies to be consistent, it is imperative that RWQCB contacts responsible parties as soon as contaminated sites are discovered and provides guidance to the owners regarding the proper procedure for site investigation. SCVWD's involvement and its plan to hire additional staff to oversee site clean-up activities is a positive step in the right direction.

5.0 RECOMMENDATIONS

Regulations on the underground storage tank (UST) are at their infancy when one considers that the federal administrative regulations were promulgated by the Environmental Protection Agency (EPA) only last year; while, the San Jose Hazardous Materials Storage Ordinance (HMSO), one of the oldest in the country, was drafted only about six years ago. Because of the urgent need for the local, state, and federal governments to take action against the growing problems associated with leaky USTs, legislations and administrative regulations had to be enacted within limited time frame and with limited knowledge. Thus, after regulatory agencies acquire experience through program implementation, it is desirable to amend and improve the regulations. It is important for regulators to constantly evaluate their regulations with the experience they have gained through program implementation. They should have a vision of a better regulatory system and work to achieve that vision when an opportunity arises.

After six years of implementing its pioneering UST program, one would expect San Jose to have acquired substantial experience and amended its regulations accordingly; however, the basic HMSO in San Jose remains much unchanged during these years. San Jose appears to be entrenched in its own regulations without much awareness of the state or federal regulations and without any vision for change. California has amended some technical aspects of its regulations, but its general regulatory approach remains unchanged. EPA acknowledges its lack of experience in many aspects and has requested state and local agencies for assistance. The federal regulations attempted to set a minimal level of regulations for the entire country; however, it is questionable whether this minimal level of regulations is adequate to protect public health and the environment for the majority of the country. If many local administering agencies elect to have more stringent regulations, then there will be many different local regulations in effect throughout the country. EPA has not considered thoroughly the resource and capability of local administrative agencies and the ability of these agencies to implement the federal regulations.

There are a number of areas where the existing federal, state, and local regulations can be improved, and they are discussed in individual sections of this chapter. These suggestions can be implemented individually; however, since many of the suggestions are interrelated, their effectiveness can be enhanced if they are implemented as a group.

5.1 Coordination Between Governmental Agencies

Coordination between the federal, state, and local UST programs should be improved to streamline the regulatory process and to minimize duplication among the different agencies. Furthermore, regulatory agencies have to adopt the attitude that their job is not limited to the protection of public health and the environment, but they must also educate the public and assist the regulated communities to come in compliance with regulations. They have to approach regulations not only from the regulators' point of view, but also from that of the regulated community.

Currently, the lack of coordination between the three levels of government makes regulations confusing and places unnecessary burden on UST owners and operators to comply with all the regulations. For examples, shortly after San Jose requested UST facilities to submit inventories of USTs, California initiated its own UST registration program which required all USTs, including those which are already registered under the San Jose program, to register with the state. With some coordination between the two programs, the burden of an extra registration process may be avoidable. However, there are often institutional barriers which impede the exchange of informations between the agencies, and it may be easier for one agency to collect its own data than to obtain them from another agency.

An example of an agency serving the public is the City of Mountain View when it sent a notification to its

UST facilities informing them of the federal UST requirements and the distinctive features of the federal regulations which differ from its own regulations. Mountain View's action may be a small step in bridging the gap between the local and federal regulations, but it was tremendously helpful to those in the regulated community who were unaware of the federal regulations. A local agency, very often, is so involved with its own program implementation and cost recovery process, that it neglects state and federal regulations and fails to see the need of inter-governmental coordination, including informing the regulated communities of other requirements besides its own local regulations.

An area where improved coordination between state and local agencies is needed is in leak detection and site mitigation. Currently, local agencies in the Santa Clara County are responsible for finding leaky USTs through their monitoring programs, and the Regional Water Quality Control Board (RWQCB) has the follow-up responsibility to oversee site clean-up once a contamination has been discovered. There is a long time lag between the two processes, and the time lay has caused unnecessary delays in real estate transactions and construction projects. Furthermore, such delays may have allowed further migration of contaminants and resulted in extra clean-up costs. Finally, the public attitude toward regulations have been damaged when regulatory agencies send out conflicting messages to the public. Local administering agencies attempt to convince the public of the importance of early leak detection, but RWQCB fails to re-affirm this point of view by its inability to address site clean-up in a timely manner once a contamination has been detected.

5.2 Uniform Regulations

A uniform set of federal regulations should be established with the intention that the regulations will be able to adequately regulate the majority of the USTs across the nation. The federal regulations should be based on sound science and be stringent enough to make it unnecessary for local administering agencies to impose additional requirements. However, state and local jurisdictions should maintain the option to amend and be more stringent than the federal regulations on a site specific basis for those sites which have compelling and unique site characteristics to justify the need for different requirements.

Current regulations are different at the three levels of government with the least stringent requirements at the federal level and the most stringent requirements at the local level. Requirements in the federal regulations are so minimal that they add little to the existing UST regulations in the Santa Clara County and many other localities which have their own UST regulations. Many local jurisdictions which do not currently have their own UST regulations will probably choose to be more stringent in one or more areas. The effect of this current regulatory scheme is that there will be many different local UST regulations throughout the country. It is difficult for the regulated community, including UST owners, operators, equipment manufacturers, and consultants, to keep current with the regulations at the various local jurisdictions.

A workable set of federal regulations which can be used by local administering agencies without extensive amendments is essential to the success of the local administering agencies. The current federal regulations provide such minimal public health and environmental protections that they may be inadequate for many local jurisdictions and prompt these jurisdictions to impose additional requirements. However, most local jurisdictions do not have resources to conduct research and to establish standards. Even for those jurisdictions which have the resources to make independent evaluations, good federal regulations can provide them a sound base and minimize the amount of variances they have to make.

Although conceptually, local jurisdictions like to be independent from the state and the federal governments, but in practice, they rather follow sound state or federal regulations and conform with the majority of the other local jurisdictions than to be different. In the early days of its Hazardous Material Program (HMP) implementation and before the formulation of the federal and the state regulations, San Jose was quite innovative and frequently formulated guidelines to address issues relating to new construction standards and leak detection requirements. However, the administration has now become more concerned with liability and revenue generation and become hesitant to formulate new guidelines. When issues such as triple rinsing and closure requirements arose, the administration surveyed other cities in the Santa Clara County and adopted their guidelines, even after its own staff had presented sufficient evidence to support different points of view. Following a standard already established by other cities relieves a city from spending resources to develop its own standard and minimizes the chance of an administrator from being the lone target of objections from the regulated community. If the federal government imposes a sound, uniform set of regulations for all USTs, it would be welcomed by most local administering agencies.

5.3 Definition of an UST

Under the current California and federal definitions of an UST, a tank which is partially burried may not be recognized as an UST. A partially burried tank or even one which is placed in direct contact with the ground surface behaves similarly to a completely burried UST that it cannot be monitored readily by visual inspection and must be monitored by one of the UST monitoring methods. The distinction between above ground and underground storage tanks should be based on the method in which a tank can be monitored. Thus, the definition of an UST should include a tank which has one or more surfaces in contact with the ground in such a way that visual monitoring of the tank is not possible.

5.4 Secondary Containment

Secondary containment should be required for all new USTs and piping, and periodic testing should be required for all secondary containment systems. In the event of a leak, a secondary containment can prevent hazardous materials from escaping into the environment; while, periodic testing ensures a secondary containment system will be able to function properly when it is needed.

Present regulations on USTs are not uniform in their requirement for secondary containment. The federal regulations do not require secondary containment for new petroleum USTs and piping, but rely instead on cathotic protection and leak detection. Cathotic protection cannot prevent leakages from USTs and piping to the same degree as secondary containment, and leakage can occur in a cathotically protected system due to a variety of reasons such as defects in USTs and piping, improper installations, and natural causes (earth movement). Loose joints and unions are common causes of leakages in piping, and they cannot be completely eliminated by cathotic protection. Furthermore, corrosion can occur if a cathotic protection system is not properly installed and maintained. A good monitoring system can provide early detection of leakages, but only a secondary containment system can prevent release of stored materials into the environment. Regulations should focus on the prevention of environmental damages instead of on detection and corrective actions after a release has occurred.

Another advantage of secondary containment is that leak detection in the interstitial space of a secondary containment system is a simpler task in comparison to monitoring in the environment outside a single-wall system. Environmental factors are often unknown and unpredictable; and there is much uncertainties in the effectiveness of monitoring single-wall USTs. In contrast, the environment inside an interstitial space is more stable and can be effectively monitored by a variety of methods including liquid and vapor monitoring.

Federal regulations require the owners of USTs to provide proof of financial responsibility for cost associated with site clean-up in the event of a leak. Private insurance is probably the most common mechanism which small and medium size companies will utilize to comply with the financial responsibility requirements. Insurance companies will probably be very selective in underwriting insurance for existing facilities, and many will provide coverage only to those facilities with secondary containments. Thus, the federal regulations may be indirectly requiring secondary containment through its insurance requirement. If the federal government takes a direct approach and ask for secondary containment of all new USTs and piping, a layer of bureaucracy can be eliminated. Resources spent by UST owners and regulatory agencies on insurance premium and administrative effort, respectively, can be directed toward the constructive upgrade of existing facilities.

Secondary containments should be constructed in a manner which allow them to be tested, and testing should be performed periodically. The existing California and San Jose regulations do not have requirements for periodic testing of secondary containments. In San Jose, besides an initial integrity test of the secondary containment at the time of an installation, additional testing is not required for the service life of the secondary containment. A secondary containment is often constructed of the same material as the primary container, and it is subjected to the same factors which cause failures in the primary tank and piping. A hole may develop in the outer wall of a double-wall UST or in the secondary containment trench of a piping system. If the hole is down-stream of a leak and up-stream from a liquid detector used to monitor the interstitial space, then products can escape the secondary containment without the activation of the detector. A vapor sensor will probably function in such a defective secondary containment system, but hazardous materials can still escape into the environment by the time an alarm is activated. A secondary containment is designed to contain the hazardous material leaded from the primary containment, and it is important to ensure that they can perform up to the original criteria as long as they are in service.

5.5 Upgrade of Existing USTs

Existing single-wall USTs and piping should be ungraded to new construction standards with secondary containment within a ten-year replacement period. In comparison to single-wall UST systems, USTs and pipes with secondary containments provide superior protection of public health and the environment. UST installation and removal contractors and environmental consultants are unlikely to be available to provide upgrading of all existing USTs at the same time. A ten-year replacement schedule is a realistic goal given the large number of USTs and the limited resources available in the country. A phase-in schedule should be utilized with the shortest replacement time for the oldest existing UST systems and up to ten years for the newest single-wall UST systems.

The federal regulations require existing USTs to be ungraded to new UST standards, but the federal standard for new UST is limited to corrosion protection without any secondary containment. In contrast, the California and the San Jose regulations require secondary containment for most new installations, but they do not have any upgrade requirement for existing USTs. The state and local regulations rely on the monitoring of existing USTs for early detection of leakages. One of the drawbacks on the reliance of monitoring systems is that it is a remedial approach as opposed to a prevention approach with secondary containment (Section 5.4). Furthermore, leak detection of single-wall USTs is more difficult and less effective than leak detection in the interstitial space within a secondary containment system.

San Jose's experience in its leak detection effort can be used to illustrate the ineffectiveness of its present approach. In the six years since the adoption of its HMSO, San Jose has devoted much time and effort in the area of single-wall UST monitoring. Despite constant discussions and meetings between the staff of the of San Jose HMP and UST facility owners, leak detection device manufacturers, and installation contractors, there are still USTs, including some of the City's own USTs, which do not have adequate leak detection systems. Among those facilities with leak detection systems, a high percentage of them are not being properly monitored. A vadose zone leak detection system for an UST at a San Jose fire station has been in an alarm condition since the day it was installed, but there has not been any actions taken to investigate the cause of the alarm until two years later. This situation is not unique but can be found in many other UST facilities. Many groundwater monitoring wells also have never been tested since their installation; some have turned into dry wells due to changes in the groundwater table and some have been paved over or simply forgotten due to neglect.

Another weakness of the present system with heavy dependence on leak detection is the long delay between the discovery of contamination and the site clean-up. RWQCB has a long back-log of contamination cases such that remedial action do not take place for months or years after the discovery of contamination from a leaky UST. In the mean time, contaminants can spread in the soil and the groundwater which can make the eventual clean-up effort more difficult.

If the present condition or situation in San Jose is unchanged for the next four years, there will still be many single-wall USTs in San Jose that are not being properly monitored and pose high risk to the environment. In retrospect, if a ten-year tank replacement program had been instituted six years ago in 1983 at the beginning of its UST program, all USTs in San Jose would have secondary containment by the year 1993, and the risk of leakage from USTs to the environment would be much reduced in comparison to the present system. A discussion and recommendation for requiring secondary containment is presented in Section 5.4. Resources spent by both industries and regulatory agencies on the development, installation, and maintenance of leak detection systems would have been better utilized if they were spent on up-grading existing USTs to double-wall systems. Furthermore, there would be reduced incidences of release into the environment and savings from the reduction in clean-up work.

The replacement of existing USTs with new, secondary contained USTs involves substantial financial resources on the part of UST owners; however, a ten-year phase-in replacement program can minimize the amount of financial impact on UST owners. Since the normal life expectancy of an UST is about 15 to 20 years, a ten-year replacement requirement advance the normal replacement schedule an UST at most five to ten years. For those USTs older than 15 to 20 years, the tank replacement program imposes limited additional costs since they already exceeded their normal operating life expectancy. Requirements for the installation of elaborate and expensive leak detection systems on existing USTs, such as those required by San Jose, can be relaxed as a trade-off for obtaining fully secondarily contained USTs in ten years. In the interim before an existing UST is upgraded, inventory reconciliation and annual tank test can be used to monitor the tank. This proposal is likely to be acceptable to most UST owners and operators because inventory reconciliation and annual tank testing impose no additional cost to existing USTs. Although this method of leak detection has many recognized drawbacks, it is a worthwhile trade-off in order to obtain the necessary support for the tank replacement requirement. Inventory reconciliation and annual tank tests will be able to detect large leaks; while, small leaks can be detected by soil sampling at the time of tank replacements. The proposed relaxation of monitoring requirements will cause delay in leak detection, but it probably will have limited impact on the environment and the eventual clean-up effort in comparison to the present system which has imperfect leak detection systems and long delays in mitigation responses.

In summary, a ten-year UST replacement program, with inventory reconciliation and annual tank testing of existing single-wall USTs and secondary containment requirement for new USTs, will provide superior long-term protection for public health and the environment than the present approach which places emphasis on leak detection of single-wall USTs and remediation work after a leak has occurred.

5.6 Simplify Regulations

Regulations should be simple for local administering agencies to implement. Simplified regulations would facilitate the uniform implementation of the regulations among local administering agencies and enable them to perform their functions without an excessive demand on manpower and financial resources.

Current regulations delegate to local administering agencies the task of reviewing monitoring systems and new construction plans. The routine review of common systems which have been previously approved is straight forward; however, it is more complicated to determine whether a new monitoring system or a construction technique meets the guidelines specified in the regulations. This review process is time consuming and requires highly trained personnel, and the cost to properly implemented such a program is high. The cost incurred by an agency will be passed on to the regulated community in the form of permit fees. The cost to society of an improperly administered program must include the increased costs associated with delay detection of leaky USTs.

The review process of leak detection systems is the most complicated aspect of the present regulations. A regulatory scheme, which includes tank replacements with secondary containment systems and allows for the relaxed monitoring of existing USTs in an interim period before the tank replacements (Section 5.5), can provide local administering agencies with a simple set of regulations to implement without the excessive burden on the administering agencies.

5.7 Centralize Technical Reviews

A technical review panel is needed at the national level to evaluate and approve new leak detection devices and to provide a list of approved systems to local administering agencies and the regulated community. This process would assist UST owners and operators in their compliance efforts and free the local administering agencies of such burdensome tasks to allow them to concentrate on enforcement efforts.

One of the weakest aspect of the San Jose UST program is in the area of enforcement to assure that existing USTs are properly monitored. San Jose's experience has demonstrated that projects which have externally imposed deadlines are given higher priority than projects with only internally imposed deadlines. Projects such as new constructions and tank removals are given high priority because of deadlines imposed by contractors on such projects. On the other hand, the annual inspection of existing USTs is only an internal goal, and existing UST owners and operators never voluntarily request inspections from the City. With limited resources, San Jose has been performing a reasonable job on UST removals and installations, but at the same time, it has neglected the enforcement of existing USTs. As of today, six years since the adoption of the HMSO, inspections have not been conducted on most UST facilities; many existing USTs still do not have monitoring systems; and most monitoring systems are not being properly used.

Currently, a new monitoring device has to go through each local administering agency for its review and approval. A centralized review mechanism would benefit both the manufacturers and the local agencies in terms of savings on time and resources. Furthermore, it would ensure a uniform and adequate review process which is often beyond the capability of most local agencies. For example, the evaluation of internal tank level sensors and tank testing devices requires highly specialized skills which is beyond the capability of even the most advance programs in the Santa Clara County. Currently, only EPA has the resources to perform thorough reviews of these sophisticated systems. Besides providing the local administering agencies a list of the approved devices, the central review group can serve as a technical resource center when such needs arise at the local level. It would allow local agencies to perform what they can do best, namely inspection and enforcement.

5.8 Performance Regulations with Best Available Technology

Regulations should be performance-oriented and allow regulators to select the best available technology to achieve the performance goal. Since leak detection and secondary containment are still relatively new in the area of UST management, there has not been sufficient time for the technology to fully develop. Regulations should be formulated to encourage technological advancement to provide the desire level of environmental protection. Performance-oriented regulations encourage the development of new technology and should be used in this early stage of UST regulations.

Currently, the state and the federal regulations are based on available technology at the time the regulations are formulated. They provide no incentive for manufacturers to improve their products to achieve a higher level of public health and environmental protection. The federal regulations established minimum detection limits for internal tank level sensors and tank test devices based on what the technology can achieve today without regard to the potential technological improvement in the future and the potential environmental damage from leaks which have leak rates below the detection limits of the current leak detection instruments. The different monitoring options under the California regulations are based on existing technologies which do not offer a consistent level of public health and environmental protection. An UST owner or operator can choose a method based straightly on its cost even through it may provide inadequate environmental protection.

An example to illustrate the desirably feature of a performance standard is San Jose's requirement for secondary containments to pass an integrity test. In the early days of the San Jose UST program, the double-wall UST was not available and the flexible membrane liner was the state-of-the-art technology for secondary containment of USTs. San Jose saw the inherent problems associated with flexible membrane liners and established a performance standard for new secondary containment systems. It required all new secondary containment systems to pass an integrity test; flexible membrane liners have to be filled with water and pass a 24-hour water test. The industrial practice at the time did not include any testing on flexible membrane liners, and there were strong oppositions from all segments of the regulated community. The difficulty of the flexible membrane liner to pass the test encouraged the development and usage of the double-wall UST which is a much superior form of secondary containment than the flexible membrane liner.

Today, piping is the weakest component in an UST system. The double-wall pipe is available, but it is not widely used due to difficulties in its installation. The fiberglass trench is the most common form of secondary containment for piping; however, it cannot be periodically tested once an installation is complete, and there is no feasible method to clean-up the trench once it becomes contaminated. Establishing a performance standard to require periodic testing of secondary containments for pipes will encourage the development of superior containment technology. Other potential improvements for piping include the use of suction piping systems which are widely used in Europe; the modification of the typical service station layout to accommodate shorter piping runs; and the use of flexible delivery hose within rigid outer containment pipes. Regulations should be written in terms of performance goals based on best available technology. This regulatory approach will encourage the development of better technologies.

6.0 CONCLUSIONS

The federal, California, and San Jose underground storage tank (UST) regulations share many common components. Some of these components are similar, but others are different in many aspects, especially with respect to their approach to regulate USTs. Differences between the regulations offer an opportunity for a cross comparative assessment of the regulations and the effectiveness of their approaches. After six years of implementing one of the earliest and most innovative UST program, San Jose has acquired experiences that the majority of the country lacks. This experience helps formulate many of the recommendations presented in this paper. The intention of these recommendations is to provide insights for a better set of UST regulations that allow easier implementation by local administering agencies, more uniform regulations for the regulated community, more efficient use of resources, and superior protection of public health and the environment.

Recommendations formulated in this paper can be implemented individually; however, since many of them are interrelated, the effectiveness of the suggestions can be enhances if they are implemented as a group. The major findings and recommendations derived in this paper include:

* A more efficient UST program for the whole country should be based on a set of uniform regulations which is simple for local administering agencies to implement but stringent enough to protect public health and the environment without the need for frequent amendments by local administering agencies. Uniformity also makes it easier for the regulated community to comply with the regulations.

* Secondary containments should be required for all new UST systems (tanks and pipes), and periodic testings should be performed for all secondary containment systems to ensure that their integrity has not been compromised. Leak detection is simpler and more accurate in the interstitial space of a double-wall UST in comparison to the natural underground environment of a single wall UST.

* Existing single-wall UST systems should be upgraded to new construction standards with full secondary containments on a ten-year replacement schedule. This upgrade requirement would shift the regulatory approach from one which depends on leak detections and clean-ups after hazardous materials have leaked into the environment to one which emphasizes on the prevention and containment of leaks. The ten year phase-in period takes into account the normal life expectancy of an UST and attempts to minimize the financial impact of tank replacement on UST owners and operators. Requirements for the installation of

elaborate and expensive leak detection systems on existing USTs can be relaxed in order to obtain fully secondarily contained USTs in ten years.

* The definition of an UST should be expanded to include a tank which is resting on the ground with one or more surfaces in contact with the ground such that visual monitoring of the tank is not possible. This type of above ground tanks behaves much like a completely burried tank in terms of its need for special leak detection devices to monitor leakages. There is no current federal or California regulations to address this issue.

* The coordination between governmental agencies should be improved to minimize duplications and to streamline the regulatory process. The coordination between leak detection and clean-up activities between the local and state agencies needs to be improved in order to maintain the credibility of the agencies.

* The federal government should provide a central clearing house for the review and approval of new construction standards and leak detection systems. Equipment manufacturers would benefit from a centralized review and approval process as opposed to the currently fragmented and often inconsistent individual approval process by local administering agencies. UST owners and operators would have a better defined list of approved systems to aid in their planning process. Local administering

agencies can rely on the federal government for technical assistance and direct their resources toward educating UST owners and operators and assisting them in their compliance effort.

* Finally, since UST technology is still in a developmental stage, the continued development of construction methods and leak detection systems should be encouraged with performance-based regulations and regulatory agencies requiring the use of best available technology which is economically feasible.

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