The Potential for Offsite Exposures Associated with Santa Susana Field Laboratory, Ventura County, California

Final Draft Report

Report Prepared by
Center for Environmental Risk Reduction
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This study was funded by the Agency for Toxic Substances and Disease Registry (ATSDR) through a contract arrangement by Eastern Research Group, Inc. (ERG) with the University of California, Los Angeles (UCLA). The study focused on assessing the potential exposures of communities surrounding Santa Susana Field Laboratory (SSFL) to contaminants associated with SSFL. The following individuals have contributed to the study:

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1.0 INTRODUCTION

1.1 Overview

This report reviews the available monitoring data and various studies that have focused on the potential environmental impact of Santa Susana Field Laboratory (SSFL) on its surrounding communities. The report's major objectives are (a) to provide an independent review of the adequacy and accuracy of available monitoring data on chemical and radionuclide contamination at the SSFL site and surrounding communities; (b) to assess the present level of contamination, due to chemicals and radionuclides, at the SSFL facility and the surrounding communities; (c) to estimate emissions of chemicals associated with various SSFL-related activities; (d) to identify, to the extent possible, locations that SSFL is likely to have impacted; (e) to assess the potential migration of contaminants from SSFL, and (f) to identify potential significant exposure pathways associated with the release of contaminants from the SSFL area.

This report was prepared by a study team whose members came from the University of California at Los Angeles (Center for Environmental Risk Reduction, Chemical Engineering Department, Civil and Environmental Engineering Department, School of Public Health), the Universitat Rovira i Virgili in Spain, and Sonoma Technology in California. In addition to reviewing available reports and conducting independent analyses, UCLA study participants have visited the SSFL site and surrounding communities on numerous occasions. UCLA study group members have also attended a number of public meetings[1.1] in which members of the community have presented their concerns. Such public meetings and personal interviews with community members have helped the authors shape the structure of this report in order to address issues that are of concern to the community.

Sources of information considered in the study included reports addressing site characterization and inspection, contaminant monitoring, exposure and risk assessment, environmental assessments, and site evaluation, as well as accident reports, emission logs, toxic release inventories, hydrogeology investigations, unpublished memos and letters from regulatory branches, Hazard Ranking System (HRS) evaluations, radiological surveys, well usage reports, meteorological records, studies of population distributions and community health,[1.2] and personal communications. Critical review of the above information along with independent data analyses and modeling were conducted to (a) screen and rank the chemicals of concern according to their toxicity, environmental persistence, emissions, and/or monitored concentrations; (b) estimate emissions of contaminants from SSFL; (c) evaluate air dispersion of contaminants from SSFL; and (d) evaluate the extent of subsurface contamination and potential offsite contaminant migration.

The study's sources were SSFL logs and reports provided by the Boeing Company, as well as various monitoring and/or assessments conducted by the Agency for Toxic Substances and Disease Registry (ATSDR), the U.S. Department of Energy (DOE), the California Department of

[1.1] Meetings attended were organized by SSFL Workgroup members, the U.S. Environmental Protection Agency (EPA), the Committee to Bridge the Gap, the Southern California Federation of Scientists, the Rocketdyne Cleanup Coalition, the California Department of Toxic Substances Control, the Los Angeles Regional Water Quality Control Board, and the U.S. Department of Energy.

[1.2] Wright et al., 1990; DHS, 1992; Reynolds et al., 1992; Morgenstern et al., 1997, 1999, and 2001.

Toxic Substances Control (DTSC), the U.S. Nuclear Regulatory Commission (NRC), Washington Mutual Bank, the U.S. Environmental Protection Agency (EPA), Atomics International (AI), the California Department of Health Services (DHS), the Committee to Bridge the Gap, the U.S. Geological Survey (USGS), Ventura County Air Pollution District (VCAPD), the Office of Environmental Health and Human Affairs (OEHHA), the Los Angeles Regional Water Quality Control Board (RWQCB), the Southern California Water Company (SCWC).

This report assesses potential exposure scenarios and identifies exposure locations that may be of greatest concern. Where possible, it discusses the implications of the various findings to human health risk. Because of the lack of reliable monitoring and emission data, it was not possible to conduct quantitative dose reconstruction and health risk assessment. Therefore, this report does not present a quantitative risk assessment. Notwithstanding, its review and analyses should be directly useful for subsequent risk assessment and epidemiological studies and to those who need to assess the future potential land use of SSFL and ensure public protection. Finally the report summarizes the potential public health hazard posed by SSFL, and makes recommendations, as deemed appropriate, that are relevant to public protection.

1.2 Site Operations and History

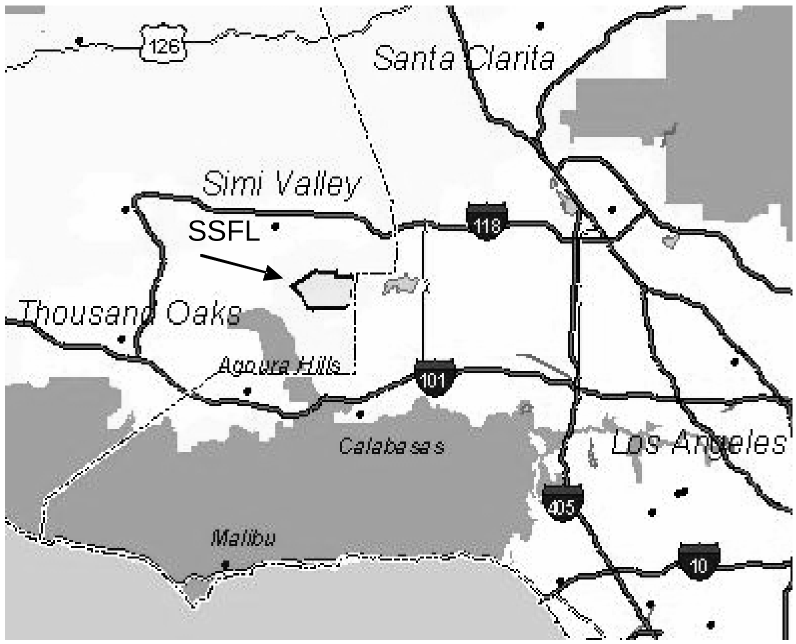
1.2.1 Location and Operational History

SSFL is a complex of industrial facilities located in the Simi Hills of southeastern Ventura County, California. The facility is approximately 30 miles northwest of downtown Los Angeles (see Figure 1-1), between Simi and San Fernando Valleys. SSFL occupies roughly 2,600 acres, at altitudes ranging from approximately 1,500 feet to 2,200 feet.

In 1948, North American Aviation acquired the land area now known as SSFL. The SSFL site has been used primarily for testing liquid fuel-propelled rocket engines, many related to the early Apollo space missions. In addition, the SSFL site was the location of research, development, and testing of MX missile engines, water jet pumps, “Star Wars” lasers, liquid metal heat exchanger components, coal gasification and liquification processes, and related technologies. In 1955, Atomics International (a division of North American Aviation) and DOE began developing and testing nuclear reactors on the site. Operations at SSFL have involved the use of organic solvents, hydrazine fuels, kerosene-based fuels, oxidizers, liquid metals, asbestos, polychlorinated biphenyls (PCBs), hydraulic oils, and various radionuclides (see Appendix C for a complete listing).

Atomic International (AI) merged with Rocketdyne in 1984 and Rocketdyne’s name was kept. In 1996, all nuclear operations ended; since that time the nuclear reactors and reactor sites have been undergoing decontamination and decommissioning (D&D) under the oversight of DOE. Boeing and Rocketdyne merged in 1996. SSFL is now jointly owned by Boeing and the National Aeronautics and Space Administration (NASA), and is operated by the Rocketdyne Propulsion and Power Division of Boeing.

Figure 1-1 Location of Santa Susana Field Laboratory



Source: ATSDR (2000)

1.2.2 Facility Description

The SSFL site is divided into four administrative areas (I, II, III, and IV) and undeveloped buffer properties to the northwest and south, as shown in Figure 1-2 (Robinson, 1998; Ogden, 1998b). A detailed map listing the various present and past use areas of SSFL is provided in Figure 1-3.

- Area I consists of 671 acres owned by Boeing and 42 acres owned by NASA in the northeast portion of the site. Area I houses administrative and laboratory facilities including the North American Kindleberger Atwood Lab (NAKA), the former Area I Thermal Treatment Facility (TTF), also known as the open pit burning facility; and three rocket engine test areas: the Bowl, the Canyon, and the Advanced Propulsion Test Facility (APTF) areas. The Bowl and Canyon test areas were phased out of operation in the late 1960s and 1970s.

- Area II consists of 410 acres at the north-central portion of the site. It is owned by NASA and operated by Rocketdyne. Area II contains two formerly used rocket test firing facilities (Coca, Delta) and two currently operating rocket test firing facilities (Alfa, Bravo), as well as the NASA-associated Systems Test Laboratories (STL). Delta test areas were phased out of operation in the late 1960s and 1970s. The Coca test area was shut down in May 1988. The Alfa and Bravo test areas are currently in operation.

- Area III consists of 114 acres at the northwest portion of the site and is owned and operated by Rocketdyne. The Systems Test Laboratories–IV (STL-IV) and the Engineering Chemistry Lab (ECL) are located in Area III.

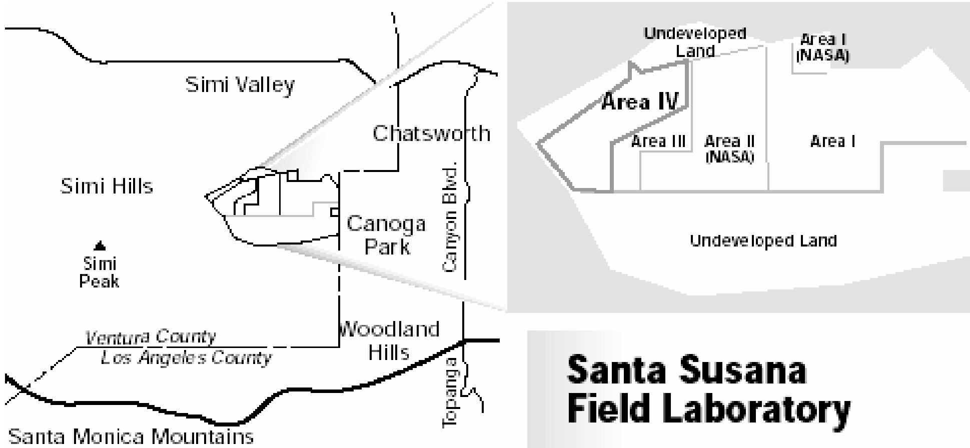
- Area IV consists of 290 acres owned by Boeing and operated by Boeing's Rocketdyne Division and 90 acres leased by the DOE. DOE and its contractors operated nuclear reactors, associated fuel facilities, and laboratories within this area from 1955 until 1988. Area IV is the location of the former Sodium Reactor Experiment complex (SRE) and the Rockwell International Hot Lab. Since 1988, the site has maintained a program to monitor and clean up radiological contamination.

- The Buffer Areas consist of two undeveloped plots (175 and 1,140 acres) northwest and south of SSFL, respectively (Figure 1-2). Two National Pollutant Discharge Elimination System (NPDES) discharge outfalls and drainage channels are located within the southern boundary area (outfalls 001-002; see Figure 3-9 for NPDES outfall locations). The northern boundary was purchased by Boeing from the adjoining Brandeis-Bardin Institute in 1997 (GRC, 1999).

Chemical waste generated at the SSFL facility was treated and stored on site, including in surface impoundments (ponds). SSFL has had 28 of these ponds over the course of its history; they are designed to collect cooling and rinse water, storm water runoff, and accidental spills (GRC, 1987). Eleven of the ponds were designated in 1977 as hazardous waste facilities under the Resource Conservation and Recovery Act (RCRA) of 1976 (GRC, 1987). Since 1977 only two of these eleven ponds were reportedly the only impoundments that were part of the water reclamation system hat stored and treated hazardous wastes on a routine basis: the Engineering Chemistry Lab (ECL) pond in Area III and the Laser Engineering Test Facility (LETF) pond in Area I (GRC, 1987). These two ponds were excavated in 1984 and the material was sent to a Class I disposal facility (Hargis, 1985). Active use of the other nine impoundments ceased in 1985, and those ponds have been undergoing RCRA closure (GRC, 1987). Five impoundments are still in use (R-1, Perimeter, Silvernale, R2-A, and R2-B ponds; Figure 1-3; Boeing, 2003).

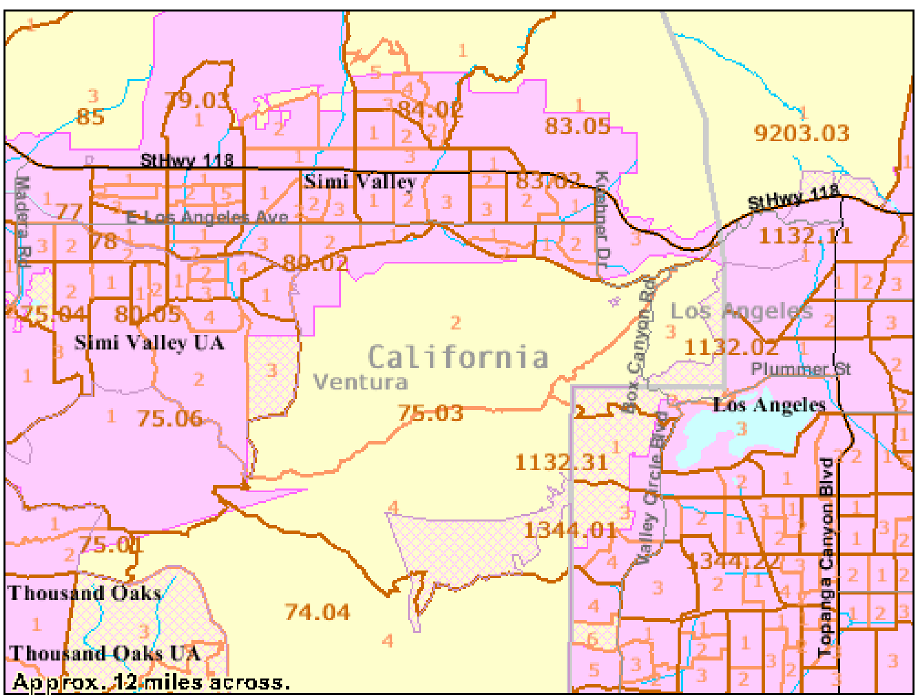
In addition to surface impoundments, there are 17 known areas where waste materials were stored or treated (Hargis, 1985). According to Groundwater Resources Consultants (GRC, 1987), many of these areas may have lacked proper containment facilities to prevent release of contaminants to the environment in the event of improper storage or spills throughout their operation. Appendix D summarizes information on these waste management facilities, including their reported use and types of waste handled.

Figure 1-2. Santa Susana Field Laboratory



Source: ATSDR, 2000

Figure 1-5. Locations of Census Tracts Corresponding to Data Used for Table 1-1



Source: U.S. Census Bureau

1.3 The Surrounding Community

Dynamic changes in population density around SSFL and continual migration of residents into and out of various areas make the association of potential exposures with specific population segments an impractical task. Nonetheless, in order to evaluate the pertinent exposure pathways, one must consider the population distribution around SSFL and land use in the SSFL area.

The communities surrounding SSFL have changed since the area's early industrialization in 1946. The area was sparsely populated before 1970. USGS maps (USGS, 1952, 1967) indicate that fewer than six buildings were present in the areas directly bordering SSFL before 1967, with approximate near-border population of 20 individuals. Development in the area and population increased significantly since the establishment of SSFL. In 2000, the population within 1 mile of SSFL was about 6,000 (U.S. Census Bureau, 2000). As Table 1-1 shows, the total population increase during the 1980–2000 period (in the selected communities shown in Figure 1-4, all of which lie within 4 miles of SSFL) was approximately 62%. (Figure 1-5 shows the census tracts from which the table's data were drawn.)

Table 1-1. Demographics of Selected Tracts Surrounding SSFL Within a 4-Mile Radius

Variable	**1980**	**1990**	**2000**
Total Population	3,597	5,118	9,488
Children 9 years of age or younger	317 (9%)	481 (9%)	1,306 (14%)
Persons 65 years of age or older	162 (4%)	290 (6%)	404 (4%)
Females 15 to 44 years of age	956 (27%)	1,325 (26%)	1,910 (20%)
Total housing units	1,211	1,834	6,771
Total housing units built in the last 10 years	—	368 (20%)	4,937 (73%)

Note: Demographic statistics within a 4-mile radius of SSFL for 1990 and 2000; data from census tracts 75.03, Ventura, and tracts 1132.31/1132.02/1344.01, Los Angeles, California (U.S. Census Bureau). The percentages in brackets designate the percent of the specific population group of the total population for the indicated year.

Figure 1-4. Communities and Land Use Surrounding SSFL

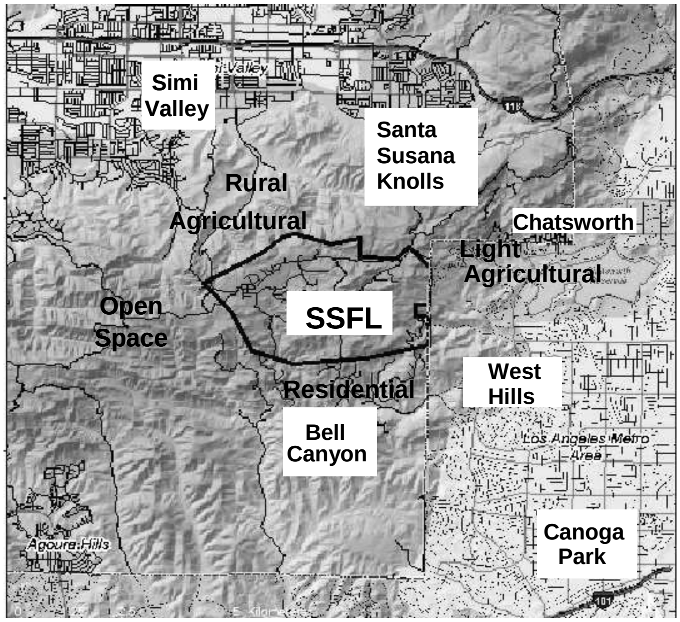
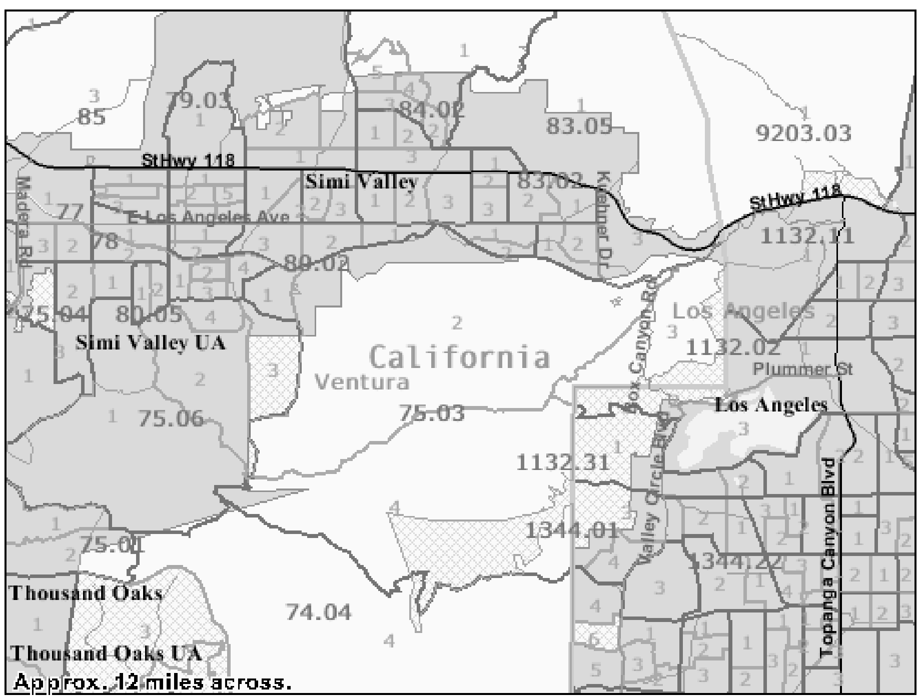


Figure 1-5. Locations of Census Tracts Corresponding to Data Used for Table 1-1



Source: U.S. Census Bureau

Currently, there are residents who live directly adjacent to the eastern and southern site boundaries. Two mobile home parks are located east of the site on Woolsey Canyon Road. The major communities surrounding SSFL are indicated in Figure 1-4. The residential areas closest to the facility are Bell Canyon to the south, Lakeside Park and Dayton Canyon to the east, and Box Canyon and Woolsey Canyon to the northeast. The nearest communities are Chatsworth (~3 miles east, population ~67,000), Canoga Park (~5 miles southeast, population ~100,000), Simi Valley (~3 miles north, population ~100,000), and Thousand Oaks (~7 miles southwest, population ~100,000).[1.3] The neighboring lands to the north and west of SSFL are zoned rural/agricultural or agricultural. Lands to the south of the facility are zoned rural. To the east, land has been designated as light agricultural.

1.4 Community Concerns

In meetings ATSDR held by the Agency for Toxic Substances and Disease Registry (ATDSR) in Chatsworth, Simi Valley, and West Hills on October 5 and 6 and November 3, 1999, the public expressed concerns about SSFL's potential impact on community health. These concerns were heightened in view of the 1992 California Department of Health Services (DHS reports suggesting high incidences of bladder and lung cancer in communities surrounding SSFL.[1.4] Particular public health concerns identified at the ATSDR meetings were asthma, immune system disorders, neurological disorders, birth defects, and several types of cancer (breast, bladder, lung, prostate, thyroid, skin, leukemia, and liver) (ATSDR, 1999). Other community concerns identified at other public meetings[1.5] and resident interviews (Appendix G) included the potential for contamination of well supplies in Simi and San Fernando Valleys, the potential for contamination of private and community gardens and/or livestock, and inadequacy of environmental sampling and monitoring programs.

The UCLA study group considered community concerns that were brought to its attention both via public meetings and directly by members of the public. The study also considered public concerns documented in available reports. Health effects implications associated with SSFL chemicals of potential concern (COPCs) are listed in Appendix F and are discussed in Section 6.2. In order to address public concerns regarding exposure to contaminants via the groundwater pathway, the study group attempted to retrieve updated well logs and well information (Appendix K; Table 4-1); unfortunately, all the necessary information was not forthcoming.[1.6] A previous assertion regarding inactivity of all wells within a 1-mile radius (ATSDR, 1999) could not be verified by the present study. Therefore, relevant conservative assumptions were made, as

[1.3] Population estimates are based on 2000 census data (U.S. Census Bureau).
[1.4] A preliminary report by DHS (DHS, 1992) suggested a high incidence of bladder cancer for the 1983–1987 period among residents near SSFL in Los Angeles County. A subsequent study (Reynolds et al., 1992) confirmed the higher rate of bladder cancer among men living near SSFL (again, in Los Angeles County) in 1983–1988. That study also reported a higher incidence of lung cancer in Ventura County residents near SSFL. As acknowledged in the Reynolds et al. study, the relatively small number of cancer cases within 5 miles of SSFL and the area's low population limited the detection sensitivity of the study.
[1.5] These meetings were held by the SSFL Workgroup (12/10/03; 3/24/04), DTSC (7/15/03; 3/17/04), the Bell Canyon Homeowners Association (1/25/04), UCLA (8/19/2003), the Los Angeles RWQCB (2/10/03; 3/14/03; 4/24/03; 6/25/03; 8/20/03; 4/14/04) and DOE (6/3/2004).
[1.6] Correspondence with agencies and private well companies is documented in Appendix J.

deemed appropriate, regarding well usage in the areas north and east of SSFL.[1.7] Given public concerns about the impact of SSFL on community livestock and edible crops, an effort was made to ascertain the existence and locations of community gardens and/or farms. That information was incomplete, so the study group considered various scenarios to assess SSFL's possible impact on community gardening and farming activities. The community has also expressed concerns about potential exposures to SSFL-associated chemicals due to outdoor activities near SSFL (e.g., gardening, camping and hiking leading to exposure to surface water originating from SSFL). Unfortunately, detailed population activity patterns are not available for the communities surrounding SSFL. Consequently, where deemed appropriate, the study group used information from local residents (Appendix G).

Finally, the report also addresses community concerns regarding the adequacy of monitoring data and confusion regarding the role and responsibilities of various government agencies with respect to SSFL. These concerns are addressed throughout the report and in recommendations about monitoring programs and implications of available monitoring data (Sections 1.4, 3, 5.1, and 6). A list of various agencies and their regulatory responsibilities and onsite activities is provided (Appendix P) based on the compilation by Montgomery-Watson Groundwater Consultants (MWG, 2000).

1.5 Evaluation of SSFL Site Assessment Reports, Quality of Monitoring Data, and Reported Emissions

1.5.1 Overview

The study group reviewed SSFL-related reports detailing site investigations and monitoring programs (Appendix O) in order to (a) assess the quality and reliability of available monitoring data, (b) identify contaminants of concern (COCs), (c) assess the level of contamination in and around the SSFL facility, and (d) evaluate the potential for offsite contaminant migration.

The type and number of documents reviewed by the UCLA study team are listed in Table 1-2. In all, the team reviewed 291 documents from 35 different sources.

1.5.2 Assessment of the Quality of Monitoring Studies and Data Reliability

The quality and reliability of reports and documents reviewed in this study were evaluated according to several critical factors. For monitoring reports, critical review factors included measurement sensitivity, randomness of sampling, sufficiency of data points, appropriateness of methodology, uncertainty, reproducibility, evidence that a monitoring sample was representative of the site or background, potential for sample contamination, acceptability of analytical methods, and adherence to standard quality assurance/quality control methods. Reports were also assessed for their overall methodology and the degree to which they supported or conflicted with the other reports. Data gaps and chemicals not routinely monitored were listed and assessed as

[1.7] Groundwater wells were not identified for the Bell Canyon community by the Ventura and Los Angeles Water Resources Departments.

COPCs (Appendix C). Assessments of data quality are presented throughout this report when relevant monitoring data are reviewed. The study team also considered details regarding specific violations cited in EPA, DTSC, and DHS inspection reports in assessing potential the potential for offsite contaminant migration and under-reporting of the extent of contamination and/or releases of contaminants (Appendix E).

Chapter 8 discusses, in detail, the available offsite monitoring reports' adequacy and the implications of their monitoring data. It is nonetheless useful to summarize here the study team's concerns about the two major SSFL-related offsite monitoring studies conducted at the Brandeis-Bardin Institute (BBI) and Santa Monica Mountains Conservancy (SMMC) areas (McLaren-Hart, 1993, 1995) and at Bell Canyon (Ogden, 1998a). Air monitoring was not conducted or reported in either of these two studies. Moreover, background samples were taken from locations that were not representative of the Bell Canyon study area (Ogden, 1998a).[1.8] Sampling was deficient with respect to the sampled media for the Bell Canyon[1.9] study (Ogden, 1998a) and the number of areas sampled for the BBI/SMMC study (McLaren-Hart, 1993).[1.10] For example, proper monitoring protocols—such as grid spacing of samples—were not followed (EPA, 2002). It is also noted that despite detections of plutonium-238, cesium-137, and strontium-90 significantly above background (McLaren Hart, 1995), re-sampling was only conducted 2 years after the initial detection, and only tritium was assessed in this second round of monitoring. Given the deficiencies in the above studies, the study team is concerned that the extent of contamination in these offsite areas was incompletely mapped.

Limited or inadequate monitoring data (see Chapter 8) have made it impossible to arrive at a definitive quantitative evaluation of the rates of contaminant migration over the lifetime of the SSFL and to rule out certain contaminant migration pathways. Data limitations that have been identified include, but are not limited to: (a) inadequate assessment of vertical and horizontal hydraulic gradients; (b) insufficient delineation of the extent of groundwater contamination in areas east of the facility; (c) lack of current well use surveys in areas east, northeast, and south of the facility; (d) lack of long-term (>4 years) historical onsite meteorological data; (e) lack of air monitoring data (historical and current) for chemicals and radionuclides; and (f) potential for non-detection of significant concentrations in past monitoring programs due to the detection limits of monitoring devices (1948–1980s).

[1.8] In the Ogden study, Bell Canyon background sampling included sampling from areas between SSFL and Bell Canyon. It is noted that background samples in the Ogden study were not from the same bedrock formation as in the residential yards from which samples were taken.

[1.9] Water samples were not taken from Bell Creek despite the fact that 90 percent of the NPDES discharges were released to streams that flow into Bell Creek (Ogden, 1998a). .

[1.10] Only four sites were sampled in the 1993 McLaren-Hart study (McClaren-Hart, 1993). .

Table 1-2. Category and Number of Reports Reviewed and Information Sources

Report/Document Category	Number of Reports/ Documents	Source of Information	Number of Reports/ Documents
Offsite monitoring reports Onsite monitoring reports	16 53	Atomics International Agency for Toxic Substances and Disease Registry	2 7
Environmental surveys ('59–'02)	26	Committee to Bridge the Gap	1
Inspection reports	10	Fireman reports	1
Accident reports	3	U.S. Environmental Protection Agency	3
Emission estimation reports	3	California Department of Health Services	3
Closure reports	8	U.S. Department of Energy	4
Risk assessments	1	Rocketdyne/Boeing	16
Epidemiologic studies	4	Ventura County Air Pollution Control District	1
Site characterization studies Unpublished correspondence Production/release reports	20 21 50	UCLA U.S. Geological Survey Department of Toxic Substances Control	4 2 1
Meteorological reports Water quality reports Scientific reviews Monitoring protocol guidelines Health Ranking System reports Well inventories	3 3 52 15 1 2	National Research Council Oak Ridge Institute Regional Water Quality Control Board Southern California Water Quality Department Rockwell Consulting firms (Techlaw, Ogden, McLaren-Hart, Montgomery-Watson, Klinefelder, ITC, ICF Kaiser, Hargis and Assoc., Haley and Aldrich, GRC, ERG, ERD, ERC, EG&G, CH2MHill, Sonoma Technology, and ABB Environmental) Other (toxicity studies, scientific papers, etc.)	1 2 2 1 8 59 134

1.5.3 Identification of Contaminants of Concern and Assessment of the Level of Contamination

Available monitoring data and chemical use data, as well as SSFL activity reports, were reviewed (Appendix O) to identify the specific COCs that have been used at SSFL (Appendix C) and their respective offsite media concentrations (Appendix H). Reported monitored concentrations above existing health-based standards (Appendix N) were compiled (Appendix H), and a ranking analysis was performed (Appendix M) for COPCs (Appendix C) using the Scoring Chemicals and Ranking Assessment Model (SCRAM). Subsequently, site-specific information was used to identify the top 20 COCs, as detailed in Chapter 2.

1.5.4 Evaluation of Potential for Offsite Contaminant Migration and Community Exposure

In order to ascertain the potential for contaminant migration and community exposure to SSFL-associated COCs (identified in Chapter 2), it is essential to first confirm that:

- The COCs have indeed been stored and/or used at SSFL.
- There is evidence or sufficient reason to assert the potential release of COCs from SSFL to one or more environmental media.
- Conditions exist for migration of chemicals from SSFL to locations where human exposure is possible.
- Chemical concentrations at receptor locations of concern are or may have been above regulated health standards.

The potential for migration of contaminants and radionuclides to offsite areas was assessed based on (a) review and analysis of available monitoring data, site assessments and activity reports, and offsite monitoring studies (Appendix H); (b) estimates of air emissions of chemicals from various activities at SSFL (Appendix I); (c) air dispersion modeling to identify receptor locations at which exposure concentrations may be of concern (Appendix S); (d) review of site-related hydrogeology and meteorology (Section 3.2.2 and Appendix I); (e) experimental evaluation of subsurface diffusive transport and retention of TCE in site core samples (Appendix U); (f) review of SSFL-related groundwater modeling studies (Section 3.2.2); (g) modeling estimates of volatilization of organics from the SSFL soil based on reported soil vapor analysis (Section 3.3.2). Sections 3 and 4 summarize information on the potential exposure pathways examined and discuss these pathways (see also Section 2.1, Table 2-1). The above analysis served as the basis for subsequent assessment of locations in the vicinity of the SSFL and exposure scenarios that could lead to exposures at above tolerable levels (Appendices H, R, and T). This analysis also considered various scenarios of exposure periods and frequency relative to the time of detection (Table 3-1 and Appendix H).

Offsite monitoring studies[1.11] have documented the presence of offsite contamination (Appendix H), suggesting that contaminants have migrated away from the site. The air migration pathway was evaluated based on available air and soil monitoring data and numerical analysis using air dispersion modeling (Appendix I). The groundwater migration pathway was evaluated based on information in available hydrogeologic characterization reports, groundwater modeling and monitoring studies, and experimental evaluation of contaminant sorption and diffusion in site soil core samples (Sections 3.3.2 to 3.4). The surface water pathway was evaluated based on NPDES (National Pollutant Discharge Elimination System) permits, NPDES monitoring reports (Appendix H), and surface water pathway analyses (Sections 3.3.1 to 3.3.3). Given evidence of offsite groundwater TCE plume migration[1.12] (Appendix H), it is reasonable to expect that some chemicals could have migrated from SSFL to offsite receptor locations via the groundwater pathway. There is also evidence that contaminants may have migrated off site via the permitted surface water outfalls northwest and south of the facility (Appendix H). An expanded discussion of the individual pathways is provided in Chapters 3 through 5.

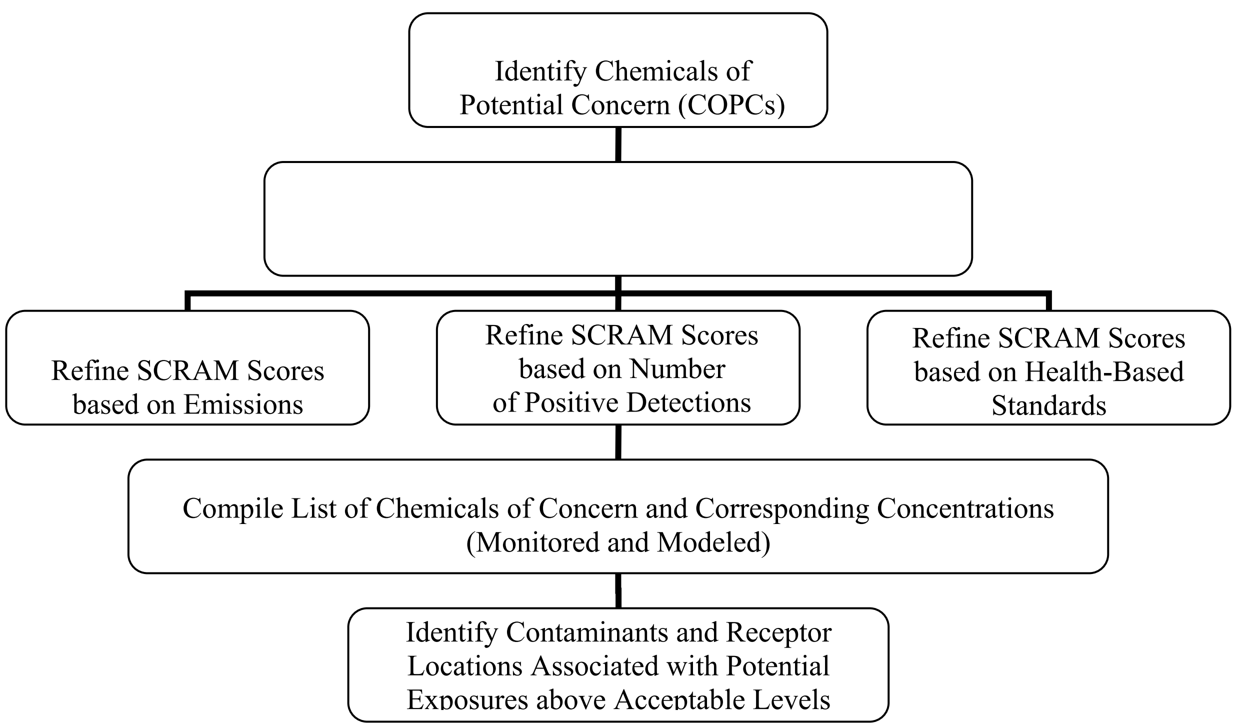
[1.11] Boeing, 1990–2003, 2002; CA EPA, 2000; CDHS, 1999; EPA, 2000; GRC, 1990a, 1990b, 2000; Klinefelder, 2000; Lawrence Livermore National Lab, 1997; Masry and Vititoe, 1998; McLaren Hart, 1993; Ogden, 1995, 1998a; PSOMAS, 2003; Rocketdyne, NPDES Annual Reports (various years), 1995.
[1.12] TCE and its degradation products have been detected in groundwater plumes emanating from the northeastern portion of the site (Appendix H).

2.0 IDENTIFICATION OF CHEMICALS OF CONCERN

Many chemicals have been detected, used, or stored on site at SSFL. Some of these are of particular concern given their toxicological properties and/or potential for persistence in the environment. In the first phase of the process of identifying the COCs, the study team considered all contaminants to avoid missing potentially significant contaminants that were infrequently monitored or for which health-based standards do not yet exist. Thus a list of contaminants used on site (i.e. COPCs) was compiled from the reports and documents listed in Section 1.4 (Appendix C).

The SSFL-associated chemicals (Appendix C) were ranked according to their toxicology and environmental persistence (Appendix M). Ranking results were then weighted with information (Appendix M; Figure 2-1) that allowed a site-specific ranking and identification of the site-specific COCs of primary concern. The COCs were then subcategorized according to the phases in which they have been detected or likely to be present (Table 2-4). Available monitoring data were subsequently reviewed to identify the time periods and locations of the monitoring sites (Appendix H) at which concentrations were detected above the relevant environmental standards (Appendix N). The study team used this information in assessing the potential for exposure to the COCs (Section 4). This process for identifying COCs is outlined in Figure 2-1; the details are presented in Sections 2.1 and 2.2.

Figure 2-1. Flowchart Illustrating the Process of Identifying the Chemicals of Concern



2.1 Chemicals of Potential Concern

COPCs associated with SSFL activities were identified based on a review of reports on those activities, as well as environmental monitoring and remediation activities between 1946 and 2003 (Appendix O). Chemicals were included in the list of COPCs (Appendix C) if they met one of the following criteria (EPA, 1989):

- Detection sensitivity was above an existing health-based standard. Detection sensitivities were assessed for all monitoring reports (for each chemical assessed) and were compared to health-based standards to determine the relevance of monitoring results.

- Detection in at least one sample.

- Detection above levels found in associated blanks or reliable background samples. Monitored background samples were assessed for reliability,[2.1] and any suspected deficiencies in monitoring accuracy were noted.

- Association with SSFL according to historical site information. Chemical usage reports and emission reports were used to identify contaminants that were not regularly sampled.

- Status as a known byproduct of chemicals detected at SSFL. Oxidation products of major air contaminants and transformation products of water and soil contaminants were identified and evaluated for potential listing as COPCs.

- Reported concentrations above an existing health-based standard. Chemicals were listed as COPCs if they were detected at concentrations above published regulatory standards for air, soil, or water.

Regulatory standards compared against COPC levels in water included EPA's Maximum Contaminant Levels, or MCLs (established for drinking water[2.2]) and, where MCLs were unavailable, DHS Action Levels (ALs). For soil, the study team used EPA Region 9's Residential Soil Screening Levels (RSSLs) and, where no RSSLs were available, DHS ALs. For air, the team used the National Ambient Air Quality Standards (NAAQS) for SO_2, NO_2, CO, O_3, Pb, and particulate matter and the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for various other toxicants. For radionuclide contamination, comparison standards included EPA National Emission Standards (for iodine, gross beta, strontium-90, and tritium; the limits are 4 millirems per year per person) and NESHAPs (for other emissions; the limits are 10 mrem/year/person).

[2.1] Reliable background samples include multiple samples taken in areas that (a) are not potentially affected by contaminants from SSFL and (b) have the same geological formation or soil type (in the case of soil background) as SSFL.

[2.2] Onsite and offsite water sources were used in the past for drinking water. Therefore, only MCLs meet the Applicable or Relevant and Appropriate Requirements (ARARs) for comparison with contaminant levels in groundwater.

The primary COPCs listed in Table 2-1 have been used, stored, or produced at the SSFL. Offsite monitoring studies[2.3] have revealed the presence of offsite contamination (Appendix H), suggesting that contaminants have migrated away from the SSFL area. Offsite contaminants that were detected above health-based standards include, but are not limited to, radionuclides (tritium, potassium-40, radium-226/-228, thorium-228/-232, plutonium-238, cesium-137), metals (lead, beryllium, manganese, chromium), aliphatic hydrocarbons (TCE, vinyl chloride, 1,1-DCE, 1,1-DCA, 1,2-DCE), aromatic compounds (PCBs, PCDD / PCDFs), and oxygenated organic compounds (perchlorate) (Appendix H).

Table 2-1. Contaminants (or Chemical Categories) of Concern: Potential Sources, Exposed Populations, Exposure Periods, and Pathway Elements

Source	Transport Medium	Chemicals of Potential Concern	Potentially Exposed Populations	Time[a]
Air stripping	Air	Radionuclides,[b] metals	Brandeis-Bardin Institute, Santa Monica Mountains Conservancy, Sage Ranch, Simi Valley, Santa Susana Knolls, West Hills, Bell Canyon, Canoga Park	1987–present
Thermal treatment (burning)	Air	Hydrazines,[c] TCE, perchlorate, dioxins, dibenzofurans, beryllium, mixtures of fuels/explosives	Brandeis-Bardin Institute, Santa Monica Mountains Conservancy, Sage Ranch, Simi Valley, Santa Susana Knolls, West Hills, Bell Canyon, Canoga Park	1958–1990
Spills/accidents/ volatilization	Air	Radionuclides, TCE, metals, hydrazines, perchlorate	Brandeis-Bardin Institute, Santa Monica Mountains Conservancy, Sage Ranch, Simi Valley, Santa Susana Knolls, West Hills, Bell Canyon, Canoga Park	1948–present
Chemical storage (unlined ponds and spills) and NPDES outfalls	Groundwater (wells)	Radionuclides, TCE, metals, hydrazines, perchlorate, VOCS,[d] PCBs, dioxins, PAHs, furans	Brandeis-Bardin Institute, Santa Monica Mountains Conservancy, Sage Ranch, Simi Valley, Santa Susana Knolls, Chatsworth, Ahmanson Ranch, Bell Canyon, West Hills, Canoga Park, Woolsey Canyon, Dayton Canyon	1948–present
Chemical storage (spills/leaks) and NPDES outfalls	Groundwater to surface water	Radionuclides, TCE, metals, hydrazines, perchlorate, VOCs, PCBs, dioxins, PAHs, furans	Brandeis-Bardin Institute, Santa Monica Mountains Conservancy, Sage Ranch, Simi Valley, Santa Susana Knolls, Chatsworth, Bell Canyon, West Hills, Canoga Park, Woolsey Canyon, Dayton Canyon	1948–present
Chemical storage (spills/leaks), NPDES outfalls, air/water deposition	Surface soil/ sediment	Radionuclides, metals, PAHs, dioxins, PCBs, furans	Brandeis-Bardin Institute, Santa Monica Mountains Conservancy, Sage Ranch, Bell Canyon, West Hills	1948–present

Notes:
a. Time period of chemical use and potential exposure to surrounding communities. **b.** Radionuclides emit alpha, beta, and gamma radiation. **c.** Hydrazines include mono-methyl hydrazine (MMH) and unsymmetrical dimethylhydrazine (UDMH) and transformation products (e.g., nitrosoamines). **d.** VOCs include, but are not limited to, carbon tetrachloride, chloroform, chloromethane, benzene, 1,1-DCA, 1,2-DCA, 1,1-DCE, 1,2-DCE, methylene chloride, tetrachloroethene, 1,1,1-TCA, TCE, trichlorofluororethane, toluene, and vinyl chloride.

[2.3] Boeing, 1990–2003, 2002; CA EPA, 2000; CDHS, 1999; EPA, 2000; GRC, 1990a, 1990b, 2000; Klinefelder, 2000; Lawrence Livermore National Lab, 1997; Masry and Vititoe, 1998; McLaren Hart, 1993; Ogden, 1995, 1998a; PSOMAS, 2003; Rocketdyne, NPDES Annual Reports (various years), 1995.

2.2 Identifying and Ranking Chemicals of Concern

The goal of contaminant ranking is to identify, among the many chemicals associated with SSFL, a subset of COPCs that are of primary concern. COPCs were initially ranked using the Scoring Chemicals and Ranking Assessment Model (SCRAM; Appendix M and Table 2-2).

SCRAM was developed to rank/order chemicals based on a composite score that considers physicochemical and toxicological parameters (Appendix M; Tables 2-3 and 2-4). SCRAM ranks chemicals based on their:

- Persistence in biota, soil, sediment, water, and air.
- Potential for bioaccumulation.
- Acute toxicity in terrestrial (plants, mammals, herps, birds, invertebrates) and aquatic (plants, amphibians, warm and cold water fish, invertebrates) environments.
- Subchronic/chronic toxicity in terrestrial and aquatic environments.
- Subchronic/chronic toxicity in humans (general, reproductive, developmental, carcinogenic, mutagenic, behavioral, immune, and endocrine effects).

The final score is a composite of the chemical and uncertainty scores. The latter is a numerical characterization of missing or substandard toxicological and physicochemical information. It is emphasized that ranking based on the SCRAM composite score is not a site-specific ranking: it depends only on chemical properties, not contaminant concentrations, the volume of chemicals present at the site, or emission rates. Therefore, the study team used site-specific factors to weight the SCRAM scores so as to arrive at a more relevant ranking for SSFL-associated COCs (Appendix M; Table 2-4). A number of different rankings that were evaluated in this study were derived (Appendix M) by weighting the SCRAM composite scores by:

- Air emissions estimates (for air contaminants).
- Air emissions estimates with respect to EPA inhalation reference concentrations (RfCs)[2.4] (for air contaminants).
- The number of NPDES water detections (for water contaminants).
- The maximum concentration detected in water or soil with respect to the health-based standards (MCLs for water and oral EPA reference doses, or RfDs, for soil contaminants).
- The number of positive offsite and onsite soil detections (for soil contaminants).

[2.4] An RfC is the estimated contaminant concentration in air (e.g., milligrams of pollutant per cubic meter of air) to at which continuous inhalation exposure over a lifetime is likely to be without risk (i.e., risk $<10^{-6}$) of deleterious effects, even for sensitive groups. The RfC is derived from various types of human or animal data, with uncertainty factors generally applied to reflect limitations of the data used. (See EPA, 2002. Review of the Reference Dose and Reference Concentration, Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, DC 20460, EPA/630/P-02/002F.)

Table 2-2. Physicochemical and Toxicological Parameters[(a)] Used in SCRAM to Rank COPCs

Overview of Toxicological and Physicochemical Parameters	**Parameter Scales Used to Estimate Magnitudes**
Acute terrestrial and aquatic effects	LD_{50} or ED_{10}
Sub-chronic/chronic terrestrial effects	LOAEL or ≥ 90 day NOAEL
Sub-chronic/chronic aquatic effects	MATC, NOEC, or LOEC
Sub-chronic/chronic human effects	LOAEL or ≥ 90 day NOAEL
Carcinogenicity	$(1/ED_{10})$ × (weight of evidence)
Reproductive toxicity	RfD
Mutagenic effects	Potency/severity
Behavioral effects	Severity
Immune system effects	Severity
Endocrine effects	Potential
Persistence in biota, air, water, soil, or sediment	Degradation half-life ($t_{1/2}$) in the specific medium
Bioconcentration/bioaccumulation	BAF, BCF, , water solubility, log(Kow)

Notes: LD_{50}, LOAEL, NOAEL, MATC, ED_{10}, and RfD are toxicological parameters determined from controlled animal studies. An LD_{50} (lethal dose-50) is the average contaminant dose at which 50 percent of a test population will die. A LOAEL (lowest observed adverse effect level) is the lowest dose at which an adverse effect is first observed; a NOAEL (no observed adverse effect level) is the highest dose at which no adverse effect is observed. A MATC is a maximum acceptable toxicant concentration for freshwater organisms. A NOEC is the highest concentration with no observable effect. An ED_{10} (effective dose) is the estimated dose at which 10 percent of a study population develops adverse effects relative to the control response. A RfD (reference dose) is EPA's estimate of the daily chemical intake (by oral route) below which no appreciable risk (i.e., > 10^{-6} risk) is expected over a lifetime of exposure (70 years). The degradation half-life in a given environmental medium is the time it takes for the chemical concentration to decrease to one-half its initial value (in the medium) through degradation reactions. Kow is the octanol-water partition coefficient for the contaminant. BAF, the bioaccumulation factor, is the steady-state ratio of chemical concentration in the organisms to the chemical concentration in the external environmental phase, taking into account chemical intake via food ingestion. BCF is the bioconcentration factor defined as the ratio of the concentration of the chemical in the organism to that in the surrounding environmental phase.

The SCRAM ranking (R_{SCRAM}) for air contaminants, R_{Air}, was refined as below:

$$R_{Air} = R_{SCRAM} E / (I_{AIR} RfC) \qquad (1)$$

in which E is the estimated or reported emission rate (mg chemical/day), I_{air} is the inhalation rate (m^3 air/day), and RfC (mg pollutant/m^3 air) is the reference inhalation concentration. With the above ranking, chemicals with significantly low emissions or high concentration thresholds of concern (i.e., RfCs) would be ranked low. Conversely, chemicals with high emissions and low RfCs would be assigned a higher rank. The resulting ranking for air contaminants is provided in Table 2-3.

Two different refined SCRAM rankings of groundwater or surface water contaminants were developed. In the first approach the score was refined as

$$R_W = R_{SCRAM} N_{MCL} \tag{2}$$

in which R_w is the weighted score for either surface water or groundwater and N_{MCL} is the number of detections at concentrations above the MCL (Appendix M and Table 2-3). In the second approach the SCRAM score was refined as follows:

$$R_w = R_{SCRAM} \left(\frac{C_w^{\max}}{MCL} \right) \tag{3}$$

where MCL is the maximum contaminant level (mg/L) health standard and $C_w^{\max}$ is the maximum detected concentration (mg/L) for the chemical under consideration. The rankings based on the above two approaches (Eqs. 1 and 2) are provided in Tables 2-3 and 2-4. The rankings were limited by a lack of monitoring data and MCL standards for some of the chemicals associated with SSFL.

The SCRAM ranking for soil contaminants was refined as follows:

$$R_{soil} = R_{SCRAM} I_{soil} \left(\frac{C_{soil}^{\max}}{RfD} \right) \tag{4}$$

in which I_{soil} is the rate of soil intake (kg soil/kg body mass), $C_{soil}^{\max}$ is the maximum detected concentration of the specific chemical in soil (mg chemical/kg soil), and *RfD* is the chemical's oral reference dose (mg/kg body mass). The ranking of soil contaminants based on the above refinement of the SCRAM scores is provided in Table 2-4.

Contaminants of greatest concern in the air include, but are not limited to, hydrazine, TCE, methyl chloroform (1,1,1-TCA), methylene chloride, carbon tetrachloride, various aromatic hydrocarbons, and various metals. COCs in the water pathway include TCE and its various degradation products, perchlorate, various metals, and soluble organics. Contaminants of greatest concern in the soil are beryllium, arsenic, carbon tetrachloride, and chromium.

Note that bias in the refined relative rankings (Tables 2-3 to 2-5) could be introduced by infrequent or inadequate monitoring data, under-reporting of releases and emissions, use of non-sensitive detection methods, inadequate accounting of oxidation byproducts, and uncertainty or lack of health-based exposure concentration standards or reference dose for the COPCs. Nonetheless, the study team's approach (using multiple weighting methods) provides greater confidence that the list of site-specific COCs does not exclude chemicals for which monitoring was inadequate, emission estimates were not available, or standards have not been set.

Table 2-3. Refined SCRAM Ranking for Air and Water Contaminant (Based on Equations 1 and 2)

Rank	SCRAM-Ranked COPCs	Air Emission-Weighted COCs[(a)]	Water Detection-Weighted COCs [(b)]
1	PCB	Hydrazine	TCE
2	Mercury	1,1,1-TCA (methylchloroform)	Perchlorate
3	2,3,7,8-TCDD	TCE	Lead
4	Hydrazine	1,2-DCA	Chromium
5	Fluorene	Methylene chloride (dichloromethane)	Carbon tetrachloride
6	Toluene	Carbon tetrachloride	Mercury
7	TCE	Xylene	PCB
8	Benzene	Benzene	DEHP
9	Beryllium	Toluene	1,1-DCE (vinylidene chloride)
10	Bis(2-ethylhexyl)phthalate (DEHP)	Manganese	Benzene
11	n-Nitrosodimethylamine	Nickel	1,1-DCA
12	Perchlorate	Lead	1,2-DCA
13	Carbon tetrachloride, selenium	Cadmium	Toluene
14	1,1-DCA, 1,1-DCE	Selenium	Nickel
15	Arsenic, chromium, 1,2-DCA, cyanide, manganese	Arsenic	Tetrachloroethene
16	Chloroform, trans-1,2-DCE, cis-1,2-DCE, copper, nickel, vanadium	Vinyl chloride	Beryllium
17	Tetrachloroethene, cadmium	Beryllium	cis-1,2-DCE
18	Xylene, cobalt, vinyl chloride, methylene chloride, strontium	Mercury	Manganese
19	Lead, 1,1,1-TCA	Chromium	Trans-1,2-DCE
20	Diethylphthalate	PCBs	Vinyl chloride

(a) Adjusted SCRAM scores based on Eq. 1.
(b) Adjusted SCRAM scores based on Eq. 2.

Table 2-4. Refined SCRAM Scores for Soil and Water Contaminants Based on Health-Based Standards and Equations 3 and 4

Weighted Rankings	Offsite		Onsite	
	Water Contaminants (MCL-Weighted Rankings)(a)	Soil Contaminants (Oral RfD-Weighted Rankings)(b)	Water Contaminants (MCL-Weighted Rankings) (a)	Soil Contaminants (Oral RfD-Weighted Rankings) (b)
1	TCE	Beryllium	TCE	Carbon tetrachloride
2	Vinyl chloride	Arsenic	Lead	Chromium (total)
3	DEHP		Chromium	Pentachlorophenol
4	Lead		Carbon tetrachloride	Arsenic
5	Carbon tetrachloride		1,2-DCA	Toluene
6	Manganese		Vanadium	1,2-Dichlorobenzene
7	Benzene		Perchlorate	1,2-Dichlorobenzene
8	1,2-DCE		Manganese	Ethylbenzene
9	Chromium (total)		1,1-DCA	
10	Perchlorate		Mercury	
11	Beryllium		1,2-DCE	
12	Nickel		Benzene	
13	1,1-DCA		Silver	

(a) Refined SCRAM scores based on maximum detected concentration with respect to MCLs (Eq. 3)
(b) Refined SCRAM scores based on maximum detected soil concentration and oral RfDs (Eq. 4).

Table 2-5. SSFL Phase-Specific Chemicals of Concern

Air	Water	Water and Air	Water, Air, and Soil
Hydrazine 1,1,1-TCA Methylene chloride Xylene Selenium Cadmium	Perchlorate 1,1-DCE cis-1,2-DCE trans-1,2-DCE 1,1-DCA DEHP Chloromethane	Vinyl chloride Benzene Cadmium Manganese Nickel NDMA	TCE 1,2-DCA Beryllium Carbon tetrachloride Tetrachloroethene Lead Chromium Arsenic

2.3 Radionuclides[2.5] of Concern

Monitoring data,[2.6] site activity reports,[2.7] and other documents were used to assess radionuclides of concern. Table 2-6 summarizes the categories and corresponding numbers of reports used in this study.

Table 2-6. Category of Reports/Documents and Sources of Information for Radionuclides

Report/Document Category	Number of Reports/ Documents	Source of Information	Number of Reports/ Documents
Epidemiologic studies	2	Atomics International	2
Monitoring surveys ('59–'02)	30	Committee to Bridge the Gap	1
Inspection reports	10	Fireman reports	1
Accident reports	3	U.S. Environmental Protection Agency	3
Emission estimation reports	3	California Department of Health Services	5
Closure reports	4	U.S. Department of Energy	11
Risk assessments	1	Rocketdyne/Boeing	16
		Various consulting firms	19
		UCLA	2
		Ventura County Air Pollution Control District	1

Radionuclides were used at SSFL between 1955 and 1996. (The NRC reactor license was terminated on September 27, 1996, and the facility was transferred to DOE for decontamination and decommissioning.) Operations at SSFL that may generated radioactive waste, discharged effluents, or emitted chemicals into the air included nuclear power generation activities, experiments using radionuclides, decladding of irradiated nuclear fuels, examination of reactor components, and decontamination and decommissioning activities. According to various archived documents, all radionuclide operations were conducted at the Energy Technology Engineering Center (ETEC) located in Area IV. This area included the

[2.5] Many naturally occurring and a few manmade chemicals can emit ionizing radiation and are, therefore, referred to as radioactive. For the sake of simplicity, radioactive materials can be grouped into alpha, beta, and photon emitters, depending on the particles or energy that they emit.

[2.6] Monitoring data include yearly reports by Atomics International (AI), Rockwell, and Boeing from 1955 to the present. Monitoring data for radionuclides are primarily reported in terms of alpha and beta levels. The gross alpha and beta measures allow screening of nearly all known radioactive materials without chemical speciation.

[2.7] AI, 1960, 1962; Committee to Bridge the Gap, undated; Dempsey, 1990, 1997; DHS, 1988a, 1989a, 1989b, 1991, 1999; DHS, 1989 a and b; DOE, 1989, various years; EG&G, 1979; EE, 1989; EPA, 1989a; ETEC, 1987; GRC, 1990a, 1990b, 1990c; Hart, 1962; Hughes, 1989; ICF Kaiser, 1993, 1995; ITC, 1999; Klinefelder, 2000; Lawrence Livermore National Lab, 1997; McLaren/Hart, 1993, 1995; Morgenstern, 1997, 2001; Oak Ridge Associated Univ., 1986; Oak Ridge Institute, 1997; Oldenkamp, 1991; Ogden, 1995, 1998a; Police and Fireman's Benefit Society Report, 1961; Robinson, 1998; Rocketdyne, 1991, 1996; Rockwell, 1987; Rutherford, 1994, 1999; Tuttle, 1992; V.C.A.P.D, 1989.

Systems for Nuclear Auxiliary Power, or SNAP (building T059); the Hot Lab; the Sodium Reactor Experiment Complex, or SRE; the former Sodium Disposal Facility, or SDF (building T886); the Radioactive Materials Disposal Facility, or RMDF; the Old Conservation Yard; and associated disposal ponds (Western, Lower and Upper).

A comprehensive assessment of radionuclide use and contamination was not possible due to the lack of historical radionuclide activity reports, breakdown of radionuclide monitors during accidental leaks, lack of air monitoring, faulty sediment monitoring procedures,[2.8] and inadequate offsite assessment and ongoing onsite assessment[2.9] of radionuclide contamination and delineation. These limitations prevent a quantitative assessment of past exposures. Irrespective of the lack of sufficient monitoring, the available data do suggest that radionuclides have been detected off site and that there has been migration of radionuclides (Appendix H).

Various studies concerning the presence of radionuclides on site and off site are consistent with the general conclusion that radionuclides from Area IV have migrated to offsite areas. Radionuclides have washed down from Area IV onto what was part of the Brandeis-Bardin Institute (BBI) property,[2.10] located north of Area IV (McLaren/Hart, 1993; 1995). Strontium-90 and tritium were detected in BBI soils at concentrations above background levels; plutonium-238 and cesium-137 were detected in BBI soils above background levels and health-based standards,[2.11] and radium-226/-228 and strontium-90 were detected in northwest NPDES surface water releases above MCLs (McLaren Hart, 1993, 1995; Rockwell, 1987). Potassium-40, thorium-228/-232, and tritium were detected in Bell Canyon soils above health-based standards (Ogden, 1998). Cesium-137, potassium-40, and thorium-228/-232 were detected in Ahmanson Ranch soils above health-based standards (Klinefelder, 2000). Cesium-137 was detected above health-based standards in Canoga Park soils (Lawrence Livermore National Lab, 1997).

In June and July of 1978, radiological surveys were conducted of the Rockwell International Facilities in Canoga Park and at the SSF (EG&G, 1979). Gamma emitters were not detected above background levels in surface water channels originating from the property. Given that the half-life for certain gamma emitters is relatively short (e.g., cobalt 60 has a ~5.3 day half-life), such sort-lived radionuclides would have decayed long before the above monitoring. It is also noted that monitoring for Uranium 233, -234, -235, and -238 was limited to Bell Canyon. In these areas levels did not exceed health-based standards or conservative background levels (Odgen, 1998).

In summary, given the radionuclides emitted from onsite activities, monitoring studies, radionuclide toxicities, offsite distributions and lifetimes, the primary radionuclides of concern were strontium-90, plutonium-238, cesium-137, tritium, radium-226/-228, potassium-40, and thorium-228/-232.

[2.8] Offsite areas have had limited sampling and radiological characterization of surface water owing, in part, to the intermittent surface water flows from the SSFL.
[2.9] DOE (June 3, 2004) announced the detection of tritium in groundwater under Area IV. The extent of this contamination is still being delineated.
[2.10] This area was purchased by Rocketdyne and is now part of the SSFL buffer zone.
[2.11] RESRAD 6.1 (ANL2001)–Soil Guidelines for Resident Farmer (most conservative) or DHS-based standards for soil.