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ABSTRACT

A comprehensive radiological survey of Building T064, its fenced-in yard, and a surrounding 2-acre area at the SSFL was performed in 1988. In accordance with that survey report's recommendation, remedial efforts were undertaken in a localized 4,500 ft^2 area, designated the Building T064 Side Yard, to reduce the cesium-137 (^{137}Cs) radionuclide contamination found in that area. Follow-up surveys were performed and analyzed using methods similar to the 1988 survey. Current U.S. Department of Energy (DOE) guidelines for residual soil activity for man-made nuclides were applied using an associated DOE computer code, RESRAD. Results show that the remaining ^{137}Cs activity and radiation levels at the Side Yard are well below the applicable limits, and that the residual activity poses no hazard to potential current or future users of the site.

Results of the surveys demonstrate that the Side Yard and other surveyed areas surrounding Building T064 meet the requirements of DOE Order 5400.5, "Radiation Protection of the Public and Environment" (February 1990), for release without radiological restrictions.

REV	SUMMARY OF CHANGE	APPROVALS AND DATE
A	1. Appendix F has been added. The appendix discusses additional excavating, sampling and sample results following the ORISE survey (reported in their draft report of December 1992) and following the DOE decision that a retroactive limit of 10 mrem/y will apply to this project. 2. Editorial changes were made on pages 3 and 7 to incorporate references to the new appendix. 3. Distribution was updated. REL. DATE 9-10-93	P. D. Rutherford 8/2/93 for A. Okuda

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SUMMARY

PURPOSE. This Safety Review Report provides an assessment of residual radioactivity present at the Building T064 Side Yard, located in Rockwell International's Santa Susana Field Laboratories (SSFL), following its decontamination. Near– and long–term consequences due to the presence of the residual activities to current and future occupants of the Yard were evaluated to determine if this location is acceptably clean of radioactive materials.

BACKGROUND. Since the late 1950s, Building T064 and its fenced–in yard were utilized by Rockwell and its predecessor firms in support of a number of the US government's nuclear programs. In the early 1960s, a contamination incident involving radioactive mixed fission products from a reactor fuel–element shipping cask occurred in an area near the eastern portion of the fenced–in yard. The area was cleaned up in 1963 to then–existing requirements for radiological cleanliness. Subsequently, a comprehensive 1988 radiological survey report on the building and surroundings recommended remedial actions to further reduce residual activities in a 4,000 ft^2 area of the Side Yard near the eastern fence to current requirements. The remaining portions of the fenced–in yard were found to be free of contamination.

WORK PERFORMED. To further reduce contamination to levels that are as low as reasonably achievable (ALARA), top layer materials from the Side Yard were removed to depths varying from several inches to several feet. The residual activity in the soil, following decontamination, was analyzed and compared with previous measurements. An analysis was performed, in accordance with the U.S. Department of Energy (DOE) guidelines, to determine the consequences resulting from the presence of this residual radioactivity.

STATUS. The Side Yard remains vacant and no radioactive materials or equipment are planned to be brought to the yard. Building T064 itself is being used as a storage facility for the soil excavated from the Side Yard and from other SSFL locations. The slightly contaminated soil is contained in tight steel boxes. Further determination of the radiological status of the building will be done after the planned disposal of the soil.

CONCLUSION. Based on results of the 1988 survey and the subsequent work described here, radiation and contamination levels in the Side Yard and other surveyed areas surrounding Building T064 are well below acceptable regulatory limits, and pose no hazard to the safety and health of potential current or future occupants. Therefore, the Side Yard and other surveyed areas can be released for use without radiological restrictions.

1. INTRODUCTION

Decontamination and decommissioning (D&D) of a number of formerly used nuclear facilities and sites is underway at Rockwell International's Santa Susana Field Laboratories (SSFL). During D&D of these facilities, reasonable efforts are being made to eliminate or reduce residual radioactive contamination to levels that are as low as reasonably achievable (ALARA). Upon completion of D&D, radiological surveys are performed, under established protocols to determine that any remaining radioactivity does not exceed applicable regulatory limits. Findings from the surveys are also used to perform additional D&D or radiological investigations, as needed. The scope of the surveys includes both known and suspected areas of contamination.

In accordance with a broad radiological survey plan for the SSFL (Ref. 1), a comprehensive radiological survey of Building T064, its fenced–in storage yard, and a surrounding 2–acre area was performed in 1988 (Ref. 2). With respect to the area surrounding T064, results of the survey showed elevated radiation levels due to ^{137}Cs radionuclide contamination in an approximately 4,000 ft^2 area, in the vicinity of the fenced–in yard. As recommended in the survey report, top soil was removed from portions of a larger 4,500 ft^2 area; follow–up investigations were carried out by performing additional surveys and analyses, which are the subject of this present safety review report (SRR). The radiological status of Building T064 per se is not addressed in this SRR because the building continues to be under radiological control, pending authorized disposal of slightly contaminated items stored there.

The findings presented in this SRR include a statistical treatment of the measured external gamma dose rates and soil activity data from the Side Yard. While gamma exposure rates can be compared with a generic regulatory acceptance limit, corresponding generic limits for allowable concentrations of artificial radionuclides in soil, such as ^{137}Cs, have not been set. Recently, however, the U.S. DOE has established dose and interpretation guidelines and developed an associated computer code called RESRAD, by means of which a limit for residual activities in soil may be derived on a site–specific basis (Ref. 3). The code was used and results of analyses of the soil activity data from the T064 Side Yard using this code are also presented in this report.

This report is organized as follows: A background on the Building T064 Side Yard that includes its location and operating history is provided in the next section (Section 2). A summary of the comprehensive radiological survey performed in 1988 and its findings

with respect to the Side Yard are highlighted in section 3. Section 4 describes the technical approach used to implement the recommendation of the 1988 survey and to analyze the resulting data using statistical techniques and the RESRAD code. Results are provided and discussed in section 5, and section 6 states the conclusions drawn from the review.

Additional data and information pertaining to the Side Yard are provided in the following appendices. Appendix A is a document describing a T064 Side Yard contamination incident in the early 1960s that led to the 1988 survey of this area. Appendices B and C provide a variety of related data obtained from the present investigation. Input data used to perform the RESRAD code calculations are included in Appendix D. Appendix E provides a list of items of record obtained during the D&D and surveys, which are archived at Rockwell. Appendix F describes additional soil removal accomplished to meet the DOE's retroactive limit of 10 mrem/y. Summary outputs of the RESRAD calculations are maintained in the archives.

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Figure 1. Map of Los Angeles Area

2. BACKGROUND

2.1 LOCATION

Building T064 is located within Rockwell International's Santa Susana Field Laboratories (SSFL) in the Simi Hills of Southeastern Ventura County, California, adjacent to the Los Angeles County Line and approximately 29 miles northwest of downtown Los Angeles. Location of the SSFL relative to Los Angeles and vicinities is shown in Figure 1. An enlarged map of neighboring SSFL communities is shown in Figure 2. Figure 3 is a plot plan of the western portion of SSFL, known as area IV, where Building T064 is located.

A drawing (plan view) of Building T064 and its adjoining areas is shown in Figure 4. As shown, T064 is totally fenced in with a chain-link fence. Two photographs of the north and east sides of T064 are shown in Figures 5 and 6, respectively. Of these, the eastern fence, shown in Fig. 6, runs through an approximately 4,500 ft^2 trapezoidal area, which is shown in Figure 7. This 4,500 ft^2 area is referred to as the "Building T064 Side Yard" and was designated for D&D after a smaller ~4,000 ft^2 area to the east of the fence was identified for remedial action following a 1988 radiological survey of the building and surrounding areas (Ref. 2). Thus, the Side Yard, although never identified as such in previous documents including the 1988 survey, is a part of the fenced-in yard and the adjoining area surrounding the fenced-in yard. Additional figures and dimensions of the affected area are provided in subsequent sections of this report.

Figure 8 shows relevant portions of a 1967 edition of the U.S. Geological Survey (USGS) topographic map of the Calabasas Quadrangle where the SSFL is located. The map in Figure 8 includes the authors' markup of the location of the Building T064 Side Yard. Using USGS terminology, the USGS description for the Building T064 Side Yard is: Township T2N; Range R17W; and Section 30, Calabasas Quadrangle.

2.2 AREA CHARACTERISTICS AND TOPOGRAPHY

Figure 9 is a photograph of Building T064 taken from the south end of the complex. The facility sits atop a plateau about 25 ft above "G" Street (Figure 3). As shown in Figure 9, the terrain throughout most of the SSFL areas is uneven due to rock outcroppings. Rock outcroppings exist upslope to the north-northeast and downslope in every other direction. Water run-off is primarily due east at the southern end of the facility. The fenced-in yard surrounding the building was paved with asphalt. Except for the portion of

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Figure 2. Map of Neighboring SSFL Communities

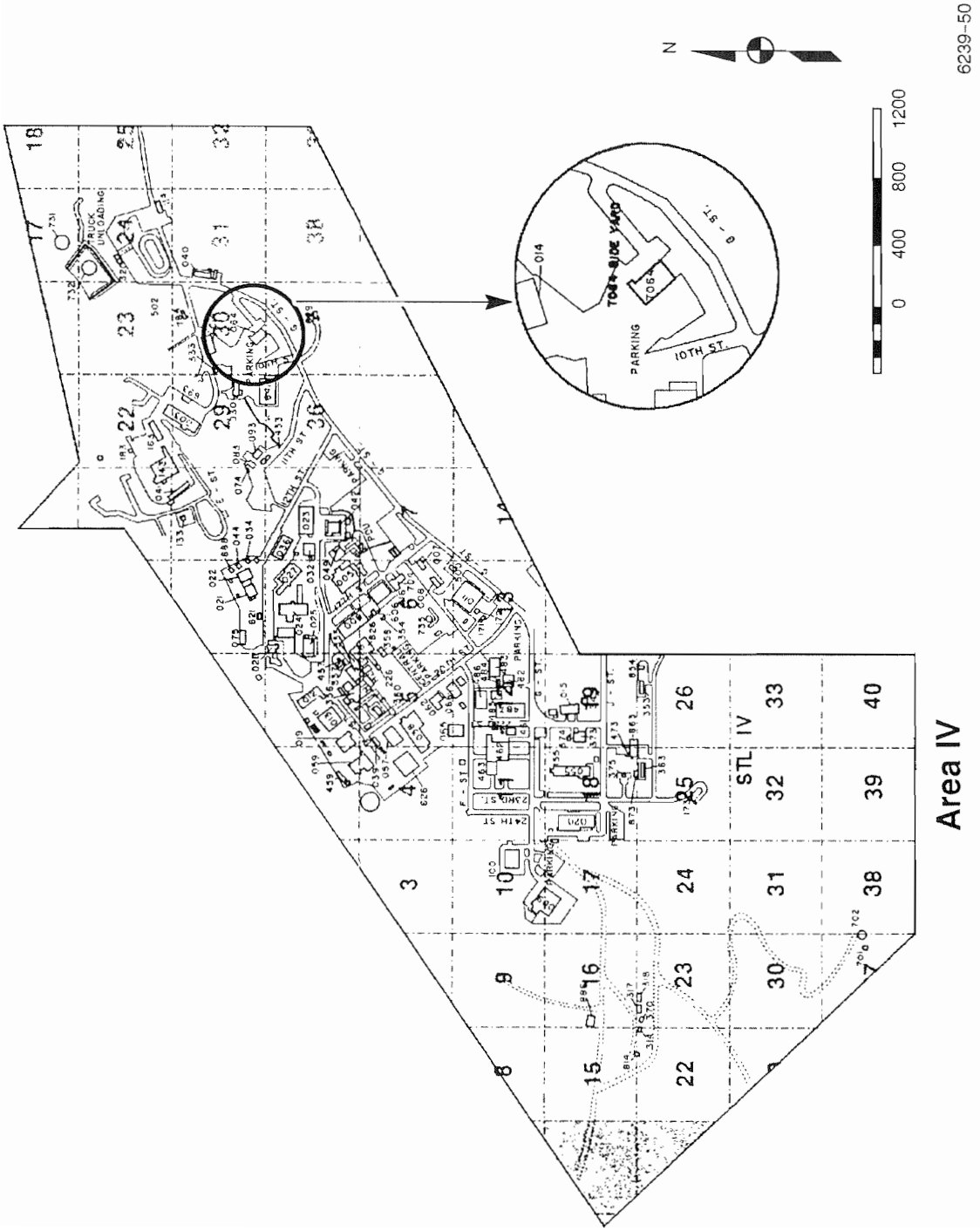

Figure 3. SSFL Layout Showing Location of the Building T064 Side Yard

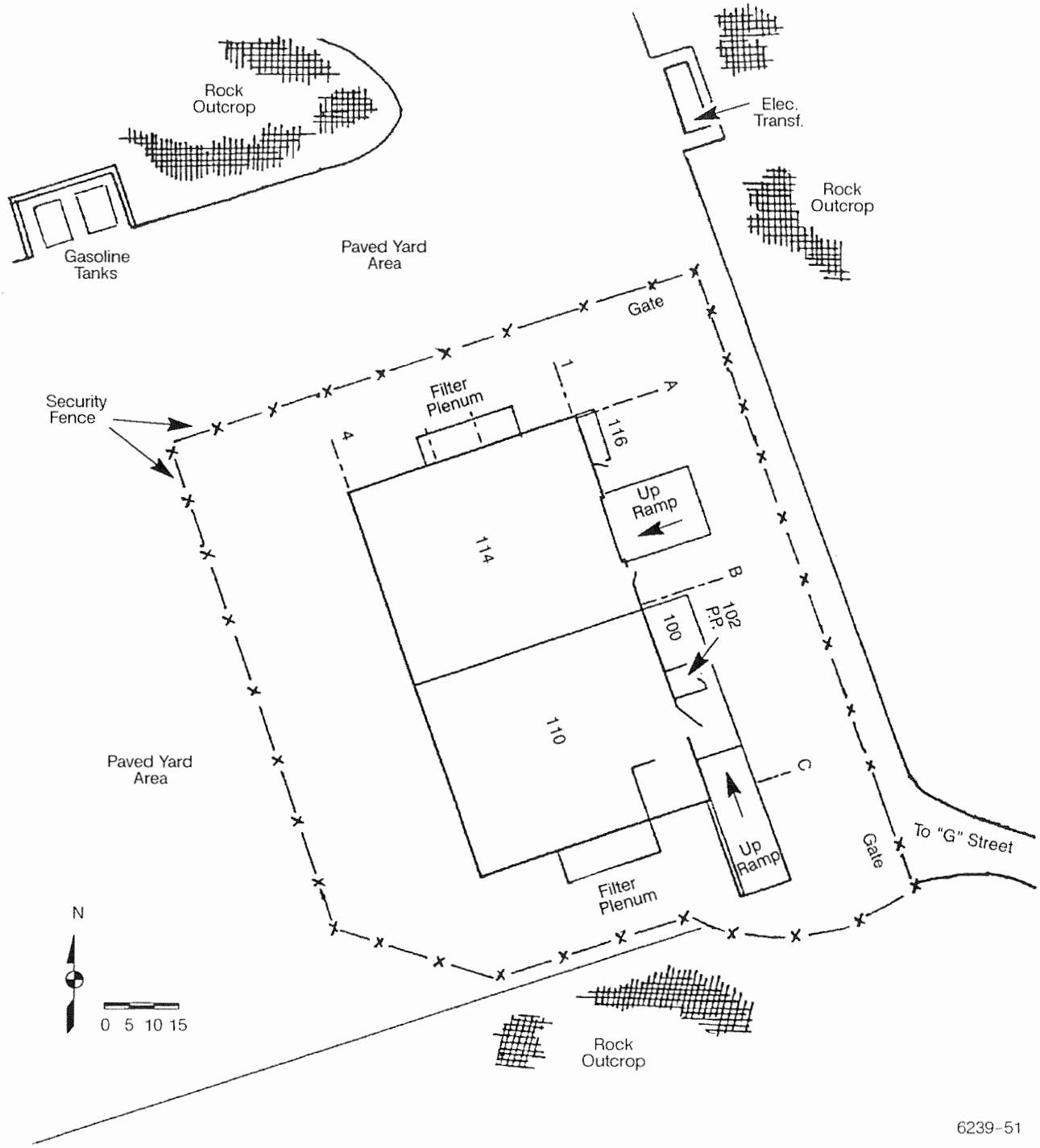

Figure 4. Source and Special Nuclear Material Storage Building, T064

Figure 5. View from North of Building T064 (1987)

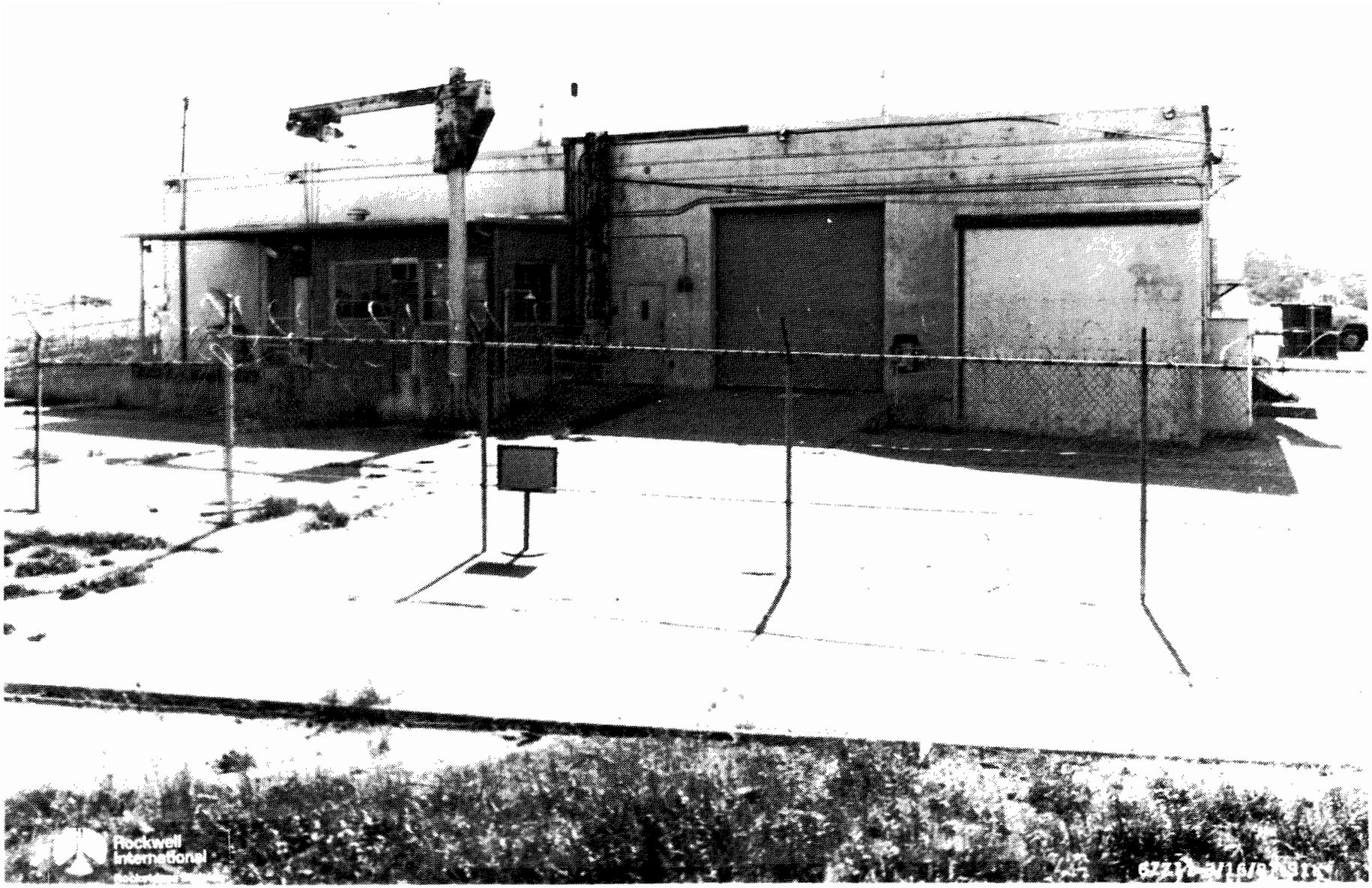

Figure 6. View from East of Building T064 (1987)

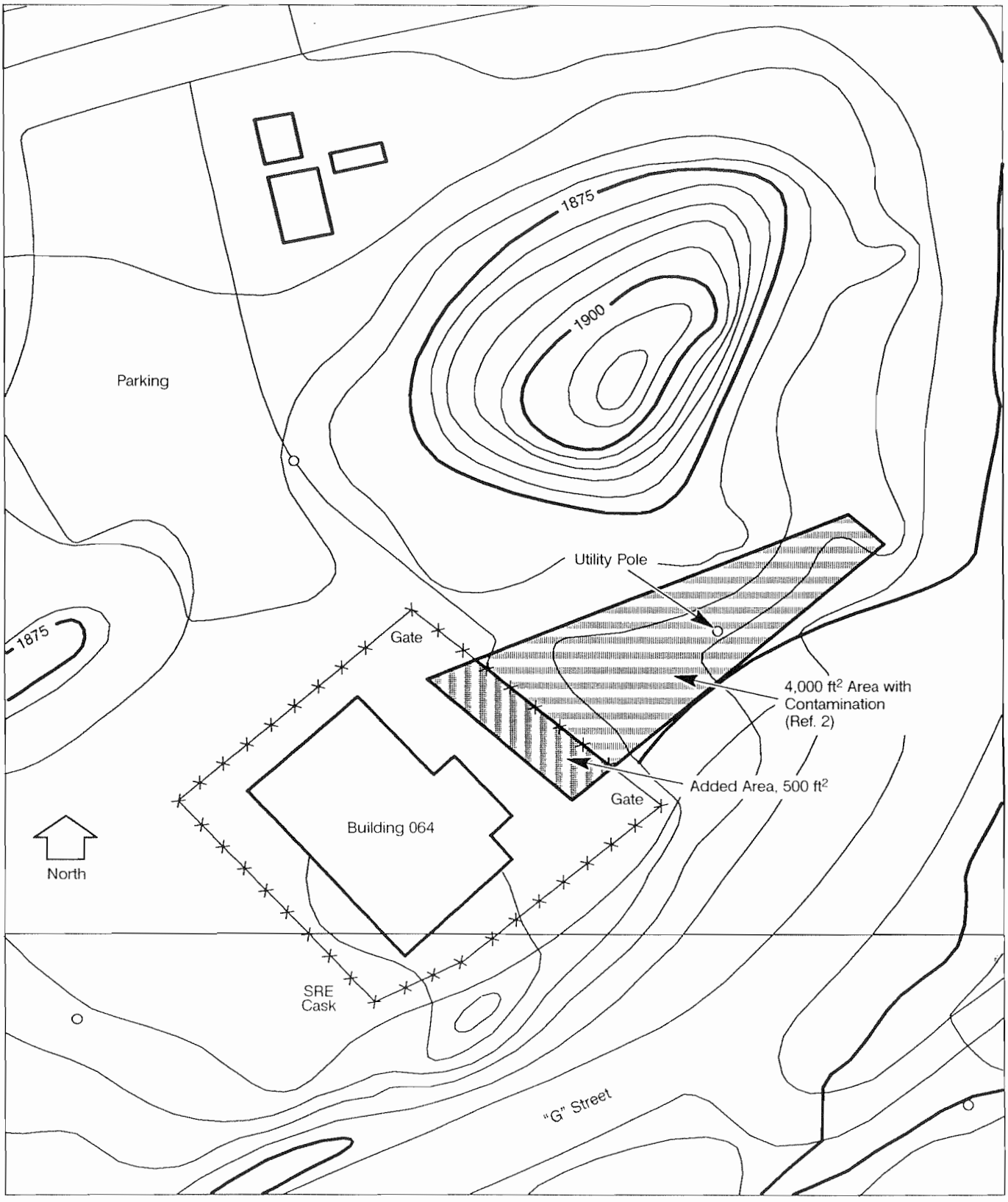

Figure 7. Building T064 Side Yard

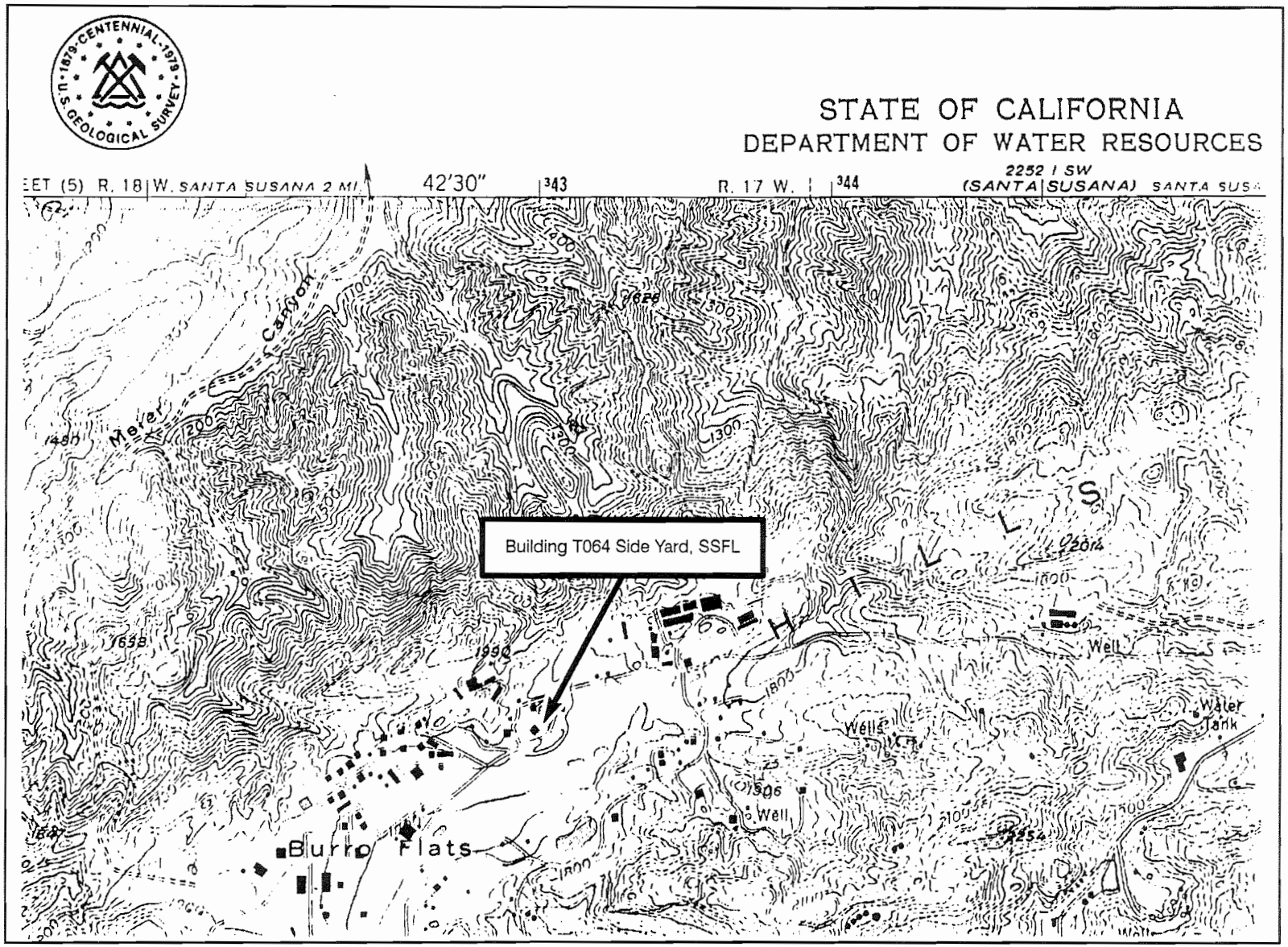

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Figure 8. USGS Topographic Map of Portions of Calabasas Quadrangle (Bottom–Left Area Corresponds to SSFL)

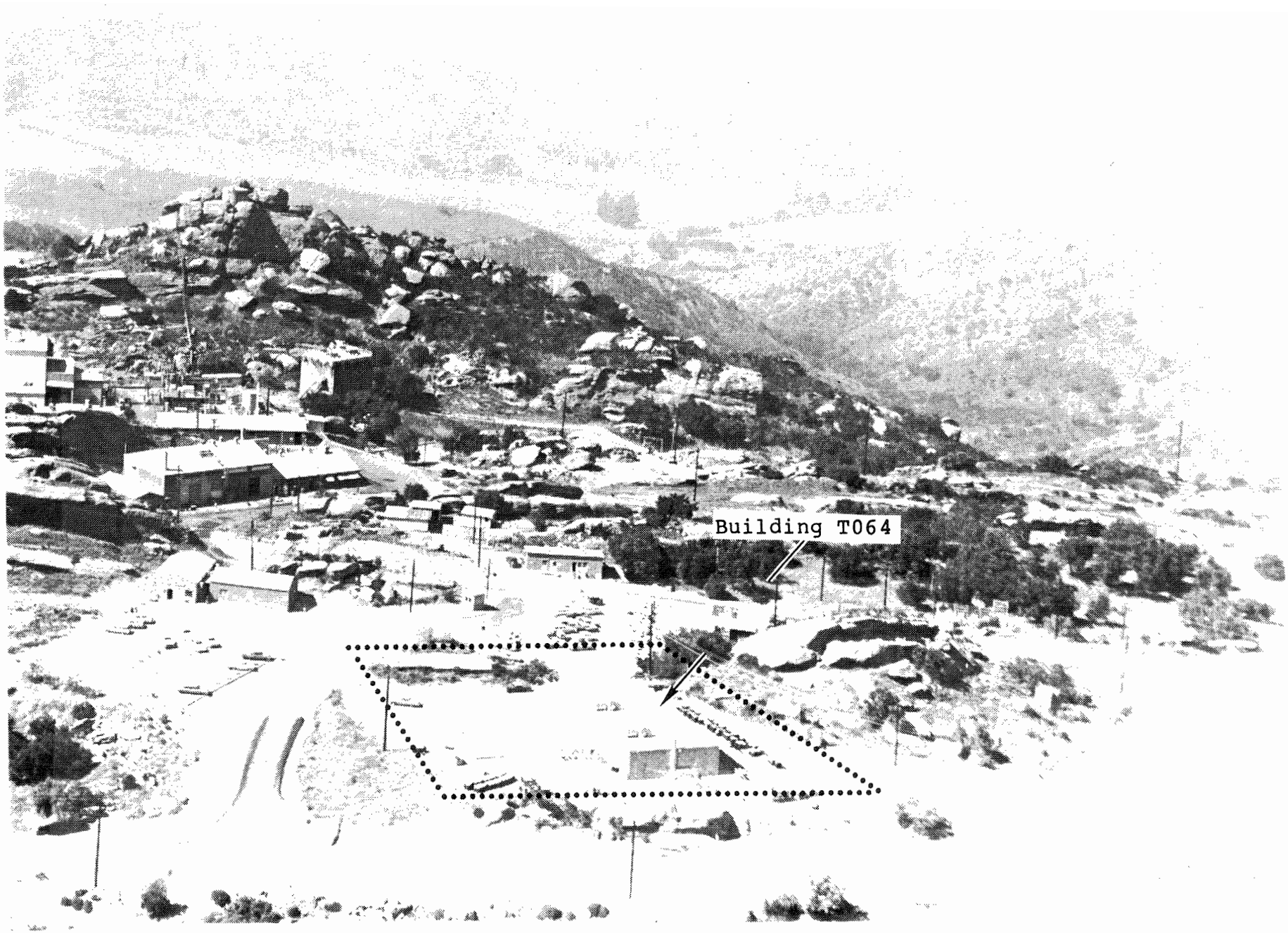

Figure 9. View of Building T064 from a Position South of the Complex (1963)

the Side Yard where the asphalt was removed during the present effort, the surrounding yard space within the fence remains paved.

Access to the open portion of the Side Yard is from G Street. A paved asphalt road leads to the gated portion of the eastern fence from this street. The fenced–in portion of the yard may be accessed through this southeastern gate or through the second gate in the northeast corner.

2.3 OPERATING HISTORY

Building T064, formerly known as the Source and Special Nuclear Material Storage Facility, has been operated by Rockwell International and its predecessor companies since 1958 in support of US DOE's (and its predecessor agencies') nuclear programs. As the name implies, T064 was used for the storage of packaged items of source material (normal uranium, depleted uranium, thorium) and special nuclear material (enriched uranium, plutonium, U–233). Since nuclear material was only stored there, there was no processing equipment within the building. Following an active period of use until the mid 1970s, most of the major DOE nuclear development and reactor contracts had ended at the facility, and by 1980, most of the material had been sent to other DOE sites. Since then, the building has been used to store non–nuclear DOE components and supplies and equipment for Atomics International. Currently, steel boxes containing soil from several SSFL decontamination operations are stored inside the building prior to their planned disposal. A detailed description of the utilization of T064 during the early years is provided in Ref. 2.

The fenced–in yard surrounding T064 was used on occasion for storing recoverable uranium scrap, irradiated fuel elements, and miscellaneous radioactive wastes. Spent fuel shipping casks and shipping trailers were also stored just outside the western fence line. Except for residual radioactivity from a contamination incident at the eastern section of the fenced–in area in the early 1960's (described below), the remaining yard areas were clean of radioactive material.

During the early 1960's, a special lead–pig cask containing irradiated "Seawolf" fuel elements was stored in the east site of the fenced–in yard. The irradiated fuel elements had probably been transferred to the cask in a fuel–storage pool at the site of their origin. Before shipping to the SSFL, the drain plug on the bottom of the cask should have been removed to drain the radioactive water, but was not. The cask was shipped and stored here while still containing water. The drain plug eventually rusted out, and water

leaked out to the yard surface. The water contained mixed fission products which contaminated the area. A large area (~700 ft^2) was excavated, and disposed of. After the removal of the contaminated material, radiation levels were measured to be between 0.04 mrad/h and 0.5 mrad/h, which was considered acceptable. Consequently, the yard was backfilled and repaved. Appendix A is an Internal Letter, dated November 11, 1963, describing the incident.

2.4 SSFL SURVEY PLAN

A broad 1985 radiological survey plan (Ref. 1) was developed for all areas at the SSFL that were involved in operations with radioactive materials. Building T064, the above mentioned yard, and a surrounding 2–acre area were included in the survey plan. In accordance with the plan, a comprehensive radiological survey of the designated areas was performed in 1988 to evaluate the building and the site for residual contamination. The survey and its results are extensively documented in Ref. 2. The survey methods and results applicable to the Side Yard are summarized in the next section of this report.

3. SUMMARY OF 1988 RADIOLOGICAL SURVEY

3.1 OVERVIEW

Upon decontamination and decommissioning (D&D) its radioactive constituents, releasing a facility or area for other unrestricted uses requires a formal radiation survey to demonstrate that the applicable regulatory limits for such a release are met. The survey is performed under an established plan, and a statistical interpretation of the resulting data is made to determine if the regulatory release criteria have been met. Together, the 1988 radiological survey of the Building T064 Side Yard and surrounding areas (Ref. 2) and the follow–up work reported in this document fulfill the requirements for such a survey. For the sake of completeness and ease of future reference, a summary of applicable portions of the 1988 survey is provided in this section.

3.2 SCOPE OF SURVEY

The overall scope of the 1988 survey included the following radiological inspections: the interior building areas were characterized by measuring average, maximum, and removable alpha/beta contamination; the fenced–in storage yard and surrounding 2–acre area were characterized by measuring ambient gamma exposure rates 1 meter above the surface. If the gamma measurements indicated contamination, surface samples were acquired and analyzed by gamma spectrometry or for gross alpha/beta activity. For purposes of comparison, natural background gamma exposure rates were measured at about the same time in the following SSFL locations where no radioactive materials were ever used, handled, or stored: (a) the Building 309 area, (b) the Well No. 13 Road (Dirt), and (c) Incinerator Road (Dirt).

As noted earlier, a 4,500 ft^2 area comprising portions of the fenced–in yard and adjoining portions of the surrounding 2–acre area constitutes the Building T064 Side Yard.

3.3 SURVEY METHODS AND PROCEDURES

3.3.1 Criteria and Their Implementation

Acceptable contamination limits and gamma exposure rates for unrestricted use of a decommissioned facility are prescribed in Department of Energy (DOE) guidelines, the Nuclear Regulatory Commission's (NRC) Regulatory Guide 1.86, the NRC's license SNM–21 to Rocketdyne, and other references. Typically, the lowest (most conservative) limits are chosen. For example, the 5 μR/h (above background) limit is used to determine

acceptance of a facility for unrestricted use even though the corresponding DOE limit is 20 μR/h, which is a factor of four larger. Table 1 shows the composite of conservative limits derived from the aforementioned references and adopted by Rocketdyne with respect to the Building T064 fenced–in yard and the surrounding 2–acre area surveyed during 1988.

Table 1. Maximum Acceptable Gamma Exposure Rate and Soil Activity Concentration Limits (1988 T064 Yard and 2–Acre Area Survey)

No.	Parameter	Limit, in Unit Specified	Reference
1	Gamma exposure rate[a] (at 1 m from surface)	5 μR/h above background[b]	4
2	Soil activity concentration[c]	a) Alpha: 46 pCi/g (for depth ≤15 cm below surface)	6 and 7
		c) Beta: 100 pCi/g	8

[a]Although DOE Guide (Ref. 5) recommends a value of 20 μR/h above background for gamma exposure rate, the NRC Dismantling Order for the L–85 reactor decommissioning (Ref. 4) required 5 μR/h above background. For conservatism, 5 μR/h above background is used at Rocketdyne to compare survey results.

[b]The average background gamma exposure rate at the SSFL has a value of about 15 μR/h with a range (maximum–minimum) of about 3.5 μR/h (Ref. 2).

[c]Alpha activity concentration limits for enriched uranium (formerly stored in Building T064) is 30 pCi/g (Ref. 6) plus that contribution from naturally occurring radioactivity (about 16 pCi/g, from Ref. 7, p. 93). The total beta activity concentration limit is 100 pCi/g (Ref. 8), including background which is about 24 pCi/g.

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During the survey, the ambient gamma exposure rate criterion (5 μR/h above background, shown in Table 1) was first applied. If the surveyor detected radiation, three "action levels" were established and initiated according to the following criteria:

1. Characterization Level – That level of exposure rate which is less than 50% of the maximum acceptable limit. This level encompasses the range of natural background levels at the SSFL and requires no further action.

2. Reinspection Level – That level of exposure rate which is between 50% and 90% of the maximum acceptable limit. A general survey of the area and a few additional soil samples are required in this case.

3. Investigation Level – That level of exposure rate which exceeds 90% of the maximum acceptable limit. Specific investigation of the occurrence is required in this case.

3.3.2 Survey Procedures

For purposes of the T064 radiological survey, the building, the fenced–in storage yard, and the surrounding 2–acre area were treated as separate sample lots for characterization and interpretation. Figure 10 shows the survey sampling area. For the fenced–in yard, a 3–meter square grid was superimposed on the area; for the 2–acre area, a 6–meter square grid was superimposed. This gridding arrangement resulted in obtaining 58 and 168 (total 226) ambient gamma exposure–rate measurements, respectively, in the two areas.

In each 9–m^2 cell (in the fenced–in yard) and in each 36–m^2 cell (in the surrounding area), a gamma exposure–rate measurement was made 1 m from the surface. The particular location in each cell was chosen randomly and identified on a map. A tripod was used to support a 1 in. x 1 in. NaI scintillation crystal (detector) 1 m from the ground. The NaI scintillation detector was coupled to a photomultiplier tube and fed to a Ludlum 2220–ESG scaler. The NaI scintillation detector is sensitive in nearly all directions (i.e., 4π–geometry) and can detect variations in exposure rates down to 0.5 μR/h from counts obtained during one minute. For comparison, if an infinite slab of 20–cm–thick soil were located 15 cm below surface and contaminated with 100 pCi/g of ^{137}Cs (see limits in Table 1), it would produce an estimated excess exposure rate of about 10 μR/h, which is readily within the sensitivity of the device.

The NaI scintillation detector is calibrated quarterly using ^{137}Cs as the calibration source in the mR/h range and, cross–calibrated against a Reuter Stokes High Pressure Ion Chamber in the μR/h range. Count rates were converted to exposure rates using the derived relationship that, at background exposure rates, 215 cpm = 1 μR/h. During the survey, the instrument response was also checked three times daily using a Ra–226 source.

Two soil samples weighing about 2 lb. each were collected during the survey of the yard for information purpose and were identified for their specific location. Each sample was dried in an oven and split into a 450–ml sample and a 2–g sample. The 450–ml

Figure 10. Building T064 Sampling Area

sample was placed in a specialized beaker for counting by gamma spectrometry. The 2–g sample was ground with a mortar and pestle, placed in a 2–in. diameter aluminum planchet, and then counted for gross alpha and beta activity. Additional details on the instruments used and their calibration are provided in Ref. 2

3.3.3 Data Analyses and Statistical Criteria

A statistical procedure is required to validate the applicability of the exposure–rate data collected at selected locations to an entire area or region (such as the fenced–in yard and the surrounding area of T064). A statistical method known as "sampling inspection by variables" (Ref. 9) was used to analyze the data from the survey. This method has been widely applied in industry and the military and is essential where destructive tests must be performed (e.g., in quality control) or where the lot size is impractically large.

In sampling inspections by variables, the number of data points on which measurements are obtained is first chosen to be large so that the distribution of the data is normal (i.e., gaussian). The mean of the distribution, $\bar{x}$, and its standard deviation, s, are then related to a "test statistic", TS, as follows:

$$TS = \bar{x} + ks.$$

TS and $\bar{x}$ are then compared with an acceptance limit, U, (such as those shown in Table 1) to determine acceptance or other plans of action, including rejection of the area. In the above expression k is known as the tolerance factor. The value of k is determined from the sample size and two other statistical sampling coefficients that are related to a consumer's risk of accepting a lot, given that a fraction of the lot has rejectable items in it. The values chosen for these coefficients for the survey correspond to assuring, with 90% confidence, that 90% of the area has residual contamination below 100% of the applicable limit (a 90/90/100 test). The choice of values for the two coefficients is consistent with industrial sampling practices and State of California guidelines (Ref. 10). The sampling coefficients and use of the resulting calculated value of TS for comparison with the acceptance criteria and establishing a plan of action for acceptance are further discussed in Ref. 2.

Data from the survey are typically treated using this statistical approach. The reduced data are plotted against the cumulative gaussian probability on a probability–grade scale. Display of data in this manner permits clear identification of values with significantly greater exposure rates than expected for the lot, based on the gaussian distribution.

Probability plots are shown in the next section for the fenced–in T064 yard and the surrounding 2–acre area. However, a complete treatment of the 1988 survey data for the purpose of determining the test statistics was not necessary because the findings readily revealed the need for remedial action.

3.4 RESULTS

Results from the 1988 survey for the fenced–in T064 yard and the surrounding 2–acre area are presented in this section with some recent corrections. These corrections apply to the portion of these areas that later became known as the Building T064 Side Yard, the subject of the present investigation. Details of the survey results for Building T064 proper may be found in Ref. 2.

3.4.1 Gamma Exposure Rates

Statistical data on the ambient gamma exposure rates measured in the fenced–in T064 yard and the the 2–acre surrounding area are summarized in Table 2. Also shown in this table are the sets of data for the three SSFL background locations. These data show the average ambient gamma exposure rates at the two T064 areas to be 20.1 μR/h and 16.6 μR/h, respectively, compared with the 14.0 μR/h to 16.2 μR/h average for the three background locations. As shown, the standard deviations and ranges (maximum – minimum) are substantially larger than the respective values for the background areas. The maximum values recorded corresponded to 76 μR/h in the fenced–in yard and 110 μR/h in the surrounding 2–acre area, respectively.

Statistical plots of the ambient gamma exposure rates for the five locations identified in Table 2 are shown in Figures 11 through 15. Effects of the large standard deviations and ranges for the data at the fenced–in yard and the 2–acre surrounding area (Figures 11 and 12) can be clearly seen when compared with the three statistical plots (Figures 13, 14 and 15) for the background areas. While the background data show a nearly uniform gaussian distribution, the fenced–in storage yard and the surrounding 2–acre area each show a gaussian–distributed "clean" area, and a set of "outlier" data corresponding to contaminated areas. Changes in the slopes of the statistical plots in Figures 11 and 12 further demonstrate the abnormal distributions obtained from the data for the two T064 area locations.

According to Ref. 2, the grid locations corresponding to the high gamma exposure rates at the fenced–in yard and the surrounding 2–acre area were in an ~4,000 ft^2 area

Table 2. Ambient Gamma Radiation at SSFL Compared to T064 Measurements (before decontamination)

Location	Number of Measurements	Average Exposure Rate (μR/h)	Standard Deviation (μR/h)	Range (μR/h)
Surveyed Areas:				
T064 fenced–in storage yard	58	20.1	14.3	63
T064 surrounding 2–acre area	168	16.6	9.4	98
Background Areas:				
Building 309 Area (1/19/88)	36	15.6	0.8	3.4
Well No. 13 Road (dirt) (4/29/88)	43	16.2	0.5	2.2
Incinerator Road (dirt) (4/29/88)	35	14.0	0.4	1.4

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which borders and is outside the eastern fence. Figure 11 shows twelve outlier data points for the fenced–in yard area, and Figure 12 shows eight outliers in the 2–acre area. However, a recent review of the 1988 survey map of the fenced–in yard showed that six of the locations were right at the fence line and the remaining six data were from inside the fenced–in yard at locations believed to be uncontaminated. This finding raises a question as to whether the additional areas within the fenced–in yard are suspect.

In an attempt to clarify the above situation, the data logs of the surveyor were reexamined and found to contain erroneous recordings for the data obtained at these six locations. In addition, an "indication only" survey was performed at these and other background locations in August 1990 with a Ludlum Model 12S–Micro–R meter. The data from this survey showed that radiation levels at the six suspect locations inside the fenced–in yard indeed correspond to background levels at the SSFL, confirming that all the

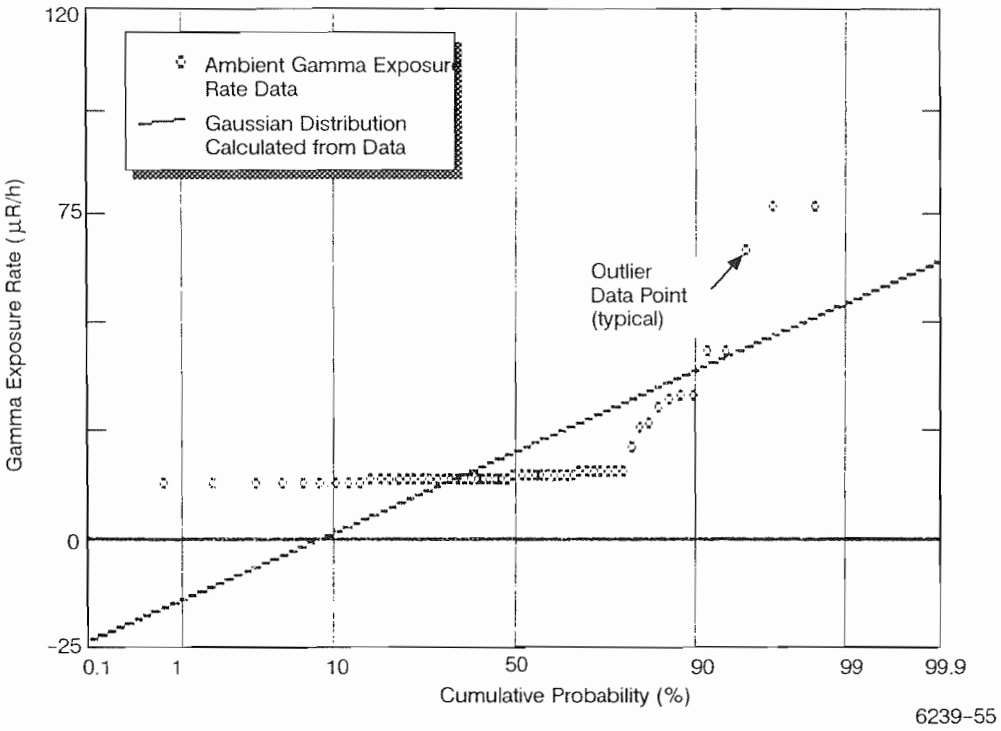

Figure 11. Ambient Gamma Radiation in Fenced–In Storage Yard (1988 Survey)

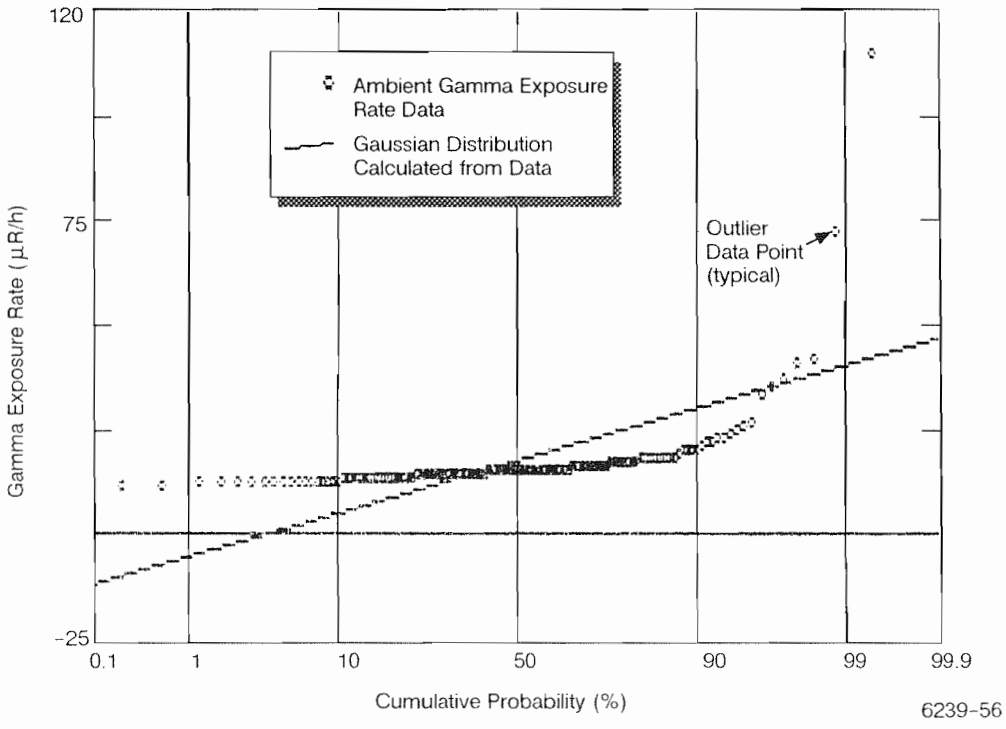

Figure 12. Ambient Gamma Radiation in Surrounding 2–Acre Area (1988 Survey)

contaminated grid points (six, instead of twelve, from Figure 11 and the eight from Figure 12) with ambient exposure rates from 20 to 110 μR/h are at the fence line and east of it.

Figure 16 shows the general vicinity of this contaminated area. Within this area, a 300 ft^2 area was seen as being significantly contaminated with gamma exposure rates in the range of about 50–100 μR/h.

Overall, it is readily seen that the outlier ambient gamma exposure-rate data at the fence line and in the adjoining 2-acre area portion constituting the 4,000 ft^2 area are well above the ambient exposure rates for the three background areas shown in Figures 13, 14, and 15, and, in most instances, exceed the 5 μR/h limit specified in Table 1.

With respect to the background gamma exposure-rate data shown in Figures 13, 14, and 15, their distributions are normal, as would be expected. However, the data also show that the relatively high variability in background gamma exposure rates measured at the SSFL (up to 3.4 μR/h) approaches the acceptance limit of 5 μR/h. This points out the need to select background locations which have similar topographic and other features with respect to the area being compared so that this variability can be minimized. Noting the availability of data from uncontaminated background areas which are topographically

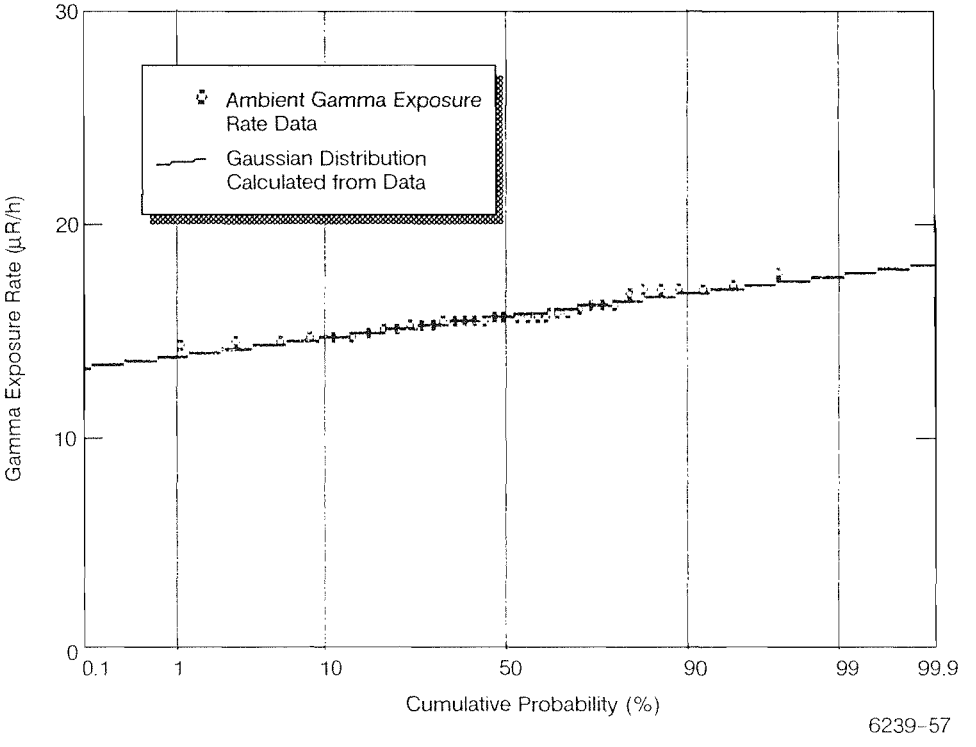

Figure 13. Ambient Gamma Radiation at Area Surrounding Building 309 (Background Distribution)

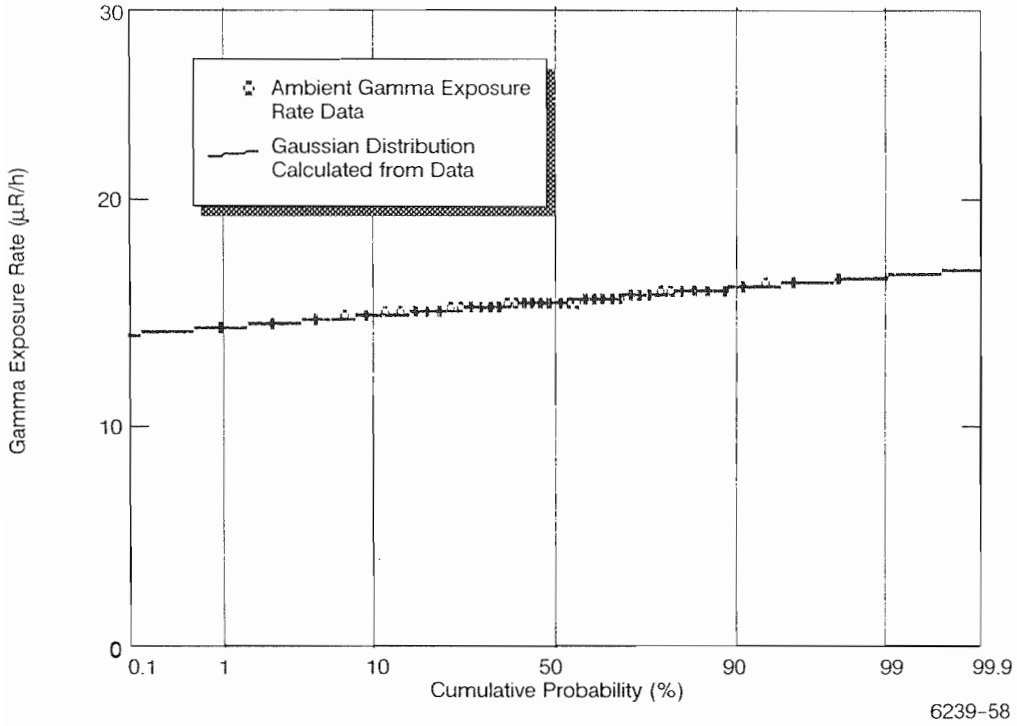

Figure 14. Ambient Gamma Radiation at Area Well No. 13 Road (Background Distribution)

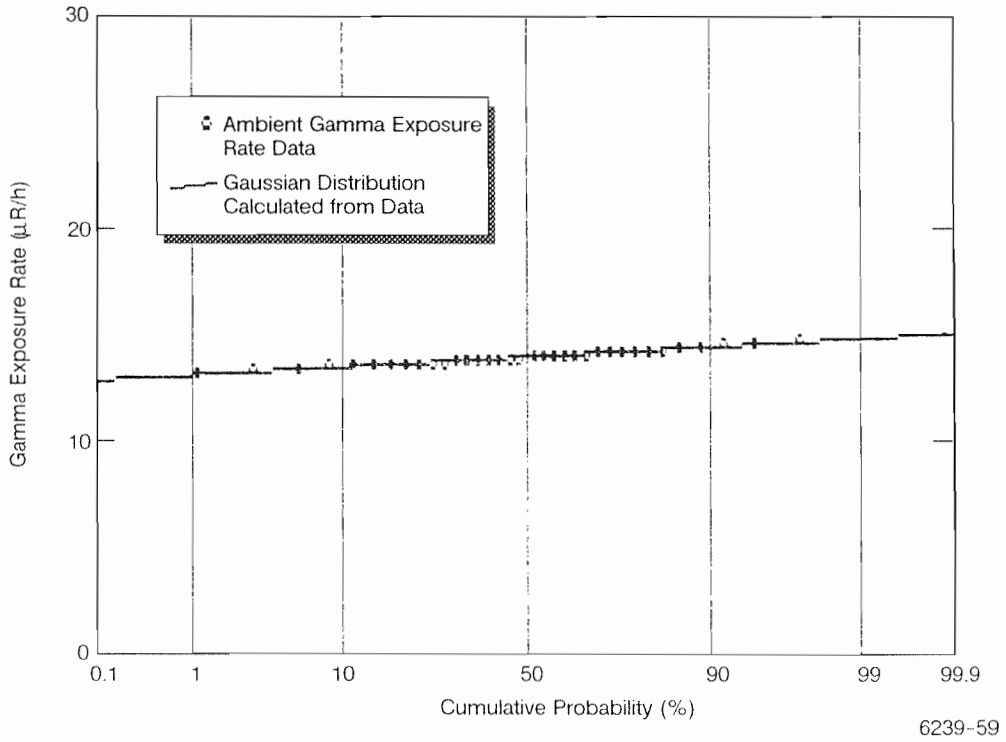

Figure 15. Ambient Gamma Radiation at Incinerator Road (Background Distribution)

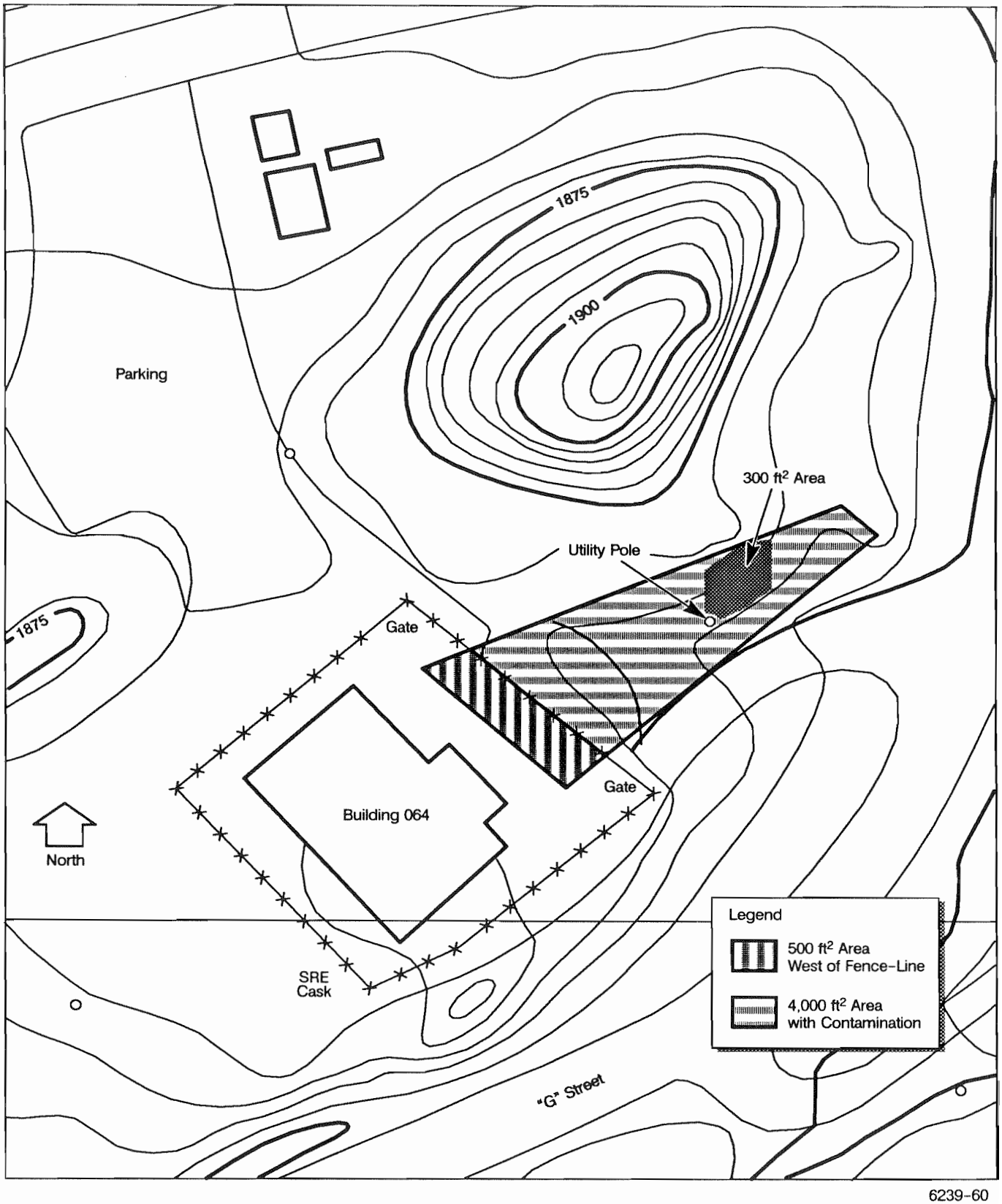

Figure 16. Topographic Map of T064 Showing Contaminated Soil Area

similar to the Side Yard, the most appropriate background exposure rate was established for the present investigation and is discussed in Section 4.3.2.1.

3.4.2 Soil Activity

Alpha analysis results of the 2–g samples from two soil samples collected from the 300 ft^2 area showed alpha activity concentrations of 23.8 and 31.4 pCi/g, which are both below the 46 pCi/g limit shown in Table 1. However, beta analysis results on the same samples showed beta activity concentrations at 1,153 and 1,187 pCi/g, much higher than the 100 pCi/g limit shown in the same table. Additionally, gamma spectrometric analysis of the two 450–ml samples from the same locations showed 2,500 and 2,700 pCi/g of ^{137}Cs activity, which are much higher than normal ^{137}Cs activity concentrations (between 0.1 and 1.0 pCi/g) at the SSFL, and further corroborated the findings of high ambient gamma exposure rates.

3.5 CONCLUSIONS OF 1988 SURVEY

Based on the data obtained, the 1988 radiological survey concluded that contamination existed in a 4,000 ft^2 area bordering and outside the T064 eastern fence (Figure 16). The remaining fenced–in yard and surrounding 2–acre area were determined to have only background radiation levels. The survey report surmised that ^{90}Sr, which usually accompanies ^{137}Cs in mixed fission product contamination, is probably present in the contaminated area. Although the gamma exposure rates and ^{137}Cs activity levels were too high to meet release limits, the survey concluded that the area was not hazardous in its contaminated condition. This conclusion was further confirmed explicitly by RESRAD analyses during this study.

3.6 RECOMMENDATION OF 1988 SURVEY

The 1988 survey report recommended remedial action with respect to the 4,000 ft^2 area identified in Figure 16, as well as further investigation to measure specifically the extent of contamination.

3.7 IMPLEMENTATION OF RECOMMENDATION

In accordance with the recommendation of the 1988 survey, remedial actions were undertaken by removing the top–layer material from contaminated parts of the designated 4,000 ft^2 area plus, as a safeguard, an additional 500 ft^2 area on the western side of the fence. This combined 4,500 ft^2 area, which approximates the trapezoid geometry

previously shown in Figure 7, was designated as the Building T064 Side Yard, as shown in Figure 16.

The investigation included collection of additional gamma exposure–rate and soil–activity data at the Side Yard following removal of the top–layer material. For comparison, soil–activity measurements were also made on the soil removed from the site. Finally, an evaluation was made of the consequences of the remaining radioactivity in the soil to potential current and future occupants of the Side Yard using the DOE computer code RESRAD. The technical approach used in performing the recommended investigation, including a description of the salient aspects of the RESRAD code, is provided in the next section. Results and conclusions from the investigation are presented in Sections 5 and 6, respectively.

4. TECHNICAL APPROACH

4.1 OVERVIEW

As recommended by the report on the 1988 radiological survey, remedial actions were undertaken during the summer of 1989 to remove the contamination found in the building T064 Side Yard. Figure 17 shows the affected 4,500 ft^2 area, including the two primary regions from which top soil and asphalt were removed to varying depths. Upon removal of the top layer, exposure rate and soil activity measurements were made to determine if the site is now acceptably free of radioactive contamination. The technical approach used to perform the investigations and the modified criteria established to determine acceptability of the decontaminated area are discussed in this section. Establishment of site–specific criteria was made possible by the availability of the DOE computer code RESRAD during the fall of 1989.

4.2 APPROACH

4.2.1 Decontamination and Survey

The decontamination efforts were performed under a documented procedure (Ref. 11). Accordingly, surface soil, up to an average 16–in. depth, was first removed from the designated areas of the Side Yard. Localization of the soil areas and the extent of soil removal was guided continually by "indication only" surveys using a Ludlum Model 12S–Micro–R meter. In addition, twenty–four 2–lb surface soil samples were collected and analyzed using the gamma spectrometer for ^{137}Cs and other radionuclide activities (see Table B1, Appendix B) at locations being decontaminated. Soil and asphalt removal was continued in this manner until the indications became indistinguishable from ambient conditions. The removal operations became focused in two primary regions, as shown in Figure 17, totalling about 2,050 ft^2, the remainder of the area having no significant indications.

The removed surface soil was stored in 64 type B–12 boxes for subsequent disposal at an authorized site. While these boxes were being loaded, 256 randomly selected 2–lb samples from the removed soil were collected, four from each box. The four 2–lb samples from each box were then uniformly mixed and then subsampled to produce a single 2–lb sample. Combining samples in this manner, 64 such 2–lb samples were obtained for subsequent analysis by gamma spectrometry.

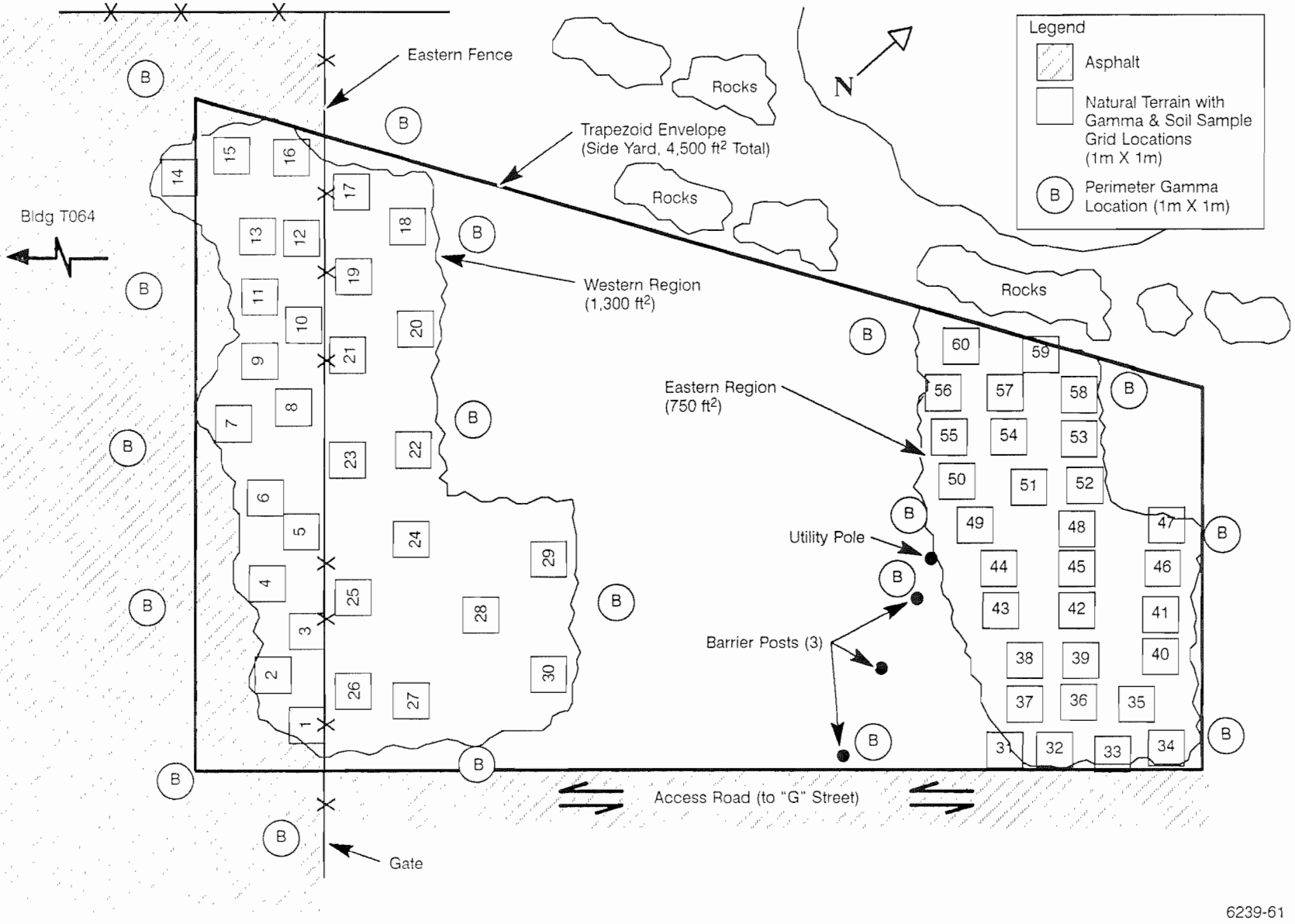

Figure 17. Building T064 Side Yard Decontamination and Survey-Grid Locations

Following removal of the surface soil, a general screening gamma survey "for indication only" was conducted over the surface of the 4,500 ft^2 area using a Ludlum Model 44–9 thin–window pancake GM probe attached to a Ludlum Model 12 countrate meter. The purpose of the survey was to determine if any "measurable" activity could be detected which would indicate the need to remove additional soil. However, no activity was indicated in any part of the Side Yard which was measurably above natural background levels.

After this screening survey, 60 new 1–m x 1–m grids were established in the decontaminated areas for detailed gamma exposure rate and soil activity measurements. These grid locations are also shown in Figure 17. Eighteen additional non–grid gamma exposure rate measurements were also obtained from locations around the perimeter of the two decontaminated regions for comparison measurements. The 1988 survey had shown only natural background activity in these locations, and hence only ambient exposure rates were expected.

4.2.2 Procedures

4.2.2.1 Laboratory Procedures

Upon completion of the soil removal operations, ambient gamma exposure rate measurements were performed using the NaI scintillation detector discussed in Section 3.3.2. Total counts at 1 m above ground were measured and the resulting count rates were then converted to exposure rates using the calibration–derived relationship that 215 cpm = 1 μR/h.

Gross alpha and gross beta determinations were made on 2–g soil samples with a Canberra proportional alpha/beta counter. Gamma spectrometry was performed on the soil samples using a Canberra Series 80 gamma spectrometer. Both the proportional counter, the spectrometer, and the procedures used to calibrate them, are described in Ref. 2.

4.2.2.2 Data Reduction

Two types of spreadsheets, both based on the EXCEL software for Personal Computers, were utilized for data reduction. The first, called SOILTEMP, was used to convert the ambient gamma exposure count data (in total counts) to dose rates (in μR/h), and for converting the total alpha and beta counts obtained (in total counts) from the proportional counter to gross alpha and gross beta values (in pCi/g). The second spreadsheet, called

MCASOIL, was used to convert the multichannel analyzer (MCA) outputs (i.e., quantity of isotope for each peak analyzed) from the gamma spectrometer, in μCi, to concentrations of selected isotopes, and to calculate the alpha and beta activities (both in pCi/g).

Appropriate formulae are included in MCASOIL* to calculate the activities of ^{238}U, and ^{232}Th, based on the activities of their daughter products, and to calculate activities for ^{40}K, ^{137}Cs, ^{134}Cs and ^{60}Co, from which the total alpha and beta activities are derived. These calculations are discussed in detail in Ref. 2. Of these, the gamma exposure rate data from SOILTEMP and the ^{137}Cs data from MCASOIL, were statistically analyzed for comparison with the acceptance limits described in Section 4.3 below. The remaining MCASOIL and SOILTEMP outputs (e.g., the derived total and gross alpha and beta activity data) were obtained for information only, and are included in Appendices B and C, respectively.

4.2.2.3 Statistical Procedures

The techniques discussed in Section 3.3.3 were also used to obtain and display statistical parameters derived from the laboratory data and to compare them against regulatory acceptance criteria to determine compliance. A program called RADSRVY was used to calculate the mean, the standard deviation, and the test statistic (TS) for each data set and to plot the data against the cumulative gaussian probability (e.g., Figure 11). RADSRVY was developed at Rocketdyne and has been extensively used to interpret data of this nature on numerous previous radiological surveys, including, for example, the recent radiological survey of the Old Conservation Yard (Ref. 12).

4.3 REVISED CRITERIA AND THEIR IMPLEMENTATION

4.3.1 Revised Criteria

The ambient gamma exposure rate limit specified in Table 1 applies to the current investigation. The soil activity concentration limits in the table, however, were replaced with the more recent guidelines provided by the DOE, which call for a site-specific determination of acceptable residual radioactive material based on a maximum "basic dose limit" of 100 mrem/year effective dose equivalent to plausible users (Refs. 3 and 13).

*The original version of MCASOIL discussed in Ref. 2 was implemented using a software program known as SMART (Smartware, Innovative Software, Inc., Lenexa, KS). With minor changes, the work reported here was implemented using the software program EXCEL (Microsoft Corp., Redmond, WA).

The site-specific determination of effective dose equivalent is accomplished by utilizing the DOE-supplied RESRAD code which performs environmental and dietary pathway analyses for measured activities of identified nuclide(s) at a given site, and estimates annual exposures to plausible current or future users based on land use scenarios defined for the site. RESRAD, which is further described in Section 4.3.2.2, provides results both in terms of a calculated activity limit corresponding to a basic radiation dose limit of 100 mrem/year, and in terms of the effective dose equivalents for the users.

Although these results are equivalent, for a given nuclide and a site-specific scenario, the code readily allows establishing two related criteria. First, conservative soil activity acceptance limits can be obtained by treating a contaminated site as being effectively infinitely large. Second, realistic dose estimates can be obtained using RESRAD, with the measured residual radionuclide concentration(s) and the actual dimensions of the affected contamination zone.

Thus, there are three criteria to be met:

1. The external gamma exposure rate, in excess of natural background, shall not exceed the 5 μR/h limit given in Table 1.

2. The site-specific residual activity of man-made nuclides shall not exceed the soil activity concentration limit calculated using the RESRAD code for a credible bounding scenario and for an effectively infinite contamination zone (defined in Section 4.3.2.2 below) for the T064 Side Yard.

3. The site-specific annual effective dose equivalent received by a plausible current or future user of the decontaminated area, calculated using RESRAD with the measured man-made radionuclide activities and with the actual dimensions of the contaminated zone, shall not exceed 100 mrem.

Of the three criteria, criteria No. 1 and No. 2 will determine the acceptability of the decontamination and, hence, the acceptability of the site. Given that criterion No. 2 provides a more restrictive limit than No. 3 for acceptance, satisfying this criterion will automatically result in satisfying criterion No. 3. Nonetheless, criterion No. 3 is specified as a requisite for demonstrating the effectiveness of the cleanup. Dose estimates calculated for this purpose may also be used to compare against similar criteria established by other agencies such as the U.S. Nuclear Regulatory Commission (NRC) for release of sites for unrestricted use. In Ref. 14, for example, the NRC requires its licensees to demonstrate that the dose equivalent not exceed 10 mrem/year.

Satisfying the above criteria is required for accepting the site as radiologically clean. Failure to satisfy the criteria will require additional investigations including remediation efforts. Statistical implementation of the criteria, and establishment of a soil activity limit and dose estimates based on RESRAD calculations, are discussed in the next section.

The criteria above are best suited for application to large open sites and yards. Additional criteria, such as those provided in Ref. 13, should be applied in cases of decontamination of buildings, equipment, etc., or for release of aqueous effluents.

4.3.2 Implementation of Criteria

4.3.2.1 Criterion No. 1

Ambient gamma exposure rate data from the decontaminated T064 Side Yard for the 60 grid locations were processed by SOILTEMP and then examined for comparison with the background measurements discussed in the following paragraphs. The background–subtracted gamma exposure rate data were then statistically compared using RADSRVY with the 5 μR/h limit.

Because the variability in the background gamma exposure rates at the SSFL approaches the 5 μR/h limit shown in Table 1, the choice of an appropriate area to determine the background gamma exposure rate value to be applied to a localized decontaminated site is of critical importance. For the present T064 Side Yard, the natural background exposure rate was determined from the portion of the surrounding 2–acre area which most closely matched the affected area topographically and in other physical features. This area corresponds to an elevated northeastern portion of the 2–acre area previously shown in Figure 10 and includes twenty–four 3m × 3m grid data points from the 1988 survey (Ref. 2, Appendix D.3).

The 24 data points are shown in Figure 18 plotted against the cumulative gaussian probability. The mean and standard deviation (1σ) of the distribution is 15.5 ± 0.8 μR/h. By comparison, the three "background" areas studied for the 1988 survey yielded ambient gamma exposure values of 15.6, 16.2, and 14.0 μR/h respectively, with an average value of 15.3 μR/h. Although the 15.5 μR/h value used here is slightly higher than the 15.3 μR/h value, the present value is well within the range of variability observed at the SSFL, and best represents the background in the immediate vicinity of the T064 Side Yard. It is also of interest to note that two of the three "background" values used in the 1988 survey are higher than 15.5 μR/h.

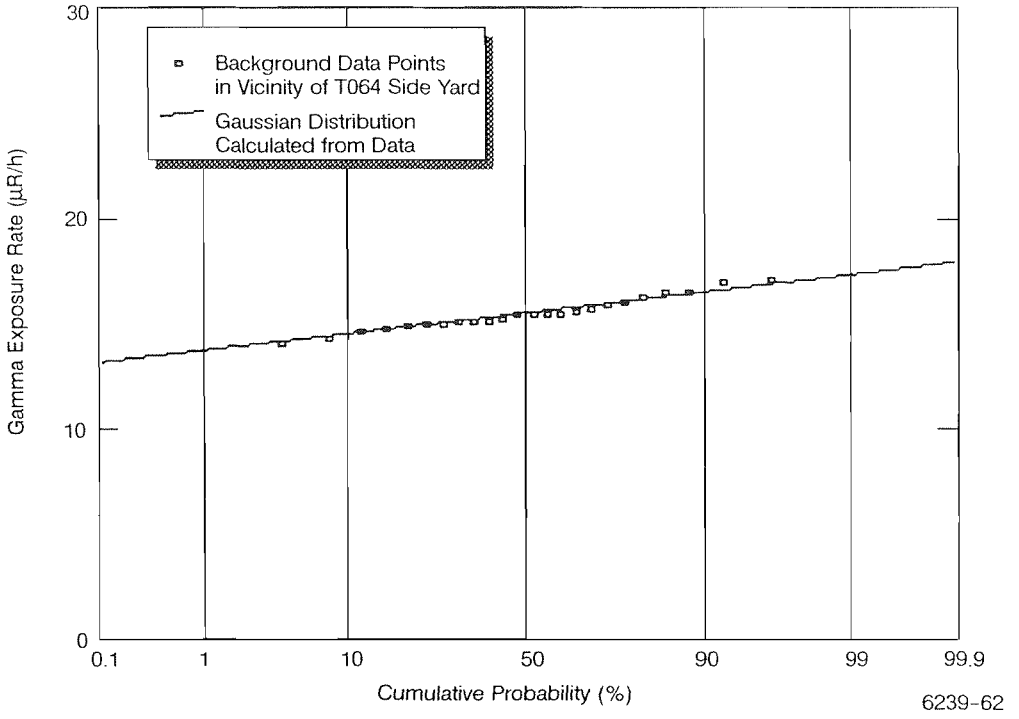

Figure 18. Background Gamma Exposure Rate Data in the Vicinity of the T064 Side Yard Site

4.3.2.2 Implementation of RESRAD (Criteria No. 2 and No. 3)

Gamma spectrometry data for the ten surveyed grid locations were reduced to derived activity values using MCASOIL. The derived soil activities for ^{137}Cs were then statistically compared, using RADSRVY, to the acceptance limits established from the RESRAD code. Although ^{90}Sr activities were not measured at the grid locations, it was assumed that the contamination incident that led to the ^{137}Cs activity in the soil was a result of mixed fission product release and hence an equal activity of ^{90}Sr was also released. Thus, an acceptance limit for ^{90}Sr was also established using RESRAD. An overview of the code, and the approach to establishing the acceptance limits, are discussed in the following paragraphs.

4.3.2.2.1 RESRAD Code Overview

RESRAD calculates the effective dose equivalent to an occupant (current or future) by performing environmental and dietary pathway analyses resulting from the presence and transport of radioactivity through terrestrial media (both living and inanimate). Figure 19 shows the exposure pathway diagram used by RESRAD for calculating the dose to an on-site resident from residual radioactive material.

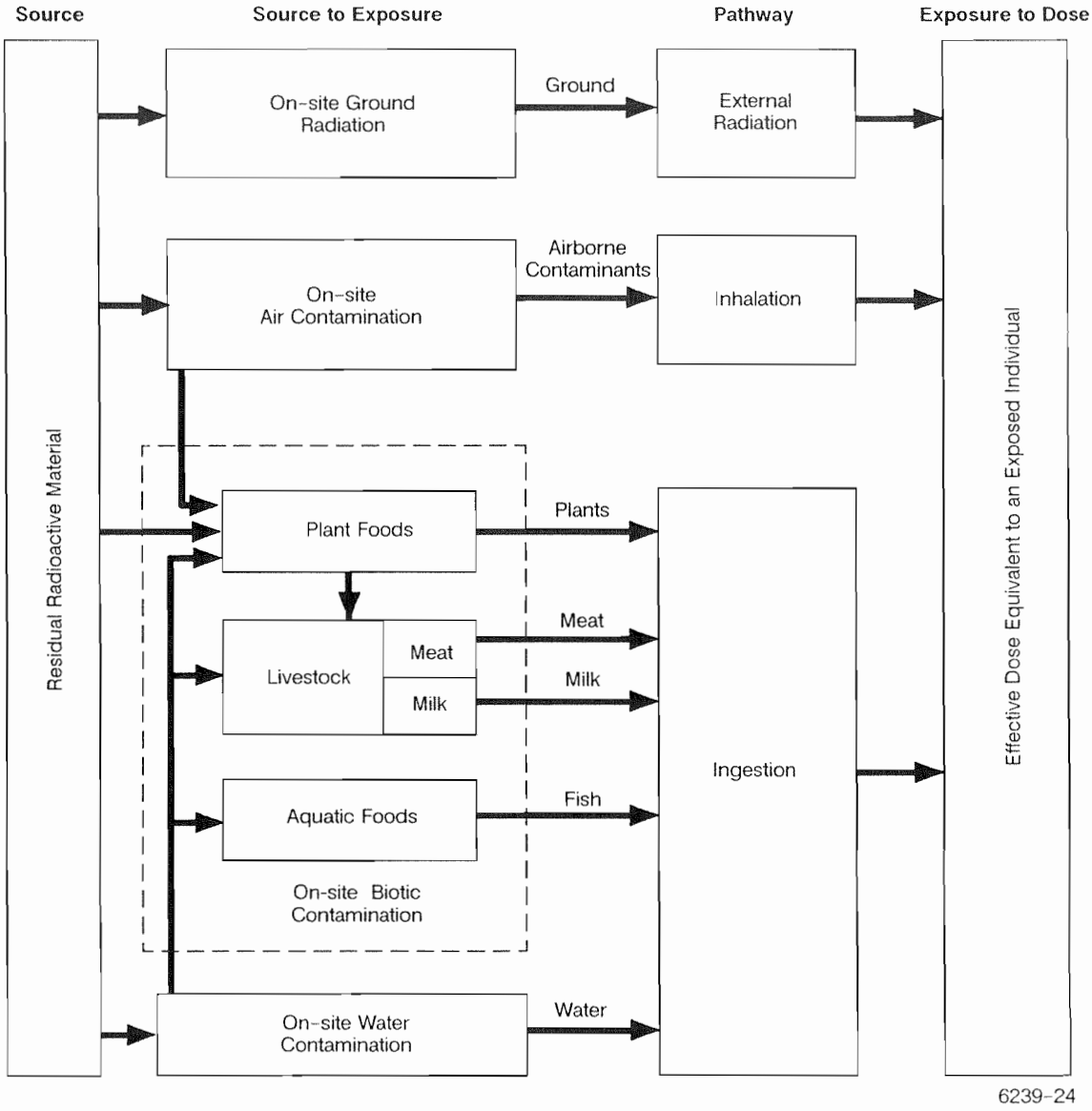

Figure 19. RESRAD Exposure Pathway Diagram (Ref. 3)

The following categories of input data are required to implement RESRAD for a given site: (1) soil activity data, (2) site–specific geohydrological parameters, (3) dietary parameters, and (4) scenario–specific parameters. In all, about 80 input parameters are required. The RESRAD manual (Ref. 3) provides ranges of input values for geohydrological parameters and representative dietary parameters for the United States, from which the code employs a set of "default" input values. The code further allows modifying or eliminating exposure pathways, as necessary, for a given scenario. Thus, using measured soil activity values for isotopes of specific concern and using the default input data, screening estimates of the annual dose (or concentration limit corresponding to the

100 mrem/year basic dose limit) can be obtained for a specified scenario. For obtaining realistic dose estimates, the manual suggests use of site–specific geohydrological parameters whenever such data are available.

For the SSFL in general, as well as the T064 side yard, four potential future land use scenarios were considered. These are:

1. Industrial
2. Residential
3. Wilderness
4. Family Farm

Of the four scenarios, the most credible for the near term is the industrial use scenario, an extension of the present use. In the longer term, either the residential or wilderness use scenarios are most plausible. The family farm scenario is included for completeness even though it is not credible, given the site size, geography, climate, and common land use in this area. Therefore, the credible scenarios for the T064 Side Yard are scenarios 1, 2, and 3.

4.3.2.2.2 RESRAD Input Parameters for Scenarios

As part of a previous effort toward the final decontamination and radiological survey of the Old Conservation Yard at the SSFL (Ref. 12), a number of screening evaluations were performed using the RESRAD code to determine which of the approximately 80 input parameters required by RESRAD were of significance to the general SSFL area. These screening evaluations also helped in determining conservative values for input to the code. In general, changes to most of the parameters were found to have a negligible effect on the final results because certain dose pathways were not applicable for the given scenarios. The critical input parameters for the scenarios identified from the screening runs are briefly discussed below:

Dimensions of Contaminated Zone. Based on data from Ref. 2 and subsequent estimates, the actual extent of the contaminated zone at the T064 Side Yard is 4,500 ft^2 (421 m^2) in area and about 32 or 16 in. (0.81 or 0.41 m) in depth before or after cleanup, respectively. Increasing the dimensions of a contaminated zone will have the effect of lowering the maximum soil activity acceptance limit. Comparison of the measured activities (or the statistical parameters related to the measured activities) with a limit corre-

sponding to an infinite size contaminated zone therefore provides the most restrictive (conservative) acceptance criterion. Therefore, soil activity acceptance limits were calculated assuming an "infinite" contamination area and depth rather than the actual values given above. The screening runs showed that using an area of ~100,000 m^2 and a depth of ~1 m lead to asymptotic convergence of the RESRAD results. For the calculations here, a depth value of 35 m (115 ft) was used, corresponding roughly to the distance from the surface to the water table at the T064 Side Yard. The actual dimensions of the site were subsequently used to estimate annual doses (see Sections 4.3.2.2.4 and 5.3).

Occupancy/Inhalation Shielding Factors. The annual dose estimates calculated by RESRAD from either direct exposure or by inhalation (dust) are functions of two linear parameters called the Occupancy and Shielding Factor (FO_1) and the Inhalation Occupancy Factor (FO_2). Equations for the calculation of these factors are provided in the RESRAD manual (Ref. 3). The factors range from 0 to 1 and may be changed by the user to accommodate different land use scenarios. The "default" RESRAD values for the two factors for the family farm scenarios are 0.6 and 0.45. These values are calculated by assuming that 50% of a person's time is spent indoors, 25% is spent outdoors in the contaminated area and 25% is spent outdoors away from the site, and by using indoor gamma dose and dust inhalation attenuation factors of 0.7 and 0.4, respectively. For the present study, the occupancy percentages and the gamma attenuation factor were each modified, as appropriate, for the three credible scenarios considered, yielding correspondingly modified values for FO_1 and FO_2, which are given in Appendix D.

For the industrial and residential scenarios, modification of the default indoor gamma attenuation factor was chosen as a more realistic method of accounting for indoor gamma shielding than the use of a cover layer over the entire affected site. Thus, it was assumed that any residence or office building occupying the site would typically have a 4–in. (0.1 m) concrete slab floor. Gamma attenuation by a 0.1 m slab is ~85%, yielding a modified gamma attenuation factor of 0.15. This attenuation factor is included in the calculation of the FO_1 and FO_2 values shown in Appendix D for these two scenarios.

Dietary Factors. RESRAD input values for consumption of food and water taken from the contaminated site are based on the default family farm scenario, where a significant fraction of the diet is grown or raised on the site. For the three credible scenarios considered here, these dietary values were modified as follows: for the industrial and wilderness scenarios, it was assumed that no water or food would be used that was taken from the contaminated area; thus, all food and water pathways were zeroed out. For the

residential scenario, it was assumed that a small fraction (10% of that for a family farm) of the leafy vegetable and fruit consumption would be from material grown on the contaminated site. The values used for this scenario are 16 kg/year and 1.4 kg/year, respectively. As in the industrial and wilderness scenarios, water consumption from the site was zeroed out for the residential scenario.

Input data used in the RESRAD code, for the various scenarios, are given in Appendix D. In all cases, site-specific data, where available, were used for the various input geohydrological parameters. Where the RESRAD default values were used, additional screening calculations showed that variation of the default parameters did not significantly influence the results.

4.3.2.2.3 Soil Activity Acceptance Limits from RESRAD (Criterion No. 2)

The ^{137}Cs and ^{90}Sr soil activity limits (in pCi/g), determined from the RESRAD code for the four different land use scenarios, are summarized in Table 3. As discussed above, for conservatism, the limits were calculated assuming an "infinite" contamination area and depth, rather than the estimated dimensions of the affected area. From the data shown in Table 3, it can be seen that, among the three credible scenarios, the residential scenario leads to the lowest permissible concentrations of ^{137}Cs or ^{90}Sr (70.8 and 409

Table 3. RESRAD-Calculated Soil Activity Limits for Future SSFL Land Use Scenarios

Land Use Scenario	Allowed Single Radionuclide Concentration Limits (pCi/g)[a]	
	^{137}Cs	^{90}Sr
1. Industrial	239	33,020
2. Residential	70.8	409
3. Wilderness	3,830	9,240,000
4. Family Farm[b]	31.7	37.2

[a]Single radionuclide soil activity limits from RESRAD for 100 mrem/year dose, and assuming an approximately infinite contamination extent (see text)

[b]RESRAD default scenario (not credible for the T064 Side Yard)

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pCi/g, respectively) that would result in a 100 mrem annual radiation dose from either nuclide. In the terminology of the DOE guideline document (Ref. 3), the residential scenario therefore corresponds to the "credible bounding scenario."

The above concentrations of ^{137}Cs and ^{90}Sr, therefore, are the acceptance limits against which the measured activities at the T064 Side Yard can be compared. In view of our assumption, however, that both ^{137}Cs and ^{90}Sr are present in equal concentrations, a more appropriate acceptance limit for the T064 Side Yard is one that takes into account both nuclides together. The corresponding two–nuclide limit for the credible bounding residential scenario is 60.4 pCi/g each of ^{137}Cs and ^{90}Sr, which would result in a combined annual exposure of 100 mrem.

Statistical implementation of the site–specific residual activity is performed in a manner similar to the gamma exposure rates discussed in Section 4.3.2.1. That is, the RADSRVY calculated test statistic for the ^{137}Cs soil activity data is compared against the corresponding two–nuclide acceptance limit stated above.

4.3.2.2.4 Dose Estimates from RESRAD (Criterion 3)

For demonstrating the effectiveness of the cleanup (criterion No. 3), estimated annual doses to plausible current or future users of the site were calculated as follows: The RESRAD code was run for each of the scenarios with input ^{137}Cs soil activity data corresponding to the average obtained from the 60 grid points, and an equal value for ^{90}Sr activity. Since both ^{137}Cs and ^{90}Sr are man–made nuclides, it is assumed that the corresponding background activities are zero, even though a small amount exists from global fallout; thus, the measured/assumed activities are already background–subtracted. Values for the area of contamination and depth of contamination for these dose calculations correspond to the actual estimated values, and are further justified in Section 5.3, in terms of the results obtained during the gamma and soil surveys. The resulting RESRAD–calculated dose was then compared with the 100 mrem/year basic dose limit and other limits. For comparison, annual dose estimates are provided for each of the scenarios for conditions prior to and after the present decontamination effort.

4.3.3 Summary

Three criteria, and corresponding acceptance limits, were established for the T064 Side Yard to determine its radiological cleanliness. For gamma exposure rates, the first criterion establishes a 5 μR/h acceptance limit. The test statistic for the background–

subtracted gamma exposure rate data is compared with 5 μR/h. For the present case, the value used for the gamma exposure rate background was determined from a 24–grid area in the vicinity of Bldg. T064, which better represents the area than the three "background" SSFL areas, and thus minimizes the effects of the inherent variability in the natural gamma background at the SSFL.

The second criterion establishes an acceptance limit for the site–specific soil activity. Using site geohydrological parameters, and based on three credible scenarios for current or future site–use, and on the basis of an infinite area and depth of contamination, the RESRAD code established the limit to be 60.4 pCi/g each of ^{137}Cs and ^{90}Sr for the credible bounding scenario. The test statistic for the measured ^{137}Cs soil activity data is compared with the 60.4 pCi/g limit. Statistical behavior of the ^{90}Sr is assumed to follow that of ^{137}Cs.

The T064 Side Yard is determined to be acceptably free of residual radioactive contamination if both test statistics are less than the corresponding acceptance limits.

The third criterion, as an adjunct to the second criterion, permits comparison of the basic dose limit (100 mrem/year) with the calculated annual doses to a plausible current or future user under realistic conditions of the actual dimensions of the contaminated zone and measured values of the extent of residual radioactivity.

Results are presented and discussed in the following section.

5. RESULTS AND DISCUSSION

5.1 GAMMA EXPOSURE RATE DATA (CRITERION NO. 1)

Ambient gamma exposure rates obtained from the 60 grid location in the 4,500 ft^2 survey area, after decontamination, are given in Table 4. Gamma exposure rates ranged from 15.21 to 20.27 μR/h, with a mean value ($\pm 1\sigma$ standard deviation) of 17.7 ± 0.9 μR/h. These exposure rates are well above the 0.5 μR/h sensitivity of the NaI detector. Plotted against a cumulative probability scale, these data are also shown in Figure 20. As is evident, the data distribution reasonably follows a gaussian, with no outliers. The outlier data, with maximum values of 76 μR/h (Figure 11) and 110 μR/h (Figure 12) obtained in the 1988 survey of these locations are now absent.

Figure 21 shows the background–subtracted T064 Side Yard gamma exposure–rate data plotted against the cumulative probability. Here, the value of 15.5 μR/h determined from the immediately adjacent area was used for background substraction. The upper limit of the graph is the acceptance limit of 5 μR/h. All of the background–subtracted data are below the acceptance limit. Furthermore, the intersecting dashed lines show that the test statistic of 3.6 μR/h for this distribution is below the acceptance limit, thus satisfying criterion No. 1. The mean of the background–subtracted data is 2.2 μR/h. Comparison of this value with the residual soil activity measured at the T064 Side Yard is provided in Section 5.3

5.2 SOIL ANALYSIS DATA (CRITERION NO. 2)

As discussed in Section 4.2.1, gamma spectrometry analyses were performed on soil samples collected from the 64 B–12 boxes, and from the 60 grid locations established for the final T064 Side Yard decontamination survey. The spectrometry results were data–reduced using the in–house spreadsheet code RADSRVY, resulting in derived activity values (in pCi/g) for certain specific isotopes, including ^{137}Cs, which was found in significantly above–normal levels in the original survey conducted in 1988. For the purpose of the present survey, only the ^{137}Cs data from the grid locations are discussed here. For completeness, however, the results of the MCASOIL analysis for all derived quantities, including data for the removed soil, and data from the 2–g sample analyses, are given in Appendices B and C, respectively.

Results of the spectrometric analyses for ^{137}Cs on soil samples from the 60 survey grids are given in Table 5. Measured activities ranged from <0.2 to 17.6 pCi/g, with an

Table 4. Ambient Gamma Exposure Rates in the T064 Side Yard Grids After Decontamination

Grid Number*	Exposure Rate (μR/h)	Grid Number*	Exposure Rate (μR/h)
G–1	17.08	G–31	17.45
G–2	16.80	G–32	18.32
G–3	17.27	G–33	18.19
G–4	15.21	G–34	18.19
G–5	16.83	G–35	17.50
G–6	16.68	G–36	16.93
G–7	18.51	G–37	16.65
G–8	16.82	G–38	18.00
G–9	16.28	G–39	19.04
G–10	16.88	G–40	19.54
G–11	16.78	G–41	19.17
G–12	17.68	G–41	18.40
G–13	17.71	G–42	18.97
G–14	17.42	G–43	18.17
G–15	17.10	G–44	17.91
G–16	17.09	G–46	17.72
G–17	16.74	G–47	18.25
G–18	18.58	G–48	18.45
G–19	17.70	G–49	17.45
G–20	18.27	G–50	18.10
G–21	16.69	G–51	18.28
G–22	18.16	G–52	17.56
G–23	17.13	G–53	18.08
G–24	18.01	G–54	17.67
G–25	17.62	G–55	17.05
G–26	17.01	G–56	17.77
G–27	18.25	G–57	17.61
G–28	18.42	G–58	17.86
G–29	19.81	G–59	18.18
G–30	20.27	G–60	16.75
Maximum:	*20.27*		
Minimum:	*15.21*		
Average:	*17.73*		

*See Figure 17 for grid locations at the T064 Side Yard.

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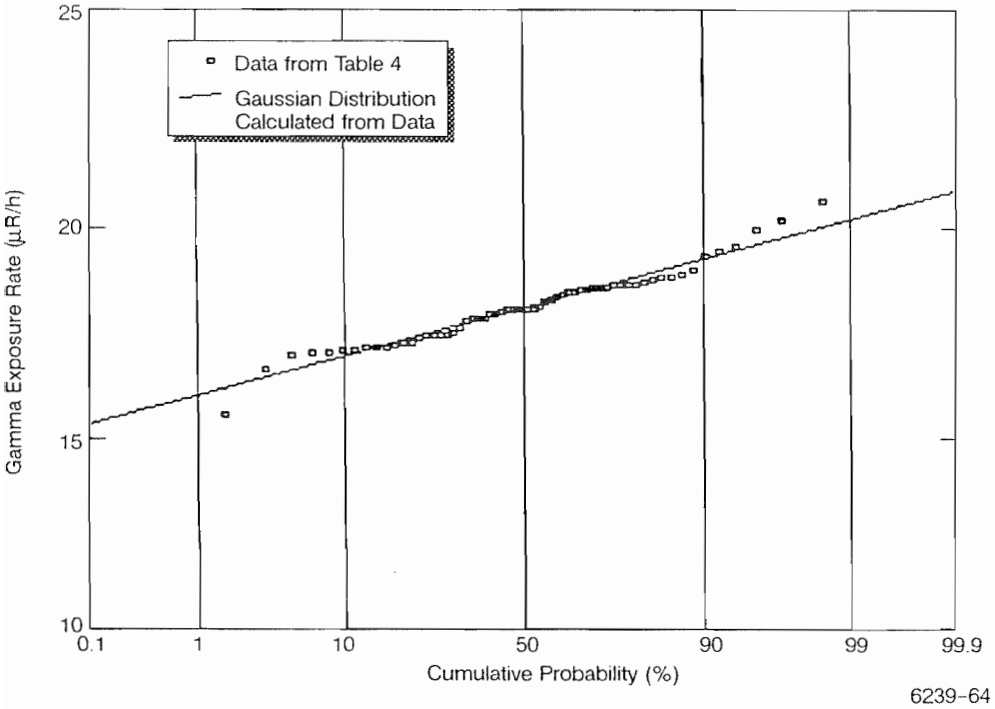

Figure 20. Ambient Gamma Exposure Rates in T064 Side Yard Grids After Decontamination

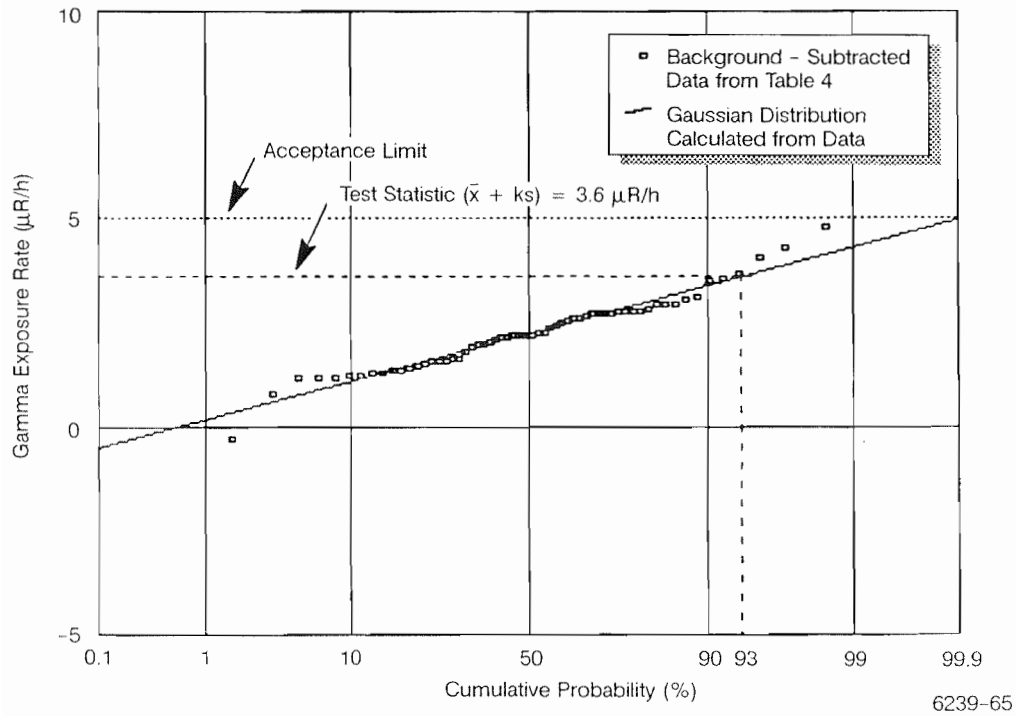

Figure 21. Background–Subtracted Gamma Exposure Rates in the T064 Side Yard After Decontamination

Table 5. Measured Residual ^{137}Cs Activity in T064 Side Yard Grids After Decontamination

T064 Site Grid Number[a]	Measured ^{137}Cs Activity (pCi/g)	T064 Site Grid Number[a]	Measured ^{137}Cs Activity (pCi/g)
G–1	11.4	G–31	5.3
G–2	17.6	G–32	8.2
G–3	10.1	G–33	4.5
G–4	17.1	G–34	6.5
G–5	5.5	G–35	9.3
G–6	3.5	G–36	8.7
G–7	<0.2	G–37	8.9
G–8	0.7	G–38	7.0
G–9	2.1	G–39	5.7
G–10	1.3	G–40	5.9
G–11	1.4	G–41	4.6
G–12	13.0	G–41	3.0
G–13	1.9	G–42	3.6
G–14	5.1	G–43	1.3
G–15	3.7	G–44	9.1
G–16	9.9	G–46	16.7
G–17	0.4	G–47	1.0
G–18	12.0	G–48	2.1
G–19	3.0	G–49	0.9
G–20	5.6	G–50	<0.2
G–21	2.0	G–51	0.2
G–22	1.3	G–52	1.7
G–23	5.3	G–53	1.9
G–24	12.8	G–54	0.4
G–25	2.1	G–55	0.3
G–26	2.8	G–56	0.3
G–27	1.7	G–57	2.1
G–28	2.7	G–58	2.0
G–29	6.2	G–59	2.6
G–30	5.4	G–60	1.0
Mean:	*4.9*		
Standard Deviation (1σ):	*4.5*		

[a]See Figure 17 for grid locations at the T064 Side Yard

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average value of 4.9 pCi/g, well above the lower detection limit of 0.2 pCi/g for the spectrometer system. This average value of 4.9 pCi/g after decontamination is lower than: (1) the average of 32.8 pCi/g for the soil removed from the decontamination operations (average of 64 samples from the B–12 boxes, Appendix B, Table B2), (2) the average of 277 pCi/g for the surface soil samples collected in the early stages of decontamination (average of 24 samples, see Appendix B, Table B1), and (3) the 2,500 and 2,700 pCi/g values obtained in the 1988 survey (two samples, see Section 3.4.2). If the 277 pCi/g ^{137}Cs activity concentration is taken as a representative average of the extent of contamination prior to cleanup, then a factor of 56.5 (277 ÷ 4.9) reduction was achieved.

In Figure 22, the ^{137}Cs results are plotted versus the cumulative probability. The intersecting dashed lines indicate the test statistic (TS) for this distribution, which is 11.7 pCi/g. The two previously calculated RESRAD limits are also shown, one corresponding to the single radionuclide limit of 70.8 pCi/g, and the second corresponding to the two–nuclide limit of 60.4 pCi/g for equal activities of ^{137}Cs and ^{90}Sr. Of significance is the fact that the TS of 11.7 pCi/g for the ^{137}Cs data distribution in the Side Yard grids is substantially below the two–nuclide (and single nuclide) acceptance limit and hence criterion

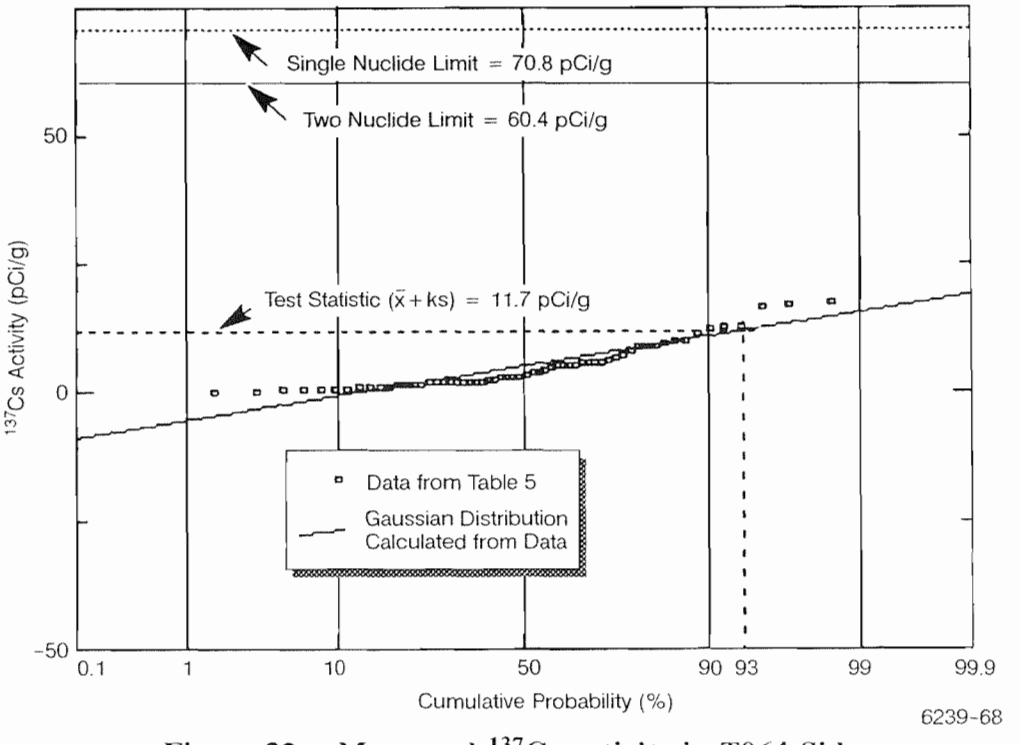

Figure 22. Measured ^{137}Cs activity in T064 Side Yard Grids After Decontamination

No. 2 is satisfied. The TS and the average are also lower than the 1988 survey's criterion of 76 pCi/g beta (Table 1 -- 100 pCi/g total minus 24 pCi/g background) for soil activity.

5.3 DOSE ESTIMATES (CRITERION NO. 3)

To demonstrate the effectiveness of the cleanup, RESRAD was used to provide annual dose estimates to plausible current or future users for each of the four scenarios, before and after decontamination. These dose values are calculated for times of 0, 1, 10, 100, and 1,000 years into the future. Using the results presented in Sections 5.1 and 5.2 above, the values chosen for the area, depth, and residual activity concentrations for performing the "before" and "after" dose calculations are explained below, following which the calculated dose estimates for the four scenarios and for the selected time periods are presented.

5.3.1 Area

The portion of the T064 Side Yard which was decontaminated consisted of two separate regions, as shown in Figure 17. The western region lies immediately adjacent to the Building T064 east fence, and the eastern region lies below the rock peak area ~75 ft east of the fence. The areas of these two regions are ~1,300 and ~750 ft^2, respectively, for a total area of ~2,050 ft^2. As a safeguard, however, the contaminated area is assumed to comprise the trapezoidal area encompassing both regions, resulting in a total assumed contaminated area of ~4,500 ft^2. This larger area is used to calculate estimated doses to potential current and future users of the site.

5.3.2 Depth and Concentrations

5.3.2.1 The "Before" Case

The 1988 survey assumed, for purposes of calculation, a depth of contamination of ~12 in. The actual average depth of soil that was removed during the decontamination, however, is calculated to be ~16 in. This value is based on the mass of soil in the 64 B–12 boxes and the area of the two decontaminated sections. For the purpose of calculating dose estimates before decontamination, the depth of the original contaminated layer is conservatively assumed to be ~32 in., or twice the calculated amount.

The average ^{137}Cs concentration measured in the removed 16 in. of soil, from Table B2 in Appendix B, is 32.8 pCi/g. Although the remaining soil at the T064 Side Yard shows an average residual activity of only 4.9 pCi/g (Table 5), in order to conservatively

calculate the surface gamma dose rate, the 32.8 pCi/g value was assumed for the entire 32–in. depth. An equal activity of ^{90}Sr was also assumed.

5.3.2.2 The "After" Case

For this "after" case, the average measured ^{137}Cs value of 4.9 pCi/g from Table 5 was used for ^{137}Cs and ^{90}Sr. The depth of the contaminated soil remaining at the side yard is assumed to be ~16 in., which is equal to the depth of original soil removed during the decontamination. The 16–in. depth value is consistent with the measured background–subtracted ambient gamma exposure rate of 2.2 μR/h for the T064 site. This is evidenced by the fact that the gamma exposure rate calculated by RESRAD for the T064 Side Yard credible bounding scenario is 19.0 mrem/yr or 2.17 μR/h. This calculation assumed a depth of 16 in. and a ^{137}Cs contamination of 4.9 pCi/g; all environmental pathways were suppressed, except for the continuous and unshielded direct gamma exposure pathway. Increasing the soil depth beyond the 16–in. value results in a negligible increase in the calculated RESRAD gamma exposure rate because of gamma shielding by the upper soil layers. Conversely, reducing the thickness to less than 16 in. unrealistically reduces the gamma exposure rate. Thus, the 16–in. value can be considered as an effective upper limit for the purpose of establishing the external gamma exposure to any potential current or future occupant of the site.

5.3.3 Results

Results are shown in Table 6. The estimated post–decontamination annual doses to a potential current (time = 0 years) occupant of the T064 Side Yard site range from 0.09 to 5.2 mrem/year for the three credible scenarios and 13.3 mrem/year for the family farm scenario. All values, including that for the family farm scenario, are significantly less than the basic dose limit of 100 mrem/year. The "after" exposure values in Table 6 are about a factor of 6 to 8 lower than those calculated to have resulted if no decontamination efforts had been undertaken.

The values shown in the table decrease further with time as a result of radioactive decay and other time–dependent site parameters. The dose for an occupant under the credible bounding residential scenario is 5.2 mrem/year, which is well below the DOE basic dose limit of 100 mrem/year for release without radiological restriction, thus satisfying Criterion No. 3. The 5.2 mrem/year is also below the 10 mrem/year NRC limit for release of the site for unrestricted use.

Table 6. Estimated Annual Dose (Above Background) from Residual Radionuclide Activity at T064 Side Yard

Time (years)	Estimated Annual Dose from Residual Contamination (mrem/year)							
	Industrial		Residential[a]		Wilderness		Family Farm	
	Before[b]	After[c]	Before	After	Before	After	Before	After
0	9.9	1.5	36.4	5.2	0.62	0.09	105	13.3
1	9.7	1.4	35.6	5.0	0.60	0.09	102	12.9
10	7.9	1.2	28.8	4.1	0.49	0.07	80	10.1
100	1.0	0.1	3.5	0.5	0.06	< 0.01	8.0	1.0
1000	≪0.01	≪0.01	≪0.01	≪0.01	≪0.01	≪0.01	≪0.01	≪0.01

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[a]Credible bounding scenario
[b]"Before" represents conditions prior to soil removal
[c]"After" represents conditions following soil removal

5.4 STATUS

Figures 23 and 24 show photographs of the T064 Side Yard taken during the 1989 decontamination efforts at the two regions previously shown schematically in Figure 17. The fenced–in and open portions of the Side Yard are not presently being used. Building T064 currently stores the slightly contaminated soil removed from the Side Yard and from other SSFL locations, pending their planned disposal at an authorized site. A final survey and safety review of the building proper should be performed following these activities. Findings from Ref. 2 that are applicable to the building should be reviewed as part of this safety review.

A decommissioning file for the T064 Side Yard site has been established and is currently archived at Rockwell's SSFL Building T100. Appendix E contains a list of items documented in this file.

Figure 23. Photograph of the T064 Side Yard Taken During the July 1989 Decontamination of the 1,300 ft^2 Area Adjoining the Eastern Fence

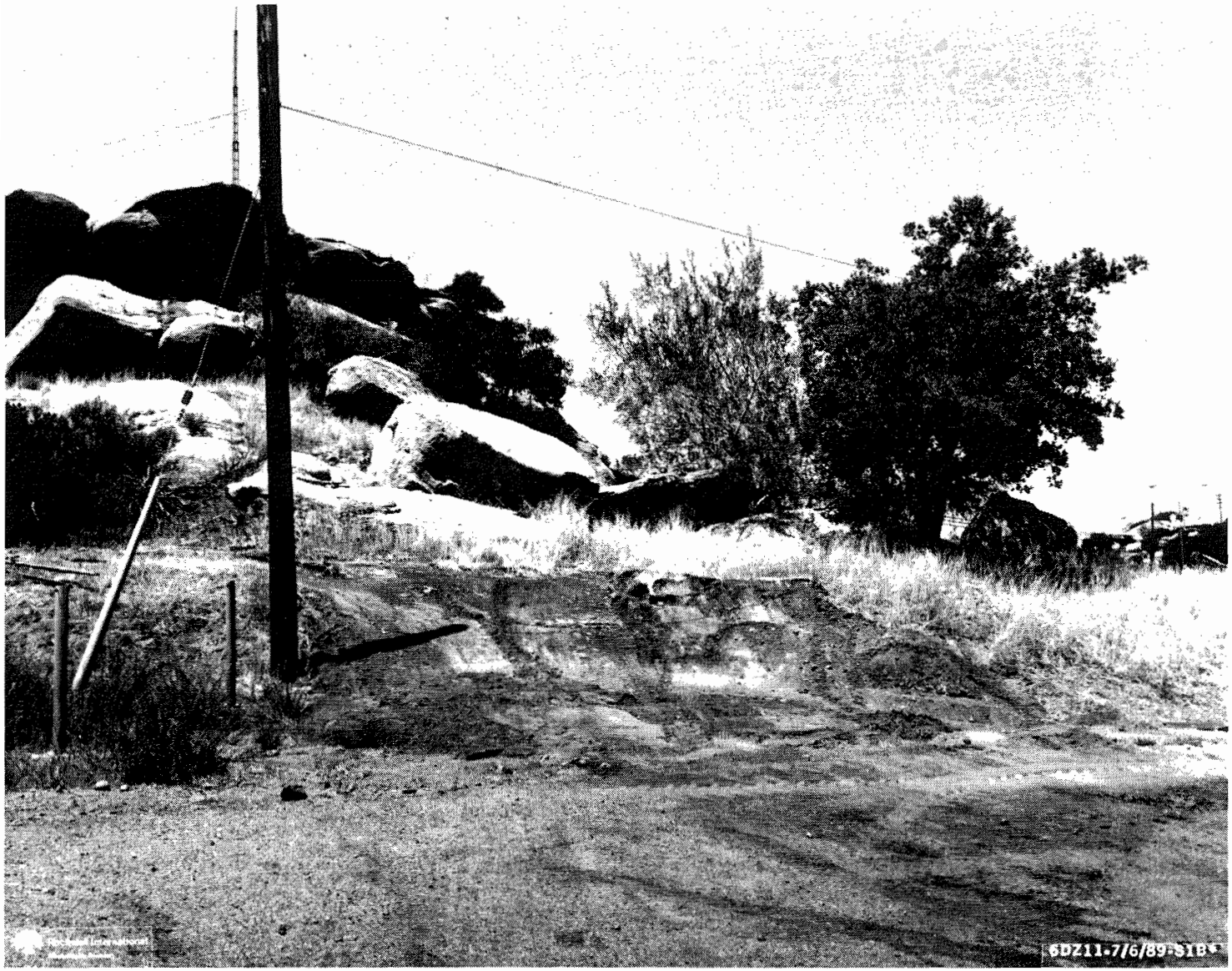

Figure 24. Photograph of the T064 Side Yard Taken During the July 1989 Decontamination of the 750 ft^2 Area, 75 ft East of the Eastern Fence

6. CONCLUSIONS

In accordance with the recommendation of the report on the 1988 radiological survey of Building T064, its fenced–in yard, and a 2–acre surrounding area at the SSFL, the topsoil layer was removed in a 4,500 ft^2 area of the Building T064 Side Yard where ^{137}Cs contamination had been found. Additional gamma exposure surveys and soil analyses were performed. The required analyses of the consequences due to the remaining activity in the soil to plausible current and future users of the affected area were also performed. The following specific and overall conclusions are drawn from these evaluations.

6.1 SPECIFIC CONCLUSIONS

1. The average of the measured ambient gamma exposure rates in the decontaminated area is 17.7 μR/h. For comparison, the background ambient gamma exposure rate in the immediate vicinity of the T064 Side Yard has an average value of 15.5 μR/h.

2. The test statistic for the distribution of the background–subtracted gamma exposure rates in the decontaminated area is 3.6 μR/h, which is below the acceptance limit of 5 μR/h (Criterion No. 1).

3. The calculated values of the allowable, site–specific single radionuclide concentration limits for the T064 Side Yard are 70.8 pCi/g of ^{137}Cs and 409 pCi/g of ^{90}Sr for a credible bounding residential use scenario. The corresponding acceptance limit for the assumed case of both isotopes being present in equal concentrations at the Side Yard is 60.4 pCi/g of each radionuclide.

4. The test statistic for the measured ^{137}Cs soil activity distribution is 11.7 pCi/g, which is well below the acceptance limit of 60.4 pCi/g (Criterion No. 2).

5. The average measured ^{137}Cs activity presently in the decontaminated area is 4.9 pCi/g, compared to the average of 277 pCi/g measured prior to decontamination. Thus, the present decontamination effort resulted in a reduction of ^{137}Cs activity by a factor of about 60.

6. A plausible occupant of the decontaminated area under the credible bounding use scenario will receive a current annual dose of 5.2 mrem/year, which is well below the 100 mrem/year basic dose limit (Criterion No. 3).

7. The 2.2 μR/h background–subtracted gamma exposure value is consistent with the assumed 16–in. depth and the 4.9 pCi/g contamination value for residual contamination at the T064 Side Yard. Increasing the assumed contaminated soil thickness beyond 16 in. results in essentially no further increase in the external gamma dose to an occupant of the site.

6.2 OVERALL CONCLUSIONS

1. Based on the results of the investigations reported here, the Building T064 Side Yard is acceptably free of radioactive contamination.
2. Based on results of the 1988 survey, the remaining surveyed fenced–in yard and 2–acre surrounding area are also acceptably free of radioactive contamination.
3. The Building T064 fenced–in yard and the 2–acre surrounding area meet all the acceptance criteria, and, therefore, may be released for use without radiological restrictions.

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APPENDIX A

INTERNAL LETTER, F. H. BADGER TO R. M. HILL, "CONTAMINATION INCIDENT SS VAULT, SANTA SUSANA," NOVEMBER 11, 1963.

APPENDIX A

INTERNAL LETTER

NORTH AMERICAN AVIATION, INC.

DATE: November 11, 1963

TO: R. M. Hill (RMH)
ADDRESS: Dept. 779-210
Building 040, SanSu

FROM: F. H. Badger ✓
ADDRESS: Dept. 779-210
Building 040, SanSu

PHONE

SUBJECT: Contamination Incident SS Vault, Santa Susana

On the 18th of February, 1963, during a routine survey, the soil east of the exclusion fence at the SS Vault at Santa Susana, was found to be contaminated with radioactive material in excess of permissible limits. Since that time, three subsequent surveys of the area by the Health and Safety Operations unit, and analysis of the soil by the Health and Safety laboratory unit, revealed an area of approximately 700 ft^2 of asphalt and soil to be contaminated with mixed fission products with a maximum of 700mrad/hr at 2 inches. A complete investigation of the area on previous surveys were impossible, do to storage of material in the area at the time of the previous surveys.

An investigation into the possible source of contamination failed to revealeconcrete evidence. Only by process of deduction, can it be ascertained what the source of contamination was. Two irradiated fuels have been stored at the vault that contained enough mixed fission products to have caused the incident. One item was an irradiated solution of uranyl sulphate from the KEWB reactor. The fuel was shipped from the vault to RMDF, where it was inspected and surveyed prior to solidification. No detectable contamination was found on the fuel containers at that time. The only other fuel container to be considered was the cask containing irradiated fuel pins from the Seawolf (submarine reactor). They were received at the vault, stored, transfered to the CDEC (Dept. 733) for inspection, and returned to the vault for storage. After storing the fuel for about 1.5 to 2 years total, it was shipped back to Westinghouse about May of 1962. Sometime during this storage period, the drain plug probably rusted through, permitting any fluid, contained within the cask, to spill onto the asphalt.

The surface contamination was first discovered on February 18, 1963. A soil sample was taken and submitted to the laboratory for analysis. The analysis indicated $1X10^6$ d/m/gram of Cs^{137} and $2X10^5$ d/m/gram of Cs^{134}. Alpha activity in all samples submitted was negligible. A survey of the area, with an air proportional alpha survey, failed to indicate the presence of any alpha emitters. The lack of alpha emitters further substantiates the discounting of the uranyl sulphate as the source of contamination.

A meeting was held between Health and Safety, and Dept. 782 Supervision, to arrange the recovery of the area. Those in attendance were J. Travillyan (Dept. 798), J. M. Young (782), D. D. Kusick (779-210, and F. H. Badger. Subsequently, J. M. Young issued an IL requesting maintenance to decontaminate and repair the area. Co-ordination with Industrial Security to prohibit violation of the vault security was also requested.

TO: L. M. Hill
FROM: F. H. Badger
SUBJECT: Contamination Incident SS Vault, Santa Susana

November 11, 1963

Approximately 2,365 gallons of soil and asphalt were removed reducing the maximum dose rate to 0.5mrad/hr. Approximately 95% of the area indicated readings of background (.04mr/hr). It was only necessary to remove the asphalt from the paved areas to reduce the dose rate to background. Maintenance removed ~3 inches of soil from all the contaminated soil areas before an attempt was made to remonitor the area. Approximately 80% of the area was found to be free of contamination upon resurveying. The remainder had to be excavated to about 1 to 1½ feet. At this point, 34 drums of R/A waste were removed from the area to RMDF using the charge number (PR 59-222) furnished by W. Martin, Supervisor of Dept. 782. The reduction in background radiation caused by the removal of the waste, revealed an additional area within or tangent to the excavated area. Nine more drums of soil were removed and transfered to RMDF for disposal effectively reducing the contamination level to 0.5mrad/hr.

After the radiological controls were removed on October 18, 1963, Industrial Security was notified, along with Maintenance and W. Martin.

Fill soil was brought in by Maintenance, returning the soil level to normal. The paved area will be replaced by outside contractor on an open contract after the exclusion fence has been returned to the normal perimeter. This will complete the recovery operation.

It is difficult to make comments on an incident occurring from 1½ years to 3½ years ago. Complete changes in personnel and procedures compounds the problem. However, a thorough review of handling and operating proceduresfrom a radiological safety standpoint will be effected in an effort to prevent similar occurrances in the future. Incidents of this nature are embarrassing to Atomics International to say the least. Every effort should be made to preclude the possibility of similar occurrence.

F. H. Badger, Senior Analyst
Health and Safety Section
Santa Susana Operations

FHB:mc
dc: D. D. Busick
H. E. Clow
F. Corning
J. C. Lang
W. Martin
R. Weed
J. M. Young

APPENDIX B

DERIVED ALPHA, BETA, AND RADIONUCLIDE DATA FROM BUILDING 064 SIDE YARD AFTER DECONTAMINATION

During the course of the decontamination of the Side Yard, gamma spectrometry data were obtained for three sets of soil samples. These included: (1) 18 randomly selected scoping samples taken from the surface prior to decontamination, (2) 64 soil samples randomly taken from the soil removed from the Side Yard area during decontamination and subsequently stored in B–12 boxes, and (3) 60 soil samples taken from the survey grids established after decontamination. Soil samples for analysis were collected in July and August 1989.

In each case, samples ranging in mass from about 600 to 900 g were analyzed using the Canberra instrument discussed in Section 4.2.2 and Ref. 2. Following analyses, the results were input to the MCASOIL spreadsheet, which in turn calculated derived quantities for total alpha and total beta activity, and derived activities for selected man–made radionuclides and for several naturally occurring radionuclides. A zero value in the data tables indicates that the signal was less than the detection limit of the Canberra instrument. For ^{137}Cs (the nuclide of interest), this detection limit was ~0.2 pCi/g.

Tables B1 through B3, present the data for the three different soil sample sets.

Table B1. Gamma Spectrometry Data from Initial Scoping Survey of the Side Yard Area

	39	40	41	42	43	44	45	46	47	48	49	50<
1	BUILDING 064 PRE-DECON SOIL SURVEY DATA											
2	(Samples Analyzed: 7/10/89 to 7/12/89)											
3	Excel File:	064Init.xls										
4												
5			picocuries per gram of each radionuclide									
6					186 keV	185.6 keV						
7			U-238	Th-232	U-235	U-235	K-40	Cs-137	Cs-134	Co-60	Derived Alpha	Derived Beta
8					(from	(from					pCi/g	pCi/g
9					Ra-226)	U-238)						
10												
11	Sample	Mass	c32*1e6/	c33*1e6/	c34*1e6/	c41*.045	c35*1e6/	c36*1e6/	c37*1e6/	c38*1e6/	8*c41+6*c42	6*c41+4*c42+4*
12	Description	(grams)	c2	c2	c2		c2	c2	c2	c2	+7*c43	c43+sum(c44:48)
13												
14	2	610.0	0.00	0.00	0.00	0.00	21.66	943.44	0.00	0.00	0.00	965.10
15	3 (12 IN. DEEP)	686.5	0.72	1.04	0.00	0.03	22.21	0.28	0.00	0.00	11.98	30.99
16	7	638.0	0.00	0.00	0.00	0.00	20.27	1341.69	0.00	0.00	0.00	1361.96
17	8	697.0	0.00	0.00	0.00	0.00	18.55	1596.28	0.00	0.00	0.00	1616.83
18	10	848.5	0.72	0.67	0.00	0.03	19.18	50.91	0.00	0.00	9.75	77.10
19	13	678.0	0.00	0.99	0.00	0.00	19.71	813.72	0.00	0.00	5.93	837.38
20	14	591.0	0.83	2.19	0.00	0.04	25.69	99.90	0.00	0.00	19.82	139.39
21	16-A	645.3	0.98	1.30	0.00	0.04	22.73	29.35	0.00	0.00	15.61	63.19
22	16-B	711.0	0.99	1.26	0.00	0.04	26.05	4.87	0.00	0.00	15.43	41.91
23	16-C	575.3	0.94	1.02	0.00	0.04	25.50	0.83	0.00	0.00	13.64	36.09
24	16-D	733.0	1.54	1.35	0.09	0.07	25.16	1.74	0.00	0.00	21.05	41.97
25	16-E	724.0	0.91	1.05	0.00	0.04	24.77	6.82	0.00	0.00	13.60	41.31
26	19	672.0	0.96	1.42	0.00	0.04	24.32	0.92	0.00	0.00	16.18	36.70
27	20	720.0	0.97	4.25	0.00	0.04	24.10	0.40	0.00	0.00	33.22	47.33
28	21	731.7	0.90	1.32	0.00	0.04	23.12	2.18	0.00	0.00	15.08	35.99
29	22	739.0	1.25	1.28	0.00	0.06	25.35	9.56	0.00	0.00	17.68	47.58
30	23	779.6	0.00	1.18	0.00	0.00	23.56	65.62	0.00	0.00	7.07	93.90
31	24	840.0	0.77	1.05	0.00	0.03	21.95	11.35	0.00	0.00	12.46	42.15

Table B2. Gamma Spectrometry Data on Randomly Selected Soil Samples Taken From the Side Yard Area During Soil Removal (Sheet 1 of 3)

	39	40	41	42	43	44	45	46	47	48	49	50
1	BLDG 064 SIDEYARD SOIL DATA FROM B-12 BOXES											
2	(Soil Analyzed: 8/4/89 to 8/9/89)											
3	Excel File:	064boxes.xls										
4												
5			picocuries per gram of each radionuclide									
6					186 keV	185.6 keV						
7			U-238	Th-232	U-235 (from	U-235 (from	K-40	Cs-137	Cs-134	Co-60	Derived Alpha	Derived Beta
8					Ra-226)	U-238)					pCi/g	pCi/g
9												
10												
11	Sample	Mass	c32*1e6/	c33*1e6/	c34*1e6/	c41*.045	c35*1e6/	c36*1e6/	c37*1e6/	c38*1e6/	8*c41+6*c42	6*c41+4*c42+4*
12	Description	(grams)	c2	c2	c2		c2	c2	c2	c2	+7*c43	c43+sum(c44:48)
13												
14	64-1	741.5	1.05	0.95	0.00	0.05	22.52	16.94	0.00	0.00	14.08	49.59
15	64-2	768.3	0.67	1.11	0.00	0.03	18.99	47.14	0.00	0.00	12.01	74.61
16	64-3	780.6	0.91	1.26	0.00	0.04	21.02	15.62	0.00	0.00	14.86	47.19
17	64-4	713.7	0.94	1.43	0.00	0.04	23.90	15.43	0.00	0.00	16.07	50.71
18	64-5	664.1	0.76	1.22	0.00	0.03	20.66	41.42	0.00	0.00	13.40	71.56
19	64-6	758.0	0.00	1.01	0.00	0.00	18.88	44.68	0.00	0.00	6.04	67.59
20	64-7	743.6	0.00	1.16	0.00	0.00	19.34	38.81	0.00	0.00	6.95	62.78
21	64-8	766.5	0.00	1.24	0.00	0.00	22.64	52.28	0.00	0.00	7.46	79.88
22	64-9	732.2	0.00	1.28	0.00	0.00	20.04	110.72	0.00	0.00	7.69	135.88
23	64-10	702.6	0.90	1.17	0.00	0.04	21.90	29.85	0.00	0.00	14.26	61.90
24	64-11	708.2	0.97	1.28	0.00	0.04	21.22	35.27	0.00	0.00	15.47	67.50
25	64-12	760.4	0.87	1.34	0.00	0.04	21.67	28.27	0.00	0.00	15.02	60.58
26	64-13	744.7	1.54	1.41	0.00	0.07	21.65	110.43	0.00	0.00	20.77	147.03
27	64-14	777.7	0.00	1.44	0.00	0.00	26.33	51.22	0.00	0.00	8.63	83.30
28	64-15	831.5	0.87	1.11	0.00	0.04	20.78	8.01	0.00	0.00	13.62	38.48
29	64-16	795.2	0.87	1.39	0.00	0.04	22.28	52.43	0.00	0.00	15.27	85.50
30	64-17	754.9	0.00	1.41	0.00	0.00	21.16	79.16	0.00	0.00	8.44	105.95
31	64-17 (resample)	756.0	0.90	1.14	0.00	0.04	24.76	29.31	0.00	0.00	14.05	64.08
32	64-18	724.4	0.88	1.06	0.00	0.04	21.45	67.48	0.00	0.00	13.38	98.47
33	64-19	842.1	0.96	1.08	0.00	0.04	17.75	24.96	0.00	0.00	14.17	52.85
34	64-20	762.9	0.77	1.37	0.00	0.03	24.93	19.96	0.00	0.00	14.38	55.03
35	64-21	827.3	1.91	1.19	0.13	0.09	22.02	7.39	0.00	0.00	23.34	46.25
36	64-22	785.6	0.00	1.29	0.00	0.00	22.54	45.67	0.00	0.00	7.75	73.38

Table B2. Gamma Spectrometry Data on Randomly Selected Soil Samples Taken From the Side Yard Area During Soil Removal (Sheet 2 of 3)

	39	40	41	42	43	44	45	46	47	48	49	50
37	64-23	801.0	0.89	1.43	0.00	0.04	22.12	25.49	0.00	0.00	15.75	58.75
38	64-24	788.0	1.02	1.12	0.00	0.05	24.96	8.49	0.00	0.00	14.83	44.06
39	64-25	758.0	0.90	1.30	0.00	0.04	22.69	31.39	0.00	0.00	15.01	64.72
40	64-26	755.9	0.96	1.69	0.00	0.04	21.80	50.28	0.00	0.00	17.83	84.66
41	64-27	818.3	1.18	1.08	0.00	0.05	20.14	51.75	0.00	0.00	15.91	83.34
42	64-28 (resample)	735.4	0.00	0.00	0.00	0.00	23.05	96.23	0.00	0.00	0.00	119.28
43	64-28	788.4	0.00	1.75	0.00	0.00	19.52	136.10	0.00	0.00	10.52	162.63
44	64-28 (2)	751.4	0.00	1.60	0.00	0.00	20.87	168.49	0.00	0.00	9.61	195.76
45	64-29	714.0	0.00	0.00	0.00	0.00	19.31	105.83	0.00	0.00	0.00	125.14
46	64-30	651.0	1.22	1.33	0.00	0.06	24.09	2.24	0.00	0.00	17.75	39.02
47	64-31	747.0	0.94	1.46	0.00	0.04	21.77	15.38	0.00	0.00	16.32	48.70
48	64-32	741.0	0.74	1.61	0.00	0.03	22.15	1.48	0.00	0.00	15.58	34.54
49	64-33	780.0	0.85	1.09	0.00	0.04	20.76	35.56	0.00	0.00	13.33	65.81
50	64-34	755.0	0.80	1.13	0.00	0.04	21.54	7.89	0.00	0.00	13.18	38.78
51	64-35	803.8	0.89	1.22	0.00	0.04	21.14	10.70	0.00	0.00	14.45	42.10
52	64-36 (resample)	698.0	1.12	1.36	0.00	0.05	23.07	10.53	0.00	0.00	17.16	45.84
53	64-36	760.4	0.98	1.26	0.00	0.04	22.44	11.60	0.00	0.00	15.41	45.01
54	64-36(2)	818.6	0.00	1.13	0.00	0.00	20.40	144.03	0.00	0.00	6.79	168.95
55	64-37	761.0	0.82	1.03	0.00	0.04	22.42	7.12	0.00	0.00	12.71	38.59
56	64-38	783.7	0.00	1.21	0.00	0.00	22.32	28.00	0.00	0.00	7.25	55.15
57	64-39	637.7	0.00	1.33	0.00	0.00	22.31	8.77	0.00	0.00	7.95	36.38
58	64-40	733.7	1.03	1.12	0.00	0.05	20.49	5.82	0.00	0.00	14.93	36.99
59	64-41	674.0	0.99	1.32	0.00	0.04	21.97	10.96	0.00	0.00	15.84	44.20
60	64-42	676.8	0.92	1.40	0.00	0.04	22.64	2.23	0.00	0.00	15.80	36.06
61	64-43	637.9	0.00	1.72	0.00	0.00	20.60	69.15	0.00	0.00	10.29	96.61
62	64-44	717.3	0.66	1.37	0.00	0.03	22.98	3.09	0.00	0.00	13.49	35.53
63	64-45	734.3	0.75	1.25	0.00	0.03	17.80	8.56	0.00	0.00	13.55	35.93
64	64-46	748.3	0.73	1.07	0.00	0.03	19.59	4.87	0.00	0.00	12.31	33.19
65	64-47	740.7	0.77	0.87	0.00	0.03	20.09	6.28	0.00	0.00	11.34	34.48
66	64-48	709.9	0.80	1.19	0.00	0.04	21.58	8.20	0.00	0.00	13.56	39.39
67	64-49	651.1	0.51	1.16	0.00	0.02	24.87	10.02	0.00	0.00	11.03	42.60
68	64-50	643.6	0.80	1.13	0.00	0.04	22.00	8.40	0.00	0.00	13.18	39.75
69	64-51	631.6	1.00	1.09	0.00	0.04	23.67	6.08	0.00	0.00	14.52	40.14
70	64-52	755.3	0.66	1.25	0.00	0.03	21.62	12.30	0.00	0.00	12.79	42.92
71	64-53	618.0	0.90	1.07	0.00	0.04	20.44	1.51	0.00	0.00	13.68	31.71
72	64-54	758.6	0.89	1.25	0.00	0.04	20.58	4.63	0.00	0.00	14.58	35.56

Table B2. Gamma Spectrometry Data on Randomly Selected Soil Samples
Taken From the Side Yard Area During Soil Removal (Sheet 3 of 3)

	39	40	41	42	43	44	45	46	47	48	49	50
73	64-55	716.5	1.12	1.13	0.00	0.05	21.48	13.92	0.00	0.00	15.77	46.71
74	64-56	849.6	0.82	1.18	0.00	0.04	20.68	6.22	0.00	0.00	13.65	36.58
75	64-57	704.4	0.77	1.11	0.00	0.03	19.89	5.41	0.00	0.00	12.83	34.40
76	64-58	643.2	0.00	1.11	0.00	0.00	24.83	41.59	0.00	0.00	6.68	70.87
77	64-59	691.9	1.02	1.11	0.00	0.05	18.89	2.17	0.00	0.00	14.83	31.68
78	64-60	822.5	1.83	1.59	0.00	0.08	22.33	13.45	0.00	0.00	24.15	53.19
79	64-61	797.8	0.87	1.30	0.00	0.04	18.56	5.96	0.00	0.00	14.77	34.99
80	64-62	789.9	0.78	1.22	0.00	0.04	21.81	23.32	0.00	0.00	13.56	54.73
81	64-63	698.4	0.68	0.99	0.00	0.03	21.35	45.73	0.00	0.00	11.39	75.16
82	64-64	755.4	0.00	1.02	0.00	0.00	20.56	13.14	0.00	0.00	6.10	37.76

Table B3. Gamma Spectrometry Data on Soil Samples Taken from the Post-Decontamination Side Yard Grids (Sheet 1 of 3)

	39	40	41	42	43	44	45	46	47	48	49	50
1	BLDG 064 SIDEYARD GRID DATA (AFTER DECONTAMINATION)											
2	(Samples Analyzed: 8/29/89 to 9/19/89)											
3	Excel File:	064Yard.xls										
4												
5			picocuries per gram of each radionuclide									
6					186 keV	185.6 keV						
7			U-238	Th-232	U-235	U-235	K-40	Cs-137	Cs-134	Co-60	Derived Alpha	Derived Beta
8	Sample				(from	(from					pCi/g	pCi/g
9	Description				Ra-226)	U-238)						
10												
11	Remarks	Mass	c32*1e6/	c33*1e6/	c34*1e6/	c41*.045	c35*1e6/	c36*1e6/	c37*1e6/	c38*1e6/	8*c41+6*c42	6*c41+4*c42+4*
12		(grams)	c2	c2	c2		c2	c2	c2	c2	+7*c43	c43+sum(c44:48)
13												
14	T/064 Sample Grid G-1	724.0	0.80	1.10	0.00	0.04	20.91	11.36	0.00	0.00	12.98	41.49
15	T/064 Sample Grid G-2	829.0	0.83	1.30	0.00	0.04	19.81	17.60	0.00	0.00	14.41	47.60
16	T/064 Sample Grid G-3	726.0	0.84	1.12	0.00	0.04	23.07	10.08	0.00	0.00	13.45	42.71
17	T/064 Sample Grid G-4	737.0	1.13	1.28	0.07	0.05	19.35	17.10	0.00	0.00	17.22	48.68
18	T/064 Sample Grid G-5	799.0	0.75	1.34	0.00	0.03	20.65	5.49	0.00	0.00	14.05	36.05
19	T/064 Sample Grid G-6	882.0	0.81	1.01	0.00	0.04	20.26	3.49	0.00	0.00	12.58	32.71
20	T/064 Sample Grid G-7	736.0	0.85	1.25	0.04	0.04	18.07	0.00	0.00	0.00	14.58	28.36
21	T/064 Sample Grid G-8	770.0	0.93	1.08	0.05	0.04	20.81	0.75	0.00	0.00	14.31	31.72
22	T/064 Sample Grid G-9	812.0	0.65	0.82	0.00	0.03	20.92	2.08	0.00	0.00	10.19	30.26
23	T/064 Sample Grid G-10	819.0	1.02	1.44	0.08	0.05	22.11	1.26	0.00	0.00	17.37	35.63
24	T/064 Sample Grid G-11	725.0	0.87	1.15	0.00	0.04	18.57	1.41	0.00	0.00	13.83	29.81
25	T/064 Sample Grid G-12	782.0	0.80	1.30	0.00	0.04	22.54	12.97	0.00	0.00	14.19	45.54
26	T/064 Sample Grid G-13	782.0	0.88	1.47	0.00	0.04	19.46	1.90	0.00	0.00	15.91	32.59
27	T/064 Sample Grid G-14	751.0	0.95	1.09	0.07	0.04	20.91	5.07	0.00	0.00	14.68	36.39
28	T/064 Sample Grid G-15	793.0	1.14	1.07	0.10	0.05	20.10	3.69	0.00	0.00	16.23	35.36
29	T/064 Sample Grid G-16	831.0	0.84	1.26	0.00	0.04	21.41	9.87	0.00	0.00	14.22	41.35
30	T/064 Sample Grid G-17	619.0	1.09	1.50	0.06	0.05	22.00	0.41	0.00	0.00	18.20	35.28
31	T/064 Sample Grid G-18	783.0	1.09	1.13	0.08	0.05	17.80	12.05	0.00	0.00	16.11	41.31
32	T/064 Sample Grid G-19	761.0	0.95	1.08	0.00	0.04	23.06	2.95	0.00	0.00	14.02	36.03
33	T/064 Sample Grid G-20	777.0	1.27	1.30	0.11	0.06	18.35	5.61	0.00	0.00	18.80	37.32

Table B3. Gamma Spectrometry Data on Soil Samples
Taken from the Post-Decontamination Side Yard Grids (Sheet 2 of 3)

	39	40	41	42	43	44	45	46	47	48	49	50
34	T/064 Sample Grid G-21	804.0	0.88	1.35	0.00	0.04	22.23	1.98	0.00	0.00	15.16	34.95
35	T/064 Sample Grid G-22	807.0	0.92	1.12	0.06	0.04	19.36	1.29	0.00	0.00	14.47	30.91
36	T/064 Sample Grid G-23	801.0	0.80	1.16	0.00	0.04	20.81	5.28	0.00	0.00	13.34	35.55
37	T/064 Sample Grid G-24	759.0	0.90	1.22	0.00	0.04	21.96	12.84	0.00	0.00	14.56	45.15
38	T/064 Sample Grid G-25	790.0	0.80	1.10	0.00	0.04	22.32	2.07	0.00	0.00	12.99	33.62
39	T/064 Sample Grid G-26	770.0	0.82	1.25	0.00	0.04	20.29	2.84	0.00	0.00	14.06	33.08
40	T/064 Sample Grid G-27	929.0	0.85	1.20	0.00	0.04	19.75	1.73	0.00	0.00	14.00	31.42
41	T/064 Sample Grid G-28	800.0	0.89	1.25	0.00	0.04	21.14	2.73	0.00	0.00	14.64	34.26
42	T/064 Sample Grid G-29	810.0	1.09	1.29	0.07	0.05	22.56	6.19	0.00	0.00	17.00	40.81
43	T/064 Sample Grid G-30	882.0	1.34	1.04	0.10	0.06	19.44	5.38	0.00	0.00	17.69	37.50
44	T/064 Sample Grid G-31	784.0	0.78	1.26	0.00	0.04	21.15	5.30	0.00	0.00	13.81	36.21
45	T/064 Sample Grid G-32	810.0	0.80	1.89	0.00	0.04	21.57	8.15	0.00	0.00	17.78	42.14
46	T/064 Sample Grid G-33	829.0	1.25	1.14	0.08	0.06	22.23	4.46	0.00	0.00	17.46	39.16
47	T/064 Sample Grid G-34	759.0	0.92	1.25	0.00	0.04	22.49	6.49	0.00	0.00	14.84	39.53
48	T/064 Sample Grid G-35	697.0	1.27	1.23	0.08	0.06	21.84	9.33	0.00	0.00	18.15	44.11
49	T/064 Sample Grid G-36	669.0	1.32	1.67	0.10	0.06	20.84	8.74	0.00	0.00	21.37	44.70
50	T/064 Sample Grid G-37	593.0	1.00	1.44	0.00	0.05	24.45	8.90	0.00	0.00	16.68	45.18
51	T/064 Sample Grid G-38	725.0	1.13	1.74	0.08	0.05	21.32	6.95	0.00	0.00	20.08	42.42
52	T/064 Sample Grid G-39	748.0	1.08	1.20	0.08	0.05	20.78	5.66	0.00	0.00	16.40	38.08
53	T/064 Sample Grid G-40	760.0	0.99	1.17	0.00	0.04	21.71	5.87	0.00	0.00	14.94	38.24
54	T/064 Sample Grid G-41	826.0	1.30	1.07	0.08	0.06	21.73	4.55	0.00	0.00	17.40	38.75
55	T/064 Sample Grid G-42	736.0	1.05	1.38	0.00	0.05	20.46	3.02	0.00	0.00	16.72	35.38
56	T/064 Sample Grid G-43	872.0	1.02	1.35	0.07	0.05	19.21	3.63	0.00	0.00	16.76	34.68
57	T/064 Sample Grid G-44	744.0	0.88	1.29	0.00	0.04	16.69	1.30	0.00	0.00	14.80	28.50
58	T/064 Sample Grid G-45	843.0	0.97	1.12	0.00	0.04	19.77	9.14	0.00	0.00	14.51	39.28
59	T/064 Sample Grid G-46	796.0	0.84	1.13	0.00	0.04	17.11	16.68	0.00	0.00	13.50	43.39
60	T/064 Sample Grid G-47	833.0	0.92	1.08	0.00	0.04	18.08	0.96	0.00	0.00	13.87	28.94
61	T/064 Sample Grid G-48	632.0	1.79	1.24	0.12	0.08	22.69	2.07	0.00	0.00	22.56	40.99
62	T/064 Sample Grid G-49	755.0	0.76	1.52	0.00	0.03	22.08	0.89	0.00	0.00	15.19	33.64
63	T/064 Sample Grid G-50	825.0	1.12	1.17	0.08	0.05	18.64	0.00	0.00	0.00	16.52	30.40
64	T/064 Sample Grid G-51	877.0	0.90	1.04	0.04	0.04	17.26	0.25	0.00	0.00	13.69	27.25
65	T/064 Sample Grid G-52	883.0	1.59	1.34	0.10	0.07	19.78	1.66	0.00	0.00	21.47	36.82
66	T/064 Sample Grid G-53	825.0	1.39	1.43	0.09	0.06	20.30	1.92	0.00	0.00	20.32	36.69

Table B3. Gamma Spectrometry Data on Soil Samples
Taken from the Post-Decontamination Side Yard Grids (Sheet 3 of 3)

	39	40	41	42	43	44	45	46	47	48	49	50
67	T/064 Sample Grid G-54	788.0	0.90	1.27	0.00	0.04	19.11	0.43	0.00	0.00	14.81	30.05
68	T/064 Sample Grid G-55	826.0	1.00	1.27	0.00	0.04	20.07	0.27	0.00	0.00	15.60	31.45
69	T/064 Sample Grid G-56	844.0	1.05	1.20	0.00	0.05	20.32	0.34	0.00	0.00	15.59	31.80
70	T/064 Sample Grid G-57	784.0	0.97	1.03	0.00	0.04	19.52	2.13	0.00	0.00	13.94	31.63
71	T/064 Sample Grid G-58	745.0	0.99	1.06	0.00	0.04	19.25	2.04	0.00	0.00	14.27	31.51
72	T/064 Sample Grid G-59	756.0	1.06	1.36	0.06	0.05	20.13	2.59	0.00	0.00	17.04	34.80
73	T/064 Sample Grid G-60	737.0	1.48	1.62	0.11	0.07	26.31	1.03	0.00	0.00	22.34	43.22

APPENDIX C

GROSS ALPHA AND GROSS BETA ACTIVITY DATA ON T064 SIDE YARD SOIL SAMPLES AFTER DECONTAMINATION

Gross alpha and gross beta measurements were performed on 2–g soil samples from the 60 grid locations within the Building T064 Side Yard decontaminated area. Soil samples for analysis were collected and analyzed in June and July 1989.

Table C1 gives the gross alpha and gross beta results for the grid locations. Shown in the table are the net counts taken over a 100 minute time period, and the resulting calculated alpha and beta activities in pCi/g. Estimates of the standard deviation in the activity values are also shown. The data were compiled using the SOILTEMP spreadsheet.

Table C1. Gross Alpha and Gross Beta Measurements on 2–g Side Yard Soil Samples (Sheet 1 of 2)

Grid Number	Alpha Activity (pCi/g)	Standard Deviation (1σ)	Beta Activity (pCi/g)	Standard Deviation (1σ)
1	42.5	3.4	34.4	1.1
2	42.5	3.4	34.0	1.0
3	44.3	3.5	50.1	1.3
4	44.3	3.5	41.9	1.2
5	40.6	3.4	29.6	1.0
6	37.9	3.3	26.8	0.9
7	27.7	2.9	22.8	0.9
8	35.0	3.2	25.7	0.9
9	37.7	3.3	26.5	0.9
10	41.1	3.4	25.3	0.9
11	43.3	3.5	27.5	0.9
12	43.8	3.5	38.5	1.1
13	43.0	3.5	28.7	1.0
14	38.9	3.3	29.8	1.0
15	41.1	3.4	27.3	0.9
16	32.6	3.1	30.7	1.0
17	33.5	3.1	26.4	0.9
18	42.8	3.5	37.6	1.1
19	37.2	3.2	27.3	0.9
20	39.1	3.3	30.7	1.0
21	31.1	3.0	27.2	0.9
22	35.5	3.2	26.2	0.9
23	37.7	3.3	27.4	0.9
24	44.5	3.5	38.5	1.1
25	33.8	3.1	26.3	0.9
26	41.8	3.4	25.6	0.9
27	33.5	3.1	27.2	0.9
28	36.2	3.2	29.4	1.0
29	33.0	3.1	31.7	1.0
30	33.0	3.1	30.2	1.0
31	41.1	3.4	30.3	1.0
32	38.9	3.3	37.9	1.1
33	35.7	3.2	29.9	1.0
34	34.3	3.1	32.0	1.0
35	38.9	3.3	32.0	1.0
36	40.1	3.4	33.4	1.0
37	40.6	3.4	35.9	1.1
38	45.5	3.5	32.4	1.0
39	34.0	3.1	31.2	1.0

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Table C1. Gross Alpha and Gross Beta Measurements on 2–g Side Yard Soil Samples (Sheet 2 of 2)

Grid Number	Alpha Activity (pCi/g)	Standard Deviation (1σ)	Beta Activity (pCi/g)	Standard Deviation (1σ)
40	45.0	3.5	31.0	1.0
41	45.0	3.5	29.3	1.0
42	37.2	3.2	28.1	1.0
43	36.9	3.2	29.7	1.0
44	44.7	3.5	27.2	0.9
45	48.4	3.6	34.7	1.1
46	49.1	3.7	43.1	1.2
47	37.7	3.3	26.1	0.9
48	47.2	3.6	27.9	1.0
49	41.8	3.4	26.7	0.9
50	44.7	3.5	26.1	0.9
51	43.8	3.5	27.0	0.9
52	37.7	3.3	27.7	1.0
53	38.4	3.3	27.1	0.9
54	45.0	3.5	27.4	0.9
55	33.0	3.1	26.7	0.9
56	35.7	3.2	27.8	1.0
57	36.5	3.2	28.7	1.0
58	38.4	3.3	28.5	1.0
59	39.6	3.3	27.7	1.0
60	34.5	3.1	27.1	0.9

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APPENDIX D

INPUT DATA FOR RESRAD CODE CALCULATIONS

RESRAD calculations were performed for four different potential current and future land use scenarios for the T064 Side Yard area. Each scenario was analyzed three times to yield acceptance limits for ^{137}Cs and ^{90}Sr (in pCi/g) and to provide realistic current and future dose estimates (in mrem/year) for the pre– and post–decontamination conditions.

Each of these 12 analyses involved the input of about 80 different parameters, many of which were researched to provide site specific values for the SSFL Side Yard area in question. The values input to RESRAD for each of the three runs for each scenario are summarized in Table D1. For comparison, the "default" values assumed by RESRAD are shown in the last column.

Table D1. Input Parameters for T064 Side Yard RESRAD Runs (Sheet 1 of 3)

RESRAD PARAMETER	Industrial Scenario			Residential Scenario			Wilderness Scenario			Family Farm Scenario			RESRAD
	Before	After	Infinite	Before	After	Infinite	Before	After	Infinite	Before	After	Infinite	Default
Area of contaminated zone (m**2)	421	421	100000	421	421	100000	421	421	100000	421	421	100000	10000
Thickness of contaminated zone (m)	0.81	0.41	34.9	0.81	0.41	35	0.81	0.41	35	0.81	0.41	35	1
Length parallel to aquifer flow (m)	34	34	316	34	34	316	34	34	316	34	34	316	100
Basic radiation dose limit (mrem/yr)	100	100	100	100	100	100	100	100	100	100	100	100	100
Times for calculations (yr)	1	1	1	1	1	1	1	1	1	1	1	1	1
Times for calculations (yr)	10	10	10	10	10	10	10	10	10	10	10	10	10
Times for calculations (yr)	100	100	100	100	100	100	100	100	100	100	100	100	100
Times for calculations (yr)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Times for calculations (yr)	0	0	0	0	0	0	0	0	0	0	0	0	10000
Times for calculations (yr)	0	0	0	0	0	0	0	0	0	0	0	0	0
Times for calculations (yr)	0	0	0	0	0	0	0	0	0	0	0	0	0
Times for calculations (yr)	0	0	0	0	0	0	0	0	0	0	0	0	0
Times for calculations (yr)	0	0	0	0	0	0	0	0	0	0	0	0	0
Initial principal radionuclide (pCi/g): Cs-137	32.8	4.9	4.9	32.8	4.9	4.9	32.8	4.9	4.9	32.8	4.9	4.9	0
Initial principal radionuclide (pCi/g): Sr-90	32.8	4.9	4.9	32.8	4.9	4.9	32.8	4.9	4.9	32.8	4.9	4.9	0
Cover depth (m)	0	0	0	0	0	0	0	0	0	0	0	0	0
Density of cover material (g/cm**3)													1.6
Cover depth erosion rate (m/yr)													0.001
Density of contaminated zone (g/cm**3)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.6
Contaminated zone erosion rate (m/yr)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Contaminated zone total porosity	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Contaminated zone effective porosity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Contaminated zone hydraulic conductivity (m/yr)	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10
Contaminated zone b parameter	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Evapotranspiration coefficient	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6
Precipitation (m/yr)	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	1
Irrigation (m/yr)	0	0	0	0	0	0	0	0	0	1	1	1	0.2
Irrigation mode	ditch	ditch	ditch	ditch	ditch	ditch	ditch	ditch	ditch	overhead	overhead	overhead	overhead
Runoff coefficient	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.5	0.5	0.5	0.2
Watershed area for nearby stream or pond (m**2)	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000

Table D1. Input Parameters for T064 Side Yard RESRAD Runs (Sheet 2 of 3)

RESRAD PARAMETER	Industrial Scenario			Residential Scenario			Wilderness Scenario			Family Farm Scenario			RESRAD
	Before	After	Infinite	Before	After	Infinite	Before	After	Infinite	Before	After	Infinite	Default
Density of saturated zone (g/cm**3)	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Saturated zone total porosity	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.4
Saturated zone effective porosity	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.2
Saturated zone hydraulic conductivity (m/yr)	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	100
Saturated zone hydraulic gradient	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Saturated zone b parameter	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Distance from surface to water table (m)	35	35	35	35	35	35	35	35	35	35	35	35	5
Water table drop rate (m/yr)	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.001
Well pump intake depth (m below water table)	10	10	10	10	10	10	10	10	10	10	10	10	10
Model: Nondispersion (ND) or Mass-Balance (MB)	MB	MB	ND	MB	MB	ND	MB	MB	ND	MB	MB	ND	ND
Individual's use of groundwater (m**3/yr)	1E-10	1E-10		1E-10	1E-10		1E-10	1E-10		150	150		150
Number of unsaturated zone strata	1	1	0	1	1	0	1	1	0	1	1	0	1
Unsat. zone 1, thickness (m)	34.19	34.59		34.19	34.59		34.19	34.59		34.19	34.59		4
Unsat. zone 1, soil density (g/cm**3)	1.4	1.4		1.4	1.4		1.4	1.4		1.4	1.4		1.6
Unsat. zone 1, total porosity	0.4	0.4		0.4	0.4		0.4	0.4		0.4	0.4		0.4
Unsat. zone 1, effective porosity	0.2	0.2		0.2	0.2		0.2	0.2		0.2	0.2		0.2
Unsat. zone 1, soil-specific b parameter	5.3	5.3		5.3	5.3		5.3	5.3		5.3	5.3		5.3
Unsat. zone 1, hydraulic conductivity (m/yr)	10000	10000		10000	10000		10000	10000		10000	10000		100
Distribution coefficients for Cs-137													
Contaminated zone (cm**3/g)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Unsaturated zone 1 (cm**3/g)	1000	1000		1000	1000		1000	1000		1000	1000		1000
Saturated zone (cm**3/g)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Leach rate (/yr)	0	0	0	0	0	0	0	0	0	0	0	0	0
Distribution coefficients for Sr-90													
Contaminated zone (cm**3/g)	30	30	30	30	30	30	30	30	30	30	30	30	30
Unsaturated zone 1 (cm**3/g)	30	30		30	30		30	30		30	30		30
Saturated zone (cm**3/g)	30	30	30	30	30	30	30	30	30	30	30	30	30
Leach rate (/yr)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D1. Input Parameters for T064 Side Yard RESRAD Runs (Sheet 3 of 3)

RESRAD PARAMETER	Industrial Scenario			Residential Scenario			Wilderness Scenario			Family Farm Scenario			RESRAD
	Before	After	Infinite	Before	After	Infinite	Before	After	Infinite	Before	After	Infinite	Default
Inhalation rate (m**3/yr)	8400	8400	8400	8400	8400	8400	8400	8400	8400	8400	8400	8400	8400
Mass loading for inhalation (g/m**3)	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Occupancy and shielding factor, external gamma	0.08	0.08	0.08	0.27	0.27	0.27	0.005	0.005	0.005	0.6	0.6	0.6	0.6
Occupancy factor, inhalation	0.14	0.14	0.14	0.48	0.48	0.48	0.005	0.005	0.005	0.45	0.45	0.45	0.45
Shape factor, external gamma	0.96	0.96	1	0.96	0.96	1	0.96	0.96	1	0.96	0.96	1	1
Mixing height for airborne dust, inhalation (m)	3	3	3	3	3	3	3	3	3	3	3	3	3
Fruits, vegetables and grain consumption (kg/yr)	0	0	0	16	16	16	0	0	0	160	160	160	160
Leafy vegetable consumption (kg/yr)	0	0	0	1.4	1.4	1.4	0	0	0	14	14	14	14
Milk consumption (L/yr)	0	0	0	0	0	0	0	0	0	92	92	92	92
Meat and poultry consumption (kg/yr)	0	0	0	0	0	0	0	0	0	63	63	63	63
Fish consumption (kg/yr)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Other seafood consumption (kg/yr)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Drinking water intake (L/yr)	410	410	410	410	410	410	410	410	410	410	410	410	410
Fraction of drinking water from site	0	0	0	0	0	0	0	0	0	1	1	1	1
Fraction of aquatic food from site	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5
Livestock fodder intake for meat (kg/day)	68	68	68	68	68	68	68	68	68	68	68	68	68
Livestock fodder intake for milk (kg/day)	55	55	55	55	55	55	55	55	55	55	55	55	55
Livestock water intake for meat (L/day)	50	50	50	50	50	50	50	50	50	50	50	50	50
Livestock water intake for milk (L/day)	160	160	160	160	160	160	160	160	160	160	160	160	160
Mass loading for foliar deposition (g/m**3)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Depth of soil mixing layer (m)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Depth of roots (m)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Drinking water fraction from ground water	0	0	0	0	0	0	0	0	0	1	1	1	1
Livestock water fraction from ground water	0	0	0	0	0	0	0	0	0	1	1	1	1
Irrigation fraction from ground water	0	0	0	0	0	0	0	0	0	1	1	1	1

APPENDIX E

LIST OF ITEMS IN THE BUILDING T064 SIDE YARD DECOMMISSIONING FILE

The following is an annotated list of documents on the decontamination of the Building T064 Side Yard. The documents listed below are archived in Building T100 of Rockwell International's Santa Susana Field Laboratory (SSFL).

1. Chapman, J. A., "Radiological Survey of the Source and Special Nuclear Material Storage Vault–Bldg. T64," Energy Technology Engineering Center Report GEN–ZR–0005, August 19, 1988.

    - The primary document reporting the comprehensive radiological survey of Building T064, its fenced–in yard, and a 2–acre surrounding area. Of the open areas (the fenced–in yard and 2–acre surrounding area) surveyed, a 4,000 ft^2 area in the vicinity of the eastern fence was found to be contaminated with ^{137}Cs and a larger, 4,500 ft^2 total area was subsequently designated as the Building T064 Side Yard. The above report recommended further investigations of the Side Yard area.

2. Parker, D., "Building 064 Soil Decontamination," Rockwell International Detailed Work Procedure N001DWP000023, July 31, 1989.

    - Describes the operational procedures used to decontaminate the Building T064 Side Yard.

3. Five photographs taken during the Side Yard decontamination operations.

4. SOILTEMP spreadsheets corresponding to data from the 78 (60 grid locations and 18 perimeter locations) gamma exposure rate, 60 soil gross alpha, and 60 soil gross beta measurements.

5. Gamma Mass Spectrometric Analysis (MCA) printouts and corresponding MCASOIL spreadsheets for the following: (1) 18 scoping analyses (pre–decon) soil sample, (2) 64 soil samples from the B–12 boxes, and (3) 60 post–decontamination soil samples from the T064 Side Yard grid locations.

6. Twelve RESRAD summary outputs (10 pages each) corresponding to (1) the industrial, (2) residential, (3) wilderness, and (4) family farm use scenarios. There are three outputs for each scenario showing (a) the estimated annual doses for a plausible current or future user "before" decontamination of the Side Yard, (b) the estimated doses "after" decontamination of the Side Yard, and (c) calculated values of radionuclide concentration limits established with "infinitely" large dimensions for the contamination zone.

7. Subbaraman, G., and Oliver, B.M., "Final Decontamination and Radiological Survey of the Building T064 Side Yard," Rockwell International Safety Review Report N704SRR990031, October 1990.

APPENDIX F

EXCAVATION AND SAMPLING FOLLOWING THE ORISE SURVEY

During the independent verification survey performed by the Oak Ridge Institute of Science and Education (ORISE), two hot spots were detected in the Building T064 Side Yard. ("Verification Survey of the Old Conservation Yard, Building T064 Side Yard and Building T028, Santa Susana Field Laboratory, Rockwell International, Canoga Park, California," ORISE, Draft Report, December 1992.)

The ORISE data is summarized below:

Location	Area (m^2)	Cs-137 (pCi/g)	Criterion* (pCi/g)	Pass/Fail
19.5N, 8.5W	1	210	604	Pass
19.5N, 8.5W	100	27.5	60.4	Pass
9N, 19.5W	1	35.1	604	Pass
9N, 19.5.W	100	7.5	60.4	Pass
*Criterion for average of $100m^2$ is 60.4 pCi/gm based or 100 mrem/y. Hot spot criterion for area $\leq lm^2$ is $(100/A)^{1/2}$ x 60.4 = 604 pCi/g (assuming equal quantities of Cs-137 and Sr-90).				

All ORISE sample data met the published Rocketdyne criteria based on 100 mrem/y.

At the March 1993 IVC meeting, DOE imposed a 10 mrem/y dose criterion on the T064 Side Yard retroactively. This resulted in the soil concentration criterion being reduced by a factor of 10 and the above table then changed to:

Location	Area (m^2)	Cs-137 (pCi/g)	Criterion* (pCi/g)	Pass/Fail
19.5N, 8.5W	1	210	60.4	Fail
19.5N, 8.5W	100	27.5	6.04	Fail
9N, 19.5W	1	35.1	60.4	Pass
9N, 19.5.W	100	7.5	6.04	Fail
*Based on retroactive DOE imposed limit of 10 mrem/year, 6.04 pCi/gm for 100 m^2 average, 60.4 pCi/gm for lm^2 hot spot (assuming equal quantities of Cs-137 and Sr-90).				

The two hot spots therefore now failed the revised soil concentration limits.

The two lm^2 hot spot locations were excavated during July 1993 and additional samples taken. One sample was taken from each hot spot location. In addition, two composite samples were prepared from each 100 m^2 area. Each composite sample included soil from the hot spot plus four additional locations from within the 100 m^2 area using the same protocol as ORISE. Each sample was submitted to gamma spectoscopy for Cs-137 and results were as follows:

Location	Area (m^2)	Cs-137 (pCi/g)	Criterion* (pCi/g)	Pass/Fail
19.5N, 8.5W	1	4.4	70.8	Pass
19.5N, 8.5W	100	3.5	7.08	Pass
9N, 19.5W	1	2.2	70.8	Pass
9N, 19.5.W	100	2.8	7.08	Pass
*Based on retroactive DOE imposed limit of 10 mrem/year for a single Cs-137 isotope, 7.08 pCi/gm for 100 m^2 average, 70.8 pCi/gm for lm^2 hot spot.				

Since the ORISE sample results confirmed very low levels of Sr-90, the combined Cs-137/Sr-90 limit of 6.04 pCi/gm has been replaced in the above table by the single Cs-137 isotope limit of 7.08 pCi/gm (see Page 50).

Based on these results, the hot spots detected by ORISE have been removed and the remaining soil meets the revised hot spot (70.8 pCi/gm) and average (7.08 pCi/gm) limits based on a 10 mrem/year limit to a residential user.