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ABSTRACT

A comprehensive radiological survey of a 5-acre area comprising three SSFL storage yards was performed in 1988. In accordance with that survey report's recommendation, remedial efforts were undertaken in a localized area of the Old Conservation Yard, to reduce a slight 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 Old Conservation Yard are well below the applicable limits, and that the residual activity poses no hazard to potential current and future users of the site.

Results of the surveys demonstrate that the 5-acre storage yard area, including the Old Conservation Yard, meets the requirements of DOE Order 5400.5, "Radiation Protection of the Public and Environment" (February 1990), for release without radiological restrictions.

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SUMMARY

PURPOSE. This Safety Review Report provides an assessment of residual radioactivity present at the Old Conservation Yard (OCY) located at Rockwell International's Santa Susana Field Laboratories (SSFL) following decontamination of a localized area of the yard. Near- and long-term consequences due to the presence of the residual activities to current and future occupants of the decontaminated area were evaluated to determine if this location is acceptably free of radioactive contamination.

BACKGROUND. A comprehensive radiological survey of portions of the SSFL was performed in 1988. Included in this survey was a 5-acre area of storage and conservation yards which had been used in support of nuclear research and development activities during the 1960s and 1970s. The survey showed a 20-ft by 20-ft area of the OCY to be slightly contaminated with ^{137}Cs and recommended further investigation. The remainder of the 5-acre area was found to contain only naturally occurring radioactivity.

WORK PERFORMED. To reduce contamination to levels that are as low as reasonably achievable (ALARA), the top layer of soil from the affected area was removed to a depth of about 4 inches and the area was resurveyed. The remaining ^{137}Cs activity in the soil 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 due to the presence of this residual activity.

STATUS. The OCY remains an open area and is used as a storage location for shipping trailers.

CONCLUSION. Based on results of the 1988 survey and the subsequent work described here, residual radioactivity levels in the decontaminated area of the OCY and the surrounding 5-acre area are well within acceptable regulatory limits, and pose no hazard to the safety and health of potential current or future occupants. Therefore, the site can be released for unrestricted use.

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 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 no residual radioactivity exceeds applicable limits. Findings from the survey 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 the Old Conservation Yard and a surrounding 5–acre area was performed in 1988 (Ref. 2). Results of the survey showed slight soil contamination (45 to 132 pCi/g of ^{137}Cs) at certain locations in the OCY, with the remaining area containing only naturally occurring radioactivity (about 25 pCi/g–beta). As recommended in the survey report, investigations were carried out, during which the contaminated top soil was removed from a portion of the OCY for disposal, and additional surveys and analyses were performed. These efforts are documented in this safety review report (SRR).

The findings presented in this SRR include results of a statistical treatment of the measured external gamma dose rates and soil residual radioactivity data, and comparisons against regulatory acceptance limits. While gamma exposure rates can be compared with a generic regulatory acceptance limit, a corresponding generic limit for allowable concentration of ^{137}Cs in soil is not available. Recently, however, the U.S. DOE has established 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 OCY using this code, are also presented in this report.

This report is organized as follows: A background on the OCY at SSFL, including 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 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. Appendices A and B provide a variety of related data obtained from the survey and analyses. Input data used to perform the RESRAD code calculations are included in Appendix C. Appendix D provides a list of items of record obtained during the D&D and surveys, which are archived at Rockwell. Summary outputs of the RESRAD calculations are maintained in the archives.

2. BACKGROUND

2.1 LOCATION

The Old Conservation Yard 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 vicinity is shown in Figure 1. An enlarged map of neighboring SSFL communities is shown in Figure 2. Figure 3 shows relevant portions of a 1967 edition of the U.S. Geological Survey (USGS) topographic map of the Calabasas Quadrangle where SSFL is located, with the authors' markup of the location of the Old Conservation Yard. Using USGS terminology, the current USGS location description for the Old Conservation Yard is: Township T2N; Range R17W; and, Section 19, Calabasas Quadrangle.

Figure 4 is a plot plan of the western portion of the SSFL, known as Area IV, where the Old Conservation Yard is located. Although the term Old Conservation Yard is used here to contrast it with the adjoining "new" conservation yard, the terminology itself is recent, and requires some clarification. Figure 5 shows an aerial photograph of three yards in SSFL: Old Energy Systems Group (ESG) Salvage Yard, Rocketdyne Barrel Storage Yard (also known as the Conservation Yard) and New Salvage Yard (also known as T583). The three yards, totaling approximately 5 acres in area, were the subject of a comprehensive radiological survey performed in 1988 (Ref. 2), and a portion of the Rocketdyne Barrel Storage Yard was identified in the survey as requiring further investigation. This area has since been termed the Old Conservation Yard. Additional figures and dimensions describing the affected area are given in Section 3 which provides an extensive summary of the 1988 radiological survey.

2.2 AREA CHARACTERISTICS AND TOPOGRAPHY

The terrain throughout most of SSFL areas is uneven due to rock outcroppings, as can be seen in the photograph shown in Figure 5. The 5–acre complex of storage/conservation/salvage yards is an irregular plateau in a mountainous area of recent geological age sprinkled with outcroppings above the more level patches. Of these, the Old Conservation Yard is a flat area which is partially paved, with the remainder being dirt and gravel. The area is open (not fenced in), and currently used as a storage location for shipping trailers.

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Figure 1. Map of Los Angeles Area

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Figure 2. Map of Neighboring SSFL Communities

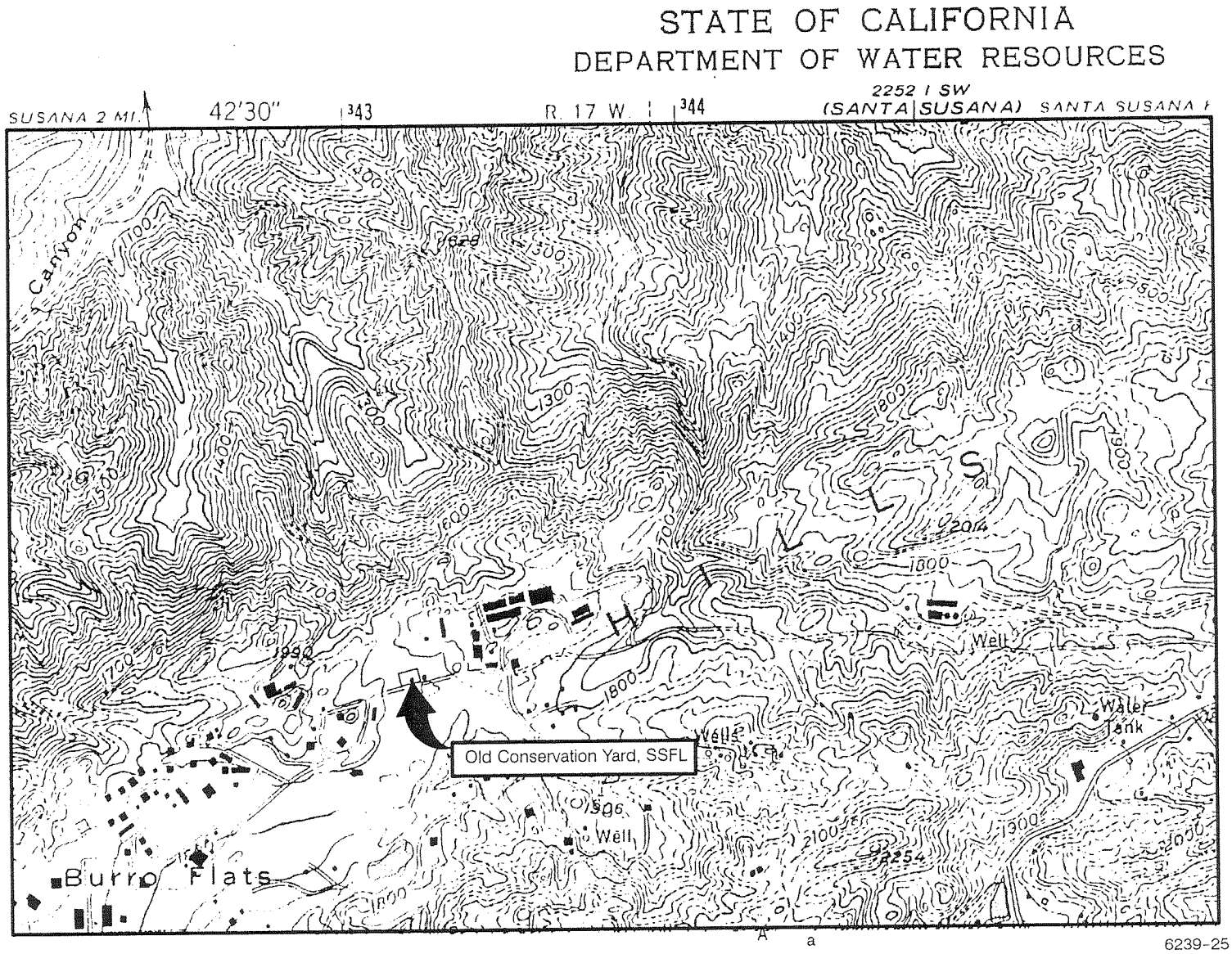

Figure 3. USGS Topographic Map of Portions of Calabasas Quadrangle; Bottom Left Area Corresponds to SSFL

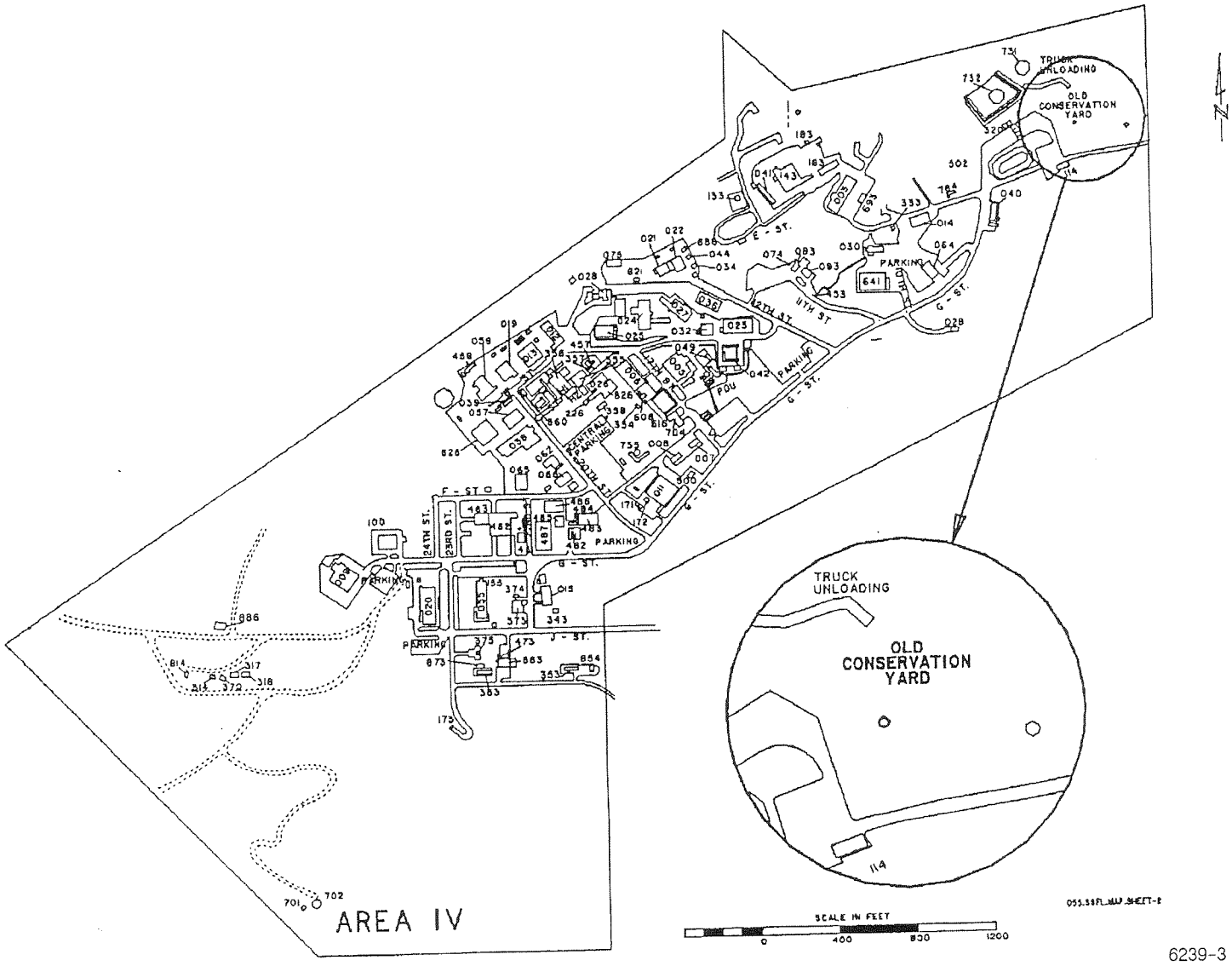

Figure 4. SSFL Layout Showing Location of the Old Conservation Yard

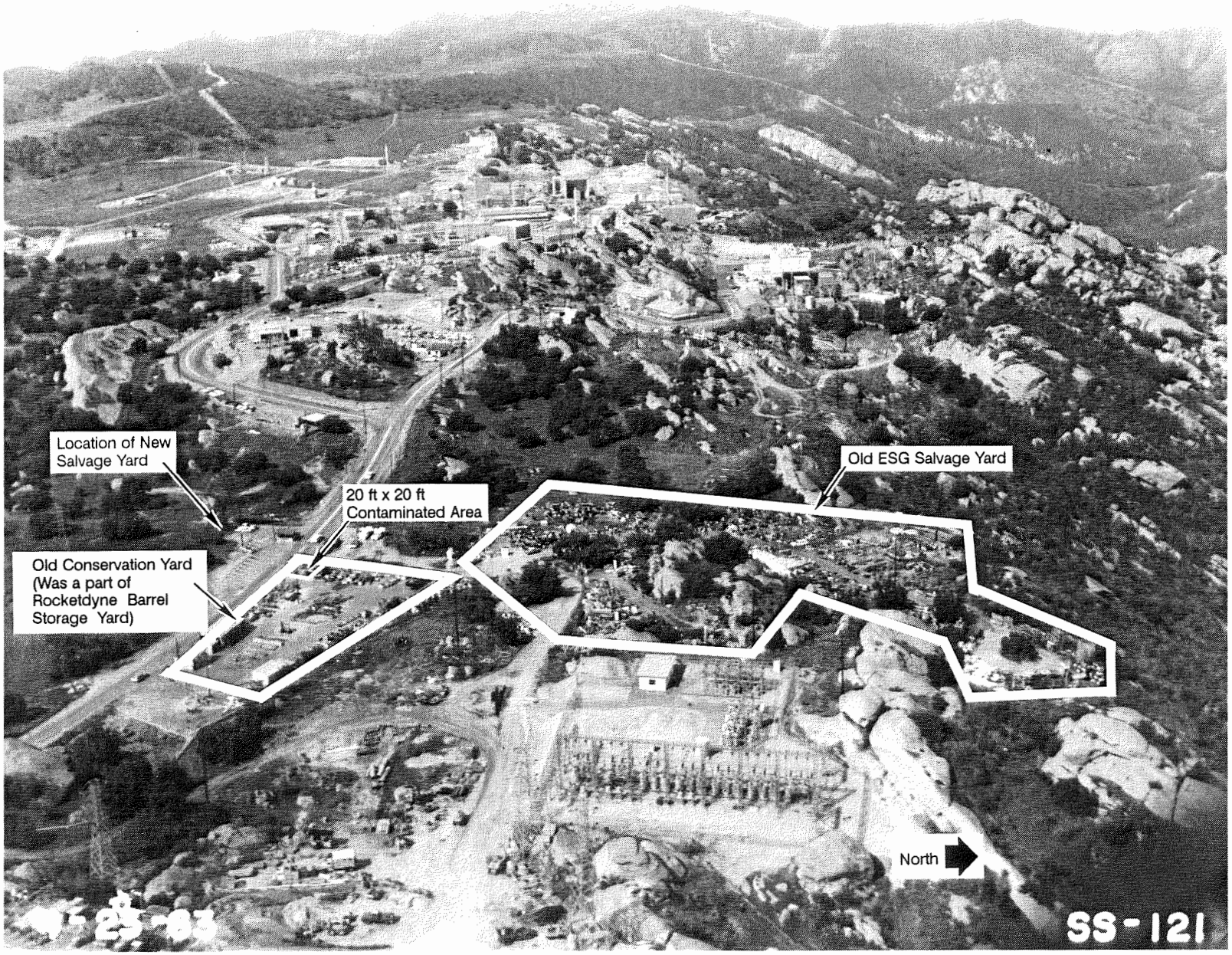

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Figure 5. Aerial Photo Showing Old ESG Salvage Yard, Rocketdyne Barrel Storage/Conservation Yard, and the New Salvage Yard (T583)

2.3 OPERATING HISTORY OF AREA

The SSFL has been involved in a variety of nuclear programs sponsored by the U.S. government since the 1950s. During various construction, refurbishing and dismantling phases of facilities which supported these programs, excess salvageable materials were kept primarily in the Old ESG Salvage Yard. This natural–terrain yard was utilized from about 1952 to 1977. Because of the large amount of materials excessed during that time, the size of the original salvage yard spread to surrounding areas. Part of this growth expanded into the Rocketdyne Barrel Storage Yard, immediately south of the ESG Salvage Yard. Although not operated as radiologically controlled facilities, these areas were surveyed for contamination on a regular basis. No deliberate dumping or placing of radioactive materials in these areas ever occurred. Because regimented radiological controls were not instituted, however, contaminated items were found on occasion during performance of routine radiation surveys. These items were contaminated with either mixed fission products (MFP) or uranium.

It is believed that a spill of MFP–contaminated liquid may have caused the contamination observed at the Rocketdyne Barrel Storage Yard, although no such incident is known to have occurred.

Two restructuring phases of the Old ESG Salvage Yard and the Rocketdyne Barrel Storage Yard took place since the 1970s to better accommodate storage needs. First, in 1970, Rocketdyne relocated the conservation function to the Canoga Park site. At that time, the Barrel Storage Yard was converted to a material storage yard for the Plant Services department, who then in 1986 relinquished control to the Transportation department. Since then, this area has been used as a parking area for trailers and other transportation vehicles. Second, in 1977, during which time major nuclear–related programs were winding down, salvageable materials were moved from the Old ESG Salvage Yard to the New Salvage Yard (also known as T583) or transported off–site. The Old ESG Salvage Yard is now completely free of debris. The new fenced–in Salvage Yard, T583, is currently in use.

Prior to the relocation of the Old ESG Salvage Yard, a thorough radiation survey of this area was performed and construction of the initial phase of a fuel oil tank farm was started in a portion of the Yard. A second fuel oil tank was added in 1982 and the area was fenced in.

2.4 SSFL SURVEY PLAN

A radiological survey plan (Ref. 1) was developed in 1985 for all SSFL areas suspect for residual contamination with radioactive materials. The 5–acre area covered by the Old ESG Salvage Yard, the Rocketdyne Barrel Storage Yard and the New Salvage Yard was included in the scope of the survey because, to quote from the survey plan, "some radioactive items were found in this area during routine inspections – MFP – U".

Accordingly, a comprehensive radiological survey of the 5–acre area was performed in 1988 to determine if any residual radioactive contamination existed. The survey and its results are extensively documented in Ref. 2 and 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 radiological 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 demonstrate that the numerical regulatory release criteria have been met. Together, the 1988 radiological survey of the Old ESG Salvage Yard, the Rocketdyne Barrel Storage Yard and the New Salvage Yard (Ref. 2), and the follow–up work reported in this document, fulfill the requirements for such a survey. For the sake of completeness, and for ease of future reference, a summary of the 1988 survey is provided in this section.

3.2 SCOPE OF SURVEY

The following areas were radiologically inspected: The Old ESG Salvage Yard, The Rocketdyne Barrel Storage Yard, and the New Salvage Yard (T583). Of these, as noted earlier, a portion of the Rocketdyne Barrel Storage Yard corresponds to the Old Conservation Yard (OCY). The total area covered is about 5 acres, with the OCY measuring approximately 1 acre.

The survey consisted of measuring gamma exposure rates 1 meter above the ground at locations established by a network of square grids measuring 36 m^2 each. On the 5–acre area, gamma exposure rate measurements were made in 438 such grid locations. Soil samples were also collected and analyzed as required by the Survey Plan (Ref. 1) or because of elevated gamma exposure rates. For purposes of comparison, natural background radiation data were also taken at about the same time in the three following SSFL locations where no radioactive materials were ever used, handled, or stored: Building 309 area, Well No. 13 Road (Dirt), and Incinerator Road (Dirt).

3.3 SURVEY

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 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 these references and adopted by Rocketdyne. During the 1988 survey, the ambient gamma exposure rate criterion (5 μR/h above background, shown in Table 1) was first applied. Three specific "action levels" were established and initiated if the survey detected radiation 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 survey, each of the three yards was treated as a single sample lot for characterization and data analysis. For convenience, the yards were subdivided into eleven zones (see Figure 6), and 6 m x 6 m-square grids were superimposed on each zone.

One ambient gamma exposure rate measurement was made in each of the 438 grid locations. A tripod was used to support a 1 in. x 1 in. NaI scintillation crystal coupled to a photomultiplier tube and fed to a Ludlum 2220-ESG scaler, 1 m above the ground. The detector is sensitive in nearly all directions (i.e., 4π geometry) and can detect variations in exposure rates down to about 0.5 μR/h, from counts obtained during one minute. For comparison, if an infinite slab of 20-cm-thick soil contaminated with 100 pCi/g of ^{137}Cs were located 15 cm below surface, it will produce an estimated excess exposure rate of about 10 μR/h, and this 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

Table 1. Maximum Acceptable Gamma Exposure Rate and Soil Activity Concentration Limits (1988 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: 21 pCi/g (for depth ≤15 cm below surface)	5 and 6
		b) Alpha: 31 pCi/g (for depth > 15 cm below surface)	5 and 6
		c) Beta: 100 pCi/g	7

[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 ^{226}Ra are 5 pCi/g (Ref. 5) plus that contribution from naturally occurring radioactivity (about 16 pCi/g, from Ref. 6, p. 93) averaged over the first 15 cm of soil below the surface. At a depth greater than 15 cm below the surface, 15 pCi/g averaged over 15-cm-thick layers of soil plus "background" is the limit. The total beta activity concentration limit is 100 pCi/g (Ref. 7), including background which is about 24 pCi/g.

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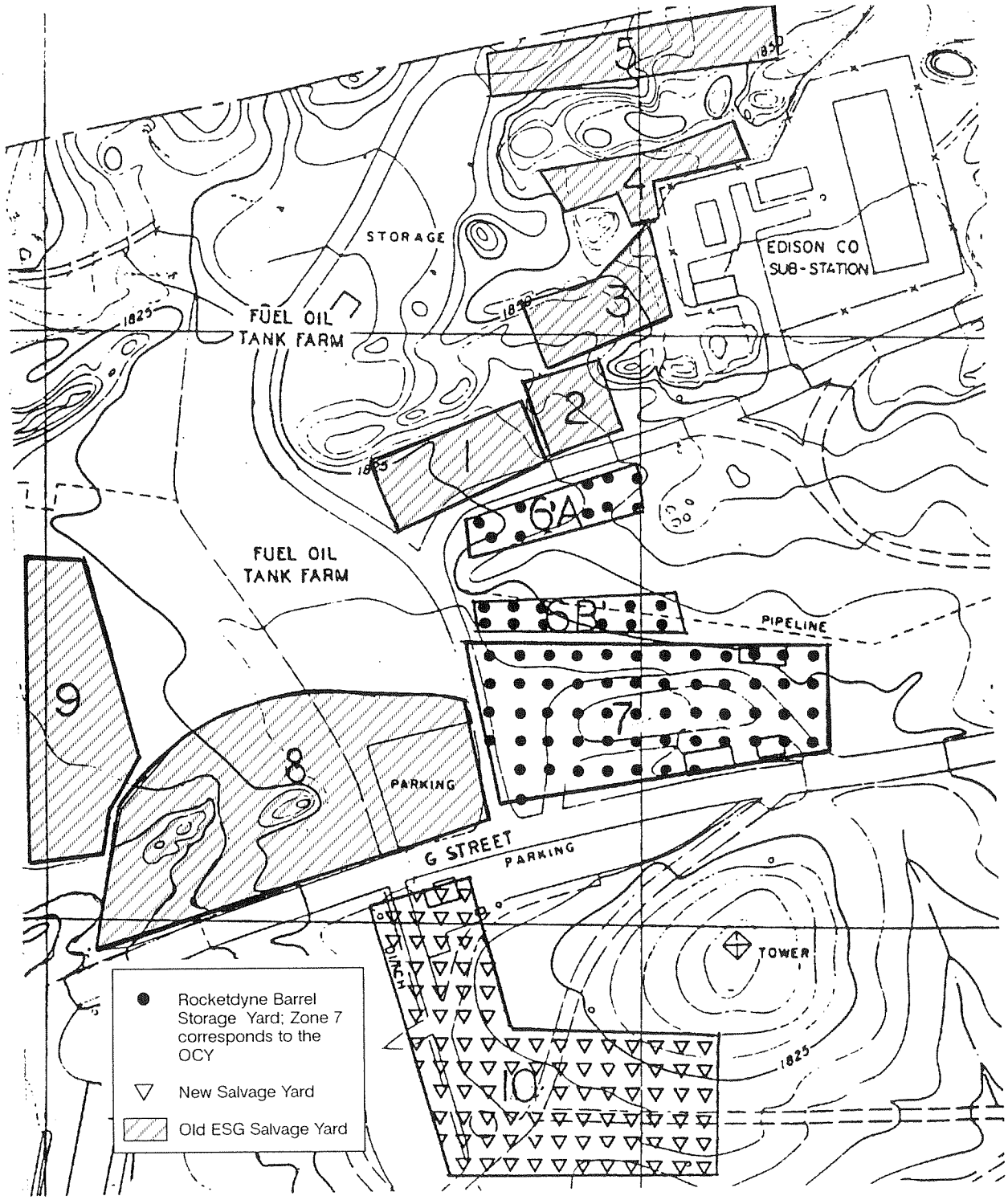

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Figure 6. Areas Covered by the 1988 Survey; Zone 7 Corresponds to the Old Conservation Yard

derived relationship that 215 cpm = 1 μR/h, at background exposure rates. During the survey, the instrument response was also checked three times daily using a ^{226}Ra source.

Soil samples weighing about 2 lb (908 g) each were collected during the survey and were identified for their specific location. Each sample was dried in an oven and then split into a 450–ml sample and a 2–g sample. The 450–ml 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 planchette, 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 three yards in this case. A statistical method known as "sampling inspection by variables" (Ref. 8) was used to analyze the data from the survey. The 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 a tolerance factor. The value of k is determined from the sample size and two other statistical sampling coefficients which 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 facility 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. 9). The sampling coefficients, and use of the resulting calculated value of TS for intercomparison

with the acceptance criteria and for establishing a plan of action for acceptance, are further discussed in Ref. 2.

Data obtained from the three yards were treated using this statistical approach. The reduced data were plotted against the cumulative probability for a gaussian distribution, with the cumulative values shown on a probability–grade scale. Display of data in this manner permits clear identification of values with significantly greater exposure rates (and thus contamination) than would be expected for the lot.

3.4 RESULTS

3.4.1 Gamma Exposure Rates

Statistical data obtained from the 1988 survey on the ambient gamma exposure rates measured in the Old ESG Salvage Yard, the Rocketdyne Barrel Storage Yard (including the Old Conservation Yard), and the New Salvage Yard locations are shown in Table 2. Also shown in this table are the three sets of data for the background locations. The data showed that the average exposure rates calculated for each of the three yards were all within one standard deviation (1σ) of each other. Examination of the data also showed that the standard deviations and the ranges for the yards were greater than those for the background locations, the values being the largest for the Rocketdyne Barrel Storage Yard. In particular, the range for the Barrel Storage Yard (17 μR/h) indicated possible localized contamination.

The 96 individual ambient gamma exposure rate data points for the Rocketdyne Barrel storage Yard were plotted on a probability–grade scale and are shown in Figure 7. Except for one significant "outlier" located in Zone 7 (now designated the Old Conservation Yard or OCY), which was measured at 27.9 μR/h, the survey data follows a representative gaussian. The calculated gaussian line is skewed with a large slope because of this single outlier. Figure 8 shows the same data set corrected for natural SSFL background, which was chosen to be the mean of the three background averages shown in Table 2. The mean of this background–subtracted data is -1.74 ± 1.73 μR/h and the test statistic, TS, is 0.81 μR/h. A comparison of these values with the acceptance criterion of 5 μR/h shows that the area is acceptably clean. However, the single outlier still required further investigation, per the criteria outlined in Section 3.3.1. Accordingly, a scoping investigation was performed and is summarized in the following section.

Table 2. 1988 Survey Data Compared to Ambient Gamma Radiation at SSFL

Location	Number of Measurements	Average Exposure Rate (μR/h)	Standard Deviation of the Distribution (μR/h)	Range (μR/h)
Surveyed Areas				
Old ESG Salvage Yard	279	14.7	0.84	6.3
Rocketdyne Barrel Storage Yard	96	13.5	1.73	17.0
New Salvage Yard (T583)	63	13.5	1.46	5.4
Background Areas				
Building 309 Area (1/19/88)	36	15.6	0.82	3.4
Well No. 13 Road (dirt) (4/29/88)	43	16.2	0.49	2.2
Incinerator Road (dirt) (4/29/88)	35	14.0	0.36	1.4

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Results and statistical data from the remaining two yards showed that the individual data, as well as the statistical parameters (TS and $\bar{x}$), were well within the 5 μR/h above background acceptance limit. Although statistical plots from Ref. 2 for the remaining two yards are not repeated here, Table 3 provides a summary of the gamma exposure rates for all three yards, corrected for background and tested against the acceptance limits.

As noted above, the background gamma exposure rate value for the 1988 survey was determined from an average of exposure rate data collected from three other SSFL areas. Because of differences inherent in the natural gamma exposure rates at various locations at the SSFL, however, this average value, 15.3 μR/h, resulted in negative background–subtracted exposure rate values for the three yards, indicating that the background value used was not completely representative of the actual background in the yard

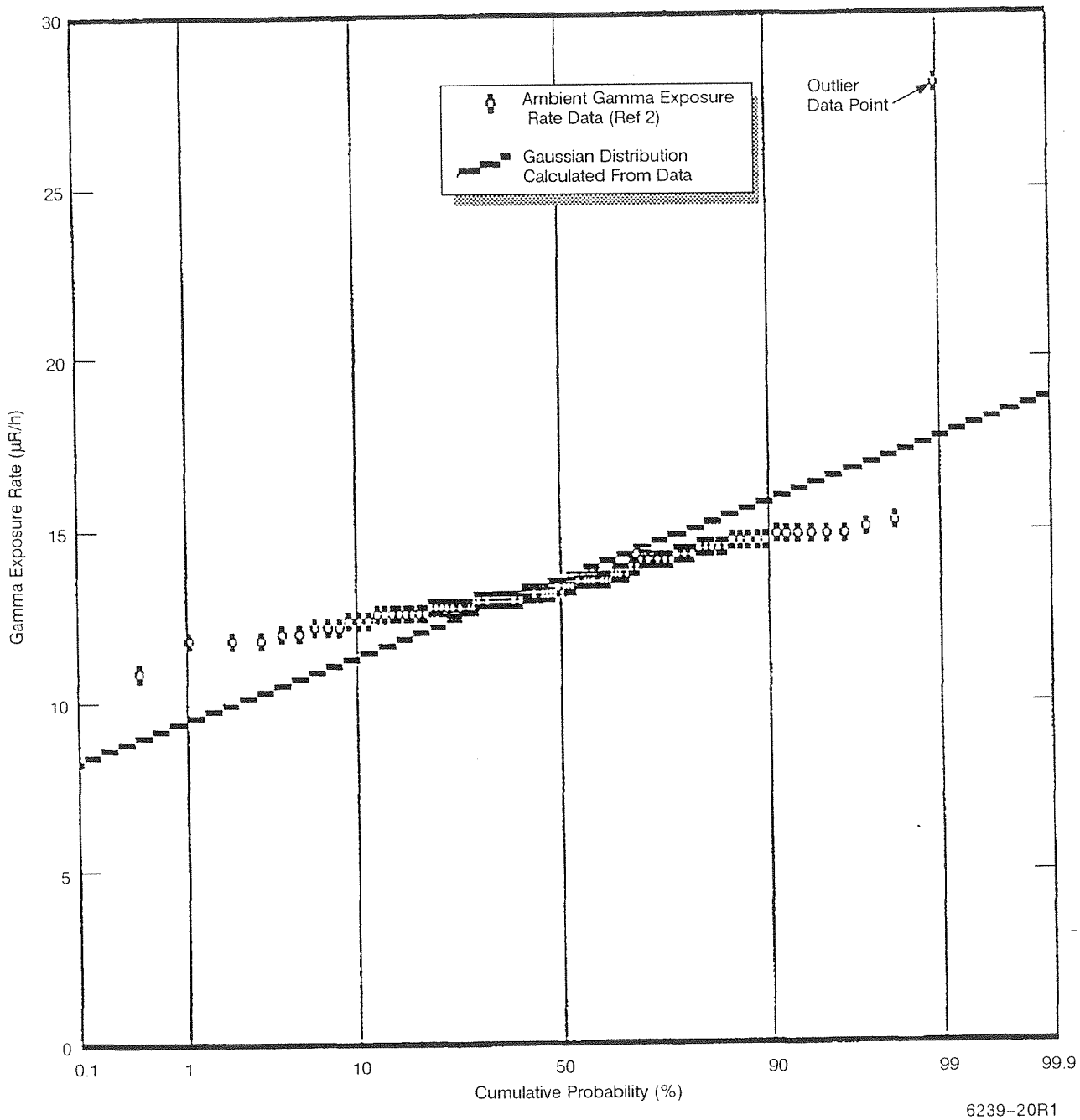

Figure 7. Total-Gross Ambient Gamma Exposure Rates at the Rocketdyne Barrel Storage Yard (1988 Survey)

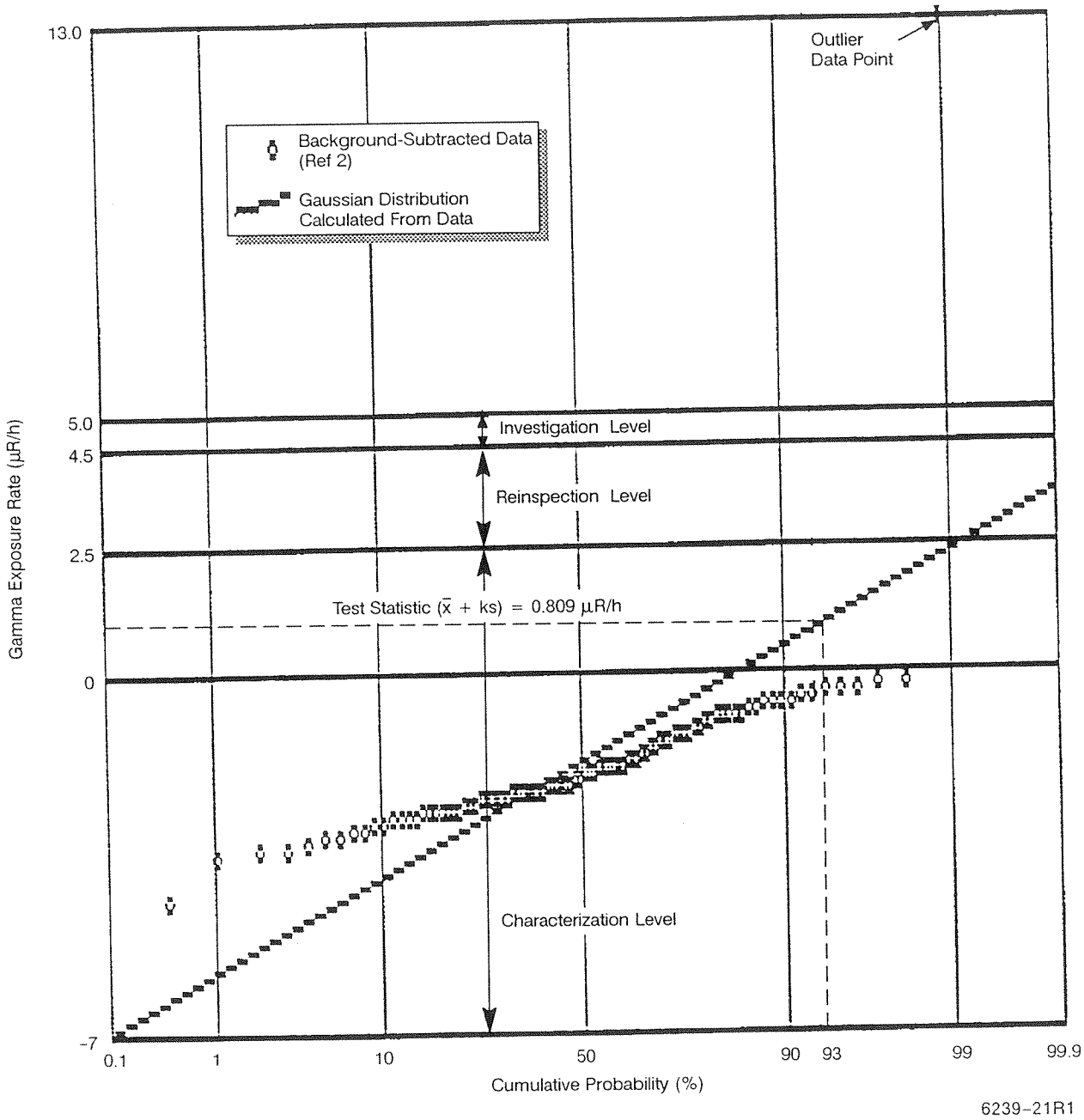

Figure 8. Background-Subtracted Ambient Gamma Exposure Rates at the Rocketdyne Barrel Storage Yard (1988 Survey)

Table 3. Summary of Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against the Acceptance Limit (1988 Survey)

Sample Lot	Number of Locations	Average Value (μR/h)	Standard Deviation (μR/h)	Maximum Value (μR/h)	Inspection Test Statistic (μR/h)	Acceptance Limit (μR/h)
Old ESG Salvage Yard	279	–0.55	0.849	2.5	0.625[a]	5
Rocketdyne Barrel Storage Yard	96	–1.74	1.73	12.6[b]	0.809[a]	5
New Salvage Yard (T583)	63	–1.78	1.46	–0.10	0.443[a]	5
All Areas	438	–0.99	1.32	12.6	0.816[a]	5

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[a]Area passes as acceptably clean based on test statistic alone
[b]Maximum value exceeded acceptance limit (see text)

areas surveyed. The variability in background gamma exposure rates measured at the SSFL, up to 3.4 μR/h, also points out the difficulty when assessing an areas's acceptability based on the NRC limit of 5 μR/h. In an effort to resolve these issues, a slightly different approach is used in this SRR to determine the most appropriate background value for the OCY area. This approach is discussed later in Section 4.3.2.1.

3.4.2 Soil Investigations

Because of the finding that one location in the OCY exceeded the gamma exposure limit noted previously, a scoping investigation was performed by collecting three soil samples at the OCY in the vicinity of the outlier data grid point. Eight more soil samples were also collected at two other locations and analyzed, as required by the original survey plan. Figure 9 shows the soil sampling locations.

Soil gross alpha and gross beta activities were obtained by analyzing the 2–g samples (see Section 3.3.2) from the above samples using a Canberra proportional alpha/beta counter. A Canberra Series 80 gamma spectrometer was used to obtain activity data on ^{238}U, ^{232}Th, ^{40}K, all of which are naturally–occurring isotopes, and on ^{137}Cs. The spectrometer is capable of measuring ^{137}Cs activity in soil down to about 0.2 pCi/g.

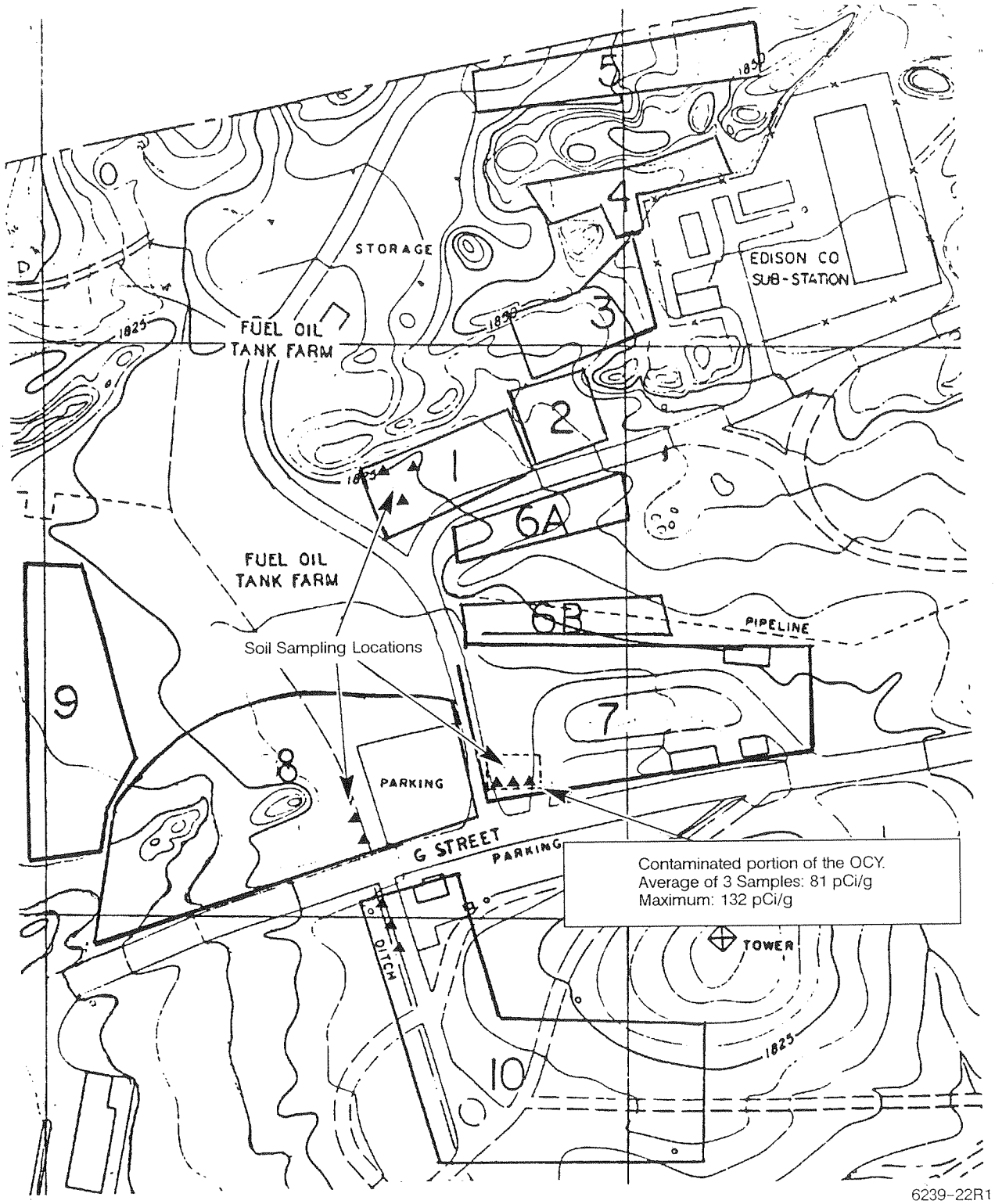

Figure 9. Soil Sampling Locations (1988 Survey); Zone 7 Corresponds to the Old Conservation Yard

Table 4 shows results of the average radioactivity concentrations obtained at the three locations. Also shown for comparison are data for background concentrations at the SSFL. An elevated concentration for ^{137}Cs (81.4 pCi/g average) was found in a localized area within the OCY, and was found to be significantly higher than the background activity for the SSFL. The average was from three values -- 45, 67 and 132 pCi/g ^{137}Cs -- of which the maximum value exceeded the acceptance limit of 100 pCi/g–beta (Table 1).

The effect of the presence of this ^{137}Cs can also be seen in the higher than background value of beta activity in Table 4 for the OCY. In all other aspects, the average soil radioactivity concentrations in this, as well as the other two yards, were all well within the corresponding background values shown in the table.

The small number of soil activity data collected during this scoping investigation were for indication only and hence no detailed statistical analyses of these data were performed during the 1988 survey.

Table 4. Soil Sample Results (1988 Survey)

Locations	Average Radioactivity Concentration (pCi/g)					
	Alpha	Beta	^{238}U	^{232}Th	^{40}K	^{137}Cs
Southwest corner of Zone 1, Old Salvage Yard[a]	19.8 ±2.7	25.37 ±1.77	1.01 ±0.27	1.19 ±0.68	18.78 ±0.93	NDA
Southwest corner of Zone 7, Rocketdyne Barrel Storage Yard[b]	15.2 ±4.9	69.2 ±37.2	0.82 ±0.11	0.97 ±0.52	17.97 ±1.42	81.38[d] ±45.20
SRE drainage gully, west of T583[a]	N/M	N/M	0.87 ±0.99	0.76 ±0.26	21.99 ±1.26	0.18 ±0.029
For comparison, burn pit[c]	15.8 ±5.7	23.5 ±2.5	0.98 ±0.18	1.25 ±0.20	20.7 ±2.89	0.34 ±0.25

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[a]Required by the Site Survey Plan

[b]Required because gamma exposure rate measurements exceeded the 50% reinspection level

[c]The burn pit results show naturally occurring background radioactivity at SSFL

[d]Maximum value of three samples was 132 pCi/g

NDA = No detectable activity

N/M = Not measured

3.5 CONCLUSIONS OF 1988 SURVEY

Based on the data obtained, the 1988 radiological survey concluded that, with the exception of a small area within the OCY (shown in Figure 9), the areas surveyed showed only natural background radiation. From the limited soil activity data, and on the basis of the observation that the OCY is a low spot with respect to its surrounding areas, the survey surmised that at one time a small radioactive spill occurred somewhere in the yard and became localized in a 20–ft x 20–ft area, perhaps 6 in. deep. Because the contamination level exceeded the acceptance limit only slightly (132 pCi/g of ^{137}Cs maximum found vs. 100 pCi/g–beta limit), the survey concluded that the area was not a health hazard.

3.6 RECOMMENDATION OF 1988 SURVEY

The 1988 survey recommended further radiological investigation of the 400 ft^2 area of the OCY be made to measure specifically the extent of contamination and to determine appropriate remedial action.

3.7 IMPLEMENTATION OF RECOMMENDATION

In accordance with the recommendation of the 1988 survey, soil was removed from the 400 ft^2 area of the OCY. Further investigations included obtaining additional gamma exposure rate and soil activity data at the OCY following removal of the top layer of soil. Comparisons were made against the 1988 survey soil activity data, and an evaluation was made, using the DOE computer code RESRAD, of the consequences of the remaining radioactivity in the soil to potential current and future occupants of the decontaminated area. The technical approach used in performing the investigations, including a description of the salient aspects of the RESRAD code, is provided in the next section. Results and conclusions from the investigations are presented in Sections 5 and 6.

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 slight contamination found in the OCY. Figure 10 shows the affected 20–ft x 20–ft area, which is located in the southwestern corner of the OCY. Upon removal of the top soil 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. 10). Accordingly, surface soil, up to an average 4–in. depth, was first removed from the designated 20–ft x 20–ft area of the OCY. The removed surface soil was stored in four type B–12 boxes for subsequent disposal at an authorized site. While these boxes were being loaded, 13 randomly selected 2–lb samples from the removed soil were taken for subsequent analysis by gamma spectrometry.

Following removal of the surface soil, a general screening gamma survey "for indication only" was conducted over the surface of the 20–ft x 20–ft area using a Ludlum Model 44–9 thin–window pancake GM probe attached to a Ludlum Model 12GM 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 affected OCY area which was greater than 5 μR/h above natural background levels.

After this screening survey, 30 new 1–m x 1–m grids were established in the decontaminated area for detailed gamma exposure rate and soil activity measurements. As shown in Figure 10, gamma exposure rate measurements were made in all grid locations, while soil samples were collected in 10 of the 30 grids. Figure 10 also shows locations where 10 additional soil samples were collected from outside the 400–ft^2 area for com-

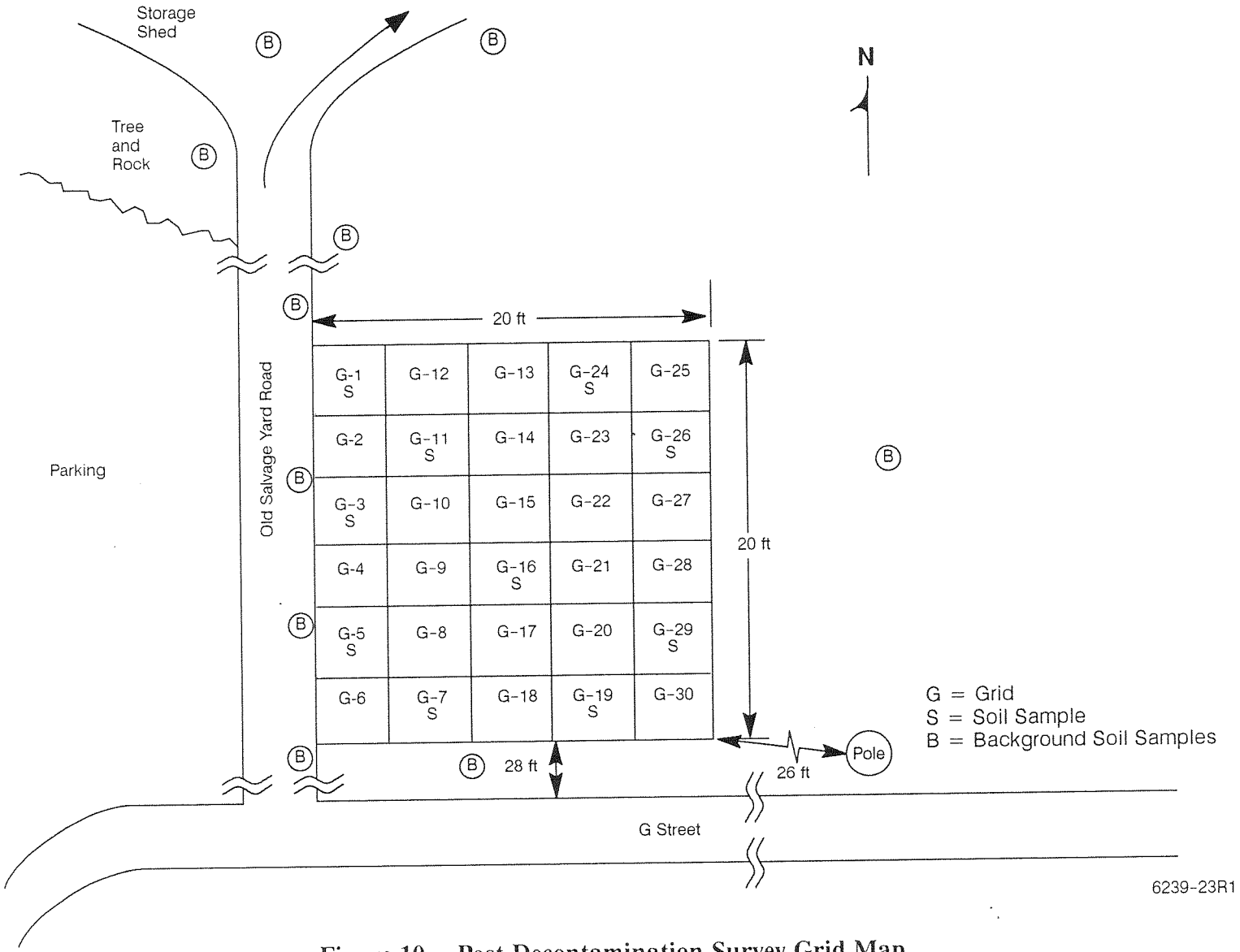

Figure 10. Post-Decontamination Survey Grid Map

parison measurements. The 1988 survey had shown only natural background activity in this vicinity, and hence only natural activities would be expected in these additional soil samples.

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 converted to exposure rates using the calibration–derived relationship that 215 cpm = 1 μR/h.

Gross alpha and 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 counts per minute) to dose rates (in μR/h), and for converting the total alpha and beta counts obtained (in counts per minute) 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 (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 data, 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

*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).

remaining SOILTEMP and MCASOIL outputs (e.g., the gross and derived total alpha and beta activity data) were obtained for information only, and are included in Appendices A and B.

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. Programs called RADSRVY and MCASRVY, developed at Rockwell, were used to calculate the mean, standard deviation and the test statistic (TS) for each data set, and to plot the data against the cumulative gaussian probabilities (e.g., Figure 8).

RADSRVY was developed at Rocketdyne and has been extensively used to obtain data of this nature on numerous previous radiological surveys, including the 1988 survey of the conservation yard area (Ref. 2). RADSRVY performs statistical analyses and plotting of gross alpha, gross beta, and gamma exposure rate data from SOILTEMP. MCASRVY is a derivative of RADSRVY to similarly analyze and plot isotope–specific output data from MCASOIL.

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 11).

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 infinitely large. This soil activity acceptance limit, along with the above-background gamma exposure rate acceptance limit of 5 μR/h, will constitute determination of the effectiveness of the remedial action or cleanup effort. Second, realistic dose estimates can be obtained using RESRAD, with the measured residual radionuclide concentration(s) and the dimensions of the affected contamination zone. The dose estimates obtained, when compared with the dose limit of 100 mrem/year, will provide a realistic demonstration of the effectiveness of the cleanup.

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 OCY site.
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 effectiveness of the decontamination and, hence, 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. 12, for example, the NRC requires its licensees to demonstrate that the dose equivalent not exceed 10 mrem/year, which is compared with the RESRAD calculated doses for the affected area (see Section 5.3).

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, provided for example in Ref. 6, 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 OCY area for the 30 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.

In contrast to the approach taken in the 1988 survey, the background value used here was determined from a subset of the original gamma measurements taken during the 1988 survey in the OCY area immediately surrounding the decontaminated area. This approach is more appropriate in view of the relatively large (~3 μR/h) variation in the natural background gamma exposure rate at various locations at the SSFL, and in view of the topography and other features of the selected area being representative of the OCY site.

In the original 1988 survey, a total of 84 gamma exposure measurements were taken in the whole OCY area (see Zone 7 in Figure 9), using a grid size of 6 m x 6 m (~388 ft^2) each. Only one measurement on these grids showed a gamma exposure rate far higher than expected for the SSFL, and this grid corresponds approximately to the 20–ft x 20–ft area which was subsequently identified as having the ^{137}Cs contamination. All the remaining grids showed gamma exposure rates which were generally slightly below the background range seen in the three "background" locations shown in Table 2.

For purposes of analyzing the present gamma exposure rates obtained from the affected area, the natural background exposure rate was determined from the remaining adjacent grid data. As a further precaution, data from the eight grids immediately adjacent to the contaminated grid were also excluded from the analysis. Analysis of the remaining 75 data points from the original 1988 survey (Ref. 2; pp. 115 and 116) gives an average value for the natural background gamma exposure rate at the OCY of 13.1 ± 0.8 (1σ) μR/h. This value is 2.2 μR/h lower (i.e., more conservative) than the

15.3 μR/h background value used in the 1988 survey, and best represents the background in the immediate vicinity of the affected 400 ft^2 area.

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 MCASRVY, 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 11 shows the exposure pathway diagram used by RESRAD for calculating the dose to an on–site resident from residual radioactive material.

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.

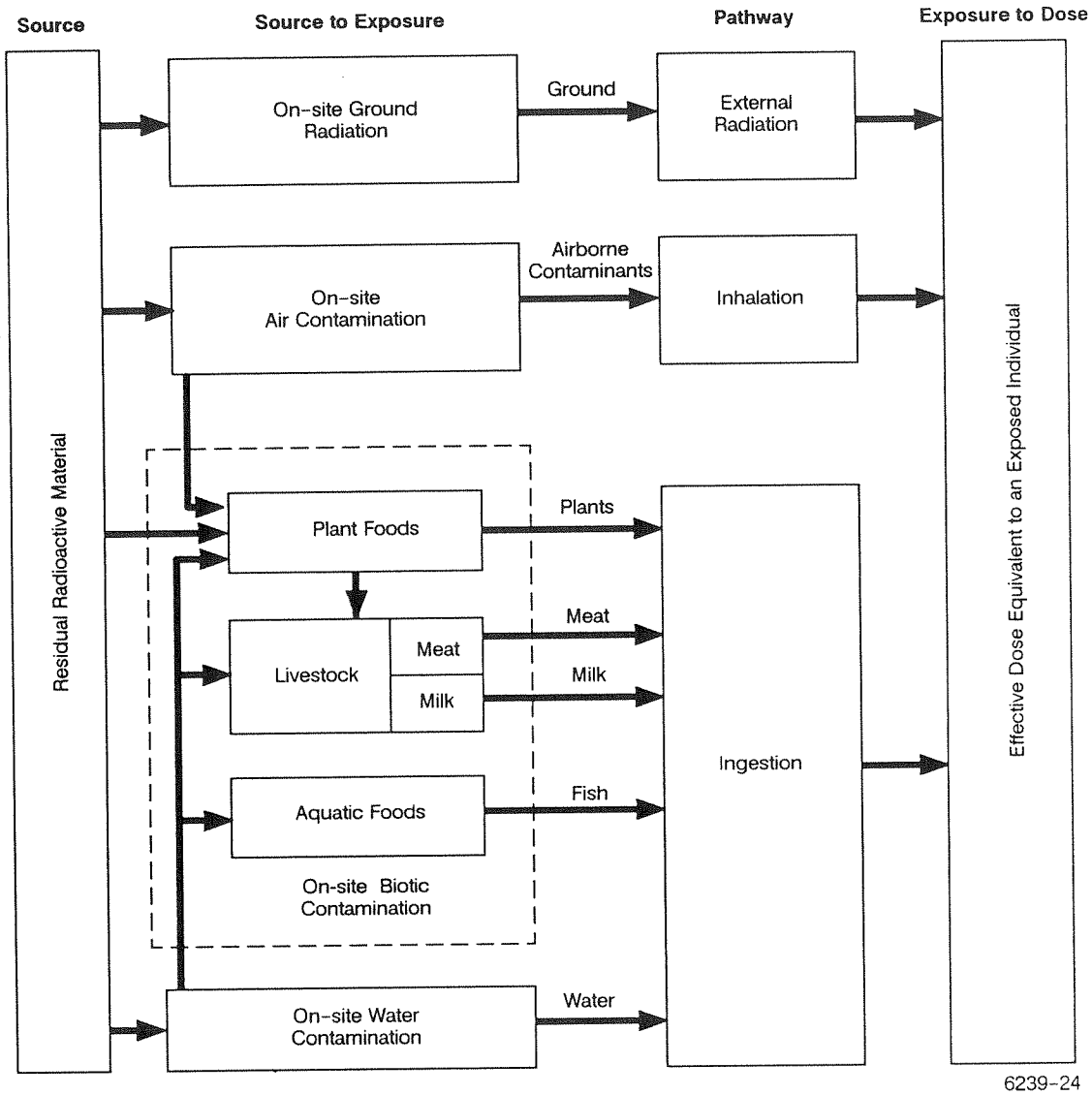

Figure 11. RESRAD Exposure Pathway Diagram (Ref. 3)

For the case of the SSFL in general, as well as for the OCY site, four potential future land use scenarios were considered. These are:

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

Of the four, the most credible in the near term is the industrial use scenario. 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 a credible scenario given the site size, geography, climate, and common land use in this area. Therefore, the credible scenarios for the OCY are scenarios 1, 2, and 3.

4.3.2.2.2 RESRAD Input Parameters for Scenarios

Prior to using the RESRAD code for the case of the OCY, a number of screening evaluations were performed to determine which of the approximately 80 input parameters required by RESRAD were of significance for the present application, and to determine 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 in the OCY is about 400 ft^2 (37.2 m^2) in area and about 8 or 4 in. (0.2 or 0.1 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 corresponding 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 calculation here, a depth value of 35 m was used, corresponding roughly to the distance from the surface to the water table at the OCY site. The actual dimensions mentioned above were subsequently used to estimate annual doses (see Sections 4.3.2.2.4 and 5.3).

Cover Depth. RESRAD can accommodate the input of a cover material above the contaminated zone to account for those instances where the contaminated region may have been deliberately or inadvertently covered over, for example, during residential construction. For the residential and industrial scenarios, it is assumed that the area will be covered by a 4–in. (0.1 m) concrete slab on which residence or offices are typically built.

The area of the slab is the same as the surface area of the contaminated region. The cover depth is zero for the wilderness and family farm scenarios.

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, and are based on the assumption 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. For the present study, these percentages were modified to yield correspondingly modified values for FO_1 and FO_2 for each of the four scenarios considered. For comparison with the default values, FO_1 ranged from 0.005 for the wilderness scenario to 0.66 for the residential scenario. Similarly, FO_2 ranged from 0.005 to 0.42 for these two scenarios, respectively.

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 C. 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 5. 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 5, 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 (984 or 461 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."

Thus, the above concentrations of ^{137}Cs and ^{90}Sr are the acceptance limits against which the measured activities at the OCY 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 OCY is one that takes into account both nuclides together. The corresponding two–nuclide limit, for the credible bounding residential scenario, is 314 pCi/g each of ^{137}Cs and ^{90}Sr, which would result in a combined annual exposure of 100 mrem.

Table 5. 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	2,520	816,000
2. Residential	984	461
3. Wilderness	3,840	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 to the OCY site)

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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 MCASRVY 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 10 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; 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 corresponding to before the present decontamination and after the decontamination.

4.3.3 Summary

Three criteria, and corresponding acceptance limits, were established for the OCY 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 the original 1988 survey data taken in the immediate vicinity of the OCY area, 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 314 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 com-

pared with the 314 pCi/g limit. Statistical behavior of the ^{90}Sr is assumed to follow that of ^{137}Cs.

The OCY site is determined to be acceptably free of residual radioactive contamination if both the 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 30 grid location in the 20–ft x 20–ft OCY survey area, after decontamination, are given in Table 6. Gamma exposure rates ranged from 13.07 μR/h to 15.31 μR/h, with a mean value (and 1σ standard deviation) of 14.2 ± 0.6 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 12. As is evident, the data distribution reasonably follows a gaussian, with no outliers. The one outlier in the 1988 survey, which showed 27.9 μR/h, is now absent.

Table 6. Ambient Gamma Exposure Rates in OCY Grids After Decontamination

Grid Number*	Exposure Rate (μR/h)	Grid Number*	Exposure Rate (μR/h)
G–1	14.78	G–16	14.14
G–2	14.70	G–17	14.49
G–3	14.51	G–18	14.72
G–4	14.76	G–19	14.34
G–5	14.77	G–20	14.34
G–6	14.58	G–21	13.96
G–7	15.31	G–22	13.70
G–8	15.12	G–23	13.39
G–9	14.67	G–24	13.30
G–10	14.65	G–25	13.07
G–11	14.76	G–26	13.31
G–12	14.79	G–27	13.73
G–13	13.82	G–28	13.80
G–14	13.88	G–29	13.88
G–15	14.05	G–30	14.04
Maximum:	*15.31*		
Minimum:	*13.07*		
Average:	*14.2*		

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*See Figure 10 for grid locations at the OCY area.

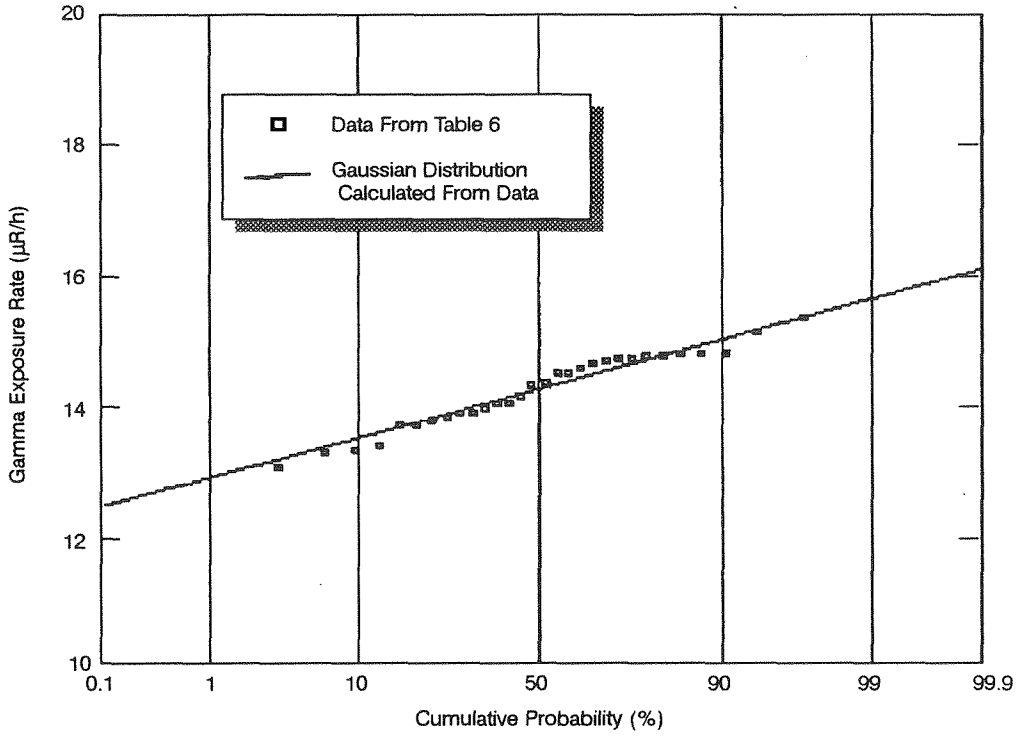

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Figure 12. Ambient Gamma Exposure Rates in OCY Grids After Decontamination

Figure 13 shows the background–subtracted OCY area gamma exposure rate data plotted against the cumulative probability. Here, the value of 13.1 ± 0.8 (1σ) μR/h determined from the immediately adjacent area was used for the background value, rather than the higher value of 15.3 ± 1.1 (1σ) μR/h used in the 1988 survey. 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 for this distribution is 2.1 μR/h, which is below the acceptance limit, thus satisfying criterion No. 1. The mean of the background–subtracted data is 1.1 μR/h. Comparison of this value with the residual soil activity measured at the OCY is provided in Section 5.3

5.2 SOIL ANALYSIS DATA (CRITERION NO. 2)

As discussed in Section 4.2.1, gamma spectrometry analysis was conducted on soil samples collected from the four B–12 boxes, and from 10 of the 30 grid locations established for the final OCY site decontamination survey. The spectrometry results were data–reduced by using the in–house spreadsheet code MCASOIL, resulting in derived activity values (in pCi/g) for certain specific isotopes, including ^{137}Cs, which was found in

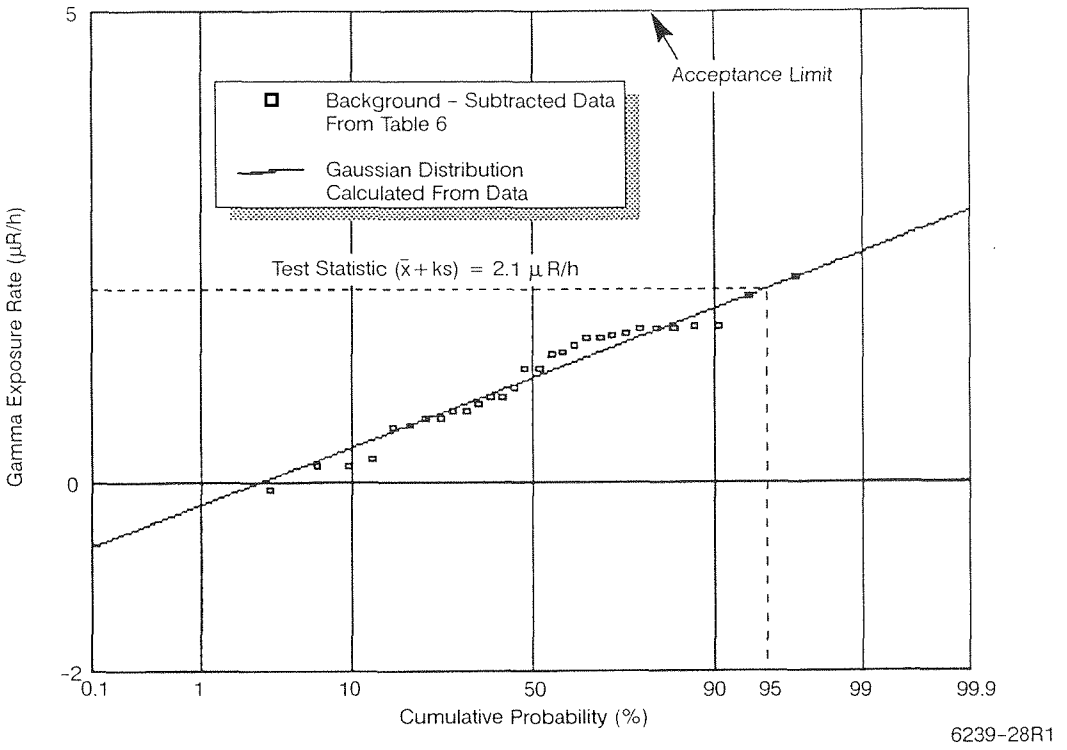

Figure 13. Background–Subtracted Gamma Exposure Rates in OCY After Decontamination

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, are given in Appendix B.

Results of the spectrometric analyses for ^{137}Cs on soil samples from the ten OCY survey grids are given in Table 7. Measured activities ranged from 3.9 to 30.6 pCi/g, with an average value of 13.1 pCi/g, and were well above the lower detection limit of 0.2 pCi/g for the spectrometer system. In comparison, the 1988 survey showed ^{137}Cs activities in the range of 45 to 132 pCi/g, with an average value of 81 pCi/g for three samples (Section 3.4.2). The present decontamination effort therefore reduced the maximum ^{137}Cs level from 132 to 30.6 pCi/g (about a factor of four), and the average value from 81 to 13.1 pCi/g (about a factor of six).

In Figure 14a, the ^{137}Cs results are plotted versus the cumulative probability. Except for the 30.6 pCi/g value, the data are closely gaussian in distribution. In Figure 14b, the same ^{137}Cs data are shown on a reduced scale to include the activity limits derived from the RESRAD code. The intersecting dashed lines indicate the test statistic (TS) for this

Table 7. Measured Residual ^{137}Cs Activity in OCY Grids After Decontamination

OCY Site Grid Number	Soil Sample Mass (g)	Measured ^{137}Cs Activity (pCi/g)
G–1	735	7.45
G–3	337	18.50
G–5	512	3.92
G–7	229	12.74
G–11	306	30.59
G–16	439	4.59
G–19	914	19.69
G–24	986	9.88
G–26	820	14.91
G–29	884	9.05
	Mean:	*13.1*
	Standard Deviation (1σ):	*8.2*

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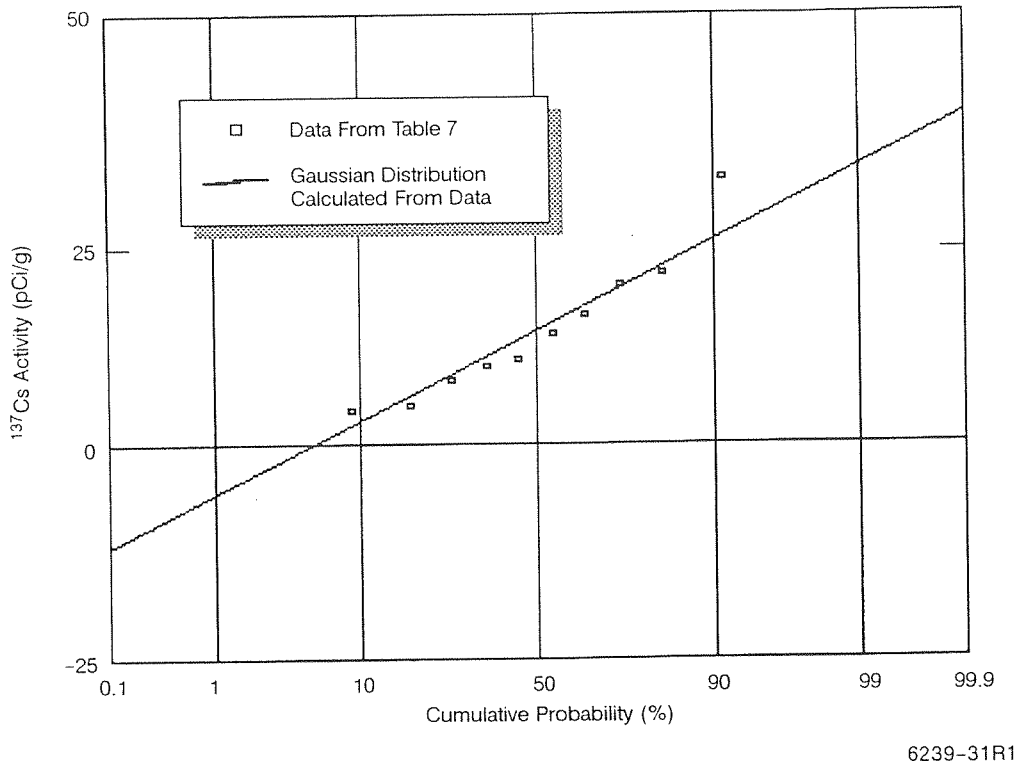
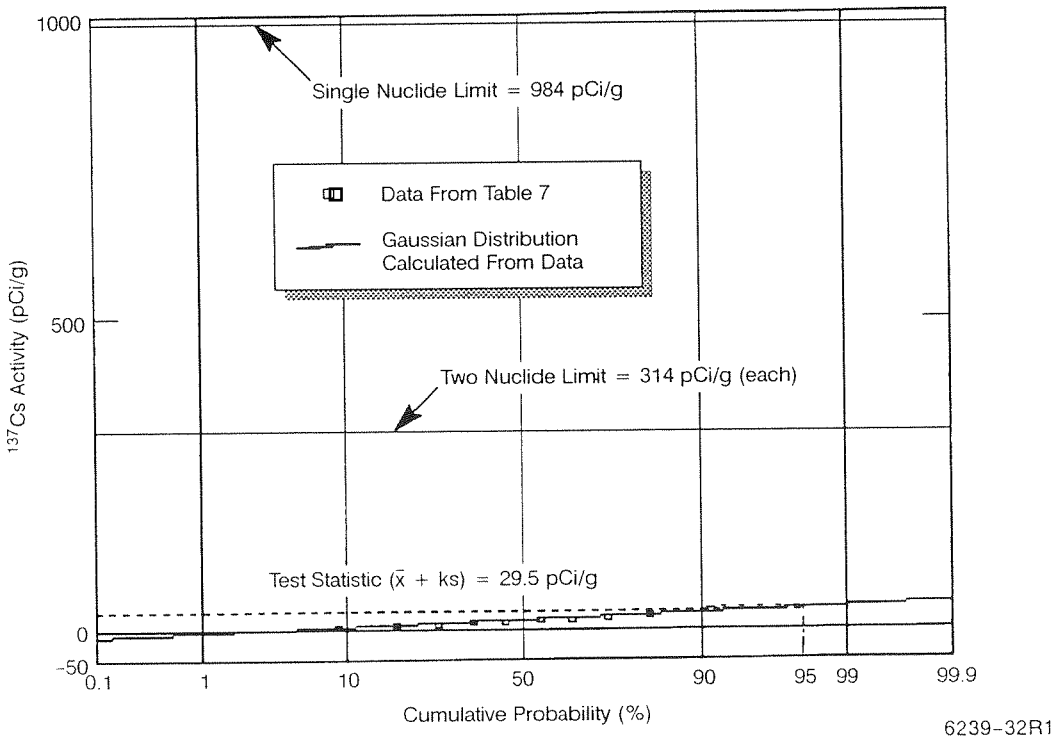
distribution, which is 29.5 pCi/g. The TS value is strongly affected (increased) by the 30.6 pCi/g datum. The two previously calculated RESRAD limits are also shown, one corresponding to the single radionuclide limit of 984 pCi/g, and the second corresponding to the two–nuclide limit of 314 pCi/g for equal activities of ^{137}Cs and ^{90}Sr. Of significance is the fact that the TS of 29.5 pCi/g for the ^{137}Cs data distribution in the OCY grids is far below the two–nuclide acceptance limit and hence criterion No. 2 is satisfied. The TS and the average are also substantially lower than the single nuclide limit, and 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



(a) Expanded Scale



(b) With RESRAD Limits

Figure 14. Measured ^{137}Cs Activity in OCY Grids after Decontamination

the calculated dose estimates for the four scenarios and for the selected time periods are presented.

5.3.1 Area

As mentioned earlier, 400 ft^2 corresponds to the area of the decontaminated portion of the OCY which itself measures approximately 1 acre. The decontaminated area has relatively higher residual ^{137}Cs activity (13.1 pCi/g) when compared with the 1.5 pCi/g of ^{137}Cs activity in the remaining area (see Tables B1 and B2). If a larger area (e.g., all of the 1 acre comprising the OCY) were chosen, then a correspondingly lower area–weighted activity would apply for the calculations, resulting in a lower annual dose. For conservatism, therefore, the 400 ft^2 area and the higher activity values were chosen.

5.3.2 Depth and Concentrations

5.3.2.1 The "Before" Case

Although Ref. 2 estimated the depth of contamination at 6 in., we assumed the depth to be 8 in. Based on the total amount of soil that was removed from the 400 ft^2 surface area, the average depth to which the soil was excavated is calculated to be 4 in. The average ^{137}Cs concentration for the removed soil, from Table B3 in Appendix B, is 12.6 pCi/g, and that for the remaining soil is 13.1 pCi/g (Table 7). The average of these two values, 12.9 pCi/g, represents the concentration for the "before" case. An equal activity of ^{90}Sr is assumed.

5.3.2.2 The "After" Case

While the choice of 13.1 pCi/g each of residual ^{137}Cs and ^{90}Sr activity for the "after" case is readily discerned, the choice of the 4–in. depth warrants additional discussion. For this purpose, we performed a particular RESRAD calculation, for the credible bounding residential scenario, in which the following were used as input: 400 ft^2 area; 4–in. depth; 13.1 pCi/g each of ^{137}Cs and ^{90}Sr residual activity; and, suppression of all environmental pathways except for the continuous and unshielded direct gamma exposure pathway. Results showed that the annual dose for this case is 19 mrem/year or 2.2 μR/h, which is about twice the 1.1 μR/h background–subtracted gamma exposure rate discussed in Section 5.1. A reduction in the RESRAD–calculated value of 2.2 μR/h can be achieved in this case only by reducing the depth. In fact, additional RESRAD calculations, in which the depth was varied, showed that the 1.1 μR/h gamma exposure rate would be obtained

for a thickness of soil of about 1.7 in. Thus, the 4.0 in. used for the "after" case is conservative.

5.3.3 Results

Results are shown in Table 8. The estimated post–decontamination annual doses to a potential current (time = 0 years) inhabitant of the OCY site, assuming the more conservative 4.0 in. thickness, range from 0.10 to 0.39 mrem/year for the three credible scenarios, and 11.8 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 9 are about 30% 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 0.39 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 0.39 mrem/year is also below the 10 mrem/year NRC limit for release of the site for unrestricted use.

Table 8. Estimated Annual Dose (Above Background) from Residual Radionuclide Activity at the OCY

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	0.19	0.15	0.52	0.39	0.13	0.10	15.5	11.8
1	0.19	0.15	0.51	0.38	0.12	0.09	15.1	11.5
10	0.15	0.12	0.41	0.31	0.10	0.07	11.9	8.6
100	0.02	0.01	0.05	0.04	0.01	$\ll$0.01	1.02	$\ll$0.01
1000	$\ll$0.01	$\ll$0.01	$\ll$0.01	$\ll$0.01	$\ll$0.01	$\ll$0.01	$\ll$0.01	$\ll$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

Figure 15 shows a photograph of the OCY area, taken during the 1989 decontamination efforts. The yard remains as an open (not fenced–in) area, occasionally used for storage of shipping trailers.

A decommissioning file for the OCY has been established, and is currently archived at Rockwell's SSFL Building T100. Appendix D contains a list of items documented in this file.

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6DZ11-6/29/89-S1E*

Figure 15. Photograph of the OCY Taken During the July 1989 Decontamination of the 20-ft by 20-ft Area

6. CONCLUSIONS

In accordance with the recommendation of the report on the 1988 radiological survey of a 5–acre storage yard area at the SSFL, the top soil layer was removed in a 20–ft by 20–ft area of the Old Conservation Yard (OCY) where slight ^{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 14.2 μR/h. For comparison, the background ambient gamma exposure rate in the immediate vicinity of the OCY area has an average value of 13.1 μR/h.
2. The test statistic for the distribution of the background–subtracted gamma exposure rates in the decontaminated area is 2.1 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 OCY are 984 pCi/g of ^{137}Cs and 461 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 at the OCY is 314 pCi/g of each radionuclide.
4. The average measured ^{137}Cs activity presently in the decontaminated area is 13.1 pCi/g, compared to the average of 81.4 pCi/g measured prior to decontamination.
5. The test statistic for the measured ^{137}Cs soil activity distribution is 29.5 pCi/g, which is well below the acceptance limit of 314 pCi/g (Criterion No. 2).
6. Comparison of the 1.1 μR/h background–subtracted gamma exposure value with the 13.1 pCi/g value for the decontaminated area indicates a residual contaminated soil thickness of ~1.7 inches, which suggests that the 4–in. value assumed here for dose calculations is conservative.
7. A plausible occupant of the decontaminated area, under the credible bounding use scenario, will receive a current annual dose of 0.39 mrem/year, which is well below the 100 mrem/year basic dose limit (Criterion No. 3).

6.2 OVERALL CONCLUSIONS

1. Based on results of the investigations reported here, the decontaminated area of the Old Conservation Yard is acceptably free of radioactive contamination.

2. Based on results of the 1988 survey, the remaining surveyed areas are also acceptably free of radioactive contamination.

3. The 5–acre storage yard area including the Old Conservation Yard meets all the acceptance criteria, and, therefore, may be released for unrestricted use.

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APPENDIX A

GROSS ALPHA AND BETA ACTIVITY DATA ON OCY AREA SOIL SAMPLES AFTER DECONTAMINATION

Gross alpha and gross beta measurements were performed on 2–g soil samples from 10 background locations adjacent to the decontaminated OCY area, and on 2–g samples from 10 of the 30 grid locations within the decontaminated area. The ten grid locations correspond to the same grids use for the larger mass gamma spectrometry analyses discussed in Section 4.0. Soil samples for analysis were collected and analyzed in June and July 1989.

Table A1 gives the gross alpha and gross beta results for the background and 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. Each of the data sets was compiled using the SOILTEMP spreadsheet.

Table A1. Gross Alpha and Gross Beta Measurements on 2-g OCY Soil Samples

Sample Description	Alpha Activity (pCi/g)	Standard Deviation (1σ)	Beta Activity (pCi/g)	Standard Deviation (1σ)
Background Areas				
#1	26.2	2.8	25.0	0.9
#2	17.2	2.3	24.0	0.9
#3	20.7	2.5	24.9	0.9
#4	19.5	2.5	25.0	0.9
#5	24.0	2.7	23.9	0.9
#6	18.6	2.4	23.5	0.9
#7	16.9	2.3	22.2	0.9
#8	21.9	2.6	23.9	0.9
#9	27.6	2.8	25.7	0.9
#10	19.5	2.5	26.5	0.9
OCY Grids				
G-1	37.1	3.2	31.8	1.0
G-3	29.7	2.9	34.9	1.1
G-5	21.7	2.6	24.4	0.9
G-7	18.8	2.4	25.7	0.9
G-11	28.1	2.8	34.4	1.1
G-16	21.7	2.6	24.3	0.9
G-19	23.6	2.6	34.3	1.1
G-24	23.8	2.7	30.0	1.0
G-26	37.3	3.2	33.1	1.0
G-29	32.6	3.0	39.3	1.1

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APPENDIX B

DERIVED ALPHA, BETA, AND RADIONUCLIDE DATA FROM OCY AREA AFTER DECONTAMINATION

During the course of the decontamination of the OCY area, gamma spectrometry data were obtained for four sets of soil samples. These included: (1) duplicate analyses of samples from the 10 background locations adjacent to the OCY area, (2) analyses of soil samples randomly taken from the soil removed from the OCY area during decontamination and subsequently stored in boxes, and (3) analyses of soil samples taken from 10 of the 30 survey grids established after decontamination. Soil samples for analysis were collected in June and July 1989.

In each case, soil samples ranging in mass from about 200 to 900 g were analyzed using the Canberra instrument discussed in Section 4.2.2. Following analyses, the results were input to the MCASOIL spreadsheet, which in turn calculated derived quantities for total alpha and beta activity, and derived activities for selected man–made radionuclides and for several naturally occurring radionuclides. The averages shown in Tables B1 through B4 include those data points with zero values, resulting in slightly lower averages than expected (for comparison, see the K–40 data shown in Tables B1 and B2). This averaging process, however, did not affect the results and conclusions presented in this report.

Tables B1 through B4, present the data for the four different soil sample sets.

Table B1. Gamma Spectrometry Data from Background OCY Soil
(Initial Analysis)

	39	40	41	42	43	44	45	46	47	48	49	50
1	OLD CONSERVATION YARD BACKGROUND AREA SOIL MCA DATA (Initial Analysis)						EXCEL FILE:		CYBKG1.XLS			
2	(SAMPLES ANALYZED BETWEEN 7/6/89 AND 7/20/89)											
3												
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	RYS #1	701.0	0.72	2.61	0.05	0.03	18.79	1.71	0.00	0.00	21.78	35.50
15	RYS #2	732.0	0.63	1.23	0.04	0.03	20.52	0.60	0.00	0.00	12.70	30.01
16	RYS #3	683.0	0.60	0.68	0.04	0.03	20.60	4.68	0.00	0.16	9.18	31.97
17	CYS #4	489.0	0.83	1.44	0.06	0.04	19.35	5.88	0.00	0.00	15.66	36.23
18	RYS #5	529.0	0.82	1.49	0.05	0.04	21.12	0.97	0.00	0.00	15.81	33.18
19	CYS #6	683.0	0.61	1.11	0.04	0.03	20.69	0.35	0.00	0.00	11.83	29.33
20	RYS #7	680.0	0.62	1.15	0.04	0.03	18.10	0.06	0.00	0.00	12.11	26.65
21	RYS #8	670.0	0.97	1.62	0.10	0.04	0.00	0.49	0.00	0.00	18.16	13.22
22	CYS #9	600.0	0.98	0.95	0.06	0.04	21.93	0.07	0.00	0.00	13.97	31.97
23	RYS #10	810.0	0.68	0.89	0.04	0.03	0.00	0.12	0.00	0.00	11.06	7.95
24												
25	Averages:		0.75	1.32	0.05	0.03	16.11	1.49	0.00	0.02	14.23	27.60
26	Standard Deviations:		0.14	0.54	0.02	0.01	8.57	2.08	0.00	0.05	3.73	9.48

Table B2. Gamma Spectrometry Data from Background OCY Soil
(Duplicate Analysis)

	39	40	41	42	43	44	45	46	47	48	49	50
1	OLD CONSERVATION YARD BACKGROUND SOIL MCA DATA (Second Analysis)						EXCEL FILE:		CYBKG2.XLS			
2	(SAMPLES ANALYZED ON 8/28/89)											
3												
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	OCY-Bkg #1	672.0	0.88	1.08	0.00	0.04	18.48	1.81	0.00	0.00	13.48	29.90
15	OCY-Bkg #2	676.0	0.56	0.87	0.00	0.03	20.86	0.65	0.00	0.00	9.70	28.37
16	OCY-Bkg #3	619.0	0.00	0.73	0.00	0.00	20.45	4.92	0.00	0.00	4.38	28.29
17	OCY-Bkg #4	474.0	0.76	0.95	0.00	0.03	21.79	6.08	0.00	0.00	11.76	36.26
18	OCY-Bkg #5	526.0	0.64	1.01	0.00	0.03	20.70	1.16	0.00	0.00	11.13	29.74
19	OCY-Bkg #6	671.0	0.54	0.88	0.00	0.02	20.89	0.37	0.00	0.00	9.56	28.02
20	OCY-Bkg #7	684.0	0.68	0.96	0.00	0.03	20.50	0.00	0.00	0.00	11.17	28.43
21	OCY-Bkg #8	670.0	1.07	0.75	0.10	0.05	20.45	0.33	0.00	0.00	13.73	30.62
22	OCY-Bkg #9	599.0	1.21	1.24	0.08	0.05	25.28	0.00	0.00	0.00	17.70	37.87
23	OCY-Bkg #10	797.0	0.74	1.04	0.04	0.03	21.02	0.00	0.00	0.00	12.39	29.77
24												
25	Averages:		0.71	0.95	0.02	0.03	21.04	1.53	0.00	0.00	11.50	30.73
26	Standard Deviations:		0.33	0.15	0.04	0.01	1.71	2.19	0.00	0.00	3.43	3.47

Table B3. Gamma Spectrometry Data on Randomly Selected Soil Samples Taken From the OCY Area During Soil Removal

	39	40	41	42	43	44	45	46	47	48	49	50
1	OLD CONSERVATION YARD B-12 BOX SOIL MCA DATA						EXCEL FILE:		CYBOXES.XLS			
2	(SAMPLES ANALYZED ON 4/21/90)											
3												
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	SY-1-A	402.1	0.62	1.12	0.00	0.03	19.16	27.31	0.00	0.00	11.69	54.70
15	SY-1-B	415.1	0.80	1.09	0.00	0.04	19.76	22.83	0.00	0.00	12.94	51.78
16	SY-1-C	407.7	0.67	0.99	0.00	0.03	21.35	45.43	0.00	0.00	11.33	74.81
17	SY-1-D	412.9	0.73	1.27	0.00	0.03	25.60	12.57	0.00	0.00	13.40	47.62
18	SY-2-A	419.5	0.98	1.46	0.00	0.04	20.25	5.20	0.00	0.00	16.63	37.23
19	SY-2-B	428.0	1.23	1.38	0.00	0.06	20.46	7.12	0.00	0.00	18.10	40.52
20	SY-2-C	415.0	1.10	1.52	0.00	0.05	19.70	6.53	0.00	0.00	17.91	38.96
21	SY-2-D	428.0	0.98	1.68	0.00	0.04	21.68	3.16	0.00	0.00	17.87	37.45
22	SY-3-A	415.4	1.25	1.64	0.09	0.06	21.33	3.59	0.00	0.00	20.46	39.38
23	SY-3-B	423.3	0.99	1.64	0.00	0.04	19.88	5.68	0.00	0.00	17.75	38.09
24	SY-3-C	427.5	0.98	1.49	0.00	0.04	22.02	2.74	0.00	0.00	16.82	36.68
25	SY-3-D	428.3	1.04	1.11	0.08	0.05	22.65	7.80	0.00	0.00	15.60	41.54
26	SY-4-A	418.4	0.67	1.29	0.00	0.03	18.16	13.41	0.00	0.00	13.10	40.78
27	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
28	Mean:		0.92	1.36	0.01	0.04	20.92	12.57	0.00	0.00	15.66	44.58
29	Standard Deviation:		0.21	0.23	0.03	0.01	1.88	12.45	0.00	0.00	2.87	10.74

Table B4. Gamma Spectrometry Data on Soil Samples Taken from 10 of the Post-Decontamination OCY Grids

	39	40	41	42	43	44	45	46	47	48	49	50
1	OLD CONSERVATION YARD AREA POST-DECONTAMINATION SOIL MCA DATA.						EXCEL FILE:		CYDECON.XLS			
2	(SAMPLES ANALYZED ON 8/29/89)											
3												
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	Mass			(from	(from					pCi/g	pCi/g
9	Description	(grams)			Ra-226)	U-238)						
10												
11	Remarks	c2	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			c2	c2	c2		c2	c2	c2	c2	+7*c43	c43+sum(c44:48)
13												
14	OSY-1 G-1	735.0	0.75	1.02	0.00	0.03	18.20	7.45	0.00	0.00	12.12	34.27
15	OSY-2 G-3	337.0	1.62	2.67	0.00	0.07	47.54	18.50	0.00	0.00	28.96	86.50
16	OSY-3 G-5	512.0	0.90	1.57	0.00	0.04	37.09	3.92	0.00	0.00	16.60	52.71
17	OSY-4 G-7	229.0	1.83	1.98	0.00	0.08	73.49	12.74	0.00	0.00	26.49	105.19
18	OSY-5 G-11	306.0	1.62	2.20	0.09	0.07	57.09	30.59	0.00	0.00	26.84	106.67
19	OSY-6 G-16	439.0	1.35	1.56	0.00	0.06	35.40	4.59	0.00	0.00	20.16	54.40
20	OSY-7 G-19	914.0	0.39	0.74	0.00	0.02	18.85	19.69	0.00	0.13	7.51	43.95
21	OSY-8 G-24	986.0	0.61	0.66	0.00	0.03	16.17	9.88	0.00	0.00	8.82	32.35
22	OSY-9 G-26	820.0	0.71	0.84	0.00	0.03	19.63	14.91	0.00	0.00	10.67	42.16
23	OSY-10 G-29	884.0	0.85	0.88	0.00	0.04	20.31	9.05	0.00	0.00	12.09	38.02
24												
25	Averages:		1.06	1.41	0.01	0.05	34.38	13.13	0.00	0.01	17.03	59.62
26	Standard Deviations:		0.50	0.70	0.03	0.02	19.66	8.15	0.00	0.04	8.06	28.85

APPENDIX C

INPUT DATA FOR RESRAD CODE CALCULATIONS

As indicated in Section 4.3, RESRAD calculations were performed for four different potential current and future land use scenarios for the OCY 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 OCY area in question. The values input to RESRAD for each of the three runs for each scenario are summarized in Table C1. For comparison, the "default" values assumed by RESRAD are shown in the last column.

Table C1. Input Parameters Used for RESRAD Runs

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)	37.2	37.2	100000	37.2	37.2	100000	37.2	37.2	100000	37.2	37.2	100000	10000
Thickness of contaminated zone (m)	0.2	0.1	35.05	0.2	0.1	35.05	0.2	0.1	35.05	0.2	0.1	35.05	1
Length parallel to aquifer flow (m)	6.1	6.1	316	6.1	6.1	316	6.1	6.1	316	6.1	6.1	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	12.9	13.1	13.1	12.9	13.1	13.1	12.9	13.1	13.1	12.9	13.1	13.1	0
Initial principal radionuclide (pCi/g): Sr-90	12.9	13.1	13.1	12.9	13.1	13.1	12.9	13.1	13.1	12.9	13.1	13.1	0
Cover depth (m)	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0	0	0
Density of cover material (g/cm**3)	2.35	2.35	2.35	2.35	2.35	2.35							1.6
Cover depth erosion rate (m/yr)	1E-10	1E-10	1E-10	1E-10	1E-10	1E-10							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 C1. Input Parameters Used for RESRAD Runs (Continued)

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)	35.15	35.15	35.15	35.15	35.15	35.15	35.05	35.05	35.05	35.05	35.05	35.05	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)	34.85	34.95		34.85	34.95		34.85	34.95		34.85	34.95		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 C1. Input Parameters Used for RESRAD Runs (Continued)

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	0.26	0.26	0.26	0.66	0.66	0.66	0.005	0.005	0.005	0.6	0.6	0.6	0.6
Occupancy factor, inhalation	0.17	0.17	0.17	0.42	0.42	0.42	0.005	0.005	0.005	0.45	0.45	0.45	0.45
Shape factor, external gamma	0.994	0.994	1	0.994	0.994	1	0.994	0.994	1	0.994	0.994	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 D

LIST OF ITEMS IN THE OCY DECOMMISSIONING FILE (MAINTAINED AT BUILDING T100, SSFL)

The following is an annotated list of documents on the decontamination of the Old Conservation Yard Area, archived in Building T100 of Rockwell International's Santa Susana Field Laboratory (SSFL).

1. Chapman, J. A., "Radiological Survey of the ESG Salvage Yard (Old), Rocketdyne Barrel Storage Yard, and New Salvage Yard (T583)," Energy Technology Engineering Center Report GEN–ZR–0008, August 22, 1988.

   - Is the primary document reporting the comprehensive radiological survey of a 5–acre area that included the three yards. Of the yards surveyed, a portion of the Rocketdyne Barrel Storage Yard was the only area found to be slightly contaminated with ^{137}Cs and was subsequently designated as the Old Conservation Yard (OCY). The above report recommended further investigations of a 20–ft by 20–ft area within the OCY.

2. Parker, D., "Conservation Yard Decontamination," Rockwell International Detailed Work Procedure N001DWP000022, July 31, 1989.

   - Describes the operational procedures used to decontaminate the 20–ft by 20–ft area within the OCY.

3. Five photographs taken during the OCY area decontamination and survey operations.

4. SOILTEMP spreadsheets corresponding to data from the 30 gamma exposure rate, 10 soil gross alpha, and 10 soil gross beta measurements.

5. Gamma Mass Spectrometric Analysis (MCA) printouts and corresponding MCASOIL spreadsheets for the following: (1) 10 background soil samples, (2) repeat analysis of 10 background soil samples, (3) 13 soil samples from the four B–12 boxes, and (4) 10 post–decontamination soil samples from OCY area grid locations.

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

7. Subbaraman, G., and Oliver, B.M., "Final Decontamination and Radiological Survey of the Old Conservation Yard," Rockwell International Safety Review Report N704SRR990030, August 1990.

   - A released copy of the report containing this list.