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TITLE: Radiological Survey of the T513 Parking Lot; Old R/A Laundry Area; Plot 333; and Areas Between the SRE to RMDF, and KEWB to RMDF"

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ABSTRACT

A radiological survey was performed in five SSFL areas used to support nuclear-related facilities by storing excess materials and components, drums and barrels, and as parking lots and access pathways from facility to facility. These natural terrain areas include: 1) T513 Parking Lot, 2) Old Radioactive Laundry Area, 3) Plot 333 (referred to as the SRE Storage and Trash Dump), 4) a field located between SRE and RMDF, and 5) a field located between KEWB and RMDF. These areas are flat, open fields surrounded by numerous sandstone outcroppings. No buildings occupy the premises. All that is left in some areas are concrete slabs. The T513 Parking Lot is the only paved area. Various materials (some perhaps contaminated with radioactivity, but unlikely) were moved from facility to facility through these pathways, or were stored for future applications. The nuclear-related facilities which these areas serviced were SRE, RMDF, KEWB, ETB, T030, and T064. No known contamination incidents occurred at these facilities to such a magnitude that would result in contaminating these inspected areas. Residual radioactivity is not suspect. The radiological survey was performed to determine if any radioactive material has been accidentally left behind to such an extent that further surveying or decontamination is warranted.

All combined, a 2.5-acre area was inspected. Ambient gamma exposure rate measurements were performed on a 6-m square plot plan. Soil sample collection and analysis was not required and not performed.

Results of this survey and analysis show that all five inspected areas are not contaminated with residual radioactivity. Gamma exposure rate measurements plotted against cumulative probability show Gaussian distributions with no outliers or anomalies. All sample lots, when corrected for ambient "background" radiation, (and this includes that background due to natural phenomena, instrument noise, and RMDF skyshine) pass acceptance criteria for unrestricted use. No further investigation is necessary in these locations.

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1.0 INTRODUCTION

Five areas located in Area IV of Rockwell International's Santa Susana Field Laboratories (SSFL) were inspected and analyzed for residual radioactive material. These areas have been used for various functions: storing excess salvageable materials and scrap components; holding equipment; parking; and as access to facilities which handled radioactive material. These natural terrain areas supported AEC, ERDA, and DOE nuclear-related programs and include:

1. T513 Parking Lot;
2. Old Radioactive (R/A) Laundry Area;
3. Plot 333, known as the SRE Storage and Trash Dump;
4. SRE-to-RMDF Field; and
5. KEWB-to-RMDF Field.

Each area was inspected for radioactivity to determine whether any radioactive material has been accidentally left behind and if further investigation is necessary or remedial action is required. This radiological survey was conducted as prescribed in the "Radiological Survey Plan for SSFL," (Reference 4, Sections 5.4.3.2, 5.4.4, 5.4.8, and 5.4.9).

Located in Ventura County, California, Area IV of Rockwell International's SSFL has been used to develop and test nuclear powered reactors; fabricate reactor-grade nuclear fuels; and disassemble irradiated fuel elements. These programs were funded by the AEC, ERDA, and DOE. Many of these government-sponsored nuclear-related programs have ended, and the facilities that supported these programs have been reassigned and modified for other non-nuclear DOE programs.

The areas inspected for radioactivity covered in this report supported several of those facilities. These inspected areas are near or were used in support of five nuclear-related facilities:

1. Sodium Reactor Experiment (SRE), Building T143;
2. Engineering Test Building (ETB), Building T003;

3. Radioactive Laundry Facility;
4. Radioactive Material Disposal Facility (RMDF); and
5. Kinetic Experiment Water Boiler, (KEWB).

The SRE and KEWB were nuclear reactors. Both were dismantled and decommissioned by the early 1980s. The SRE building is still in place; the facility is in use as a warehouse. The KEWB consisted of three small buildings constructed mostly underground. These buildings were removed from the site. The area is now a natural terrain field. ETB contained a large hot cell used in support of SRE projects for examination and tests of SRE components. ETB was decommissioned. The building is still in place and used on a limited basis for miscellaneous equipment storage. The Radioactive Laundry Facility was torn down about the same time SRE was dismantled. The only remaining structure is the concrete-slab floor. When the SRE, ETB, Radioactive Laundry, and KEWB facilities were dismantled and decommissioned, a radiation survey was performed to ensure that residual radioactivity levels met unrestricted-use acceptance limits. The four facilities are known to be "clean." The RMDF is still in use and contains significant amounts of radioactive material awaiting disposition to a burial site. RMDF operations elevate the surrounding ambient gamma-radiation exposure rate.

Areas inspected for radioactivity were used as pathways between, parking lots for, and equipment storage yards of these nuclear-related facilities. The T513 Parking Lot survey covered asphalt areas which supported ETB, and two other nuclear-related facilities: Buildings T030 and T064. It was used as a pathway between these facilities and the R/A Laundry facility. Some spills of radioactive material may have occurred between these facilities. The Old R/A Laundry Area is natural terrain except for the remaining concrete pads. Contaminated laundry from SRE, ETB, and RMDF was brought here for cleaning. Residual contamination is not suspect. Plot 333 is a natural terrain field now and contains no debris; it was used for storing SRE equipment. No contaminated items are known to have been found there. The SRE-to-RMDF Field was used in the same capacity as Plot 333. No contamination incidents are known. Skyshine from the RMDF affects ambient exposure rate in this location. The KEWB-to-RMDF Field supported KEWB, and is very close in proximity to a previously operated nuclear reactor--the L-85 (Building T093). KEWB and L-85 are known to be "clean." No residual contamination is suspect in the surrounding field which was inspected. Although some minor radiological contamination incidents might have occurred in these areas, it was common practice to decontaminate and return an affected location to its natural condition. The purpose of this survey was to detect any radioactive material accidentally left behind.

As part of the DOE SSFL Site Survey (Reference 4, sections 5.4.3.2, 5.4.4, 5.4.8 and 5.4.9), a radiation survey was performed in these areas to determine if any residual contamination exists. Ambient gamma exposure rates were measured on a 6-m by 6-m grid. These radiation measurements are sensitive to radiations emitted from radioactive materials handled at the nuclear facilities: mixed fission products and activation products. If radioactive contamination was indicated during performance of the gamma measurements, samples were to be collected and analyzed for radioactivity. Further sampling inspection was not required for this particular survey.

All ambient gamma exposure rate data were input into a Personal Computer (PC) graphics program which plots the radiation measurement value against its cumulative probability. The software also calculates a test statistic using inspection by variables techniques. This test statistic is that value greater than the mean value of the distribution, which corresponds to a consumer's risk of acceptance of 10% probability with a Lot Tolerance Percent Defective (LTPD) of 0.10. This method assumes the data follow a Gaussian probability density function. Inspection by variables techniques allows a thorough, understandable, and conclusive study for assessing the contamination level in an area.

Radiation measurements are compared against DOE residual radioactivity limits specified in "Guidelines for Residual Radioactivity at FUSRAP and Remote SFMP Sites," (Reference 1). This guide generally agrees with previously published guides and standards, including ANSI Standard N13.12 (Reference 7), Regulatory Guide 1.86, and USNRC License SNM-21 (Reference 2). Limits for acceptable ambient gamma exposure rates differ between the DOE and NRC. DOE specifies 20 μR/h above background while NRC specifies 5 μR/h above background as acceptable gamma exposure rate limits. Natural "background" at SSFL is very difficult to determine because of a large observed variability in the measurements. Because of this large variation, total-gross gamma measurements made in a survey area are plotted and compared against three independent "natural" background distributions. Then the average "background" exposure rate of the three "natural background" distributions is subtracted from each data set to compare the results against the 5 μR/h above background criteria. Finally, because the ambient exposure rate in some of these inspected areas is influenced by RMDF operations, an estimate of that contribution is necessary and was performed.

2.0 IDENTIFICATION OF FACILITY PREMISES

2.1 Location

The areas covered in this report are identified in the "Radiological Survey Plan for SSFL," (Reference 4) as follows:

1. T513 Parking Lot (section 5.4.3.2);
2. Old Radioactive (R/A) Laundry Area (section 5.4.3.2);
3. SRE Storage and Trash Dump, Plot 333 (section 5.4.4).
4. SRE-to-RMDF Field (section 5.4.8); and
5. KEWB-to-RMDF Field (section 5.4.9).

SRE refers to Sodium Reactor Experiment; RMDF to Radioactive Materials Disposal Facility; and KEWB to Kinetic Experiment Water Boiler. Each of these facilities handled radioactive material, or radioactively contaminated equipment. Most of the surveyed areas are interconnecting fields.

These areas are close to each other, and are located within Rockwell International's Santa Susana Field Laboratory (SSFL) in the Simi Hills of southeastern Ventura County, California. SSFL is adjacent to the Los Angeles County line and is approximately 29 miles northwest of downtown Los Angeles. The SSFL location relative to the Los Angeles area and surrounding vicinity is shown in Figure 2.1. Figure 2.2 is an enlarged map of neighboring SSFL communities.

The five areas covered in this report are located in the western portion of SSFL, referred to as Area IV. Figure 2.3 is a plot plan of Area IV showing the locations of subject areas. All of the areas are located within the 90.26-acre Government-Optioned Area.

Figure 2.1 Map of Los Angeles Area

Figure 2.2 Map of Neighboring SSFL Communities

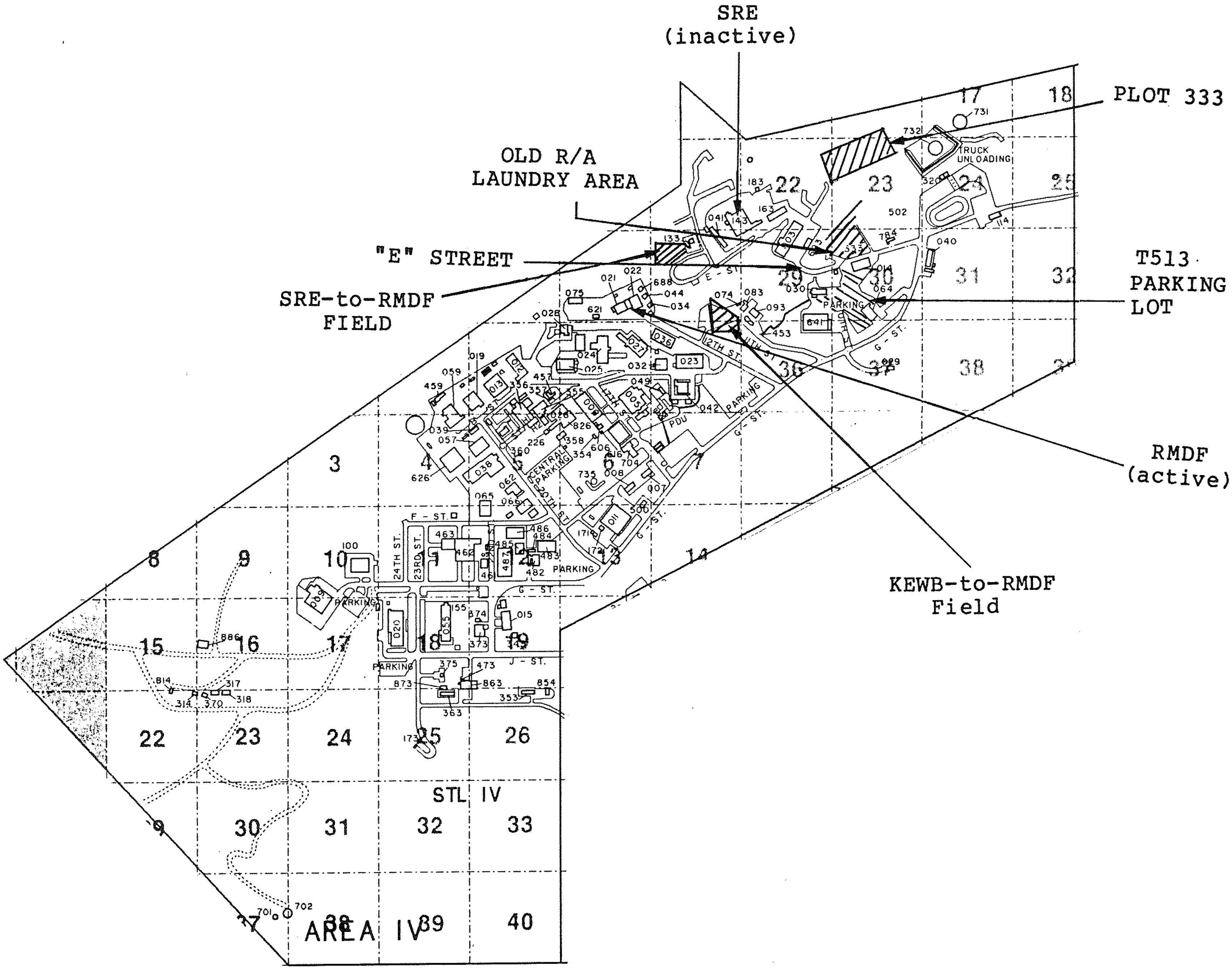


Figure 2.3 SSFL Layout, Showing Locations of T513 Parking Lot, Old R/A Laundry Area, Plot 333, SRE RMDF, and KEWB to RMDF

2.2 Topography, Utilization, and Present Radiological Condition

These sites are located on an irregular plateau in a mountainous area of recent geological age sprinkled with outcroppings above the more level patches. Outcroppings of Chico sandstone formation are numerous. Many of the areas are surrounded by large sandstones, some towering up to 50 ft. Topography maps of these areas are presented in Figures 2.4 and 2.5.

The general slope of Area IV is in a southerly direction. Water runoff is directed to the retention reservoirs which are part of the SSFL industrial effluent control system. Liquid effluent discharge from the property into the Bell Canyon drainage occurs only after controlled effluent hold-up and sampling. Because some of the subject areas border the northern property line, however, some surface drainage is northerly to Simi Valley.

Most of the subject areas consist of natural terrain with some asphalt paving. The natural terrain areas were primarily used during operation of the SRE as equipment holding areas. Paved locations were parking lots or access roads serving the SRE vicinity. Figure 2.6 is a photograph of the areas surveyed. The following sections describe in more detail each area's terrain, use, and present radiological condition.

2.2.1 T513 Parking Lot

This area is located on the east side of 10th Street. Over the years it has served as a parking area for personnel working in Buildings T030, T641, and T064. The asphalt concrete paving is connected with a yard area paving just north of T064 and has, therefore, also served as an access to T064. Also included as part of this sampling designation, is part of "E" Street from the Engineering Test Building (T003) to its intersection with 10th Street. This road is constructed with asphalt concrete, and a large portion of the road is cut through a rock outcropping. This entire paved area was used for parking and access to the Sodium Reactor Experiment (SRE)

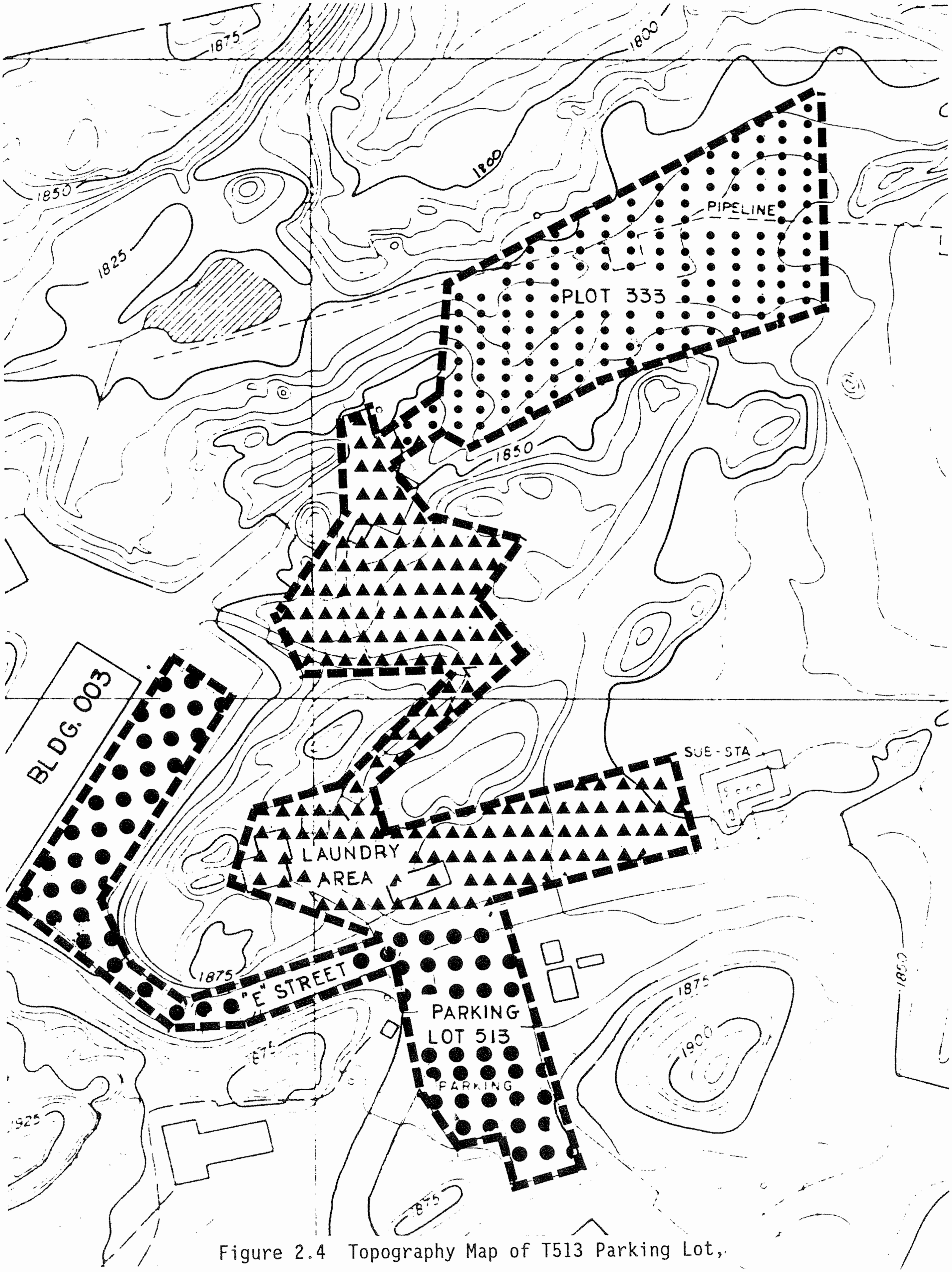


Figure 2.4 Topography Map of T513 Parking Lot, Old R/A Laundry Area, and Plot 333

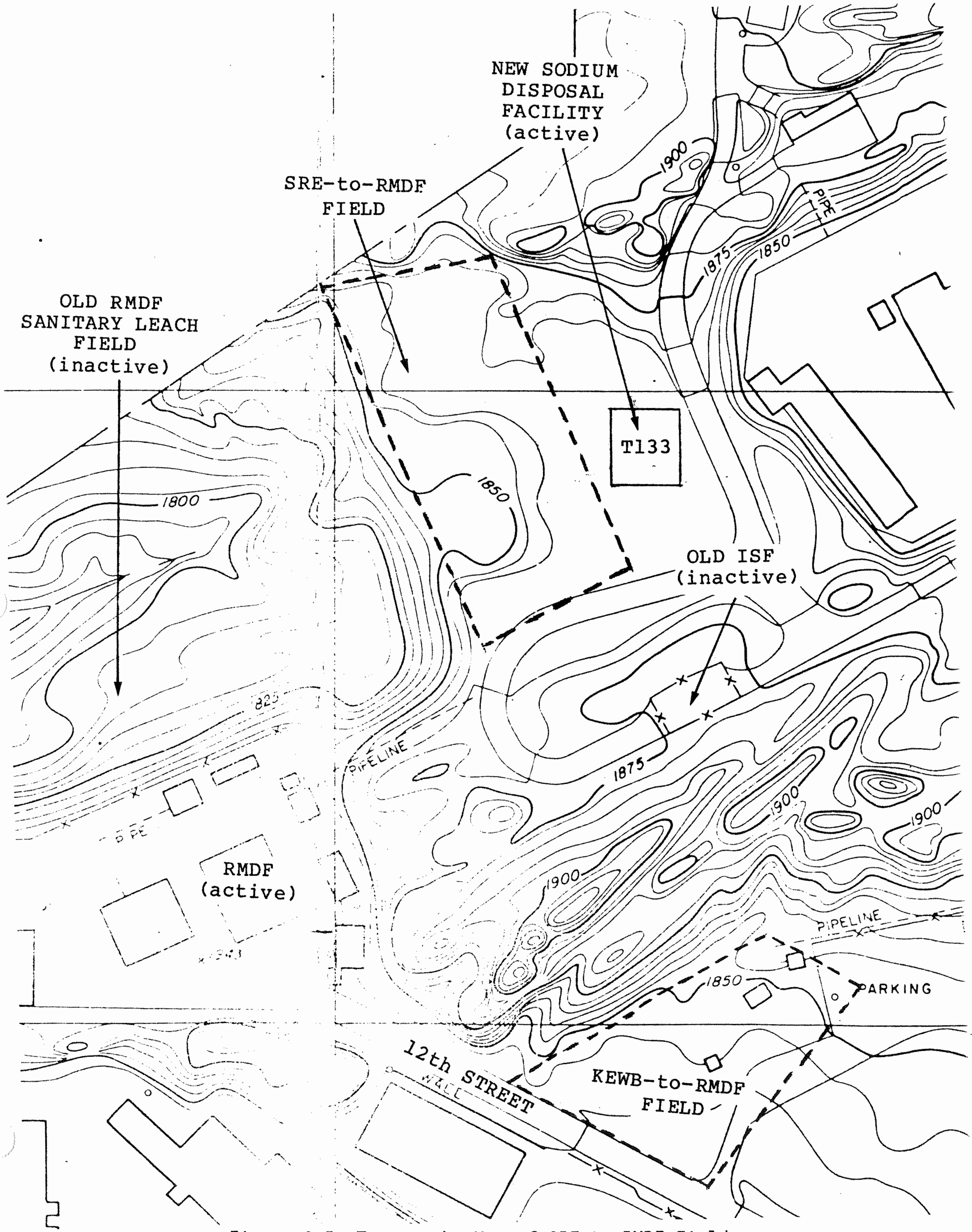


Figure 2.5 Topography Map of SRE-to-RMDF Field, and KEWB-to-RMDF Field

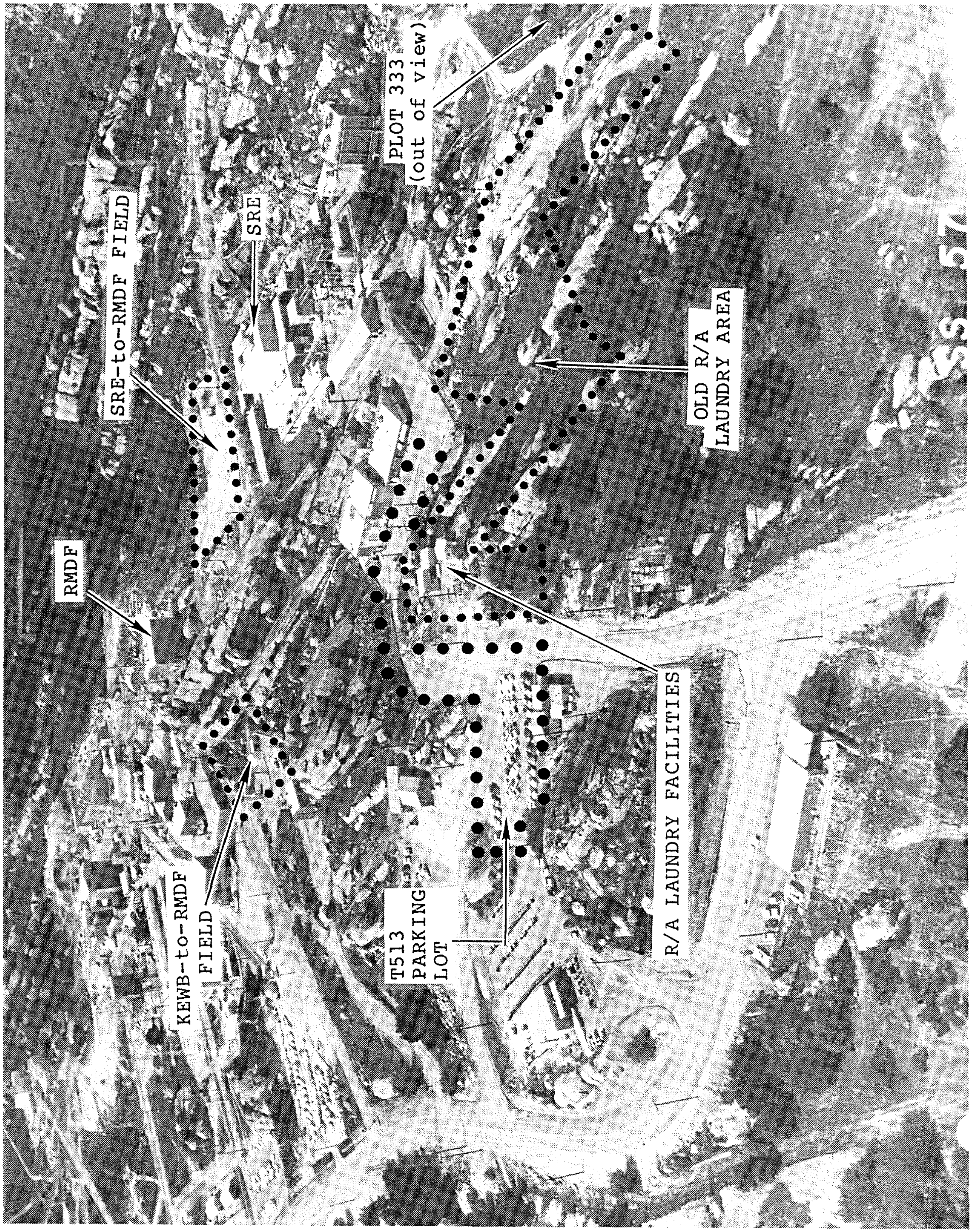


Figure 2.6 Photograph (1962) of Areas Surveyed

complex, ETB (T003), and the Source and Special Nuclear Material Storage Vault, T064. All of these facilities handled radioactive material or radioactively contaminated equipment. Radioactive contaminants are slightly suspect in this pathway because of spills and other minor incidents which are thought to have occurred during operation of these facilities.

2.2.2 Old Radioactive (R/A) Laundry Area

The area identified as the Old R/A Laundry Area covers an area north of "E" Street at its intersection with 10th Street. All that remains of the R/A protective clothing laundry and storage buildings (T273 and T283), are the concrete slabs. Most of the area is natural terrain. These facilities supported operation of the SRE. Operation was discontinued in 1971, and the buildings were demolished in 1976. Another small general storage building known as Building T063 was demolished at the same time. Only the concrete floors remain of these structures, which for several years were utilized for storing bottled industrial gases. A pathway connecting the laundry area with the old component cleaning facility to the north was also included in this survey. The old cleaning enclosure which was identified as Building 724 was removed in 1976, and only the concrete pad remains.

No major incidents are known to have occurred at the R/A laundry facility, although minor contamination incidents and spills may have occurred. Because contaminated protective clothing was stored in these facilities, contamination may have been spread during operation. When the facilities were dismantled, a radiation survey was performed to ensure that no contamination was left behind. Currently, the area is not suspect of radioactive contamination.

2.2.3 SRE Storage and Trash Dump, Plot 333

Plot 333 is an open natural terrain area east of the SRE complex that was used as a holding or staging area for equipment and/or material awaiting disposition. It is adjacent to the old ESG Salvage Yard (Reference

21), and was also cleared of all materials prior to the relocation of the salvage yard in January 1977.

No contamination incidents are known to have occurred. Currently, the area is not suspect of radioactive contamination.

2.2.4 SRE-to-RMDF Field

Figure 2.7 shows this location. Just west of the currently existing Sodium Disposal Facility (T133) is this plateau area where construction materials and trash from the SRE were stored in the 1970s. Some radioactive material storage barrels may have been stored there. At the western boundary of this area is a significant drop-off of about 25 ft into the old RMDF sanitary leach field (shown in the figure). The photograph in Figure 2.7 was taken in 1974; it shows that an area just east of the field surveyed was used for material storage. That location is currently occupied by T133. There is a rock ridge on the south (pictured) and one on the north (out of view). Just south of this field was an area which housed the Interim Storage Facility (ISF). This facility was used to store spent fuel elements, shipping and storage casks, and hot waste from the SRE. Decontamination and decommissioning of ISF was completed in 1975. A final radiation survey performed then showed that the area met unrestricted-use requirements (Reference 25). Figure 2.8 shows the ISF location surveyed in 1975. This area was not resurveyed under our current plan -- it is considered "clean."

No radioactive contamination incidents are known to have occurred in this field. The area is presently clean of debris; contamination is not suspect.

2.2.5 KEWB-to-RMDF Field

This field between T093 and the RMDF is currently natural terrain. This area used to support a nuclear reactor. Figure 2.9 is a photograph which shows what this area used to look like during operation as the KEWB through the early-1970s. The Kinetic Experiment Water Boiler (KEWB) Test

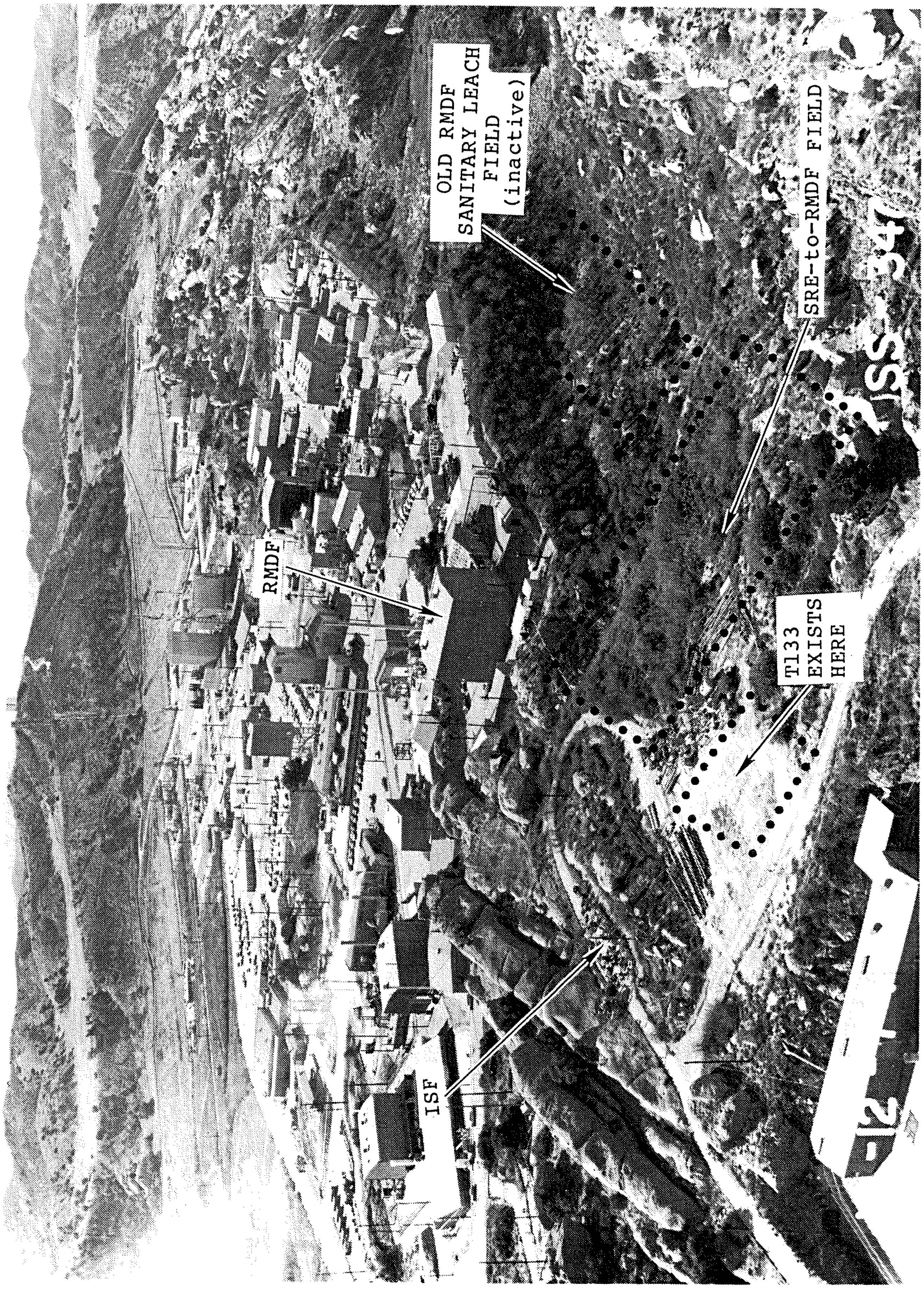


Figure 2.7 Photograph (1974) of SRE-to-RMDF Field

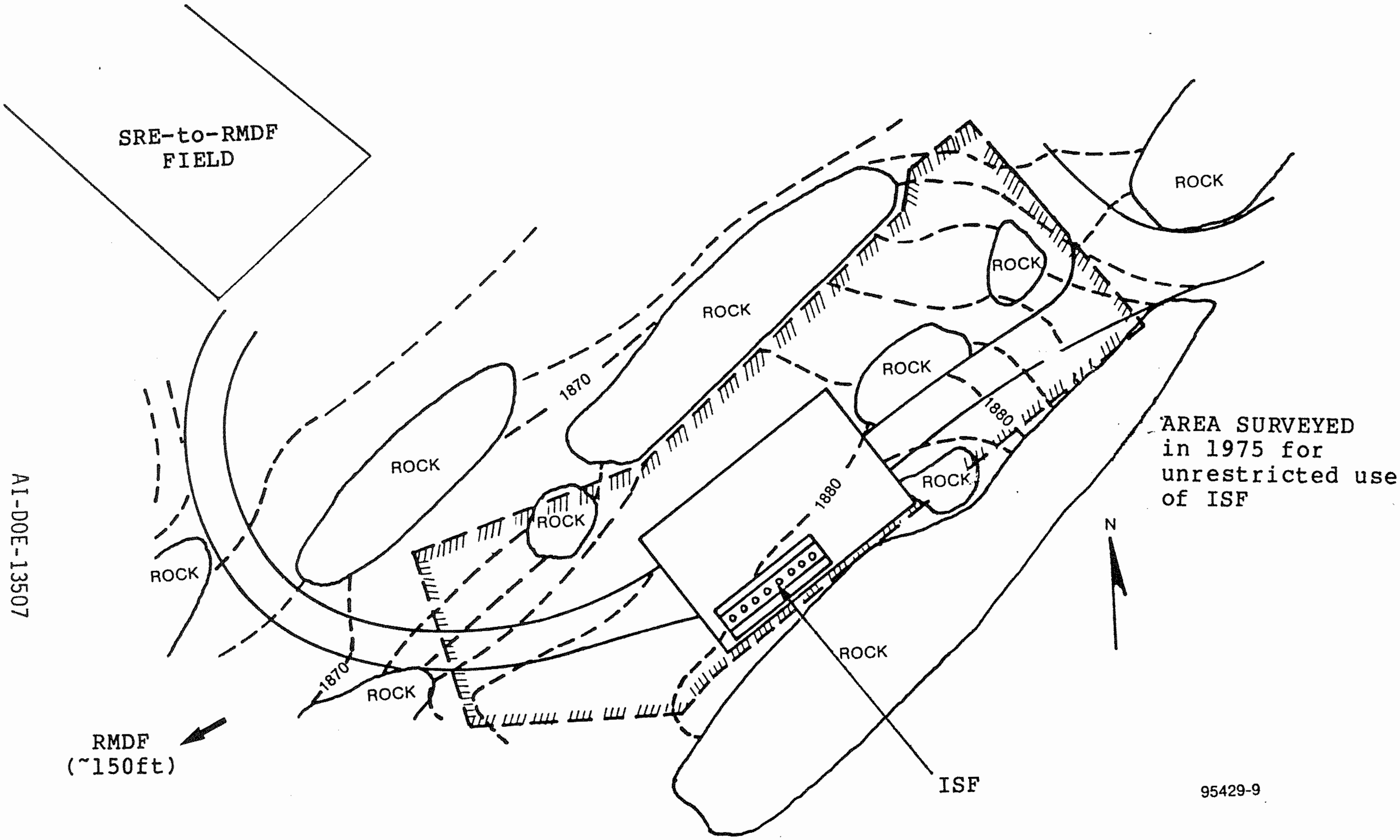
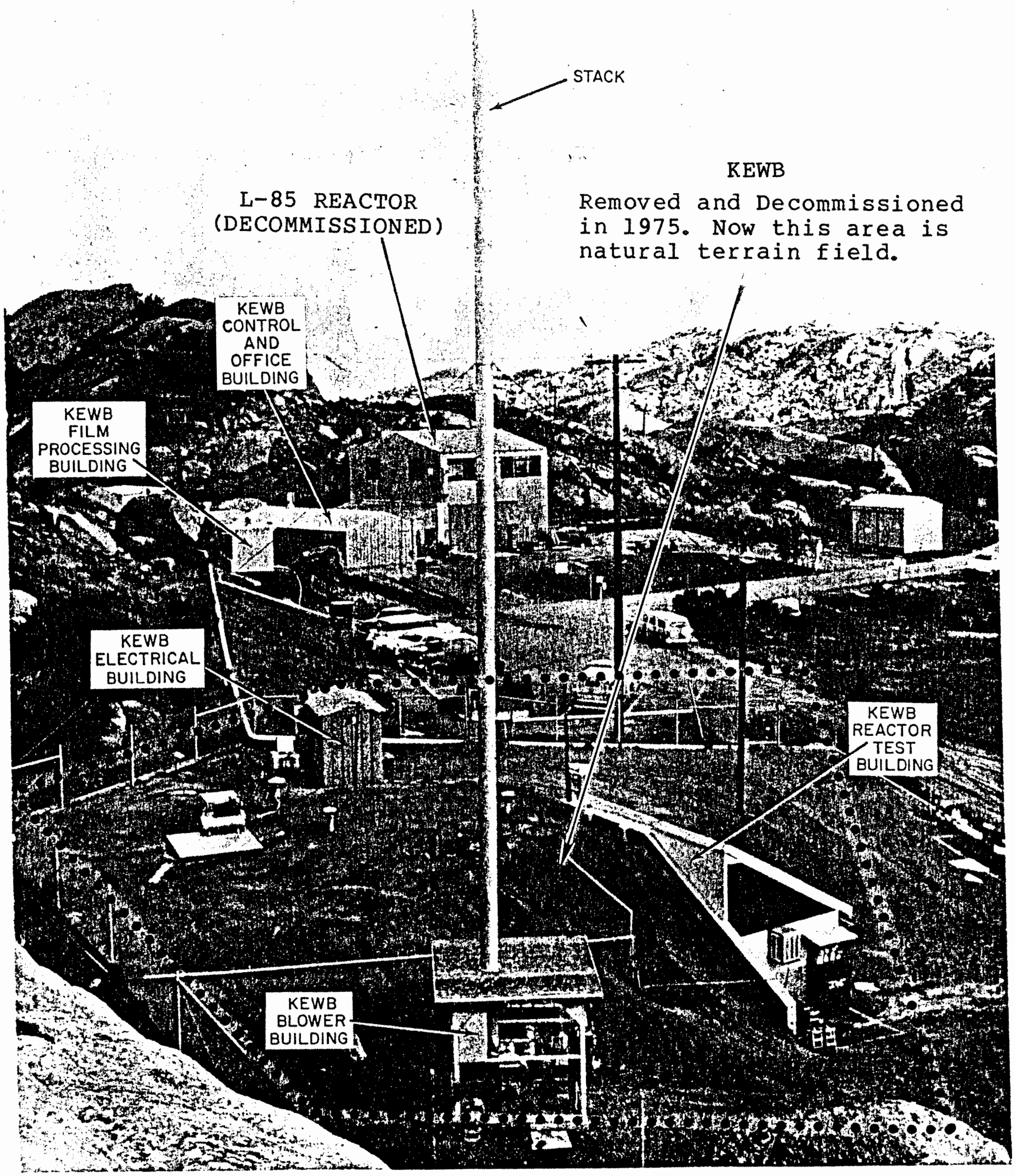


Figure 2.8 Interim Storage Facility Location and Survey Area (1975)

Figure 2.9 Photograph of KEWB-to-RMDF Area (1961)



Facility was located in an area between 12th Street, the RMDF, and the L-85 reactor facility (T093). KEWB provided the means for experimentally determining the dynamic behavior of homogenous, water-boiler type reactors (Reference 22). KEWB was dismantled and decommissioned in 1975, although parts of the underground concrete structure are still in place. Every effort was made to be certain that all induced radioactivity had been removed. Remaining concrete is not activated (Reference 26). The site was graded and a radiological survey performed. Radiation levels observed during that 1975 survey did not exceed normal radiation background levels (References 24 and 26).

This area is now overgrown with natural vegetation. At the northern boundary is a very large outcropping at least 50 ft high. Although some contamination incidents did occur at KEWB, by the time of facility decommissioning, no residual radioactivity existed. This field area is currently considered to be "clean."

3.0 SURVEY SCOPE

The following areas were radiologically inspected by measuring ambient gamma exposure rates 1 meter above the ground in locations specified by the "Radiological Survey Plan for SSFL," (Reference 4):

1. T513 Parking Lot (Reference 4, section 5.4.3.2)

    * Survey the parking lot surface for mixed fission products.
    * Survey 10th Street and "E" Street for mixed fission products.

2. Old Radioactive Laundry Area (Reference 4, section 5.4.3.2)

    * Survey old R/A laundry area including path to sodium steam pad for mixed fission products.

3. SRE Storage and Trash Dump, Plot 333 (Reference 4, section 5.4.4)

    * Survey surface for mixed fission products. On indication perform gamma spectrometry on samples.

4. SRE-to-RMDF Field (Reference 4, section 5.4.8)

    * Survey surface, west form parking lot to RMDF leach field and north and south between rock ridges. Survey for mixed fission products.

5. KEWB-to-RMDF Field (Reference 4, section 5.4.9)

    * Survey open-field for mixed fission products.

These areas are shown in Figures 2.4. and 2.5, topography maps; and Figure 2.6, an aerial photograph.

Gamma exposure rate measurements were made at 294 locations in the combined areas: 69 (T513 Parking Lot); 53 (R/A Laundry Area); 52 (Plot 333); 55 (SRE-to-RMDF), and 65 (KEWB-to-RMDF). Soil samples were not collected and analyzed because no indication of contamination occurred. Ambient gamma exposure rates are reported in micro-roentgens per hour (μR/h).

3.1 Unrestricted-use Acceptable Contamination Limits

A sampling inspection plan using variables, discussed in Section 4.2, was used to compare radiological contamination quantities against unrestricted-use acceptable contamination limits prescribed in DOE guidelines (Reference 1), Regulatory Guide 1.86, NRC license SNM-21, and other references. The limits shown in Table 3.1 have been adopted by Rocketdyne.

Limits for soil and water radioactivity concentrations are applicable on an as-required basis. The limits used here for alpha contamination in soil, are based on Ra-226 (Reference 1).

Three specific action levels were established for the survey. These are proactive action levels initiated when the surveyor detects radiation according to the following criteria:

1. Characterization Level - that level of radioactivity which is below 50% of the maximum acceptable limit. This level is typical of natural background levels, or slightly above, and requires no further action.

2. Reinspection Level - that level of radioactivity which is above 50% of the maximum acceptable limit. A general resurvey of the area and a few additional samples are required in this case.

3. Investigation Level - that level of radioactivity which exceeds 90% of the maximum acceptable limit. Specific investigation of the occurrence is required in this case.

Table 3.1 Maximum Acceptable Contamination Limits

Criteria	Alpha	Beta
Ambient Gamma Exposure Rate*	5 μR/h above background	
Soil Activity Concentration**	21 pCi/g 31 pCi/g	100 pCi/g
Water Activity Concentration***	$1x10^{-4}$ μCi/ml	$1x10^{-5}$ μCi/ml

* Although DOE Guide (Reference 1) recommends a value of 20 μR/h above background for ambient gamma exposure rate, NRC has required 5 μR/h. For conservatism, we use 5 μR/h above background to compare survey results.

** The alpha activity concentration limit for Ra-226 is 5 pCi/g (Reference 1) plus that contribution from naturally occurring radioactivity, (about 16 pCi/g from Reference 17, 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, including background which is about 24 pCi/g.

*** The most restrictive alpha/beta water radioactivity concentrations for a restricted area taken from DOE Order 5480.1 Chapter XI, Table 1, Column 2. Alpha corresponds to Pu-239, beta to Sr-90.

3.2 Sample Lots

For purposes of this radiological survey, each of the five areas was treated as a single sample lot for characterization and interpretation. The areas, as demonstrated by the topography map, are somewhat cluttered with sandstone outcroppings. Figures 2.4 and 2.5 show the survey sampling lot plan.

6-m square grids were superimposed over the terrain. One ambient gamma exposure rate measurement was made in each 36-m^2 cell. Location (1,1) was the northwestern-most grid in each area. Each measurement location was marked on a map with its corresponding two figure Cartesian coordinate indicating the location from a local benchmark. The sampling inspection plan used was based upon a uniform 6-meter square grid superimposed on a uniform inspection area. Radiological conditions and physical surroundings fell into two categories: 1) Paved asphalt (T513 Parking Lot); or 2) natural terrain (all other test-areas).

3.3 Ambient Gamma Exposure Rate Measurements

In each 36-m^2 cell, a gamma exposure rate measurement was made 1 m from the surface. The particular location in each cell was chosen randomly, and identified on a map. A tripod was used to support a 1 in. x 1 in. NaI crystal coupled to a photomultiplier tube and fed to a Ludlum 2220-ESG scaler, at 1 m from the ground. In each cell, a 1-min. count was collected and converted to μR/h. The measurement location and exposure rate were recorded in tabular form. 294 1-min. measurements were acquired over the total area.

3.4 Surface Soil Samples

Soil sampling was required by the Site Survey Plan (Reference 4) only if gamma exposure rate measurements indicated possible radioactivity. Exposure rate measurements did not indicate possible contamination. Soil samples were not collected.

3.5 Goals and Limitations of Survey Scope

These salvage yards, excess material storage areas, and facility connecting-pathways cover an extensive territory; almost 2.5 acres. Certain areas have been used for many years and were used quite vigorously in the 1960s and 1970s for storing scrap and junk. Limited inventory controls were used during the active periods to ensure that only truly salvageable materials were brought to those areas. Radiation controls were well-known and were complied with. Radioactive materials and radioactively contaminated equipment were prohibited from the area. Radiation surveys were performed regularly to ensure compliance with this policy. We believe that no contaminated items or debris were ever discovered in these storage areas. Other areas were used as access paths and roadways to the various facilities. It is believed that a few radioactive material spills occurred just outside T003, and between T003 and the R/A Laundry Building. This is not documented. A thorough radiation survey was performed when each area was dismantled and cleaned-out. No radioactivity was found then. Radioactivity is not suspect now. The goal of this survey is to determine if contamination exists to such an extent that further surveying or remedial action is warranted.

Ambient gamma exposure rate measurements are sensitive enough to detect contaminants left behind. Most probable contaminants are mixed-fission products and activation products. It is unlikely that any subsurface (greater than a foot) debris is currently on site; these areas were never dumping grounds or landfills. Subsurface transport of contaminants is also considered negligible. If any contaminants do exist on-site, they are most likely still on the surface.

Because of the large area surveyed, exposure rates were measured every 36 m^2. This sampling plan is sufficient for two reasons:

1) gamma measurements made on a 6-m square would detect Cs-137 at 100 pCi/g (the beta activity limit) if the surface layer was thicker than 1 cm. A 1 mCi Cs-137 source would be detectable

at the greatest separation distance of 6 meters. These sensitivities meet the requirements of this survey; and

2) By applying Lot Tolerance Percent Defective techniques, we can determine with a statistical confidence of 0.90, that there is a probability of 90% that radioactive contamination does not exceed some predetermined acceptance limit. This determination varies inversely to the number of samples taken. This technique, along with the graphical representations of cumulative distribution functions will identify trends, anomalies, outliers, and perturbations in the radiation levels.

We are able to conclude whether:

1. Any surface deposition, migration, or dispersion of radioactive materials has occurred; and

2. Any relatively intense gamma-emitting debris is buried (see Section 5.4.4).

We cannot conclude whether:

1. Any slight subsurface migration has occurred; or

2. Any buried debris with low intensity radiation is present.

The likelihood for occurrence of the above two conditions is small. First, migration periods of contaminants below the surface are typically very long. It is much easier for surface water flowing downslope to carry with it any contaminants. The settling out of these contaminants into the subsurface also takes a long time. Second, no known burial or dumping activities took place in any of these areas.

4.0 STATISTICS

4.1 Counting Statistics

The emission of atomic and nuclear radiation obeys the rules of quantum theory. As a result of this, only the probability that an emission will occur is determined. The absolute number of particles emitted by a radioactive source in a unit of time, is not constant in time; it has a statistical variability because of the probabilistic nature of the phenomenon under study. The number of particles emitted per unit time is different for successive units of time. Therefore, only the average number of particles emitted per unit time and per unit area or mass can be determined. The number of particles, x, emitted by a radiation source in time, T, obeys the Poisson distribution:

$$P_x = \frac{m^x e^{-m}}{x!} \qquad \text{(Eq. 4-1)}$$

where m is the average number of emissions in that time. x is what we measure each time an area or sample is surveyed. The standard deviation is the square root of the average squared deviation of x from its mean, m. For the Poisson distribution, the standard deviation is given by:

$$s = \sqrt{x}\ , \qquad \text{(Eq. 4-2)}$$

the square root of the counts observed, ($x = \overline{x} = m$). Since background radiation is always inherent in a given sample measurement, propagation of errors tells us that the total standard deviation is:

$$s = \frac{\sqrt{C + B}}{T} \qquad \text{(Eq. 4-3)}$$

where C = the number of counts recorded in time, T, of the sample

B = the number of counts recorded in time, T, of the background radiation environment

Equal values of the time, T, must be used for the sample and background counts for equation 4-3 to apply. This Poisson distribution and standard deviation applies for single radiation measurements, of the discrete random variable, x, and is applicable only when the observation times are short compared with the half-life. This is the case for the site survey.

Because of the probabilistic nature of particles emitted by radioactive elements, repeated measurements of the average number of emissions per unit time shows a distribution approximated by the Gaussian (or normal) probability density function (pdf); this is known as the central limit theorem. This theorem holds for any random sample with finite standard deviation. If measurements are made at many similar locations, these measurements will show a greater variability, but the distribution will remain adequately represented by a Gaussian function. This Gaussian approximation is good when the number of samples collected is at least 30. Thus the number of occurrences of particular mean radiological contamination values, g(x), shows a Gaussian pdf relative to the contamination value, and the data can be plotted accordingly. Subsequently, based on the results of the data analysis, a conclusion can be made regarding the amount of radioactive material in an area, and any anomalous values can be identified.

The Gaussian probability density function, g(x), is given by:

$$g(x)dx = \frac{1}{(\sqrt{2\pi})\sigma} \exp\left(\frac{-(x-m)^2}{2\sigma^2}\right) dx \qquad \text{(Eq. 4-4)}$$

where g(x)dx = probability that the value of x, lies between x and x+dx

m = average, or mean of the population distribution

σ = standard deviation of the population distribution.

A graph of x vs. g(x) gives the following bell-shaped curve:

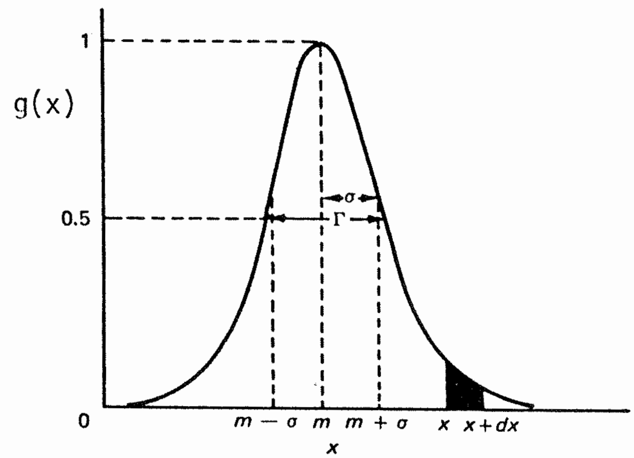


Figure 4.1 The Gaussian Probability Density Function

The cumulative distribution function (cdf), G(x), is equal to the integral of the pdf, for a continuous random variable, hence:

$$G(x) = \int_{\infty}^{X} g(x)dx \qquad \text{(Eq. 4-5)}$$

$$= P(x < X)$$

This function is commonly referred to as the error function, (erf). The graph of the Gaussian cdf is:

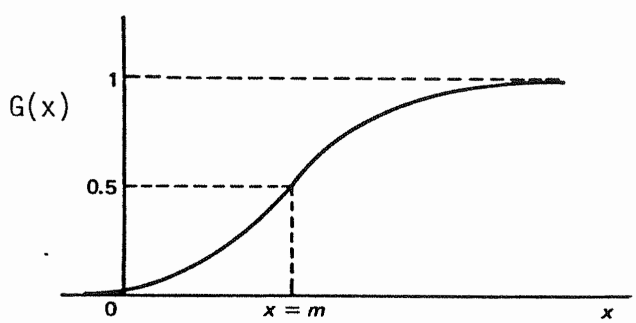


Figure 4.2 The Caussian Cumulative Distribution Function

By plotting multiple measurements we make in the field; i.e. the average contamination values approximated by the Poisson distribution, as a cdf of the Gaussian distribution, we can identify whether the entire area is unacceptably contaminated, part of the area is contaminated more than the rest, or further radiological measurements are necessary. Furthermore, by making use of the Gaussian approximation, we can easily calculate the mean contamination value with its associated standard deviation, and apply inspection by variables techniques to either accept the area as clean or reject the area as contaminated.

This statistical summary presents fundamental principles used to reduce and analyze radiological measurement data from the site survey.

4.2 Sampling Inspection

4.2.1 By Variables

Acceptance inspection by variables is a method of judging whether a lot of items is of acceptable quality by examining a sample from the lot, or population. In the case of determining the extent of contamination in an area, it would be unacceptably time consuming and not cost effective to measure 100% of the population. However, by applying sampling inspection by variables methods, the accuracy of the conclusion made about the level of contamination is not sacrificed because of a decrease in number of sampling locations. We estimate the level of contamination in an area by making at least 30 measurements. This allows us to approximate a Gaussian distribution through the Central Limit Theorem. The entire area must have similar radiological characteristics and physical attributes. In acceptance inspection by variables, the result is recorded numerically and is not treated as a Boolean statistic, so fewer areas need to be inspected for a given degree of accuracy in judging a lot's acceptability.

4.2.2 By Attributes

By contrast, in acceptance inspection by attributes, the radiation measurement in a given area is recorded and classified as either being defective or nondefective, according to the acceptance criteria. A defect means an instance of a failure to meet a requirement imposed on a unit with respect to a single quality characteristic. Second, a decision is made from the number of defective areas in the sample whether the percentage of defective areas in the lot is small enough for the lot to be considered acceptable. More areas need to be inspected to obtain the same level of accuracy using this method. Consequently, we use inspection by variables.

4.3 Sampling Inspection by Variables

4.3.1 Calculated Statistics of the Gaussian Distribution

The test statistic for each sample area, $\overline{x} + ks$, is compared to the acceptance limit U, where:

$\overline{x}$ = average (arithmetic mean of measured values) of sample
s = observed sample distribution standard deviation
k = tolerance factor calculated from the number of samples to achieve the desired sensitivity for the test
U = acceptance limit.

The sample mean is given by:

$$x = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \text{(Eq. 4-6)}$$

where: x_i = individual measurement values
n = number of measurement values

The standard deviation, s is given by:

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - x)^2}{n-1}} \qquad \text{(Eq. 4-7)}$$

The sample mean, standard deviation, and acceptance limit are easily calculable quantities; the value of k, the tolerance factor, bears further discussion. Of the various criteria for selecting plans for acceptance sampling by variables, the most appropriate is the method of Lot Tolerance Percent Defective (LTPD), also referred to as the Rejectable Quality Level (RQL). The LTPD is some chosen limiting value of percent defective in a lot. Associated with the LTPD is a parameter referred to as consumer's risk (β), the risk or probability of accepting a lot with a percentage of defective items equal to the LTPD. It has been standard practice to assign a value of 0.10 for consumer's risk (β). Conventionally, the value assigned to the LTPD has been 10%. These a priori determinations are consistent with the literature and regulatory position, and are the same values used by the state of California (Reference 2). Thus, based on sampling inspection, we are willing to accept the hypothesis that the probability of accepting a lot as not being contaminated which is in fact 10 percent defective (i.e. above the test limit, U) is 0.10. The value of k, which is a function of the a priori determinations made for β and LTPD is given by equation 4-8.

Figure 4.3 demonstrates this principle. The operating characteristics curve of a Gaussian sample distribution shows the principles of consumer's and producer's risk, LTPD (or RQL), and acceptable quality level, (AQL). The criteria for acceptance of a lot are presented in section 4.3.3.

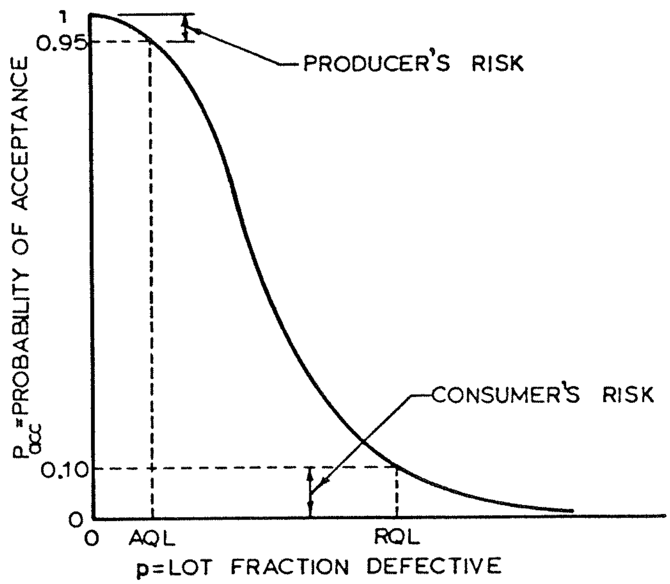


Figure 4.3 Operating Characteristics Curve

The value of k, and thus the value of $\overline{x} + ks$, on which ultimately a decision is made whether the area is acceptably clean, is based on the conditions chosen for the test. k is calculated in accordance with the following equations, (Reference 8):

$$k = \frac{K_2 + \sqrt{K_2^2 - ab}}{a}\ ; \quad a = 1 - \frac{K_\beta^2}{2(n-1)}\ ; \quad b = K_2^2 - \frac{K_\beta^2}{n} \qquad \text{(Eq. 4-8)}$$

where:

k = tolerance factor

K_2 = the normal deviate exceeded with probability of β, 0.10 (from tables, $K_2 = 1.282$)

K_β = The normal deviate exceeded with probability equal to the LTPD. 0.10 (from tables, $K_\beta = 1.282$)

n = number of samples

As mentioned previously, the State of California has stated that the consumer's risk of acceptance (β) at 10% defective (LTPD) must be 0.1. For these choices of β and LTPD, $K_\beta = K_2 = 1.282$.

The coefficients $K\beta$ and K_2 are equal because of the choice for the values of both β and LTPD as 0.10. Refer to statistics handbooks listed in the reference section for additional description of this sampling principle. The values chosen for the sampling coefficients are consistent with industrial sampling practice and regulatory guidance.

4.3.2 Graphical Display of Gaussian Distribution

When the cdf G(x), the integral of the Gaussian pdf, (Eq. 4-4), is plotted against x, the measurement value, a graph of the error function is generated (Fig. 5.2) on a linear-grade scale. For convenience of this survey and for readability, G(x) is plotted as the abscissa (x-axis) and the measurement value, x, is plotted as the ordinate (y-axis) on a probability-grade scale for the abscissa. G(x) values arranged in order of magnitude from left to right form a straight line on probability-grade paper, when the sample lot contamination is normally distributed. Figure 4.4 shows this output.

The power of this graphical display is that it permits identification of values with significantly greater contamination than expected for that lot. Calculated statistics numerically indicate the average and dispersion of the distribution, but are not effective for identifying trends or anomalies. For instance, identification of an isolated area in a sample lot which is contaminated at levels significantly greater than the fitted Gaussian line are easily observable in the plot, but $\overline{x} + ks$ may still show acceptability. Upon further inspection and analysis, these graphical displays are used to show contamination level differences between areas or structures in a sample lot. The power of the fitted Gaussian graphical display is important in assessing significant variations in the contamination levels within sample lots.

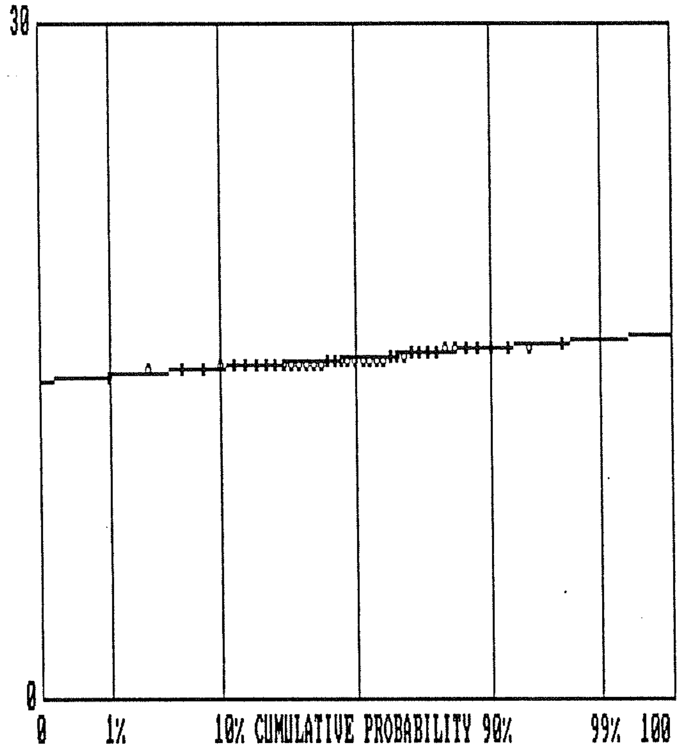


Figure 4.4 Gaussian cdf Plotted on Probability-Grade Paper

4.3.3 Acceptance Criteria for an Uncontaminated Area

Once the test statistic, $\overline{x} + ks$, is calculated and the Gaussian cdf probability plot is generated, a decision is made as to the extent of contamination in the area. Is the area clean? Is part of the area contaminated? Is the entire area contaminated? Are additional measurements necessary to make a determination?

First, the Gaussian distribution will identify significant variations in the radiological measurements. The sample output, if it represents the entire area well, should approximate a straight line. Measurements made which represent radiological conditions in a separate population from the one assumed, are easily observable as severe deviations in the straight line. The location of these anomalous measurements can be determined and subsequent follow-up is applied.

Second, the test statistic, $\overline{x} + ks$, is calculated for the distribution. The criteria for acceptance are presented as a plan of action. The plan of action is:

1) Acceptance: If the test statistic ($\overline{x} + ks$) is less than or equal to the limit (U), accept the region as clean. (Any single value, x, less than 50% of the limit is considered the <u>Characterization Level</u>, which requires no further action. If any single measured value, x, exceeds 50% of the limit, reinspect that location and take a few additional samples in the immediate area for the analysis. This is the <u>Reinspection Level</u>. If any single measured value, x, exceeds 90% of the limit, investigate the source of occurrence. This is the <u>Investigation Level</u>. These proactive action levels were presented in section 3.1.)

2) Collect additional measurements: If the test statistic ($\overline{x} + ks$) is greater than the limit (U), but $\overline{x}$ itself is less than U, independently resample and combine all measured values to determine if $\overline{x} + ks \leq U$ for the combined set; if so, accept the region as clean. If not reject the region.

3) Rejection: If the test statistic ($\overline{x} + ks$) is greater than the limit (U) and $\overline{x} \geq U$, reject the region. Investigate the source of occurrence.

5.0 ANALYTICAL TECHNIQUES

The statistical methods presented in Section 4.0 were used to judge whether an area is not contaminated, slightly contaminated, contaminated above acceptance limits, or whether additional investigation is required. For this particular survey, that judgement is based on one type of radiological measurement: ambient gamma exposure rate.

Analytical techniques used to acquire, evaluate, and interpret these radiological measurements are presented in detail in this section. These techniques include instrument calibration, determination of "background" radiation, and computerized data analysis through inspection by variables.

5.1 Data Acquisition

In each designated 6-m square grid, ambient gamma exposure rate was measured. Each square grid was stepped-off from a local benchmark and marked with its coordinates. The exact location within that square grid where the measurement was made was left to the surveyor's judgement: it was to be the area that, in his judgement, was most likely to have retained the greatest amount of contamination in that square grid. This decision is based on discoloration, debris, crevices, or cracks in the soil. The use of a predetermined grid with discretion for the exact location provides a uniform survey biased towards the high end of the distribution. Locations of noticeably greater exposure rates were reinspected. Reinspection and further investigation were not required for this particular survey.

5.2 Data Reduction Software Program

Each gamma exposure rate measurement value was input into SMART SPREADSHEET. This is an off-the-shelf computer software package which allows multiple computations to be performed on raw data values. Columns were established to calculate the surface ambient gamma exposure rate and its standard deviation in μR/h. Software was developed in a program language called Quick Basic by Microsoft to read data from a SMART file into a graphics program which plots the radiological measurements against the Gaussian cdf. For convenience, the distribution function, G(x) is plotted as the abscissa (probability grades), and x, the measurement value, is plotted as the ordinate (linear grades).

Input for data reduction of these measurements was:

1) Grid location, ex. (10,6)
2) Ambient Gamma Exposure Rate (counts in 1 min.; cpm);
3) Gamma survey instrument background (1 min.); and
4) Efficiency factor (μR/h/cpm).

Output for Gaussian plots of these measurements:

1) Ambient gamma exposure rate and standard deviation (μR/h).

5.3 Data Analysis

An arithmetic mean and standard deviation of the radiological measurement values is calculated for each data set. The test statistic, $\overline{x}$ + ks, based on a consumer's risk of acceptance of 0.10 at 10% defective, is also calculated for each distribution. The acceptance criteria presented in Section 4.3.3 is applied to each sampling distribution.

From the plot of measurement values vs. cumulative probability, the mean radiological value of the lot is the point on the ordinate axis where the fitted-distribution intersects the 50% cumulative probability. In test cases where an acceptance limit has been established for acceptably clean, a vertical line is plotted corresponding to the test statistic, $\overline{x}$ + ks. When an acceptance limit is applied to a test case, horizontal lines are displayed on the graph at 0 (zero), 50% of the acceptance limit (Reinspection), 90% of the acceptance limit (Investigation), and at the acceptance limit. The figures display the results on an expanded scale so that the variations in the data can be seen in detail.

5.4 Ambient Gamma Exposure Rate

Measurements of ambient gamma exposure rate were made by use of a 1 in. x 1 in. NaI scintillation crystal coupled to a Ludlum Model 2220 portable scaler, (Appendix A). This device was mounted on a tripod so that the sensitive crystal was 1 meter from the ground. The detector is nearly equally sensitive in all directions, i.e. 4-π geometry, and can show variations in exposure rate down to one-half of a μR/h, using the digital scaler for a 1-min. count time. Because of the natural variability of ambient radiation, however, a 3 to 5 μR/h exposure rate above "background" is considered the instrument sensitivity in practice. At this level, a surveyor would decide to collect additional measurements.

5.4.1 Instrument Calibration

This detector is calibrated quarterly by the calibration laboratory using Cs-137 as the calibration source. A voltage plateau is plotted and the voltage is set at a nominal 800 V. The detector is placed on a calibration range and readings taken at 5, 2, 1, 0.9, 0.5, 0.4, 0.3, and 0.2 mR/hr. A detector efficiency plot as a function of exposure rate is generated in this regard, (μR/h/cpm).

Because of an exposure rate-dependent effect and because our calibration range does not read less than 200 μR/h (0.2 mR/h), this instrument was cross-calibrated against a Reuter Stokes High Pressure Ion Chamber (HPIC). Count rates were converted to exposure rates by the relationship that about 215 cpm = 1 μR/h, at background exposure rates. This calibration was performed several times.

Instrument response was checked three times a day using a Ra-226 source. The source was placed 1 ft from the detector and counted for 1 min. If the scaler reading fell within $\pm$ 5% of the nominal value, then the instrument was qualified as operable for the day, under the calibration conditions previously described. Recalibration because of "instrument out of tolerance" was never necessary.

5.4.2 Data Acquisition and Reduction

Each location where a gamma measurement was made was identified on a map and in matrix notation. The gross number of counts recorded in 1 min. along with the matrix notation location was input into SMART SPREADSHEET. Columns were established to calculate the total exposure rate (μR/h) and its standard deviation according to equations 5-1 and 5-2. Gamma scintillations produced by a NaI detector were converted from gross counts to exposure rate (μR/h) by:

$$R = \frac{(C) * (EF)}{1 \text{ min.}} \qquad \text{(Eq. 5-1)}$$

where R = exposure rate (μR/h)
C = gross counts in 1 min.
EF = efficiency factor (0.0047 μR/h/cpm) based on cross calibration with HPIC.

The standard deviation of a single measurement then becomes by Eq. 4-3:

$$s = \frac{\sqrt{C} *(EF)}{1 \text{ min.}} \qquad \text{(Eq. 5-2)}$$

5.4.3 Data Analysis

Analysis and interpretation of gamma exposure rate data is a five step process:

1. Plot, in order of magnitude from left to right, total-gross exposure rates in μR/h against cumulative probability for three independent areas considered to be "natural background" at SSFL. These survey locations should be from areas where no radioactive material has ever been used, handled, stored, or disposed. These areas should be of similar geologic characteristics to those of the inspected areas. Calculate the average, standard deviation, and range for each distribution.

These three distributions give the baseline for "natural" variability.

2. Plot total-gross exposure rates in μR/h against cumulative probability for each subject sampling lot. Calculate the average, standard deviation, and range for each distribution. Compare these statistics and probability distributions against "background" distributions.

3. Determine if there are any trends indicated by the probability plots of each subject sampling lot which show a potentially contaminated area.

4. Determine whether the "background" distributions adequately represent "background" for the tested areas. Determine if any nuclear-related operations in the area are influencing ambient "background" in the tested areas. If so, make corrections.

5. Subtract "natural background" from each tested-area measurement and compare the results against acceptance criteria. Use inspection by variables techniques to test for acceptance. Calculate the average, standard deviation, and test statistic, $\overline{x} + ks$, for each test-area distribution.

The most critical step in the analysis is assessing what true "background" radiation is for a test area. Both the NRC and DOE criteria for acceptance as unrestricted use are given in μR/h above background, 5 and 20, respectively. During the survey we observed significant deviations in natural "background" radiation as a function of landscape geometry. For example, when the detector is placed near a large sandstone outcropping, the exposure rate may increase by almost 4 μR/h. This increase is due to primordial radionuclides in the sandstone, and a change in source geometry, from a planar 2π-steradian surface to a rocky 3π-steradian surface.

The best solution for evaluating the potential or existence of residual contamination in an area where the radiation field varies naturally by swings as large as the acceptance limit, is to compare test-area total-gross exposure rates against "background" total-gross exposure rates. "Background" measurements were taken on flat and rugged terrain, with Chico Formation sandstone, similar to conditions of each test-area.

Another component of ambient "background" must also be assessed: that contribution resulting from nearby operations using radioactive material or radiation producing machines. These operations can significantly increase local area "background." This is the case in several SSFL locations. If the test area distribution is well-represented by a Gaussian at a uniformly greater value than the "background" distributions, then one of two conditions exist:

1. The area is uniformly contaminated; or

2. Contribution to ambient "background" from nearby facilities is elevating test-area "background."

This determination is made on a case by case basis. Because condition 1 is unlikely for these surveys, condition 2 is addressed. A correction for facility-influenced gamma "background" is made when a facility known to emit radiation is clearly visible in the test-area. An estimate for inverse-square attenuation and skyshine is made based on fence-line measurements and the median value of the test area distribution. This assessment is more of a benchmark analysis rather than a detailed analytical model.

Once all the best corrections for ambient "background" have been made, resulting distributions are compared against the 5 μR/h above "background" acceptance limit. The test statistic, $\overline{x} + ks$, is calculated for each distribution. Statistical acceptance criteria presented in section 4.3.3 apply.

5.4.4 Sensitivity of Gamma Exposure Rate Measurements

The purpose of performing these exposure rate measurements is to detect any significant quantity of gamma-emitting radionuclides. Operational history and surveys performed years ago show that the most probable radiological contaminant in these areas is Cs-137, and associated mixed-fission-products. Since Cs-137 is a gamma emitter, it is detectable with the NaI detector.

The sensitivity of these measurements, or rather, the amount of contamination which could be there and which would not be detected, is based on two possibilities:

1) A uniformly contaminated region of soil; a layer on the surface, or a layer several feet below the surface; or

2) A piece of contaminated debris located on the surface, or buried several feet below.

Our acceptance criteria specify that no soil activity exceeding 100 pCi/g-beta is acceptable for unrestricted-use. In comparison, 10 μCi of Cs-137, total, is the limit for exempt quantity according to 10CFR30. If only Cs-137 were contained in the soil, 10 μCi of activity would be present in 100 kg of soil, or about 70,000 cm^2 of surface area, if the layer were 1 cm thick.

Natural ambient gamma "background" radiation is about 12-16 μR/h at 1 meter from the ground, so the radioactive material would have to produce an exposure rate of about 3 μR/h above background in order to detect it to such an extent that further investigation would commence. Table 5.1 shows theoretical exposure rates calculated for some uniformly contaminated soil and miscellaneous contaminated debris. The contaminant is assumed to be Cs-137. Condition (1) assumes a uniformly distributed layer of soil with 100 pCi/g Cs-137. Condition (2) assumes a point source of Cs-137 with total activity equal to 1 mCi.

Table 5.1 Exposure Rates of Cs-137 Contaminated Soil and Debris

(1) Contaminated Soil (100 pCi/g)	Exposure Rate (μR/h) 1 meter above surface	
Infinite Slab on the Surface		
0.3 meters thick	72	
1 meter thick	74	
Infinite Slab, 20 cm thick/10 cm thick		
at Surface	68	55
at 5 cm depth	32	25
at 10 cm depth	17	13
at 15 cm depth	9	7
at 30 cm depth	2	1
Rectangular Volume, 20 cm thick/10 cm thick		
1 square meter, surface	6.5	4.2
36 square meters, surface	47	34
(2) Contaminated Debris, (1 mCi total activity)		
at Surface	155	
at 15 cm depth	36	
at 30 cm depth	8	

For condition (1), 100 pCi/g Cs-137 layer of contaminated soil, these measurements would detect a surface layer greater than one cm thick, but would not detect a small thickness of soil (10 cm) buried much more than a half-foot from the surface. This is very good sensitivity, particularly since the likelihood of a thin layer of contaminated soil located more than 6 in. below the surface is small. For condition (2), contaminated debris, whose activity exceeded 1 mCi Cs-137 activity could be seen if it wasn't buried much deeper than about a foot. 10 mCi could probably be seen down to 2 feet. The likelihood of buried or scattered debris occurring in these areas is very small; however, this is probably the most likely scenario for residual contamination.

5.5 Surface Soil

Soil sampling was not required, and therefore not performed.

6.0 PROCEDURES

The following radiological procedures were used in performing this survey.

6.1 Sample Selection Gridding

Superimpose 6-meter square grids on each surface to be radiologically characterized. Designate each square meter in matrix notation with location (1,1) being the northwestern-most square in a sample lot. Five sample lots should be established, one for each of the subject test-areas. From this northwestern-most location, mark a location off every 6 meters east, and south. Where it is not convenient to make a measurement because of rock outcroppings, step to the nearest clear area.

6.2 Calibration and Instrument Checks

Instruments are calibrated and checked every morning, noon, and evening for the duration of the project as follows.

Portable Ludlum 2220-ESG Survey Instruments coupled to a 1 in. x 1 in. NaI crystal:

1) Turn the instrument 'ON' and allow to warm up for 5 min.

2) Check high voltage (800V gamma).

3) Check threshold (400 gamma).

4) Set window in/out switch to "out."

5) Check battery (greater than 500).

6) Set range selector to 1, response to fast, and count time for ambient gamma exposure rate measurements to 1 min.

7) Take and record a 1 min. background count in an uncontaminated area which typifies the area to be surveyed. Verify that ambient background falls within ± 20% of daily-averaged background measurements.

8) Use a Ra-226 check source located 1 ft from the NaI detector to check operability of the gamma instrument. The count rate should not vary by more than ± 5% from the initially established standard. The gamma calibration efficiency factor is determined by comparison against a Reuter Stokes High Pressure Ion Chamber (HPIC).

6.3 Radiological Measurements

6.3.1 Ambient Gamma Exposure Rate Measurements

1) Mount the detector on a tripod which centers the detector 1 meter from the ground.

2) Set the count time to 1 min. and take a measurement at each applicable location for that length of time.

3) If any single reading exceeds about 400 cpm above normal readings, recount.

4) Record the location, total counts, background, and efficiency factor (μR/h/cpm).

5) Enter the data into SMART SPREADSHEET.

6) Take at least 30, 1-min. counts in an area of similar topography where no radioactive materials were ever handled, stored, or used. This is the background distribution. Enter data in SMART SPREADSHEET.

7.0 SURVEY RESULTS

A radiological survey of five areas was performed using the survey plan previously described:

1. T513 Parking Lot;
2. Old Radioactive (R/A) Laundry Area;
3. Plot 333 (SRE Storage and Trash Dump);
4. SRE-to-RMDF Field; and
5. KEWB-to-RMDF Field.

Each inspected test-area was treated as a sample lot for analyzing and interpreting radiological data. Uniform 6-m square grids were established to measure ambient gamma exposure rates. Probability plots of these measurements show in all cases, well-fitted Gaussian distributions with no outliers or anomalies. One distribution of data (the SRE-to-RMDF field) showed a Gaussian-fit well above natural "background." This expected increase is due to nuclear operations performed at the RMDF. No localized area was originally suspect of residual contamination; therefore, no soil samples were required or performed. Analytical interpretation of gamma exposure rate measurements show that all five areas are uncontaminated.

In this section, the format used for presenting data, analyzing probability plots, and interpreting results is presented first. Then the gamma exposure rate measurement results are presented according to this format. Each sampling lot is discussed separately.

7.1 Statistical Results Format

Gamma exposure rate data collected for this survey are displayed as Gaussian cumulative distribution functions in Figures 7.1 through 7.15. Figures 7.1 through 7.3 are distributions of gamma exposure rate measurements made at 3 independent SSFL locations to demonstrate the variability of "natural" background. Figures 7.4, 7.6, 7.8, 7.10 and 7.12 are distribu-

tions of gross-total gamma exposure rates for each test-area. Figures 7.5, 7.7, 7.9, 7.11 and 7.13 are distributions of the same five data sets corrected for "natural" background based on the average of the results presented in Figures 7.1 through 7.3. Figure 7.14 is a probability plot of the sum of all gross-total exposure rate data collected in all five areas. Figure 7.15 is the same graph corrected for natural "background" radiation. These figures show each measurement value, arranged in order of magnitude from left to right, and a straight line representing the derived fitted-Gaussian distribution.

The mean of each distribution is approximately that value on the ordinate which corresponds to a 50% cumulative probability on the abscissa. One, two, and three standard deviations above the mean correspond to 84%, 97.7%, and 99.8% cumulative probability for a one-sided test, respectively. Inspection by variables is used to test only "background-corrected" data sets against the NRC acceptance limit of 5 μR/h. The value of k used in the inspection test is very nearly 1.5 for each case; thus, the Test Statistic (TS) line ($\bar{x}$ + ks) will run perpendicular to the abscissa corresponding to about a 93.3% cumulative probability. The Gaussian distribution line must pass below the intersection of the "TS" line (about 93%) and the horizontal line showing the acceptance limit at that point in order to accept the lot as being uncontaminated. "k" and thus the "TS" line increase as the number of samples in a lot decrease.

At the top left hand corner of each output is the data file name for the sample lot. For "uncorrected" data sets, 30 μR/h is normally used for convenience, as the maximum ordinate value. If measurements exceed 30 μR/h, then the greatest measurement value is the upper bound of the ordinate axis. In cases where the measurements have been corrected for "background," 5 μR/h (the NRC acceptance limit) is used as the maximum ordinate value. The lower bound of the ordinate is either the smallest measured value (minus background, if applicable) or the smallest value calculated for a Gaussian fit. Negative numbers result when the measured value is less than back-ground. Cumulative probability (abscissa) is plotted in probability grades, i.e. the distance between any two successive points increases as the distance from the 50% cumulative probability line increases. If an acceptance limit is applicable, four horizontal lines extending across each plot show, from top to bottom, 100% of the test limit, 90% of the test limit (Investigation), 50% of the test limit (Reinspection), and zero.

In cases where an acceptance limit is not appropriate, for example, gamma exposure rate measurements not corrected for "background," the four horizontal lines are not shown. Furthermore, a test statistic is not calculated because we were not testing the data against an acceptance limit. Since the variability in naturally occurring ambient gamma exposure rates at SSFL is wide, background was not subtracted at first. In these cases, the mean is calculated and the shape of the distribution is observed to identify any areas of increased radioactivity. Then the shape of the curve is compared against three "background" distributions. Finally, "background" is subtracted and inspection by variables techniques are applied to prove or disprove the hypothesis that the area is not contaminated.

7.2 Ambient Gamma Exposure Rates

Ambient gamma exposure rate measurements were made at 294 locations. Appendix C shows the data sets. Table 7.1 shows the computed statistics for each data set compared against data from three independent areas where no radioactive material was ever handled, used, or stored. These areas are considered "natural background." This type of comparison is necessary for two reasons: 1) to demonstrate variability of "background" gamma-radiation at SSFL; and 2) to estimate "true" background at SSFL because the limits for unrestricted-use by which we use to demonstrate an "acceptable" area are based on above "background" criteria. So, unless we confidently know what "background" is, the area under study may be found incorrectly acceptable if the background used was too high, or incorrectly unacceptable if the background used was too low.

Table 7.1 Ambient Gamma Radiation at SSFL Compared to Survey Data

Location	No. of Measurements	Mean Exposure Rate (μR/h)	Expected Standard Deviation at the Mean (μR/h)*	Standard Deviation of the Distribution (μR/h)**	Range μR/h
T513 Parking Lot	69	14.0	0.25	0.96	3.7
Old R/A Laundry Area	53	15.3	0.27	0.96	4.4
Plot 333	52	15.1	0.27	0.64	3.2
SRE-to-RMDF Field	55	20.7	0.31	1.34	6.6
KEWB-to-RMDF Field	65	17.4	0.28	0.82	3.9
Total Sum	294	16.4	0.28	2.55	11.2
Background					
Building 309 Area (1/19/88)	36	15.6	0.27	0.82	3.4
Well #13 Road (Dirt) (4/29/88)	43	16.2	0.27	0.49	2.2
Incinerator Road (Dirt) (4/29/88)	35	14.0	0.25	0.36	1.4

* The expected standard deviation at the mean is calculated based on counting statistics, equation 4.2.
** The standard deviation of the data points accounts for dispersion in the measurements, equation 4.7.

Descriptive statistics presented in Table 7.1 show that average exposure rates calculated for each test-area, including the "background" locations, are within one standard deviation of each other except for abnormally higher averages of 17.4 and 20.7 μR/h in the KEWB-to-RMDF and SRE-to-RMDF Fields, respectively.

The first three test-area results presented in the table show greater standard deviations and ranges than those for "background" areas. This variability is attributed to naturally occurring causes; the terrain is much more rough. Building 309 "background" data compare favorably to these first three test-areas. However, before we incorrectly conclude that these three test-areas are uncontaminated, cumulative probability plots must be studied and compared against "background" distributions. This analysis is presented separately.

As for the fourth and fifth test-areas (SRE-to-RMDF and KEWB-to-RMDF fields), the average exposure rate values are greater than normal. The variability and range of measurement values for SRE-to-RMDF is also greater than normal. By observation of these statistics, both test-areas appear contaminated. Before any judgments can be made about the existence of residual contamination; however, we must investigate the probability plots and determine whether a few large non-Gaussian points are influencing the average, or whether "background" is uniformly higher in these test-areas.

7.2.1 Non-Radiological Areas

Because the background gamma-radiation environment is quite variable at SSFL and because the limits for unrestricted use are based on limits above background, further demonstration of this natural variability is necessary. For comparison against the test-area measurements, three independent areas were surveyed, all in locations where no radioactive material was ever handled, used, stored, or disposed. All three areas are located on the eastern side of SSFL: (1) Area surrounding building 309 on Area I Road; (2) well #13 Road; and (3) Incinerator Road. Table 7.1 shows the results of these measurements.

Figures 7.1 through 7.3 are probability plots of these three independent "background" areas. At least 30 measurements were made in each area on the same day. In the plots, a uniform background rate (unbiased by spatial effects), would appear as a straight line with a minimal slope.

Figure 7.1 Ambient Gamma Radiation at Area Surrounding Building 309
(Background Distribution)

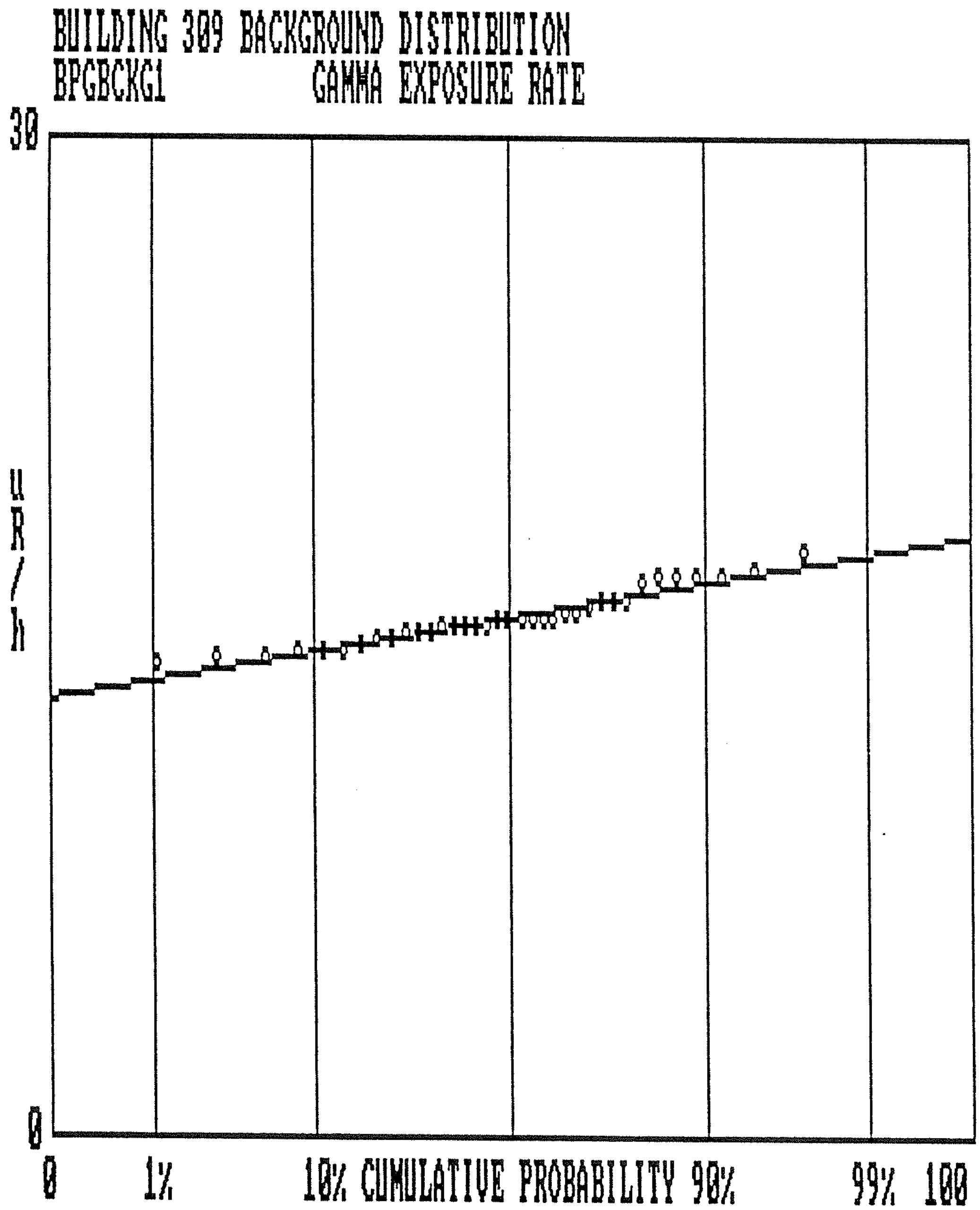


Figure 7.2 Ambient Gamma Radiation at Area Well #13 Road (Background Distribution)

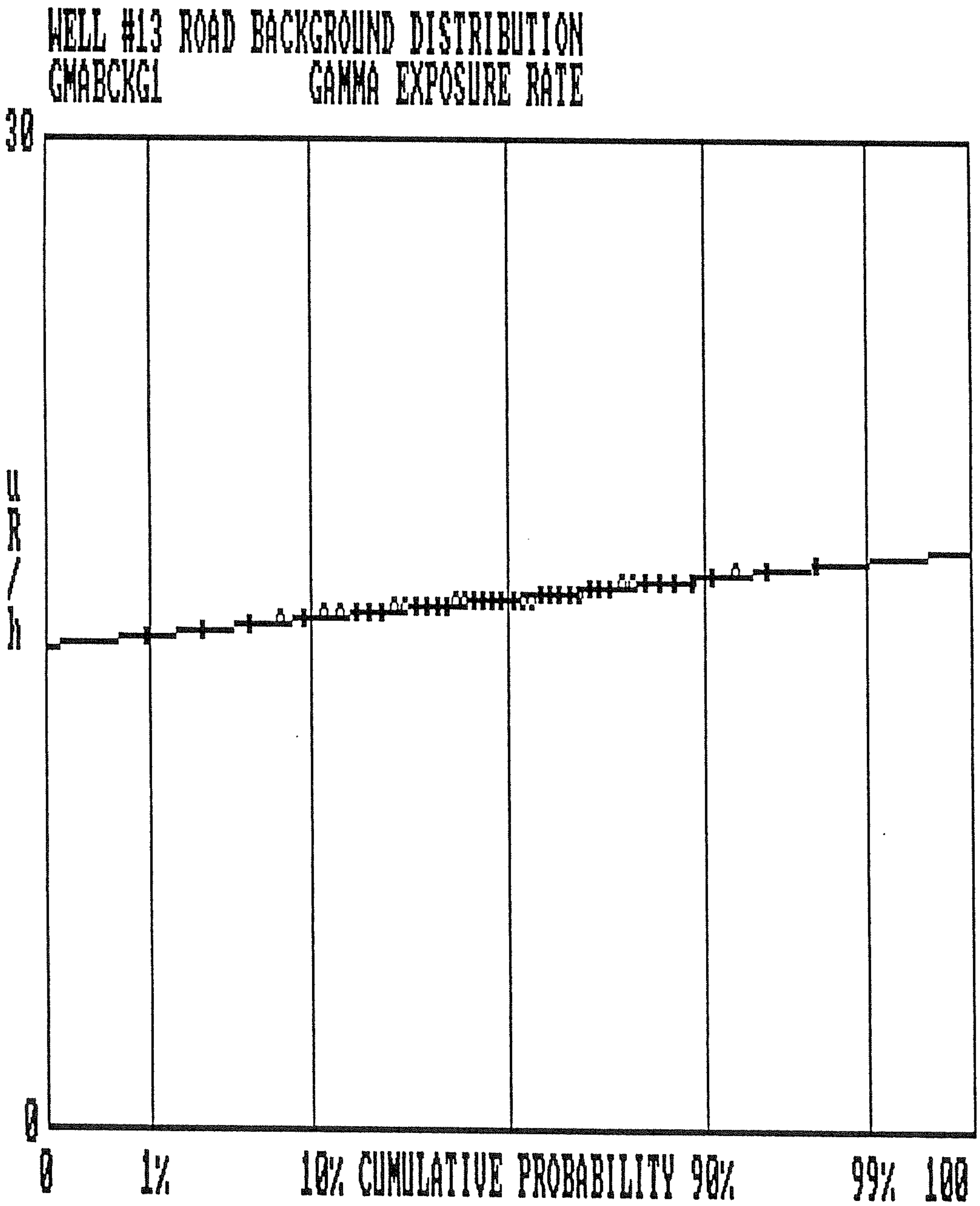
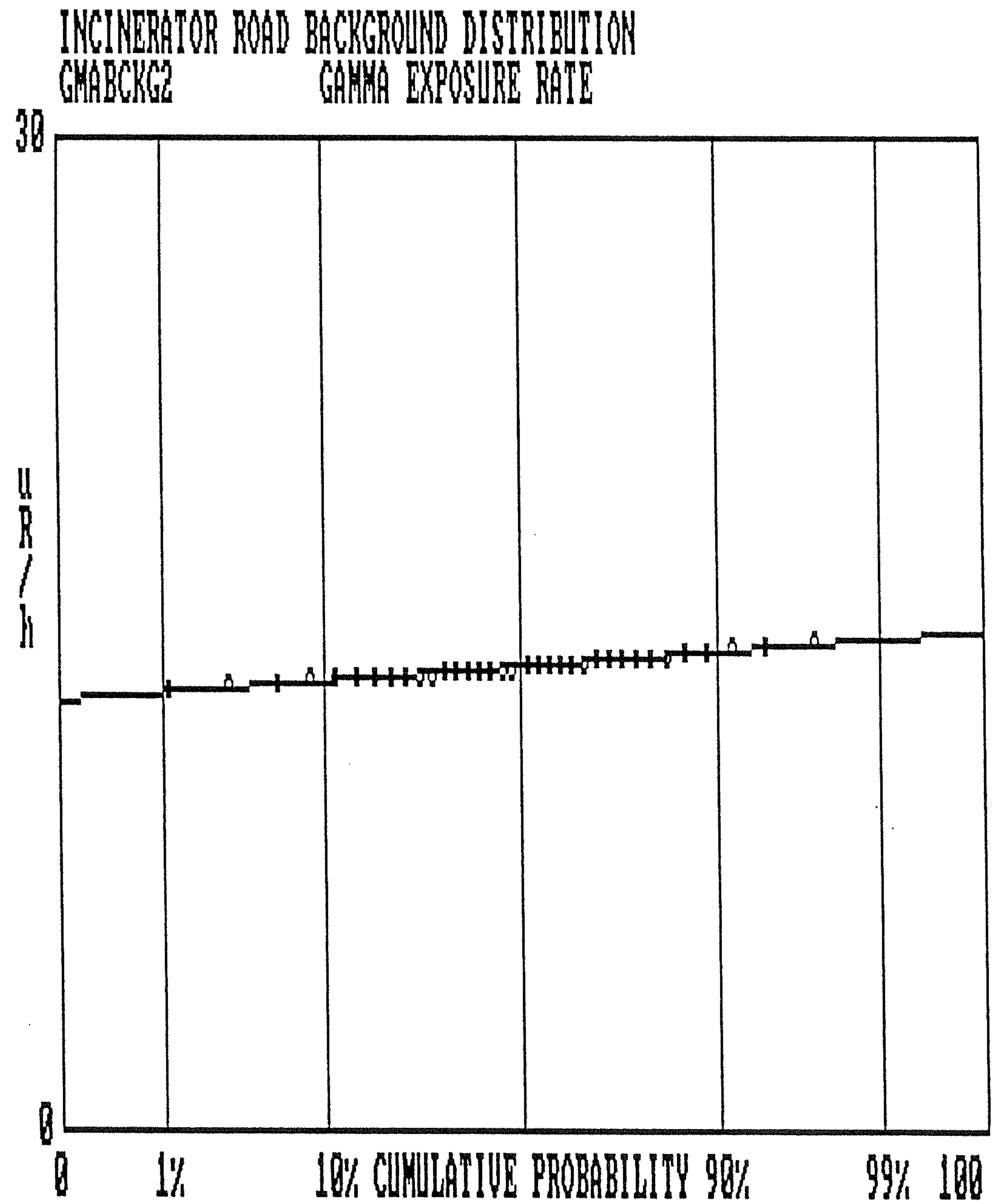


Figure 7.3 Ambient Gamma Radiation at Incinerator Road
(Background Distribution)



That slope would show that 1 standard deviation from the mean of values would be equivalent to the mean-value standard deviation (i.e. the square root of the counts of the mean multiplied by an appropriate efficiency factor). If this was the case, the values in columns 4 and 5 of Table 7.1 would be equivalent. Obviously, this ideal condition is impossible to achieve in terrain at SSFL. All three plots show model Gaussian distributions, but with greater variability than would be expected from unaffected measurements. Variability is greatest near Building 309.

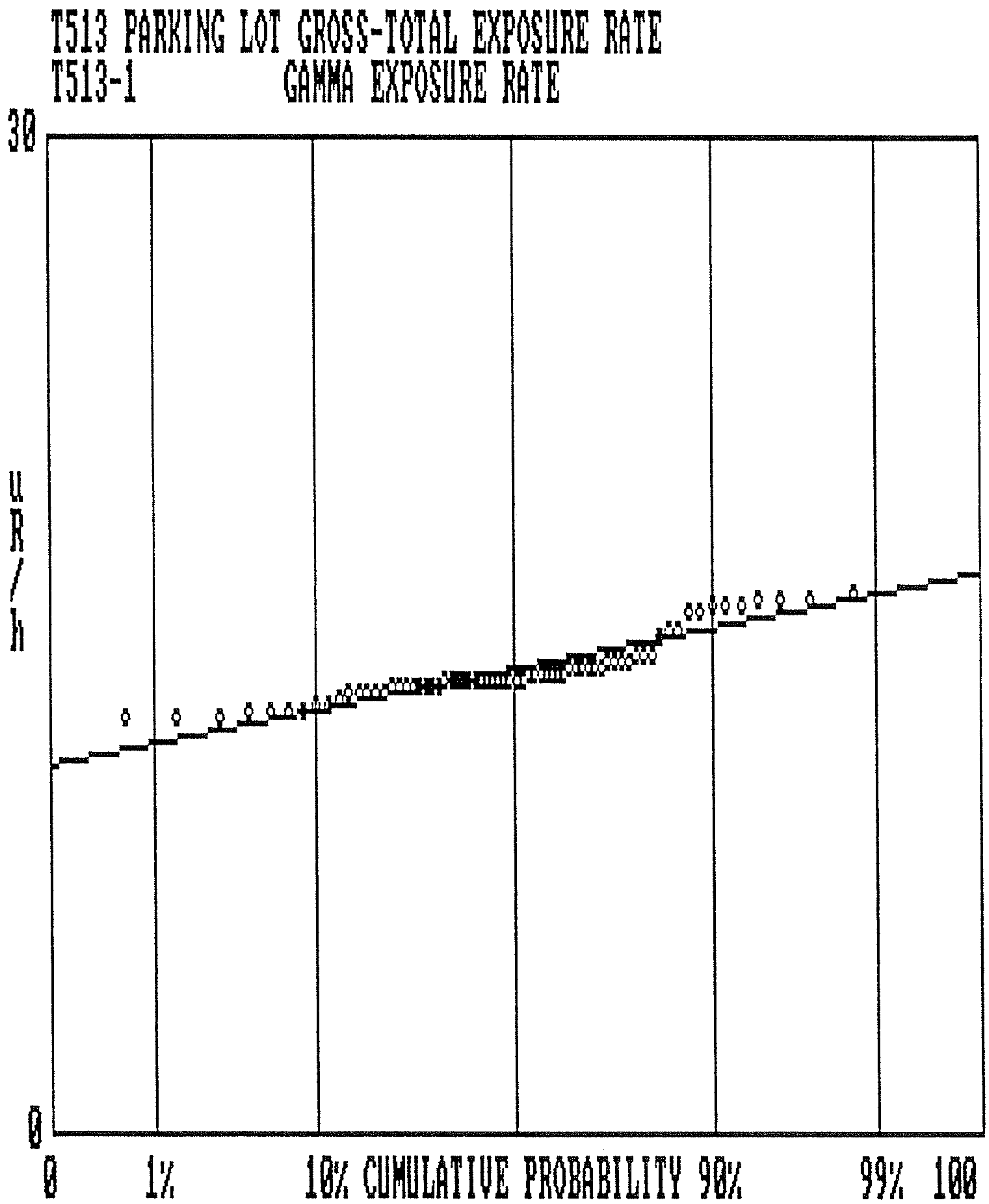
Measurements from the area surrounding Building 309 show the most variability of all three background areas. This is attributed to large sandstone outcroppings in the area; the spatial dependency of each measurement is observable in this case. The topography of these locations is somewhat similar to that of the test-areas, except on occasion the test-areas are cluttered with more sandstone outcroppings. The variability of each distribution depends on the number of measurements made directly against the rock versus the number made many feet from the rock. Also of importance here is the range of measurement values with a maximum of 3.4 μR/h. "Background" variability approaches the NRC limit.

This "background" analysis shows the great difficulty in assessing whether an area is contaminated based on the NRC acceptance limit of 5 μR/h above background. The DOE limit of 20 μR/h is more reasonable. Ambient radiation is significantly variable at SSFL. We'll now compare this "natural" variability against the five test-areas presented in this report.

7.2.2 T513 Parking Lot

Figure 7.4 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the T513 Parking Lot. This test-area is paved, but surrounded in certain locations by large sandstone outcroppings. This particular terrain affects these gamma measurements, as observed in the figure; nine data points at the high end and five data points at the low end deviate slightly from a fitted-

Figure 7.4 Total-Gross Ambient Gamma Exposure Rates at the T513 Parking Lot



Gaussian. All of the greatest measurements were made on "E" Street between two large outcroppings. This explains the deviation. No trends or anomalies are identified. Descriptive statistics show this test-area to be similar to "background."

Figure 7.5 shows the same data set, in which case a correction for natural "background" was made uniformly to each measurement value. 15.3 μR/h was used for "background" subtraction; this value is the average of exposure rates calculated for the three background data sets (Figure 7.1, 7.2 and 7.3). Deviations observed in the measurements because of terrain changes are expanded in this figure because the ordinate scale has been expanded. The large standard deviation value of these measurements reflects this occurrence. Appendix D.1 shows the measurement locations and these locations where greatest exposure rates were taken. An average of -1.26 ±0.96 μR/h is less than the 5 μR/h acceptance limit. The test statistic, 0.185 μR/h, is less than the 50% reinspection level. We accept the area as uncontaminated by this inspection method. No further investigation is required.

7.2.3 Old R/A Laundry Area

Figure 7.6 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the Old R/A Laundry Area. This test-area is natural terrain with numerous sandstone outcroppings which affect the measurements being made. Locations of these measurements are shown in Appendix D.2. A few points at the high end deviate slightly from a fitted-Gaussian. These points are anomalous and do not indicate a trend. Descriptive statistics show this test-area to be similar to "background" within the deviations observed. Although the range is 4.4 μR/h, slightly greater than the greatest "background" range of 3.4 μR/h (Building 309), this is an indication of variable terrain conditions and its impact on ambient exposure rate.

Figure 7.5 Background-Corrected Ambient Gamma Exposure Rates at the T513 Parking Lot

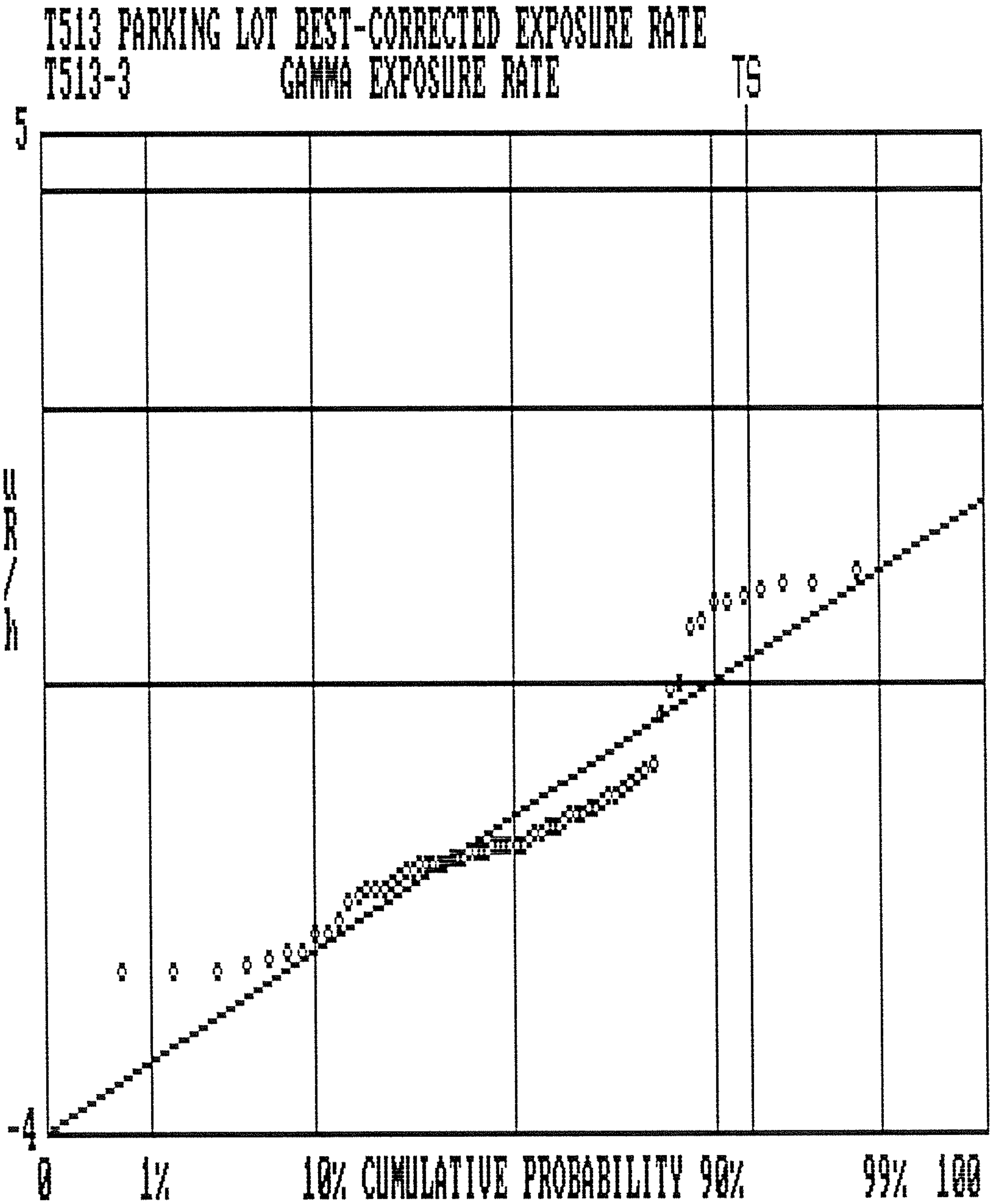


Figure 7.6 Total-Gross Ambient Gamma Exposure Rates at the Old R/A Laundry Area

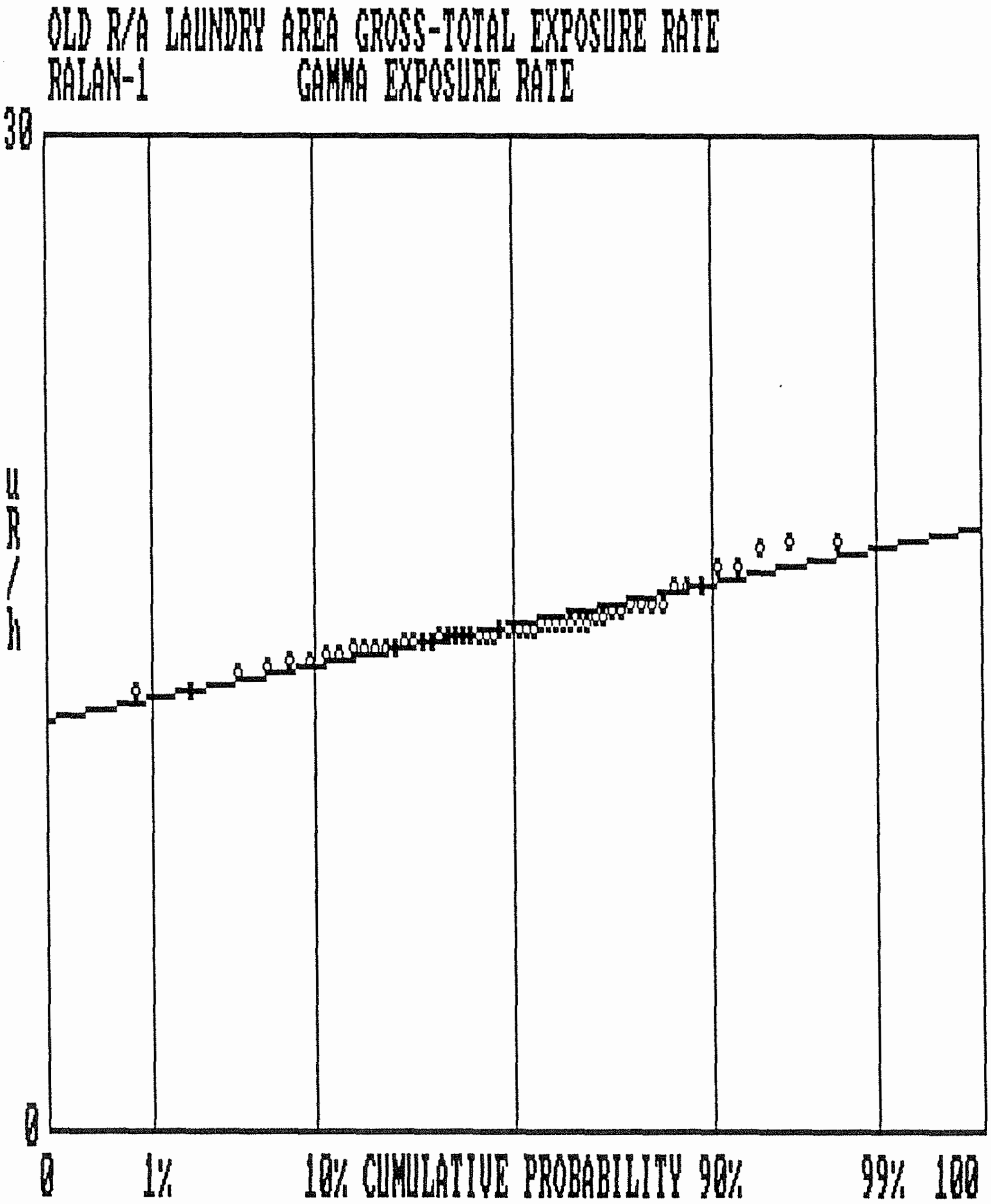


Figure 7.7 shows the same data, corrected for natural "background" as in section 7.2.2. Because the ordinate scale has been expanded, deviations from the fitted-Gaussian are easily observed. This shows exposure rate variability as a function of terrain. An average of 0.04 ± 0.96 μR/h is less than the 5 μR/h acceptance limit. The test statistic, 1.53 μR/h, is less than the 50% reinspection level. We accept the area as uncontaminated by this inspection method. No further investigation is required.

7.2.4 Plot 333 - SRE Storage and Trash Dump

Figure 7.8 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for Plot 333. Measurement locations are presented in Appendix D.3. This test-area is an open-field, surrounded in a few locations by sandstone outcroppings. This flat terrain explains the occurrence of only two slight deviations from the fitted-Gaussian. No radiological trends are indicated by the plot. Descriptive statistics show this test-area to be similar to "background" within the deviations observed.

Figure 7.9 shows the same data, corrected for "background" as in section 7.2.2. Because the ordinate scale has been expanded, deviations from the fitted-Gaussian are easily observed. An average of -0.13 ± 0.63 μR/h is less than the 5 μR/h acceptance limit. The test statistic, 0.856 μR/h, is less than the 50% reinspection level. We accept the area as uncontaminated by this inspection method. No further investigation is required.

7.2.5 SRE-to-RMDF Field

Figure 7.10 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the SRE-to-RMDF Field. Measurement locations are presented in Appendix D.4. Figure 7.10 shows that the measurements follows a Gaussian distribution with no outliers. No trends indicating specific areas of contamination are

Figure 7.7 Background-Corrected Ambient Gamma Exposure Rates at the Old R/A Laundry Area

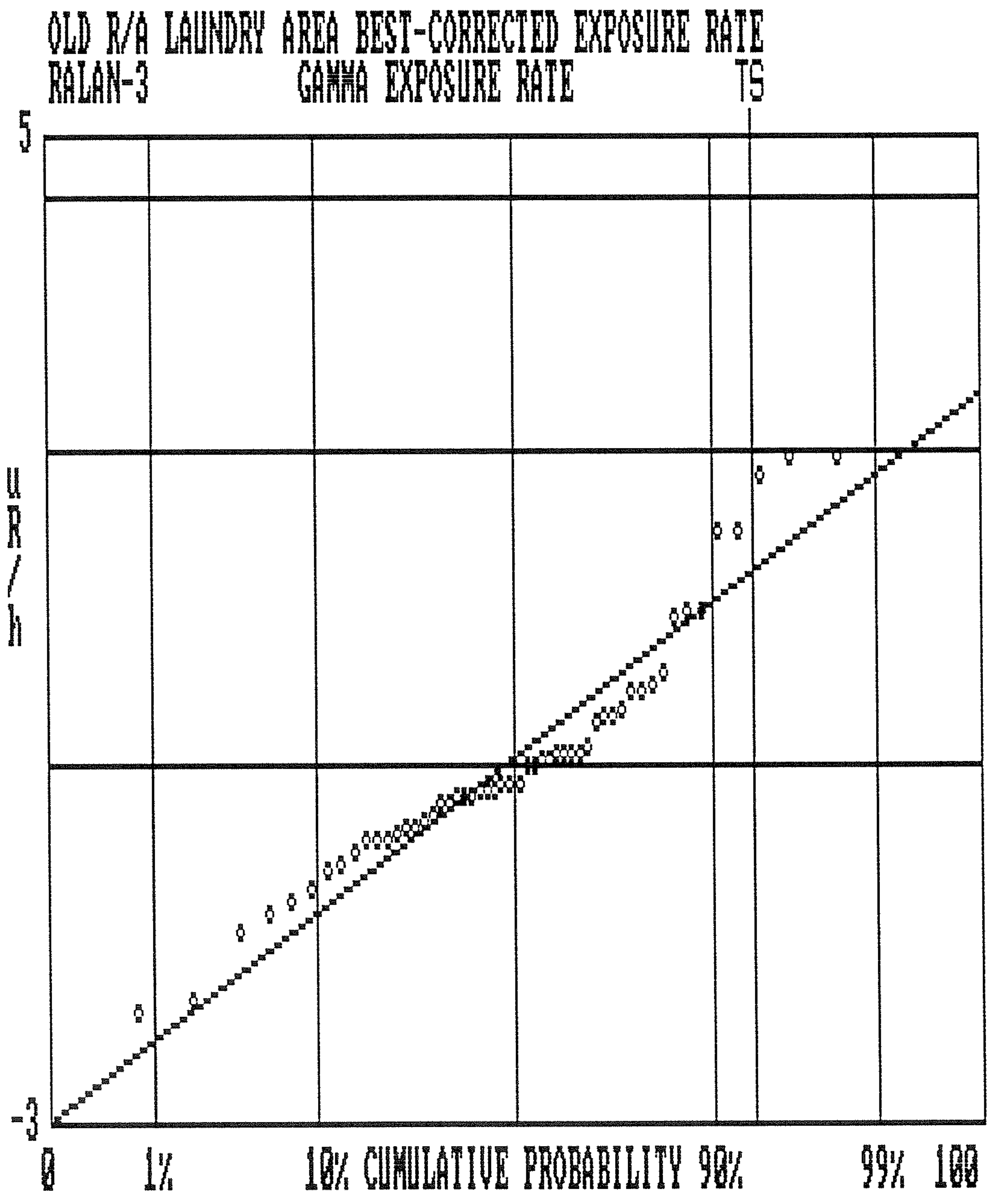


Figure 7.8 Total-Gross Ambient Gamma Exposure Rates at Plot 333

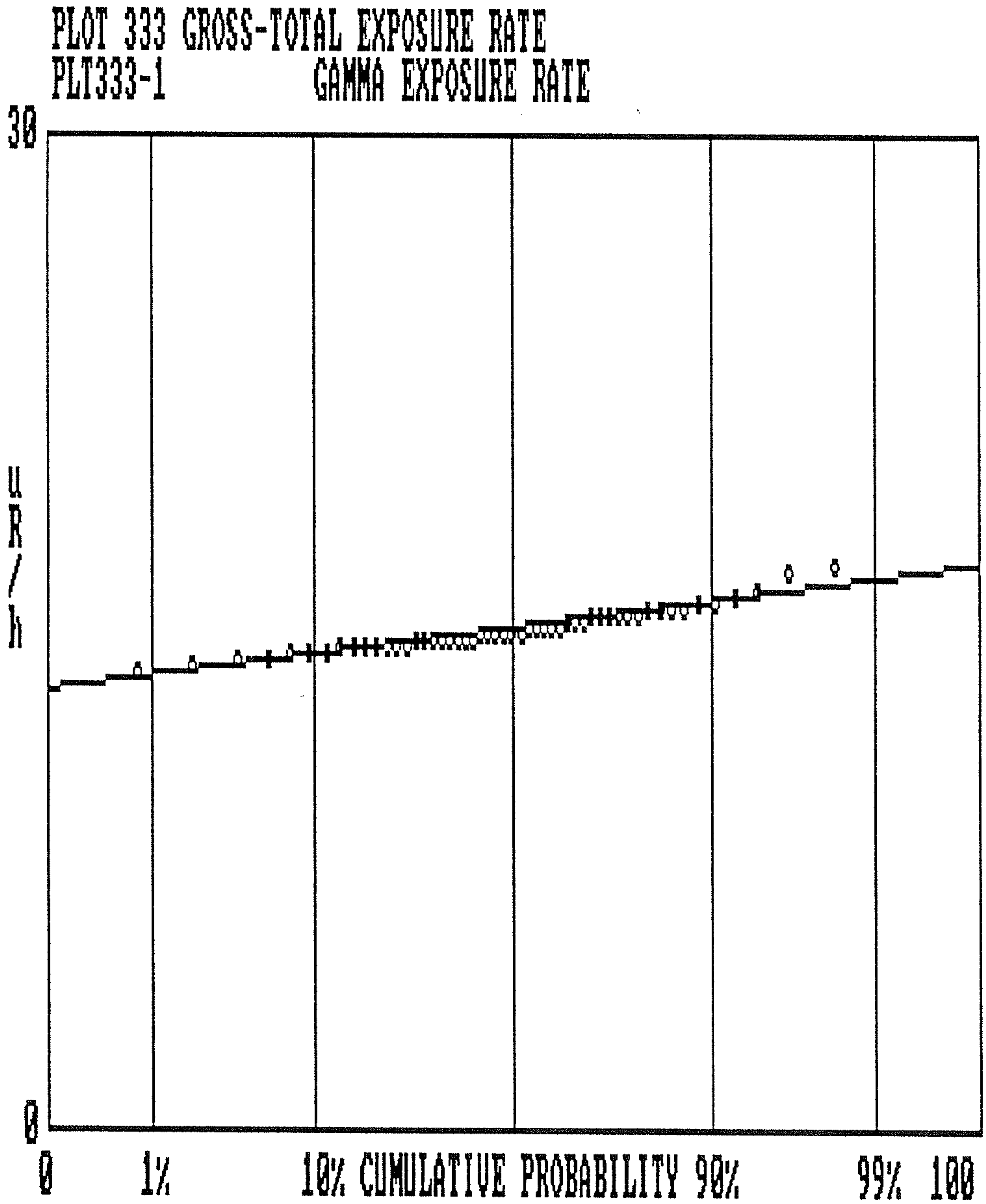


Figure 7.9 Background-Corrected Ambient Gamma Exposure Rates at Plot 333

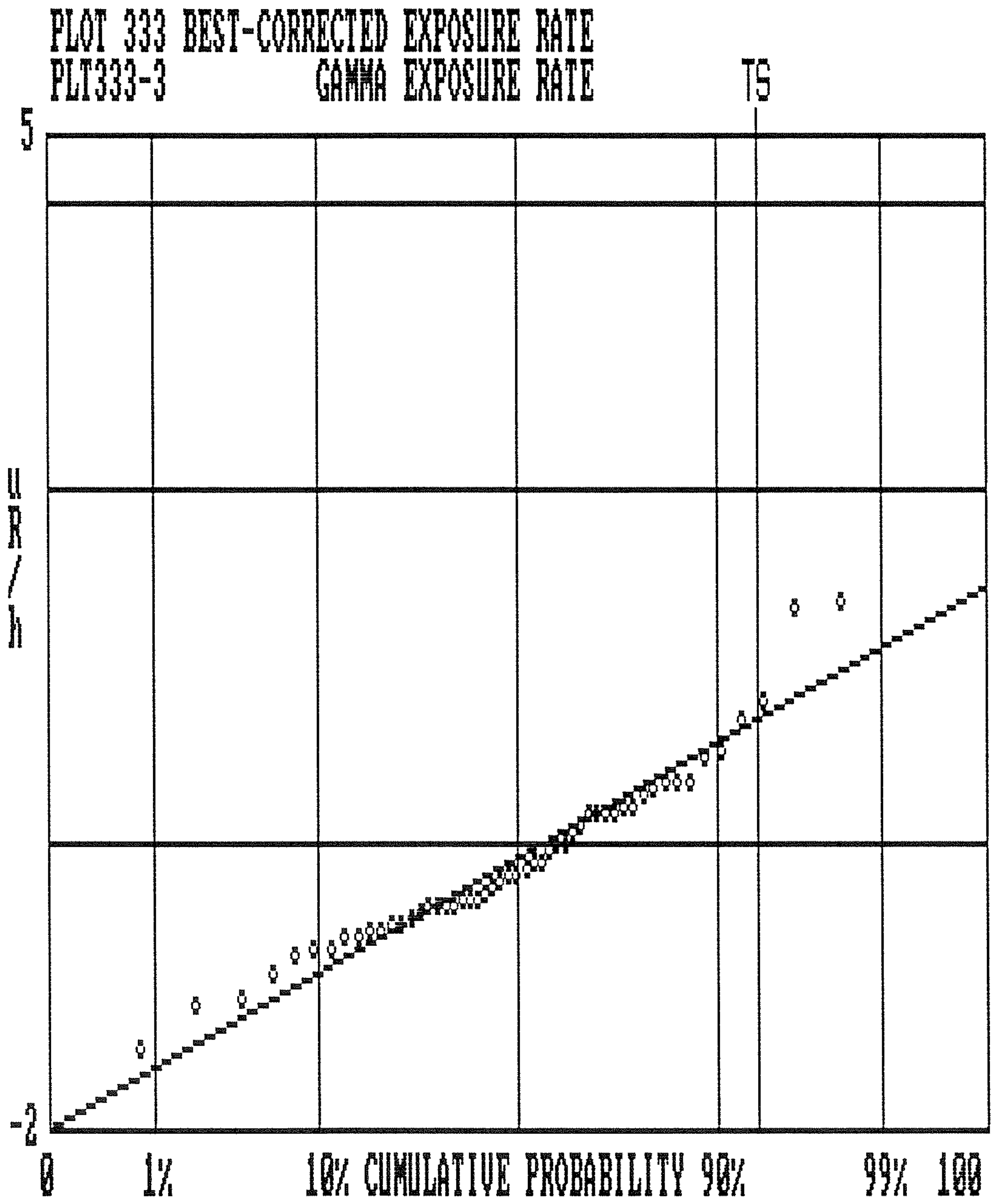
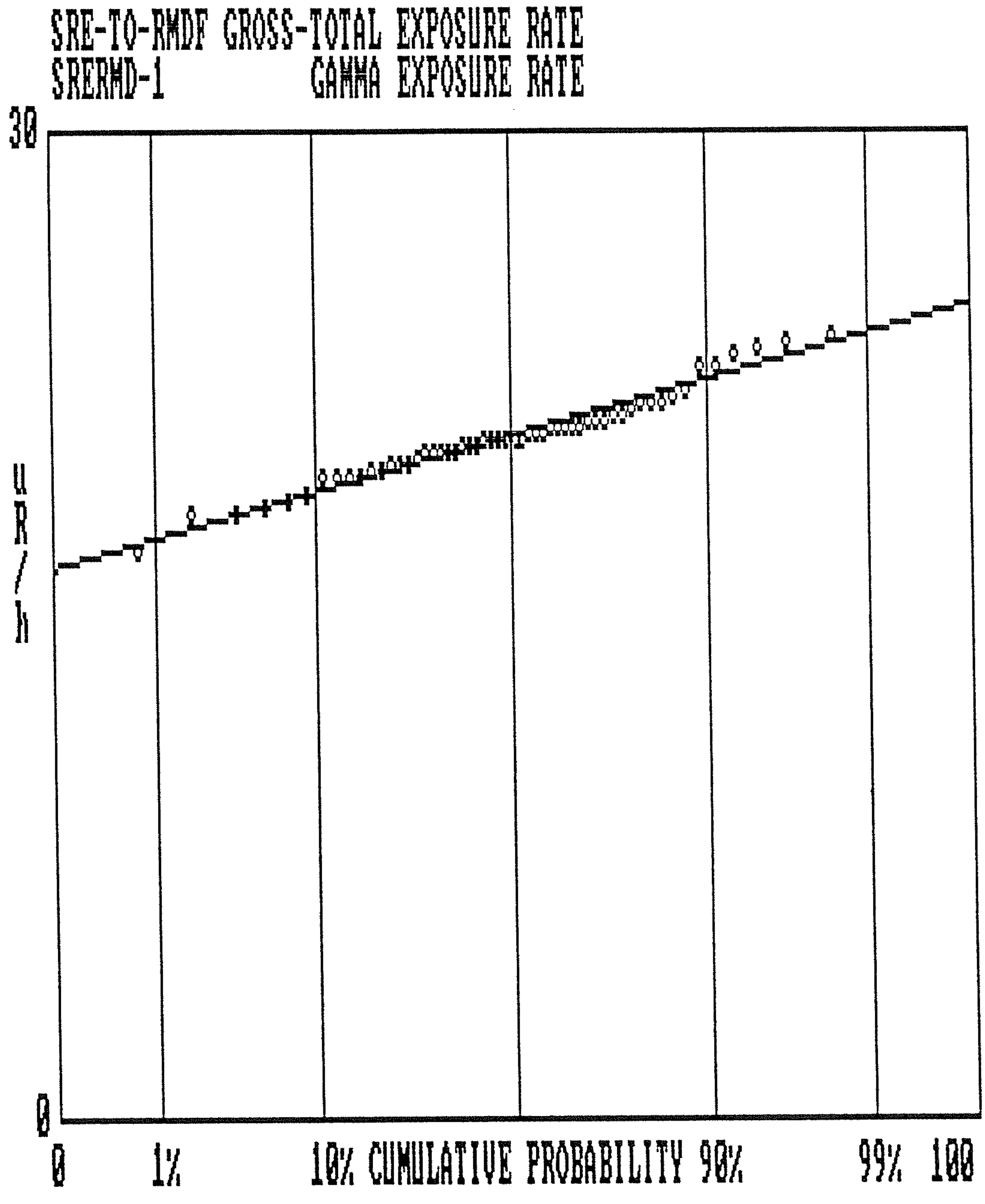


Figure 7.10 Total-Gross Ambient Gamma Exposure Rates at the SRE-to-RMDF Field



shown. However, the distribution is uniformly greater than the "background" distributions (Figures 7.1, 7.2, and 7.3). This test-area is either uniformly contaminated or ambient background is greater in this location. Since the RMDF is in line-of-sight about 150 ft away, and fenceline exposure rates measure about 34 μR/h, we suspect that ambient background is greater than normal. A thermoluminescent dosimeter (TLD) placed near T133 showed for the four calendar quarters of 1987 cumulative exposures of 35, 58, 42, and 37 mR per quarter. The average exposure rate is calculated to be 19.7 μR/h. These TLDs read greater than those placed in surrounding locations. Skyshine and direct radiation from RMDF is influencing these measurements.

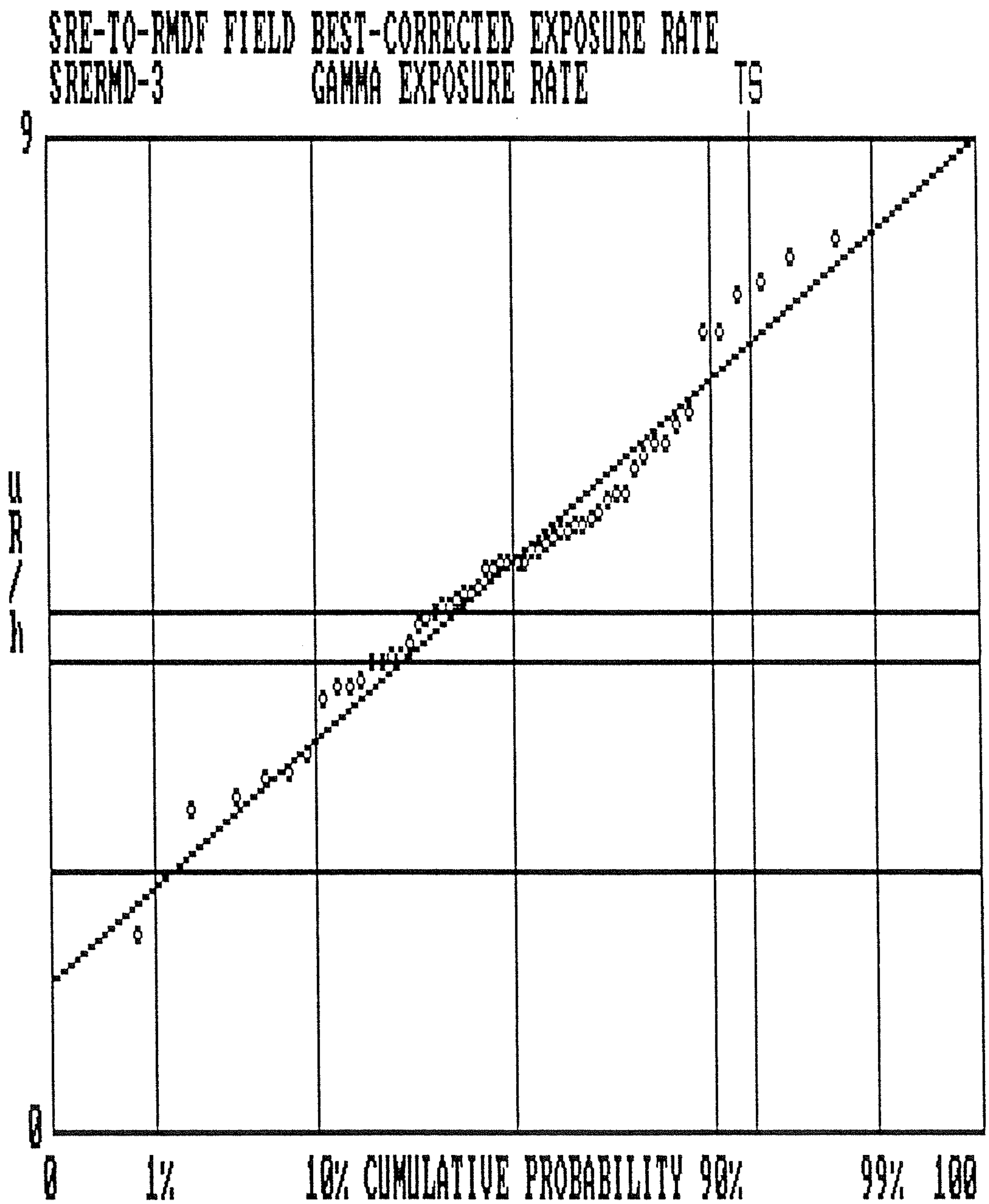
Figure 7.11 shows the same data set, corrected for natural (uninfluenced) "background" based on the average of measurements shown in Figures 7.1, 7.2, and 7.3. The Gaussian is well represented; however, as in all cases before, the deviations are easily observed because the ordinate scale has been expanded. An average of 5.45 $\pm$ 1.34 μR/h exceeds the 5 μR/h acceptance limit. Based on known operational history, observance of no outliers in the distribution, and the significance of RMDF operations on ambient exposure rate, we conclude the "ambient background" for this test-area has been underestimated at 15.3 μR/h. True "ambient background" is probably closer to 20 μR/h. This estimate is substantiated two ways:

1) 20 μR/h is the average exposure rate in a nearby location as measured by a TLD; and

2) the median of gross-total measurements approximates "background" for a test-area and in this case the median is 20 μR/h.

The greatest exposure rates were found in locations nearest the RMDF. Using a background of 20 μR/h, the average becomes 0.75 $\pm$ 1.34 μR/h and the test statistic is 2.8 μR/h. Although the test statistic is still slightly greater than the 50% reinspection level, we accept the area as uncontaminated by this inspection method. Further investigation is not

Figure 7.11 Background-Corrected Ambient Gamma Exposure Rates at the SRE-to-RMDF Field



required; however, when all radioactive material has been removed from the RMDF, a check may be performed, to show that ambient "background" has been reduced to "natural background."

7.2.6 KEWB-to-RMDF Field

Figure 7.12 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the KEWB-to-RMDF Field. Also included as part of this test-area were some measurements made between the KEWB and T003. Refer to Appendix D.5 for these measurement locations. Figure 7.12 show that these measurements follow a Gaussian distribution with no outliers; however, the average of 17.4 $\pm$ 0.82 μR/h is slightly greater than measurements made in "background" areas (Figures 7.1, 7.2, and 7.3). This figure shows no trends indicating specific contaminated locations.

Figure 7.13 shows the same data set, corrected for natural "background." Deviations from a fitted-Gaussian are more pronounced because of the expanded ordinate scale. There is a large sandstone outcropping which borders this field on the north which influences ambient radiation. Skyshine from the RMDF also influences ambient radiation in this test-area an undetermined amount. The greatest measurements were made in the vicinity of outcroppings; the greatest two were made very close to rock. An average of 2.20 $\pm$ 0.82 μR/h is less than the 50% reinspection level; however, the test statistic of 3.44 μR/h is not. Additional inspection shows that "ambient background" for this test-area has been underestimated. An adjustment to "background" should be made to account for the large sandstone outcroppings and the RMDF skyshine. Background is probably closer to the median gross-total value of 17.6 μR/h, in which case we conclude that this test-area is uncontaminated by this inspection method. No further investigation is required.

Figure 7.12 Total-Gross Ambient Gamma Exposure Rates at the KEWB-to-RMDF Field

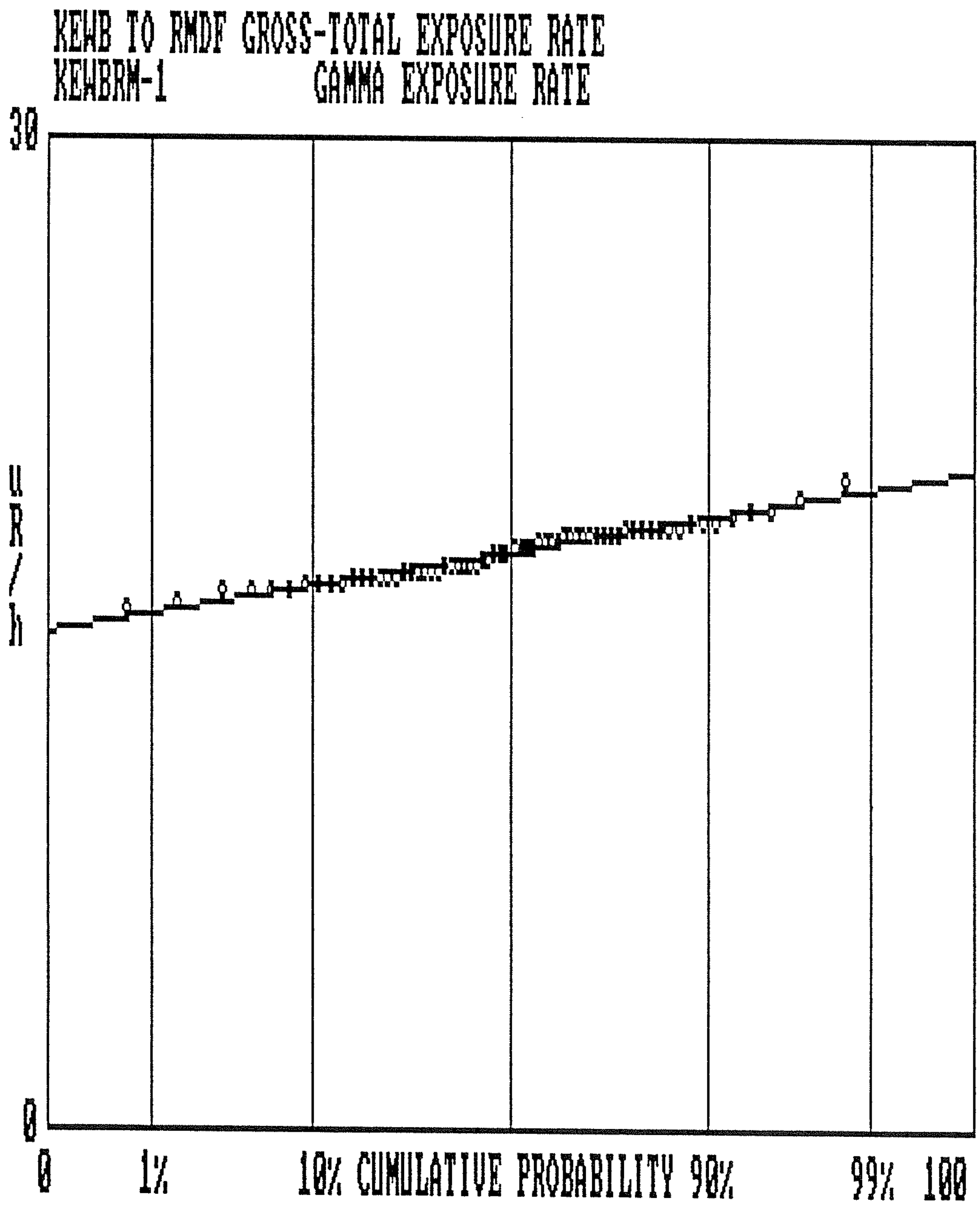
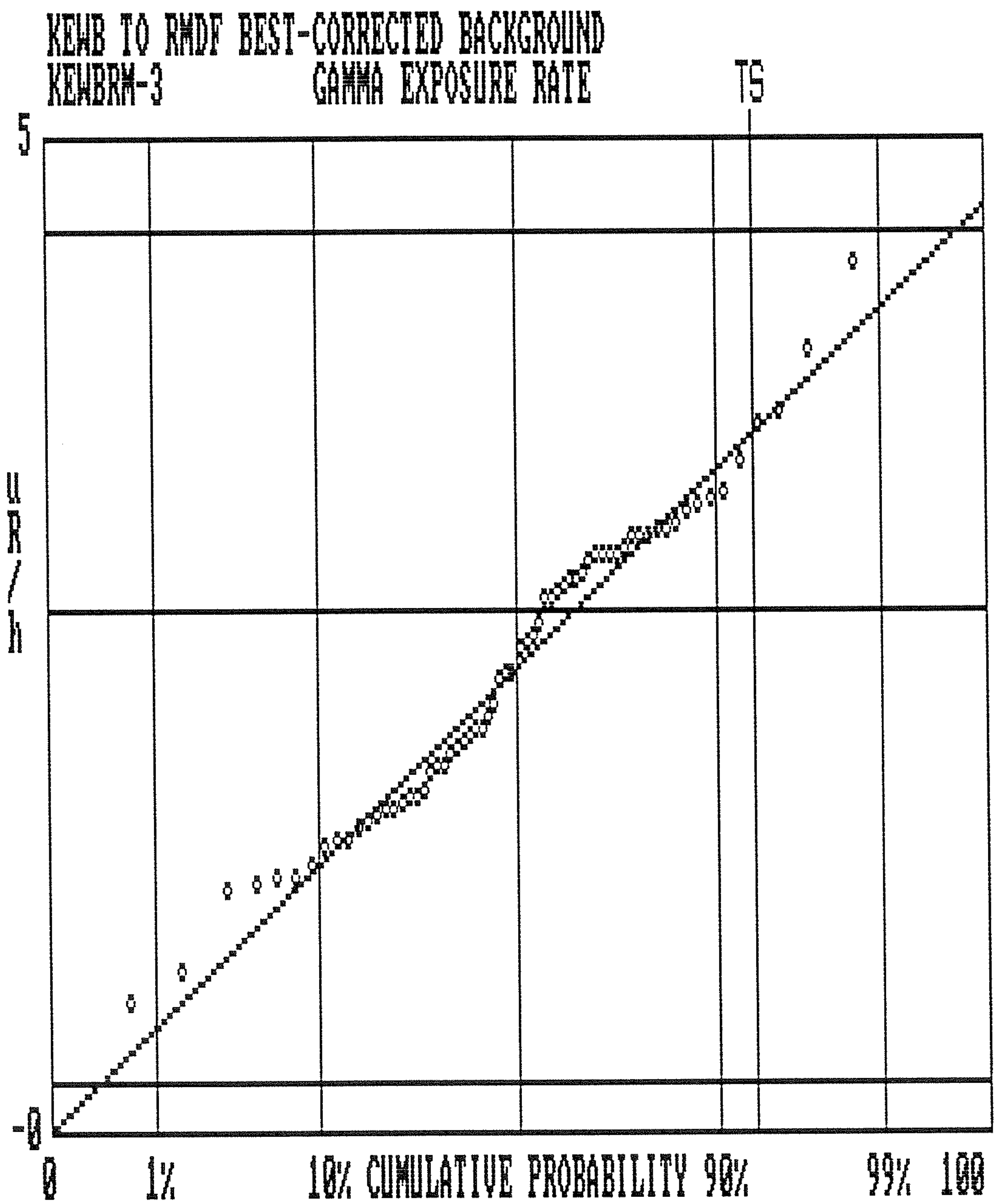


Figure 7.13 Background-Corrected Ambient Gamma Exposure Rates at the KEWB-to-RMDF Field



7.2.7 Combination of All Five Test-Areas

Figure 7.14 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the 294 measurements made for all five test-areas. This figure shows that there are two distinct distributions of points. This behavior was expected because of the difference observed between the RMDF-influenced measurements and the non-influenced measurements. A distribution such as this combined data set shows the power of graphical representation; had individual sample lots not been treated separately, further investigation would be required based on this output.

Figure 7.15 shows the "background-corrected" data with an average of 1.19 $\pm$ 2.55 μR/h and test statistic of 4.74 μR/h. Although no trends are evident, the test statistic is greater than our 90% investigation level. The large standard deviation suggests unexpected variability of the data. This variability, as pointed out before, is due to RMDF influence on ambient gamma radiation. It was shown on a test-area by test-area basis that we conclude all areas to be uncontaminated.

7.3 Assessment of Radiological Condition

Results of this radiological survey show that all areas tested have no measurable residual radioactivity. Interpretation of ambient gamma exposure rate data show that all five sample lots are acceptably clean. A summary of background-corrected statistics of this data is presented in Table 7.2. In the first three cases, the inspection test statistic is less than 50% of the acceptance limit (reinspection level). In the fourth and fifth cases, ambient background was not corrected for increases in "background" due to RMDF operations and significant changes in topography. Our best estimate for "background" in these areas shows that all areas inspected pass criteria for unrestricted-use. We are confident that the sensitivity and sampling frequency of exposure rate measurements is sufficient for identifying suspect contamination.

Figure 7.14 Total-Gross Ambient Gamma Exposure Rates of the Combined Test-Areas

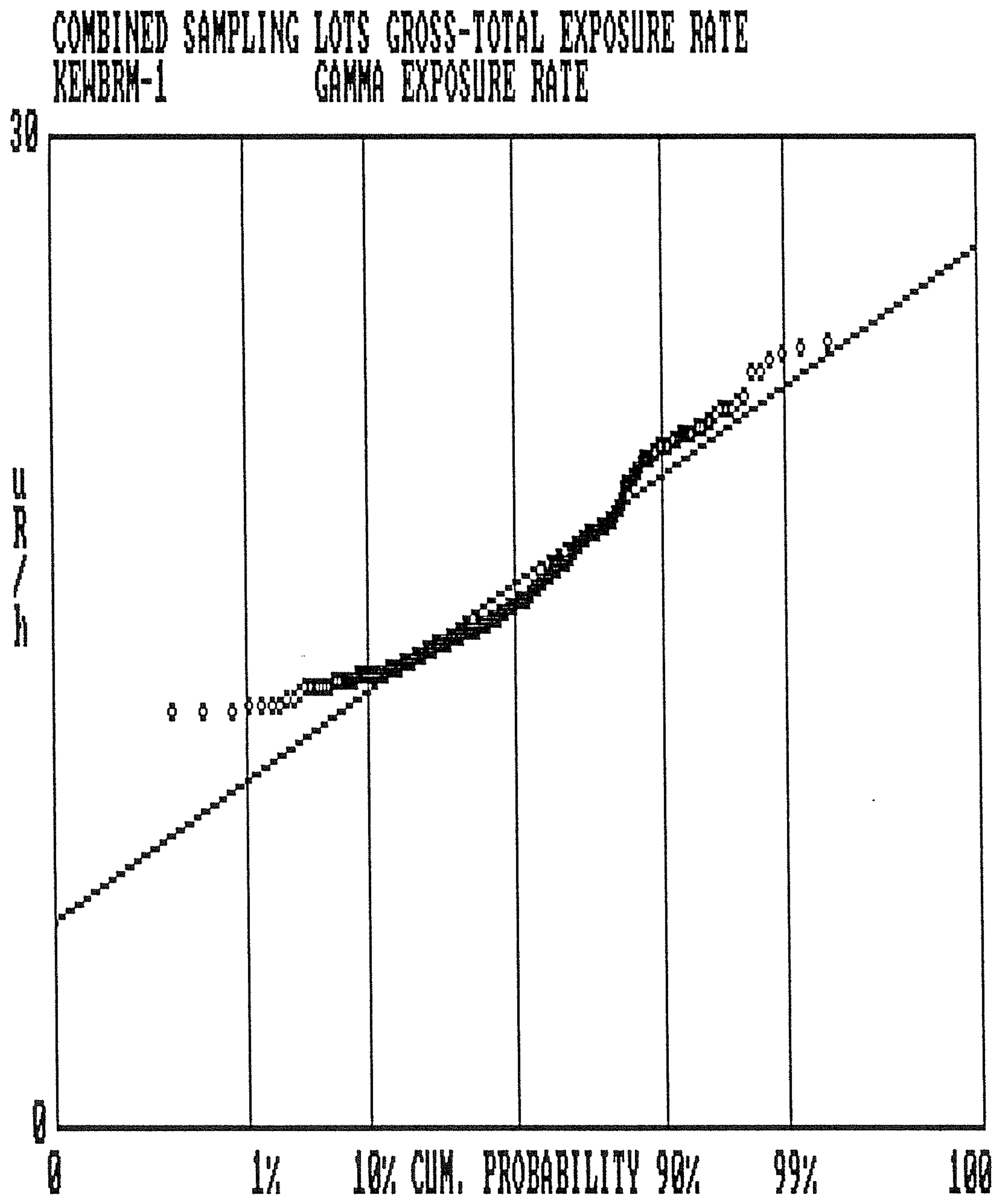


Figure 7.15 Background-Corrected Ambient Gamma Exposure Rates of the Combined Test-Areas

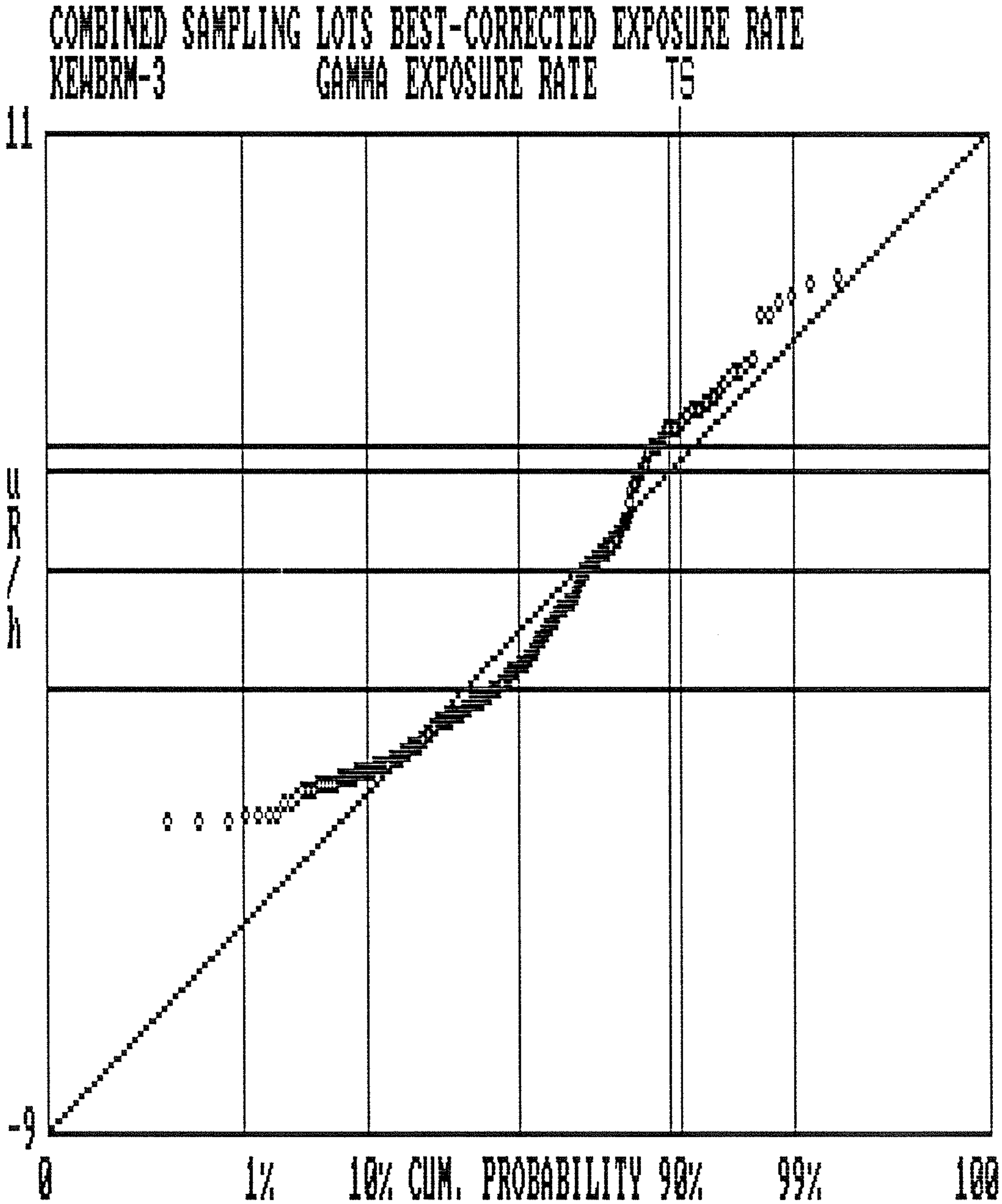


Table 7.2 Summary of Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against Acceptance Limits

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)
T513 Parking Lot	69	-1.26	0.96	1.0	0.185	5
Old R/A Laundry Area	53	0.04	0.96	2.5	1.53	5
Plot 333	52	-0.13	0.63	1.7	0.856	5
SRE-to-RMDF* Field	55	5.45	1.34	8.5	7.52*	5
KEWB-to-RMDF* Field	65	2.20	0.82	4.3	3.44*	5
Total-Sum	294	1.19	2.55	8.5	4.74	5

* Ambient "background" used for these sample lots did not account for contributions from RMDF skyshine and significant changes in area topography. "Background" was underestimated in these reported cases.

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8.0 CONCLUSIONS

The T513 Parking Lot, Old R/A Laundry Area, Plot 333, SRE-to-RMDF Field, and KEWB-to-RMDF Field were inspected for radioactive contaminants. Gamma exposure rate measurements were made on a 6-m square sampling grid, according to the Site Survey Plan (Reference 4). Exposure rate measurements plotted against cumulative probability show in all five cases, well-fitted Gaussian distributions with no outliers or anomalous readings. These distributions showed no trends indicating possible contaminated locations above the expected Gaussian distribution of measurements. Three of the inspected-areas results are equivalent to the results found for three independent areas considered to represent SSFL "natural background." Two of the inspected-area results show normally-distributed values at a greater exposure rate than "natural background." Further investigation was required to determine the source of this occurrence.

Based on these statistical distributions of exposure rate measurements corrected for what we found to be "natural background" at SSFL, we conclude through inspection by variables, that the T513 Parking Lot, Old R/A Laundry Area, and Plot 333 do not contain residual radioactivity. Measurements meet our acceptance criteria for acceptably "clean." The boundary condition of this statistical test assumes a consumer's risk of acceptance of 0.1 at an LTPD of 10%. No further inspection is required in these three inspected areas.

The two fields inspected for radioactivity (SRE-to-RMDF and KEWB-to-RMDF) are, as their name implies, adjacent to the RMDF, a facility which currently stores significant quantities of gamma-emitting radionuclides. Skyshine and direct radiation affect ambient gamma radiation exposure rate in these two fields. Large sandstone outcroppings located in these regions also affect exposure rate. Measurements made next to sandstone can increase by 4 μR/h. Further inspection of measurement data, TLD results from locations near RMDF, and known influences of RMDF operations on ambient exposure rate show that "natural background" correction for these measurements underestimates true "ambient background." We conclude that these two fields are uncontaminated under the same premise as stated before. Further investigation is not necessary.

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23. "Procedure for Decontamination and Disposal of the Kinetics Experiment Water Boiler Facility, Building 073", DWP-704-990-002, W. K. Majors and V. A. Swanson, Atomics International/Rockwell, September 18, 1974

24. IL from R. K. Owen to R. J. Tuttle, "Radiation Survey - T073 (KEWB) Site", Rockwell International, July 17, 1975

25. "Interim Storage Facility Decommissioning Final Report", ESG-DOE-13507, Rocketdyne/Rockwell International, March 15, 1985

26. "KEWB Facilities Decontamination and Disposition Final Report", AI-ERDA-13159, Atomics International/Rockwell International, February 25, 1976

APPENDIX A. DESCRIPTION OF NUCLEAR INSTRUMENTATION

During the radiological survey, direct radiation measurements were made by using portable instruments. Because sample collection was not necessary, analytical laboratory equipment was not required.

A Ludlum model 2220-ESG portable scaler/ratemeter was coupled to a Ludlum model 44-10 NaI gamma scintillator for detecting gamma radiation. The NaI (Tl) crystal is extremely sensitive to changes in gamma flux. The probe efficiency varies with exposure rate. At background ambient gamma exposure rates, the efficiency is about 215 cpm/μR/h. This determination was made by calibrating the 2220-ESG against a Reuter Stokes High-Pressure Ion Chamber (HPIC). The HPIC displays a digital readout every 3 to 4 seconds in μR/h.

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APPENDIX B. COPY OF DOE REPORT,

"GUIDELINES FOR RESIDUAL RADIOACTIVITY AT

FUSRAP AND REMOTE SFMP SITES," March, 1985

MAR 6 '85 PM

Department of Energy

Richland Operations Office
P.O. Box 550
Richland, Washington 99352

MAR 05 1985

RECEIVED
CORRESPONDENCE

Addressees

GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES

The attached guidelines, "U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites," (January 1985) have been issued by the Division of Remedial Action Projects for implementation by FUSRAP and SFMP in order to establish authorized limits for remedial actions. While these Guidelines are specifically intended for "remote" SFMP sites (those located outside a major DOE R&D or production site), they should be taken into consideration when developing authorized limits for remedial actions on major DOE reservations. The guidelines provide specific authorized limits for residual radium and thorium radioisotopes in soil, for airborne radon decay products, for external gamma radiation, and for residual surface contamination levels on materials to be released for unrestricted use. These guidelines will be supplemented in the near future by a document providing the methodology and guidance to establish authorized limits for residual radioisotopes other than radium and thorium in soil at sites to be certified for unrestricted use. The supplement will provide further guidance on the philosophies, scenarios, and pathways to derive appropriate authorized limits for residual radionuclides and mixtures in soil. These guidelines are based on the International Commission on Radiation Protection (ICRP) philosophies and dose limits in ICRP reports 26 and 30 as interpreted in the draft revised DOE Order 5480.1A. These dose limits are 500 mrem/yr for an individual member of the public over a short period of time and an average of 100 mrem/yr over a lifetime.

The approval of authorized limits differing from the guidelines is described in Section D, last sentence of the attached document. If the urgency of field activity makes DRAP concurrence not cost effective, a copy of the approval and backup analysis should be furnished to DRAP as soon as possible, although not necessarily prior to beginning field activities. This does not remove the requirement for approval by SFMPO.

As a result of a recent court decision, the Environmental Protection Agency (EPA) has issued airborne radiation standards applicable to DOE facilities. These final standards, issued as revisions to 40 CFR 61, are:

- 25 mrem/yr-whole body
- 75 mrem/yr-organ
- waiver of these standards will be granted if DOE demonstrates that no individual would receive 100 mrem/yr continuous exposure whole body dose equivalent from all sources within 10 km radius, excluding natural background and medical procedures
- radon and radon daughters are excluded (these standards are covered in 40 CFR 192)

The attached guidelines were written to be consistent with the revision of the DOE Order 5480.1A now in draft at Headquarters and have received the concurrence of the Public Safety Division, Office of Operational Safety. The guidelines will be included in the SFMP Program Plan beginning with the next revision (for FY 1986-1990).

Please refer any questions to Paul F. X. Dunigan, Jr. (FTS 444-6667), of my staff.

Clarence E. Miller

Clarence E. Miller, Jr., Director
Surplus Facilities Management
Program Office

SFMPO:PFXD

Attachment:
As stated

cc: R. N. Coy, UNC
E. G. DeLaney, NE-24, HQ

U.S. DEPARTMENT OF ENERGY GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

(February 1985)

A. INTRODUCTION

This document presents U.S. Department of Energy (DOE) radiological protection guidelines for cleanup of residual radioactive materials and management of the resulting wastes and residues. It is applicable to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and remote sites identified by the Surplus Facilities Management Program (SFMP).* The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactivity, and requirements for control of the radioactive wastes and residues.

Protocols for identification, characterization, and designation of FUSRAP sites for remedial action; for implementation of the remedial action; and for certification of a FUSRAP site for release for unrestricted use are given in a separate document (U.S. Dept. Energy 1984). More detailed information on applications of the guidelines presented herein, including procedures for deriving site-specific guidelines for allowable levels of residual radioactivity from basic dose limits, is contained in a supplementary document--referred to herein as the "supplement" (U.S. Dept. Energy 1985).

"Residual radioactivity" includes: (1) residual concentrations of radionuclides in soil material,** (2) concentrations of airborne radon decay products, (3) external gamma radiation level, and (4) surface contamination. A "basic dose limit" is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined by the International Commission on Radiological Protection (ICRP 1977, 1978). Basic dose limits are used explicitly for deriving guidelines for residual concentrations of radionuclides in soil material, except for thorium and radium. Guidelines for

*A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE research and development or production area.

**The term "soil material" refers to all material below grade level after remedial action is completed.

residual concentrations of thorium and radium and for the other three quantities (airborne radon decay products, external gamma radiation level, and surface contamination) are based on existing radiological protection standards (U.S. Environ. Prot. Agency 1983; U.S. Nucl. Reg. Comm. 1982). These standards are assumed to be consistent with basic dose limits within the uncertainty of derivations of levels of residual radioactivity from basic limits.

A "guideline" for residual radioactivity is a level of residual radioactivity that is acceptable if the use of the site is to be unrestricted. Guidelines for residual radioactivity presented herein are of two kinds: (1) generic, site-independent guidelines taken from existing radiation protection standards, and (2) site-specific guidelines derived from basic dose limits using site-specific models and data. Generic guideline values are presented in this document. Procedures and data for deriving site-specific guideline values are given in the supplement.

An "authorized limit" is a level of residual radioactivity that must not be exceeded if the remedial action is to be considered completed. Under normal circumstances, expected to occur at most sites, authorized limits are set equal to guideline values for residual radioactivity that are acceptable if use of the site is not be restricted. If the authorized limit is set higher than the guideline, restrictions and controls must be established for use of the site. Exceptional circumstances for which authorized limits might differ from guideline values are specified in Sections D and F. The restrictions and controls that must be placed on the site if authorized limits are set higher than guidelines are described in Section E.

DOE policy requires that all exposures to radiation be limited to levels that are as low as reasonably achievable (ALARA). Implementation of ALARA policy is specified as procedures to be applied after authorized limits have been set. For sites to be released for unrestricted use, the intent is to reduce residual radioactivity to levels that are as far below authorized limits as reasonable considering technical, economic, and social factors. At sites where the residual radioactivity is not reduced to levels that permit release for unrestricted use, ALARA policy is implemented by establishing controls to reduce exposure to ALARA levels. Procedures for implementing ALARA policy are described in the supplement. ALARA policies, procedures, and actions must be documented and filed as a permanent record upon completion of remedial action at a site.

B. BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 500 mrem/yr for a period of exposure not to exceed 5 years and an average of 100 mrem/yr over a lifetime. The committed effective dose equivalent, as defined in ICRP Publication 26 (ICRP 1977) and calculated by dosimetry models described in ICRP Publication 30 (ICRP 1978), shall be used for determining the dose.

C. GUIDELINES FOR RESIDUAL RADIOACTIVITY

C.1 Residual Radionuclides in Soil Material

Residual concentrations of radionuclides in soil material shall be specified as above-background concentrations averaged over an area of 100 m^2. If the concentration in any area is found to exceed the average by a factor greater than 3, guidelines for local concentrations shall also be applicable. These "hot spot" guidelines depend on the extent of the elevated local concentrations and are given in the supplement.

The generic guidelines specified below are for concentrations of individual radionuclides occurring alone. If mixtures of radionuclides are present, the concentrations of individual radionuclides shall be reduced so that the dose for the mixture would not exceed the basic dose limit. Explicit formulas for calculating residual concentration guidelines for mixtures are given in the supplement.

The generic guidelines for residual concentrations of Th-232, Th-230, Ra-228, and Ra-226 are:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface

- 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface

The guidelines for residual concentrations in soil material of all other radionuclides shall be derived from basic dose limits by means of an environmental pathway analysis using site-specific data. Procedures for deriving these guidelines are given in the supplement.

C.2 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.* In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive materials are not the cause.

C.3. External Gamma Radiation

The level of gamma radiation at any location on a site to be released for unrestricted use, whether inside an occupied building or habitable structure or outdoors, shall not exceed the background level by more than 20 μR/h.

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*A working level (WL) is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

C.4 Surface Contamination

The following generic guidelines, adapted from standards of the U.S. Nuclear Regulatory Commission (1982), are applicable only to existing structures and equipment that will not be demolished and buried. They apply to both interior and exterior surfaces. If a building is demolished and buried, the guidelines in Section C.1 are applicable to the resulting contamination in the ground.

Radionuclides†[2]	Allowable Total Residual Surface Contamination (dpm/100 cm^2)†[1] Average†[3],†[4]	Maximum†[4],†[5]	Removable†[6]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000α	15,000α	1,000α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000β-γ	15,000β-γ	1,000β-γ

†[1] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

†[2] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

†[3] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

†[4] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

†[5] The maximum contamination level applies to an area of not more than 100 cm^2.

†[6] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

D. AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVITY

The remedial action shall not be considered complete unless the residual radioactivity is below authorized limits. Authorized limits shall be set equal to guidelines for residual radioactivity unless: (1) exceptions specified in Section F of this document are applicable, in which case an authorized limit may be set above the guideline value for the specific location or condition to which the exception is applicable; or (2) on the basis of site-specific data not used in establishing the guidelines, it can be clearly established that limits below the guidelines are reasonable and can be achieved without appreciable increase in cost of the remedial action. Authorized limits that differ from guidelines must be justified and established on a site-specific basis, with documentation that must be filed as a permanent record upon completion of remedial action at a site. Authorized limits differing from the guidelines must be approved by the Director, Oak Ridge Technical Services Division, for FUSRAP and by the Director, Richland Surplus Facilities Management Program Office, for remote SFMP--with concurrence by the Director of Remedial Action Projects for both programs.

E. CONTROL OF RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES

Residual radioactivity above the guidelines at FUSRAP and remote SFMP sites must be managed in accordance with applicable DOE Orders. The DOE Order 5480.1A requires compliance with applicable federal, state, and local environmental protection standards.

The operational and control requirements specified in the following DOE Orders shall apply to both interim storage and long-term management.

a. 5440.1B, Implementation of the National Environmental Policy Act

b. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations

c. 5480.2, Hazardous and Radioactive Mixed Waste Management

d. 5480.4, Environmental Protection, Safety, and Health Protection Standards

e. 5482.1A, Environmental, Safety, and Health Appraisal Program

f. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities

g. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements

h. 5484.2, Unusual Occurrence Reporting System

i. 5820.2, Radioactive Waste Management

E.1 Interim Storage

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 50 years and, in any case, at least 25 years.

b. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed: (1) 100 pCi/L at any given point, (2) an annual average concentration of 30 pCi/L over the facility site, and (3) an annual average concentration of 3 pCi/L at or above any location outside the facility site (DOE Order 5480.1A, Attachment XI-1).

c. Concentrations of radionuclides in the groundwater or quantities of residual radioactive materials shall not exceed existing federal, state, or local standards.

d. Access to a site should be controlled and misuse of onsite material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These control features should be designed to ensure, to the extent reasonable, an effective life of at least 25 years. The federal government shall have title to the property.

E.2 <u>Long-Term Management</u>

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years.

b. Control and stabilization features shall be designed to ensure that Rn-222 emanation to the atmosphere from the waste shall not: (1) exceed an annual average release rate of 20 $pCi/m^2/s$, and (2) increase the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates is not required.

c. Prior to placement of any potentially biodegradable contaminated wastes in a long-term management facility, such wastes shall be properly conditioned to ensure that (1) the generation and escape of biogenic gases will not cause the requirement in paragraph b of this section (E.2) to be exceeded, and (2) biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph a of this section (E.2).

d. Groundwater shall be protected in accordance with 40 CFR 192.20(a)(2) and 192.20(a)(3), as applicable to FUSRAP and remote SFMP sites.

e. Access to a site should be controlled and misuse of onsite material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These controls should be designed to be effective to the extent reasonable for at least 200 years. The federal government shall have title to the property.

F. EXCEPTIONS

Exceptions to the requirement that authorized limits be set equal to the guidelines may be made on the basis of an analysis of site-specific aspects of a designated site that were not taken into account in deriving the guidelines. Exceptions require approvals as stated in Section D. Specific situations that warrant exceptions are:

a. Where remedial actions would pose a clear and present risk of injury to workers or members of the general public, notwithstanding reasonable measures to avoid or reduce risk.

b. Where remedial actions--even after all reasonable mitigative measures have been taken--would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

c. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and where the residual radioactive materials do not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this risk. Remedial actions will generally not be necessary where only minor quantities of residual radioactive materials are involved or where residual radioactive materials occur in an inaccessible location at which site-specific factors limit their hazard and from which they are costly or difficult to remove. Examples are residual radioactive materials under hard-surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. In order to invoke this exception, a site-specific analysis must be provided to establish that it would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in Section B, and a statement specifying the residual radioactivity must be included in the appropriate state and local records.

d. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be effected by remedial action, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of remedial actions that would be less costly than removal of the residual radioactive materials. A statement specifying the residual radioactivity must be included in the appropriate state and local records.

e. Where there is no feasible remedial action.

G. SOURCES

Limit or Guideline	Source
Basic Dose Limits	
Dosimetry Model and Dose Limits	International Commission on Radiological Protection (1977, 1978)
Guidelines for Residual Radioactivity	
Residual Radionuclides in Soil Material	40 CFR 192
Airborne Radon Decay Products	40 CFR 192
External Gamma Radiation	40 CFR 192
Surface Contamination	U.S. Nuclear Regulatory Commission (1982)
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	DOE Order 5480.1A; 40 CFR 192

H. REFERENCES

International Commission on Radiological Protection. 1977. Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977). ICRP Publication 26. Pergamon Press, Oxford. [As modified by "Statement from the 1978 Stockholm Meeting of the ICRP." Annals of the ICRP, Vol. 2, No. 1, 1978.]

International Commission on Radiological Protection. 1978. Limits for Intakes of Radionuclides by Workers. A Report of Committee 2 of the International Commission on Radiological Protection. Adopted by the Commission in July 1978. ICRP Publication 30. Part 1 (and Supplement), Part 2 (and Supplement), Part 3 (and Supplements A and B), and Index. Pergamon Press, Oxford.

U.S. Environmental Protection Agency. 1983. Standards for Remedial Actions at Inactive Uranium Processing Sites; Final Rule (40 CFR Part 192). Fed. Regist. 48(3):590-604 (January 5, 1983).

U.S. Department of Energy. 1984. Formerly Utilized Sites Remedial Action Program. Summary Protocol: Identification - Characterization - Designation - Remedial Action - Certification. Office of Nuclear Energy, Office of Terminal Waste Disposal and Remedial Action, Division of Remedial Action Projects. April 1984.

U.S. Department of Energy. 1985. Supplement to U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites. A Manual for Implementing Residual Radioactivity Guidelines. Prepared by Argonne National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory for the U.S. Department of Energy. (In preparation.)

U.S. Nuclear Regulatory Commission. 1982. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, DC. July 1982. [See also: U.S. Atomic Energy Commission. 1974. Regulatory Guide 1.86. Termination of Operating Licenses for Nuclear Reactors. Table I.]

APPENDIX C. RADIOLOGICAL SURVEY DATA

T513 Parking Lot Sorted by Location

T513.WS

SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
T513	10-14	3133	14.51	0.26
	10-14	2924	13.54	0.25
	9-15	2953	13.68	0.25
	9-16	2930	13.57	0.25
	9-16	2880	13.34	0.25
	10-14	3034	14.05	0.26
	10-15	3070	14.22	0.26
	10-15	3046	14.11	0.26
	10-16	2949	13.66	0.25
	10-17	2855	13.22	0.25
	11-14	3088	14.30	0.26
	11-15	2954	13.68	0.25
	11-15	2800	12.97	0.25
	11-16	3013	13.96	0.25
	11-17	2931	13.58	0.25
	12-14	3044	14.10	0.26
	12-15	2989	13.85	0.25
	12-16	2826	13.09	0.25
	12-16	2929	13.57	0.25
	11-17	2975	13.78	0.25
	13-14	2981	13.81	0.25
	13-15	2956	13.69	0.25
	13-16	2718	12.59	0.24
	13-16	2926	13.55	0.25
	12-17	3050	14.13	0.26
	14-14	2875	13.32	0.25
	14-15	2971	13.76	0.25
	14-16	2969	13.75	0.25
	14-17	3007	13.93	0.25
	14-18	2958	13.70	0.25
	15-15	3121	14.46	0.26
	15-15	2750	12.74	0.24
	15-16	2883	13.35	0.25
	15-17	2943	13.63	0.25
	15-18	2998	13.89	0.25
	1-6	2936	13.60	0.25
	2-5	2900	13.43	0.25
	3-5	2720	12.60	0.24
	4-4	2754	12.76	0.24
	5-3	2800	12.97	0.25
	6-3	2763	12.80	0.24
	7-2	2719	12.59	0.24
	8-1	2739	12.69	0.24
	2-7	3064	14.19	0.26
	3-7	2970	13.76	0.25
	4-6	2965	13.73	0.25
	5-5	2919	13.52	0.25
	6-5	2941	13.62	0.25
	7-4	2902	13.44	0.25
	8-3	3000	13.90	0.25
	9-3	3029	14.03	0.25
	9-4	3280	15.19	0.27
	10-5	3481	16.12	0.27
	11-5	3471	16.08	0.27
	11-6	3484	16.14	0.27

T513.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	11-7	3448	15.97	0.27
	11-8	3399	15.74	0.27
	11-8	3517	16.29	0.27
	11-9	3416	15.82	0.27
	10-10	3460	16.03	0.27
	10-10	3447	15.97	0.27
	10-11	3284	15.21	0.27
	9-12	3225	14.94	0.26
	9-13	3100	14.36	0.26
	9-13	3082	14.28	0.26
	9-14	3035	14.06	0.26
	8-15	3008	13.93	0.25
	8-15	2964	13.73	0.25
	8-16	2880	13.34	0.25

T513 Parking Lot Sorted by Exposure Rate

T513.WS

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
			SORTED BY EXPOSURE RATE	
	11-8	3517	16.29	0.27
	11-6	3484	16.14	0.27
	10-5	3481	16.12	0.27
	11-5	3471	16.08	0.27
	10-10	3460	16.03	0.27
	11-7	3448	15.97	0.27
	10-10	3447	15.97	0.27
	11-9	3416	15.82	0.27
	11-8	3399	15.74	0.27
	10-11	3284	15.21	0.27
	9-4	3280	15.19	0.27
	9-12	3225	14.94	0.26
	10-14	3133	14.51	0.26
	15-15	3121	14.46	0.26
	9-13	3100	14.36	0.26
	11-14	3088	14.30	0.26
	9-13	3082	14.28	0.26
	10-15	3070	14.22	0.26
	2-7	3064	14.19	0.26
	12-17	3050	14.13	0.26
	10-15	3046	14.11	0.26
	12-14	3044	14.10	0.26
	9-14	3035	14.06	0.26
	10-14	3034	14.05	0.26
	9-3	3029	14.03	0.25
	11-16	3013	13.96	0.25
	8-15	3008	13.93	0.25
	14-17	3007	13.93	0.25
	8-3	3000	13.90	0.25
	15-18	2998	13.89	0.25
	12-15	2989	13.85	0.25
	13-14	2981	13.81	0.25
	11-17	2975	13.78	0.25
	14-15	2971	13.76	0.25
	3-7	2970	13.76	0.25
	14-16	2969	13.75	0.25
	4-6	2965	13.73	0.25
	8-15	2964	13.73	0.25
	14-18	2958	13.70	0.25
	13-15	2956	13.69	0.25
	11-15	2954	13.68	0.25
	9-15	2953	13.68	0.25
	10-16	2949	13.66	0.25
	15-17	2943	13.63	0.25
	6-5	2941	13.62	0.25
	1-6	2936	13.60	0.25
	11-17	2931	13.58	0.25
	9-16	2930	13.57	0.25
	12-16	2929	13.57	0.25
	13-16	2926	13.55	0.25
	10-14	2924	13.54	0.25
	5-5	2919	13.52	0.25
	7-4	2902	13.44	0.25
	2-5	2900	13.43	0.25
	15-16	2883	13.35	0.25

T513.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	9-16	2880	13.34	0.25
	8-16	2880	13.34	0.25
	14-14	2875	13.32	0.25
	10-17	2855	13.22	0.25
	12-16	2826	13.09	0.25
	5-3	2800	12.97	0.25
	11-15	2800	12.97	0.25
	6-3	2763	12.80	0.24
	4-4	2754	12.76	0.24
	15-15	2750	12.74	0.24
	8-1	2739	12.69	0.24
	3-5	2720	12.60	0.24
	7-2	2719	12.59	0.24
	13-16	2718	12.59	0.24

Old R/A Laundry Area Sorted by Location

RALAN.WS — SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
R/A	16-9R	3794	17.57	0.29
LAUNDRY	16-9R	3424	15.86	0.27
AREA	16-10R	3382	15.67	0.27
	15-11R	3063	14.19	0.26
	15-12R	3432	15.90	0.27
	15-13R	3551	16.45	0.28
	17-9C	3261	15.10	0.26
	17-9C	3009	13.94	0.25
	16-10C	3261	15.10	0.26
	16-11CR	3165	14.66	0.26
	16-12	3182	14.74	0.26
	15-13A	3126	14.48	0.26
	15-14	3041	14.09	0.26
	15-15	3079	14.26	0.26
	14-16	3316	15.36	0.27
	14-17	3387	15.69	0.27
	15-16	3297	15.27	0.27
	15-15	3162	14.65	0.26
	16-14	3237	14.99	0.26
	16-13C	2891	13.39	0.25
	17-12C	2870	13.29	0.25
	17-11A	3114	14.42	0.26
	18-10R	3323	15.39	0.27
	18-9R	3378	15.65	0.27
	19-9R	3367	15.60	0.27
	18-10R	3450	15.98	0.27
	18-11A	3167	14.67	0.26
	18-12A	3264	15.12	0.26
	17-13A	3232	14.97	0.26
	17-14A	3183	14.74	0.26
	17-15	3146	14.57	0.26
	16-16AR	3699	17.13	0.28
	15-17AR	3825	17.72	0.29
	16-18AR	3555	16.47	0.28
	17-17AR	3253	15.07	0.26
	14-12AR	3699	17.13	0.28
	13-13AR	3825	17.72	0.29
	12-14AR	3555	16.47	0.28
	11-15AR	3253	15.07	0.26
	10-16R	3205	14.85	0.26
	10-17R	3316	15.36	0.27
	10-13A	3245	15.03	0.26
	9-13	3173	14.70	0.26
	9-14R	3200	14.82	0.26
	8-15	3307	15.32	0.27
	10-11	3312	15.34	0.27
	9-10R	3424	15.86	0.27
	9-11R	3234	14.98	0.26
	9-12	3312	15.34	0.27
	8-12	3290	15.24	0.27
	7-13R	3306	15.31	0.27
	6-14	3240	15.01	0.26
	5-14	3254	15.07	0.26

Old R/A Laundry Area Sorted by Exposure Rate

RALAN.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	15-17AR	3825	17.72	0.29
	13-13AR	3825	17.72	0.29
	16-9R	3794	17.57	0.29
	16-16AR	3699	17.13	0.28
	14-12AR	3699	17.13	0.28
	16-18AR	3555	16.47	0.28
	12-14AR	3555	16.47	0.28
	15-13R	3551	16.45	0.28
	18-10R	3450	15.98	0.27
	15-12R	3432	15.90	0.27
	16-9R	3424	15.86	0.27
	9-10R	3424	15.86	0.27
	14-17	3387	15.69	0.27
	16-10R	3382	15.67	0.27
	18-9R	3378	15.65	0.27
	19-9R	3367	15.60	0.27
	18-10R	3323	15.39	0.27
	14-16	3316	15.36	0.27
	10-17R	3316	15.36	0.27
	10-11	3312	15.34	0.27
	9-12	3312	15.34	0.27
	8-15	3307	15.32	0.27
	7-13R	3306	15.31	0.27
	15-16	3297	15.27	0.27
	8-12	3290	15.24	0.27
	18-12A	3264	15.12	0.26
	16-10C	3261	15.10	0.26
	17-9C	3261	15.10	0.26
	5-14	3254	15.07	0.26
	17-17AR	3253	15.07	0.26
	11-15AR	3253	15.07	0.26
	10-13A	3245	15.03	0.26
	6-14	3240	15.01	0.26
	16-14	3237	14.99	0.26
	9-11R	3234	14.98	0.26
	17-13A	3232	14.97	0.26
	10-16R	3205	14.85	0.26
	9-14R	3200	14.82	0.26
	17-14A	3183	14.74	0.26
	16-12	3182	14.74	0.26
	9-13	3173	14.70	0.26
	18-11A	3167	14.67	0.26
	16-11CR	3165	14.66	0.26
	15-15	3162	14.65	0.26
	17-15	3146	14.57	0.26
	15-13A	3126	14.48	0.26
	17-11A	3114	14.42	0.26
	15-15	3079	14.26	0.26
	15-11R	3063	14.19	0.26
	15-14	3041	14.09	0.26
	17-9C	3009	13.94	0.25
	16-13C	2891	13.39	0.25
	17-12C	2870	13.29	0.25

Plot 333 Sorted by Location

PLT333.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
PLT333	5-3R	3317	15.36	0.27
	5-4	3164	14.66	0.26
	4-5	3203	14.84	0.26
	4-5	3482	16.13	0.27
	4-6R	3285	15.22	0.27
	3-7	3259	15.10	0.26
	3-8R	3380	15.66	0.27
	2-8R	3514	16.28	0.27
	2-9R	3370	15.61	0.27
	2-10R	3237	14.99	0.26
	1-10	3092	14.32	0.26
	1-11R	3159	14.63	0.26
	2-11R	3176	14.71	0.26
	2-10	3195	14.80	0.26
	3-10	3223	14.93	0.26
	3-9R	3199	14.82	0.26
	3-8	3243	15.02	0.26
	4-8	3117	14.44	0.26
	4-7	3342	15.48	0.27
	5-6	2984	13.82	0.25
	5-5	3351	15.52	0.27
	5-5	3205	14.85	0.26
	6-4	3383	15.67	0.27
	6-3	3427	15.87	0.27
	7-3R	3432	15.90	0.27
	7-4R	3351	15.52	0.27
	6-5	3134	14.52	0.26
	6-6R	3243	15.02	0.26
	5-6	3129	14.49	0.26
	5-7	3186	14.76	0.26
	5-8R	3202	14.83	0.26
	4-9	3154	14.61	0.26
	4-9	3058	14.16	0.26
	3-10R	3202	14.83	0.26
	3-10	3161	14.64	0.26
	3-11	3041	14.09	0.26
	4-11R	3269	15.14	0.26
	4-10R	3342	15.48	0.27
	5-10R	3313	15.35	0.27
	5-9R	3336	15.45	0.27
	5-9R	3341	15.48	0.27
	6-8	3172	14.69	0.26
	6-7	3210	14.87	0.26
	6-6R	3287	15.23	0.27
	7-6R	3254	15.07	0.26
	7-5R	3219	14.91	0.26
	7-4R	3292	15.25	0.27
	8-3R	3153	14.60	0.26
	8-3	3666	16.98	0.28
	8-2	3650	16.91	0.28
	9-2	3385	15.68	0.27
	9-1	3391	15.71	0.27

Plot 333 Sorted by Exposure Rate

PLT333.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	8-3	3666	16.98	0.28
	8-2	3650	16.91	0.28
	2-8R	3514	16.28	0.27
	4-5	3482	16.13	0.27
	7-3R	3432	15.90	0.27
	6-3	3427	15.87	0.27
	9-1	3391	15.71	0.27
	9-2	3385	15.68	0.27
	6-4	3383	15.67	0.27
	3-8R	3380	15.66	0.27
	2-9R	3370	15.61	0.27
	5-5	3351	15.52	0.27
	7-4R	3351	15.52	0.27
	4-7	3342	15.48	0.27
	4-10R	3342	15.48	0.27
	5-9R	3341	15.48	0.27
	5-9R	3336	15.45	0.27
	5-3R	3317	15.36	0.27
	5-10R	3313	15.35	0.27
	7-4R	3292	15.25	0.27
	6-6R	3287	15.23	0.27
	4-6R	3285	15.22	0.27
	4-11R	3269	15.14	0.26
	3-7	3259	15.10	0.26
	7-6R	3254	15.07	0.26
	6-6R	3243	15.02	0.26
	3-8	3243	15.02	0.26
	2-10R	3237	14.99	0.26
	3-10	3223	14.93	0.26
	7-5R	3219	14.91	0.26
	6-7	3210	14.87	0.26
	5-5	3205	14.85	0.26
	4-5	3203	14.84	0.26
	3-10R	3202	14.83	0.26
	5-8R	3202	14.83	0.26
	3-9R	3199	14.82	0.26
	2-10	3195	14.80	0.26
	5-7	3186	14.76	0.26
	2-11R	3176	14.71	0.26
	6-8	3172	14.69	0.26
	5-4	3164	14.66	0.26
	3-10	3161	14.64	0.26
	1-11R	3159	14.63	0.26
	4-9	3154	14.61	0.26
	8-3R	3153	14.60	0.26
	6-5	3134	14.52	0.26
	5-6	3129	14.49	0.26
	4-8	3117	14.44	0.26
	1-10	3092	14.32	0.26
	4-9	3058	14.16	0.26
	3-11	3041	14.09	0.26
	5-6	2984	13.82	0.25

SRE-to-RMDF Field Sorted by Location

SRERMD.WS			SORTED BY LOCATION	
ROOM	GRID	GAMMA	uR/h	
NUMBER	NAME	TOTAL	TOTAL	STD DEV
SRE TO	3-2	4501	20.85	0.31
RMDF	3-3	4343	20.12	0.31
	3-4	4381	20.29	0.31
	3-5	4279	19.82	0.30
	3-6	4264	19.75	0.30
	3-7	4269	19.77	0.30
	3-8	4077	18.88	0.30
	3-9	3705	17.16	0.28
	4-8	3958	18.33	0.29
	4-7	4222	19.56	0.30
	4-6	4309	19.96	0.30
	4-5	4470	20.71	0.31
	4-4	4465	20.68	0.31
	4-3	4607	21.34	0.31
	4-2	4616	21.38	0.31
	5-2	4682	21.69	0.32
	5-3	4468	20.70	0.31
	5-4	4461	20.66	0.31
	5-5	4667	21.62	0.32
	5-6	4454	20.63	0.31
	5-7	4510	20.89	0.31
	5-8	4021	18.63	0.29
	6-9	4038	18.70	0.29
	6-8	4410	20.43	0.31
	6-7	4407	20.41	0.31
	6-6	4469	20.70	0.31
	6-5	4385	20.31	0.31
	6-4	4541	21.03	0.31
	6-3	4946	22.91	0.33
	7-3	4570	21.17	0.31
	7-4	4709	21.81	0.32
	7-5	4497	20.83	0.31
	7-6	4520	20.94	0.31
	7-7	4424	20.49	0.31
	7-8	4538	21.02	0.31
	7-9	3983	18.45	0.29
	8-10	4213	19.51	0.30
	8-9	4367	20.23	0.31
	8-8	4389	20.33	0.31
	8-7	4593	21.27	0.31
	8-6	4714	21.84	0.32
	8-5	4192	19.42	0.30
	8-4	4948	22.92	0.33
	9-6	5134	23.78	0.33
	9-7	4775	22.12	0.32
	9-8	4285	19.85	0.30
	9-9	4214	19.52	0.30
	10-7	4360	20.20	0.31
	10-6	4532	20.99	0.31
	10-5	4750	22.00	0.32
	11-5	5014	23.22	0.33
	11-6	4562	21.13	0.31
	12-5	5050	23.39	0.33
	13-5	5094	23.60	0.33
	13-5	4542	21.04	0.31

SRERMD.WS

SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	14(-3)	8201	37.99	0.42
	14(-2)	7451	34.51	0.40
	15(-1)	7332	33.96	0.40
	16(-1)	7021	32.52	0.39

SRE-to-RMDF Field Sorted by Exposure Rate

SRERMD.WS — SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	14(-3)	8201	37.99	0.42
	14(-2)	7451	34.51	0.40
	15(-1)	7332	33.96	0.40
	16(-1)	7021	32.52	0.39
	9-6	5134	23.78	0.33
	13-5	5094	23.60	0.33
	12-5	5050	23.39	0.33
	11-5	5014	23.22	0.33
	8-4	4948	22.92	0.33
	6-3	4946	22.91	0.33
	9-7	4775	22.12	0.32
	10-5	4750	22.00	0.32
	8-6	4714	21.84	0.32
	7-4	4709	21.81	0.32
	5-2	4682	21.69	0.32
	5-5	4667	21.62	0.32
	4-2	4616	21.38	0.31
	4-3	4607	21.34	0.31
	8-7	4593	21.27	0.31
	7-3	4570	21.17	0.31
	11-6	4562	21.13	0.31
	13-5	4542	21.04	0.31
	6-4	4541	21.03	0.31
	7-8	4538	21.02	0.31
	10-6	4532	20.99	0.31
	7-6	4520	20.94	0.31
	5-7	4510	20.89	0.31
	3-2	4501	20.85	0.31
	7-5	4497	20.83	0.31
	4-5	4470	20.71	0.31
	6-6	4469	20.70	0.31
	5-3	4468	20.70	0.31
	4-4	4465	20.68	0.31
	5-4	4461	20.66	0.31
	5-6	4454	20.63	0.31
	7-7	4424	20.49	0.31
	6-8	4410	20.43	0.31
	6-7	4407	20.41	0.31
	8-8	4389	20.33	0.31
	6-5	4385	20.31	0.31
	3-4	4381	20.29	0.31
	8-9	4367	20.23	0.31
	10-7	4360	20.20	0.31
	3-3	4343	20.12	0.31
	4-6	4309	19.96	0.30
	9-8	4285	19.85	0.30
	3-5	4279	19.82	0.30
	3-7	4269	19.77	0.30
	3-6	4264	19.75	0.30
	4-7	4222	19.56	0.30
	9-9	4214	19.52	0.30
	8-10	4213	19.51	0.30
	8-5	4192	19.42	0.30
	3-8	4077	18.88	0.30
	6-9	4038	18.70	0.29

SRERMD.WS

SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	5-8	4021	18.63	0.29
	7-9	3983	18.45	0.29
	4-8	3958	18.33	0.29
	3-9	3705	17.16	0.28

KEWB-to-RMDF Field Sorted by Location

KEWBRM.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
KEWB-RMDF	1-8R	3543	16.41	0.28
KEWB-RMDF	1-9R	3596	16.66	0.28
KEWB-RMDF	2-7R	3527	16.34	0.28
KEWB-RMDF	2-8R	3756	17.40	0.28
KEWB-RMDF	2-9R	3588	16.62	0.28
KEWB-RMDF	3-4R	4130	19.13	0.30
KEWB-RMDF	3-4R	3952	18.31	0.29
KEWB-RMDF	3-5R	3965	18.37	0.29
KEWB-RMDF	3-6R	3611	16.73	0.28
KEWB-RMDF	3-8R	3571	16.54	0.28
KEWB-RMDF	3-9R	3675	17.02	0.28
KEWB-RMDF	3-10R	3390	15.70	0.27
KEWB-RMDF	4-1R*	3923	18.17	0.29
KEWB-RMDF	4-2R*	4231	19.60	0.30
KEWB-RMDF	4-2R*	4060	18.81	0.30
KEWB-RMDF	4-3R	3899	18.06	0.29
KEWB-RMDF	4-4R	3658	16.94	0.28
KEWB-RMDF	4-5R	3798	17.59	0.29
KEWB-RMDF	4-6R	3651	16.91	0.28
KEWB-RMDF	4-6R	3823	17.71	0.29
KEWB-RMDF	4-7R	3862	17.89	0.29
KEWB-RMDF	4-8R	3565	16.51	0.28
KEWB-RMDF	5-2R	3946	18.28	0.29
KEWB-RMDF	5-3R	4002	18.54	0.29
KEWB-RMDF	5-3R	3521	16.31	0.27
KEWB-RMDF	5-4R	3920	18.16	0.29
KEWB-RMDF	5-5R	3687	17.08	0.28
KEWB-RMDF	5-6R	3657	16.94	0.28
KEWB-RMDF	5-7R	3761	17.42	0.28
KEWB-RMDF	6-3R	3629	16.81	0.28
KEWB-RMDF	6-4R	3761	17.42	0.28
KEWB-RMDF	6-5R	3920	18.16	0.29
KEWB-RMDF	6-5R	3692	17.10	0.28
KEWB-RMDF	7-5R	3608	16.71	0.28
KEWB-RMDF	7-6R	3604	16.69	0.28
KEWB-T003	1-5R	3574	16.55	0.28
KEWB-T003	1-6R	3601	16.68	0.28
KEWB-T003	2-4R	3624	16.79	0.28
KEWB-T003	2-4R	3527	16.34	0.28
KEWB-T003	2-5R	3625	16.79	0.28
KEWB-T003	2-5R	3701	17.14	0.28
KEWB-T003	2-6R	3516	16.29	0.27
KEWB-T003	2-6R	3425	15.86	0.27
KEWB-T003	3-3R	3715	17.21	0.28
KEWB-T003	3-4R	3847	17.82	0.29
KEWB-T003	3-5R	3869	17.92	0.29
KEWB-T003	3-5R	3728	17.27	0.28
KEWB-T003	4-2R	3897	18.05	0.29
KEWB-T003	4-3R	3876	17.95	0.29
KEWB-T003	4-4R	3699	17.13	0.28
KEWB-T003	5-2R	3855	17.86	0.29
KEWB-T003	5-3R	3892	18.03	0.29
KEWB-T003	5-3R	3795	17.58	0.29
KEWB-T003	5-3R	3926	18.19	0.29
KEWB-T003	5-4R	3849	17.83	0.29

KEWBRM.WS — SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
KEWB-T003	6-2R	3869	17.92	0.29
KEWB-T003	6-2R	3679	17.04	0.28
KEWB-T003	6-3R	3901	18.07	0.29
KEWB-T003	6-3R	4049	18.75	0.29
KEWB-T003	6-3R	3961	18.35	0.29
KEWB-T003	6-3R	3930	18.20	0.29
KEWB-T003	6-4R	3927	18.19	0.29
KEWB-T003	7-3R	3898	18.06	0.29
KEWB-T003	7-4R	3902	18.07	0.29
KEWB-T003	7-4R	3808	17.64	0.29

KEWB-to-RMDF Field Sorted by Exposure Rate

KEWBRM.WS — SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
KEWB-RMDF	4-2R*	4231	19.60	0.30
KEWB-RMDF	3-4R	4130	19.13	0.30
KEWB-RMDF	4-2R*	4060	18.81	0.30
KEWB-T003	6-3R	4049	18.75	0.29
KEWB-RMDF	5-3R	4002	18.54	0.29
KEWB-RMDF	3-5R	3965	18.37	0.29
KEWB-T003	6-3R	3961	18.35	0.29
KEWB-RMDF	3-4R	3952	18.31	0.29
KEWB-RMDF	5-2R	3946	18.28	0.29
KEWB-T003	6-3R	3930	18.20	0.29
KEWB-T003	6-4R	3927	18.19	0.29
KEWB-T003	5-3R	3926	18.19	0.29
KEWB-RMDF	4-1R*	3923	18.17	0.29
KEWB-RMDF	5-4R	3920	18.16	0.29
KEWB-RMDF	6-5R	3920	18.16	0.29
KEWB-T003	7-4R	3902	18.07	0.29
KEWB-T003	6-3R	3901	18.07	0.29
KEWB-RMDF	4-3R	3899	18.06	0.29
KEWB-T003	7-3R	3898	18.06	0.29
KEWB-T003	4-2R	3897	18.05	0.29
KEWB-T003	5-3R	3892	18.03	0.29
KEWB-T003	4-3R	3876	17.95	0.29
KEWB-T003	3-5R	3869	17.92	0.29
KEWB-T003	6-2R	3869	17.92	0.29
KEWB-RMDF	4-7R	3862	17.89	0.29
KEWB-T003	5-2R	3855	17.86	0.29
KEWB-T003	5-4R	3849	17.83	0.29
KEWB-T003	3-4R	3847	17.82	0.29
KEWB-RMDF	4-6R	3823	17.71	0.29
KEWB-T003	7-4R	3808	17.64	0.29
KEWB-RMDF	4-5R	3798	17.59	0.29
KEWB-T003	5-3R	3795	17.58	0.29
KEWB-RMDF	5-7R	3761	17.42	0.28
KEWB-RMDF	6-4R	3761	17.42	0.28
KEWB-RMDF	2-8R	3756	17.40	0.28
KEWB-T003	3-5R	3728	17.27	0.28
KEWB-T003	3-3R	3715	17.21	0.28
KEWB-T003	2-5R	3701	17.14	0.28
KEWB-T003	4-4R	3699	17.13	0.28
KEWB-RMDF	6-5R	3692	17.10	0.28
KEWB-RMDF	5-5R	3687	17.08	0.28
KEWB-T003	6-2R	3679	17.04	0.28
KEWB-RMDF	3-9R	3675	17.02	0.28
KEWB-RMDF	4-4R	3658	16.94	0.28
KEWB-RMDF	5-6R	3657	16.94	0.28
KEWB-RMDF	4-6R	3651	16.91	0.28
KEWB-RMDF	6-3R	3629	16.81	0.28
KEWB-T003	2-5R	3625	16.79	0.28
KEWB-T003	2-4R	3624	16.79	0.28
KEWB-RMDF	3-6R	3611	16.73	0.28
KEWB-RMDF	7-5R	3608	16.71	0.28
KEWB-RMDF	7-6R	3604	16.69	0.28
KEWB-T003	1-6R	3601	16.68	0.28
KEWB-RMDF	1-9R	3596	16.66	0.28
KEWB-RMDF	2-9R	3588	16.62	0.28

KEWBRM.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
KEWB-T003	1-5R	3574	16.55	0.28
KEWB-RMDF	3-8R	3571	16.54	0.28
KEWB-RMDF	4-8R	3565	16.51	0.28
KEWB-RMDF	1-8R	3543	16.41	0.28
KEWB-T003	2-4R	3527	16.34	0.28
KEWB-RMDF	2-7R	3527	16.34	0.28
KEWB-RMDF	5-3R	3521	16.31	0.27
KEWB-T003	2-6R	3516	16.29	0.27
KEWB-T003	2-6R	3425	15.86	0.27
KEWB-RMDF	3-10R	3390	15.70	0.27

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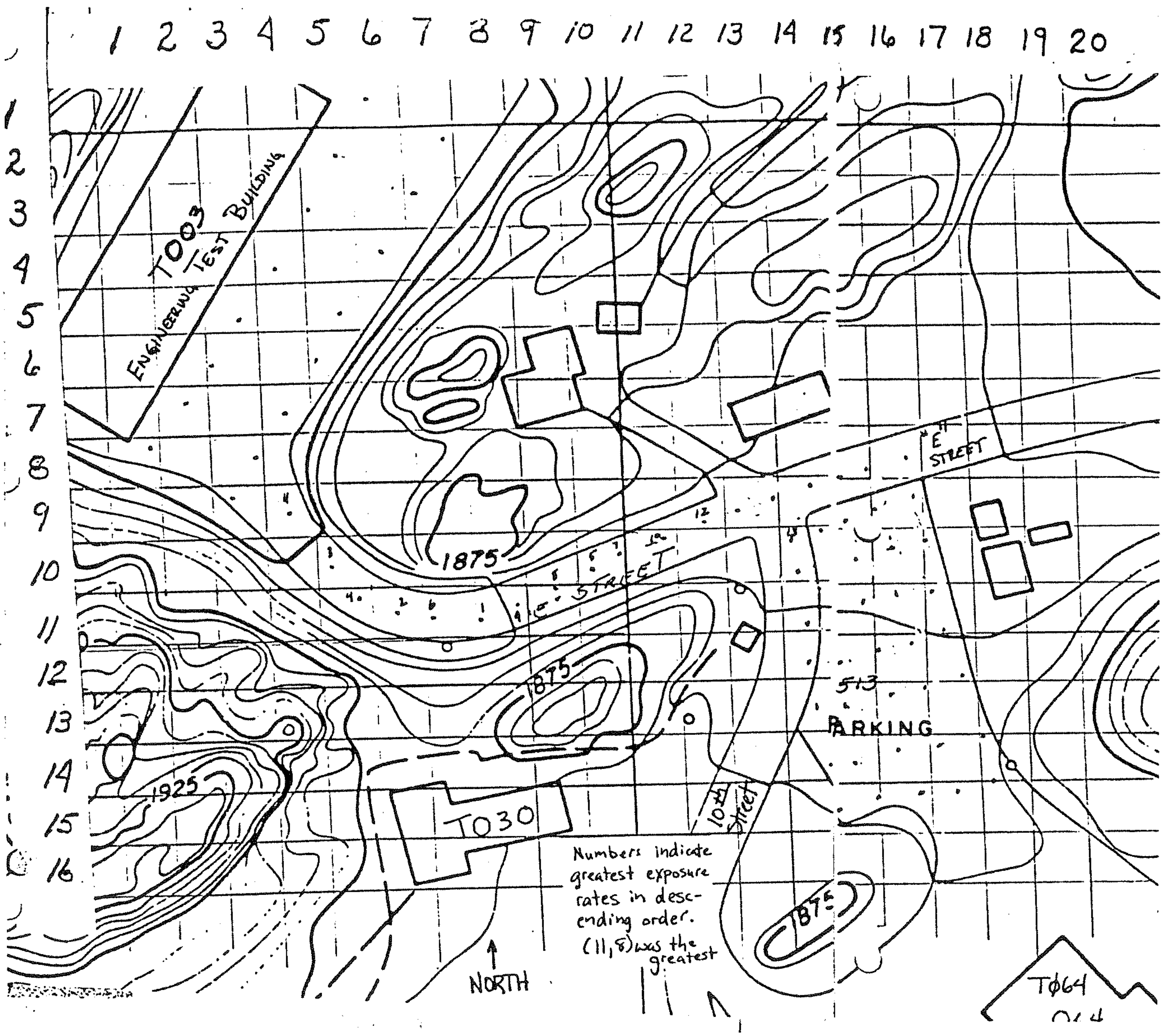
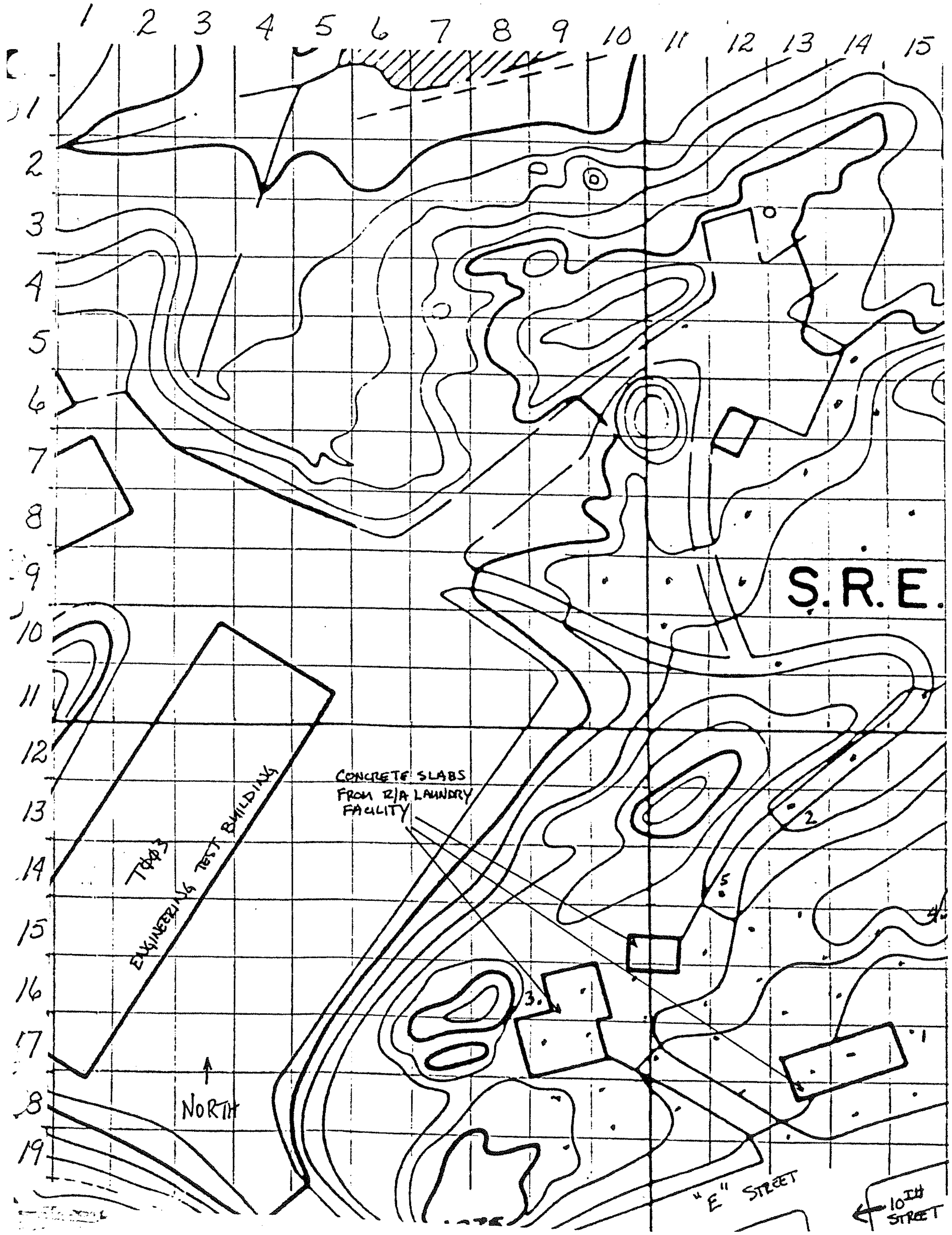
APPENDIX D. SURVEYOR MAPS USED DURING RADIOLOGICAL SURVEY

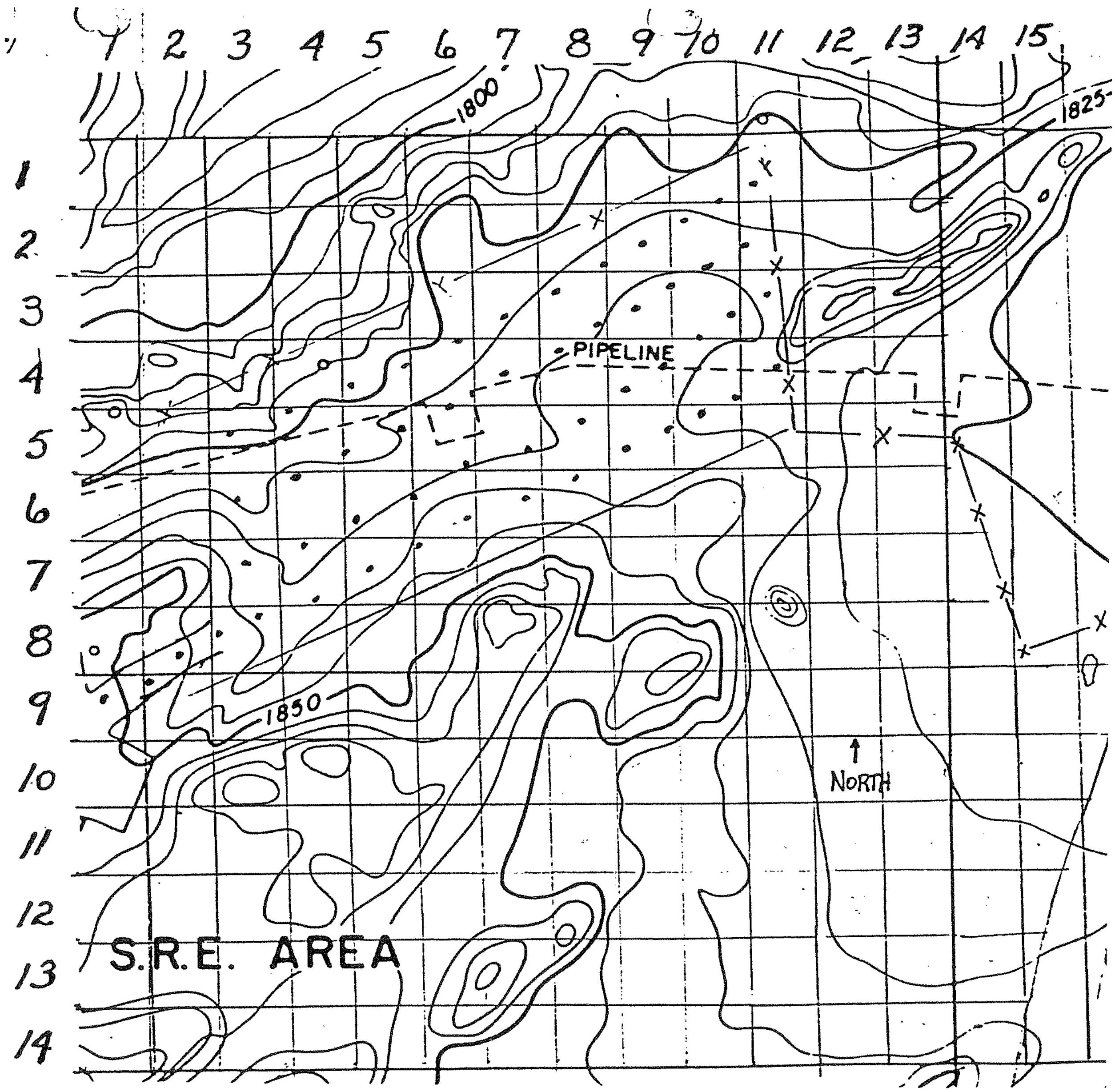
D.1 T513 Parking Lot



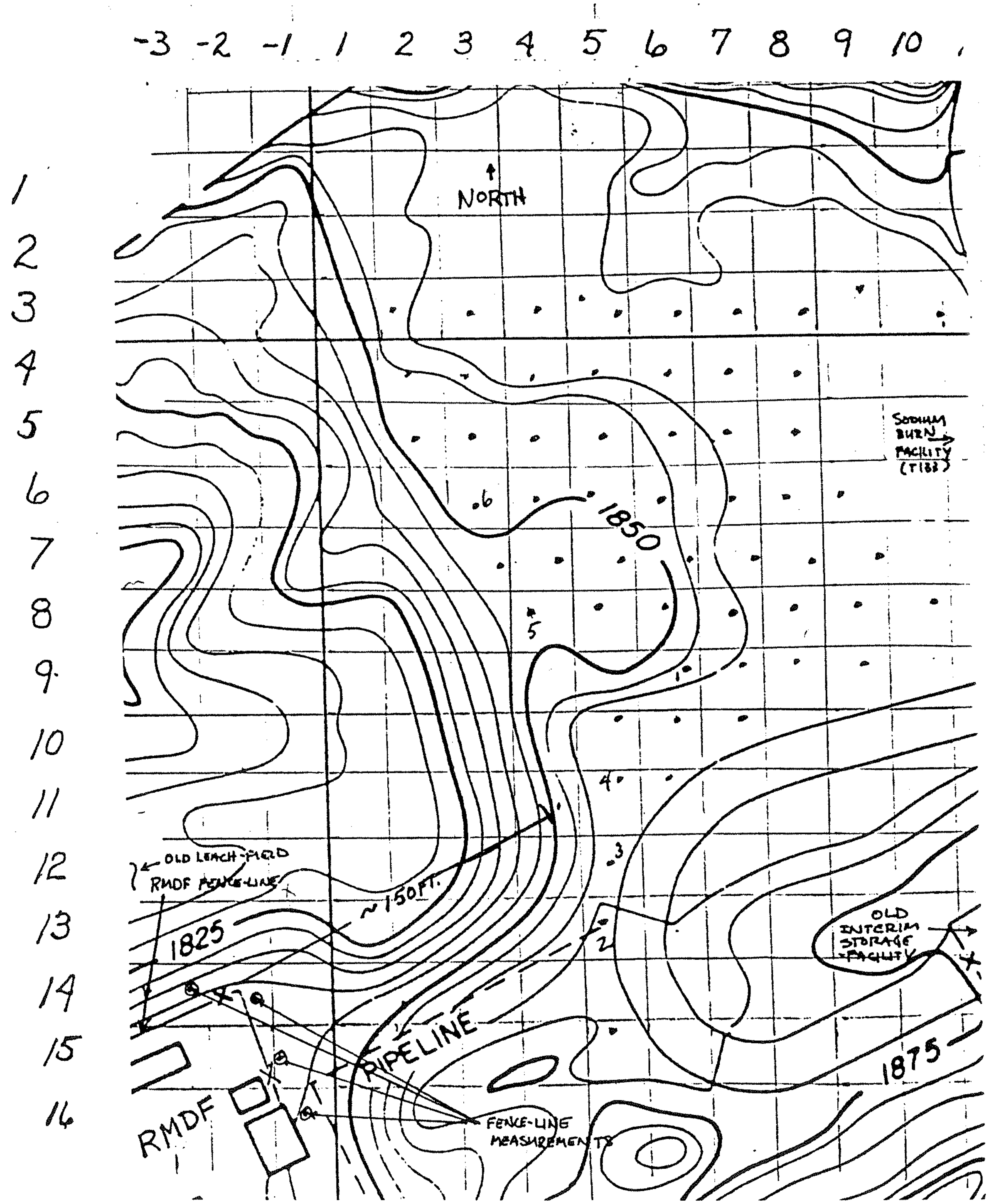
D.2 Old Radioactive (R/A) Laundry Area

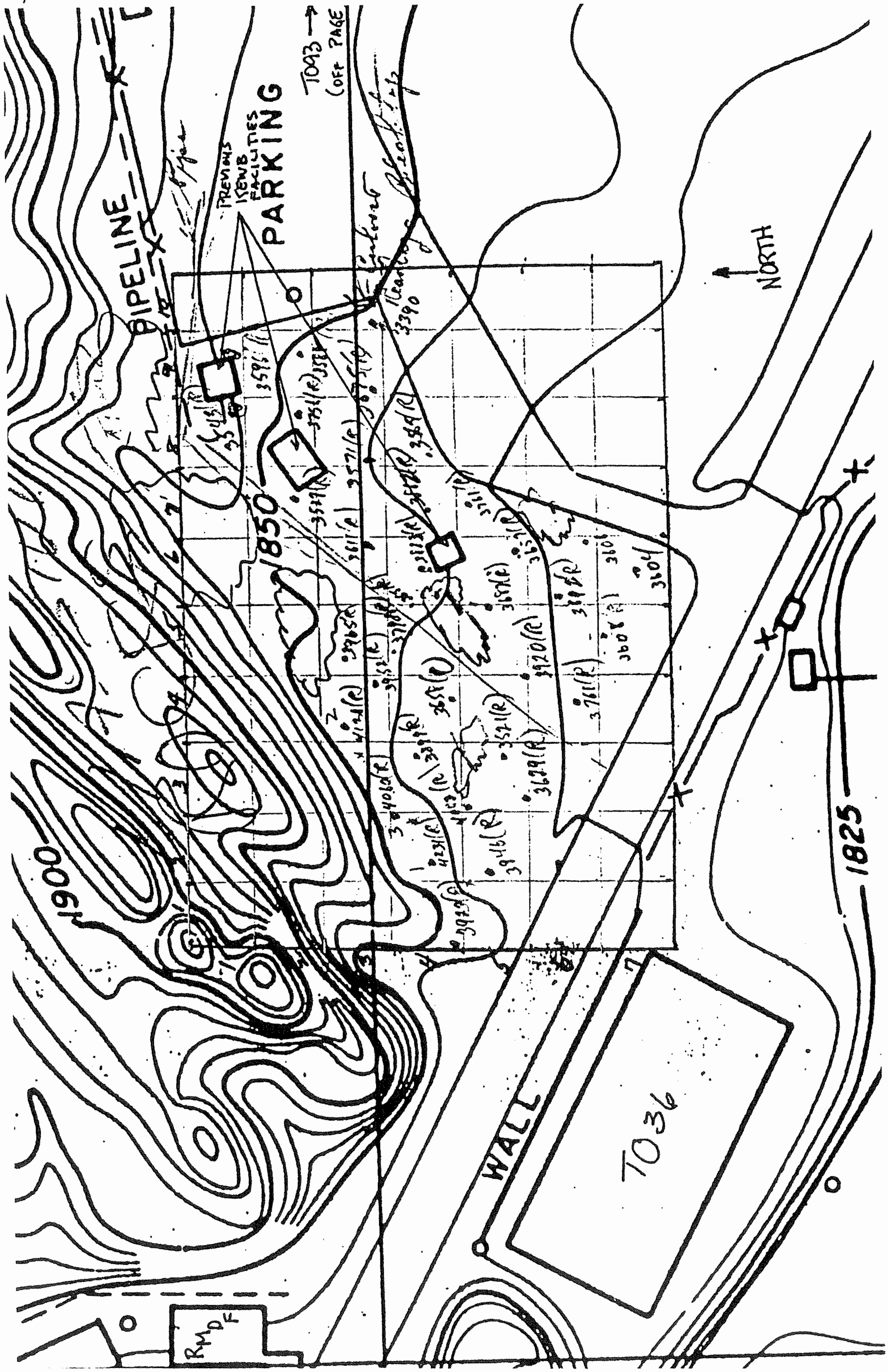


D.3 Plot 333 - SRE Storage and Trash Dump



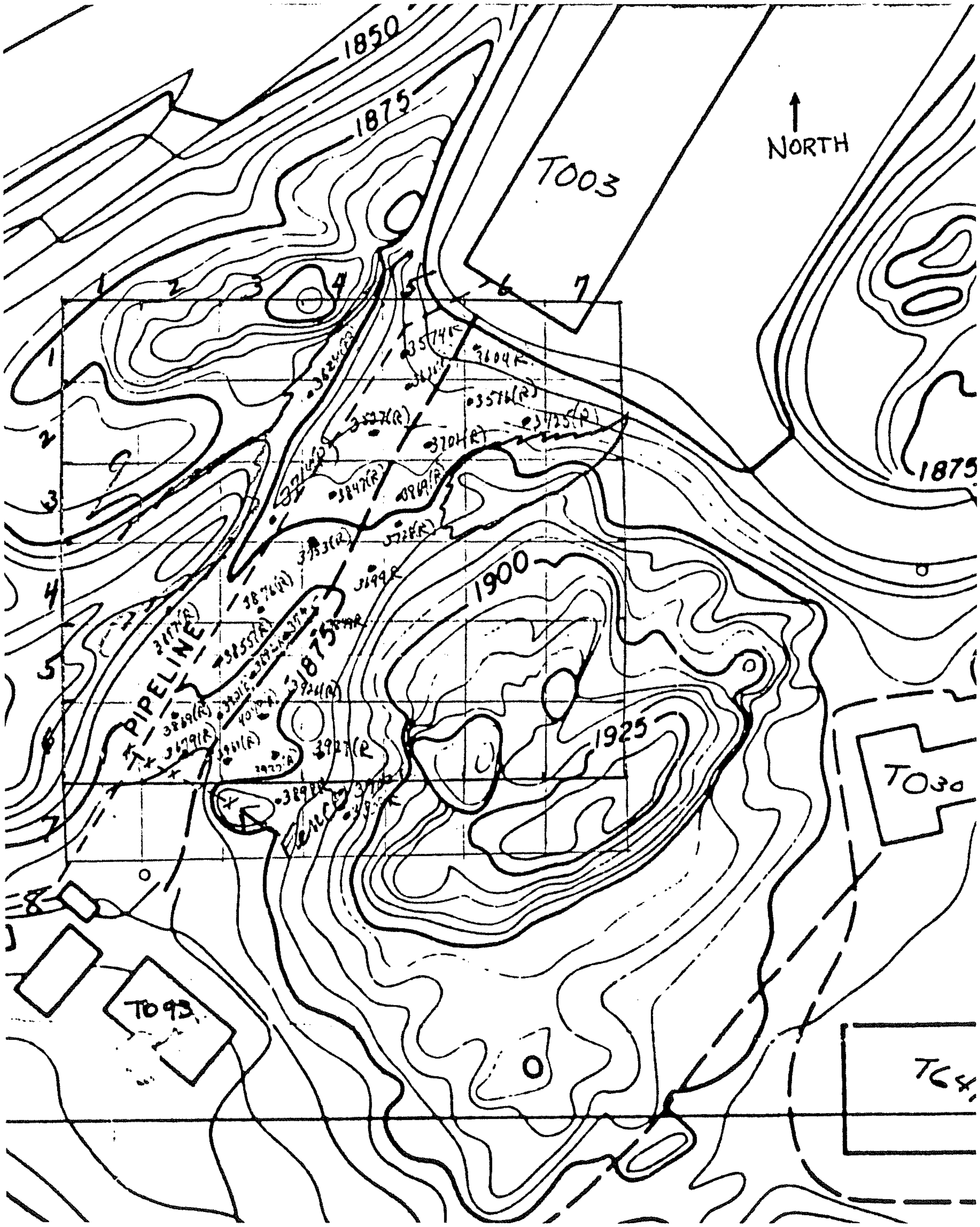
D.4 SRE-to-RMDF Field





KEWB-to-RMDF Field

D.6 KEWB Surrounding Area to Building T003



Energy Technology Engineering Center — **DOCUMENT RELEASE RECORD** — **No.** 23179

FACILITY OR PROJECT NAME AND PROGRAM NO.:

DOCUMENT NO.	REV.	TITLE	NO. OF SHEETS	CONFIGURATION SUMMARY RECORD: YES	NO
GEN-ZR-0009		"Radiological Survey of the T513 Parking Lot; Old R/A Laundry Area; Plot 333; and Areas Between the SRE to RMDF, and KEWB to RMDF"		✓	

TYPE OF RELEASE	
CONCEPTUAL	
NEW	✓
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MANAGER R. J. Tuttle (signed)	9/16/88
QUALITY ASSURANCE S. Benjamin (signed)	9-16-88
FUNDING MANAGER K. T. Stafford (signed)	
MGR. RESP. FOR ACTION K. T. Stafford (signed)	
REVIEW CHAIRMAN R. Fuhrer (signed)	9-16-88

LEVEL 1: "FOR CUSTOMER APPROVAL" ☐ "APPROVED BY CUSTOMER" ☐

COMMENTS
DUPLEX, 3-HOLE PUNCH, STAPLE
*STAFFORD TO TRANSMIT

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