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Revision 0

Hanford SX-Farm Leak Assessments Report

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EXECUTIVE SUMMARY

Washington State Department of Ecology along with the tank farm contractor for the U.S. Department of Energy developed a process to reassess selected tank leak estimates (volumes and inventories), and to update single-shell tank leak and unplanned release volumes and inventory estimates as emergent field data is obtained (RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*). This process does not represent a formal tank leak assessment in accordance with procedure TFC-ENG-CHEM-D-42, "Tank Leak Assessment Process." This report documents reassessment of past leaks in the 241-SX Tank Farm.

Tank waste loss events were reassessed for tanks 241-SX-104, 241-SX-107, 241-SX-108, 241-SX-109, 241-SX-110, SX-111, 241-SX-112, 241-SX-113, 241-SX-114 and 241-SX-115 which have previously been designated as suspected of having released waste to the ground. Table ES-1 summarizes the results of the reassessment of tank waste loss events for these single-shell tanks and provides a comparison to the waste loss estimates contained in HNF-EP-0182, Rev. 261, *Waste Tank Summary Report for Month Ending December 31, 2009*. In addition, tanks currently assumed as "sound" were reviewed to assess the potential for loss of waste containment. Where known, the estimated volume of waste lost and the waste composition (type) was evaluated to update the estimated inventory of constituents in RPP-26744, *Hanford Soil Inventory Model, Rev. 1*.

DOE/RL-88-30, *Hanford Site Waste Management Units Report*, contains the official listing of unplanned releases identified at the Hanford Site. The operational history for the 241-SX Tank Farm was reviewed to determine if additional information exists for the unplanned releases within the 241-SX Tank Farm that are not associated with tank waste loss events. No significant new information was located for these unplanned releases. However, potential new unplanned releases as a result of pipeline failures were identified through review of the operational histories for the 241-SX Tank Farm, as summarized in Section 5.11. Insufficient information was available to estimate a volume or inventory of tank waste potentially discharged to the soil from most of the identified pipeline failures.

Table ES-1. Summary of Tank Waste Loss Events

Tank	Description	HNF-EP-0182 (Rev 261) Estimate	Revised Estimate
241-SX-104	Tank SX-104 was classified as questionable integrity based on ILL decreases from 1994 to 1998. ILL decreases were also observed in 1998 and 2008. Previous assessments concluded that the 1998 and 2008 ILL decreases were not attributed to a tank leak. There are several potential explanations for the ILL decrease observed from 1984 to 1988; evaporation is the most likely explanation. Assessment team members concluded there is no evidence tank SX-104 lost containment.	6,000 gal	0 (leak unlikely)
241-SX-107	Tank SX-107 was classified a suspect leaker in 1967 based on dry well and lateral activity. The revised ^{137}Cs inventory is based on vadose zone data and kriging analyses. No representative sample data was found, so the leak volume was calculated assuming an average, model based, REDOX waste concentration at the time of the leak (2.7 Ci/gal for ^{137}Cs).	<5,000 gal	6,000 gal ^{137}Cs: 14,500 Ci SIM Ratio: 0.81
241-SX-108	Tank SX-108 was removed from service and identified as a confirmed leaker in 1964 based on dry well and lateral activity. The revised ^{137}Cs inventory is based on vadose zone data and kriging analyses. The waste concentration at the time of the leak (3.8 Ci/gal for ^{137}Cs) is based on 12/1965 SX-108 sample data. This equates to a leak volume of 11,000 gal; the revised leak volume range is based on this estimate plus unaccounted for water losses.	2.4 – 35 kgal	50 -100 kgal ^{137}Cs: 34,900 Ci SIM Ratio: 0.83
241-SX-109	Tank 241-SX-109 was identified as a suspect leaker in 1967 based on dry well and lateral activity. The revised ^{137}Cs inventory was based on vadose zone data and kriging analyses. No representative sample data was found, so the leak volume was calculated assuming an average, model based, REDOX waste ^{137}Cs concentration.	<10,000 gal	1,000 gal ^{137}Cs: 2,270 Ci SIM Ratio: 0.95
241-SX-110	Tank SX-110 was removed from service and identified as a potential leaker in July 1976 as a result of an apparent unexplained liquid level decline of ~0.75 in. Based on the lack of drywell and lateral radiation readings, along with no evidence of corrosion of the steel liner, the assessment team concluded that a tank leak is unlikely and no leak inventory is assigned.	5,500 gal	0 (leak unlikely)
241-SX-111	Tank SX-111 was declared an assumed leaker on May 1974 based on a liquid level decline and an increase in radiation detected in lateral 44-11-02. The revised ^{137}Cs inventory was based on a maximum leak volume in an occurrence report and 9/1/1974 sample analyses. The HDW model estimates for RSLTCK should be used to estimate inventory for other analytes.	500 gal	2,800 gal ^{137}Cs: 1,830 Ci Other analytes: Multiply HDW RSLTCK concentration by 0.55 and multiply by 2,800.

Table ES-1. Summary of Tank Waste Loss Events

Tank	Description	HNF-EP-0182 (Rev 261) Estimate	Revised Estimate
241-SX-112	Tank SX-112 was declared a leaking tank in January 1969 due to liquid level decreases and increased activity in tank laterals. The revised leak volume and ^{137}Cs inventory are from a 1969 ARCHO report* and appears to be consistent with drywell data. The high ratio is needed because SIM uses a leak volume of only 1,000 gal.	30,000 gal	27,000 gal ^{137}Cs: 19,200 Ci SIM Ratio: 16.1
241-SX-113	SST SX-113 was confirmed as leaking in 1962 based on the leak test and gamma activity detected in laterals underneath the tank. No change was made to earlier leak volume estimates. A small change in the ^{137}Cs inventory was made based on October 1962 sample data.	15,000 gal	15,000 gal ^{137}Cs: 4,080 Ci SIM Ratio: 0.96
241-SX-114	Tank SX-114 was classified a potentially leaking tank in 1972 based on increasing drywell activity. No previous leak volume or inventory was given. A review of data confirmed the probability of a tank leak. The leak is assumed to be less than 2,000 gal based on uncertainty in manual tape liquid level measurements. The ^{137}Cs inventory estimate is based on a 1974 SX-111 sample. Inventories for other analytes are assumed to be the same as the revised SX-111 inventory multiplied by a volume ratio of 0.715.	No estimate	<2,000 gal ^{137}Cs: 1,310 Ci Other analytes: SX-111 * .715
241-SX-115	Tank SX-115 was confirmed as a leaking tank in 1965 based on measured liquid level decreases and gamma activity in drywells and laterals. The revised leak volume is the upper volume in a process report (HW-83906-E-RD, page 62c**) and the revised ^{137}Cs inventory is based on September 1964 tank sample results. The SIM ratio accounts for volume and sample differences from current SIM estimates.	50,000 gal	51,000 gal ^{137}Cs: 16,800 Ci SIM Ratio: 1.13

Note: Except as noted, ^{137}Ci inventories are decayed to January 1, 2001 consistent with values in Hanford Soil Inventory Model (SIM).

Reference: HNF-EP-0182, Rev. 261, *Waste Tank Summary Report for Month Ending December 31, 2009*

ARCHO = Atlantic Richfield Hanford Company
HDW = Hanford Defined Waste
ILL = interstitial liquid level
SIM = Hanford Soil Inventory Model
REDOX = Reduction Oxidation
RSLTCK = R-Saltcake waste type
SST = single-shell tank

* ARH-1100-DEL, *200 Areas Operation Monthly Report January 1969*, page G-4
** HW-83906-E-RD, *Chemical Processing Department 200 West Area Tank Farm Inventory and Waste Reports July 1961 Through 1966*

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Acronyms and Abbreviations

ARHCO	Atlantic Richfield Hanford Company
bgs	below ground surface
cfm	cubic feet per minute
c/m, cpm	counts per minute
c/s, cps	counts per second
CY	calendar year
dpm	disintegrations per minute
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
ERDA	Energy Research and Development Administration
$e^{106}Ru$	equivalent ^{106}Ru
FIC	Food Instrument Corporation conductivity gauge
HDW	Hanford Defined Waste
HGL	HydroGeologic, Inc.
HLM	Historical Leak Model
HLW	high-level waste
HRLS	high rate logging system
ILL	interstitial liquid level
IX	ion exchange
LOW	liquid observation well
ORP	U.S. Department of Energy, Office of River Protection
R1	Reduction Oxidation high-level waste (1952-1958)
R2	Reduction Oxidation high-level waste (1959-1966)
RAS	radionuclide assessment system
REDOX	Reduction Oxidation
RHO	Rockwell Hanford Operations
RIX	Reduction Oxidation ion exchange (REDOX IX) waste type
RSLTCK	R-Saltcake waste type
SGLS	spectral gamma logging system

SIM	Hanford Soil Inventory Model
SST	single-shell tank
UPR	unplanned release
WMA	Waste Management Areas
WRPS	Washington River Protection Solutions, LLC

Units

Ci	curie
kgal	kilogallon (10^3 gallons)
kL	kiloliter (10^3 liters)
M	moles per liter
mrem	millirem
mR	milliroentgen
pCi	picocurie (10^{-12} curies)
rad	radiation adsorbed dose
µCi	microcuries
µg	micrograms
µS/cm	microsiemens per centimeter

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1. INTRODUCTION

Vadose zone inventories are estimated by multiplying the leak volume by the contaminant concentration in the leak. This concentration is based on process knowledge of the composition of waste in the tank at the time the release occurred. For some major tank leaks and unplanned releases (UPR), historical records confirm the waste loss event and provide a strong technical basis for leak volume and inventory estimates. However, for many tank leaks and UPRs little data is available.

Numerous studies and investigations have estimated the inventory of contaminants in the tank farms vadose zone. Document HNF-EP-0182, Rev. 261, *Waste Status Summary Report for Month Ending December 31, 2009* provides the commonly accepted basis for tank leak volume estimates, but it does not provide associated inventory estimates or UPR volumes. Tank leak volume estimates reported in HNF-EP-0182 have not been updated for many years. Document RPP-23405, *Tank Farm Vadose Zone Contamination Volume Estimates* summarizes vadose zone tank leak characterization and investigations. The information is consistent with many of the tank leak volume estimates listed in HNF-EP-0182 and provides UPR volume estimates. However, information in RPP-23405 shows large differences in estimated leak volumes, both higher and lower, compared to some tank leak volume estimates in HNF-EP-0182. The RPP-23405 volume estimates were used in RPP-26744, *Hanford Soil Inventory Model, Rev. 1* to estimate leak inventories for DOE/ORP-2005-01, *Initial Single-Shell Tank System Performance Assessment for the Hanford Site*. RPP-23405 does not address volume uncertainties and some of the leak volume estimates, data interpretations, and conclusions presented in RPP-23405 required further review.

Washington State Department of Ecology (Ecology) along with CH2M Hill Hanford Group (the then-Tank Operations Contractor for the U.S. Department of Energy [DOE]) developed a process to reassess selected tank leak estimates (volumes and inventories), and to update tank leak and UPR volumes and inventory estimates as emergent field data is obtained (RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*). This report documents the results of applying the process described in RPP-32681 to reassess tank and UPR waste discharge (leak) estimates in the 241-SX Tank Farm.

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2. BACKGROUND

Approximately 57 million gal of radioactive waste from chemical processing and plutonium processing operations are stored in 177 underground storage tanks on the Hanford Site. Of these tanks, 149 are single-shell tanks (SST), which consist of a single steel liner inside a concrete shell. Nominal capacities range from 55,000 to 1,000,000 gal. For the immediate future, plans call for retrieval of waste from the SSTs and transfer to the 28 double-shell tanks (DST), with eventual transfer for treatment in the Waste Treatment and Immobilization Plant.

2.1 IN-TANK MEASUREMENTS

Historically, SST integrity was assessed by two independent methods. From the beginning of Hanford Site tank farm operations, the primary leak detection system was routine monitoring of liquid-surface levels within each tank. Originally liquid levels were measured using pneumatic dip tubes (HW-10475-C, *Hanford Technical Manual Section C*, page 908). This practice was later replaced and a manual tape with a conductivity electrode was used to detect the liquid surface (H-2-2257, *Conductor Reel for Liquid Level Measurement*). The biggest limitations of the manual tape measurements were failures of the electrodes, solids forming on the electrode and measurement precision. The statistical accuracy of the manual tape and electrode measurement technique was 0.75 in. (~2,060 gal), as determined in July 1955 (HW-51026, *Leak Detection – Underground Storage Tanks*, page 4). Later, liquid-level determinations were automated in many of the SSTs to provide more accurate and reliable measurements. However, surface-level measurements remain highly uncertain in the waste tanks that contained boiling wastes (e.g., 241-A, 241-AX and 241-SX Tank Farms), when supernate has been removed from tanks leaving solids or precipitated salts, or where solid crusts have formed on the waste surfaces. In addition to uncertainty in measurements, liquid level decreases may be caused by a leak or evaporation or physical changes in waste surfaces (i.e., floating solids, surface collapse or forming salt crystals).

Liquid observation wells (LOWs) were installed in many of the tanks to measure interstitial liquid levels using gamma and neutron probe measurements. Following is a description of in-tank monitoring instrumentation summarized from RPP-9645, S*ingle-Shell Tank System Surveillance and Monitoring Program*.

ENRAF™. The ENRAF[1] gauge is the most accurate level gauge currently used in the tank farms. This gauge tracks level changes in tank waste by using a load cell to monitor the weight of a displacer. For the purposes of leak detection, the ENRAF gauge needs a free liquid surface below the displacer. The vendor quotes an ENRAF precision of ± 0.004 in. and an accuracy of ± 0.04 inches. However, in-tank ENRAF instruments are calibrated to an accuracy of ± 0.1 in. and the 2-decimal readout on the gauge provides a precision of ± 0.01 inch.

[1] ENRAF - Nonius Series 854 is a trademark of ENRAF-Nonius, N.V. Verenigde Instrumentenfabrieken, ENRAF Nonius Corporation Netherlands, Rontegenweg 1, Delft, Netherlands.

The condition providing the highest sensitivity to a potential leak is a smooth, pure liquid waste surface combined with the most accurate gauge (ENRAF). These measurements are impacted very little by day-to-day variation from either the waste surface or gauge error. If the waste surface becomes more irregular or a gauge with lower resolution is used, the measurement data becomes more scattered (increases) during the normal day-to-day readings. For a heavy slurry waste with a highly irregular surface and a low-resolution instrument, the day-to-day readings exhibit a higher degree of nominal data scatter. Surface level gauges are not used for leak detection if the waste has a solid surface, since the level would not decrease in response to a leak. Liquid levels can not be measured accurately during waste transfer operations or in self-boiling tanks with a dynamic surface.

Manual Tape. The manual tape is still used in a few tanks. It relies on a metal tape with a plummet contacting an electrically conductive waste surface. A manual tape in good working order on a highly conductive surface should be accurate and repeatable to about ¼ inch. As the waste dries out, the device becomes less accurate, until ultimately no signal is received. Uncertainty for different tanks varied from ¼ in. to 2 inches. The drying out of the waste surface is typically observed as increasing levels of data scatter during routine data reviews. Most DSTs use the manual tape as a backup to the ENRAF.

The Food Instrument Corporation conductivity gauge (FIC[2]) is no longer used. The FIC was functionally equivalent to the manual tape, except that the tape and plummet are raised and lowered by a motor rather than manually. All FICs have now been replaced by ENRAF gauges.

Interstitial Liquid Level (ILL) Measurements. Levels of waste phases can be measured by using geophysical techniques deployed inside a LOW placed in a tank. The LOWs were installed in tanks containing permeable waste (i.e., tanks containing salt cake vs. sludge) and/or tanks with a solid waste surface. Originally the uncertainty of waste surface level measurements varied from 1 to 3 in. depending on the waste and barometric pressure changes. Interpreting LOW measurements is complicated, especially when the liquid level was moved between two waste layers with different permeability (e.g., saltcake and sludge). Updated methodologies have improved the accuracy of current LOW measurements, including such actions as calibrating the waste depth measuring system daily before going to the field to ensure measurements are within ± 0.25 in. of its known value; verifying the neutron and gamma probes before each use; and comparing all of the measurement scans to a “reference scan” to identify any spikes, drifting, dead zones, or other anomalous problems.

2.2 EX-TANK MEASUREMENTS

Routine monitoring of gross gamma activity in drywells near the SSTs provides the second leak detection method. For 241-A SSTs and some 241-SX SSTs, laterals (horizontal boreholes) were installed approximately 10 ft beneath the tank bottom for gross gamma monitoring beneath these

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[2] FIC is a product of Food Instrument Corporation, Federalsburg, Maryland.

tanks. As with the tank waste surface-level measurements, there are uncertainties associated with these secondary leak detection methods. Three sources of uncertainty are as follows.

1. Number and location of wells / laterals / leak detection pits: There were rarely more than six drywells surrounding the 100-series SSTs (circumference ~235 ft) and often fewer. These drywells are generally 6 in. diameter steel casings that extend vertically 75 to 125 ft below ground surface (bgs) (groundwater is between 245 and 300 ft bgs) and that allow access to geophysical probes. Because the holes had to be cased to prevent collapse and loss of the borehole, only gamma-emitting radionuclides within about a 12 in. radius of a drywell are detected. Alpha- and beta-emitting radionuclides, including daughter products, are not detected, and most of the long-lived, mobile radionuclides do not emit gamma radiation during decay. With the exception of tank 241-SX-113 (SX-113) which has five laterals, there are three laterals beneath tanks 241-SX-105 (SX-105) through 241-SX-115 (SX-115). The location and number of laterals did not represent full coverage beneath these SSTs. Consequently, the absence of gamma activity in a well, lateral, or leak detection pit does not necessarily indicate that a tank did not leak. Over the course of historical drywell logging, probe types changed several times, thus changing detection limits. The rate of withdrawal of any probe from a borehole and count times also affect the detection capability of any instrument and these too changed with time.

2. Waste type: The overall effectiveness of gross gamma logging in drywells as a leak detection system depends on the waste type in the tank. The gross gamma logging system is most effective with waste types containing high concentrations (activities) of gamma emitting radionuclides (e.g., ^{137}Cs or ^{60}Co) and large releases, and less effective with low-activity waste types such as aluminum cladding waste. In addition to limitations on the effectiveness of gamma measurements for different waste types, lags of months to years between release and detection were possible wherein multiple waste transfers may have occurred. Consequently, the type of waste in a tank when a leak was detected may not be the same as the waste that leaked. This contributes to uncertainty in inventory and leak volume estimates.

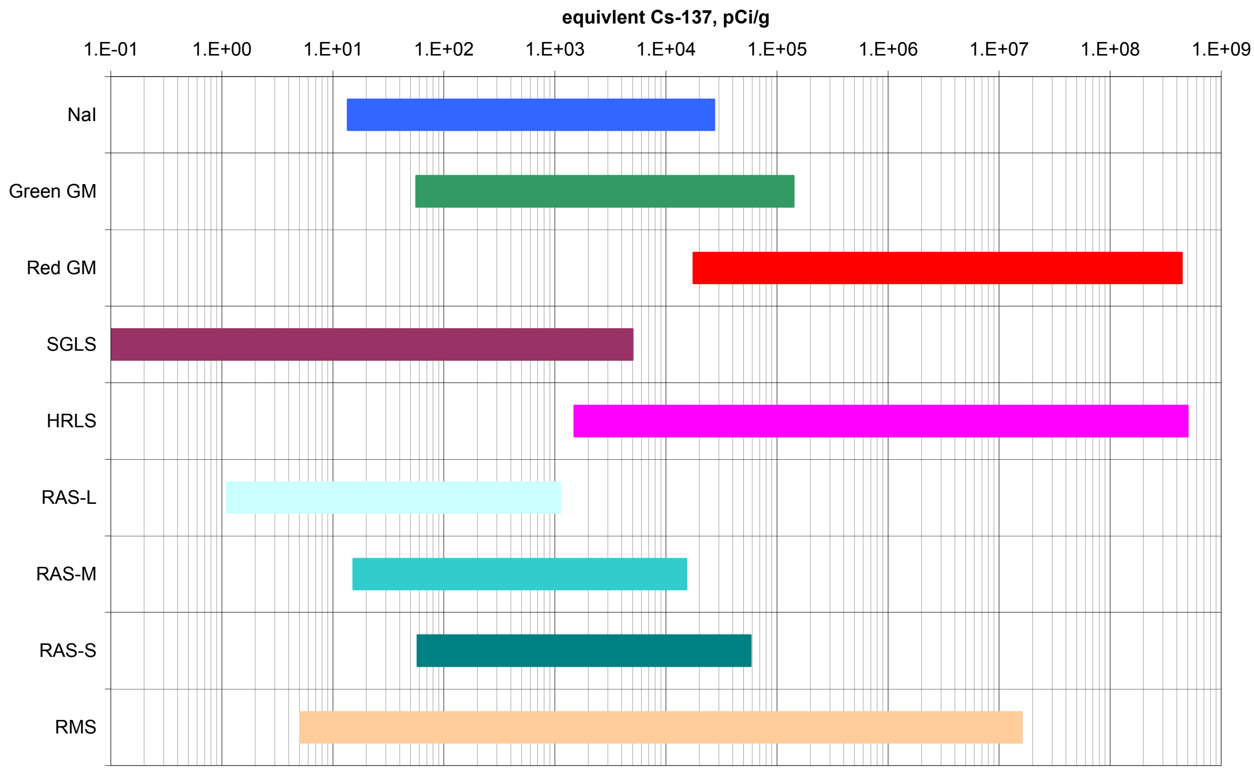
3. Other contamination sources: Gamma activity observed in drywells may also have originated from near-surface waste loss events, transfer line leaks,or tank overfills in which case there is no loss of integrity of the steel liner in the tank.

Geophysical techniques can also be used outside of a tank to measure increased moisture and gamma-emitting contaminants. Dry borehole neutron moisture and/or radionuclide assessment system (RAS) total gamma leak detection monitoring is performed during retrieval in accordance with tank waste retrieval work plans. The accuracy of dry borehole logging count rate is roughly the square of the total number of counts (*Radiation Detection and Measurement*, 3rd Ed., [Knoll 2000] pp 94-96). The correlation between counts per second (c/s) and radioactivity or moisture measurements varies by detector.

Leak detection monitoring for retrieval is conducted by observing changes in neutron readings (c/s) compared to an established baseline for the detector being used. Therefore, for a given detector, accuracy of calibration is not a factor. The level of moisture change that triggers additional RAS monitoring is specified in process control plans.

The RAS truck was designed for routine gamma monitoring against the baseline established from the spectral gamma logging system (SGLS) data. The RAS uses a series of three interchangeable NaI(Tl)-based scintillation detectors (RAS-L, RAS-M, and RAS-S) for measurement over the range from background levels to about 10^5 pCi/g ^{137}Cs. The size of a leak that can be detected by RAS depends on the radioactivity level of the waste leaked, the leak rate, proximity of a dry borehole to the leak, and subsurface soil properties controlling flow rate and direction. Consequently, there is no single value that can be stated as the maximum leak that could go undetected by drywell monitoring for an SST. Leak detection approximations presented in Appendix B of RPP-10413, *Tank S-112 Saltcake Waste Retrieval Demonstration Project Leak Detection, Monitoring, and Mitigation Strategy* range from a mean of 100 gal for a leak located 10 ft from a drywell to a mean of 6,200 gal for a leak 45 ft from a drywell. Approximate measurement ranges of different types of gamma radiation detectors are shown in Figure 2-1.

Figure 2-1. Measurement Ranges of Tank Farm Gamma Detectors



In addition to the RAS truck and instrumentation which perform only total gamma measurements, the SGLS provides isotope specific gamma measurements. For areas of higher activity (> 2,000 pCi/g) a high rate logging system (HRLS) is used to quantify activity levels as high as 10E8 pCi/g. The SGLS uses a high-purity germanium detector. Baseline spectral gamma logging of tank farm drywells was performed between 1995 and 2000. Figure 2-1 shows measurement ranges for SGLS and HRLS.

Ex-Tank High Resolution Resistivity. High resolution resistivity is used during retrieval operations and measures changes in resistivity against baseline conditions as specified in tank waste retrieval work plans. Because tank waste is high in sodium and nitrate, changes in resistivity/conductivity are a potential indicator of a tank leak. In leak injection tests in S-Farm, where 13,000 gal of saline solution were injected to the soil near tank 241-S-102 it was determined that high resolution resistivity could detect a leak of 2,100 gal or more with 95% accuracy. Initial tests showed responses after only a few hundred gallons of saline solution were injected (RPP-30121, *Tank 241-S-102 High-Resolution Resistivity Leak Detection and Monitoring Test Report*). In comparison, drywell neutron moisture measurements showed negligible changes during leak injection tests. The high resolution resistivity system does not quantify leak volume or rate, but provides a continuous measure of resistivity during retrieval as compared to weekly moisture measurements and provides more special measurements compared to measurements indicating conditions within about a radius of one foot from a drywell.

2.3 TANK LEAKS

Sixty-seven of 149 SSTs have been designated as "confirmed or suspected leakers" over the SST operational timeline (1945 to 1980) (HNF-EP-0182). During the active operation of the SST farms, either an anomalous liquid-level measurement or a significant increase in gamma activity in a drywell, lateral or leak detection pit was generally a sufficient reason for the tank to be listed as "questionable integrity" or an "assumed leaker" as discussed in SD-WM-TI-356, *Waste Storage Tank Status and Leak Detection Criteria*. When a tank was designated as "questionable integrity" it was pumped to a "minimum heel" and taken out of service. In a limited number of cases the "questionable integrity" designation was followed up with additional investigations. However, in many cases no additional investigations were performed. In the late 1980s, all SSTs that had been flagged as potential or known leakers were combined into the list contained in the monthly waste tank summary report (HNF-EP-0182) and flagged as "confirmed or assumed leakers." Because of the uncertainty associated with the measurements, unexplained waste level decreases were generally considered as an inadequate basis for designating a tank as a "confirmed leaker." The "confirmed leaker" designation required an observed waste level decrease combined with increasing gamma activity in a nearby drywell. The "assumed leaker" designation could be assigned based on either measurement (an observed waste level decrease or increasing gamma activity in a nearby drywell), without confirmation from the other measurement.

These uncertainties, associated with both the primary and secondary leak detection systems for the SSTs, led to a number of decisions. By the early 1960s, decisions were made to move from an SST design to a DST design for construction of new tanks. The double-shell design provided both secondary containment and reliable leak detection systems. A decision was also made to pump liquids stored in the SSTs into the DSTs to remove pumpable liquid and term the SSTs as interim stabilized.

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3. SCOPE AND CRITERIA

An assessment team comprised of representatives from DOE's Office of River Protection (DOE-ORP), Ecology, and Washington River Protection Solutions, LLC (WRPS) was assembled to review available information relating to waste loss events in the 241-SX Tank Farm and estimate the inventory of leaks to the soil. The assessment team membership is listed in Table 3-1. Minutes from team meetings are included in Appendix B.

Table 3-1. Waste Loss Event Assessment Team

Name	Organization	Role
Joe Caggiano	Washington State Department of Ecology	Regulatory oversight (primary focus vadose zone and groundwater data)
Jim Field	Washington River Protection Solutions	Process lead Knowledge and experience in reviewing, analyzing, and interpreting in-tank (i.e., surface liquid level and liquid observation well) data and vadose zone data, and of tank process history.
Les Fort	Washington State Department of Ecology	Lead regulatory oversight (primary focus tank waste processing operations)
Michael E. Johnson	CH2M HILL Plateau Remediation Contract	Knowledge and experience with operations of the tank farm and individual tank, tank history, tank waste characteristics, and in-tank processes.
Paul Henwood	S. M. Stoller, Inc.	Knowledge and experience in obtaining and analyzing drywell data.
Bob W. Lober	U.S. Department of Energy Office of River Protection	Tank Farms Programs and Project Division representative
Beth Rochette	Washington State Department of Ecology	Regulatory oversight (primary focus: UPRs and direct exposure pathway)
Marcus I. Wood	CH2M HILL Plateau Remediation Contract	Knowledge and experience in reviewing, analyzing, and interpreting drywell and groundwater monitoring data.

In accordance with RPP-32681, the following steps were conducted to reassess waste losses within the 241-SX Tank Farm:

- Collect information and data regarding past tank leaks in SX-Farm.
- Collect information and data regarding UPRs, including pipeline leaks, spills, and near surface contamination, in SX-Farm.
- Compile information from previously reported waste tank leaks and UPRs to estimate the volume of tank waste which leaked to the vadose zone and the time at which these leaks occurred.

- Compile data regarding the waste composition at the time of a tank leak or UPR from the available sources, such as sample data, Tank Waste Information Network System, Best Basis Inventory, Hanford Defined Waste (HDW) model, etc.

- Combine waste leak volume estimates with waste composition estimates to estimate radionuclide and chemical inventory of tank leaks and UPRs.

4. REASSESSMENT OF WASTE LOSS EVENTS IN 241-SX TANK FARM

The 241-SX Tank Farm is comprised of fifteen SSTs. The 241-SX tanks are arranged in rows of three tanks each, forming a cascade. Each of the 241-SX tanks has a nominal 1-million-gal storage capacity. Each 241-SX tank consists of a carbon steel liner inside a reinforced concrete shell. The concrete shell is a domed structure approximately 46 ft in height and 86 ft in diameter at the footings. The steel tank liner covers the 75-ft inner diameter tank bottom and sidewalls to a height of ~32 ft as measured from the tank center. The tank bottom is dish shaped and slopes approximately 3.3% from the sidewall to the tank center (i.e., 14.875-in. elevation drop over 37.5-ft radius). Unlike earlier SSTs that had a knuckle-shaped sidewall, the 241-SX tank sidewalls are square (H-2-39511, *75 FT. Storage Tanks Composite Section Waste Disposal Facility 241-SX*). The steel bottom of the tank intersects the sidewalls orthogonally, similar to 241-A and 241-AX tanks rather than the dished bottoms of earlier designed tank farms.

Waste can be transferred directly into each tank through a 3 1/2-in. stainless steel pipeline, number as shown in Table 4-1. These 3 1/2-in. stainless steel pipelines are contained in a concrete encasement that extends from diversion box 241-SX-151 to about 80 ft away from the east side of the first tank in each row. Each 3 1/2-in. stainless steel pipeline exits the concrete encasement and is then separately encased in an 8-in. schedule 80 steel pipe. The exterior of the 8-in. schedule 80 steel pipes are coated with waterproofing asphalt and a membrane. The pipe-in-pipe encased 3 1/2-in. stainless steel pipelines are attached to pre-cast concrete beams using anchor straps. The concrete beams are supported by concrete (H-2-39501, *General Layout Waste Disposal Facility 241-SX*). The 3 1/2-in. pipelines enter each tank at an elevation approximately 12 in. beneath the top of the tank liner.

Table 4-1. Waste Addition Pipelines – 241-SX Tank Farm

Tank	Pipeline	Tank	Pipeline	Tank	Pipeline
241-SX-101	V578	241-SX-107	V576	241-SX-113	V592
241-SX-102	V579	241-SX-108	V575	241-SX-114	V591
241-SX-103	V580	241-SX-109	V574	241-SX-115	V590
241-SX-104	V584	241-SX-110	V570		
241-SX-105	V583	241-SX-111	V571		
241-SX-106	V582	241-SX-112	V572		

Waste can also be transferred from one 241-SX tank to another by overflowing through cascade pipelines that connect between the first and second tanks and the second and third tanks in a cascade. The cascade pipeline between tanks consists of a 4-in. schedule 80 carbon steel pipe with a 10-in. seal loop inside each tank (see detail 2 on drawing H-2-39908, *Tanks 107-115 Manifold Facilities Vapor Manifold Support Details*). The cascade pipeline is encased in an 8-in. schedule 80 carbon steel pipe. Two 2-in. schedule 40 carbon steel pipes are connected to the 4-in. cascade pipeline to facilitate cleanout (H-2-39544, *Cascade Line Cleanout Waste Disposal Facility 241-SX*). The cascade pipeline is located 373 in. above the tank base and is supported between tanks by a pre-cast concrete beam, which is supported by a concrete pilaster that is part of the tank concrete shell. The cascade pipelines from tank SX-113 to tank 241-SX-114 (SX-114) and tank SX-114 to tank SX-115 were cut and capped per drawings H-2-73215, *Piping Waste Tank Isolation 241-SX-113* and H-2-73216, *Piping Waste Tank Isolation 241-SX-114*. Tank waste surface level histograms show that the waste surface level remained well below the height of the cascade overflow lines for all of the SX-Farm tanks.

Tanks SX-105 and 241-SX-107 (SX-107) through SX-115 each contain four airlift circulators (H-2-39951, *Arrangement Air-Lift Circulators* and H-2-39952, *Air Lift Circulators Plot Plan & Outside Lines*) that were used to remove heat from the self-boiling wastes by increasing the heat convection at the sludge interface with the supernate. All of the 241-SX tanks were also connected to an underground 24-in. diameter vapor header used to exhaust vapors and condense water evaporated from the boiling waste stored in these tanks. Condensate collected by the exhaust ventilation system could be returned to a tank through a series of valves and a direct buried 3-in. steel pipeline. These features allowed the 241-SX tanks to be operated at a maximum of 350 °F at the tank bottom (RPP-10435, *Single-Shell Tank Integrity Assessment Report*, page A-54). Operating at higher temperatures could result in bulging of the steel tank bottom and/or structural damage to the concrete shell.

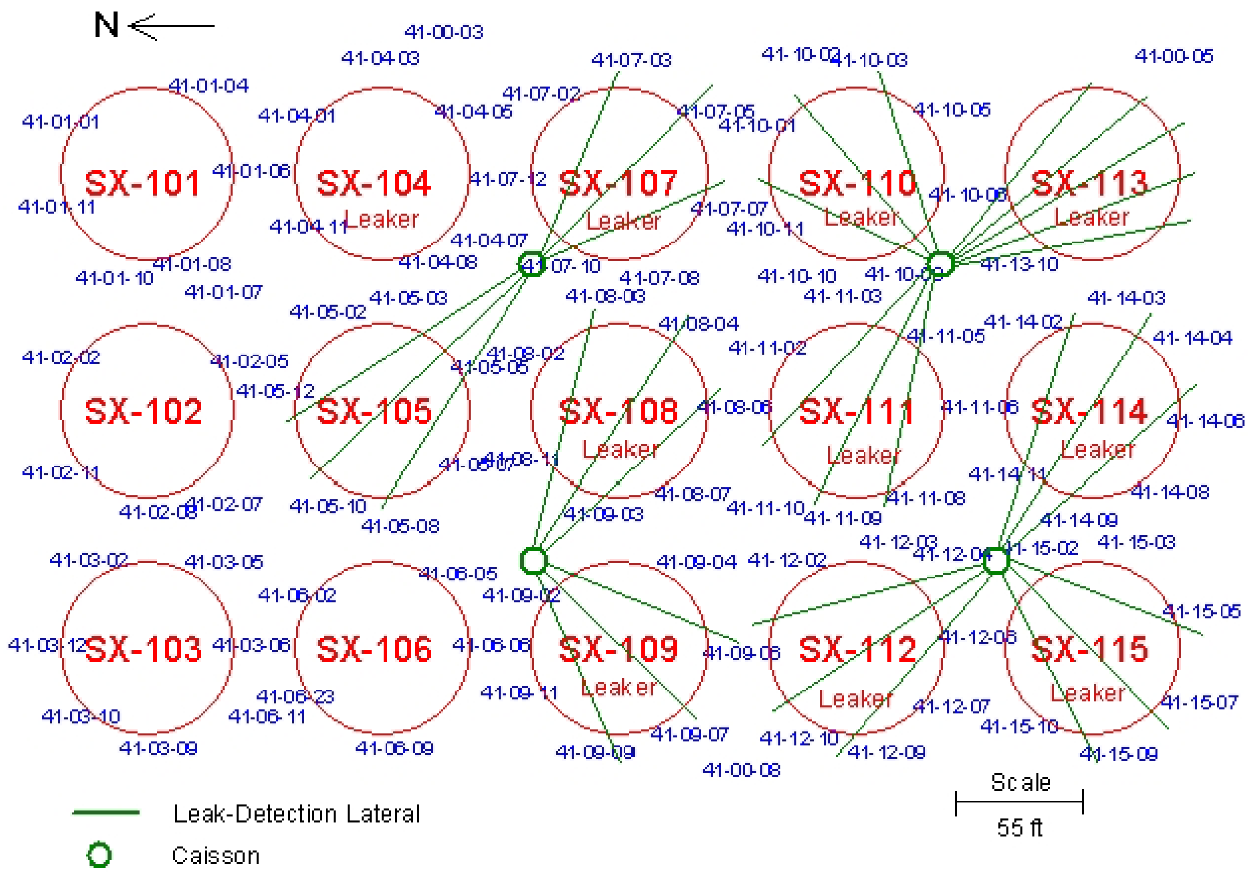
A number of tanks in the 241-SX Tank Farm had laterals installed below the tank bottoms as part of the secondary leak detection system. Laterals were installed beneath tank SX-113 in 1958 and beneath tanks SX-107 through 241-SX-112 (SX-112), SX-114 and SX-115 in 1963. Laterals were installed beneath tank SX-105 in 1966 (*Monthly Report Waste Handling and Decontamination REDOX Section August 1966*, Rough Draft [McCullugh 1966], page 1). In addition to laterals, dry boreholes or drywells 75 to 125 ft deep were installed around the SX-Farm tanks. Eleven drywells were installed in the mid 1950s, several more in the 1960s and most in the 1970s. Some of the pre-existing boreholes were deepened or modified in the 1970s. The 241-SX Tank Farm drywells and laterals are shown in Figure 4-1.

4.1 SURFACE GEOPHYSICAL EXPLORATION

A Surface Geophysical Exploration survey was conducted in August 2008 to collect and analyze electrical resistivity data to identify and locate low resistivity regions in and around the 241-SX Tank Farm area indicative of potential areas of high nitrate or sodium contamination (RPP-RPT-38322, S*urface Geophysical Exploration of the S and SX Tank Farms at the Hanford Site*). The initial part of the survey integrated ground penetrating radar and electrical resistivity. High-resolution electrical resistivity data were collected in a well-to-well survey using 21 existing groundwater wells and 132 vadose zone wells in the 241-SX Tank Farm area. A correction factor was developed to correct the raw data to account for the area infrastructure, thereby adjusting the final interpretive results.

Figure 4-2 displays survey results for well-to-well resistivity measurements. Well-to-well measurements provide two-dimensional results only and do not indicate depth. Resistivity anomalies less than 1.5 ohm-m are shown in red. Resistivity values between 1.5 and 3 ohm-m are shown in green. Low resistivity is an indicator of increased moisture or increased concentration of electrolytes compared to background conditions. The results of the modeling show lowest resistivity near tanks that have been designated as historically leaking. In particular, these include the tanks in the central to south portion of SX-Farm. The low resistivity appears to be centered on tank 241-SX-108 (SX-108).

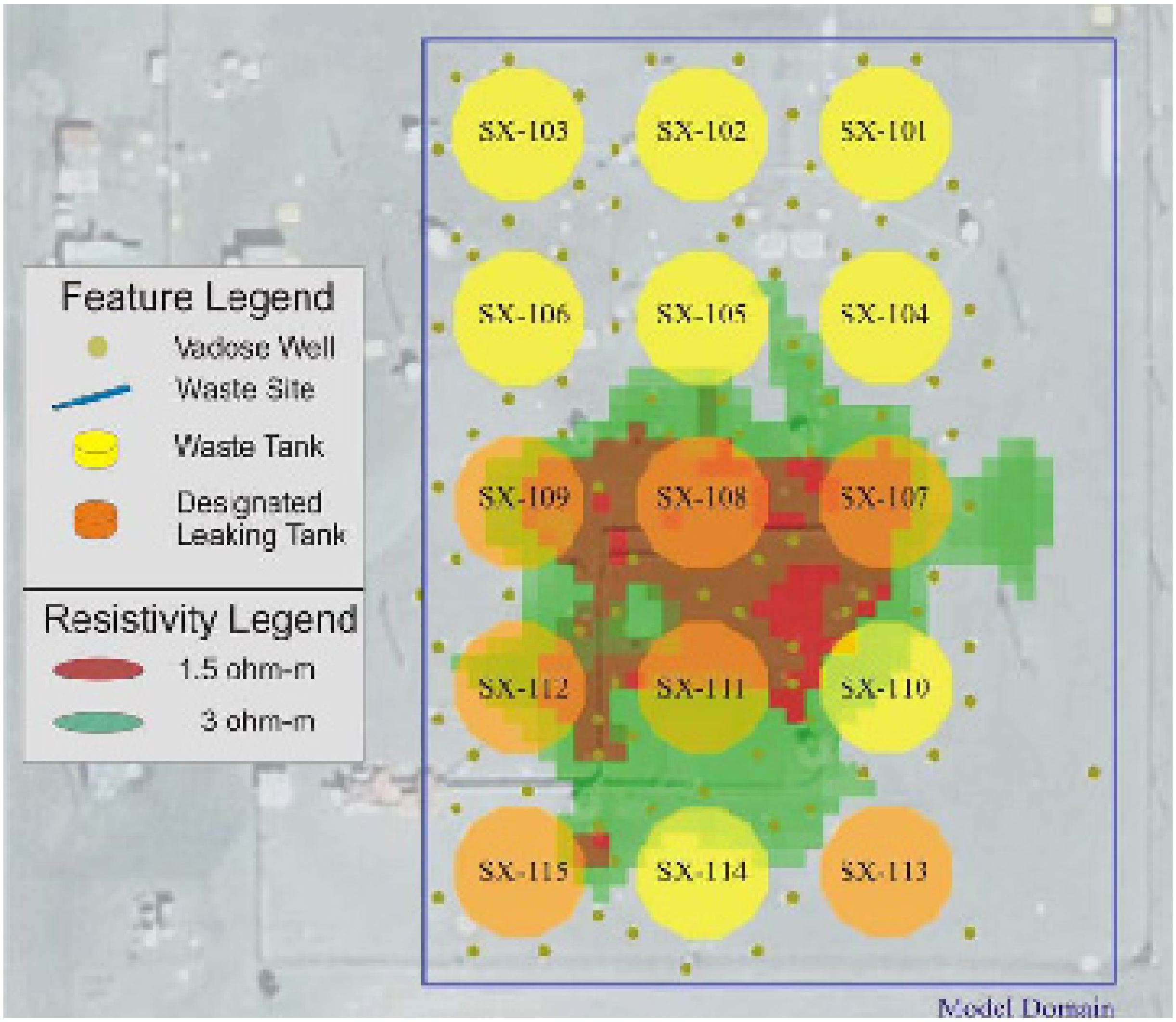
Figure 4-1. 241-SX Tank Farm Laterals and Drywells



4.2 241-SX TANK FARM HISTORICAL LEAK MODEL ESTIMATES

The Historical Leak Model (HLM) is one of many tools/lines of evidence that can be used to estimate release volumes and masses in a situation of limited real time data. The HLM uses a simplified heat and material balance scheme to estimate past losses in four boiling waste tanks in SX-Farm. Heat loss calculations generated from the decay of short-lived radionuclides coupled with tank waste transfer records were developed to calculate tank leak volumes for SX-108, 241-SX-109 (SX-109), 241-SX-111 (SX-111) and SX-112. The HLM approach is described in HNF-3233, *Re-Analysis of SX Farm Leak Histories with the Historical Leak Model Rev.1 (HLMr1)*.

Figure 4-2. 241-SX Tank Farm Surface Geophysics Exploration Results



There is a large uncertainty in estimating evaporative losses and conductive losses to the soil because of the terse waste transfer and condensate data making the heat and mass balance premise difficult to ascertain. HNF-3233 concludes that after assigning unaccounted inventory losses to leaks it is important to carefully weigh other evidence that might suggest different leak sizes. For example, previous estimates often reported specific volume losses that do not always appear in the waste transfer records. The extensive drywell logging and borehole assays data often bound leak sizes by better defining contaminated layers near a tank. Laterals also provide data on radioactivity at a depth of about 10 ft below the tank. The HLM leak volume estimates for the SX-Farm tanks modeled are comparable to other estimates. However, the HLM estimates for ^{137}Cs mass appear higher compared to estimates based on lateral and drywell measurements. Given the large uncertainties in any of these approaches there is no completely definitive answer for any of these leak inventories. Rather, one must consider all the evidence associated with each leak event.

4.3 GROUNDWATER CONTAMINATION FROM TANK WASTE LEAKS AT 241-SX TANK FARM

Tank waste contamination of groundwater south of the 241-SX Tank Farm is inferred from anomalously high groundwater concentrations of ^{99}Tc, nitrate and chromium. The earliest indications of tank waste contamination in this area occurred in 1992 when ^{99}Tc concentrations > 5,000 pCi/g were measured at groundwater monitoring well 299-W23-15 (Figure 4-3). After construction of groundwater monitoring well 299-W23-19 in 1999 (Figure 4-3), unconfined aquifer contamination from a tank waste source or sources became more clearly evident and with the addition of new groundwater monitoring wells south and west of 299-W23-19 over the last decade, the shape of the individual contaminant plumes has become better defined. The most recent conceptualizations of the plume distributions for these contaminants in the unconfined aquifer (DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*) are shown in Figures 4-3 and 4-4. The ^{99}Tc and chromium plumes are most tightly constrained and show similar distributions, although the ^{99}Tc plume is more developed. The nitrate plume is less obvious because tank waste nitrate is being added to a regional nitrate plume derived from numerous sources (e.g., historic long-term high-volume pond discharges northwest of the 241-SX Tank Farm).

The assumption of tank waste sources for these contaminated portions of the unconfined aquifer is based on several observations. The set of events proposed in RPP-7884, *Field Investigation Report for Waste Management Area S-SX* as necessary to enable current groundwater contamination from tank waste losses were present at the southwest corner of 241-SX Tank Farm. These events included vadose zone contamination from a tank waste leak, followed by a water discharge event that contacted contaminated soil and accelerated contaminant discharge into the unconfined aquifer. Multiple leak events from tanks in SX Tank Farm (e.g., SX-115, SX-107, SX-108 and SX-109), discussed throughout this report, occurred in the 1960s. In the late 1980s to early 1990s, chronic leakage from a local large water transfer line was indicated by observations of vegetation in this location requiring a steady source of water. Subsequent characterization of sediments collected from borehole 299-W23-19 showed unusually high moisture content in the vadose zone. Of these leaks, the leak from tank SX-115 seems to be the dominant source of tank waste contamination at this location in the unconfined aquifer, given its close proximity to well 299-W23-19.

The apparent source of the ^{99}Tc and chromium plume is at the groundwater monitoring well 299-W23-19 located at the southwest corner of the 241-SX Tank Farm and adjacent to tank SX-115. Of the groundwater monitoring wells shown in the plumes in Figures 4-3 and 4-4, the highest concentrations of ^{99}Tc, nitrate and chromium have occurred at this well. Figure 4-5 shows ^{99}Tc concentrations to be 3 to 10 times greater at well 299-W23-19 than at two downgradient wells (see Figures 4-3 and 4-4 for locations). This observation is consistent with the assertion that contaminant concentrations will be greatest at the point of entry into an aquifer. Further away from the point of entry, mixing with the groundwater causes dilution and dispersion of contaminants. The southeasterly direction of plume evolution is consistent with the natural easterly gradient and a southeasterly component created by the groundwater mound centered under U Pond.

Figure 4-3. Current Conceptualization of the Technetium-99 and Chromium Plumes South of the 241-SX Tank Farm

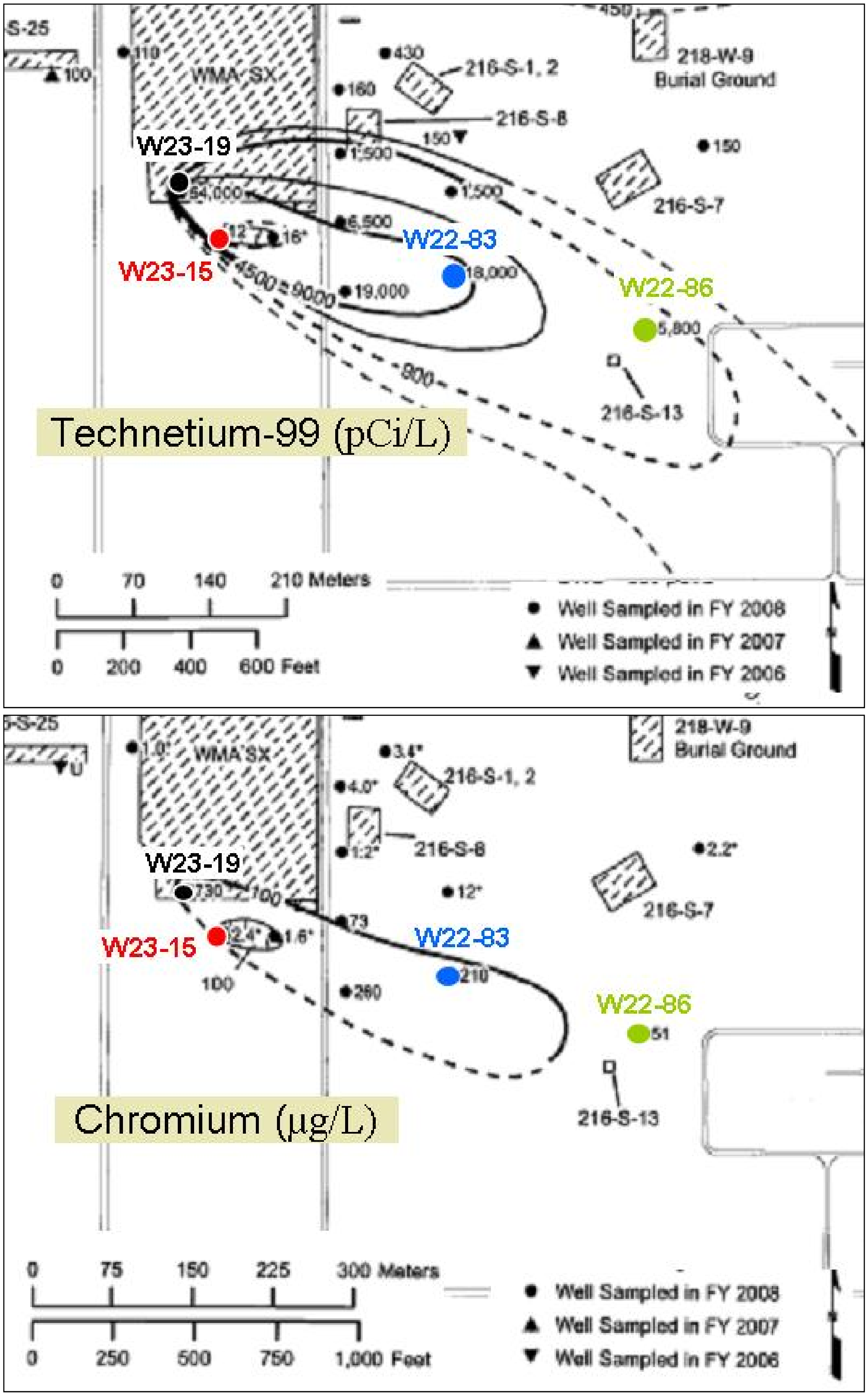
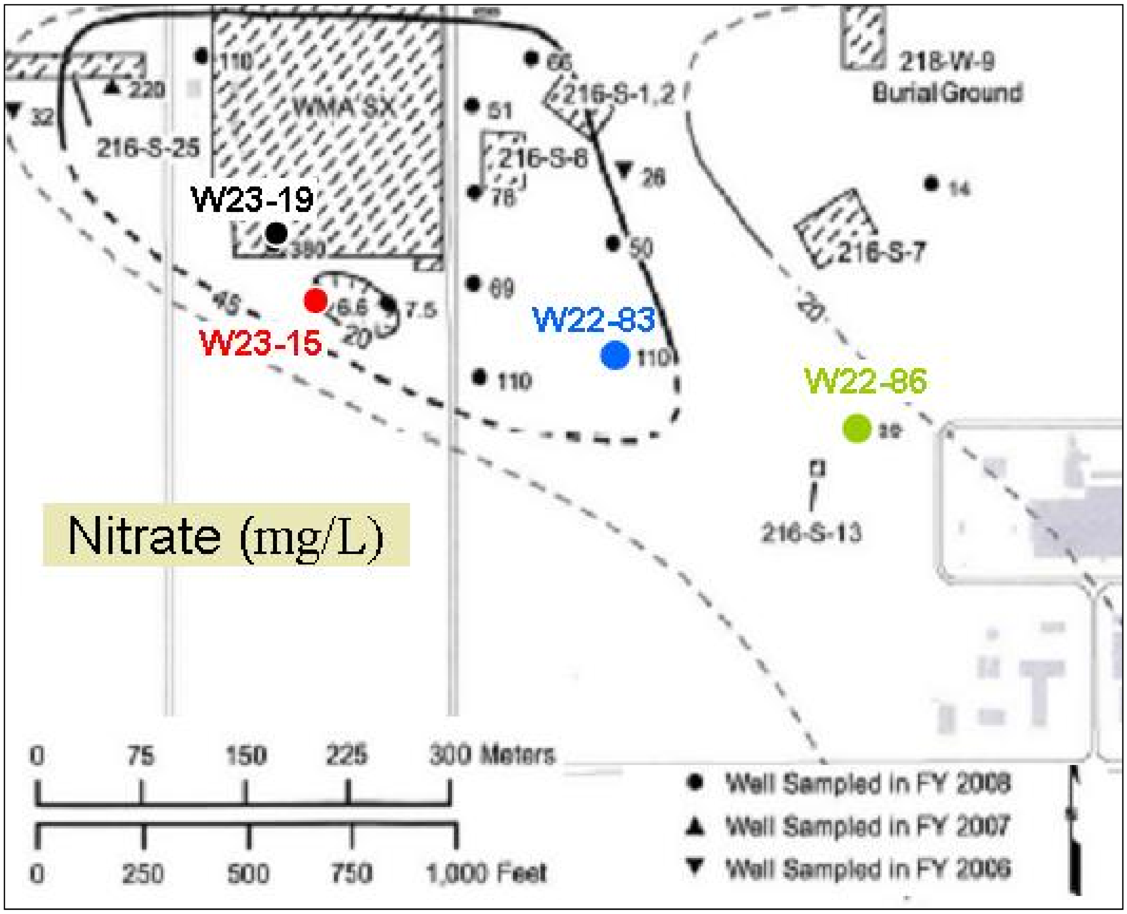


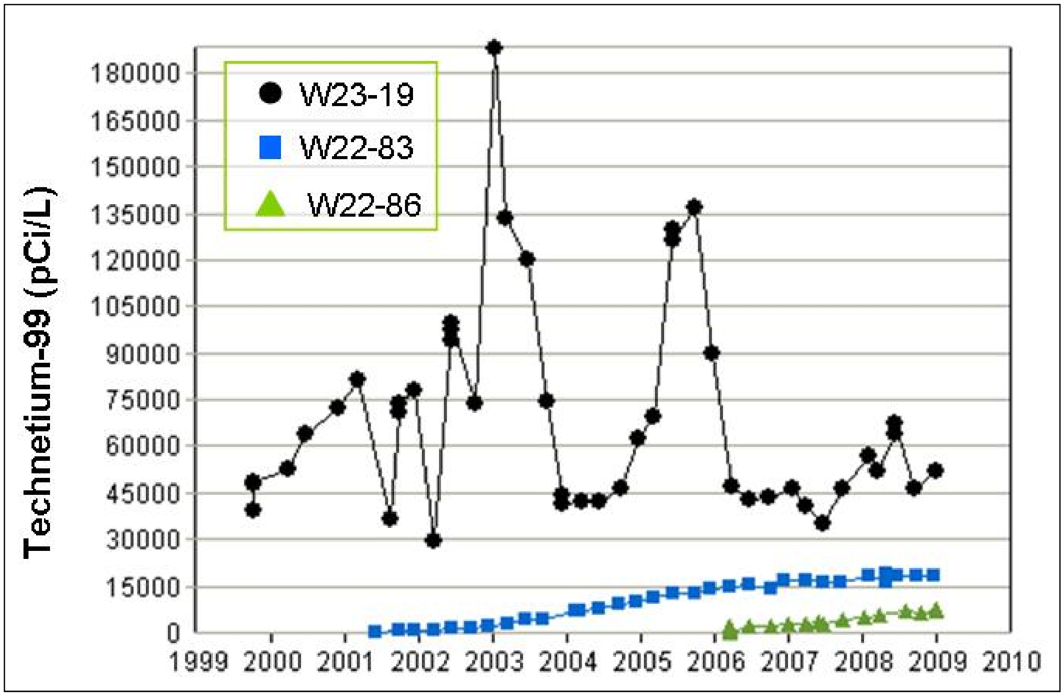
Figure 4-4. Current Conceptualization of the Nitrate Plume South of the 241-SX Tank Farm



A common contaminant source in this area is also indicated by the similarities of contaminant ratios both temporally and spatially. Comparison of ^{99}Tc and nitrate behavior is particularly useful with respect to tank waste sources because both are present in the waste and both are essentially non-reactive with subsurface soils. Thus, their migration rates are similar and should be essentially the same if both contaminants are derived from the same source. Figure 4-6 shows that the concentration versus time patterns for ^{99}Tc and nitrate are nearly identical. The relatively constant ^{99}Tc-to-nitrate ratio calculated from the combined data points shown in Figure 4-5 (~120 ±20 pCi/mg) is interpreted to approximate the source term ratio. This ratio is somewhat biased towards a low value because other regional sources also contribute nitrate to the groundwater.

Concentration trend similarities shown in Figure 4-5 for ^{99}Tc and nitrate also hold for calcium, magnesium, and sodium at well 299-W23-19. This observation is consistent with the hypothesis of cationic exchange that occurs in the vadose zone upon contact between tank waste fluids rich in sodium and vadose zone soil phases. That is, concentrated sodium effectively displaces naturally sorbed calcium and magnesium, a chemical reaction that temporarily increases the mobility of the displaced cations such that their transport resembles anionic species such as ^{99}Tc and nitrate. Because of its high concentrations in the waste fluid, excess sodium also migrated in anionic fashion because available sorption sites were filled. However, once in the unconfined aquifer calcium, magnesium and sodium quickly revert to normal sorptive behavior as sorption sites become available during transport away from the point of entry. Similarity in concentration trends between technetium versus calcium, magnesium and sodium are not observed at the downgradient wells.

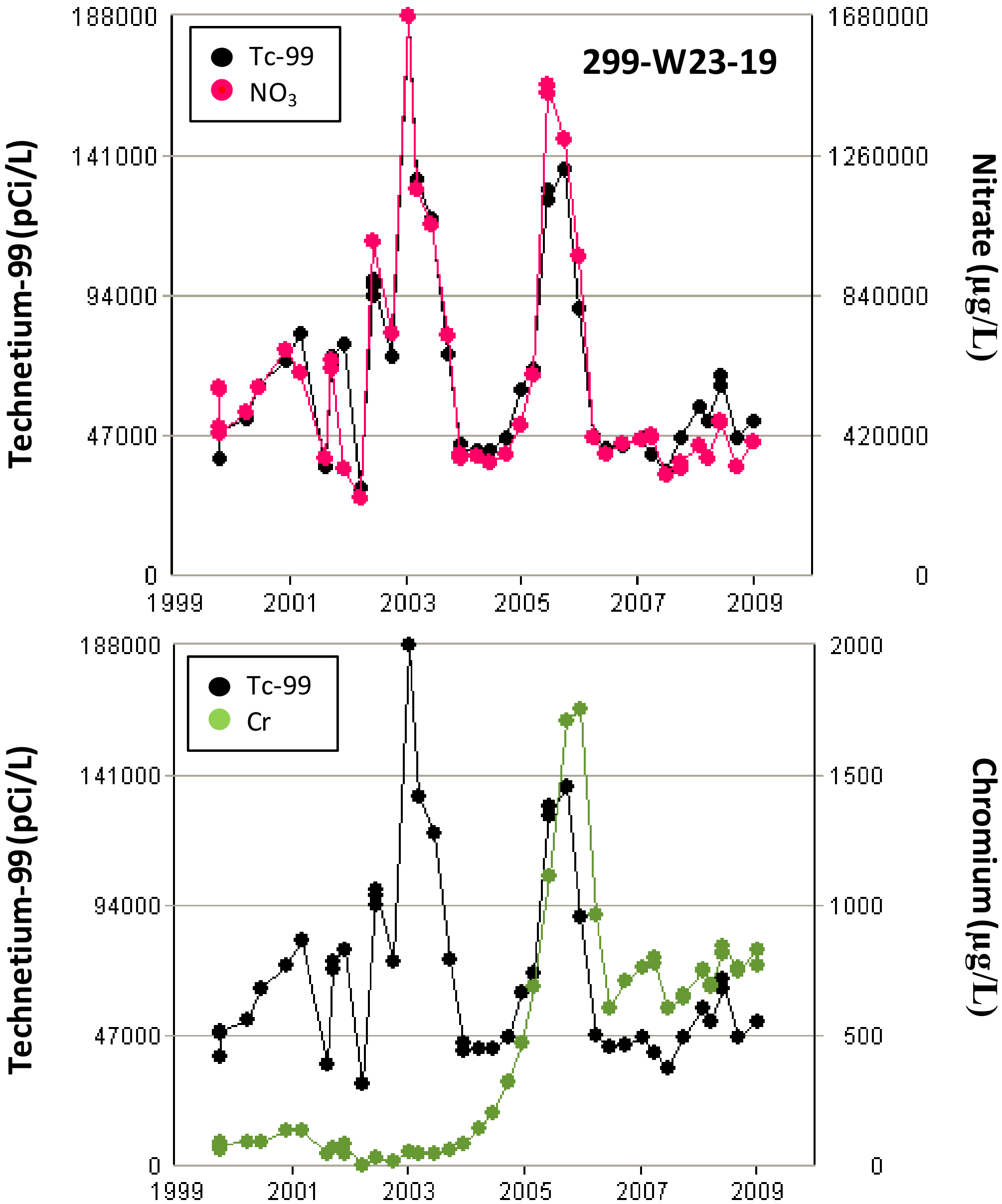
Figure 4-5. Comparison of Technetium-99 Concentrations in Three Wells in the Presumed Tank Waste Plume South of 241-SX Tank Farm



Comparison of ^{99}Tc to chromium migration patterns (Figure 4-6) are more complicated because some retardation of chromium through chemical reactions with subsurface soils is apparently occurring and causing chromium to migrate more slowly than ^{99}Tc. Unlike the ^{99}Tc/nitrate trends which were consistent for all measurements, the chromium concentration trend does not begin to match ^{99}Tc concentration trends until 2005. At that time, the ^{99}Tc-to-chromium ratios which had been steadily decreasing became relatively stable (~65 ±20 pCi/µg). Given the retardation of chromium migration compared to ^{99}Tc, the contamination ratios taken in the same groundwater sample may not be the correct comparison. However, the ratio consistency over time suggests a common source. Additional sampling may provide more insight into the relationship between ^{99}Tc and chromium migration patterns.

At groundwater wells farther downgradient from well 299-W23-19, such as wells 299-W22-83 (Figure 4-7) and 299-W22-86, ^{99}Tc and nitrate concentration trends show the later arrival of the plume at these locations and continued similarity in ratios. At well 299-W22-83, significantly increasing ^{99}Tc and nitrate concentrations began in early 2002, signifying the approach of the central mass of the contamination. Over time the ^{99}Tc/nitrate ratios increased and stabilized. The ratio first exceeded 100 pCi/mg in June 2003 and the average value since then has been ~150 pCi/mg.

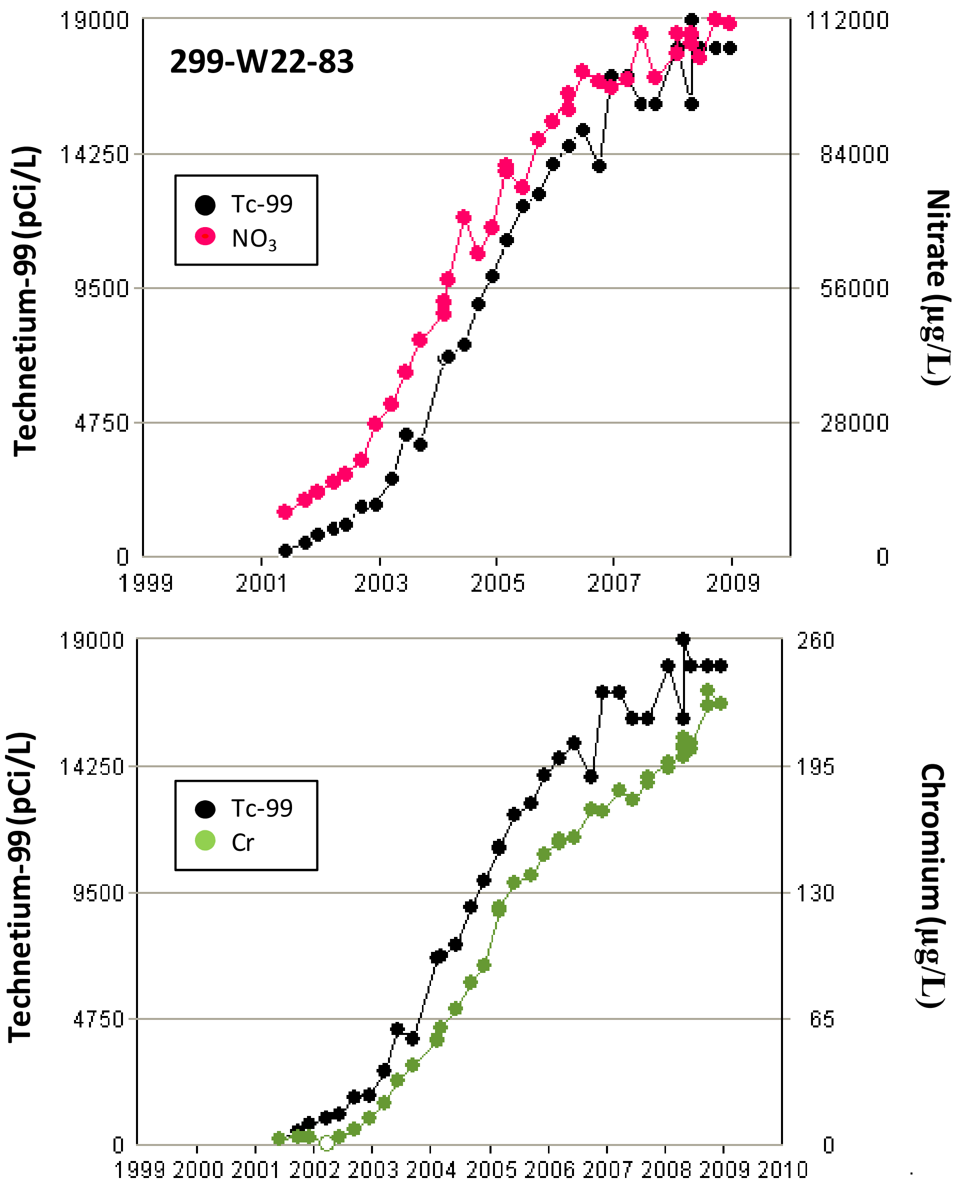
Figure 4-6. Technetium-99 and Nitrate Concentrations Data at Groundwater Monitoring Well 299-W23-19



At well 299-W22-86 farther downgradient, this sequence is apparently repeating with the initial arrival of the main part of the contaminant mass in 2006. Since the middle of 2006, both ^{99}Tc and nitrate contaminants have been steadily increasing and the ^{99}Tc/nitrate ratios appear to be leveling off at ~145 pCi/mg as of mid 2008.

Increases in chromium concentrations have lagged behind ^{99}Tc and nitrate at both downgradient wells, not becoming increasingly consistent until late 2002 and 2008 at wells 299-W22-83 and 299-W22-86, respectively. Again, the retarded migration of chromium is indicated and its migration patterns with respect to ^{99}Tc and nitrate require additional data for better understanding.

Figure 4-7. Technetium-99, Chromium and Nitrate Concentrations Data at Groundwater Monitoring Well 299-W22-83



Continued migration of this plume is expected and will move in an easterly direction as the natural gradient becomes more dominant and the U Pond groundwater mound continues to diminish. There is some indication that dispersion and dilution is occurring because the maximum value to date at the downgradient well 299-W22-83 has been 18,000 pCi/L versus the maximum of 188,000 pCi/L at well 299-W23-19. On the other hand the peak value has not yet been observed at well 299-W22-83 and will be occurring at some later time. There may also be multiple peaks given the observation of a double peak at well 299-W23-19, though this has not been observed elsewhere. Thus, future peak values and the time of their occurrence at the downgradient wells are uncertain. Finally, there is no clear indication that the source term feeding the plume near well 299-W23-19 has been exhausted. The head of the plume remains at well 299-W23-19 and high ^{99}Tc concentrations continue to be measured.

5. LEAK ASSESSMENT RESULTS

The information gathered and the reassessment results for each of the SSTs and UPRs in the 241-SX Tank Farm are discussed in the following sections. Several processes were conducted at the Hanford Site that generated wastes transferred to the 241-SX Tank Farm. These processes and the waste types generated are discussed in HNF-SD-WM-TI-740, *Standard Inventories of Chemicals and Radionuclides in Hanford Tank Wastes*.

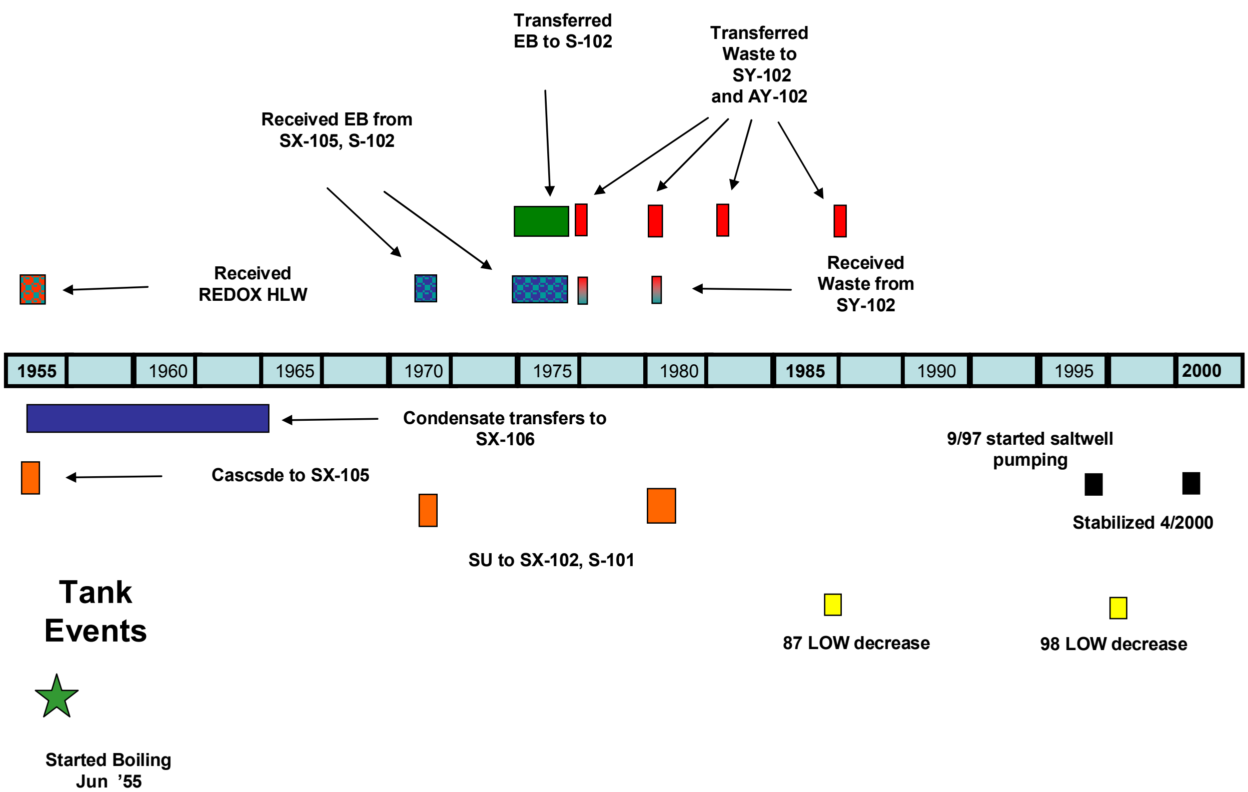
5.1 TANK 241-SX-104 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with tank 241-SX-104 (SX-104). This tank is first in the cascade series with tanks SX-105 and 241-SX-106 (SX-106). The cascade lines are located 20 ft bgs on the sides of the tanks. There are nine boreholes located around tank SX-104: 41-04-01, 41-04-03, 41-00-03, 41-04-05, 41-07-12, 41-04-07, 41-04-08, 41-04-11 and 41-01-06 (see Figure 4-1).

5.1.1 Tank 241-SX-104 Waste Operations Summary

The following subsections provide a brief discussion of the waste transfer history for tank 241-SX-104 summarized in Figure 5.1-1.

Figure 5.1-1. Tank 241-SX-104 Operating History (Fiscal Years 1955 to 2000)



5.1.1.1 Tank 241-SX-104 Waste History. Tank 241-SX-104 is the first in a cascade series of three tanks including 241-SX-105 and 241-SX-106. Tank SX-104 was put into service February 2, 1955 (RHO-R-39, *Boiling Waste Tank Farm Operational History*) and received Reduction Oxidation (REDOX) waste from the first quarter of 1955 until November 1956 (HWN-1991-DEL, *Chemical Processing Division - Waste Storage and Experience*, page 45). Cooling water was added as needed and waste cascaded to tank SX-105 from July through December 1955. The tank started evaporating in June of 1955 and condensate from tank SX-104 was sent to tank SX-106 (HWN-1991-DEL page 45). The tank continued to transfer condensate to tank SX-106 through 1963. In September 1971, 496 kgal of supernate were transferred to tank 241-SX-102 (ARH-2074 C, *Chemical Processing Division Waste Status Summary July 1, 1971 Through September 30, 1971,* page 10).

Tank SX-104 then received 669 kgal of REDOX evaporator bottoms from tank SX-105 (received into SX-105 from 1967 to 1969) and REDOX ion exchange (IX) waste (waste type RIX) (post-B Plant cesium removal) from SX-105 in the fourth quarter of 1971 (ARH-2074 D, *Chemical Processing Division Waste Status Summary October 1, 1971 Through December 31, 1971,* page 10). There were no transfers from 1972 through the second quarter of 1975. From the third quarter of 1975 until the second quarter of 1976, tank 241-SX-104 received evaporator bottoms and recycle wastes from the 242-S Evaporator via tank 241-S-102 and transferred supernate (ARH-CD-336 B, *Production and Waste Management Division Waste Status Summary April 1, 1975 through June 30, 1975*, ARH-CD-336 C, *Production and Waste Management Division Waste Status Summary July 1, 1975 through September 30, 1975*, and ARH-CD-702 A, *Production and Waste Management Division Waste Status Summary January 1, 1976 through March 31, 1976*). Tank SX-104 received concentrated evaporator feed and residual evaporation liquid during the third quarter of 1976 until the third quarter of 1977. During the fourth quarter of 1977, the tank received partial neutralized feed waste. In the first quarter of 1980, the content of the tank was classified as double-shell slurry feed and in August 1980 the tank was removed from service (WHC-MR-0132, *A History of 200 Area Tank Farms*). Prior to pumping in 1998 the tank had a 12- to 18-in. thick surface crust (WHC-SD-WM-ER-332, *Evaporation Analysis for Tank SX-104*) overlying a liquid. Prior to saltwell pumping and interim stabilization in September 1997 the tank was on the flammable gas watch list with an estimated retained gas volume of 250 m^3. The tank experienced three hydrogen release events, the last one occurring November 22, 1996 (RPP-7771, *Flammable Gas Safety Issue Resolution*).

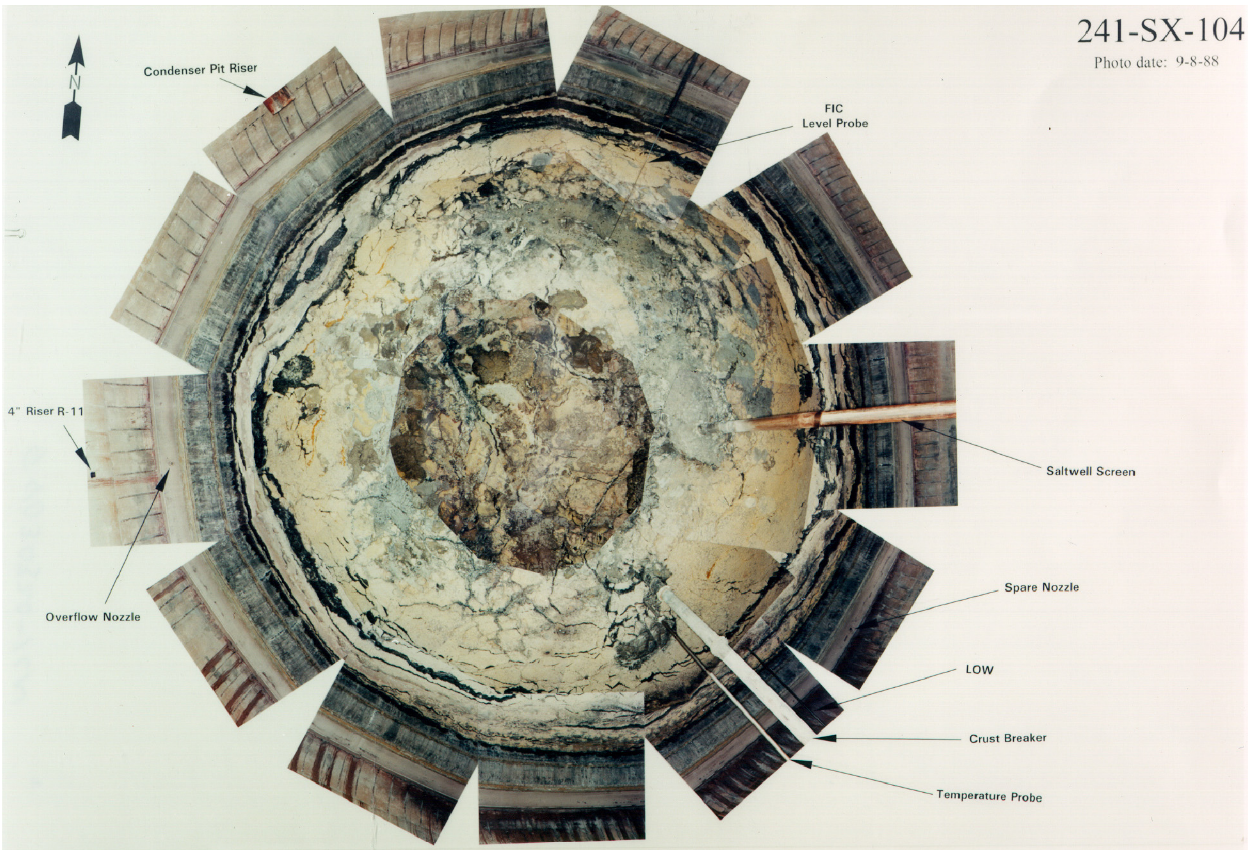
5.1.1.2 Integrity of Tank 241-SX-104. The current leak volume estimate for tank SX-104 is 6,000 gal (HNF-EP-0182) based on ILL decreases over a three-year period. Leak status assessments for ILL decreases were conducted for this tank in 1988, 1998 and 2008. The assessments are described in sections 5.1.2.3, 5.1.2.4 and 5.1.2.5 of this report.

5.1.1.3 Interim Stabilization. Saltwell pumping began on September 26, 1997; 757 L (200 gal) were pumped in September before the transfer line between tanks 241-SX-104 and 244-S became plugged. Pumping resumed on March 19, 1998, following the installation of a dilution system to dilute the waste in the saltwell in order to make it easier to pump the waste to tank 241-SY-102. Pumping was interrupted on March 23 then restarted on July 23, 1998, and continued until July 27, 1999, when the rear seal of the jet pump ruptured and a major spray leak ensued within the pump pit. A total of 436 kL (115 kgal) of liquid waste was transferred to

241-SY-102 before failure occurred. Waste volume calculations showed 182 kL (48 kgal) of drainable interstitial liquid remaining in tank SX-104, of which approximately 167 kL (44 kgal) is estimated to be pumpable. On April 26, 2000, tank 241-SX-104 was stabilized based on the major equipment failure (HNF-SD-RE-TI-178, *Single–Shell Tank Interim Stabilization Record*).

Figure 5.1-2 depicts a mosaic of the waste surface in tank SX-104 as of September 8, 1988.

Figure 5.1-2. Tank 241-SX-104 Waste Surface (September 1988)

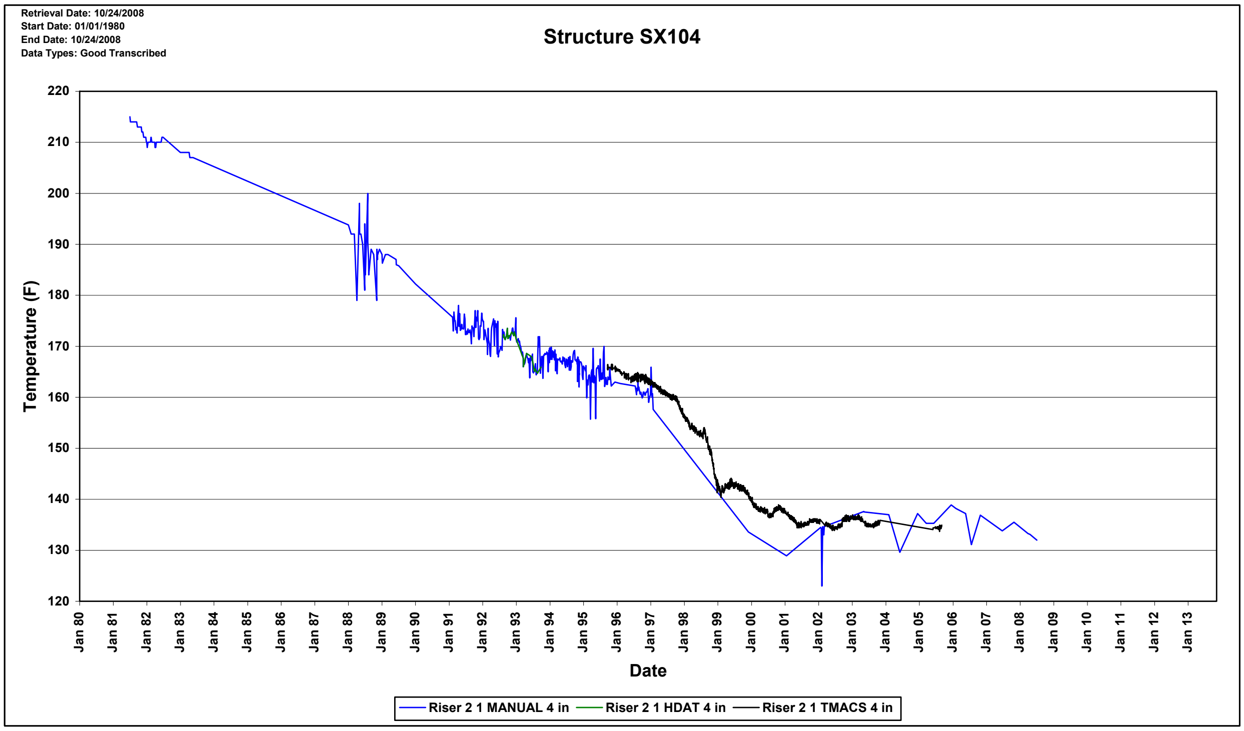


A video taken when the tank was stabilized showed a rough, yellowish gray saltcake waste with an irregular surface of visible cracks and shelves that were created as the surface was dried out. The waste surface was dry and showed no standing water in the tank (HNF-SD-RE-TI-178).

As of September, 2008 tank SX-104 contains an estimated 310 kgal of saltcake, 136 kgal of sludge and 48 kgal of drainable liquid (HNF-EP-0182).

5.1.1.4 Tank 241-SX-104 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172, *Survey of the Single-Shell Tank Thermal Histories*. The thermal history for tank SX-104 starts in August 1956 and continues through November 1964 (RHO-CD-1172 pages B-73 through B-88). Temperature plots (Appendix A) show tank SX-104 waste temperature reached a maximum of 300 °F in December 1956, then decreased and varied between 230 and 260 °F through December 1960. By August 1961 waste temperature decreased to 200 ± 10 °F and stayed at that level through November 1964. There is a gap in the temperature data for tank SX-104 until Surveillance Analysis Computer System records started in 1981. Figure 5.1-3 shows Surveillance Analysis Computer System temperature profiles for tank SX-104 between 1981 and October 2008.

Figure 5.1-3. 241-SX-104 Tank Waste Temperature (1981 to 2008)

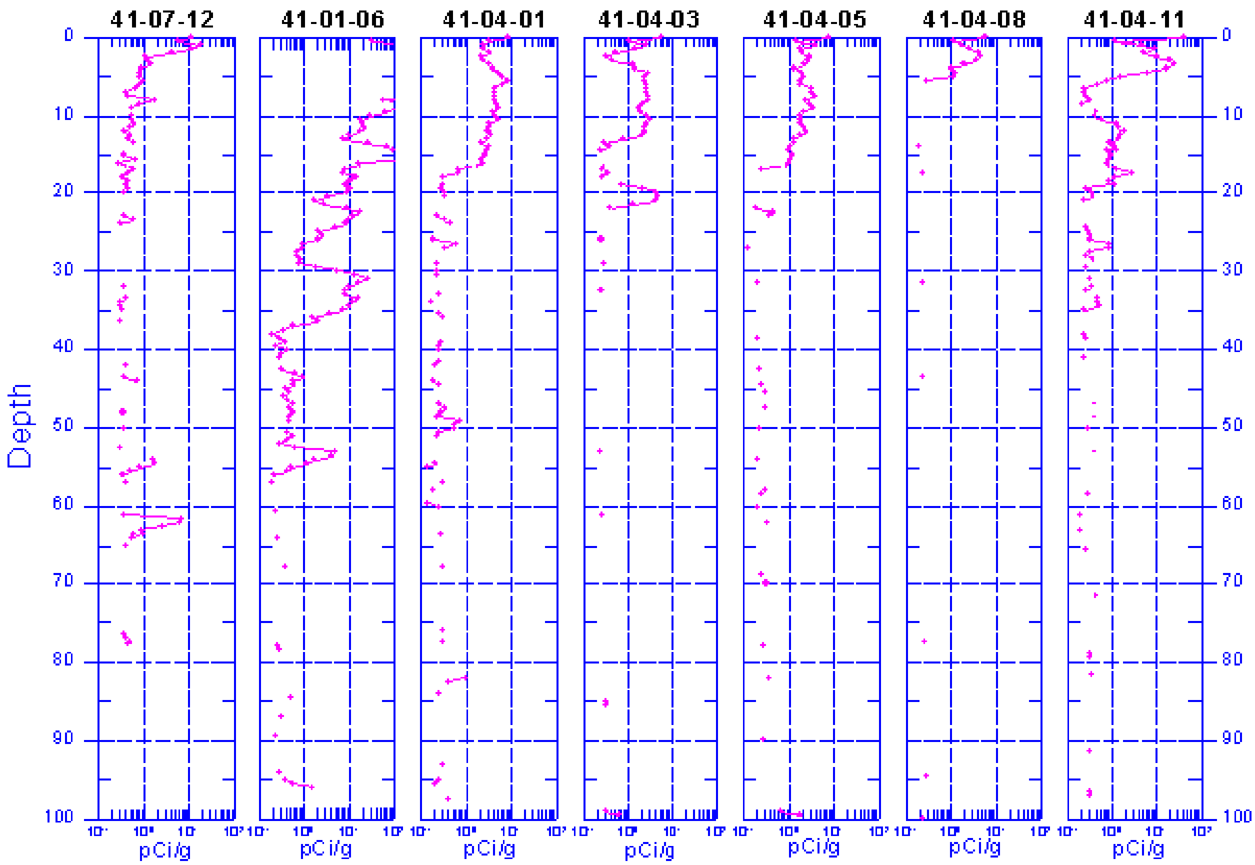


5.1.2 Data Review and Observations

5.1.2.1 Drywell Results. Historical gross gamma logs for the period 1975 through mid-1994 are compiled in HNF-3136, *Analysis Techniques and Monitoring Results, 241-SX Drywell Surveillance Logs*. Between April and June 1995, the Vadose Zone Characterization Project performed spectral gamma analyses of the drywells 41-04-01, 41-04-03, 41-04-05, 41-04-07, 41-04-08, 41-04-11, 41-07-12 and 41-01-06 (surrounding and in the vicinity of SX-104), and attempted 41-00-03. The results showed extensive surface contamination from surface spills or pipeline leaks around the tank, and that the surface contamination had been migrating downward. However, after analyzing the distribution of soil contamination around the tank, the report concluded that there was no evidence that the tank had ever leaked, and recommended a review to determine if the tank should continue to be listed as an “assumed leaker” (GJ-HAN-3, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank SX-104*). Spectral gamma-ray data collected from seven boreholes in the vicinity of tank SX-104 are shown in Figure 5.1-4 (GJ-HAN-3).

In January 1998 spectral gamma scans of the drywells were repeated in response to a decrease in the ILL during 1997. The scans were compared to the baseline data from the 1995 scans. The evaluation showed that no increase in soil contamination had occurred since the 1995 scans (GJPO-HAN-4, *Hanford Tank Farms Vadose Zone Addendum to the SX Tank Farm Report*). Neutron moisture scans showed a moisture peak at the interface between the undisturbed soil at the base of the tank and backfilled soil above the foundation. The evaluation concluded that there was no evidence of a leak from tank SX-104 (HNF-2617, *241-SX-104 Level Anomaly Assessment*).

Figure 5.1-4. Cesium-137 Concentrations in Drywells Surrounding Tank 241-SX-104



5.1.2.2 1988 Assessment. In 1987 a gradual liquid level decrease was detected from in-tank measurements using a neutron-neutron tool through a LOW. As a result, an Unusual Occurrence Report (8855768, *Revision of Unusual Occurrence Report for Tank 241-SX-104 Number WHC-UO-028-TF-03*) and an Environmental Protection Deviation Report (88-03, *Liquid Observation Wells (LOWS) Interstitial Liquid Level (ILL) in Tanks 241-SX-104 and 241-SX-105 Has Exceeded the 0.3 Foot Decrease Criteria with the Gamma Probe*) were issued. An engineering investigation was undertaken (Internal Memo 13331-88-416, "Engineering Investigation: Interstitial Liquid Level Decrease in Tank 241-SX-104") during which all available tank data were reviewed and in situ gamma-ray spectra were acquired in various boreholes surrounding the tank (SD-CP-TI-132, *In-situ Gamma Spectroscopy Scans of Dry Wells Surrounding 241-SX-104 Tank*).

The engineering investigation concluded there was no proof that the tank was leaking. However, the LOW decrease could not be attributed to evaporation with 95% certainty and although spectral gamma measurements did not identify a subsurface contamination source, the measurements did not preclude the possibility of a leak. Because the liquid loss could not be accounted for with 95% certainty, the tank was classified as an assumed leaker and subsequently jet pumped to remove some of the remaining free liquid in the tank. A worst-case estimate of liquid loss was 5,300 gal over a three-year period. This estimate was based on the liquid level decrease that was inferred from the measurements through the LOW. The tank is currently classified as an assumed leaker based on this assessment.

5.1.2.3 1998 Assessment. In 1998, ILL variations of up to 6 in. were observed in the tank and it was suspected of re-leaking. Empirical measurements from water additions in February 1997 and February 1998 showed reduced waste porosity. The ILL changes were shown to correlate with barometric pressure changes attributed to the reduced porosity and resultant increases in capillary strength. The downward slope of the ILL baseline was attributed to evaporation due to increased wicking of interstitial liquids to the waste surface from the increased capillary strength. Drywell spectral gamma scans in January 1998 showed no changes from the 1995 baseline scans. The assessment recommended that the tank not be declared a re-leaker (HNF-2617).

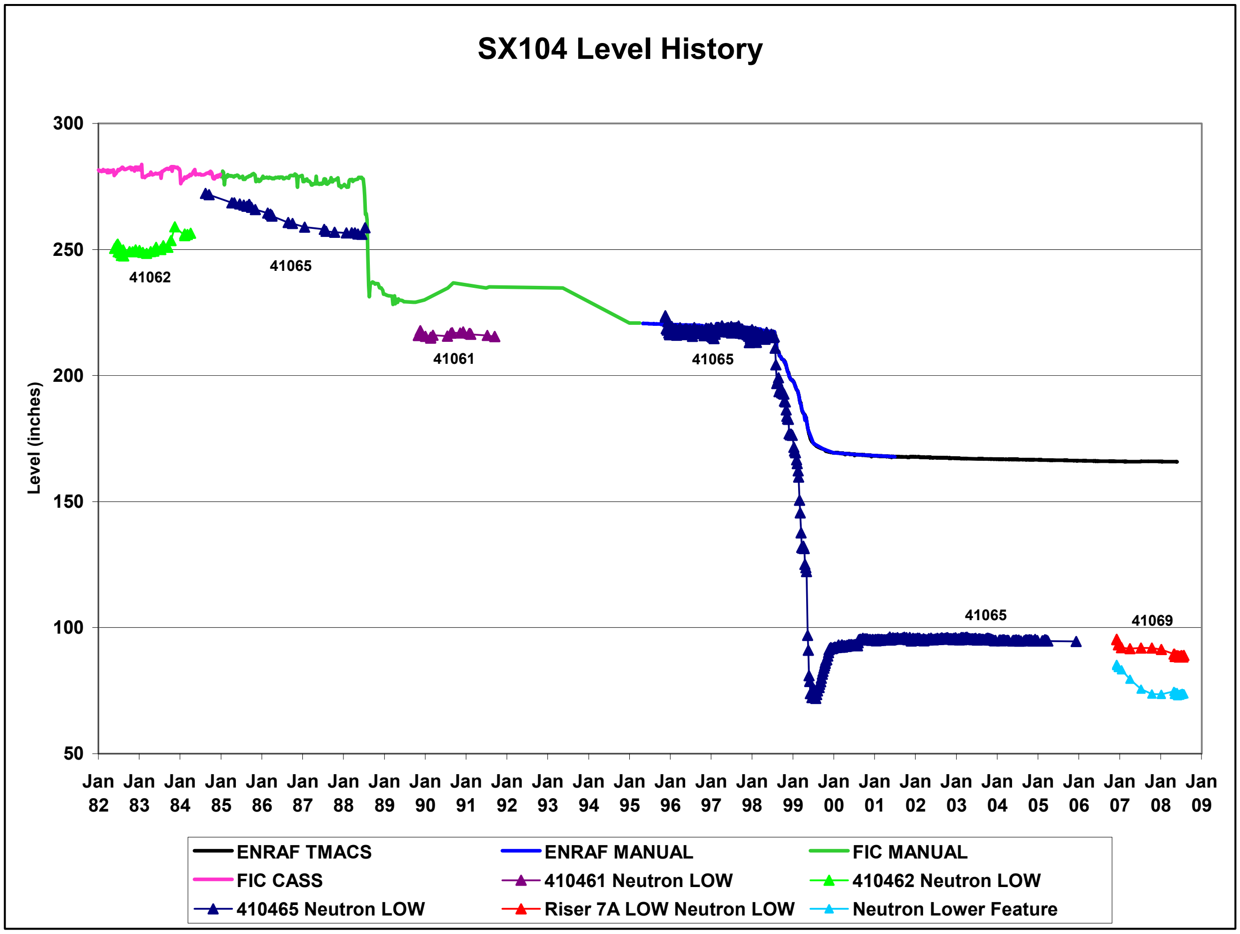
5.1.2.4 2008 Assessment. The LOW was replaced and reinstalled nearer the center of tank SX-104 in Riser 7A in December 2006. Interstitial liquid level monitoring using the new well showed the predictable increase in ILL from the installation water, followed by a natural decline and re-stabilization of the level by January 2008, as the free water dissipated through the waste. However, the May 1, 2008 reading showed a decrease that exceeded the allowable -1.2 in. criterion. On May 1, 2008 the quarterly neutron LOW scan was found to be significantly below baseline and recent data (-6.20 standard deviations, approximately 2.5 in. lower than expected). Further decreases were measured on May 6 and May 12, 2008. On May 19, 2008 a formal leak assessment was initiated to determine if the tank was re-leaking (RPP-ASMT-38450, *Tank 241-SX-104 Leak Assessment Report*). Additional drywell and LOW gross gamma measurements were obtained and weekly neutron LOW scans were performed through June 2008. No change in drywell data was observed. Gross gamma measurements showed a potential different and more stable liquid level than was being tracked by the neutron probe and the "true" liquid level was confirmed by the weekly LOW neutron scans.

The panel concluded that "the water used to install the liquid observation well in December, 2006 obscured the true interstitial liquid level feature because of localized impermeability in the sludge-saltcake mixture and the interstitial liquid's capability to generate and release small amounts of gas. These waste characteristics impeded the redistribution of the liquid observation well installation water in the waste. When the correct, latent, feature was identified and tracked, the data showed a stable interstitial liquid level and no indication of a new leak." The consensus of the assessment team was that tank SX-104 was not actively leaking (RPP-ASMT-38450).

Although the 2008 assessment concluded that the tank was not re-leaking in 2008, the assessment did not review the original 1987 classification of the tank as an assumed leaker.

5.1.2.5 Surface Level Measurements. Figure 5.1-5 shows surface level measurements from 1982 to 2008. During this time three different LOWs were installed in the tank at different locations. There are several potential explanations for the ILL decrease observed from 1984 to 1988.

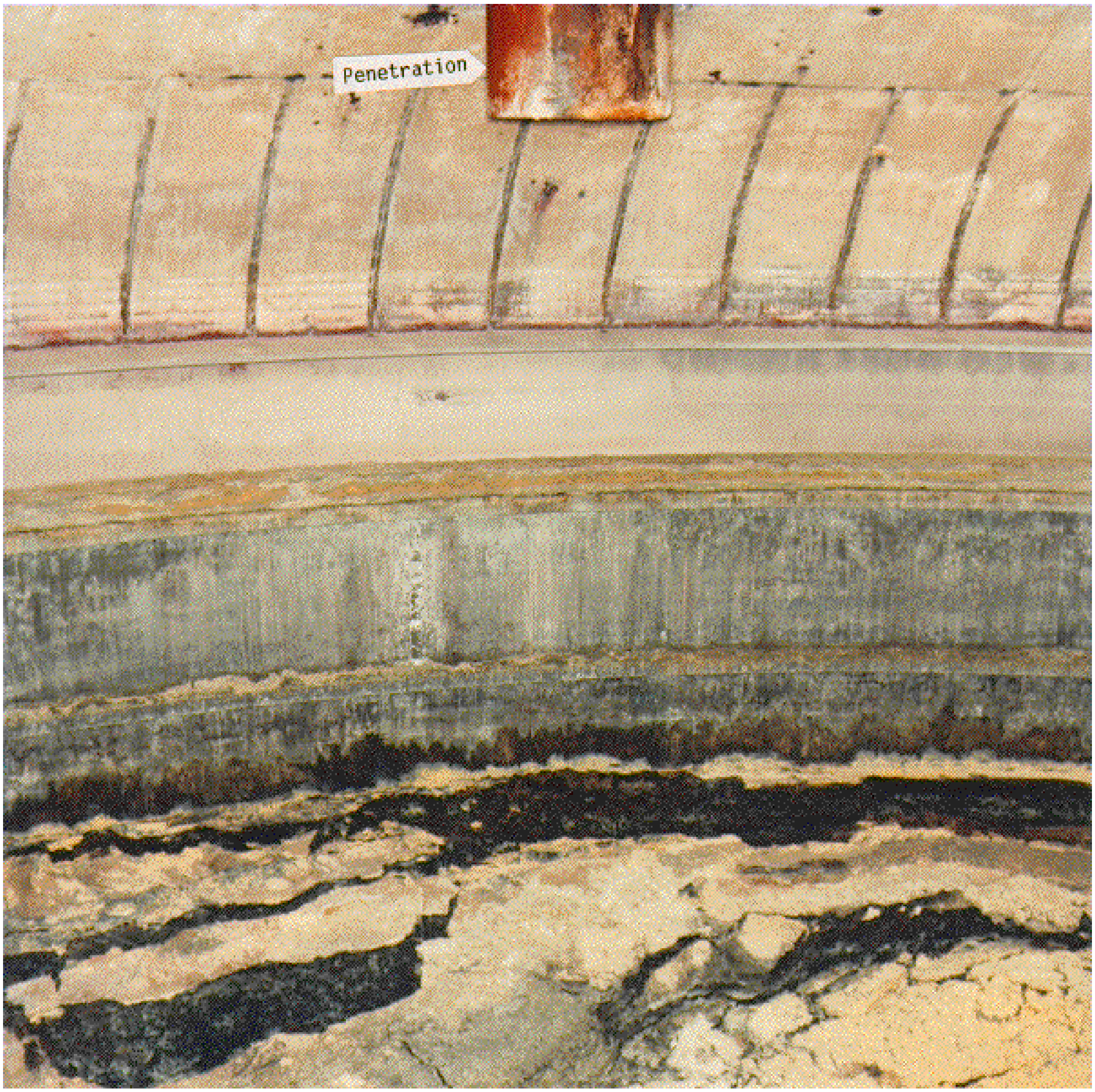
Figure 5.1-5. Tank 241-SX-104 Surface Level Measurements (1982 to 2008)



1. Evaporation: The ILL decrease is a gradual steady trend not indicative of a one time or sudden leak event. As stated in the 1988 assessment (Internal memo 13311-88-049, "Evaluation of Integrity of Tank 241-SX-104"), there was sufficient evaporation to explain the ILL decrease. However, the data was insufficient to provide a 95% confidence level to conclude the tank was sound. A 1994 study (WHC-SD-WM-ER-332) showed that diffusion through the SX-104 crust explained liquid level decreases from October 1989 to October 1991 of 0.75 in./yr provided there was a 3% free liquid area in the crust. In-tank photos of the crust show cracking and appear to indicate > 3% of the crust open to liquid on the crust edges and in cracks (see Figures 5.1-6 and 5.1-7). High evaporation rates were due to waste temperatures ranging from 150 to 190 °F from 1984 to 1988 (97 °F was used for the crust temperature for the 1994 diffusion model calculations) and a 50 to 60 cubic feet per minute (cfm) flow rate created by active ventilation of the tank through a central sludge cooler (WHC-SD-WM-ER-332,

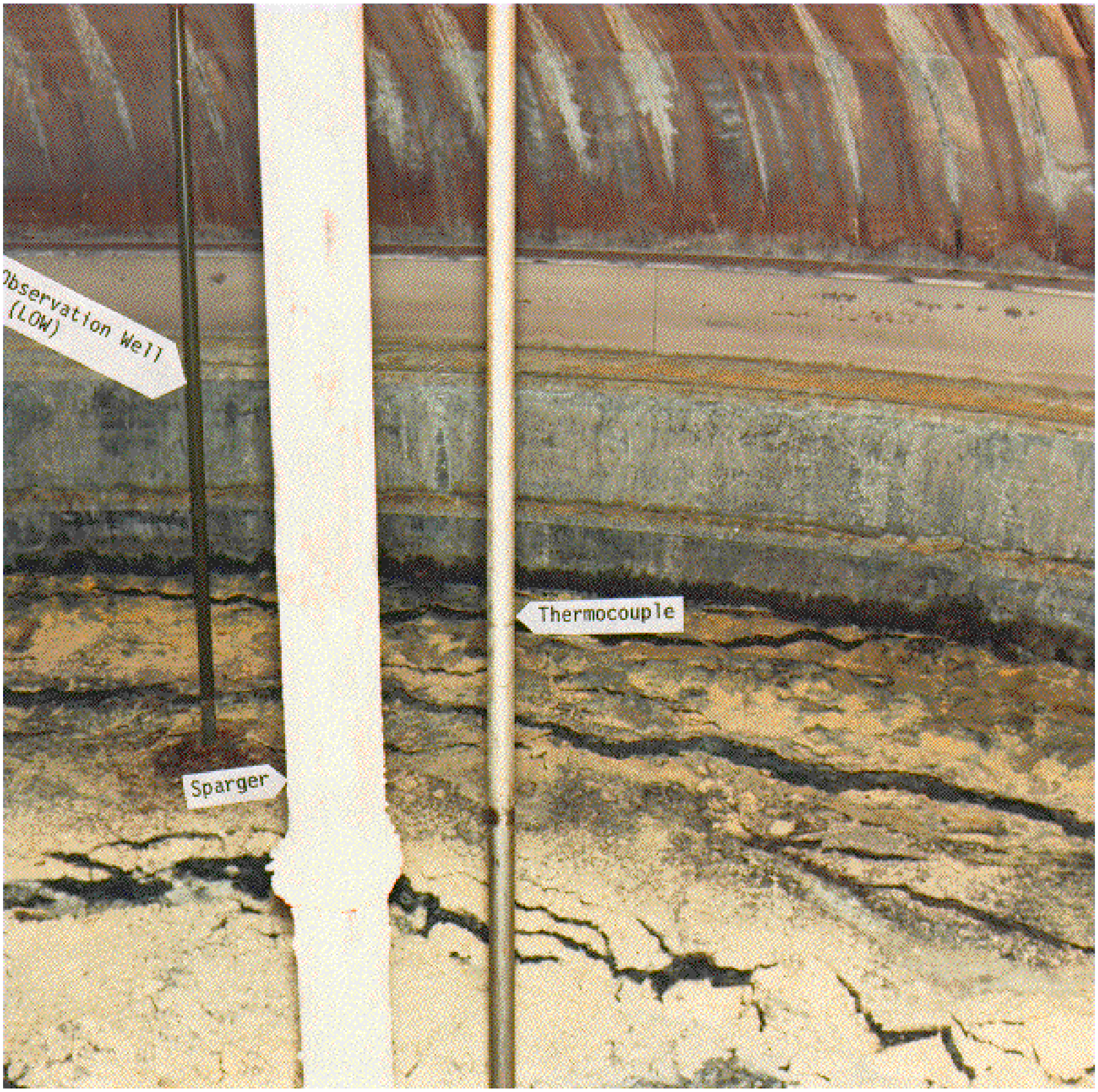
RPP-7771). Similar ILL decreases were observed and evaporation estimates shown for tanks SX-102 and SX-105 (WHC-SD-WM-ER-202, *Evaporation Analysis for Tank SX-105*).

Figure 5.1-6. Photograph of 241-SX-104 Inside Tank



2. The ILL was first installed and reported in August 1984. One year later the water used to lance the well may not have come to equilibrium. This phenomenon was observed in the 2008 investigation after a new well was lanced in December 2006. Although the results appear similar, the 2006 LOW was lanced into sludge as opposed to saltcake as for the 1984 LOW; consequently the 2006 LOW would be expected to come to equilibrium more slowly.

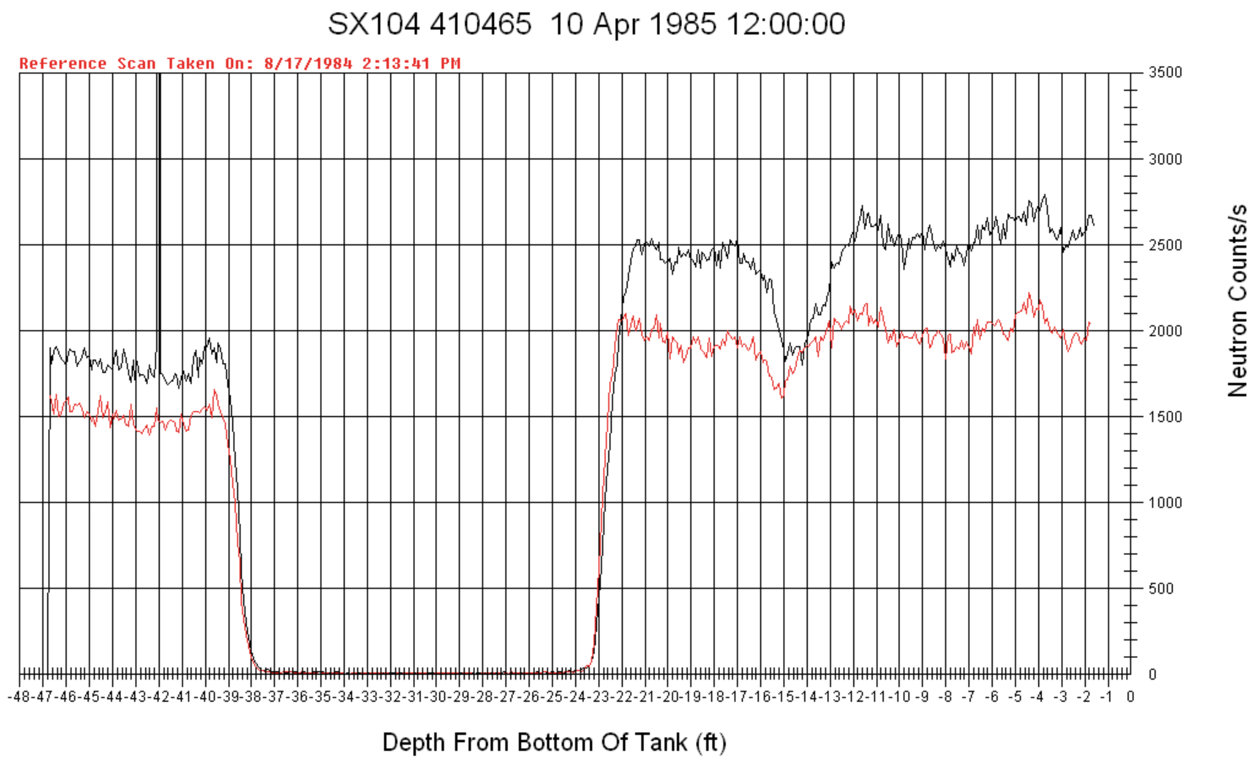
Figure 5.1-7. Photograph of Tank 241-SX-104 Liquid Observation Well, Sparger and Thermocouple



3. The crust on the surface of SX-104 and movement of liquid used to lance the LOW make it more difficult to identify the "true" ILL from the neutron scans shown in Figures 5.1-8 and 5.1-9 because there is more than one feature that could be identified as the ILL.

4. Tank SX-104 was one of the flammable gas tanks and experienced hydrogen release events between 1984 and 1988 (RPP-7771). A hydrogen release event would be expected to reduce the ILL.

Figure 5.1-8. Tank 241-SX-104 Liquid Observation Well Neutron Scan (April 1985) (Standard and Zoom)



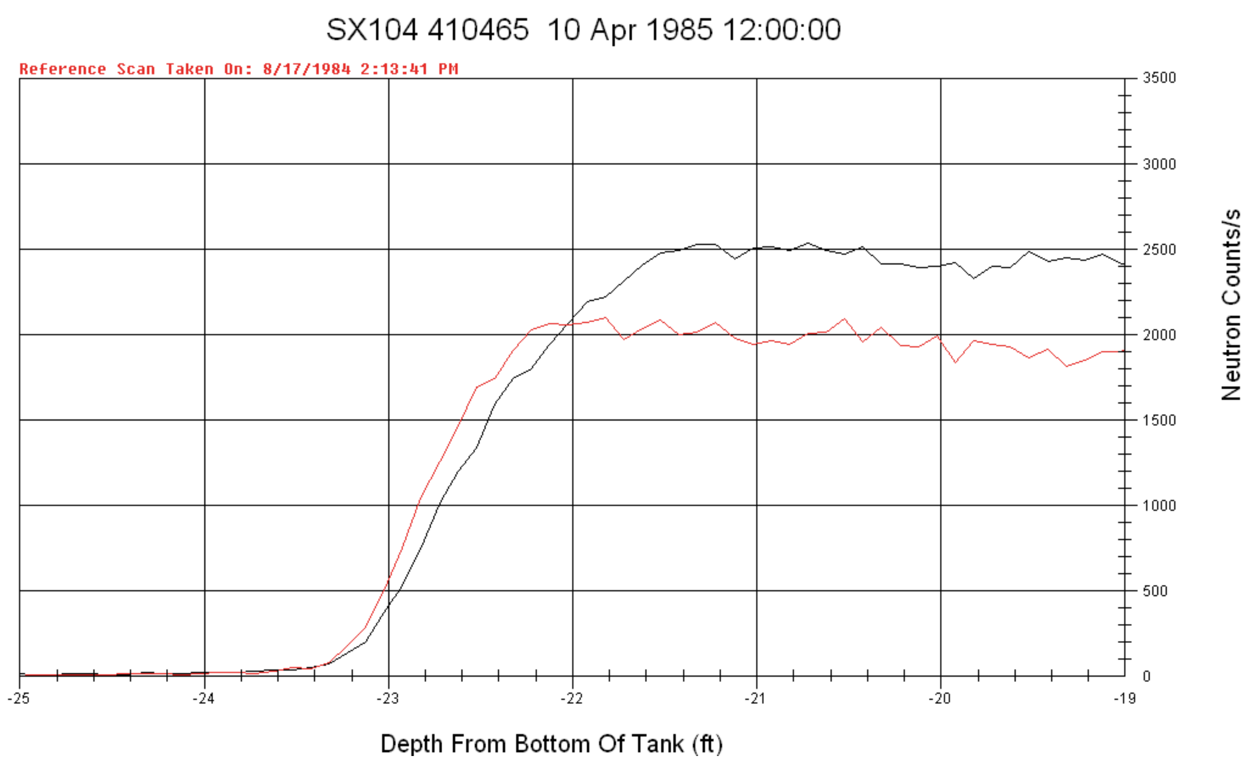
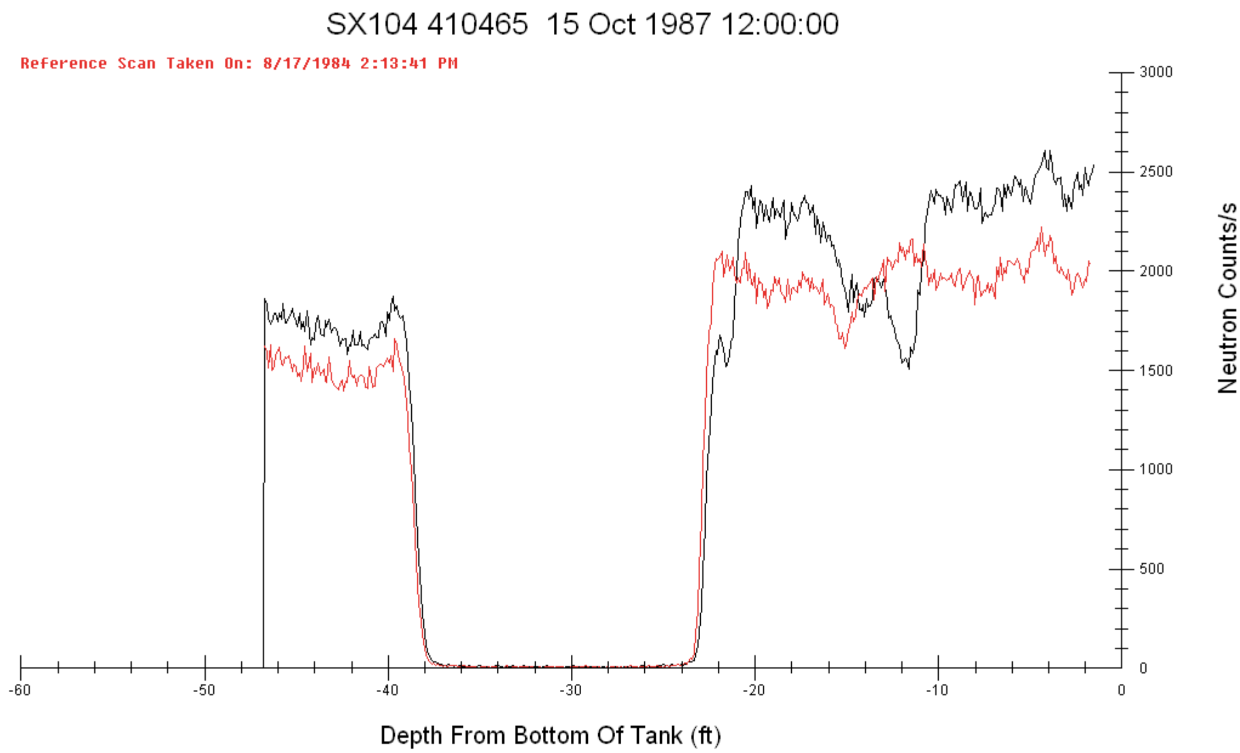
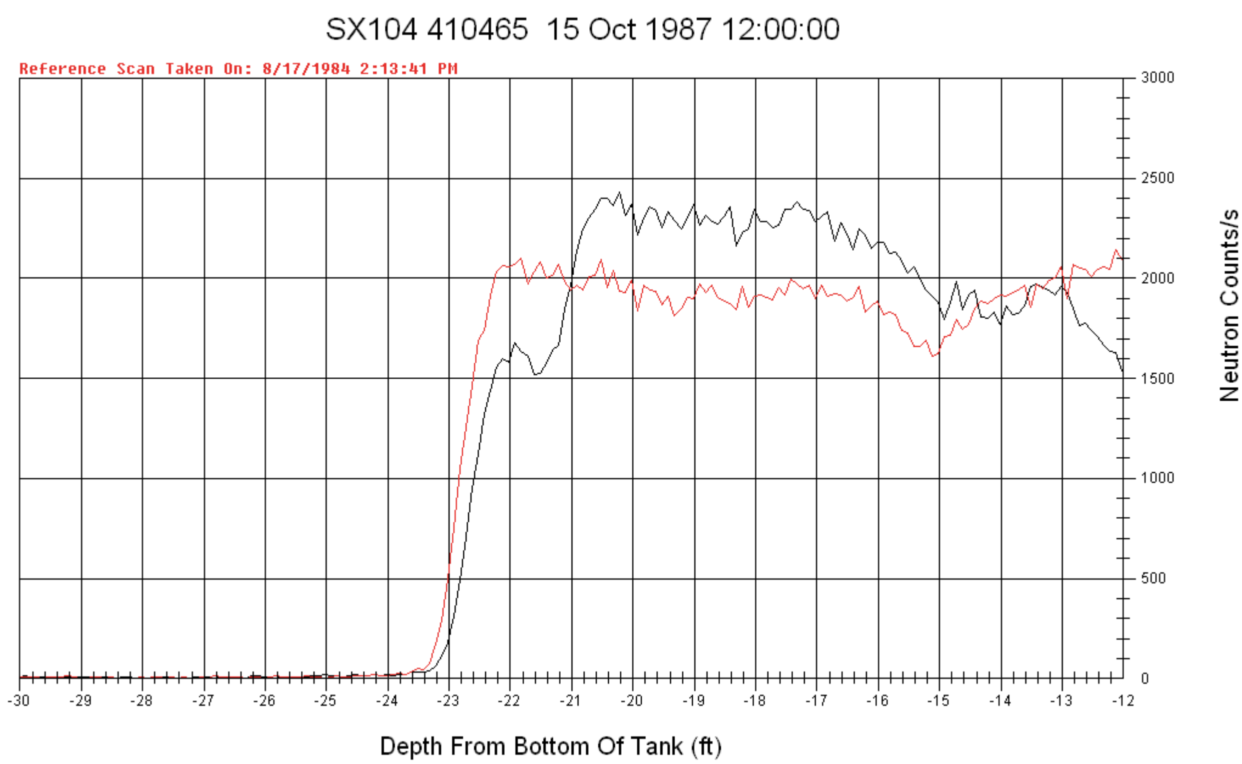


Figure 5.1-9. Tank 241-SX-104 Liquid Observation Well Neutron Scan (October 1987) (Standard and Zoom)





5. Tank leak: Although possible, this appears to be the least likely since there are alternate explanations and no evidence other than the ILL decrease of a tank leak (i.e., no surface liquid level decrease and no increasing radioactivity in drywells).

5.1.3 Conclusions

Tank SX-104 was classified as "questionable integrity" based on ILL decreases from 1994 to 1998; ILL decreases were also observed in 1998 and 2008. Previous assessments concluded that the 1998 and 2008 ILL decreases were not due to a tank leak. There are also several potential explanations for the ILL decrease observed from 1984 to 1988; evaporation is the most likely explanation. Assessment team members concluded there is no evidence tank SX-104 lost containment, and no leak inventory was assigned for this tank. The tank was previously classified as "questionable integrity" primarily due to the procedural aspects of a 95% confidence associated with the no-leak alternative. The current assessment concluded that it is reasonably certain the tank was sound. As a result no leak inventory is assigned for this tank.

5.2 TANK 241-SX-107 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST 241-SX-107. Tank SX-107 has three laterals (horizontal boreholes) installed in December 1962 about 10 ft under the tank, as depicted in Figure 4-1. There are seven boreholes located around tank SX-107: 41-07-02, 41-07-03, 41-07-05, 41-07-07, 41-07-08, 41-07-10 and 41-07-12.

5.2.1 Tank 241-SX-107 Waste Operations Summary

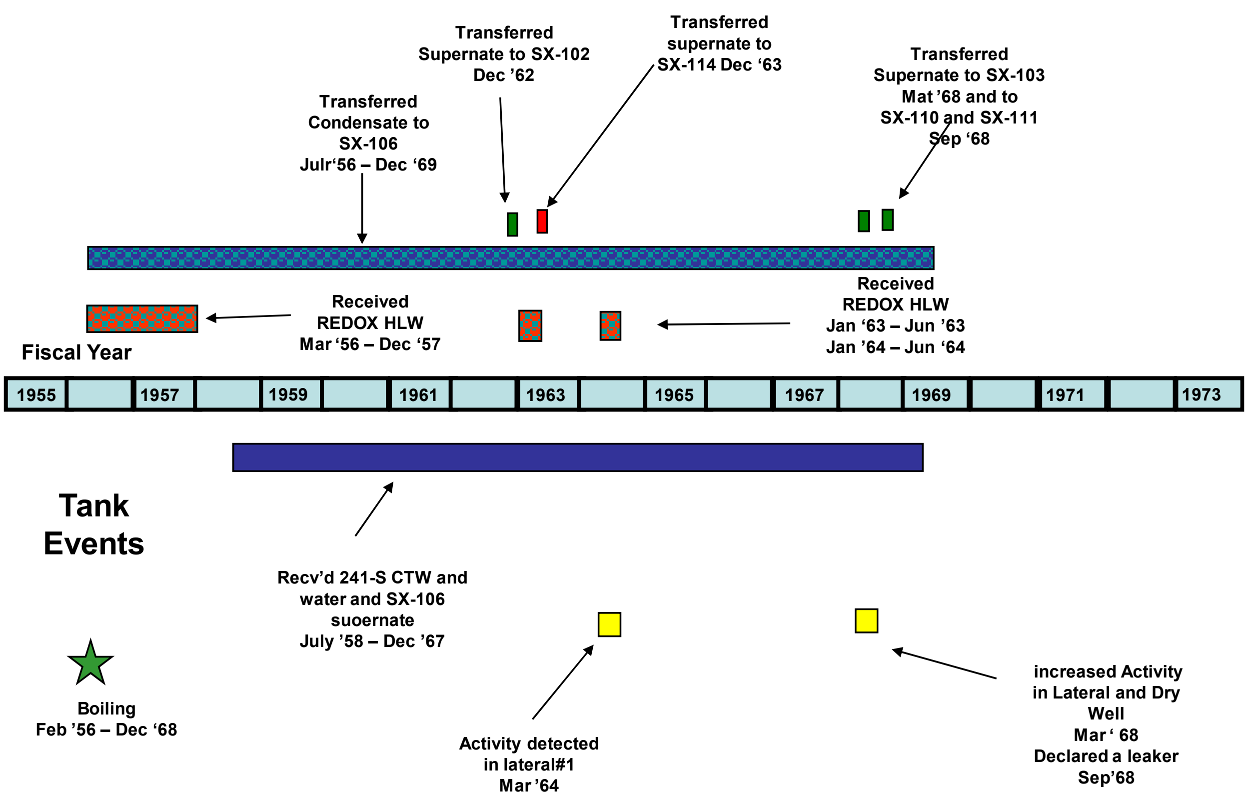
The following subsections summarize the waste operating history for tank SX-107 shown in Figure 5.2-1.

5.2.1.1 Tank 241-SX-107 Waste History. Tank 241-SX-108 was completed in 1954 and put into service March 3, 1956 (RHO-R-39) when REDOX high-level waste (HLW) was transferred into the tank. The tank continued to receive REDOX waste until December 1957. REDOX waste was again added January through June of 1963 and early 1964. In March 1964 REDOX waste additions were stopped due to increased radioactivity detected in one of the SX-107 underground laterals (HW-82526, *Chemical Processing Department Monthly Report May 1964*, p. C-2). The REDOX HLW in tank SX-107 self-condensed (boiled –off) and was sent to tank SX-106 from July 1956 throughout the life of the tank. A small amount of REDOX cladding removal waste was added to the tank in January 1960. The tank sent supernate to tank SX-102 in December 1962 and to tank SX-114 in June 1963. Starting in July 1958 and throughout the life of the tank, caustic makeup water from catch tank 241-S and cooling water was added to maintain the waste temperature and pH within operating limits.

In June 1964 a "possible leak in the 107-SX underground storage tank" was identified (Internal letter LET-111368, "Disposal of Irradiated Cobalt Scrap"). Radioactivity increased in July

(HW-83508, *Chemical Processing Department Monthly Report for July, 1964*, p. C-3) but no significant increases were observed in October 1964 and no material losses were observed in tanks SX-107 or SX-108 (RL-SEP-52, *Chemical Processing Department Monthly Report for October, 1964*). A possible leak in SX-107 was again identified in March 1968 and supernate was sent to tank SX-103 (ARH-534, *Chemical Processing Division Waste Status Summary January 1, 1968 through March 31, 1968*). In September 1968 new evidence of leakage was observed in the laterals and drywells and supernate was sent to tanks 241-SX-110 (SX-110) and SX-111 (ARH-308-DEL, *200 Areas Operation Monthly Report September 1968*); air drying of sludge was initiated December 19, 1968 (ARH-1061, *Chemical Processing Division Waste Status Summary October 1, 1968 Through December 31, 1968*). Steel liner measurements made in June 1969 showed no bulge in the tank (RPP-RPT-29191, *Supplemental Information Hanford Tank Waste Leaks*, PR-REPORT-JUN69-DEL, *Monthly Status and Progress Report June 1969*, page AIV-6).

Figure 5.2-1. Tank 241-SX-107 Operating History (Fiscal Years 1955 to 1968)



Supernate samples analyzed January 1977 showed a ^{137}Cs concentration of 0.49 Ci/gal at that time. Samples taken March 1961 showed a ^{137}Cs concentration of 3.9 Ci/gal (HW-69443, *Chemical Processing Department – Waste Status Summary, April 1961*, page G-5). Additional March 1961 sample results are shown in Table 5.2-1. No other sample data for tank SX-107 were located. RHO-ST-33, *The System For Retrieval Of Solidified Hanford High-Level Defense Wastes A Design Description* shows that 41 bottles of neutralized waste from the 100 °F area were added to tank SX-107 each with less than 1 gram of ^{239}Pu (date unknown).

Table 5.2-1. March 1961 Sample Results for Tank 241-SX-107 Supernate

Analyte	Units	Result
SpG		1.747
Free NaOH	g/l	50.6
NO_3	g/l	53.6
NO_2	g/l	29.8
Cl	g/l	9
SO4	g/l	0.3
R	g/l	32
Na	g/l	153
Gross Beta	Ci/gal	3.7
Gross Gamma	Ci/gal	3.8
Gamma Scan (^{137}Cs)	Ci/gal	3.9
^{90}Sr	Ci/gal	.02
^{237}Np	g/gal	< 1.5 E -4

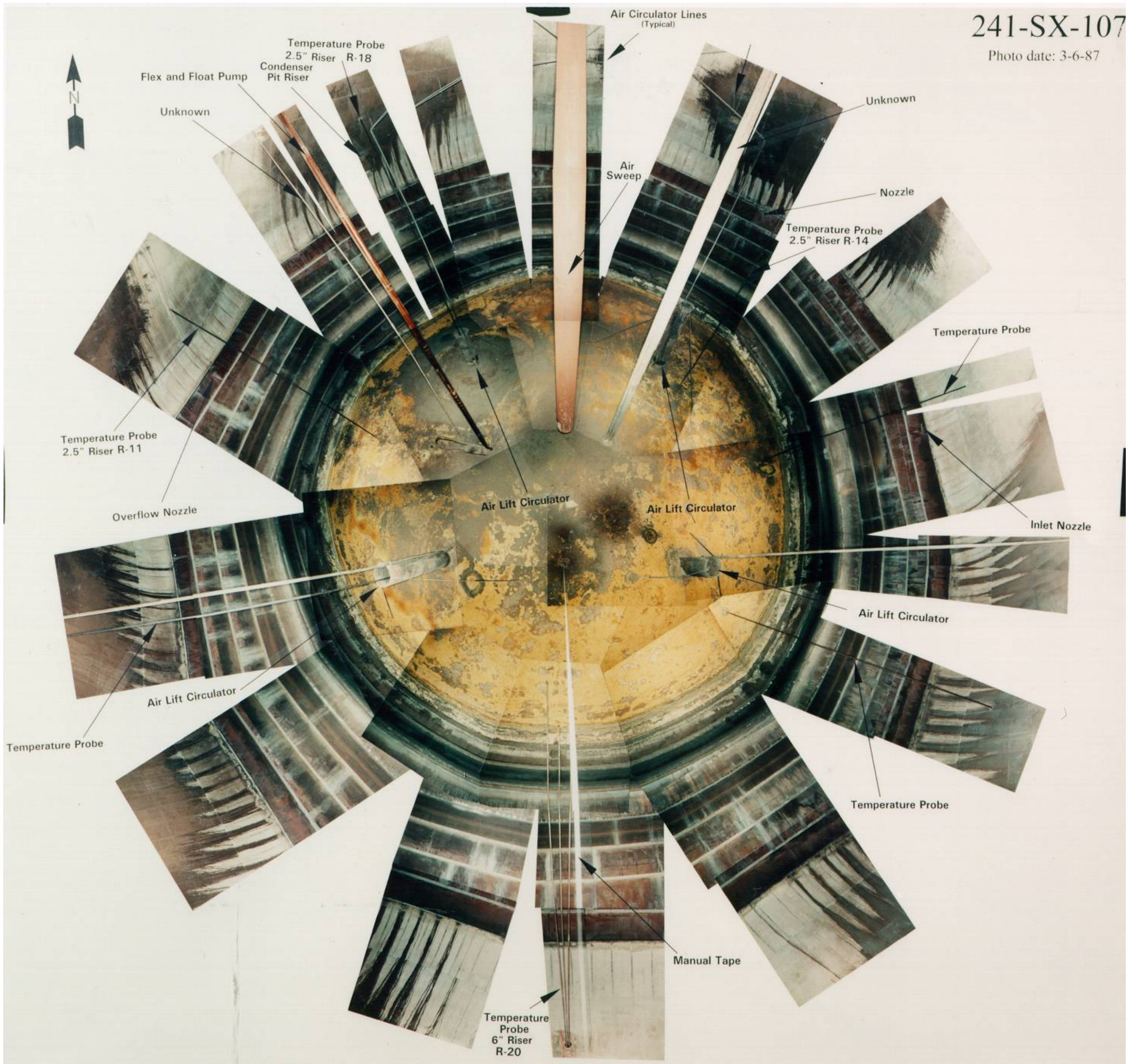
5.2.1.2 Integrity of Tank 241-SX-107. In 1967 tank 241-SX-107 was identified as a suspect leaker based on drywell and lateral activity and was removed from service. In 1968, the tank was connected to an exhauster, which was used at the end of the tank's service life to aid in the air-cooling of the waste in the tank. This resulted in a relatively dry waste form. The current leak volume estimate for tank SX-107 is less than 5,000 gal (HNF-EP-0182) based on a leak volume recorded in PNL-4688, *Assessment of Single-Shell Tank Residual Liquid Issues at Hanford Site, Washington*. No technical basis was given for this leak volume estimate.

5.2.1.3 Interim Stabilization. Tank 241-SX-107 was administratively stabilized in October 1979 after photos of the waste were reviewed (HNF-SD-RE-TI-178).

Figure 5.2-2 depicts a mosaic of the waste surface in tank SX-107 as of March 1987, indicating a dry surface and no supernate present in this tank. As of September 2008 the tank is estimated to contain 94,000 gal of sludge and no saltcake (HNF-EP-0182).

5.2.1.4 Tank 241-SX-107 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-107 starts in August 1956 and continues through June 1968 (RHO-CD-1172 pages B-75 through B-116). Temperature plots (Appendix A) show tank SX-107 waste temperature reached a maximum of 390 °F in February 1958. The waste temperature gradually decreased to between 240 and 260 °F in August 1961 after REDOX additions stopped and stayed at that level until October 1964, after resumed REDOX additions, when it increased to a peak of 310 °F in February 1966. Temperature then dropped to ~280 °F in May 1966 and stayed between 280 and 290 °F until June 1968. These relatively high tank waste temperatures are consistent with the operating practices for tanks that contained boiling REDOX HLW.

Figure 5.2-2. Tank 241-SX-107 Waste Surface (March 1987)



5.2.2 Data Review and Observations

5.2.2.1 Lateral and Drywell Results. The first indications of a leak in SX-107 were recorded March 9, 1964 when radioactivity was detected in lateral no. 1, ~15 ft from the outer edge of the tank (see Table 5.2-2). Activity levels in the lateral continued to increase to a peak of 1,600,000 counts per minute (cpm) in August 1964. No further change was detected until October 1965 when an increase to 1,700,000 cpm is recorded. No activity was measured in laterals 2 or 3. Results of spectral logging through June 1995 (see Figure 5.2-3) show elevated ^{137}Cs activity near 1,000 pCi/g between 50 and 70 ft in drywells 41-07-05 and 41-07-08 and saturating the detector in drywell 41-07-07 (GJ-HAN-9, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank SX-107*). Additional 1995 results using the HRLS (see Figure 5.2-3) show elevated ^{137}Cs activity from 10^5 to 10^8 pCi/g between

58 and 66 ft in drywell 41-07-07 and 41-07-05 (GJPO-HAN-4). On the basis of the highest concentration profile existing in borehole 41-07-07, it is likely this borehole is closest to the location of the leak. Drywell 41-07-07 activity has increased since at least 1976. Drywell results for borehole 41-10-01 indicate a slight increase in concentration suggesting contaminants may be moving to the south.

2005 Lateral Information
Tank SX-107 laterals were re-logged in May 2005 (RPP-RPT-27605, *Gamma Surveys of the Single-Shell Tank Laterals for A and SX Tank Farms*). Results are shown in Figures 5.2-4, 5.2-5 and 5.2-6 and appear consistent with lateral measurements and plume distribution estimates used for the Goodman kriging analyses. The detection ranges for detectors used are:

- Sodium iodide: 5 to 90,700 pCi/g
- Green GM: 1,160 to 16.9 million pCi/g
- Red GM: 20,500 to 298 million pCi/g.

5.2.2.2 Kriging Analysis. Kriging analysis, documented in the S/SX Field Investigation Report (RPP-7884), was used to estimate a ^{137}Cs leak inventory. "The goal of kriging analysis of the ^{137}Cs data was to establish mathematically defensible estimates associated with the gamma contamination around each tank in SX-Farm" (RPP-7884 page 3-22). Kriging estimates were based on the gross gamma and spectral gamma data collected from drywells and laterals. The mass of the SX-107 tank leak calculated by this method was 17,100 Ci ^{137}Cs (decay corrected to January 1, 1994) (RPP-6285, *Inventory Estimates for Single-Shell Tank Leaks in S and SX Tank Farms*).

HydroGeologic, Inc. (HGL) performed another kriging analysis after obtaining slant borehole samples at tank SX-108 and updated spectral gamma data. This analysis resulted in a larger inventory estimate for tank SX-107 (48,000 pCi decayed to January 1, 1994) (RPP-8209, *Geostatistical Analysis of Gamma-Emitting Radionuclides in the SX Tank Farm Vadose Zone*). However, the S/SX Field Investigation report (RPP-7884) states, "the HGL kriging analysis results for tank SX-107 were driven by gamma logging data from the three laterals. One lateral was projected to have cesium-137 activity at levels close to $8.0X10^8$ pCi/g." RPP-7884 concludes that this "strongly influenced the SX-107 ^{137}Cs estimates" and that this high lateral value "appears to be an artifact of the data handling methodology" and "resolution of this issue will likely require re-logging of the laterals under the tank SX-107 with a calibrated spectral gamma tool." As shown in Figures 5.2-4, 5.2-5 and 5.2-6, the 2005 lateral data show a peak ^{137}Cs concentration of 6×10^7 in 2005 or 7.7×10^7 pCi/g decayed to January 1, 1994. This indicates that gamma activity in the lateral below tank SX-107 was lower than at tank SX-108 and, as previously suspected, the Montana State University kriging calculation (RPP-6285) appears to provide a better estimate for the ^{137}Cs inventory at SX-107. Although sources of error and uncertainty have been identified for the kriging methodology (Internal letter LTR 081246, "Hanford Groundwater Vadose Zone Integration Project Expert Panel Closeout Report for Panel Meeting Held May 24-26, 2000," Appendix A), kriging results for SX-107, SX-108 and SX-109 tank leaks compare favorably with simplified calculations using current vadose zone data (see Figure 5.2-7).

Table 5.2-2. Tanks 241-SX-107, 241-SX-108 and 241-SX-109 Lateral Radioactivity (counts per minute) (December 1962 through June 1987) (RPP-RPT-29191) (1 of 6 sheets)

Date	Reference	241-SX-107 No. 1	241-SX-107 No. 2	241-SX-107 No. 3	241-SX-108 No. 1	241-SX-108 No. 2	241-SX-108 No. 3	241-SX-109 No. 1	241-SX-109 No. 2	241-SX-109 No. 3
12/62	A	No activity detected								
1/63	B				No change in readings					
2/63	C				“Continued probing revealed no increase in radiation readings”					
3/63	D E				“Took radiation reading under the 108-SX Tank with no increase noted” Activity detected in laterals no.1 and 2; max. 18,000					
4/63	F									
5/63	G									
6/63	H				“Laterals under the 108-SX, 109-SX, 111-SX, 112-SX and 115-SX were monitored; no readings were obtained except under the 108-SX”					
7/63	I	“Continued checking of the laterals under the SX storage tanks. No change was detected.”								
8/63	J	“Continued checking of the laterals under the SX storage tanks. No change was detected.”								
9/63	K	“Continued checking of the laterals under the SX storage tanks. No change was detected.”								
10/63	L	“Continued checking of laterals, no change in readings noted.”								
11/63	M	“Continued checking of laterals, no change in readings noted.”								
12/63	N	“Continued checking of laterals, no significant change in readings noted.”								
1/64	O	“Continued with no significant changes noted.”								
2/64	P	“No changes noted except for a 550 c/m reading detected in the South lateral under the 114-SX Tank. Daily checking revealed no change at the end of the month.”								
3/9/64	Q	2,500 ~15 ft from outer edge of tank								
3/10/64	R page 41	5,500 ~15 ft from outer edge of tank	No activity	No activity						

Table 5.2-2. Tanks 241-SX-107, 241-SX-108 and 241-SX-109 Lateral Radioactivity (counts per minute) December 1962 through June 1987 (RPP-RPT-29191) (2 of 6 sheets)

Date	Reference	241-SX-107			241-SX-108			241-SX-109		
		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
3/21/64	R page 45	10,000 ~15 ft from outer edge of tank								
3/31/64	Q	26,000 ~15 ft from outer edge of tank								
5/1/64	R page 92	80,000 ~15 ft from outer edge of tank	No activity	No activity						
5/28/64	R page 92	138,000 ~15 ft from outer edge of tank	No activity	No activity						
7/1/64	R page 140				22,000 ~5 ft from west side of tank					
7/30/64	R page 140				52,000 ~5 ft from west side of tank					
8/31/64	R page 153	1,600,000	No activity	No activity	158,000					
9/30/64	R page 176	No change			260,000	Increase from 27,000 to 52,000				
11/1/64	R page 185				340,000	114,000	No indications of vapor header leak			
12/30/64	R page 205				670,000	180,000				

Table 5.2-2. Tanks 241-SX-107, 241-SX-108 and 241-SX-109 Lateral Radioactivity (counts per minute) December 1962 through June 1987 (RPP-RPT-29191) (3 of 6 sheets)

Date	Reference	241-SX-107			241-SX-108			241-SX-109		
		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
1/16/65	S page 16				Increase slightly at 96 ft 1,000,000 at 108 ft >1,000,000 at 112 ft	52,000 at 88 ft 300,000 at 104 ft				
2/6/65	S page 28							"Tank 109-SX has been reported to give evidence of leakage, in addition to the three leak peaks now being monitored as above scale under 108-SX. New instrumentation to better monitor these tanks is being considered, since current measuring instruments are limited to 500,000."		
2/20/65	S page 36									5,000
3/20/65	S page 54				"Contamination readings are static, no new report."					
3/31/65	S page 65	"No significant change in lateral activity or dry wells around tank."			"Activity in both "hot" laterals increased… On 3/30/65, soil science group took a soil sample from 108-SX air cooled condenser base 16' below grade and drilled 30'. None of the soil samples were radioactive."				14,100	
4/29/65	S page 87	"No change."			"Activity in both hot laterals continued to increase."			200	40,000	2,000 at 95 ft
5/26/65	S page 99	"No significant change in laterals or dry well readings."			"Peak readings in each lateral increased slightly."					

Table 5.2-2. Tanks 241-SX-107, 241-SX-108 and 241-SX-109 Lateral Radioactivity (counts per minute) December 1962 through June 1987 (RPP-RPT-29191) (4 of 6 sheets)

Date	Reference	241-SX-107			241-SX-108			241-SX-109		
		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
6/23/65	S page 111	"No significant change in laterals or dry well readings noted."			"Lateral readings are continuing to show an activity spread near the laterals. Peak readings are continuing to increase."					
7/14/65	S page 120	"No significant change in laterals or dry well readings."			"Peak readings in the laterals under this tank have continued to show slight increase."					
8/4/65	S page 129	"No significant change in laterals or dry well readings."			"Peak readings in the laterals under this tank appear to be leveling out."					
9/1/65	S page 141					132,000 at 92 ft			60,000 to 65,000	
9/8/65	S page 144	"No significant change in laterals or dry well readings."								
9/15/65	S page 147								79,000	
9/29/65	S page 153					150,000 at 92 ft				
10/6/65	S page 156	1,700,000 at 96 ft 8,000 at 118 ft			1,080,000 at 110 ft	385,000 at 102 ft		57,000 at 98 ft	93,000 at 86 ft	90,000 at 108 ft
10/13/65	S page 159	1,700,000 at 96 ft 8,000 at 118 ft			1,035,000 at 110 ft	390,000 at 102 ft		58,000 at 98 ft	99,000 at 96 ft	90,000 at 108 ft
10/20/65	S page 162	1,700,000 at 96 ft 8,000 at 118 ft			1,095,000 at 110 ft	390,000 at 102 ft		63,000 at 98 ft	99,000 at 96 ft	99,000 at 108 ft
10/27/65	S page 165	"No significant change in laterals or dry well readings."			"Lateral readings are continuing to show slight increase."			"Lateral readings are continuing to show slight increase."		
11/24/65	S page 177	"No significant change in laterals or dry well readings."			"Lateral readings under this tank appear to have leveled off this month but leveling may be due to lower reading No. 2 caisson probe replacements."			"Lateral readings under this tank appear to have leveled off this month may be due to the reason listed above." (see SX-108)		

Table 5.2-2. Tanks 241-SX-107, 241-SX-108 and 241-SX-109 Lateral Radioactivity (counts per minute) December 1962 through June 1987 (RPP-RPT-29191) (5 of 6 sheets)

Date	Reference	241-SX-107			241-SX-108			241-SX-109		
		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
12/22/65	S page 189	"No significant change in laterals or dry well readings."			"No significant change under this tank. No loss of material has been detected."			"No significant change in lateral readings during this report period."		
1/31/66	T page 10	1,700,000			600,000	250,000		19,500	29,000	42,000
2/28/66	U page 11	1,710,000			960,000	600,000		24,000	50,000	130,000
3/31/66	V page 13	1,700,000			930,000	705,000	945,000	55,500	160,000	22,000
4/30/66	W page 13	1,700,000			1,200,000	960,000	960,000	30,000	57,000	not reported
5/31/66	X page 11	1,650,000			1,050,000	1,020,000	970,000	38,000	54,000	150,000
6/30/66	Y page 11	1,620,000			885,000	930,000	1,020,000	40,000	660,000	180,000
9/9/68 9/23/68	Z pages D-2, G-4		2 M-3 M	Increased activity						
1/2/73	AA page 41-07-08	420,000	780,000	975,000						
12/31/73	AA page 41-07-08	190,000	1,245,000	570,000						
9/4/74	AA page 41-07-08	132,000	780,000	300,000						
7/28/80	AA page 41-07-08			257K/180K						
6/15/81	AA page 41-07-08	102,000	624,000	253K/NA						
7/26/82	AA page 41-07-08	90,000	580K/42K	246K/192K						
6/14/83	AA page 41-07-09	83,000	614K/45K	249K/NA						
6/5/84	AA page 41-07-08	78K/115K	629K/48K	249K/216K						

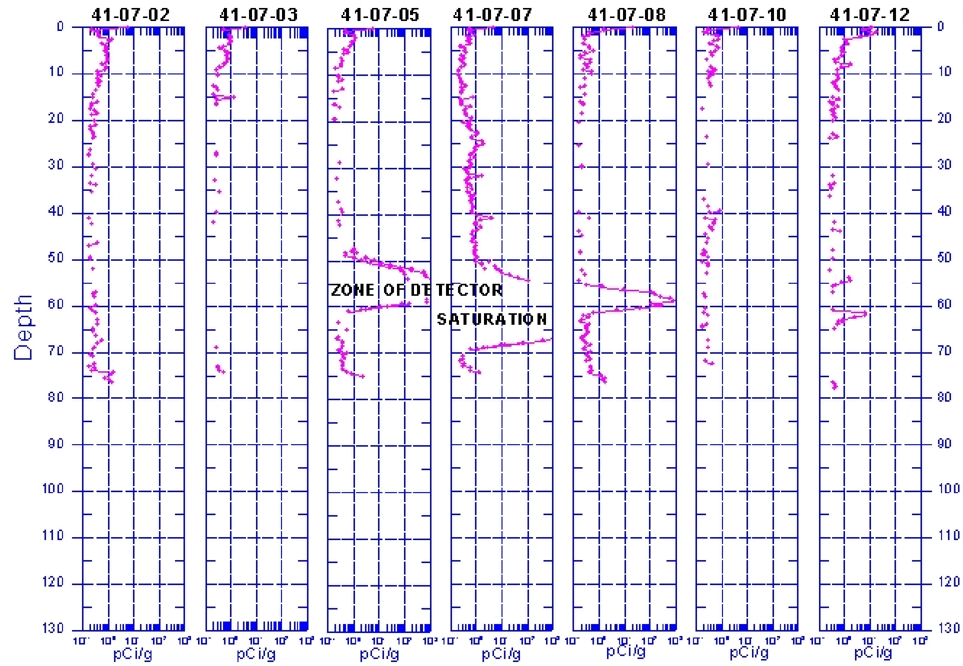
Table 5.2-2. Tanks 241-SX-107, 241-SX-108 and 241-SX-109 Lateral Radioactivity (counts per minute) December 1962 through June 1987 (RPP-RPT-29191) (6 of 6 sheets)

Date	Reference	241-SX-107			241-SX-108			241-SX-109		
		No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
6/17/85	AA page 41-07-08	57K/124K	499K/45K Stable	241K/204K						
6/23/87	AA page 41-07-08	46K/141K Stable	651K/45K Stable	255K/213K Stable						

Title reference is RPP-RPT-29191, *Supplemental Information Hanford Tank Waste Leaks*
Reference A is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation December 1962*, Rough Draft (Harmon 1963a)
Reference B is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation January 1963*, Rough Draft (Harmon 1963b)
Reference C is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation February 1963*, Rough Draft (Harmon 1963c)
Reference D is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation March 1963*, Rough Draft (Harmon 1963d)
Reference E is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation March 1964*, Rough Draft (Smolen 1964)
Reference F is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation April 1963*, Rough Draft (Harmon 1963e)
Reference G is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation May 1963*, Rough Draft (Harmon 1963f)
Reference H is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation June 1963*, Rough Draft (Harmon 1963g)
Reference I is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation July 1963*, Rough Draft (Harmon 1963h)
Reference J is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation August 1963*, Rough Draft (Harmon 1963i)
Reference K is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation September 1963*, Rough Draft (Harmon 1963j)
Reference L is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation October 1963*, Rough Draft (Harmon 1963k)
Reference M is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation November 1963*, Rough Draft (Harmon 1963l)
Reference N is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation December 1963*, Rough Draft (Harmon 1963m)
Reference O is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation January 1964*, Rough Draft (Harmon 1964a)
Reference P is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation February 1964*, Rough Draft (Harmon 1964b)
Reference Q is *Monthly Report Waste Handling and Decontamination Operation REDOX Operation March 1964*, Rough Draft (Harmon 1964c)
Reference R is HW-80202, *REDOX Weekly Process Reports January through December, 1964*
Reference S is RL-SEP-297, *REDOX Weekly Process Reports January through December, 1965*
Reference T is HAN-93855-1, 1966, *200 Area Monthly Report for January 1966*
Reference U is HAN-93855-2, 1966, *200 Area Monthly Report for February 1966*
Reference V is HAN-93855-3, 1966, *200 Area Monthly Report for March 1966*
Reference W is HAN-93855-4-DEL, 1966, *200 Area Monthly Report for April 1966*
Reference X is HAN-93855-5, 1966, *200 Area Monthly Report for May 1966*
Reference Y is HAN-93855-6-DEL, 1966, *200 Area Monthly Report for June 1966*
Reference Z is ARH-308-DEL, 1968, *200 Areas Operation Monthly Report September 1968*
Reference AA is SD-WM-TI-356, 1988, *Waste Storage Tank Status and Leak Detection Criteria*

Figure 5.2-3. Cesium-137 Concentrations in Drywells Surrounding Tank 241-SX-107

Spectral Gamma-Ray Logging System



High Rate Logging System

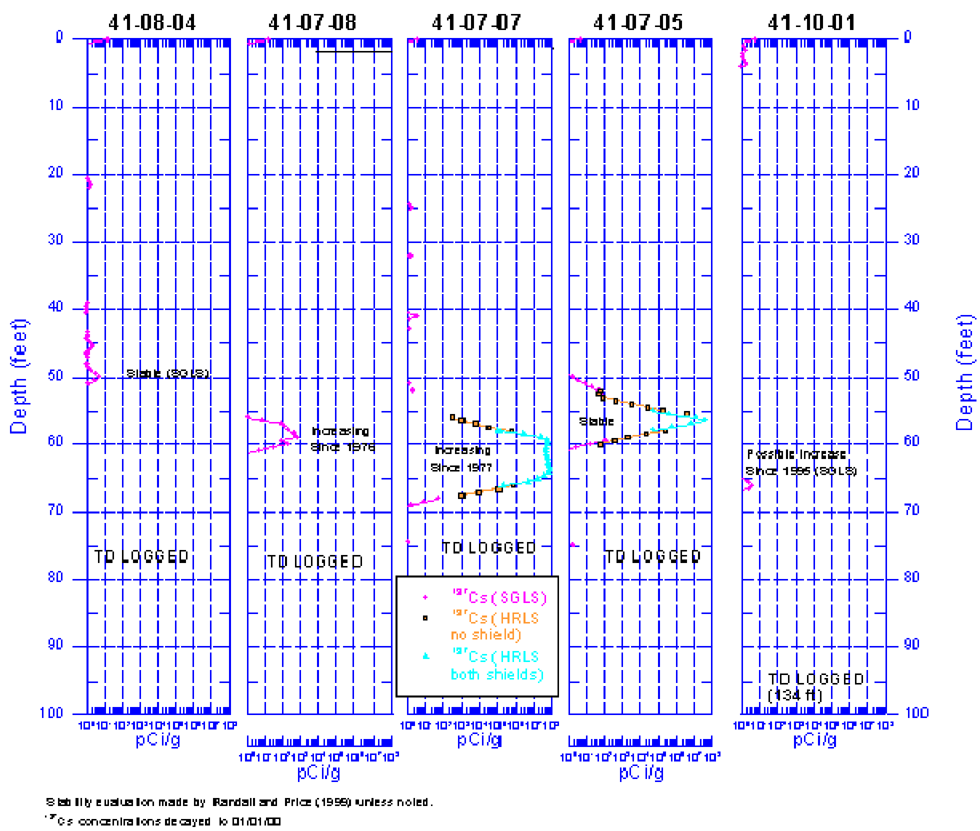
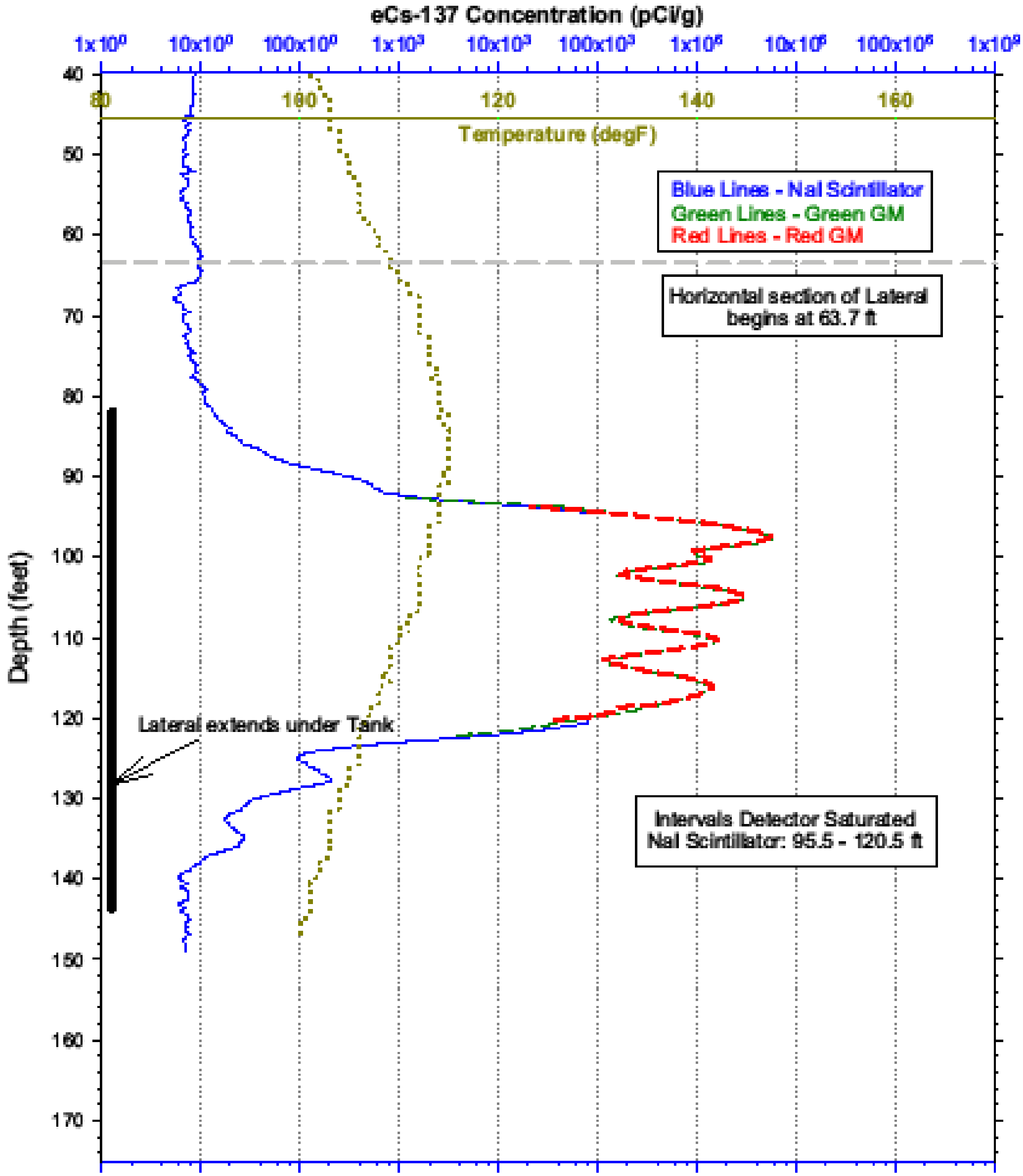
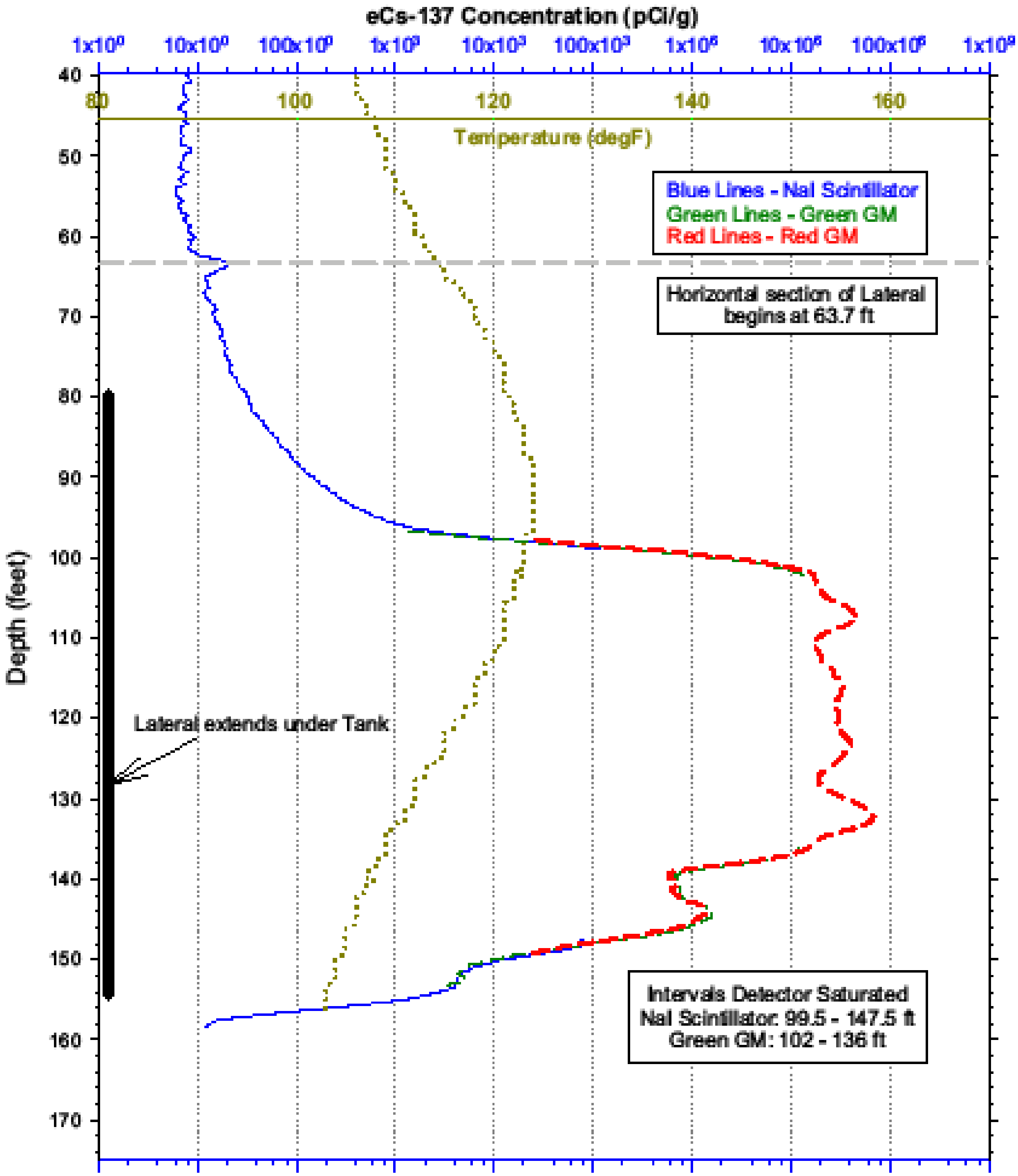


Figure 5.2-4. Gamma Survey for Lateral 44-07-01 on Log Scale (May 2005)



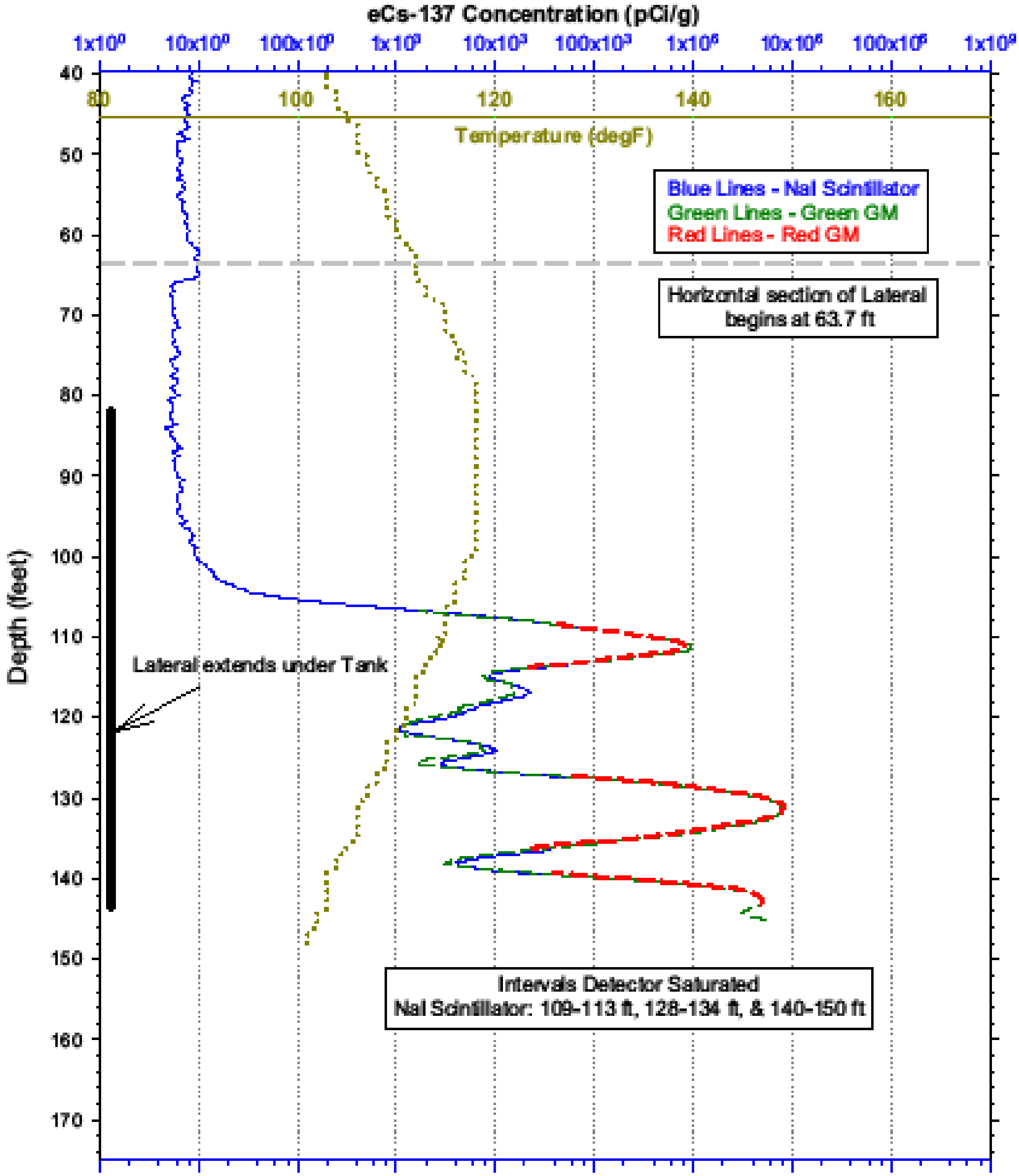
Log date: May 2005. Reference depth: ground level.

Figure 5.2-5. Gamma Survey for Lateral 44-07-02 on Log Scale (May 2005)



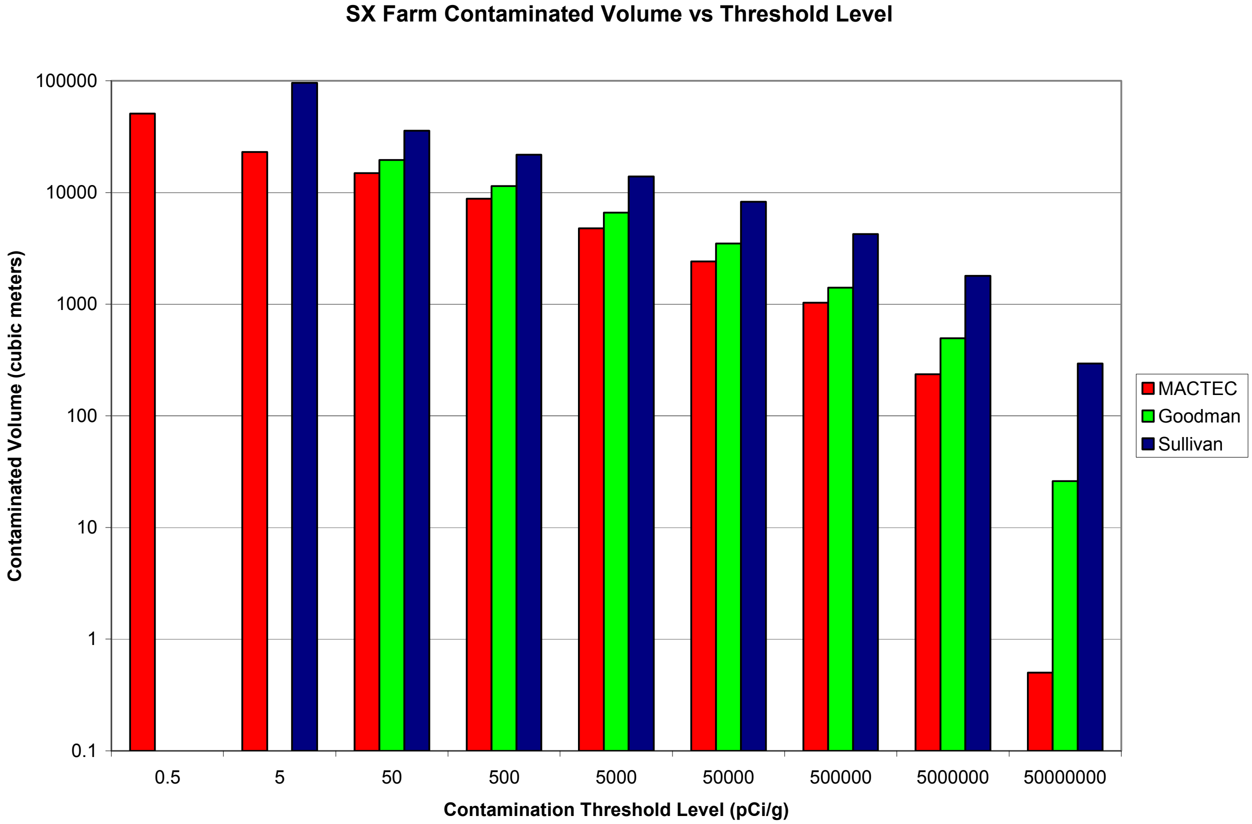
Log date: May 2005. Reference depth: ground level.

Figure 5.2-6. Gamma Survey for Lateral 44-07-03 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

Figure 5.2-7. Comparison of Leak Volume Estimates Using Different Methods



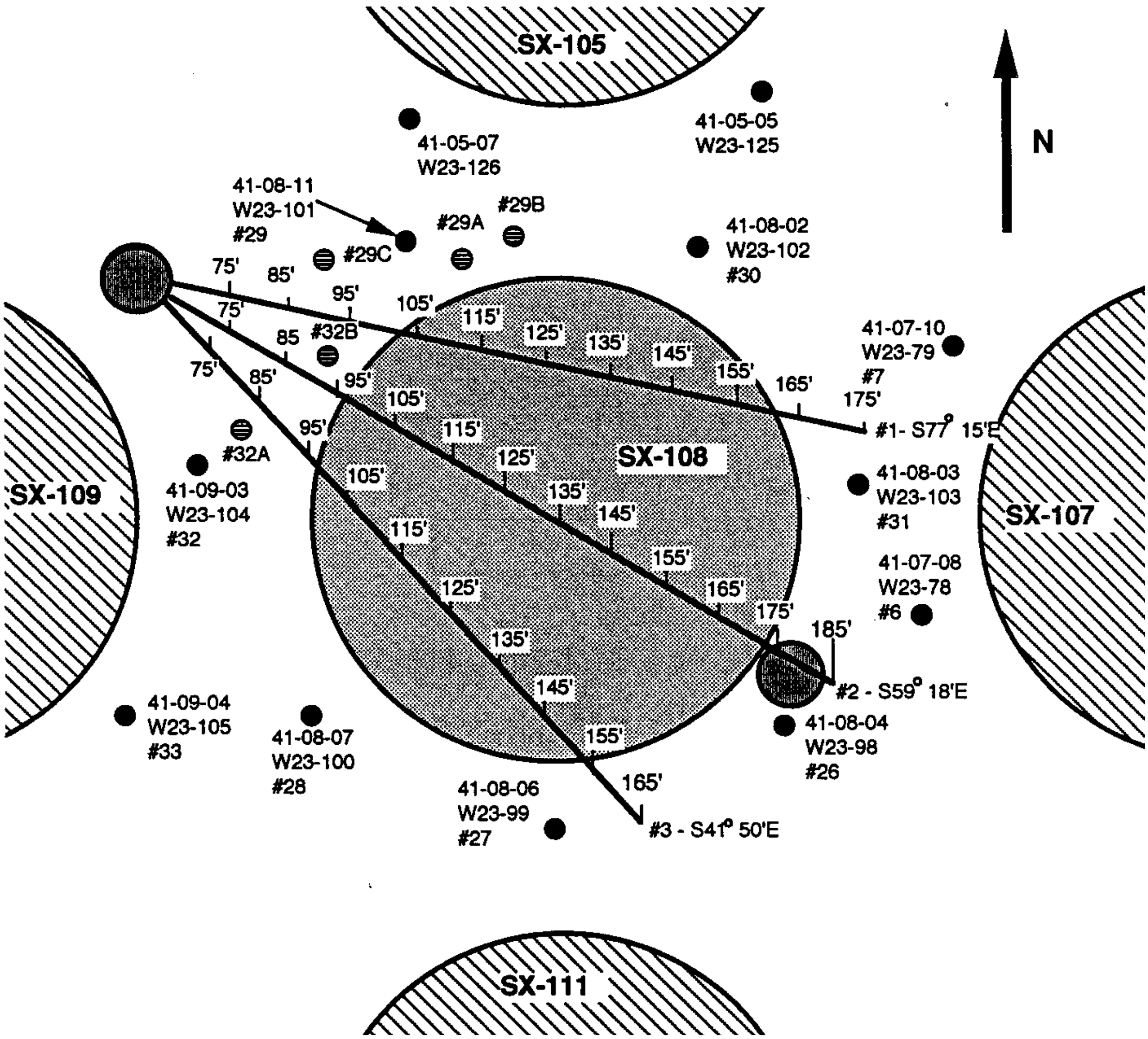
5.2.3 Conclusions

The estimated SX-107 tank leak inventory for ^{137}Cs is 17,000 Ci decayed to January 1994 or 13,400 Ci decayed to January 2001 based on vadose zone data and kriging analyses. For an inventory of 17,000 Ci, a leak volume of 6,400 gal was calculated based on an average, model based, REDOX tank waste composition estimate at the time of the leak of 2.7 Ci/gal (RPP-6285). This is close to the estimate of <5,000 gal in HNF-EP-0182. As noted previously, no sample data for tank SX-107 was available near the time of the leak. The only SX-107 supernatant samples were collected in 1977 (well after the leak occurred) and after additional REDOX waste, supernate and condensate were added to tank SX-107. Like tank SX-108, because of the large amount of water added to tank SX-107 (RPP-6285) the ^{137}Cs leak concentration may have been smaller and the leak volume larger; this would change the distribution of mobile contaminants, but would not change the ^{137}Cs inventory. To calculate the inventory for other analytes, multiply the ratio of the revised ^{137}Cs inventory (14,500 Ci) and the HDW/Soil Inventory Model (SIM) ^{137}Cs inventory (17,900 Ci) by the SIM inventory for the selected analyte.

5.3 TANK 241-SX-108 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST 241-SX-108. Tank SX-108 has three laterals (horizontal boreholes) installed about 10 ft under the tank, as depicted in Figure 5.3-1 (GJPO-HAN-4) and drawing H-2-31881, *241-SX Tank Farm Leak Detection System Plan – Section*. There are seven boreholes (41-08-02, 41-08-03, 41-08-04, 41-08-06, 41-08-07, 41-09-03 and 41-08-11) located around tank SX-108.

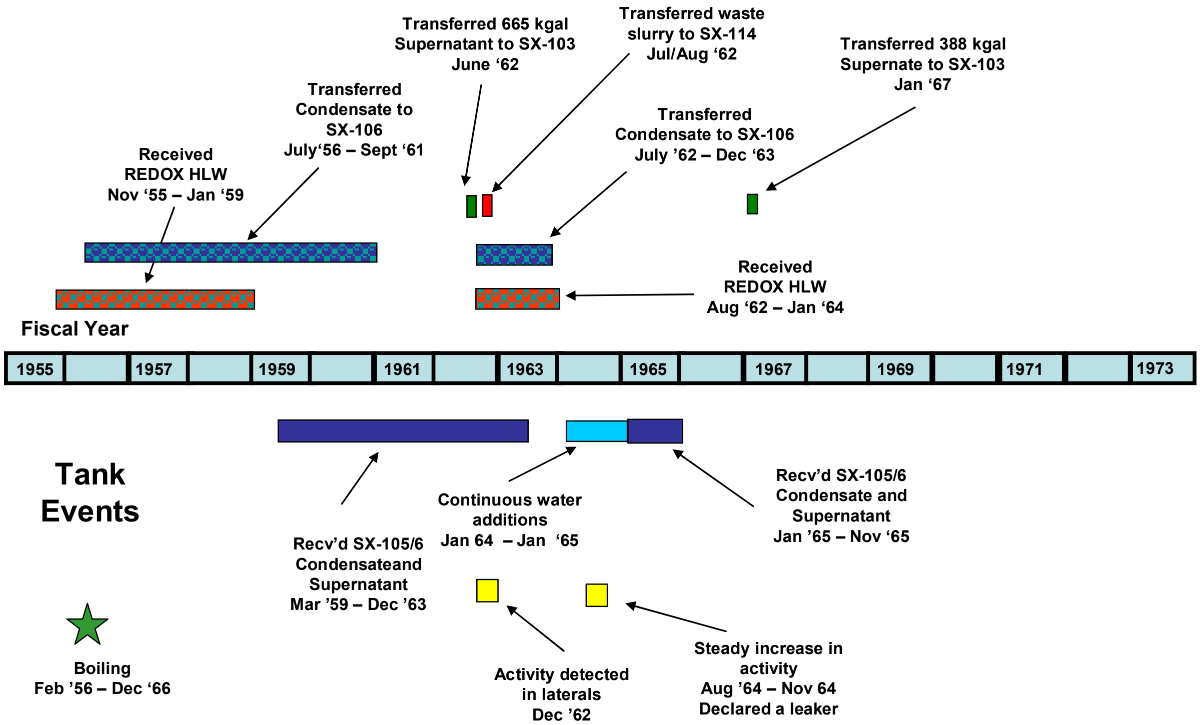
Figure 5.3-1. Tank 241-SX-108 Drywell Locations



5.3.1 Tank 241-SX-108 Waste Operations Summary

The following subsections provide a brief discussion of the waste transfer history for tank SX-108 summarized in Figure 5.3-2.

Figure 5.3-2. Tank 241-SX-108 Operating History (Fiscal Years 1955 to 1967)



5.3.1.1 Tank 241-SX-108 Waste History. Tank 241-SX-108 was put into service November 8, 1955 when REDOX HLW was transferred into the tank. Normally tanks receiving boiling waste were preheated prior to use to minimize transfer stresses. However, tanks in the SX-Farm were not fitted with steam coils and SX-108 was not preheated prior to use. In June 1956 tank SX-108 started boiling (RHO-R-39) and by December 31, 1956, 532,000 gal of aged REDOX HLW supernate[3] were added to the tank with 32,000 gal of water (HWN-1991-DEL p. 48). REDOX additions continued, waste losses occurred due to evaporation and boil off and supernate was added from tank SX-106 through 1959 (WHC-SD-WM-TI-614, *Waste Status and Transaction Record Summary for the Southwest Quadrant of the Hanford 200 Area*). Water evaporated from SX-108 was condensed and collected in tank SX-106. By December 31, 1958 the tank was filled with 785,000 gal of REDOX waste (HW-58201, *Chemical Processing Department Waste Status Summary October 1, 1958 – October 31, 1958*, page 8). In April 1961 the supernate was analyzed (HW-69443 page G-5). Small REDOX additions, evaporation and boil off continued until May 1962 when 665,000 gal of supernate was pumped to tank 241-SX-103 (SX-103) (HW-83906-E-RD, *Chemical Processing Department 200 West Area Tank Farm Inventory and Waste Reports July 1961 Through 1966*, page 13). The sludge in tank SX-108 was leached with condensate from tank SX-106, resulting in the reduction of the sludge height from 30 in. to 14 in. (HW-74522 C, *Chemical Research and Development Operation Monthly Report – July 1962*, page C-6). Rotary core sludge samples were obtained in July and August 1962 (HW-74522 C page C-6, HW-74505, *Chemical Processing Department Monthly Report July, 1962*, page G-4,

[3] Aged REDOX HLW supernate refers to supernate that no longer generated sufficient heat to cause self-boiling.

and HW-74804, *Chemical Processing Department Monthly Report August, 1962*, page G-6). No results from these sludge core samples were located. The sludge leachate, known as sodium nitrate waste, was transferred in July and August 1962 to tank SX-114 and then to the 202-S Facility (REDOX). .

Dilute non-boiling REDOX waste supernate was transferred from tank SX-105 into tank SX-108 in August 1962 for concentration. Tank SX-108 again received REDOX HLW supernate from August 1962 through January 1964. The REDOX HLW in tank SX-108 self-concentrated and water was evaporated. Condensate was periodically transferred from tank SX-106 into tank SX-108 from January 1965 through November 1965 to maintain the waste temperature and density within operating limits.

Waste transfer volumes from May 1962 through December 1965 are shown in Table 5.3-1. In addition to waste transfers in and out of the tank, the table shows that large volumes of water unaccounted for in WHC-SD-WM-TI-614 or WHC-MR-0300, *Tank 241-SX-108 Leak Assessment* were added to the tank from January through December of 1964. In 1964 the tank was declared a leaker. In November 1965 tank SX-108 was isolated from the tank farm condensate system and fitted with its own condenser (RL-SEP-874-DEL, *Chemical Processing Department Monthly Report for November 1965*, page C-3). Supernate samples were obtained in December 1965 and 388 kgal of supernate was transferred from SX-108 to tank SX-103 in January 1967 (ISO-806, *Chemical Processing Division Waste Status Summary January 1, 1967 Through March 31, 1967*, page 8).

5.3.1.2 Tank 241-SX-108 Integrity Status. Tank SX-108 was removed from service and identified as a confirmed leaker in 1964 based on drywell and lateral activity. The current estimated leak volume ranges from 2,400 to 35,000 gal (HNF-EP-0182).

5.3.1.3 Interim Stabilization. The waste surface in tank SX-108 was estimated to be 100% dry cracked solids based on in-tank photographs obtained in July 1977 (HNF-SD-RE-TI-178 page 269). Based on these photographs, tank SX-108 was administratively interim stabilized in August 1979. Figure 5.3-3 depicts a mosaic of the waste surface in tank SX-108 as of March 1987, indicating no supernate is present in this tank. The tank is estimated to contain 74,000 gal of sludge and no saltcake (HNF-EP-0182).

5.3.1.4 Tank 241-SX-108 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-108 starts in January 1957 and continues through May 1969 (RHO-CD-1172 pages B-81 through B-119). Appendix A provides plots showing the maximum temperature (°F) of the waste stored in tank SX-108. These temperature plots show tank SX-108 waste temperature exceeded 300 °F in February and May 1958 and reached a maximum of ~320 °F in September 1958. The waste temperature dropped to 240 °F in January 1959, then increased to 280 ± 20 °F until a drop in temperature to ~150 °F in May and July 1962 corresponding to supernate transfers to tanks SX-103 and SX-114. The waste temperature increased until November 1963 when it peaked at ~290 °F, then gradually increased to greater than 300 °F from January through October 1963. The temperature then began to decrease. There is a break in the thermal history from September 1966 to March 1967. In January and February 1968 the temperature dropped to below 180 °F and has continued to gradually decrease due to radioactive decay. These relatively high tank waste temperatures are consistent with the operating practices for tanks that contained boiling REDOX HLW. The maximum operating temperature for boiling waste tanks was 300 °F (RL-SEP-269, *Specifications and Standards for Operational Control of the PUREX Self-Boiling Tank Farms*, page 5.4-1). As noted, the temperature exceeded this level several times during the periods tank SX-108 received and stored REDOX HLW. Temperature data for drywells and laterals near tank SX-108 were not available.

5.3.2 Data Review and Observations

5.3.2.1 1965 Lateral and Drywell Results. The first indications of a leak in tank SX-108 were recorded in December 1962 when minor amounts of radiation were detected in laterals no. 1 and no. 2 (Table 5.3-2), but the tank was kept in service because further monitoring detected no radiation increases. In August 1964, "a steady increase in radiation was detected in two of the horizontal laterals beneath the108-SX storage tank (Max. 150,000 c/m at month end)" (HW-83876, *Chemical Processing Department Monthly Report for August, 1964*, page C-2). The radioactivity in the laterals increased to 260,000 cpm during September (HW-84354, *Chemical Processing Department Monthly Report September 1964*, page C-2) and 720,000 cpm in November 1964. In mid-1965 readings increased in all laterals. Lateral no. 3, which showed no activity in late 1965, showed the highest activity of all the laterals (see Table 5.2-2) in March 1966, indicating that the plume had spread and moved toward the south. Similarly, drywell 41-08-07 showed no activity in mid-1965, but in 1991 showed the highest readings of all the wells. This may indicate a spreading plume, or it may be evidence of a new leak under the southwest quadrant of the tank, near the well. Support for considering this a new leak is that drywell 41-09-03, situated roughly between the original leak and drywell 41-08-07, showed lower radiation readings.

Test wells were added and soil samples obtained in mid-1965 to further define the affected area. By December 1965 the lateral readings leveled off, and the leak was judged to again have become inactive (BNWL-CC-701, *Characterization of Subsurface Contamination in the SX Tank Farm*). In November 1965, tank SX-108 was isolated from the tank farm condensate system and was fitted with its own condenser. With all condensate being returned to the tank, no loss of level could be detected, within the accuracy of the level readings, which was ± 1,375 gal. Consistent liquid level readings were taken as further confirmation that the leak had become inactive.

The leaked material spread horizontally in two layers at depths of 55 and 60 ft bgs. In March 1967, persistent activity in the laterals led to the conclusion that the leak was again active, and the tank was taken out of service. The liquid contents of the tank were pumped into tank SX-103, leaving the sludge and some supernate in tank SX-108. An induced-draft ventilation system was provided to remove heat and to evaporate the supernate (BNWL-CC-2042, *Thermal Characteristics of Tank 108-SX Sludge*).

Table 5.3-1. Tank 241-SX-108 Waste and Water Transfers (May 1962 through December 1965) (2 sheets)

Date	Activity	Volume (gallons)	HW-83906-E-RD page
Jan 1, 1962	Total waste in storage 702,000 gal sludge temperature 267 °F		10
May 1962	Waste pumped from 108-SX to 103-SX	639,928	13
May 1962	Condensate pumped from 106-SX to 108-SX (dilution)	49,594	13
May 1962	Condensate pumped from 106-SX to 108-SX (sludge removal)	90,923	13
June 1962	Condensate pumped from 106-SX to 108-SX	130,862	13
July 1, 1962	Total waste in storage 316,000 gal; sludge temperature 198 °F (1)		19
July 1962	Waste (slurry) pumped from 108-SX to 114-SX	42,018	22
August 1962	Sludge slurry pumped from 108-SX to 114-SX	162,561	22
August 1962	Dilute waste pumped from 105-SX to 108-SX	326,504	22
August 1962	REDOX D-8 waste received in 108-SX	10,614	22
September 1962	REDOX D-8 waste received in 108-SX	131,703	22
October 1962	REDOX D-8 waste received in 108-SX	106,087	23
November 1962	REDOX D-8 waste received in 108-SX	69,683	23
December 1962	REDOX D-8 waste received in 108-SX	78,760	24
January 1, 1963	Total waste in storage 715,000 gal; sludge temperature 262 °F		28
January 1963	REDOX D-8 salt waste received in 108-SX	165,695	33
June 1963	REDOX D-8 waste received in 108-SX	19,396	31
July 1, 1963	Total waste in storage 525,000 gal; sludge temperature 259 °F Receiving REDOX waste 6-26-63		37
July 1963	REDOX Salt waste received in 108-SX	123,701	42
August 1963	REDOX D-8 waste received in 108-SX	104,652	42
September 1963	REDOX D-8 waste received in 108-SX	116,975	41
October 1963	REDOX D-8 waste received in 108-SX	95,114	41
November 1963	REDOX D-8 salt waste received in 108-SX	47,822	40
November 1963	Condensate pumped from 106-SX to 108-SX (2)	92,989	40
December 1963	REDOX D-8 salt waste received in 108-SX	61,262	40
December 1963	Condensate pumped from 106-SX to 108-SX (2)	38,574	40
January 1, 1964	Total waste in storage 633,000 gal; Liquid temperature 260 °F (1) Began receiving D-8 waste 6-26-63		46
January 1964	REDOX D-8 salt waste received in 108-SX	33,686	50
January 1964	Continuous water addition to 108-SX	16,533	50
February 1964	Continuous water addition to 108-SX	68,708	50
March 1964	Continuous water addition to 108-SX	64,438	50
April 1964	Continuous water addition to 108-SX	70,404	49
May 1964	Continuous water addition to 108-SX	65,186	49
June 1964	Continuous water addition to 108-SX	67,761	49

Table 5.3-1. Tank 241-SX-108 Waste and Water Transfers (May 1962 through December 1965) (2 sheets)

Date	Activity	Volume (gallons)	HW-83906-E-RD page
July 1, 1964	Total waste in storage 660,000 gal; Liquid temperature 250 °F Began receiving D-8 waste 6-26-63		54
July 1964	Continuous water addition to 108-SX	66,932	56c
August 1964	Continuous water addition to 108-SX	50,210	56c
September 1964	Continuous water addition to 108-SX	62,099	56b
October 1964	Continuous water addition to 108-SX	56,350	56b
November 1964	Continuous water addition to 108-SX	52,968	56a
December 1964	Continuous water addition to 108-SX	47,875	56a
January 1, 1965	Total waste in storage 678,000 gal; Sludge temperature 294 °F Liquid temperature 245 °F		60
January 1965	Continuous water addition to 108-SX	13,788	62a
January 1965	Condensate pumped from 106-SX to 108-SX	8,954	62a
February 1965	Condensate pumped from 106-SX to 108-SX	5,510	62a
March 1965	Condensate pumped from 106-SX to 108-SX (3)	33,064	62b
April 1965	Condensate pumped from 106-SX to 108-SX	45,468	62b
May 1965	106-SX condensate pumped to 108-SX	19,285	62c
June 1965	106-SX condensate pumped to 108-SX (4)	19,285	62c
July 1, 1965	Total waste in storage 638,000 gal; Sludge temperature 298 °F		66
July 1965	106-SX condensate pumped to 108-SX (5)	31,683	68a
August 1965	106-SX condensate pumped to 108-SX	27,550	68a
September 1965	106-SX condensate pumped to 108-SX (5)	23,418	68b
October 1, 1965	Total waste in storage 638,000 gal; Sludge temperature 294 °F		72
October 1965	106-SX condensate pumped to 108-SX	11,709	75
November 1965	106-SX condensate pumped to 108-SX	15,153	75
December 1965	No water or condensate additions to 108-SX reported		76
January 1, 1966	Waste height 20 ft, 3 in. (calculated waste volume in storage 649,000 gal); Sludge temperature not reported		80

(1) Temperature of sludge approximately 3 in. off tank bottom; temperature of liquid approximately 5 ft off tank bottom. Total waste in storage = previous waste volume (Jan 1, 1962) +/- transfers – boil-off.

(2) Reported in WHC-MR-0300, *Tank 241-SX-108 Leak Assessment*, page 3-4 as 132,000 gal water added during fourth quarter 1963.

(3) Reported in WHC-MR-0300 page 3-4 as 22,729 gal condensate added on March 31, 1965.

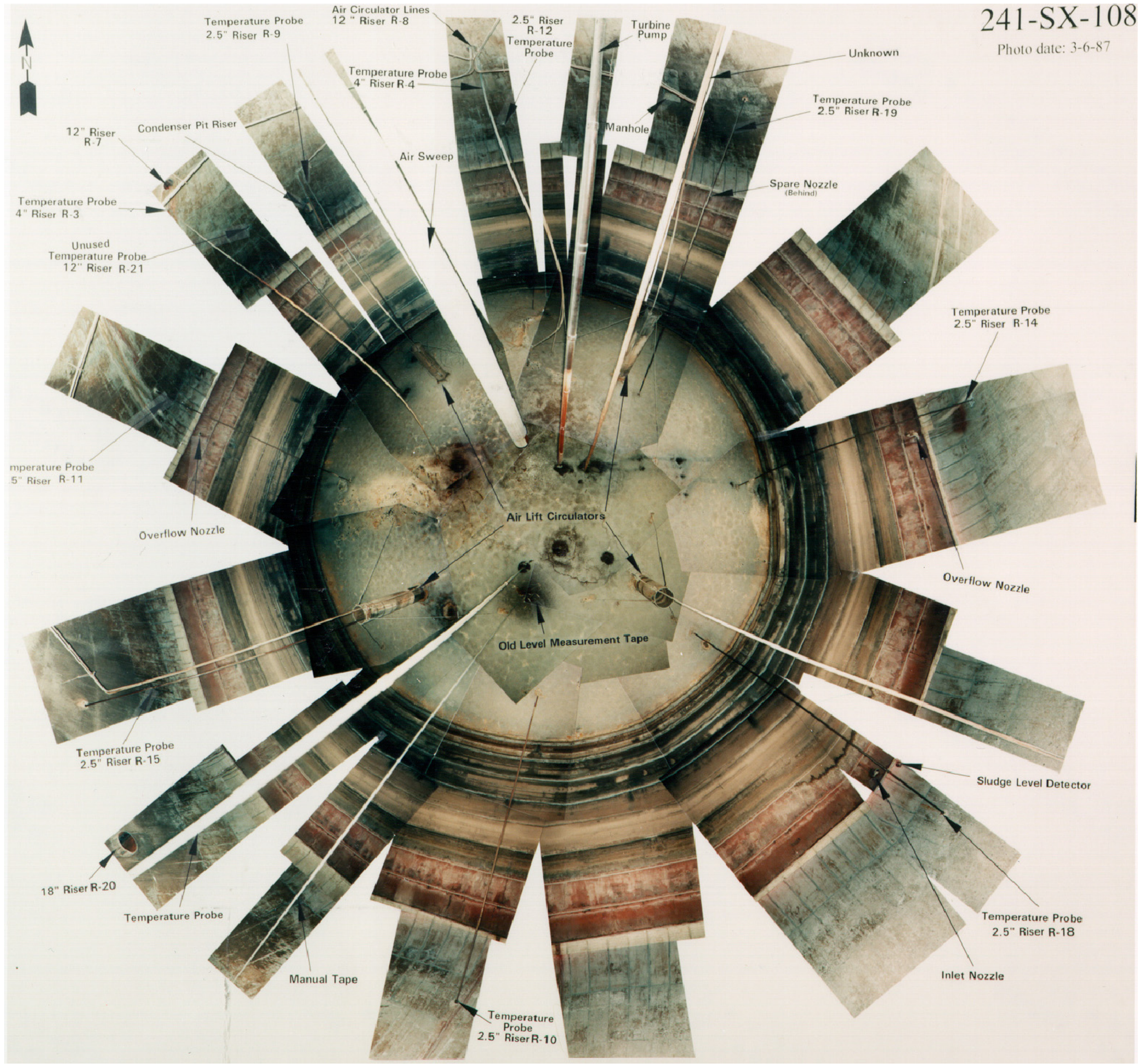
(4) Reported in WHC-MR-0300 page 3-4 as 11,000 gal condensate added on June 16, 1965.

(5) Not reported in WHC-MR-0300 page 3-4.

REDOX = Reduction Oxidation

HW-83906-E-RD, *Chemical Processing Department 200 West Area Tank Farm Inventory and Waste Reports July 1961 Through 1966*

Figure 5.3-3. Tank 241-SX-108 Waste Surface (March 1987)



In September 1967, the bottom liner was determined to be bulged upward (ARH-R-43, *Management of Radioactive Wastes Stored in Underground Tanks at Hanford*). A month later the bottom liner had bulged about 2.5 ft in the northwest quadrant of the tank (ARH-59-DEL, *Monthly Report 200 Areas Operation September 1967*). This indicates either a gradual increase in the bulging of the liner or possibly multiple bulging events. Radioactivity in the laterals generally increased through July 1987. In April 1989 the readings decreased in all laterals. Monitoring of the laterals was stopped at that time, because of an equipment failure in the installed lateral system. Activity measurements made in the drywells at the same time showed that the drywells had changed only slightly, except for drywell 41-08-07. The readings in this well increased in 1989, which is consistent with a general southward movement of the underground plume.

Table 5.3-2. Peak Radioactivity in Tank 241-SX-108 Laterals (counts per second)

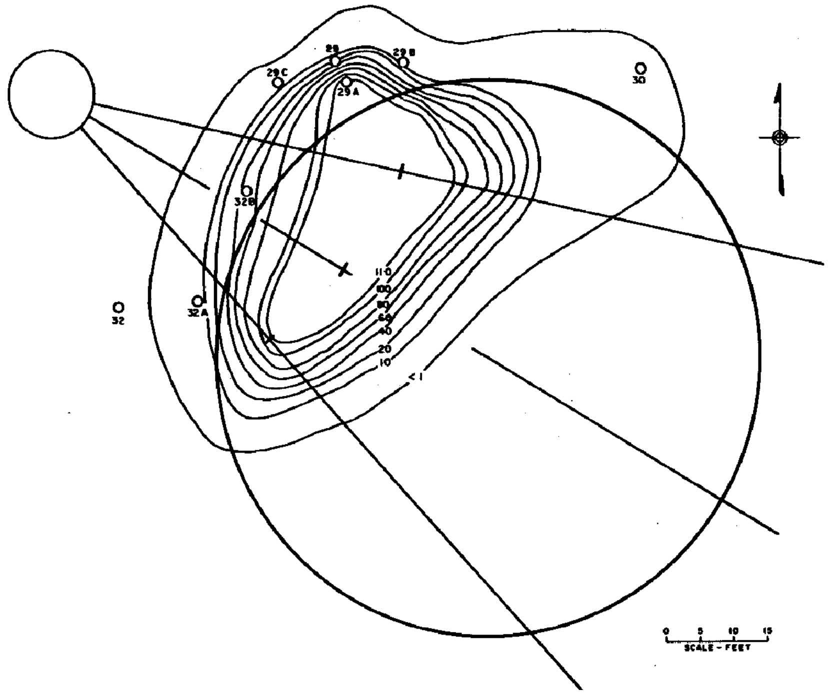
Date	Lateral No. 1	Lateral No. 2	Lateral No. 3
12/62	100[2]	280[2]	–
5/63	140[2]	470[2]	–
12/64	16,700	5,000	–
1965	16,250	11,000	8,500
1970	11,500[1]	16,500[3]	18,000[3]
1971	14,000[3]	20,000[3]	24,000[3]
1972	7,750[1]	10,500[1]	12,250[1]
1/73	9,000[1]	10,250[1]	11,000[1]
8/73	10,000	14,280	16,070
4/74	12,500	20,000	21,000
9/74	8,000[1]	15,500	15,750
2/75	15,750	18,000	18,750
7/75	6,000[1]	7,200[1]	7,250[1]
10/75	6,700[1]	7,500[1]	7,500[1]
3/76	6,150[1]	7,300[1]	7,750[1]
2/77	16,000	17,000	17,000
10/77	16,666	13,000	17,500
7/78	16,000	17,550	17,000
7/79	16,600	17,700	17,100
7/80	14,900	17,000	16,750
6/81	16,000	18,100	18,100
7/82	15,633	18,700	18,650
6/83	16,633	20,650	21,500
6/84	16,667	21,650	23,000
6/85	16,667	22,100	23,733
6/86	16,667	23,250	24,100
7/87	20,200	25,250	26,900
4/89[4]	16,583[2]	19,600	20,000[2]

Notes:
1. Questionable data - possible defective probe
2. From operator's charts and lateral radiation traverses
3. The highest reading for each year was used
4. Last readings taken

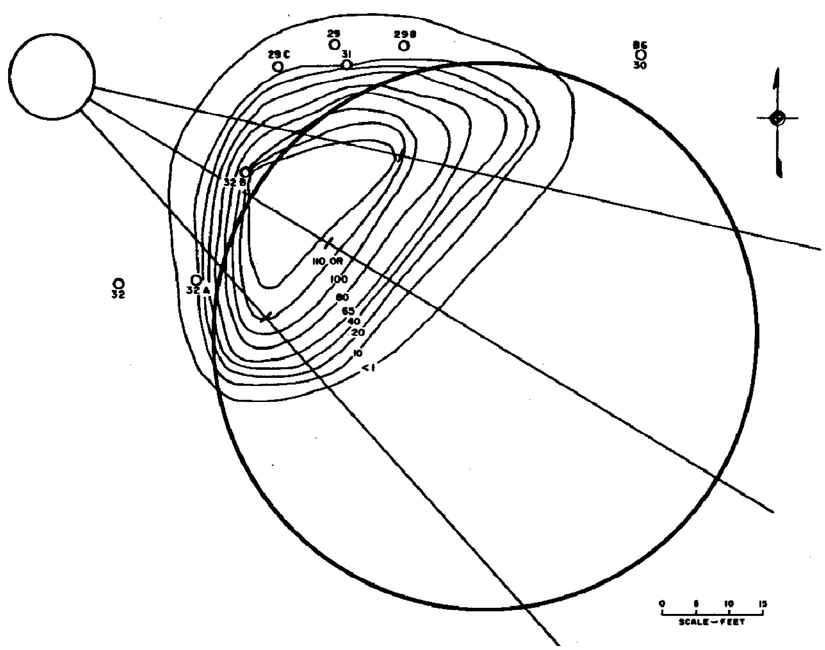
Based on the lateral measurements, logging of seven existing drywells drilled in 1962 and sample analyses results for five additional test wells (29A, 29B, 29C, 32A and 32B) drilled near the tank in 1965, ^{137}Cs concentration iso-plumes were plotted at 55 and 60 ft bgs (Figure 5.3-4). BNWL-CC-701 states that "The leak probably originated at or near the Northwest edge of the tank bottom inboard from well 29A. The waste solution moved downward and to the South at a shallow angle. The area and volume of each iso-concentration zone through 1965 was measured and the total curies of ^{137}Cs within the zone determined." The ^{137}Cs concentration from tank samples taken on December 14, 1965 was 7.22 Ci/gal. The total volume of waste contained in the upper zone (55 ft) was 1,650 gal assuming a 1.8 g/cc soil density. The lower zone (60 ft) contains an estimated 740 gal of ^{137}Cs for a total of 2,400 gal containing 17,400 Ci of ^{137}Cs (BNWL-CC-701).

Figure 5.3-4. Tank 241-SX-108 Lateral ^{137}Cs Contours

Contours at 55 ft

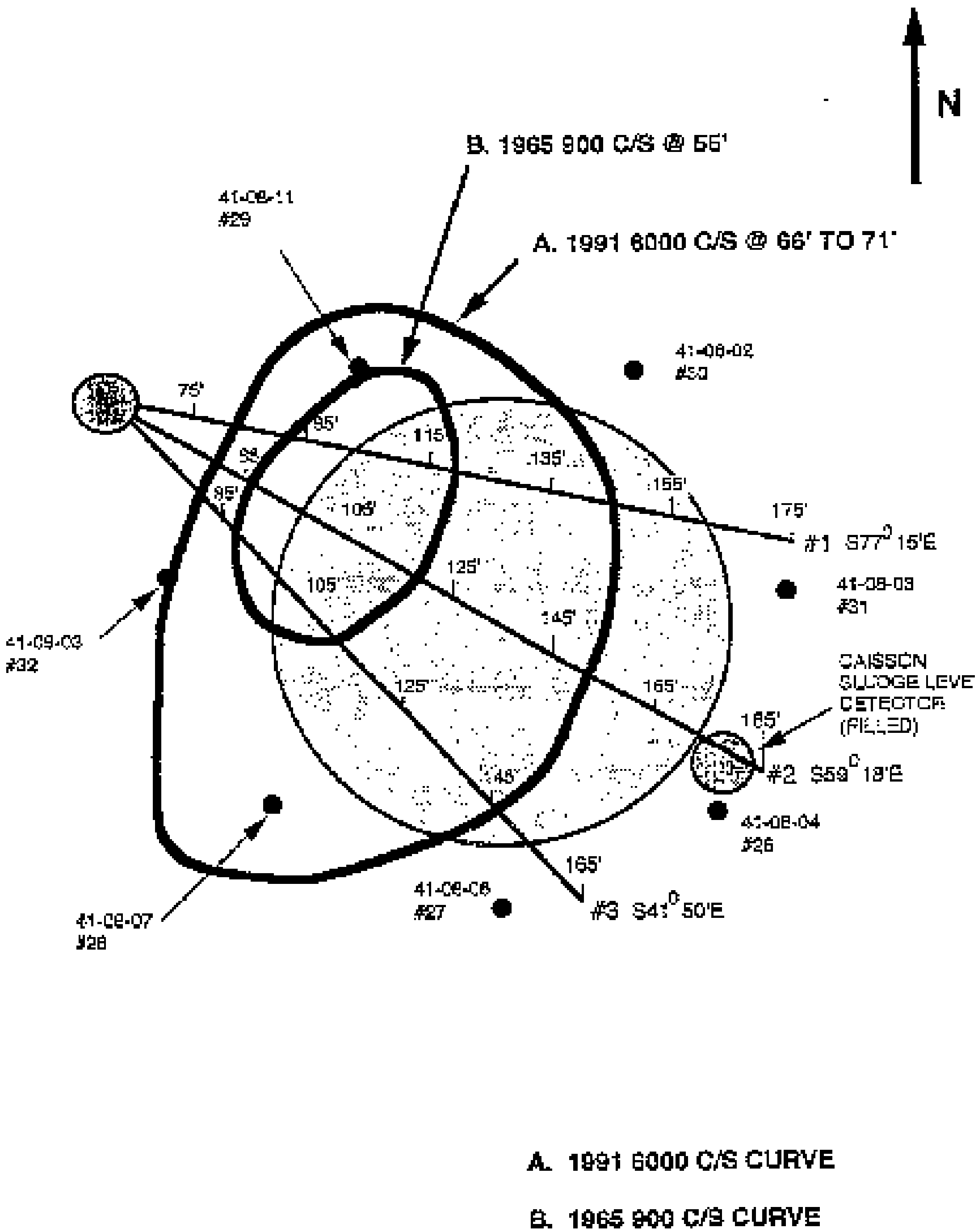


Contours at 60 ft



5.3.2.2 WHC-MR-0300 Evaluation (1992). The leak evaluation performed in mid-1965 documented the amount of leakage (2,400 gal) up to that date. Figure 5.3-5 illustrates the leakage that took place after the mid-1965 leak evaluation. The inner circle is based on readings in drywell 41-08-11 and data obtained for the leak evaluation performed in 1965 (BNWL-CC-701). The outer circle is based on later drywell readings and the April 1989 lateral readings.

Figure 5.3-5. Extent of Tank 241-SX-108 Leak (1965 and 1991)



Further leakage after 1965 is supported by the increased radiation levels in drywells 41-08-07, 41-08-11 and 41-08-02. Also, the activity detected in all three laterals continued to increase from 1973 through 1987, as reported in SD-WM-TI-356 and shown in Table 5.3-3. Analysis of the waste leaking from tank SX-108 shows ^{137}Cs concentrations of 7.22 Ci/gal in December 1965 which decayed to 4.07 Ci/gal by January 1, 1991 (BNWL-CC-701). The tank SX-108 leak volume was estimated to be 2,400 gal to mid-1965 (based on BNWL-CC-701) and 0 to 33,000 gal from March 1967 to August 1968.

The 33,000-gal leak estimate is based on a 24-in. level change observed in photos taken inside the tank. "To allow observation of changes in the liquid level of tank SX-108, and thereby obtain a direct measurement of the amount of leakage, the tank was provided with its own condenser in November 1965. All water evaporating from the tank was condensed and returned to the tank, so that any change in liquid level could be observed" (WHC-MR-0300, page 4-12). No change in liquid levels was observed through June 1966 (BNWL-CC-701). In-tank photos taken in early 1968 show liquid below the sludge surface and indicate an approximate 24-in. liquid level drop. The effective liquid level decrease was taken as 12 in. recognizing "substantial error may be present" due to error in photo estimates, sludge contours, bulged tank surfaces and porosity uncertainty. The volume of liquid lost from tank SX-108 between March 1967 and August 1968 due to evaporation and leakage was estimated at 12 in. or 33,000 gal. WHC-MR-0300 notes that much of this was most likely evaporated and "actual leakage during this period is probably closer to zero than to 33,000 gal" based on rough heat load calculations showing the tank heat load was sufficient to evaporate 48 in. of liquid. However, given the uncertainties in the heat load calculation, evaporation estimates were determined to be inconclusive.

WHC-MR-0300 concluded that:

1. Tank SX-108 was suspected of leaking in December 1962. It was thought to have self-sealed, and the tank was kept in service.

2. Tank SX-108 was definitely observed to have leaked in August 1964. By late 1965 the leak was thought to have self-sealed, but in March 1967 the tank was confirmed to be a leaker and was taken out of service.

3. Total estimated leakage through August 1991 is between 2,400 gal and 35,000 gal. It is probably closer to 2,400 gal than to 35,000 gal.

4. Water or condensate was pumped into the tank on many occasions, all of which appear to be consistent with normal operating practices. No evidence was found of water addition specifically for cooling; when cooling was required, it was done by induced-draft ventilation.

5. Based on a leak ranging from 2,400 to 35,000 gal, the 1965 supernate analysis, and decay calculations to January 1, 1991, the mass of ^{137}Cs leaked from SX-108 was estimated to be between 10,000 and 140,000 Ci.

Table 5.3-3. Tank 241-SX-108 Liquid and Sludge Levels (December 1965 through March 1967)

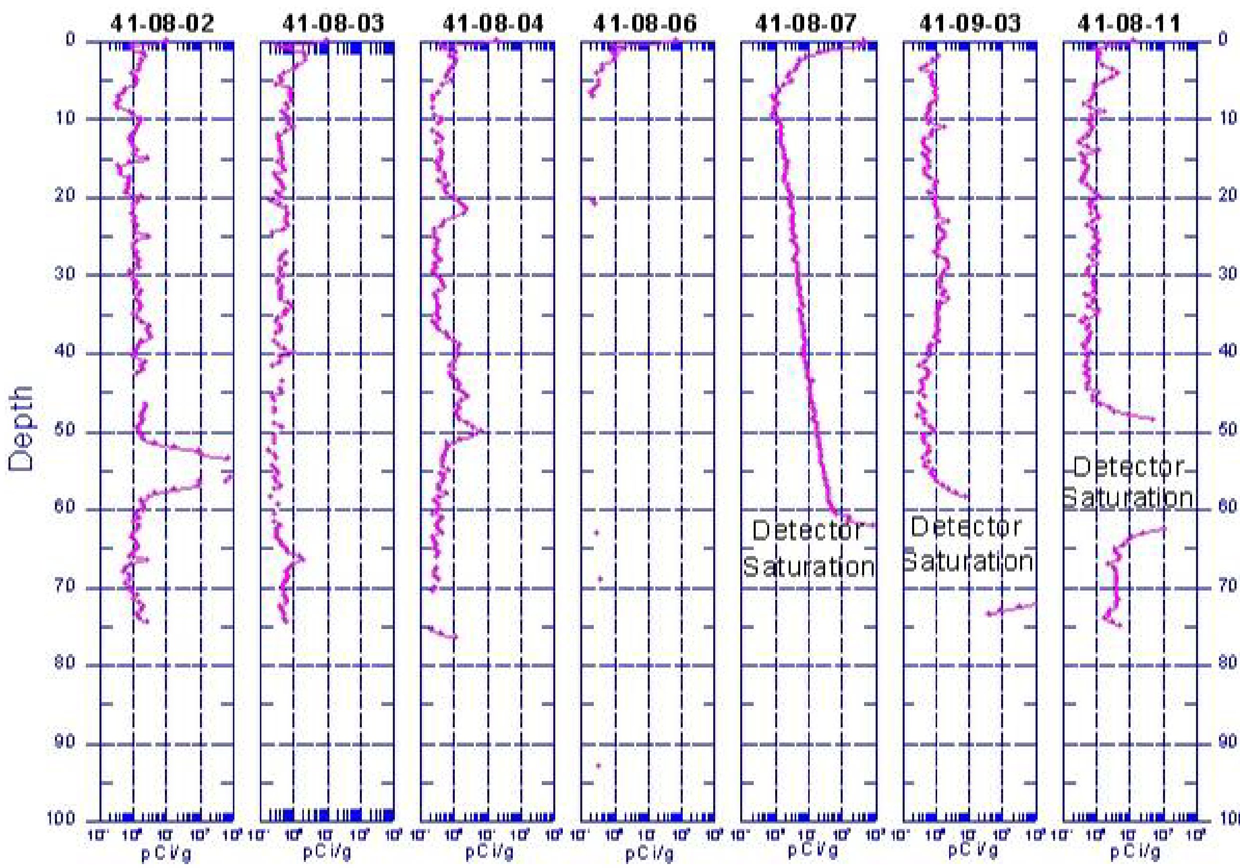
Date	Liquid Depth (inches)	Sludge Depth (inches)	Liquid Temperature
December 1965[a]	242.5 (647,780 gallons)	14	137.2 °C
January 1966[b]	243.0	18	135.6 °C
February 1966[c]	243	14	140 °C
March 1966[d]	242	17	140.6 °C
April 1966[e]	241	20	138.9 °C
May 1966[f]	238.5	24	136.1 °C
June 1966[g]	237.75	28	137 °C
July 1966[h]	237.50	25	276 °C[1]
August 1966[i]	234.5	26	273 °C[1]
September 1966[j]	233.5	26	274 °C[1]
October 1966[k]	230.25	27	271 °C[1]
November 1966[l]	228	28	197 °C[1]
December 1966[m]	224	30	197 °F
January 1967[n]	223.25	42	196 °F
February 1967[o]	218.5 (581,650 gallons)	42	198 °F
March 1967[p]	84	42	265 °F

Note 1: Liquid temperature readings reported for July 1966 through November 1966 were reported as degrees Celsius. However, it is likely that these liquid temperature readings should have been reported as degrees Fahrenheit given the temperature plot on page B-111 of RHO-CD-1172, which indicates the tank SX-108 waste temperature was ~280 °F to 270 °F for July 1966 through October 1966.

[a]HAN-93551, 1966, *Monthly Status and Progress Report December, 1965*, page 14
[b]HAN-93802, 1966, *Monthly Status and Progress Report January, 1966*, page 14
[c]HAN-94040-DEL, 1966, *Monthly Status and Progress Report February, 1966*, page 15
[d]HAN-94330, 1966, *Monthly Status and Progress Report March, 1966*, page 16
[e]HAN-94591-DEL, 1966, *Monthly Status and Progress Report April, 1966*, page 14
[f]HAN-94842-DEL, 1966, *Monthly Status and Progress Report May, 1966*, page 18
[g]HAN-95105-DEL, 1966, *Monthly Status and Progress Report June, 1966*, page 16
[h]HAN-95284, 1966, *Monthly Status and Progress Report July, 1966*, page 14
[i]HAN-95491-DEL, 1966, *Monthly Status and Progress Report August, 1966*, page 17
[j]HAN-95695-DEL, 1966, *Monthly Status and Progress Report September, 1966*, page AIII-3
[k]HAN-95918-DEL, 1966, *Monthly Status and Progress Report October 1966*, page AIII-3
[l]HAN-96143-DEL, 1966, *Monthly Status and Progress Report November 1966*, page AIII-3
[m]HAN-96350-DEL, 1967, *Monthly Status and Progress Report December 1966*, page AIII-4
[n]HAN-96590-DEL, 1967, *Monthly Status and Progress Report January 1967*, page AIII-4
[o]HAN-96805-DEL, 1967, *Monthly Status and Progress Report February 1967*, page AIII-4
[p]HAN-97066-DEL, 1967, *Monthly Status and Progress Report March 1967*, page AIII-4

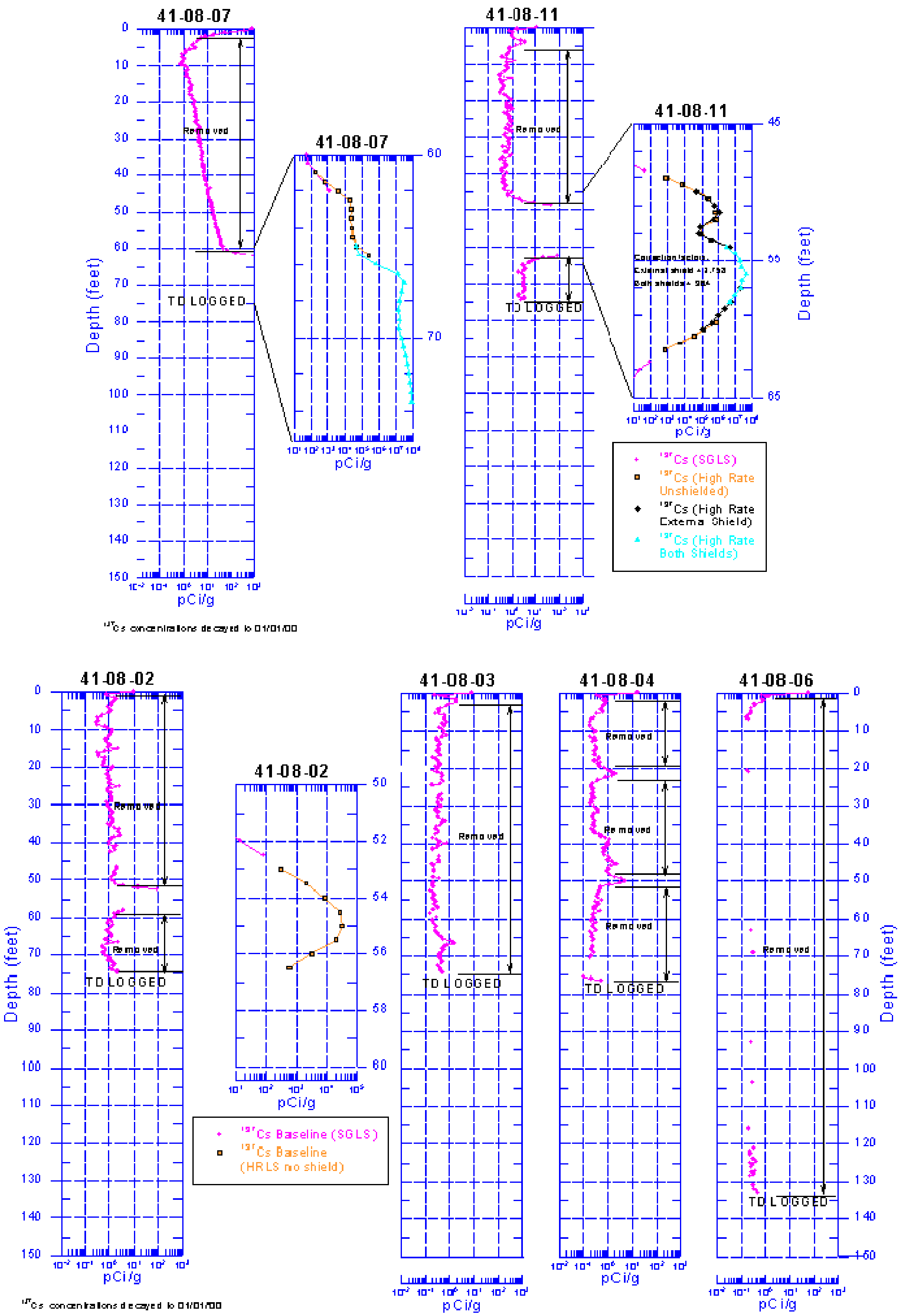
5.3.2.3 More Current Drywell Results. More current drywell logging results are reported in GJ-HAN-10, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank SX-108* (Figure 5.3-6) and GJPO-HAN-4 (Figure 5.3-7). Figure 5.3-6 shows 1995 gamma results for logging where logging results were saturated at 1,000 pCi/g. Figure 5.3-7 shows additional results from 1998 to 1999 using the HRLS to further assess saturated regions in drywells 41-08-07 and 41-08-11. The HRLS showed 10^8 pCi/g activity between 50 and 74 ft bgs. The depth of 74 ft bgs was the bottom of drywell 41-08-07; consequently, contamination extends beyond this depth.

Figure 5.3-6. Cesium-137 Concentrations in Drywells Surrounding Tank 241-SX-108



5.3.2.4 Supplemental Information. Additional information has been found which shows WHC-MR-0300 leak volume estimates may be low. WHC-MR-0300 surmised the REDOX HLW supernate was removed from tank 241-SX-108 in December 1962, the sludge water leached and the tank refilled with REDOX HLW in 1963; Table 5.3-1 summarizes information that supports these assumptions. WHC-MR-0300 also reports that no make-up water was added to tank 241-SX-108 after 1963. However, Table 5.3-1 shows that 703,252 gal of water were added to tank 241-SX-108 from January 1964 through January 1965. Also, 372,642 gal of condensate from tank 241-SX-106 were transferred into tank 241-SX-108 from November 1963 through November 1965, which is consistent with the total reported in WHC-MR-0300, pages 3 and 4.

Figure 5.3-7. Cesium-137 High Rate Logging System Concentrations in Drywells Surrounding Tank 241-SX-108



The WHC-MR-0300 estimate of 2,400 gal of waste leaked from tank 241-SX-108 from August 1964 through 1965 appears to be correct. However the 0 to 33,000 gal estimate from mid-1965 to December 1967 may be low. WHC-MR-0300 reports a condenser was installed on tank 241-SX-108 in November 1965 and "*All water evaporating from the tank was condensed and returned to the tank, so that any change in liquid level could be observed. In June 1966, about seven months later, it was reported that no leak had been detected within the ± 1,375 gal accuracy of measurement*". The statement that "*…no leak had been detected within the ± 1,375 gal accuracy of measurement*" seems incorrect given the liquid level measurements summarized in Table 5.3-3. Based on the information presented in Table 5.3-3, the liquid level in tank 241-SX-108 dropped from 242.5 in. in December 1965 to 218.5 in. in February 1967, a 24-in. or 66,130-gal decrease.

The liquid level decrease reported in tank 241-SX-108 during December 1965 through February 1967 may have been partially due to water evaporation and discharge to the tank exhaust ventilation system. An estimated 1,200 to 1,300 gal of water per month was discharged to the tank exhaust ventilation system during January 1966 through April 1966 (ISO-75 RD, *Fission Products Process Engineering Monthly Reports January – December, 1966*, pages 36, 53 and 70). However, 500 gal of water were added in January 1966 to flush the circulators, followed by 500 gal in February 1966 and 700 gal in March 1966, for a total of 1,700 gal (ISO-75 RD, pages 36, 53, and 70). No other information was located that provides estimates of water additions or evaporation to the tank exhaust ventilation system.

Based on an evaporation rate of 1,300 gal per month, a total of 17,800 gal of water (15 months × 1,300 gallons per month minus 1,700 gal) may have been discharged through the tank exhaust ventilation system during December 1965 through February 1967. However, no information was located that documents water evaporative loss to the tank exhaust ventilation system. Therefore during this period an additional 48,300 gal to 66,100 gal may have leaked from the tank.

The liquid level in tank 241-SX-108 was reduced from 18 ft to 7 ft in March 1967 (ISO-709-DEL, *Chemical Processing Division Monthly Report for March, 1967*). WHC-MR-0300 discusses the use of in-tank photographs taken in 1968 through 1970 to determine an estimated 12-in. decrease in the liquid level (33,000 gal), attributed to either evaporation or waste leakage. This volume decrease occurred after March 1967 and should be added to the liquid level decrease that occurred from December 1965 through February 1967.

The total SX-108 tank leak range is 2,400 + 48,300 to 66,100 + 0 to 33,000 gal = 50,700 gal to 101,500 gal.

5.3.2.5 Borehole 41-09-39 Characterization. This section from the Waste Management Area S/SX Field Investigation Report (RPP-7884, Appendix B) summarizes data reported in PNNL-13757-3, *Characterization of Vadose Zone Sediment: Borehole 41-09-39 in the S-SX Waste Management Area*. The location of borehole 41-09-39 (W23-234) is shown in Figure 5.3-8. This borehole was completed in December 1996 to further characterize the nature and extent of vadose zone contamination from the tank SX-108 leak. The initial borehole was drilled to a depth of 130 ft bgs (HNF-2855, *Finding of the Extension of Borehole 41-09-39, 241-SX Tank Farm*). In December 1997 the borehole was extended to groundwater, and soil samples were taken and analyzed from 40 m (130 ft) bgs to 68.6 m (225 ft) bgs. Also, sidewall coring samples were collected between 8 and 40 m (25 and 130 ft) bgs as the borehole was being decommissioned. Analyses of sediment samples were also completed. The method used to advance and sample this borehole may have contributed to cross-contamination of portions of each sample interval.

Elevated concentrations of several constituents were measured in soils between 61 and 130 ft bgs. The primary radionuclides present in this zone are ^{137}Cs and ^{99}Tc. Maximum ^{137}Cs concentrations are present between 65 and 83 ft and at lesser amounts between 83 and 108 ft. The presence of high levels of ^{137}Cs at borehole 41-09-39 is indicative of strong lateral movement of tank fluid and attributed to unusually high ^{137}Cs mobility shortly after release from tank SX-108. Maximum ^{99}Tc concentrations are present between 79 and 129 ft. The primary chemical characteristics attributed to tank fluid-soil interaction within this zone are elevated pH, sodium, chromium, and nitrate. The depth of maximum ^{99}Tc concentration coincides with high nitrate concentrations and marks the leading edge of vertical tank fluid migration in the direction measurable in this borehole.

Geophysical and Physical Property Measurements

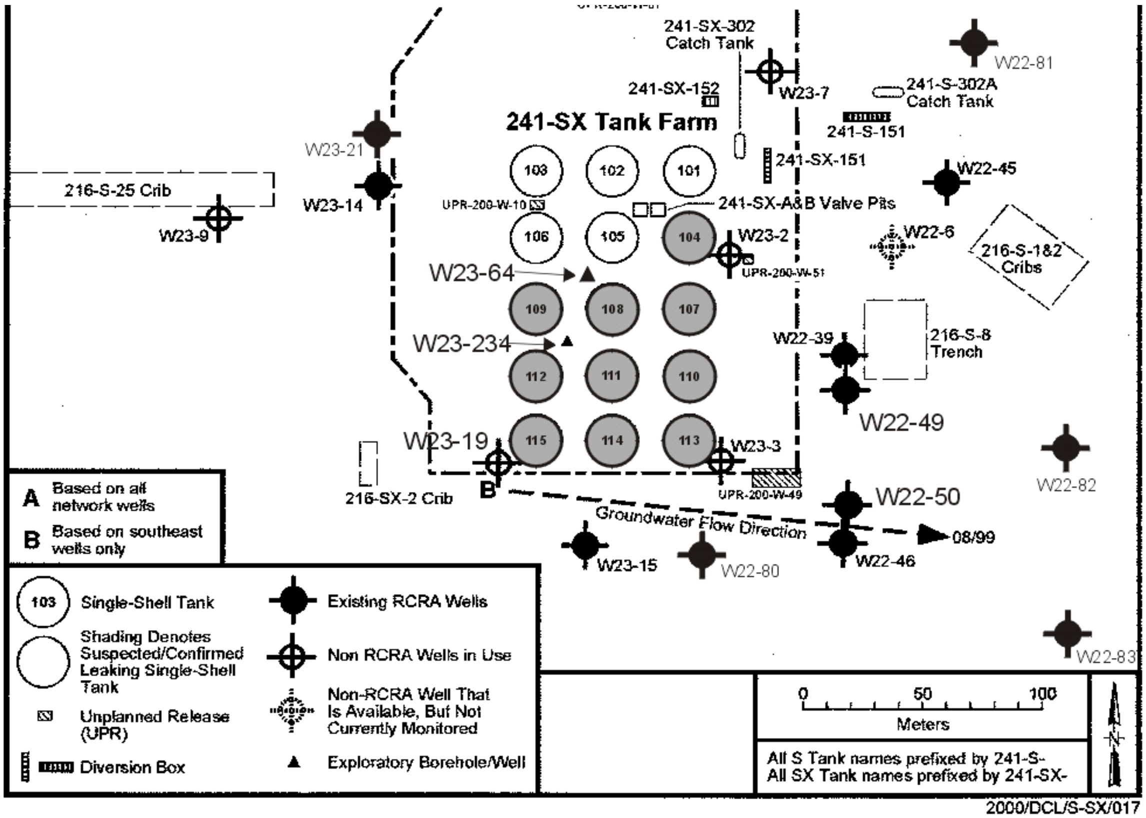
Downhole geophysical measurements at borehole 41-09-39 included a cadmium zinc tellurium gross gamma log and a drilling resistance log down to 40 m (130 ft) bgs, high-purity germanium spectral gamma logs from 40 m (130 ft) bgs to groundwater (about 65 m [214 ft] bgs),and neutron-neutron logs over the entire depth. Geophysical data for between 8 and 40 m (25 and 130 ft) bgs and between 40 and 65 m (130 and 214 ft) bgs are shown in Figures 5.3-9 and 5.3-10, respectively. Laboratory measurements of soil moisture content (see Figure 5.3-11) show similar trends in relative concentrations as the neutron-neutron moisture measurements.

Soil Water Chemistry Measurements

In addition to soil physical property measurements, water chemistry analysis has been completed for borehole 41-09-39 samples collected between 25 and 215 ft bgs. Water extract pH and electrical conductivity measurements with depth are shown in Figure 5.3-12. Elevated pH values (8.5 to 9.7) are measured between 65 and 83 ft bgs. The location of maximum pH values suggests the approximate initial depth of tank fluid interaction with the vadose zone at this location. Increases in electrical conductivity values compared to undisturbed soil water values are also an indicator of tank fluid occurrence in soil. Substantive increases are measured between 65 and 132 ft bgs with maximum values (~98,000 to 524,000 µS/cm) between 83 and 127 ft bgs.

Nitrate, chloride, and sulfate concentrations with depth are shown in Figures 5.3-12 and 5.3-13. Elevated nitrate concentrations were measured in this borehole between 65 and 136 ft bgs with maximum values between 83 and 127 ft bgs. Elevated levels of chloride (between 83 and 127 ft bgs) and sulfate (between 65 and 127 ft bgs) are also observed. Chloride maximum concentrations (between 90 and 112 ft bgs) track closely with nitrate. An isolated chloride peak occurs at 197 ft bgs, which may be a residual from groundwater present when the water table was elevated and has since drained. The sulfate peak occurs between 83 and 112 ft bgs and coincides with chloride and nitrate peaks. Also, sulfate shows a slight increase in concentration at 185 and 189 ft bgs. Between 185 and 189 ft bgs represents the high groundwater elevation.

Figure 5.3-8. Location of Borehole 41-09-39 (W23-234) and Slant Borehole (W23-64)



Slant Borehole Detail

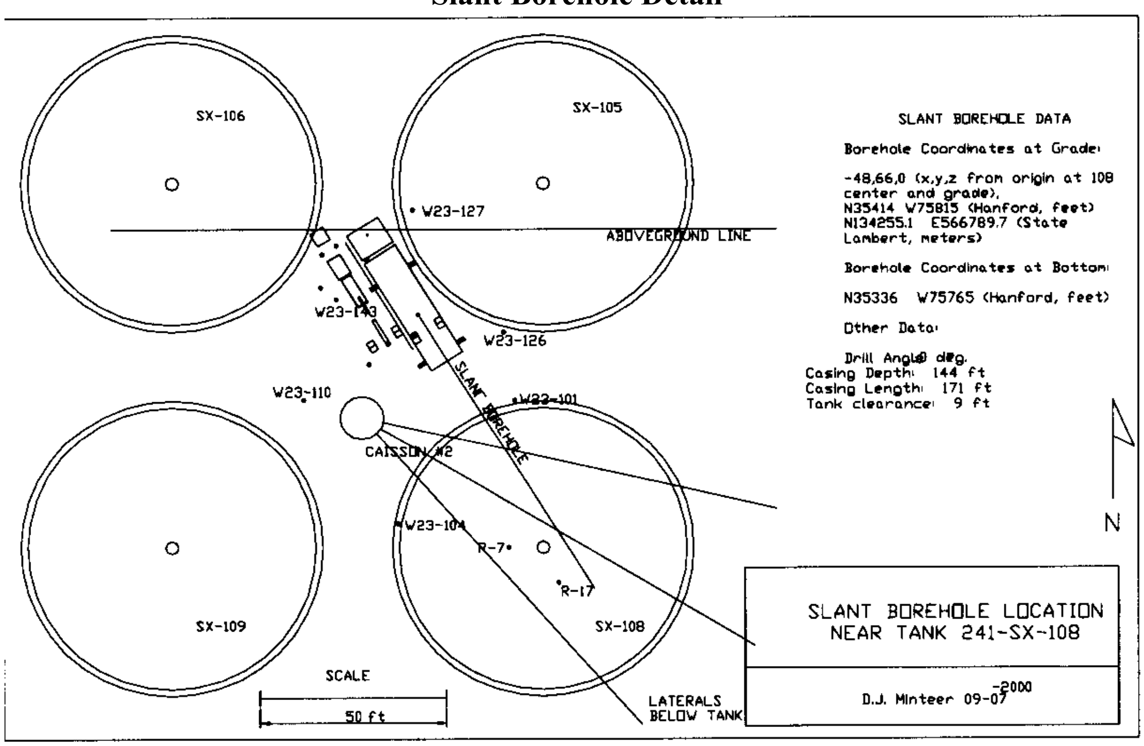
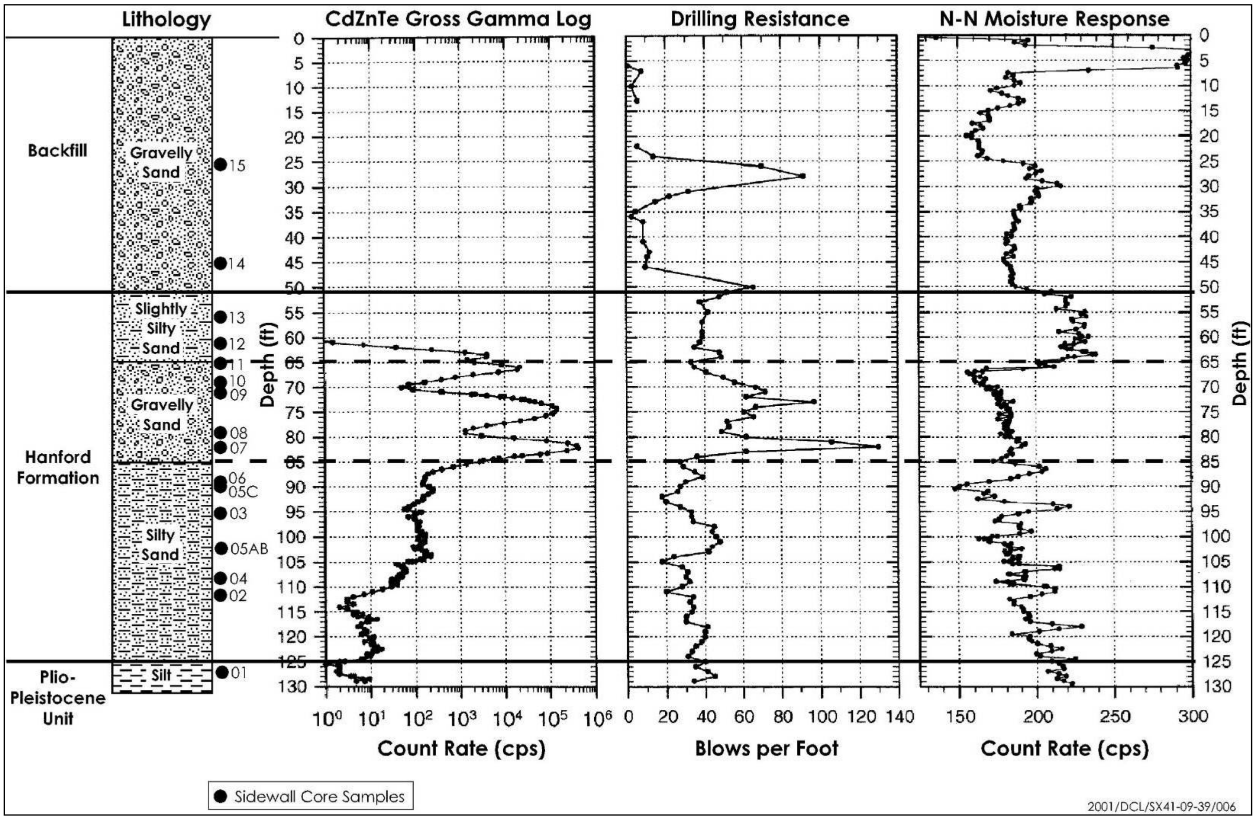


Figure 5.3-9. Gamma-Ray, Drilling Resistance, and Moisture Logs for the Upper Portion of Borehole 41-09-39

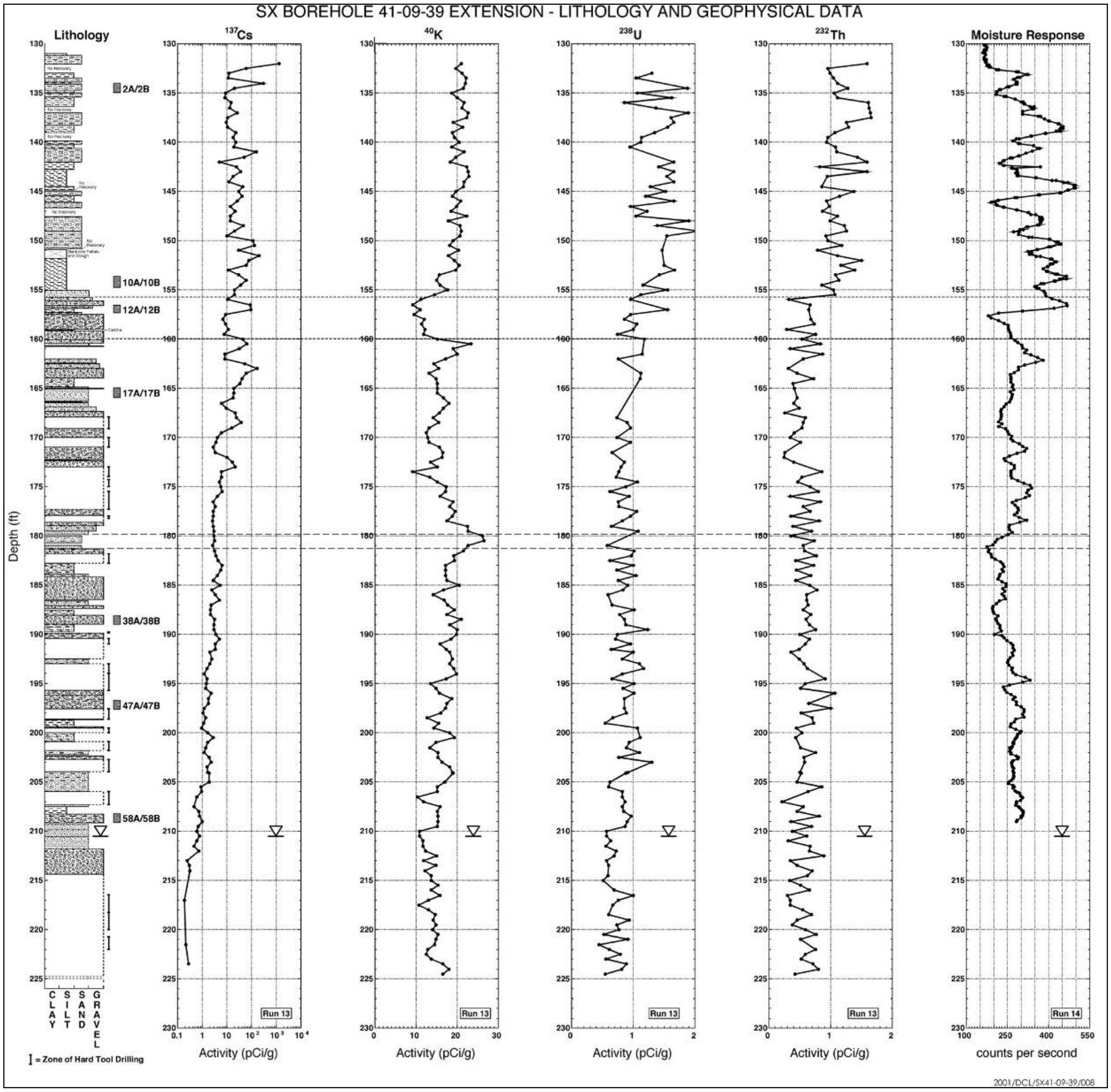


Water extract cation concentrations as a function of depth are shown in Figure 5.3-14. Among the cations, elevated sodium concentrations are the primary tank fluid indicator. Maximum values begin at 83 ft bgs and remain elevated above 10,000 mg/L until 112 ft bgs. Calcium, magnesium, potassium, and natural strontium show depleted concentrations at 61 to 80 ft bgs and above the high sodium zone and show elevated concentrations between 90 and 127 ft bgs. The relative positioning of sodium concentration ranges versus that of the other cations supports the hypothesis that sodium preferentially replaces these cations in sorption sites as it migrates vertically and pushes them ahead to the leading edge of a leak plume.

^{137}Cs, ^{99}Tc and chromium are present in concentrations above background and indicators of tank waste. Water extract concentrations of ^{137}Cs are shown in Figure 5.3-15. Above-background ^{137}Cs concentrations are measured between 25 and 137 ft bgs. Figure 5.3-15 shows ^{137}Cs activity versus depth.

The primary zone of true contamination is between 60 and 127 ft bgs. In this zone three peaks occur at 66, 82.5 and 102 ft bgs at concentration levels of $4{\times}10^6$, $2{\times}10^7$ and $2{\times}10^6$ pCi/g respectively. Overall, the vast majority of ^{137}Cs mass resides between 66 and 84 ft bgs. Just below these peaks, ^{137}Cs concentrations drop by orders of magnitude.

Figure 5.3-10. Detailed Lithology and Analytical Values of Split-Spoon Samples from the Lower Portion of Borehole 41-09-39



The primary zone of elevated ^{99}Tc concentration lies between 79 and 127 ft bgs, where maximum concentrations of greater than 1×10^7 pCi/L are measured at 108 ft bgs. Water extract concentrations of ^{99}Tc with depth are shown in Figure 5.3-16. This pattern closely mimics the nitrate concentration distribution. Chromium concentration values increase above background beginning at 66 ft bgs and reach maximum concentrations of greater than 100,000 µg/L between 82 and 112 ft bgs.

Figure 5.3-11. Moisture Content (wt%) versus Depth for Vadose Sediments from Borehole 41-09-39

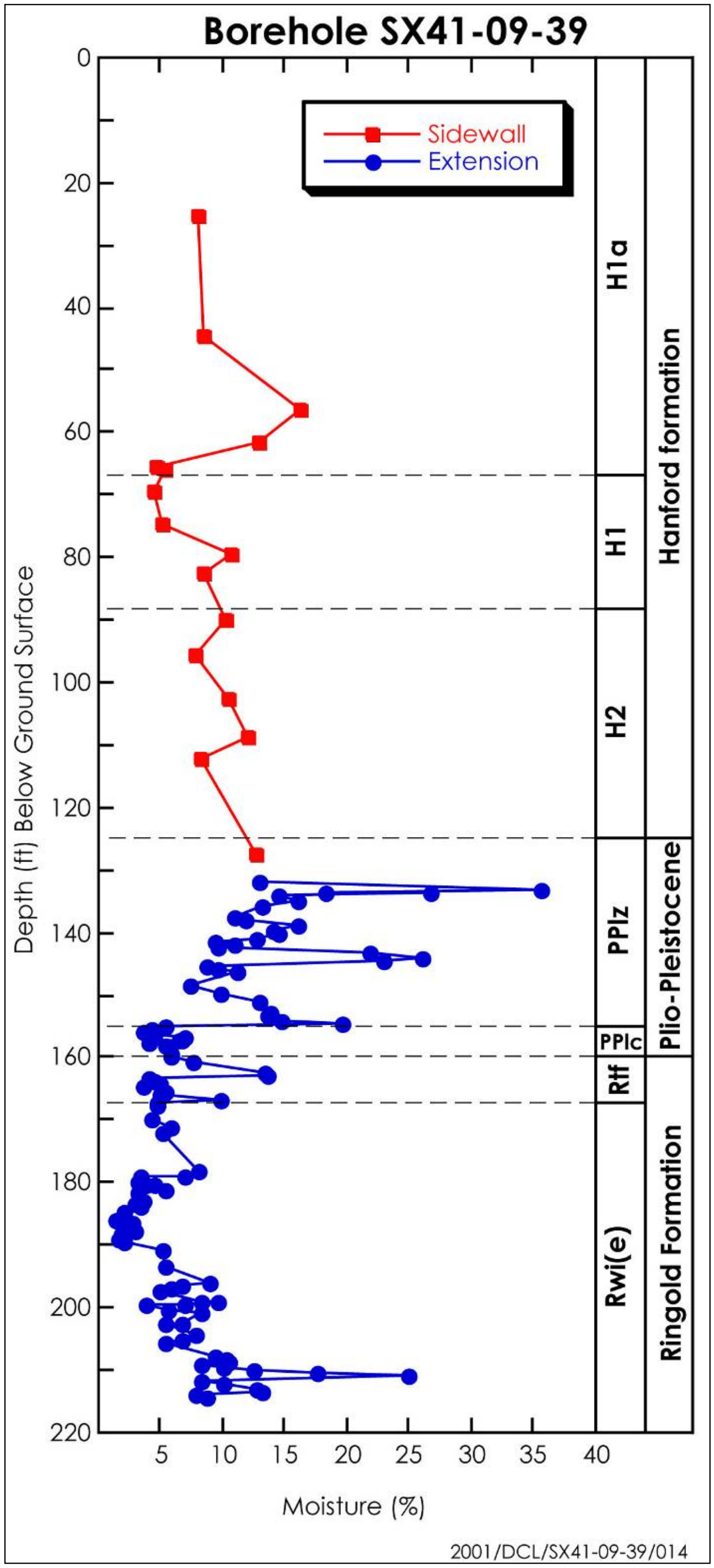


Figure 5.3-12. Concentrations of pH, Electrical Conductivity, and Nitrate in Dilution-Corrected Water Extract

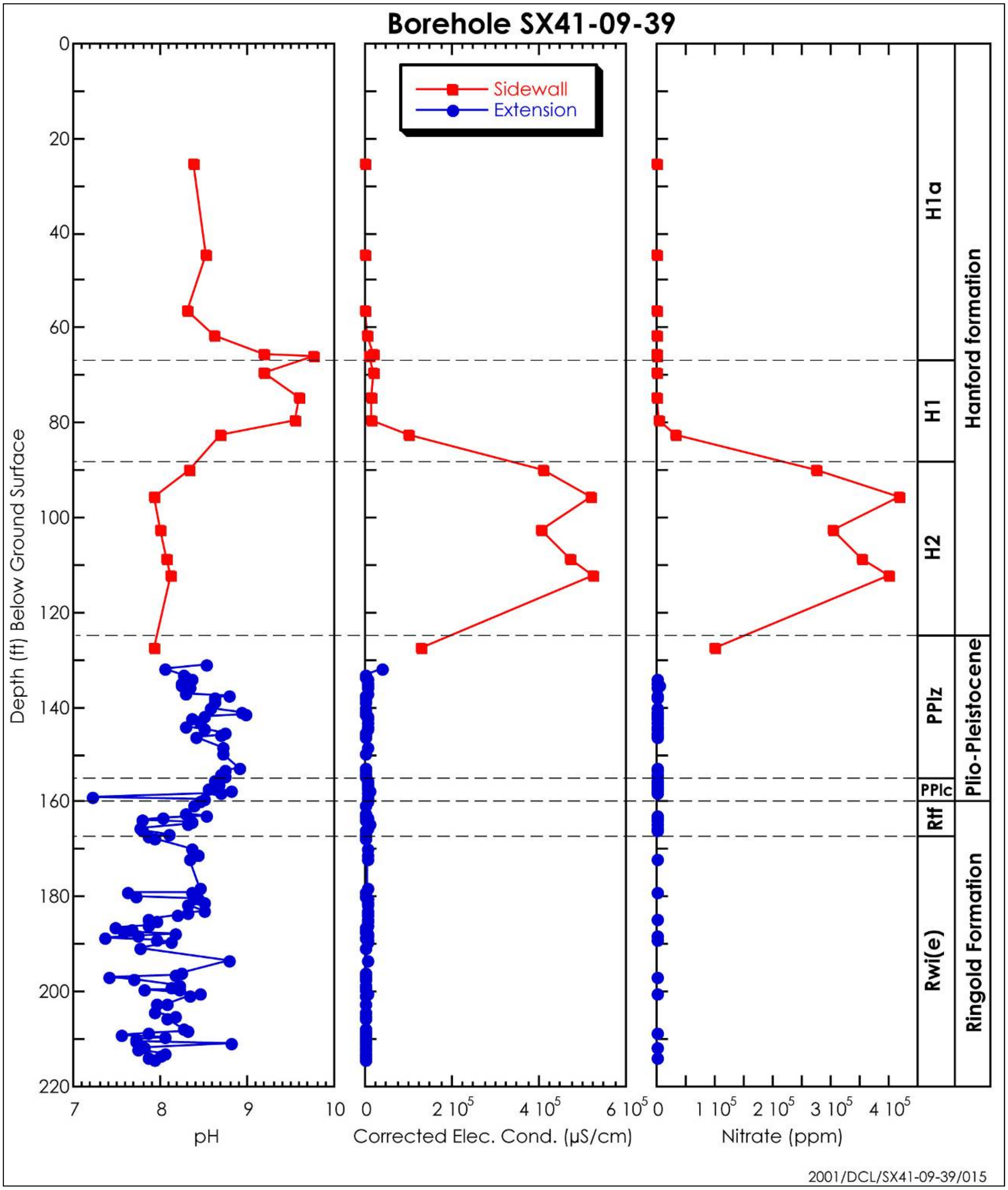
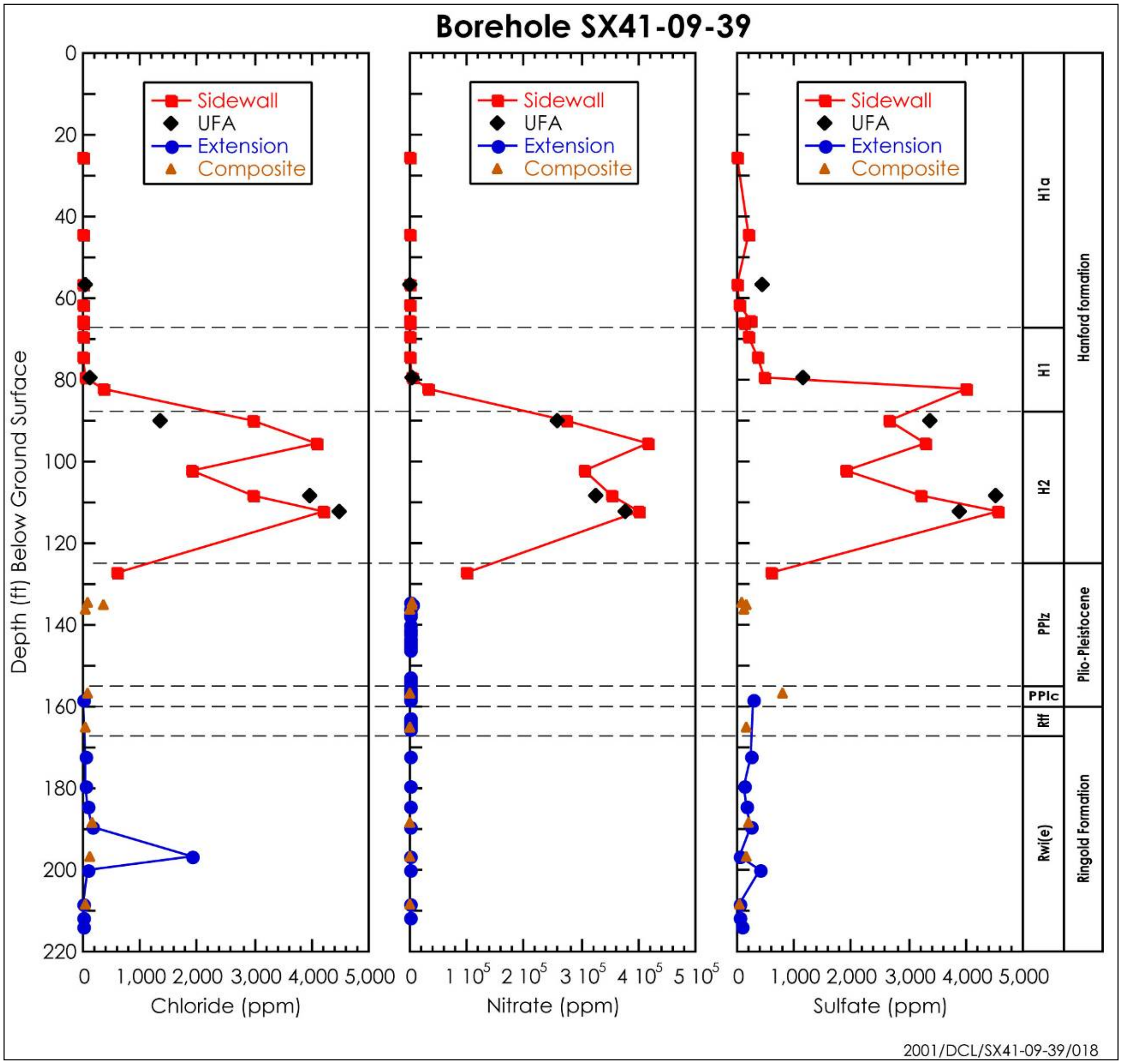
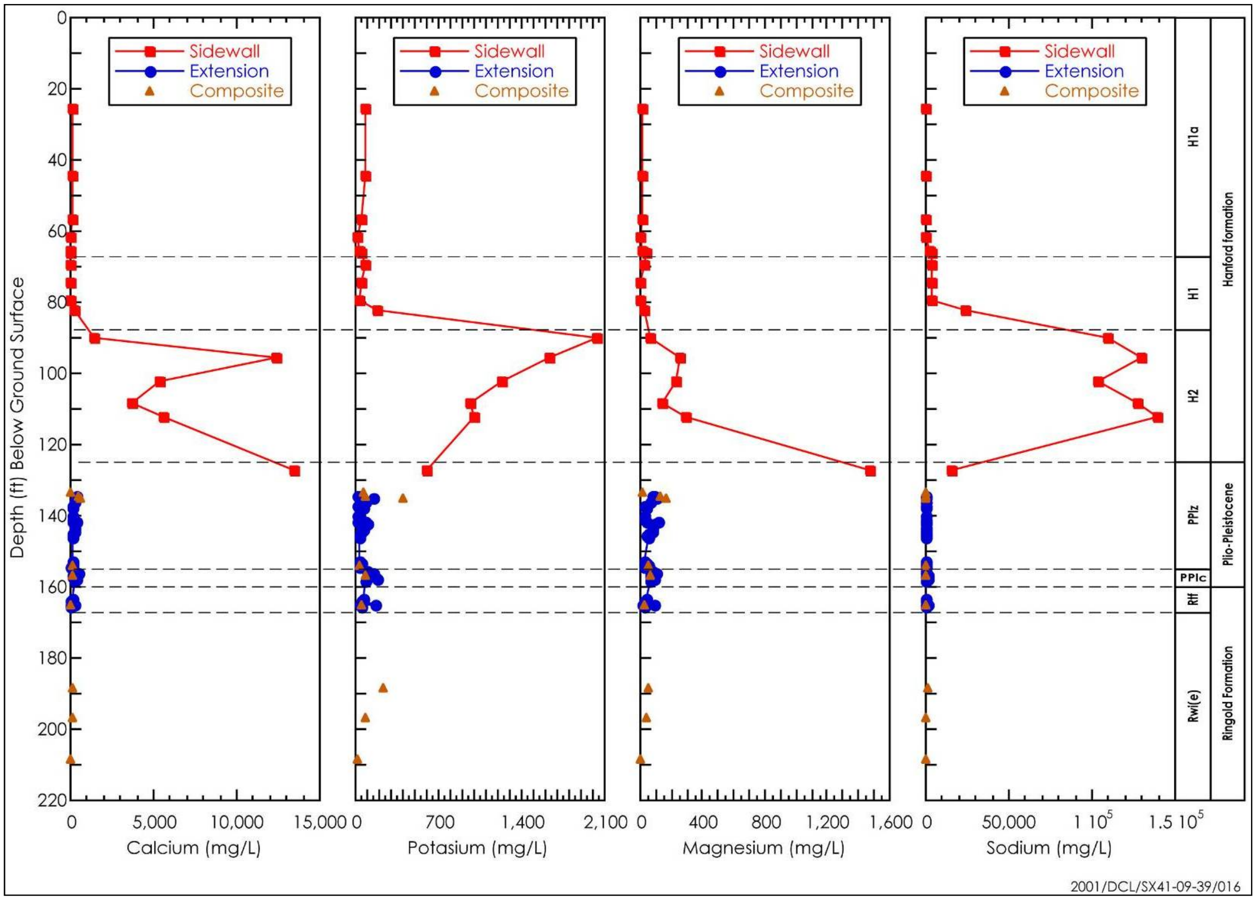


Figure 5.3-13. Dilution-Corrected 1:1 Sediment to Water Extract Anions and Actual Porewater Anion Concentrations versus Lithology and Depth



5.3.2.6 Tank 241-SX-108 Slant Borehole. This section from the Waste Management Area S/SX Field Investigation Report (RPP-7884, Appendix B) summarizes data reported in PNNL-13757-4, *Characterization of Vadose Zone Sediment: Slant Borehole SX-108 in the S-SX Waste Management Area*. The location of the slant borehole (W23-64) is shown in Figure 5.3-8. The SX-108 slant borehole was completed in July 2000 to further characterize the nature and extent of vadose zone contaminants from the tank SX-108 leak. This borehole was drilled to sample soils as close to the tank leak site as possible and to investigate tank fluid migration underneath the tank, an area which has received no evaluation other than gross gamma measurements along laterals in the 1970s. The slant borehole goes through the "umbrella" region under the tank where little if any natural infiltration is anticipated, compared to the region between the tanks.

Figure 5.3-14. Dilution-Corrected Cation Concentrations at Borehole 41-09-39 in 1:1 Sediment to Water Extracts



Elevated concentrations of several constituents were measured in soils throughout the length of the slant borehole from 55 to 135 ft bgs. The primary radionuclides present in this zone are ^{137}Cs and ^{99}Tc. Maximum ^{137}Cs concentrations are present between 55 and 88 ft bgs. Maximum ^{99}Tc concentrations are present between 85 and 138 ft bgs. The primary chemical characteristics attributed to tank fluid-soil interaction within this zone are elevated: pH, sodium, chromium and nitrate. The depth of maximum ^{99}Tc concentration coincides with high nitrate concentrations and marks the leading edge of vertical tank fluid migration at this location. Also, ^{129}I is detected between 80 and 130 ft bgs at ~18,000 to 43,000 pCi/L.

Backfill

The backfill was not sampled. The contact depth of the backfill with the Hanford formation at 53.1 ft bgs is supported by tank farm engineering drawings (H-2-37985, *Civil South Section Contoured Excavation, 241-SX-Tank Farm*, sheet 2 of 2) and an increase in apparent moisture content as indicated in the neutron moisture log.

Figure 5.3-15. Cesium-137 Activity in Sediment versus Lithology and Depth

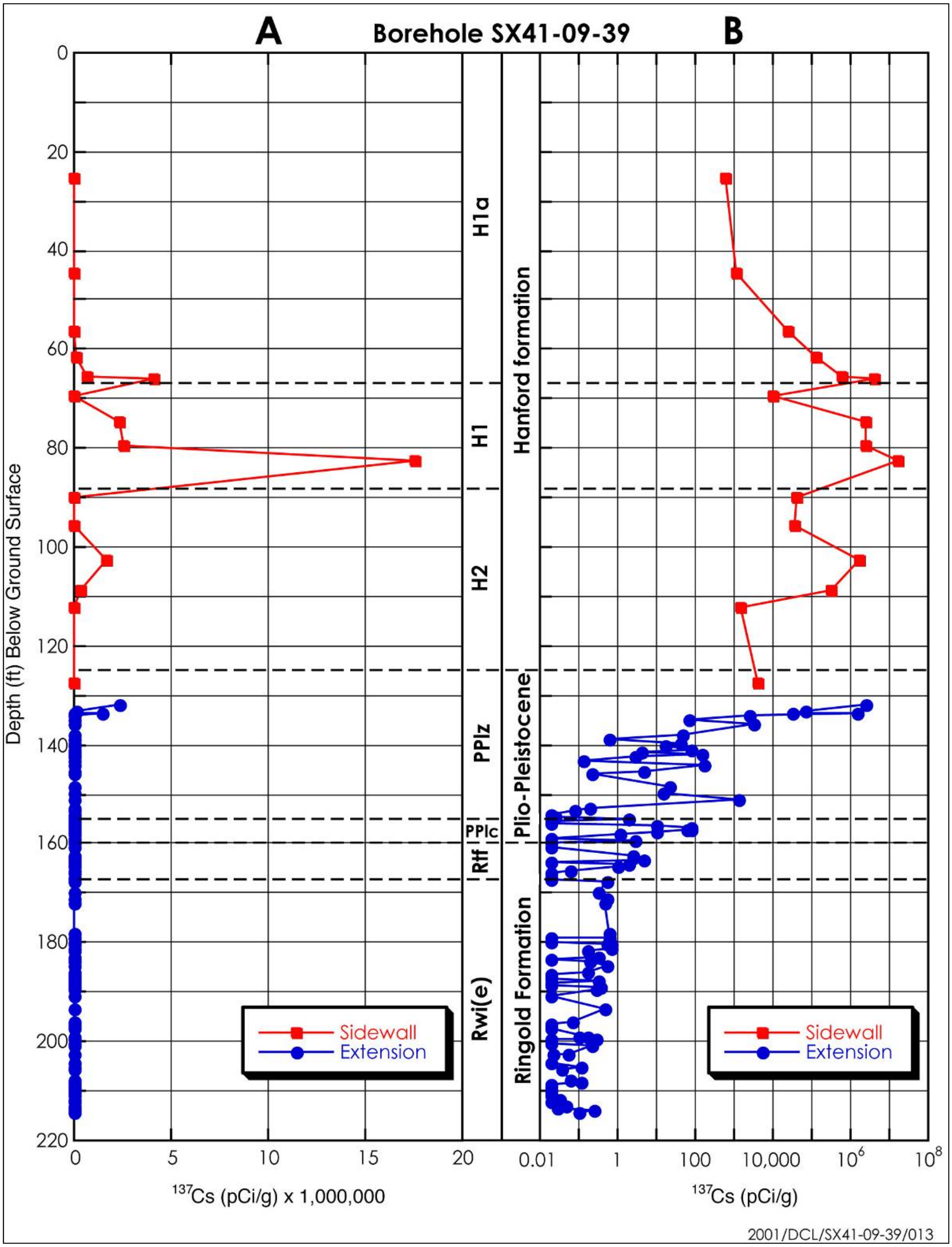
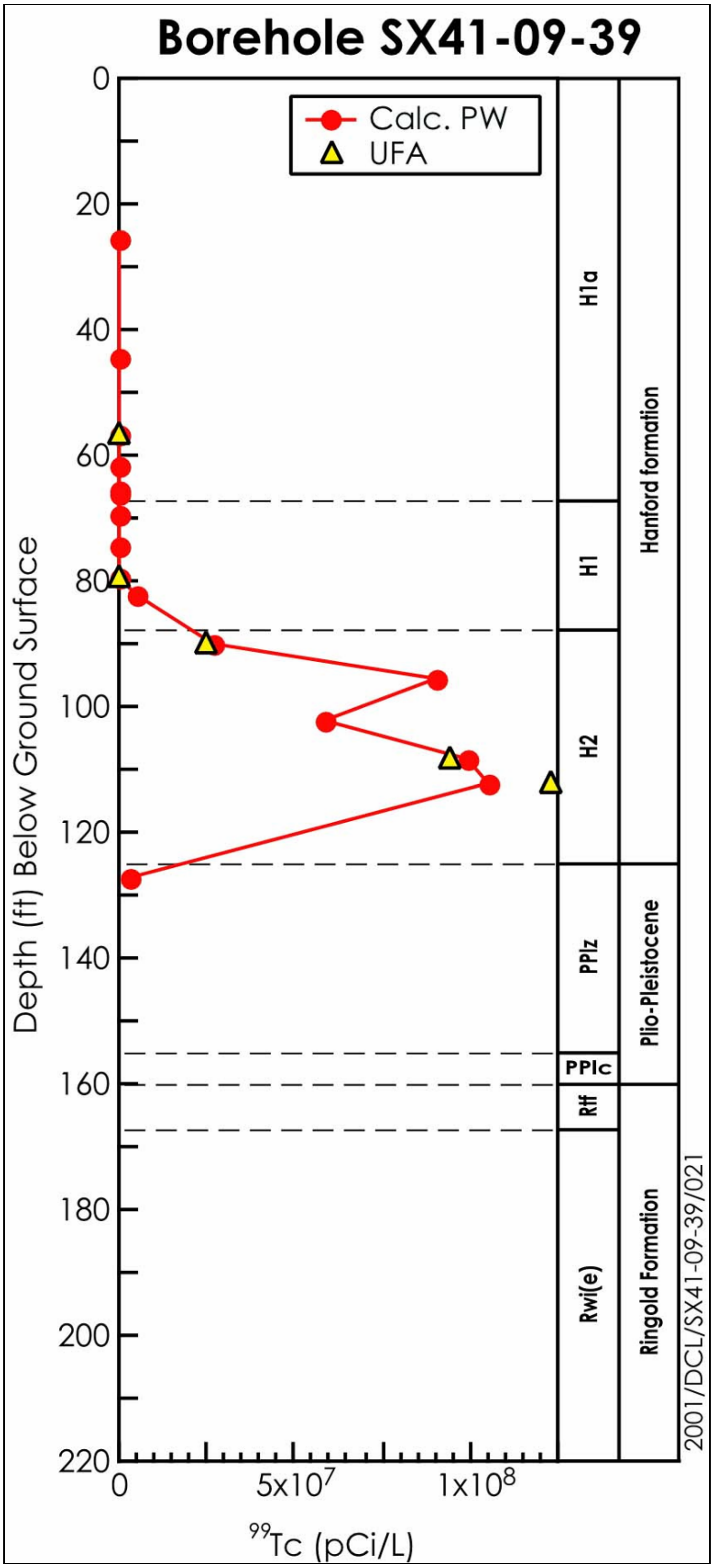


Figure 5.3-16. Technetium-99 Activity in Porewater in Borehole 41-09-39

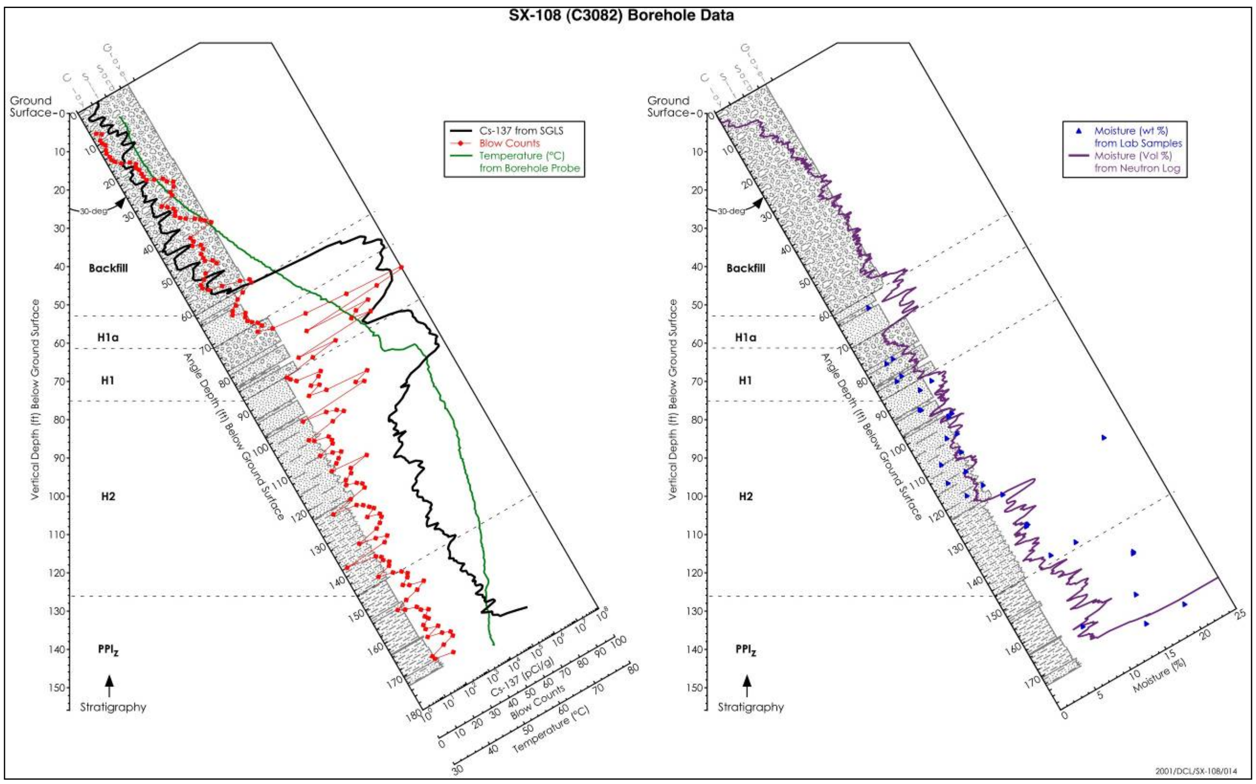


Geophysical and Physical Property Measurements
Several geophysical logging techniques were used during and after installation of the SX-108 slant borehole. These techniques included the following:

- Gyroscopic borehole surveys
- Casing wall temperature logging using an infrared sensor
- Neutron-neutron moisture logging
- High-purity germanium spectral gamma logging
- High-rate gamma logging.

A composite of the temperature, moisture, spectral gamma and high-rate gamma logs (RPP-6917, *SX-108 Slant Borehole Completion Report*) is shown in Figure 5.3-17.

Figure 5.3-17. Geophysics Logging Graph for 241-SX-108 Slant Borehole

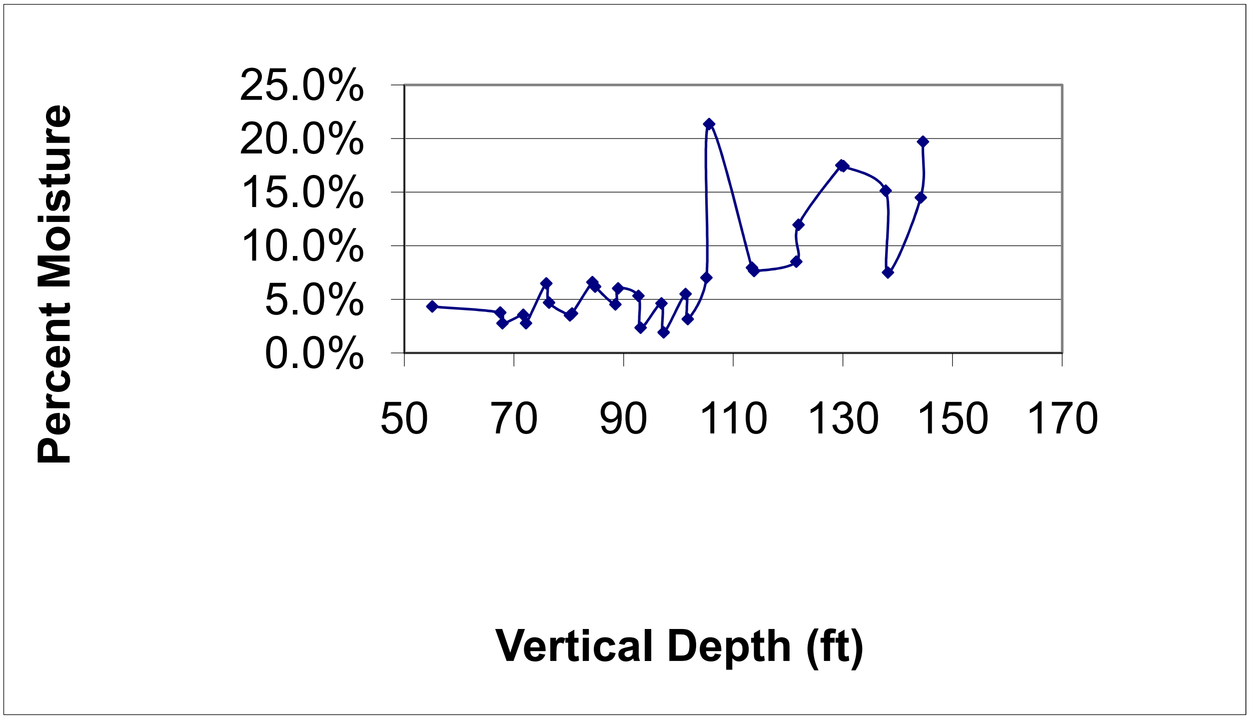


The neutron-neutron moisture log recorded the average volumetric moisture content within an 8- to 12-in. radius. Slightly increased moisture content was noted between vertical depths of 50 and 60 ft bgs, and second significant moisture content change noted at 107 ft bgs. These moisture content changes correlate well with changes in the geologic materials.

Several spectral-gamma and high-rate gamma logging events were conducted using different logging systems, shielding configurations, and counting times. At the high activity levels present, ^{137}Cs was the only gamma-emitting contaminant that could be detected. Above 52 ft bgs, ^{137}Cs concentrations were generally less that 20 pCi/g, and were attributed (most likely) to internal casing contamination (RPP-6917) from the loss of sample S0070-02 down the borehole. Between depths of 53 and 90 ft bgs very high concentrations of ^{137}Cs (on the order of 10^8 pCi/g) were measured. Low activity internal contamination and/or dragdown most likely dominate contamination detected below 90 ft bgs.

Laboratory measurements of soil moisture content (Figure 5.3-18) show similar trends in relative concentrations as the neutron-neutron moisture measurements.

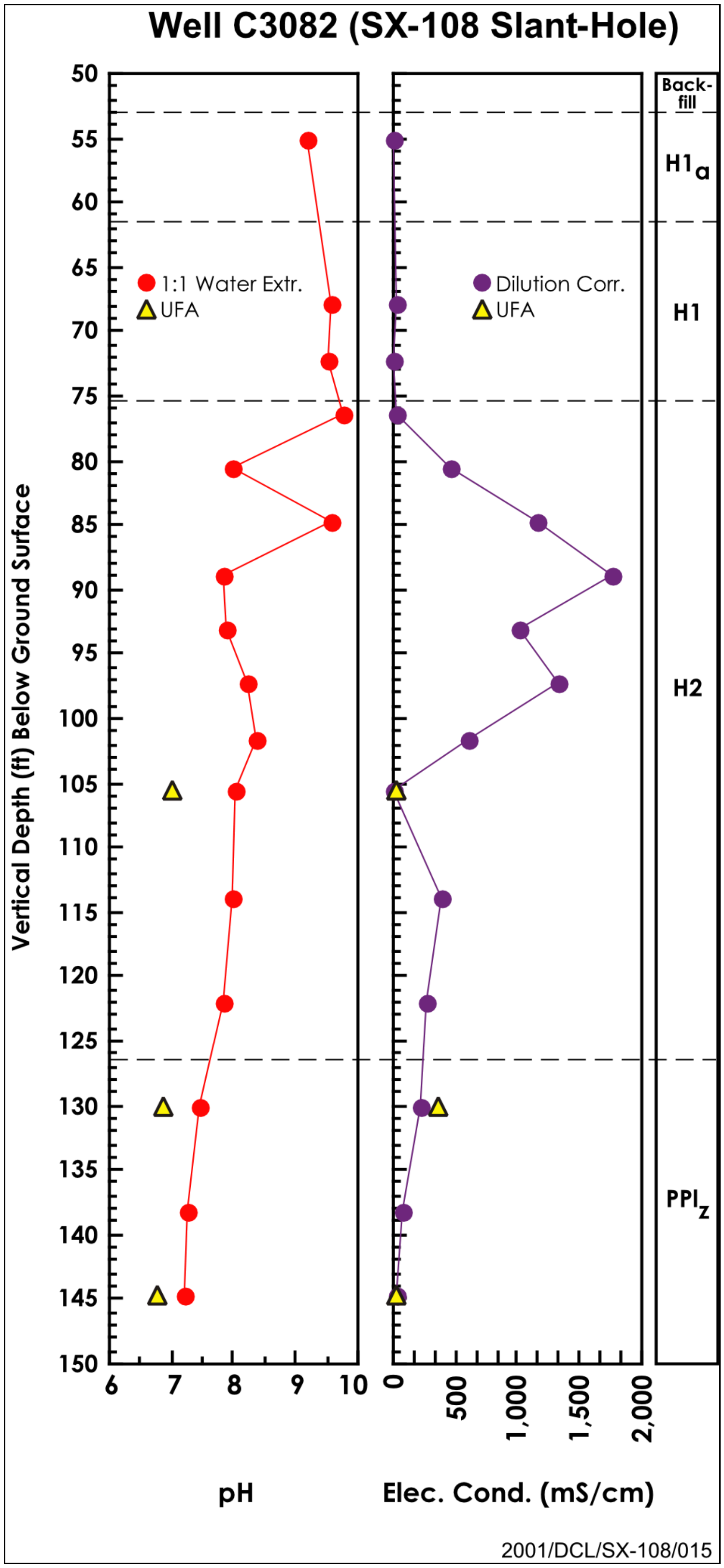
Figure 5.3-18. Moisture Content (wt%) in Vadose Zone Sediment Profile at 241-SX-108 Slant Borehole



Soil Water Chemistry Measurements

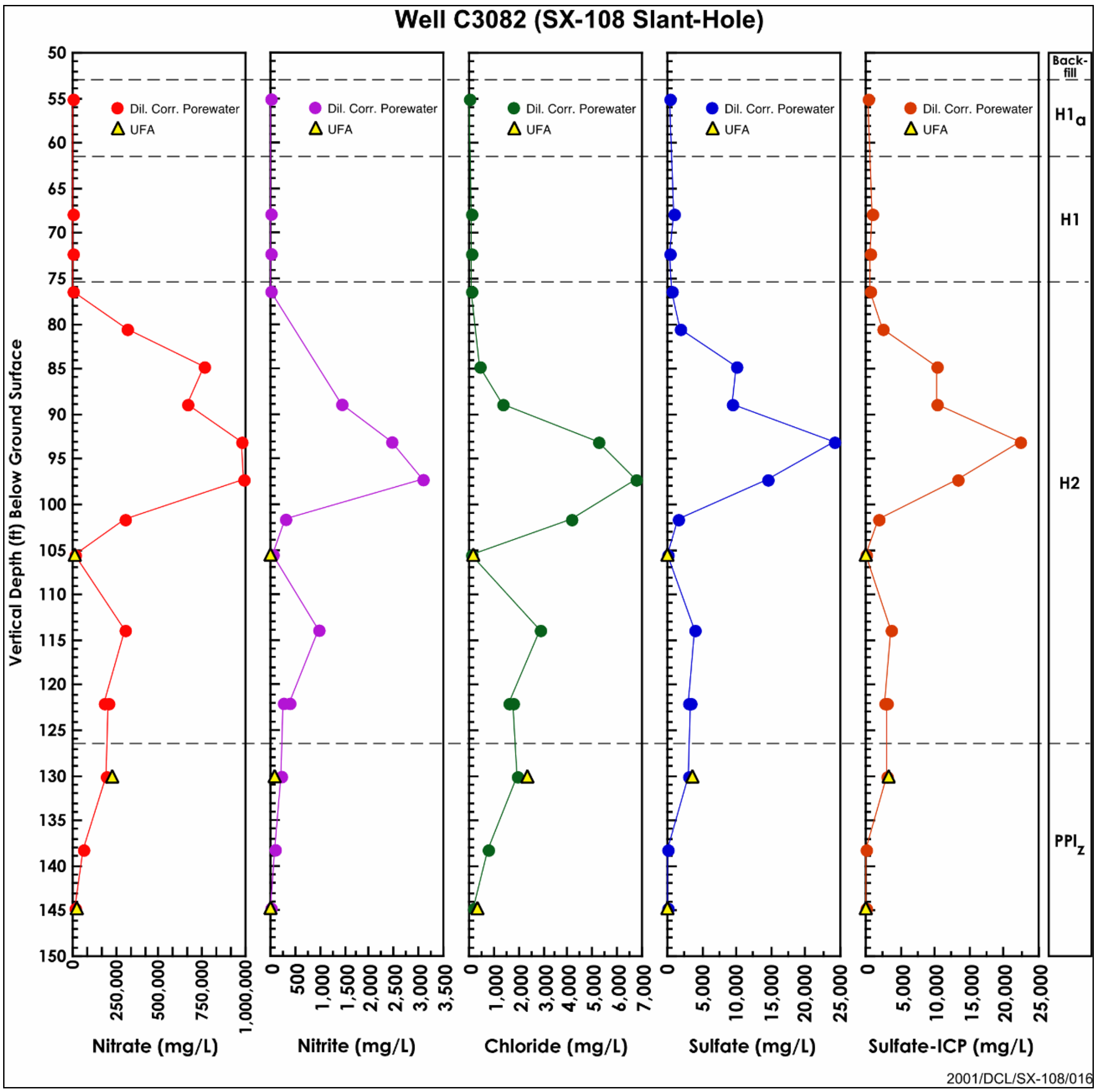
Water chemistry analysis was completed for samples collected at the SX-108 slant borehole between 55 and 145 ft bgs (PNNL-13757-4). Water extract pH and electrical conductivity measurements with depth are shown in Figure 5.3-19. Elevated pH values (greater than 9) are measured between 55 and 85 ft bgs. Because pH values are expected to decrease as increasing interaction with soil and soil water occurs, the location of maximum pH values suggests the approximate initial depth of tank fluid interaction with the vadose zone at this location. An apparent bimodal distribution of pH values is created by the low pH value (8) measured in the middle of the elevated zone at 80.6 ft bgs.

Figure 5.3-19. 241-SX-108 Slant Borehole pH and Electrical Conductivity Profiles with Depth



Nitrate, chloride, and sulfate concentrations with depth are shown in Figure 5.3-20. The primary indicator of tank fluid occurrence is elevated nitrate concentrations, which are measured through the borehole with maximum values between 180,000 and 995,000 mg/L between 81 and 130 ft bgs. It is probable that the bottom of the nitrate range was not reached in this sampling effort. Like the electrical conductivity measurements, an apparent bimodal distribution of nitrate values is created by the low nitrate value (7,191 mg/L) measured in the middle of the elevated zone at 105.6 ft bgs. The soil at 105.6 ft is a thin fine grained lens within the Hanford formation H2 laminated sand. This layer has high moisture content but relatively low salt content and little indication of tank liquor impact. It has been hypothesized that this fine-grained lens, low permeability layer may have been bypassed by the tank liquor (PNNL-13757-4).

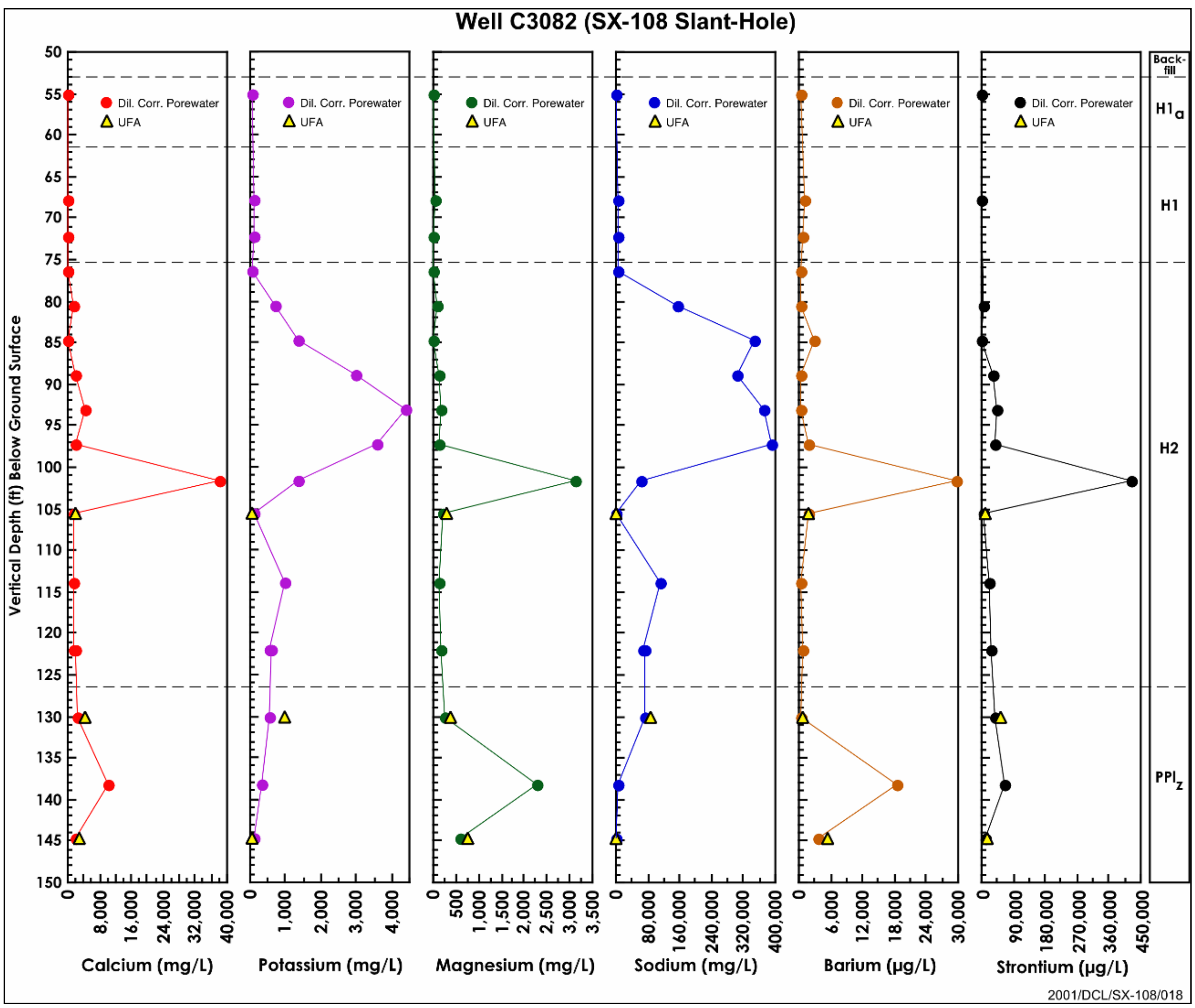
Figure 5.3-20. Anions Calculated and Actual Porewaters for 241-SX-108 Slant Borehole Sediments



Elevated levels of chloride (between 85 and 145 ft) and sulfate (between 65 and 127 ft) are also observed. Chloride maximum concentrations (between 89 and 130 ft bgs) and sulfate maximum concentrations (between 81 and 130 ft bgs) track closely with nitrate. Overall, the anion concentrations appear to be diminishing rapidly in the deepest sample and indicate the leading edge of the tank fluid migration near the bottom of the borehole (145 ft).

Water extract cation concentrations as a function of depth are shown in Figure 5.3-21. Maximum sodium values begin at 81 ft bgs, remaining elevated above 65,000 mg/L through 130 ft bgs except at 105.6 ft bgs where sodium concentration drops to 691 mg/L. The potassium concentration distribution with depth mimics that of sodium. Calcium, magnesium, barium and natural strontium show depleted concentrations above the high sodium depth range at 55 to 90 ft bgs and elevated concentrations between 90 and 145 ft bgs, a depth range slightly ahead of the high sodium range. The relative positioning of sodium versus that of the other cations supports the hypothesis that sodium and potassium preferentially replace these cations in sorption sites as they migrate vertically and push them ahead to the leading edge of the plume.

Figure 5.3-21. Cations Calculated and Actual Porewaters for 241-SX-108 Slant Borehole Sediments



The last group of constituents analyzed included radionuclides and trace metals. Of these, ^{137}Cs, ^{99}Tc and chromium are present in concentrations above background. Gamma logs of ^{137}Cs are shown in Figure 5.3-22. Above background ^{137}Cs concentrations are measured throughout the borehole. The primary contamination zone is between 55 and 90 ft bgs. In this zone two peaks occur at 60 and 80 ft bgs at concentration levels of ~8×10^7 pCi/g. For laboratory analyses the majority of ^{137}Cs mass resides between 80 and 85 ft bgs. Below these peaks, ^{137}Cs concentrations drop by orders of magnitude (less than 1000 pCi/g at 93 ft bgs and deeper). The relative depths of high ^{137}Cs and high sodium suggests that cesium is more reactive with the sediment at this location than sodium, trace metals such as chromium and technetium (PNNL-1357-4).

^{99}Tc is found at elevated concentrations throughout the SX-108 slant borehole. The ^{99}Tc elevated concentration pattern shows an apparent bimodal distribution in the primary high contamination zone between 85 and 130 ft bgs (see Figure 5.3-23). As with other constituents, the low ^{99}Tc concentration at 105.6 ft bgs creates this distribution. The largest concentration peak occurs at 97 ft bgs at a maximum of ~237,000 pCi/mL. This pattern closely mimics the nitrate concentration distribution. It is probable that the bottom of the ^{99}Tc range was not reached in this sampling effort. Chromium concentration values increase above background beginning at 68 ft bgs and show maximum values between 81 and 130 ft bgs. The peak concentrations of greater than 22,000 mg/L occur at 97 ft bgs. The deepest entire chromium range may have been captured by these soil samples as indicated by very small concentrations in the two deepest samples.

^{129}I was measured between 80 and 130 ft bgs in 4 samples. The maximum concentration of ~43,000 pCi/L occurs at 80 ft bgs and values decrease to ~19,000 pCi/L at the bottom of the SX-108 slant borehole, suggesting that the bottom of the ^{129}I contamination zone occurs below the borehole. Elevated selenium concentrations show a pattern that is nearly identical to those of ^{99}Tc. Elevated molybdenum concentrations are more restricted and lie between 80 and 93 ft bgs.

Generally speaking, the data suggest that tank SX-108 fluid chemistry had a substantial, but limited, effect on contamination behavior at the SX-108 slant borehole. Given the depth below the tank SX-108 bottom at which very high concentrations of ^{137}Cs occur, ^{137}Cs was initially highly mobile in the leaked tank fluid. Over time natural infiltration and recharge subsequently separated sodium from ^{137}Cs, permitting ^{137}Cs to sorb in-situ. Constituent anions (e.g., nitrate and ^{99}Tc) have migrated the most rapidly and mark the leading edge of vertical tank fluid migration.

The SX-108 slant borehole provides one of the only vadose data sets with both sample data and vadose monitoring data to assess ^{137}Cs sorption capacity. From 55 to 90 ft bgs the 1999 data shown in Figure 5.3-24 have an average ^{137}Cs concentration of 2.0×10^7 pCi/g with a maximum of 8.0×10^7 pCi/g. Back decaying these values to 1965 (the estimated SX-108 leak date) gives an average ^{137}Cs sorption capacity of 4.3×10^7 pCi/g and a maximum value of 1.7×10^8 pCi/g.

5.3.2.7 2005 Lateral Information. SX-108 laterals were re-logged in May 2005 (RPP-RPT-27605). Results are shown in Figures 5.3-25 and 5.3-26 and are consistent with lateral measurements and plume distribution estimates in the 1992 evaluation (WHC-MR-0300).

Figure 5.3-22. Cesium-137 in Vadose Sediments at the 241-SX-108 Slant Borehole

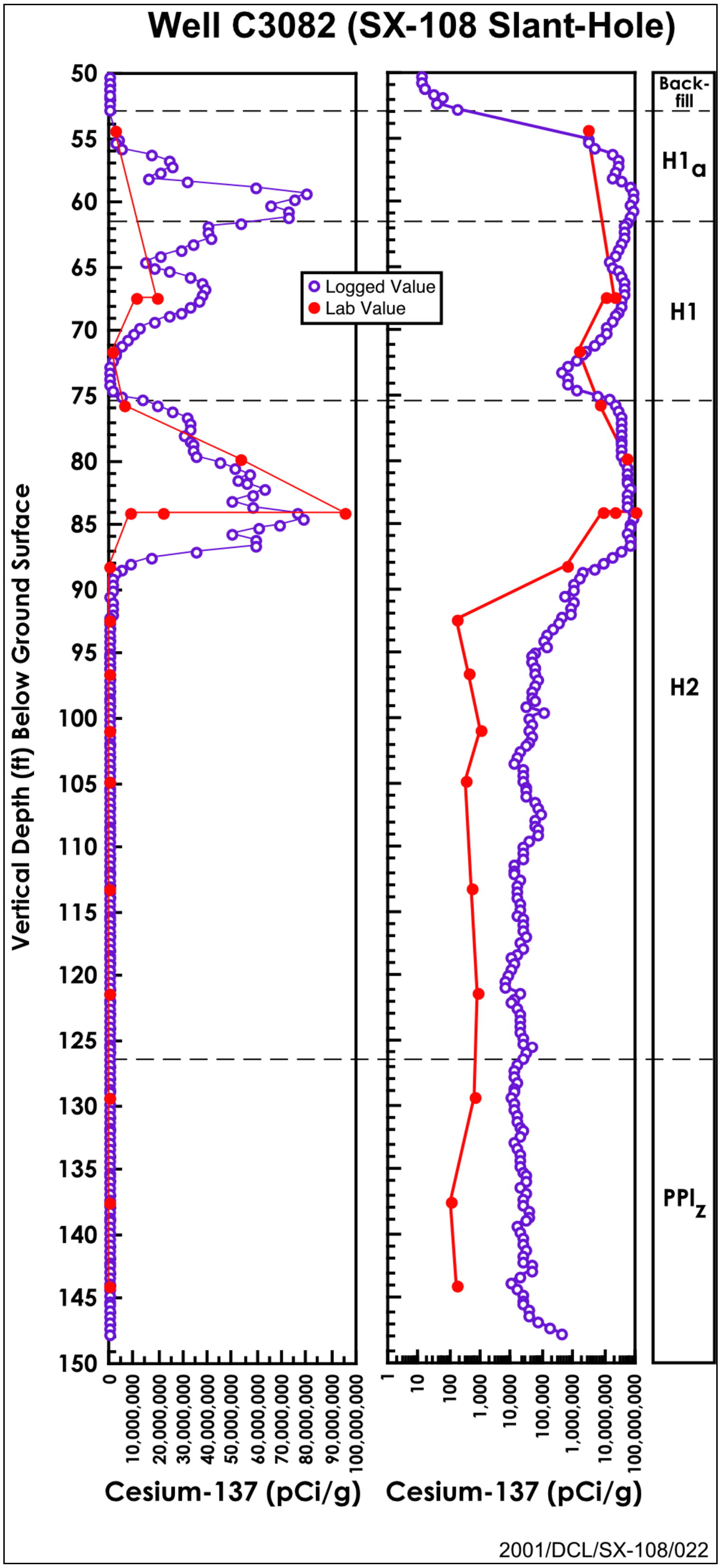
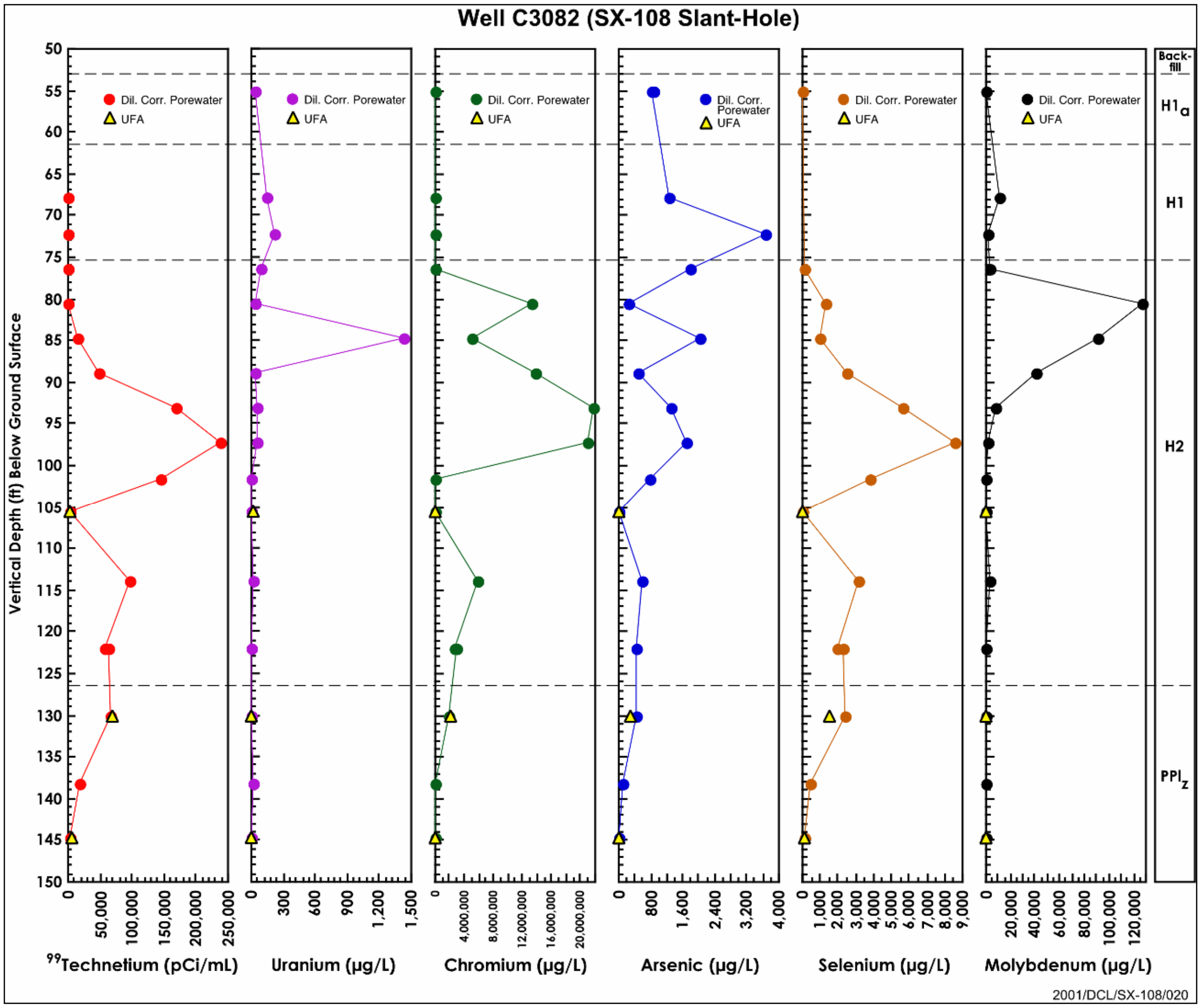


Figure 5.3-23. Trace Metals Calculated and Actual Porewaters for 241-SX-108 Slant Borehole Sediments



5.3.2.8 Plume Size Estimate Based on New Lateral and Drywell Data. The previously estimated leak volume up to mid-1965 of 2,400 gal appears to be correct, but leak volume estimates after mid-1965 of 0 to 35,000 appear to be low based on supplemental information presented in RPP-RPT-29191. The 2005 lateral measurements and more recent drywell measurements indicate a slightly larger plume size than estimated in WHC-MR-0300 and borehole sample results provide alternate methods to estimate total Ci of ^{137}Cs in the soil.

5.3.2.9 Kriging Analysis. Kriging analyses, documented in the S/SX Field Investigation Report (RPP-7884), were used to estimate the leak inventory. The goal of the ^{137}Cs kriging analyses was to establish mathematically defensible estimates associated with the gamma contamination around each tank in SX-Farm (RPP-7884 page 3-22). Kriging estimates were based on the gross gamma, spectral gamma and sample data collected from drywells, laterals and boreholes (HNF-5782, *Estimation of SX-Farm Vadose Zone Cs-137 Inventories from Geostatistical Analysis of Drywell and Soil Core Data*). The mass of the leak calculated by this method was 41,000 Ci of ^{137}Cs (decay corrected to January 1, 1994).

Figure 5.3-24. 241-SX-108 Slant Borehole Data

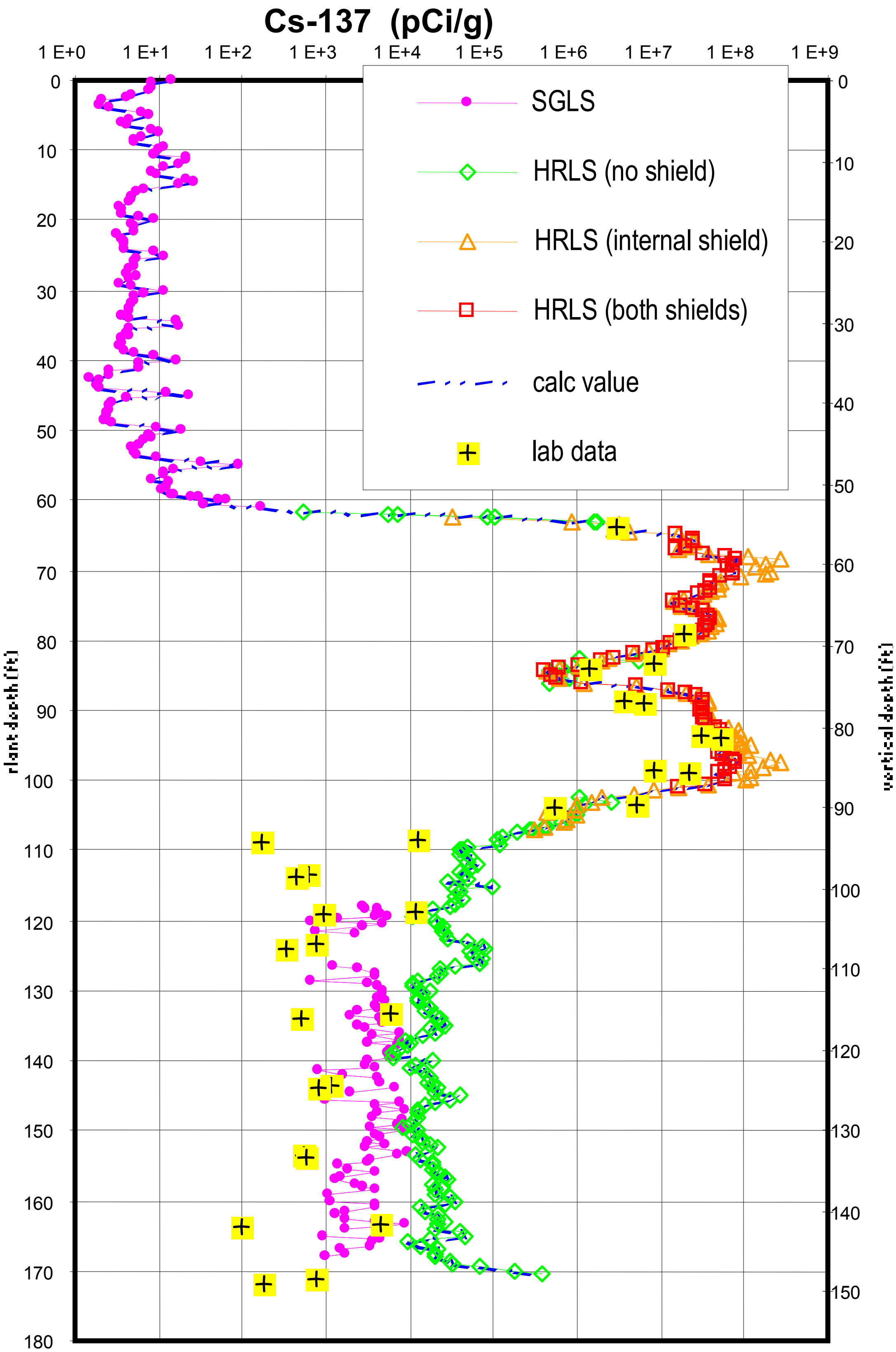
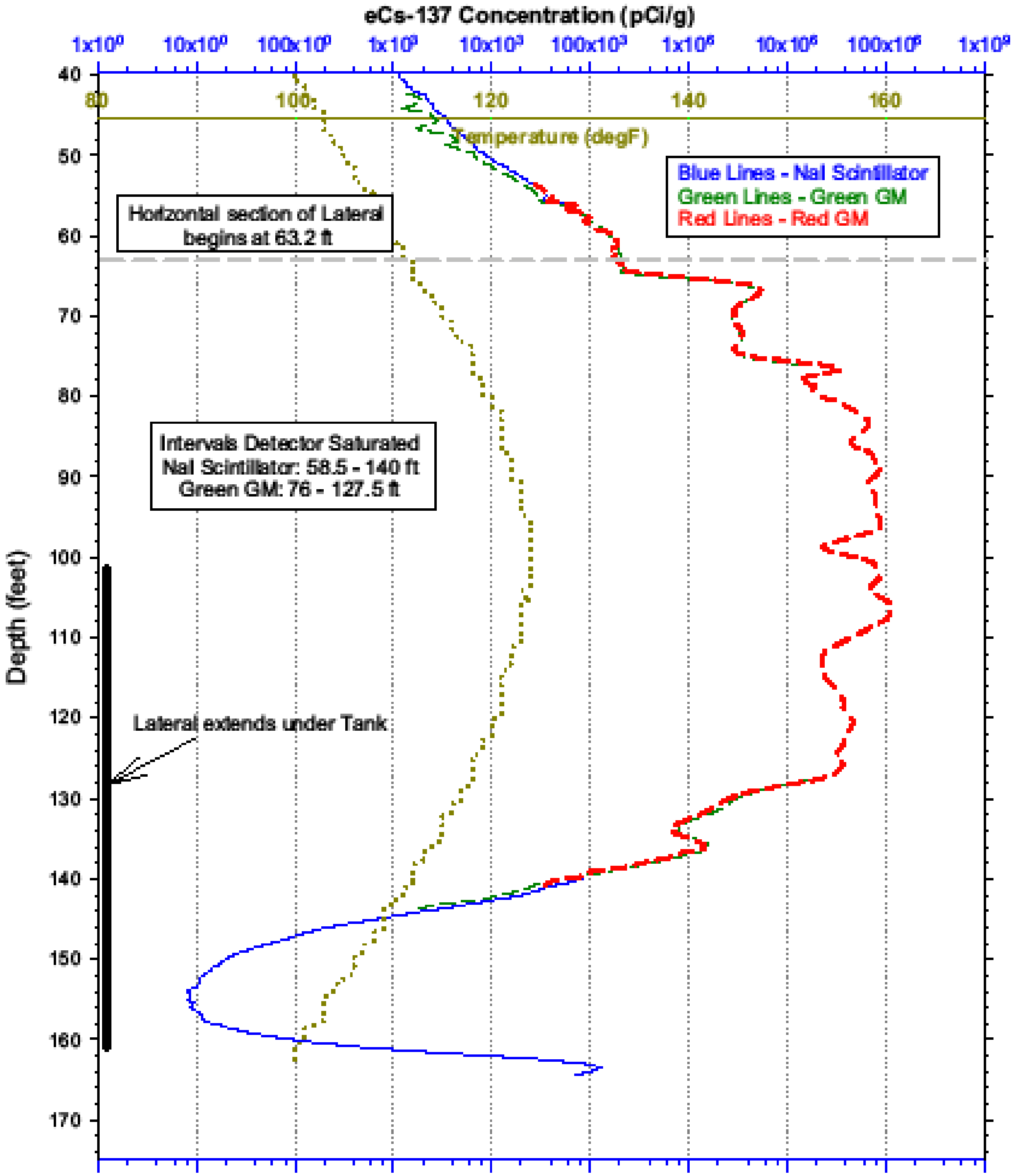
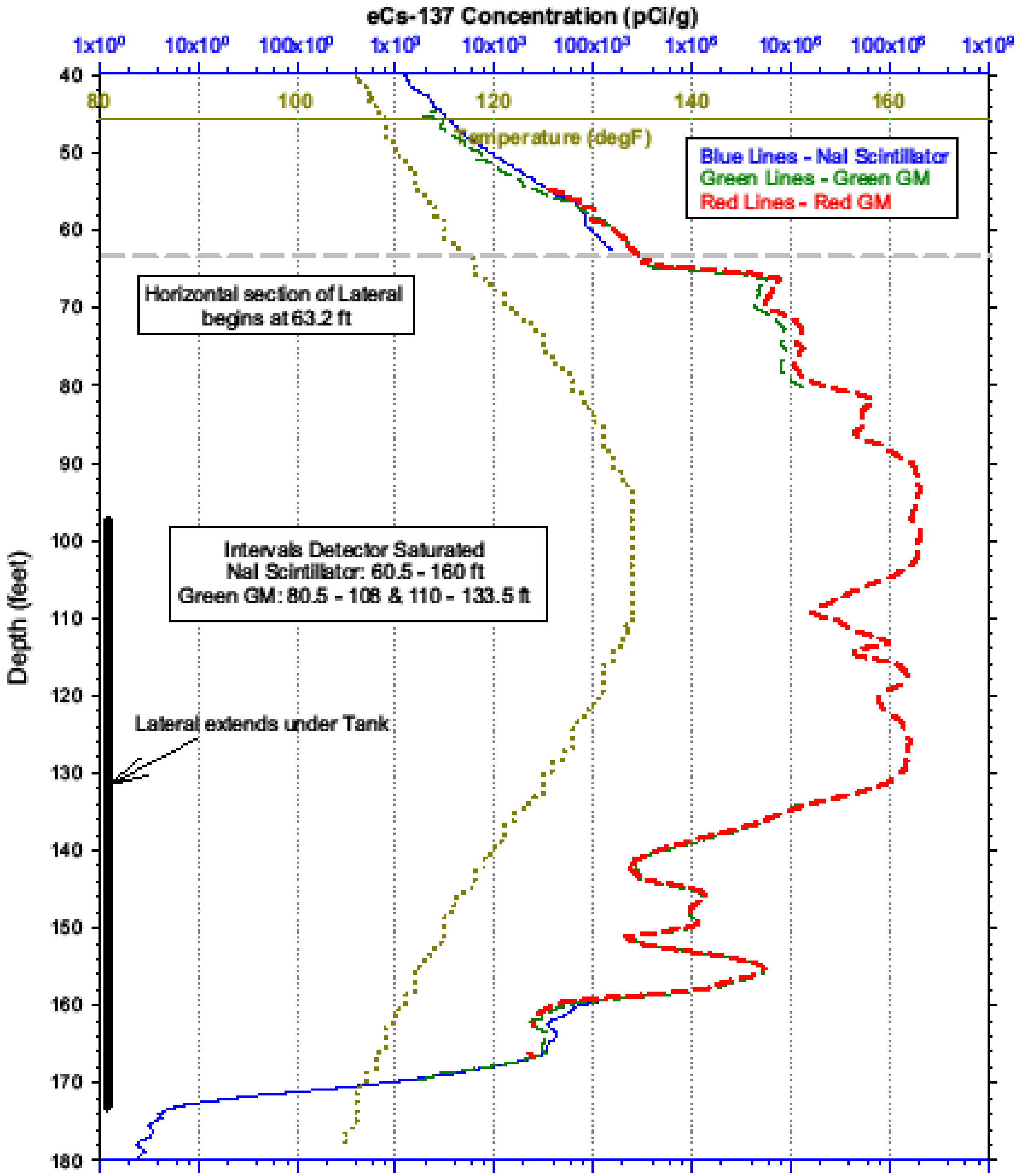


Figure 5.3-25. Gamma Survey for Lateral 44-08-01 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

Figure 5.3-26. Gamma Survey for Lateral 44-08-02 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

The analysis uses 95 percentile ^{137}Cs data (7.7×10^{-1} Ci/L or 2.92 Ci/gal). This value is consistent with the December 1965 BNWL-CC-701 sample data of 7.2 Ci/gal. However, the estimated ^{137}Cs loss using this method was 41,000 Ci decayed to January 1994 (RPP-6285). Therefore, the concentration should have also been decayed to January 1994 resulting in a value of 3.8 Ci/gal. Using the 1994 concentration the leak loss estimate is 41,000/3.8 =11,000 gal vs. the 15,200 gal reported in RPP-6285. For additional discussion of the kriging analysis refer to Section 5.2 (Tank 241-SX-107).

5.3.3 Conclusions

The estimated ^{137}Cs inventory for the SX-108 tank leak was 34,900 Ci decayed to January 1, 2001 or 78,000 Ci on December 1965 based on vadose zone data and kriging analyses. The ^{137}Cs concentration for sample data from tank SX-108 taken December 1965 was 7.22 Ci/gal. This equates to a leak volume of 11,000 gal (78,000/7.22). Because water was added to the tank, the leak concentration was likely below 7.22 Ci/gal after mid-1965 and the leak volume larger. Based on water losses not accounted for (see section 5.3.2.4), the tank is estimated to have leaked as much as 50 to 101 kgal. This would change the distribution of mobile contaminants, but would not change the ^{137}Cs inventory. To calculate the inventory for other analytes, multiply the ratio of the ^{137}Cs inventory (34,900 Ci) and the HDW/SIM ^{137}Cs inventory (41,800 Ci) to the SIM inventory for the selected analyte.

5.4 TANK 241-SX-109 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST SX-109. Tank SX-109 has three laterals (horizontal boreholes) installed about 10 ft under the tank (GJ-HAN-11, 1995, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank SX-109* and drawing H-2-31881). There are seven boreholes (41-09-02, 41-09-03, 41-09-04, 41-09-06, 41-09-07, 41-09-09 and 41-09-11) installed in 1962, and one borehole (41-00-08) installed in 1956, located around tank SX-109 as depicted in Figure 4-1.

5.4.1 Tank 241-SX-109 Waste Operations Summary

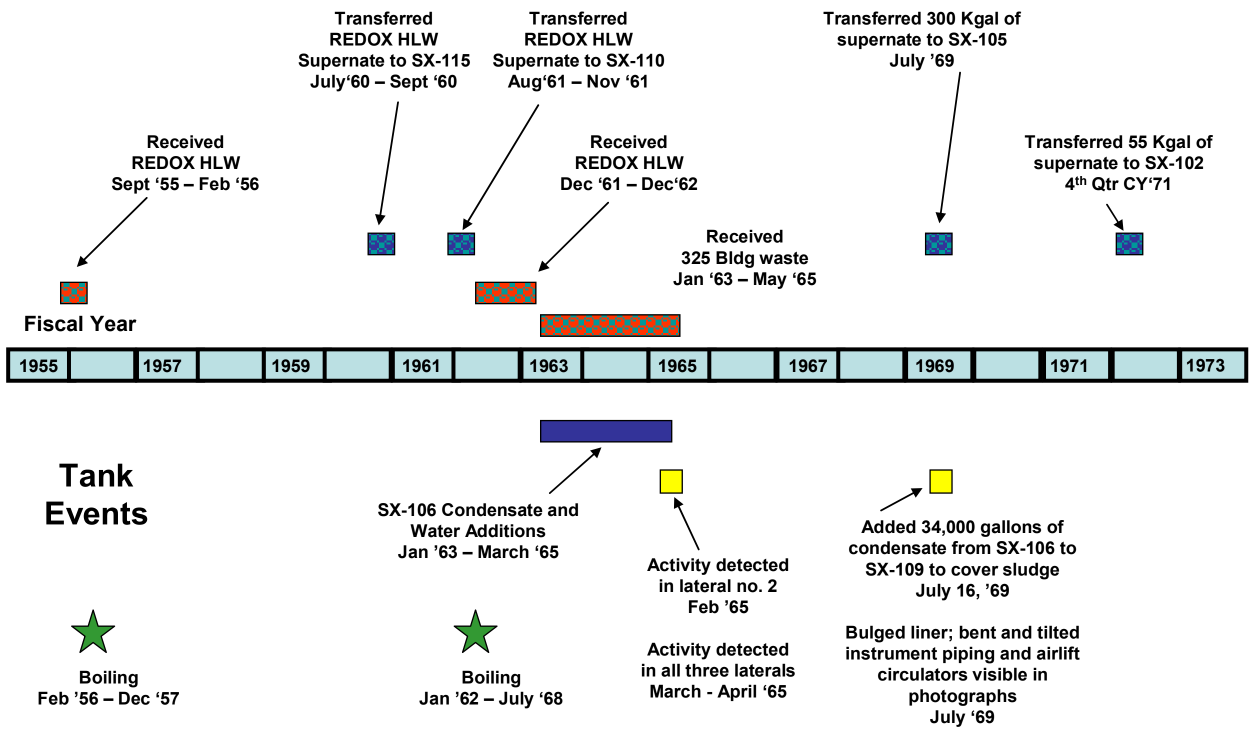
The following subsections provide a brief discussion of the waste transfer history for tank SX-109. A tank history timeline is shown in Figure 5.4-1.

5.4.1.1 Tank 241-SX-109 Waste History

REDOX High-Level Waste Storage (1955 to 1956)
Tank SX-109 was released for operations in September 1955 and received 187,000 gal of REDOX HLW from the 202-S REDOX Plant (HW-39216, *Separations Section Waste – Status Summary for September 1955*, page 8). Tank SX-109 continued to receive REDOX HLW from the 202-S REDOX Plant until November 8, 1955 (HW-40208, *Separations Section Waste – Status Summary for November 1955*, page 8), at which time the REDOX HLW was diverted to tank SX-108. REDOX HLW from the 202-S REDOX Plant was again routed to tank SX-109 from January 1956 (HW-41038, *Separations Section Waste – Status Summary for January 1956*,

page 8) through February 1956 (HW-41812, *Separations Section Waste – Status Summary for February 1956*, page 8), resulting in a total of 977,000 gal of waste in this tank.

Figure 5.4-1. Tank 241-SX-109 Operating History (Fiscal Years 1955 to 1972)



No waste was reported to be added to or removed from tank SX-109 from March 1956 until 1961. However, there is a discrepancy in the waste transfer records for this tank. From March 1956 through September 1956, the waste inventory in tank SX-109 showed a steady decline as a result of self-evaporation. However, in October, November and December 1956, the waste volume in tank SX-109 was reported to have increased by 3,000, 67,000 and 32,000 gal, respectively. The waste transfer records for October (HW-46382, *Chemical Processing Department Waste – Status Summary October 1, 1956 – October 31, 1956*, page 8), November (HW-47052, *Chemical Processing Department Waste – Status Summary November 1, 1956 – November 30, 1956*, page 8) and December 1956 (HW-47640, *Chemical Processing Department Waste – Status Summary December 1, 1956 – December 31, 1956*, page 8) do not identify the source (e.g., receipt of waste, water or condensate) leading to the increase in waste volume in this tank.

Self-evaporation of the waste stored in tank SX-109 continued through 1957, as reported in the waste transfer records and supported by the ~260 °F to ~220 °F temperature readings shown in Appendix A. No appreciable self-evaporation of waste in tank SX-109 was reported for 1958 (only 3,000 gal evaporated) or 1959 (only 5,000 gal evaporated), which is supported by the waste temperature decreasing from ~210 °F to ~170 °F in this time (see Appendix A).

Approximately 284,000 gal of REDOX HLW supernate were transferred from tank SX-109 to tank SX-115 (see section 5.10.1.1) from July through September 1960, leaving 334,000 gal of supernate and 333,000 gal of sludge in tank SX-109 (HW-66557, *Chemical Processing Department Waste Status Summary*, *July 1, 1960 – July 31, 1960*, page 8, HW-67696, *Chemical Processing Department Waste Status Summary*, *September 1, 1960 – September 30, 1960*, page 8, and HW-83906-D-RD, *Chemical Processing Department 200 West Area Tank Farm Inventory and Waste Reports January 1959 Through June 1961*, pages 147, 155 and 163). In August, September and November 1961, ~386,000 gal of supernate were transferred from tank SX-109 into tank SX-110 (HW-72625, *Chemical Processing Department – Waste Status Summary*, *July – December 1961*, page 8 and HW-83906-E-RD pages 4 and 5). These transfers were conducted to evaporate the tank SX-109 supernate using the radiolytic decay heat generated by the REDOX HLW stored in tank SX-115 and SX-110, thus recovering valuable tank space for additional storage of waste from the 202-S REDOX Plant.

Second Filling with REDOX HLW (1961 to 1962)

In December 1961, the routing of HLW from the 202-S REDOX Plant was switched from tank SX-112 to tank SX-109 (HW-72625 page 8 and HW-83906-E-RD page 5), which received 58,000 gal of waste. An additional 507,000 gal of 202-S REDOX Plant HLW and 89,000 gal of dilute waste from tank SX-102 were added to tank SX-109 from January through June 1962 (HW-74647, *Chemical Processing Department – Waste Status Summary*, *Planning and Scheduling Production Operation*, *January – June 1962*, page 8 and HW-83906-E-RD pages 13 and 14). The temperature of the waste in tank SX-109 rapidly increased from ~140 °F in November 1961 to ~270 °F in June 1962, which caused the evaporation of ~447,000 gal from January through June 1962.

Tank SX-109 continued to receive REDOX HLW from July through December 1962, receiving 147,000 gal of REDOX HLW from 202-S Plant and 234,000 gal of dilute REDOX HLW from tank SX-105. After receipt of these additional wastes and water, the waste temperature in tank SX-109 increased to ~280 °F. In order to control the waste temperature in this tank, 120,000 gal of water and 87,500 gal of condensate from SX-106 were also added from July through December 1962 (HW-76223, *Chemical Processing Department – Waste Status Summary*, *Planning and Scheduling Production Operation, July – December 1962*, page 8 and HW-83906-E-RD pages 22, 23 and 24).

Water continued to be added to tank SX-109 to control the waste temperature through evaporative cooling. A total of 390,000 gal of water and 55,800 gal of tank SX-106 condensate were added to tank SX-109 from January 1963 through May 1965 (HW-83906-E-RD pages 31, 32, 33, 40, 41, 42, 49, 50, 56a, 56b, 56c, 62a, 62b and 62c). Tank SX-109 also received ~128,000 gal of miscellaneous wastes from the 325 Building (via catch tank 151-SX) during this period. The water additions to tank SX-109 were successful in maintaining the waste temperature at ~280 °F throughout 1963 and 1964.

No additional waste transfer or water additions to tank SX-109 occurred after May 1965. The tank waste was allowed to slowly evaporate and the waste temperature slowly declined from ~280 °F to ~230 °F from June 1965 through June 1968, which is the last date for historical temperature records (see Appendix A). The apparent reduction in the waste inventory from 1974 (257,000 gal) to the present (241,000 gal) is due to evaporation of interstitial liquid present in the sludge and saltcake waste.

Neither the sludge nor saltcake waste in this tank have been sampled and analyzed.

5.4.1.2 Tank 241-SX-109 Integrity. Radioactivity was first detected in lateral no. 3 beneath this tank in February 1965 (see section 5.4.2.3); the tank was suspected of leaking and declared a confirmed leaker (SD-WM-TI-356, WHC-MR-0301, *Tank 241-SX-109 Leak Assessment*). The leak either spread or new leaks developed as radioactivity was subsequently detected in the other laterals beneath tank SX-109 in March and April 1965.

Although an average liquid level decrease of 4 in. per year was calculated based on liquid level decreases between 1965 and 1973, some early reports estimated that the amount of leakage was "small" and others "less than 5,000 gal" (WHC-MR-0301). It was noted that a portion of the liquid level decrease can be attributed to evaporation. In 1983, based on an airflow of 1,000 cfm and post 1977 psychometric data (no psychometric data were available between 1965 and 1973) the evaporation rate for the the tank was estimated at 2.5 in./yr or more (WHC-MR-0301 Supplement 1, *Waste Tank 241-SX-109 Supporting Documentation*, page 24-3); concluding that 33,000 gal of waste may have leaked to the soil. This conservative estimate assumed that the evaporation rate after 1977 for a moist sludge surface would be the same as for a liquid surface and the tank temperature and conditions in earlier years (WHC-MR-0301 Supplement 1 page 24-1).

In 1992, a review of historical information concluded that the volume of waste leaked from tank SX-109 was unknown, but was likely less than 10,000 gal based on comparison of the contaminated area and activity levels in drywells and laterals under tank SX-109 with that under tank SX-108 and the earlier estimated waste loss of 2,400 to 35,000 gal for tank SX-108 (WHC-MR-0301 pages iv, 15, 16 and 17). This is the current estimate in the tank waste summary report (HNF-EP-0182).

5.4.1.3 Tank 241-SX-109 Interim Stabilization. Tank SX-109 was declared interim stabilized in January 1992 based on May 1986 in-tank photographs that showed no liquid surface and an estimated 47,900 gal of drainable interstitial liquid (HNF-SD-RE-TI-178 page 270). Tank SX-109 is estimated to contain 66,000 gal of REDOX R1 (HLW 1952-1958) and R2 (HLW 1959-1966) sludge and 175,000 gal of REDOX saltcake waste (HNF-EP-0182 page 17).

5.4.1.4 Tank 241-SX-109 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-109 starts in August 1956 and continues through June 1968. Appendix A provides plots showing the maximum temperature (°F) of the waste stored in tank SX-109. These temperature plots show tank SX-109 waste temperature reached a maximum of ~280 ± 10 °F in August 1962, staying at this temperature through May 1965, then gradually declining to ~230 °F by June 1968. These relatively high tank waste temperatures are consistent with the operating practices for tanks that contained boiling REDOX HLW.

5.4.2 Data Review and Observations

5.4.2.1 Early Lateral and Drywell Data. The first reported survey of the laterals beneath tank SX-109 was in December 1962 (*Monthly Report Waste Handling and Decontamination*

Operation REDOX Operation December 1962, Rough Draft [Harmon 1963a]). The laterals under tank SX-109 were monitored and no radiation readings were obtained. A survey of the laterals in June 1963 also indicated no radioactivity in the laterals (*Monthly Report Waste Handling and Decontamination Operation REDOX Operation June 1963*, Rough Draft [Harmon 1963g]). The historical information on radioactivity measured in the laterals beneath tank SX-109 from December 1962 through June 1966 is reported in Table 5.2-2. Subsequent surveys of the laterals beneath tank SX-109 from 1973 through 1987 are reported in SD-WM-TI-356. No lateral surveys were located for July 1966 through 1972.

There continued to be no indication of waste leakage from tank SX-109 until February 6, 1965, when radioactivity was reported to be detected beneath this tank (RL-SEP-297, *REDOX Weekly Process Reports January through December, 1965*, page 28). On February 20, 1965, 5,000 cpm radioactivity was detected in lateral no. 3 (69° S 15′ W) beneath tank SX-109 (RL-SEP-297 page 36). On March 31, 1965, 14,100 cpm radioactivity was detected in lateral no. 2 (45° S 0′ W) beneath tank SX-109 (RL-SEP-297 page 65), indicating either spreading of leaked waste or a new leak site from tank SX-109. The radioactivity detected in laterals no. 2 and 3 continued to increase and 200 cpm radioactivity was detected in lateral no. 1 (20° S 45′ W) beneath tank SX-109 on April 29, 1965 (RL-SEP-297 page 87). Radioactivity detected in all three laterals beneath tank SX-109 continued to increase from May 1965 through June 1966, the last date measurements were reported.

Higher levels of radioactivity detected in drywells 41-09-02 and 41-09-04 (formerly labeled as 241-SX no. 38 and no. 33) during 1965, but were attributed to waste leakage from tank SX-108, which had earlier started leaking (RL-SEP-297 pages 40, 66, 87 and 99). No radioactivity was reported in drywells 41-09-06, 41-09-07, 41-09-09 or 41-09-11 (formerly labeled as 241-SX nos. 34, 35, 36 and 37) during 1965.

Although radioactivity was detected in the laterals beneath tank SX-109, the tank farm contractor (General Electric from 1948 to 1965 and ISOCHEM from 1966 to 1967) continued to store REDOX HLW supernate and sludge in this tank because there was a shortage of storage space for HLW and the leak was thought to have self-sealed (WHC-MR-0301). Tank SX-109 was actively ventilated at an airflow rate of approximately 1,000 cfm (WHC-MR-0301 Supplement 1 page 24-3) and supernate in the tank was allowed to evaporate and concentrate, reaching a maximum reported specific gravity of 1.66 on August 25, 1965 (RL-SEP-297 page 138), but was generally 1.63 ± 0.03 during 1964 and 1965. No other data was located on the specific gravity of the supernate in tank SX-109. The tank farm contractor thought the concentrated REDOX HLW supernate would not migrate very far from the leak site based on field tests conducted with simulated REDOX HLW supernates (HW-57088, *Interim Report -- Simulated Leak in an Underground REDOX Waste Storage Tank*). The tank farm contractor believed the waste leakage from tank SX-109 was the result of relatively low seepage (BNWL-CC-701 page 4).

5.4.2.2 Tank Photos and Liquid Level Changes. On July 1, 1969, 3 ft of liquid (~99,800 gal) was pumped from tank SX-109 to tank SX-105, leaving the liquid level at ~13 ft in tank SX-109 (ARH-1023-3-DEL, *Chemical Processing Division Daily Production Reports July, 1969 through September, 1969*, page 1). Pictures of the liner inside tank SX-109 were obtained. On July 8, 1969, an additional 3 ft of liquid (~99,200 gal) was pumped from tank SX-109 to tank SX-105, leaving the liquid level at ~10 ft in tank SX-109 (ARH-1023-3-DEL page 9).

Photographs obtained when the liquid level in tank SX-109 was at ~10 ft were reported to indicate that a portion of the sludge was uncovered near the tank edge and confirm the existence of a bulged liner, bent and tilted instrument piping and airlift circulators (ARH-1106-DEL, *200 Areas Operation Monthly Report July 1969*, page G1-3). These photographs were not located and reported observations could not be confirmed by viewing photographs taken in 1986, however if the liner was bulged this suggests the potential for a leak along the outer edge of the tank bottom. The sludge level had been estimated to be only 7 to 8 ft. Approximately 34,000 gal of condensate was pumped from tank SX-106 into tank SX-109 on July 16, 1969 to cover and cool the sludge until a separate air cooling system could be installed (ARH-1023-3-DEL page 21).

In the fourth quarter of calendar year (CY) 1971, ~55,000 gal of supernate was transferred from tank SX-109 to tank SX-102, leaving ~88,000 gal of liquid and 189,000 gal of solids in tank SX-109 (ARH-2074-D page 10). The supernate in tank SX-109 was allowed to evaporate. The liquid level within tank SX-109 continued to decline until the first quarter of CY 1974 when the tank inventory was revised to indicate that only 257,000 gal of solids were present (ARH-CD-133A, *Operations Division Waste Status Summary, January 1, 1974 through March 31, 1974*, page 8).

5.4.2.3 Additional Drywell Logging Data. In September 1972, drywell readings using a GM probe showed significant increases in radiation at levels below the tank bottom in four drywells adjacent to tank SX-109. The waste leaked from tank SX-109 may have spread from 1980 through 1988 based on increased radioactivity detected in drywells 41-09-09 (73-ft level) and 41-00-08 (68-ft level) and lateral 44-09-02 (WHC-MR-0301 Supplement 1, sections 16 through 19, 22, 25, 26 and 28 through 33). Logging data for drywells 41-09-03, 41-09-04, 41-09-07 and 41-09-09 collected using the high rate tool after 1990 is shown in Figures 5.4-2 through 5.4-5. Figures 5.4-6 through 5.4-9 show total gamma logging results for drywells 41-09-03, 41-09-04, 41-09-07 and 41-09-09 from 1975 through 1995.

Contamination is present at the ~65-ft depth in drywell 41-09-03. Contamination is also present at three distinct depths in drywell 41-09-04: ~65 ft, 74 to 82 ft, and 82 to 87 ft. The contamination detected at the 82- to 87-ft depth in drywell 41-09-04 does not correlate with the decay of ^{137}Cs. The contamination detected in drywells 41-09-03 and 41-09-04 are likely associated with past waste loss events from tank SX-108, since similar radioactivity at the ~65-ft depth has been detected in drywell 41-08-07 and at the 45- to 65-ft depth in drywell 41-08-11. Contamination is present at the 60- to 75-ft depth in drywell 41-09-07. Contamination is present at the ~64-ft and ~74-ft depths in drywell 41-09-09. The contamination detected in these drywells generally correlates with the decay of ^{137}Cs. The concentration of radioactivity detected in drywell 41-09-07 at the 60- to 75-ft depth and in drywell 41-09-09 at the 74-ft depth has been increasing since about 1982 and has been previously attributed to migration of existing waste leakage from tanks SX-107, SX-108 and SX-109 (RPP-7884).

Figure 5.4-2. Drywell 41-09-03 Gamma Logging Results

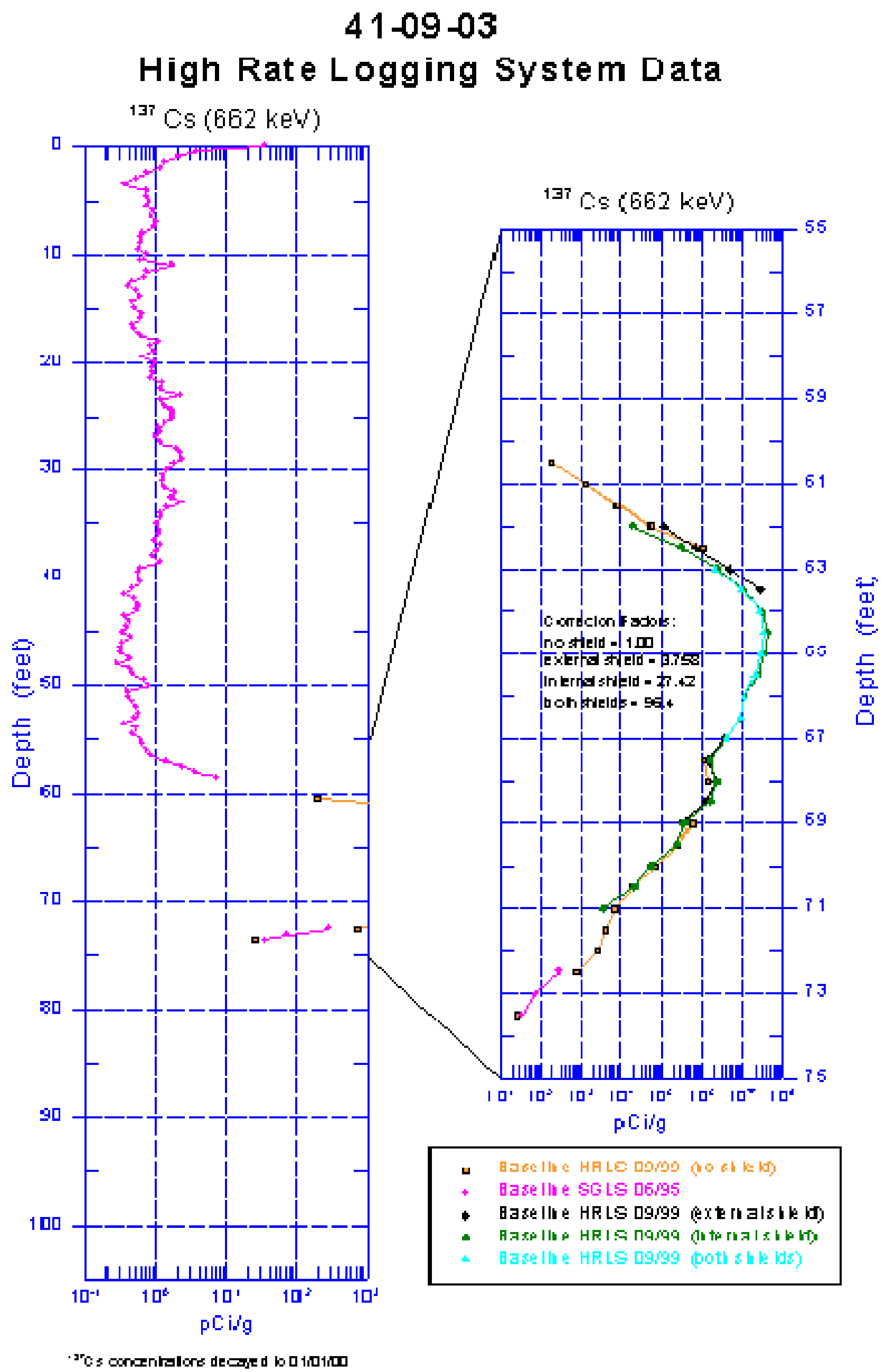


Figure 5.4-3. Drywell 41-09-04 Gamma Logging Results

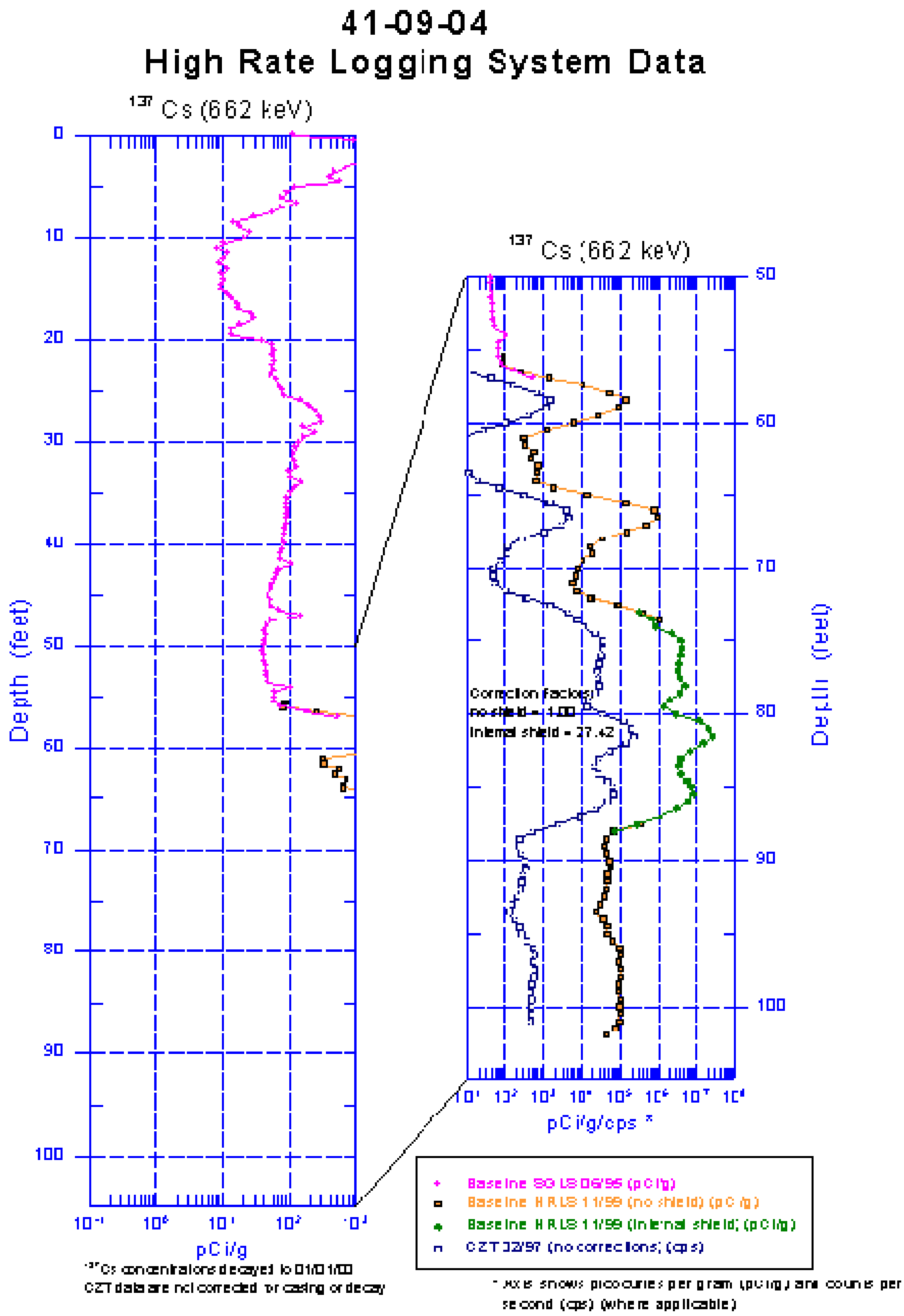


Figure 5.4-4. Drywell 41-09-07 Gamma Logging Results

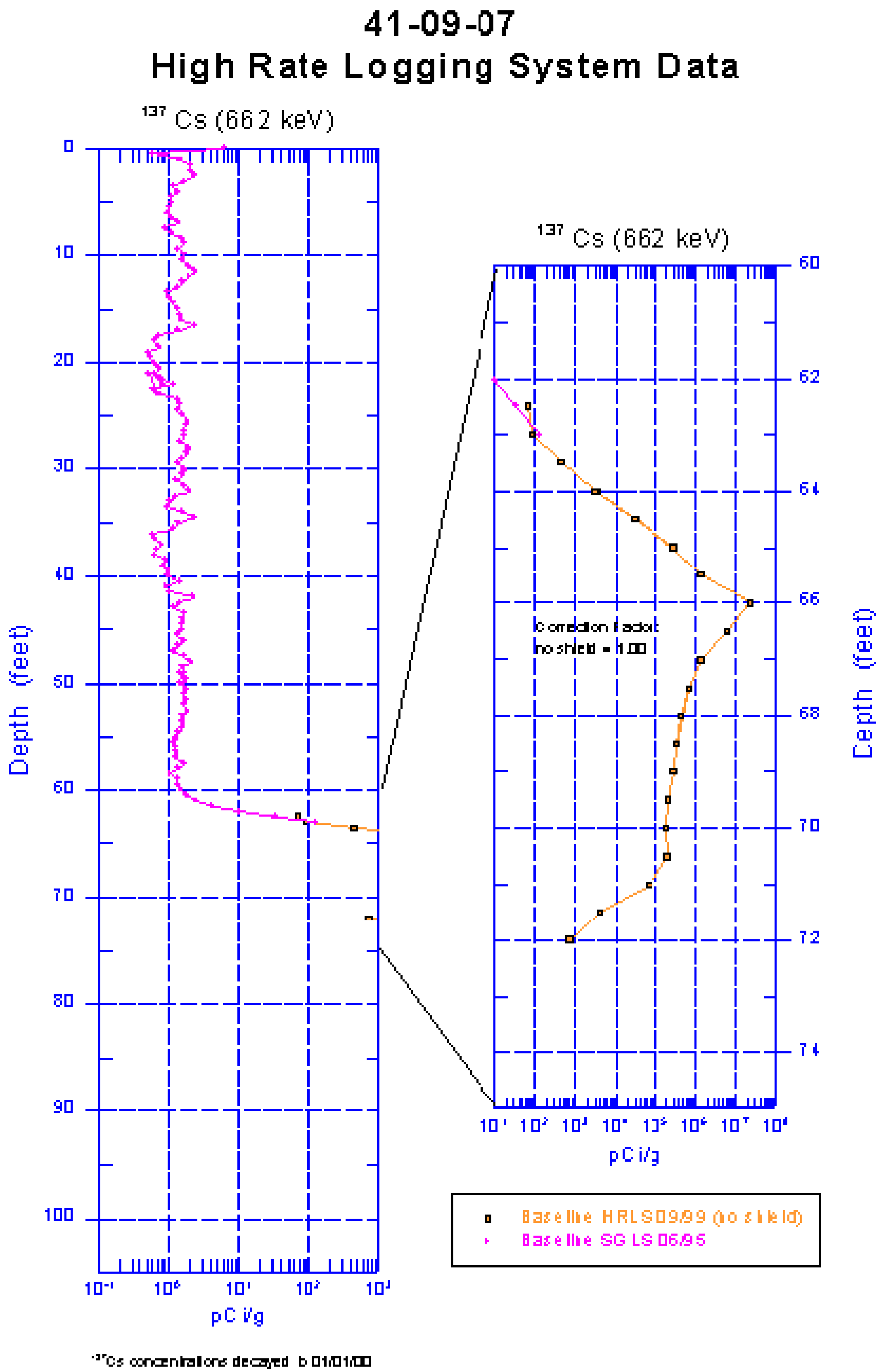


Figure 5.4-5. Drywell 41-09-09 Gamma Logging Results

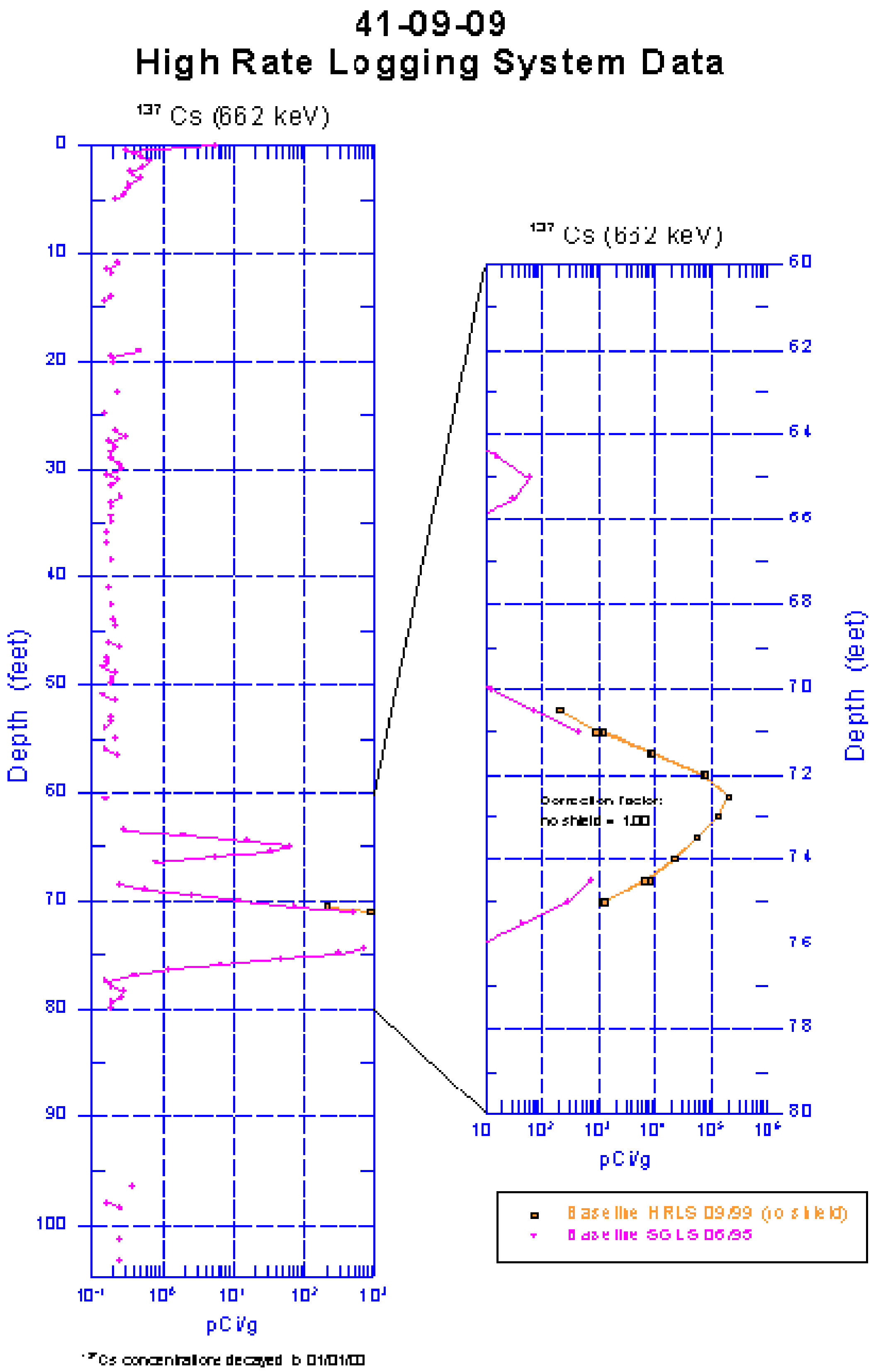


Figure 5.4-6. Drywell 41-09-03 Total Gamma (1975 to 1995)

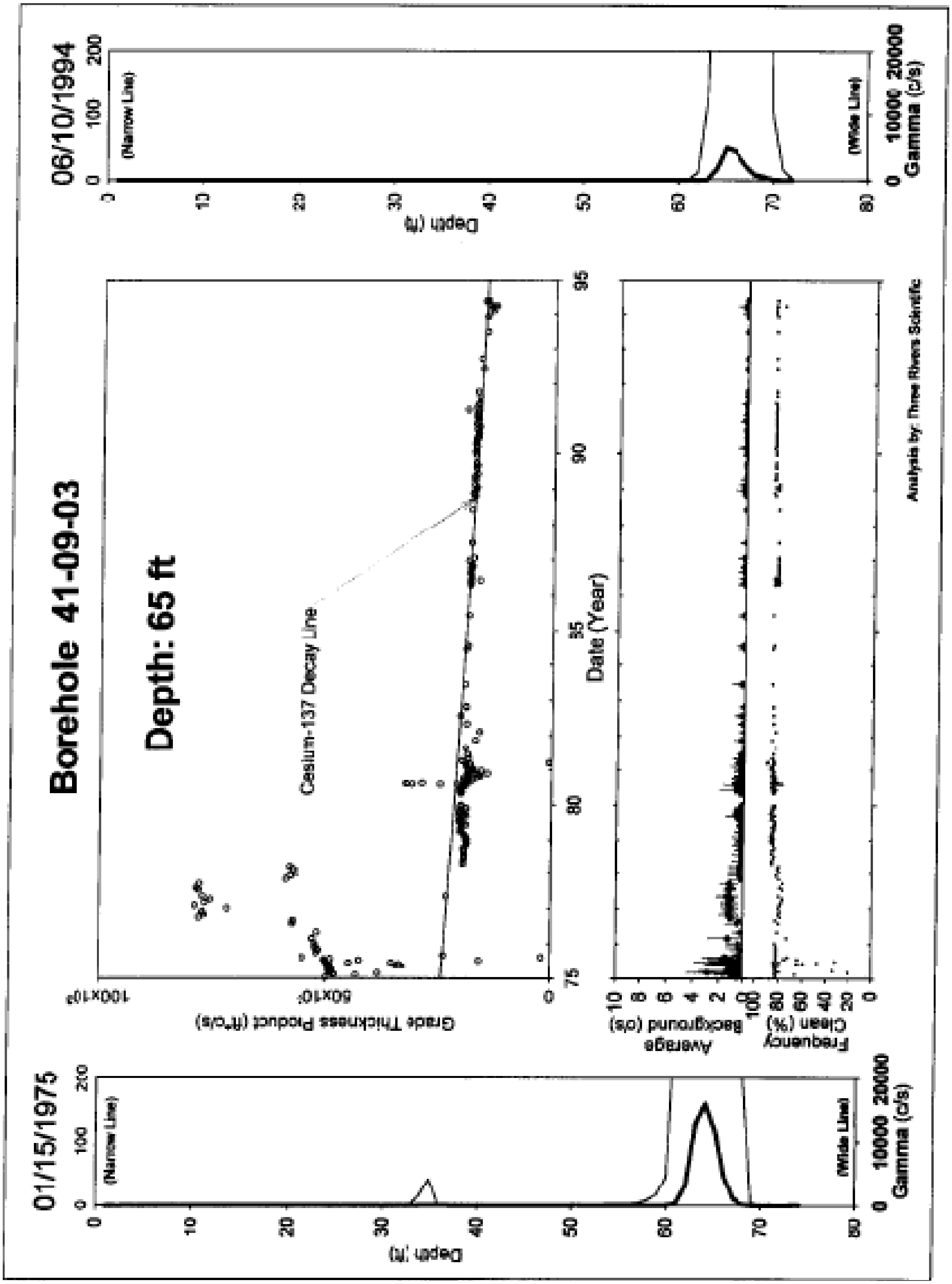


Figure 5.4-7. Drywell 41-09-04 Total Gamma (1975 to 1995) (1 of 3 sheets)

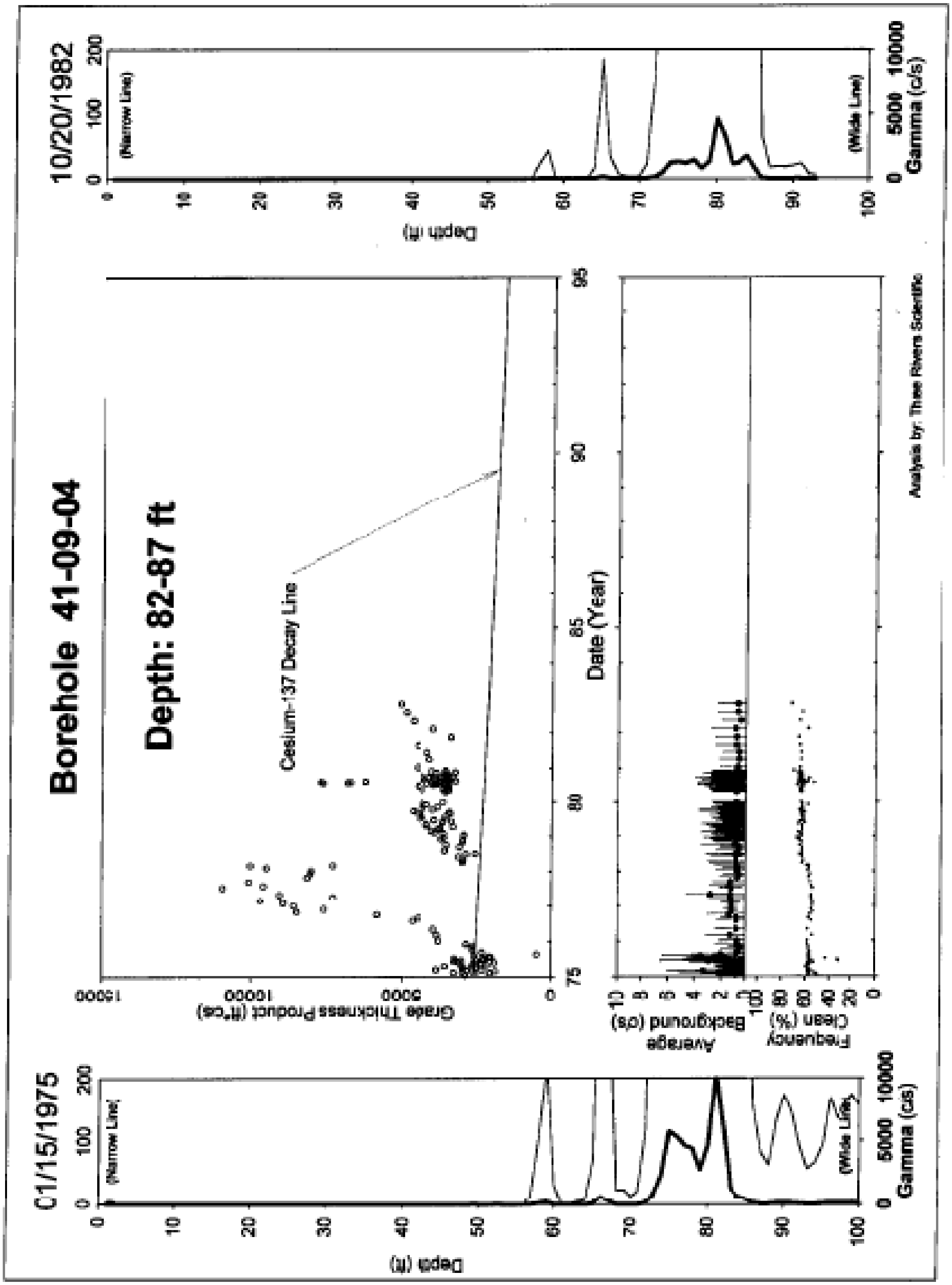


Figure 5.4-7. Drywell 41-09-04 Total Gamma (1975 to 1995) (2 of 3 sheets)

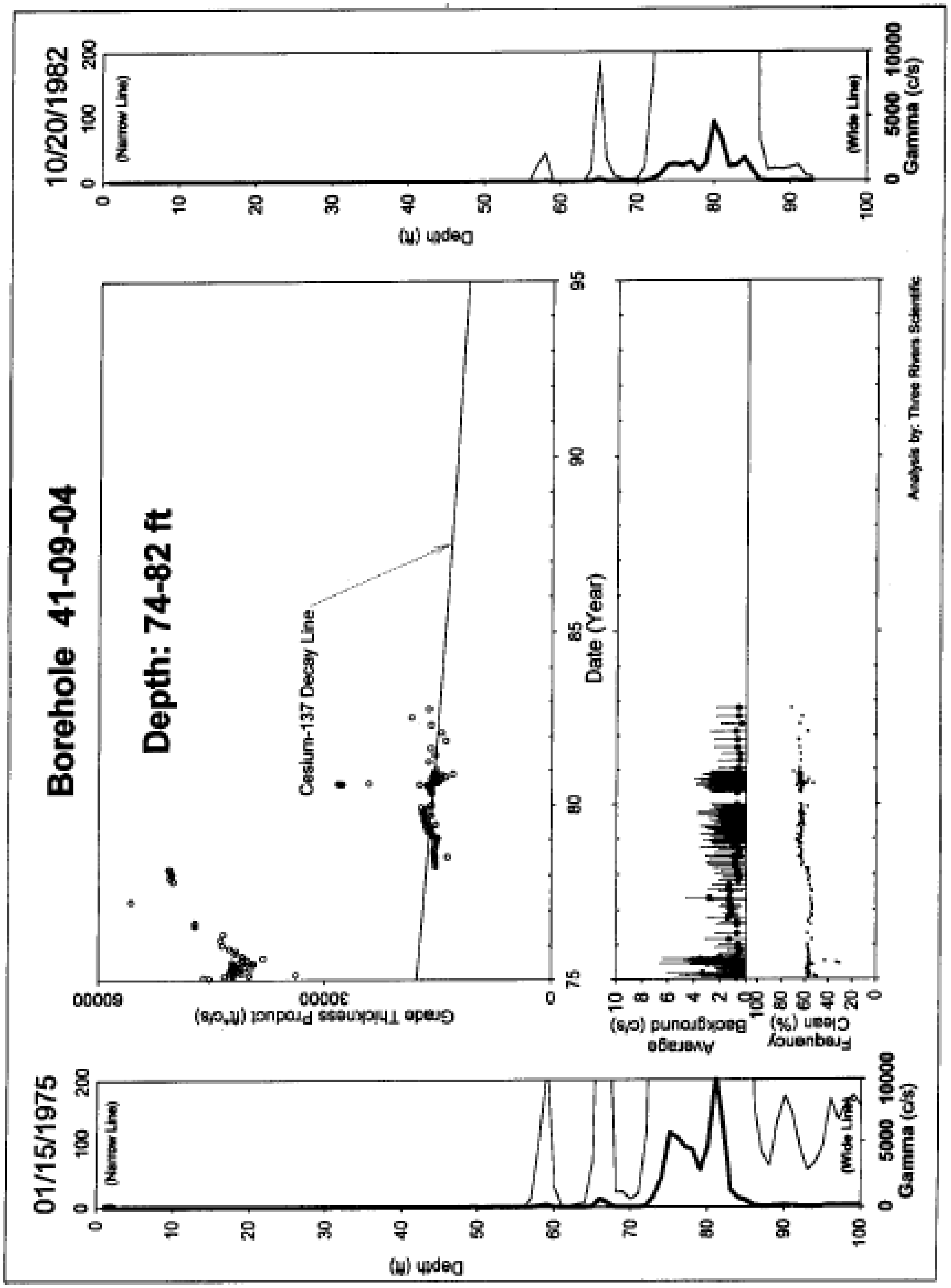


Figure 5.4-7. Drywell 41-09-04 Total Gamma (1975 to 1995) (3 of 3 sheets)

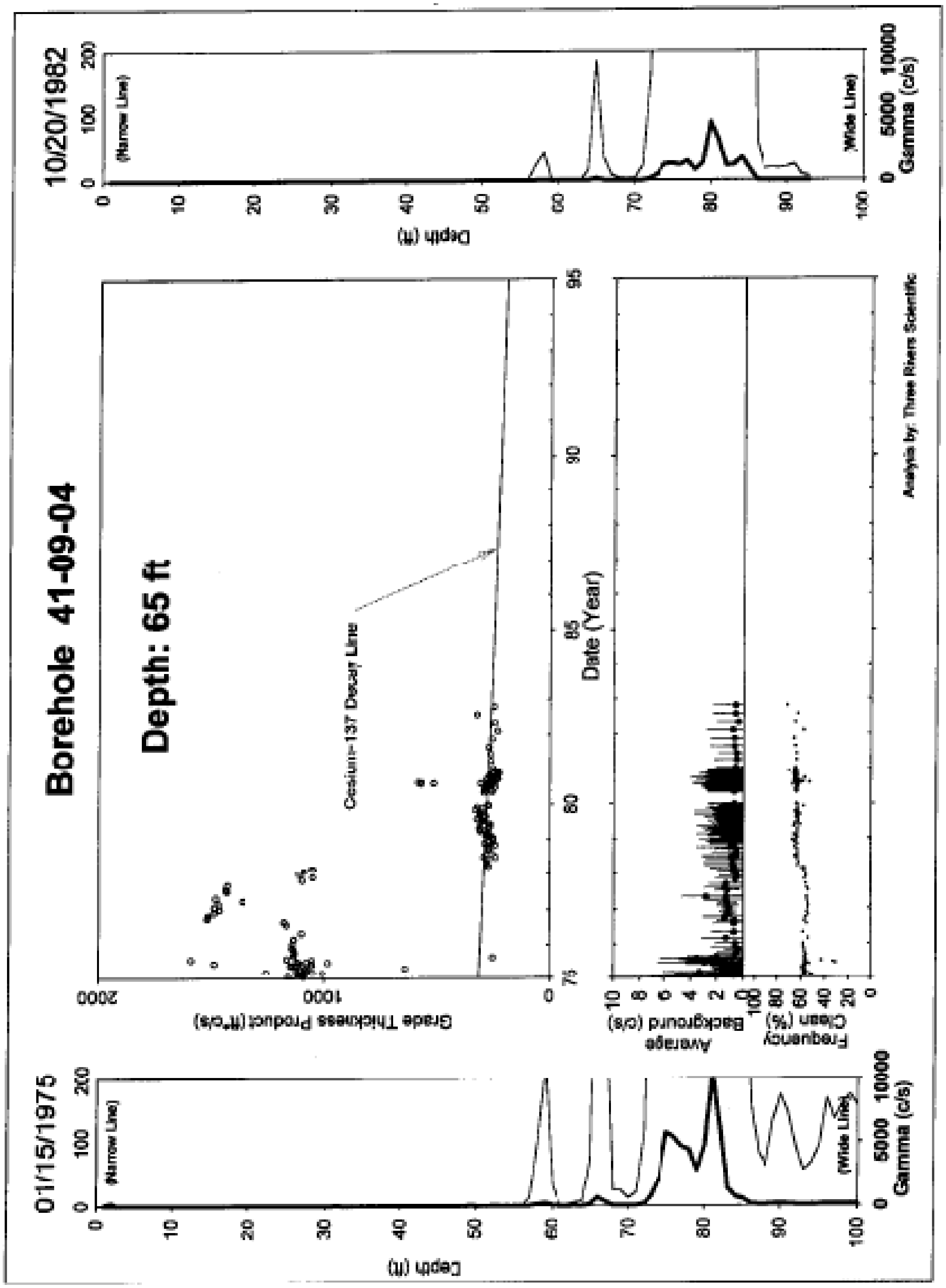


Figure 5.4-8. Drywell 41-09-07 Total Gamma (1975 to 1995)

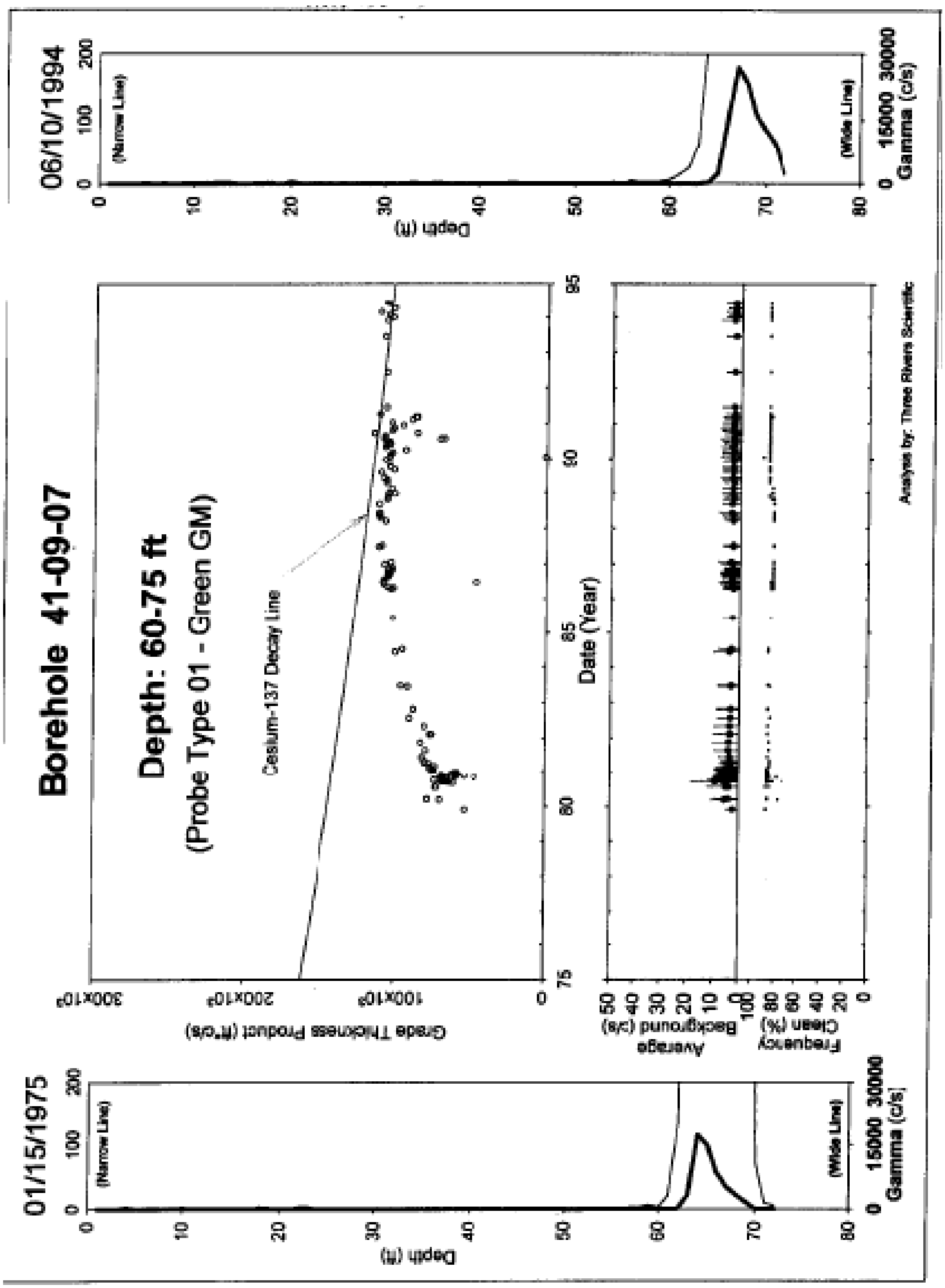


Figure 5.4-9. Drywell 41-09-09 Total Gamma (1975 to 1995) (1 of 2 sheets)

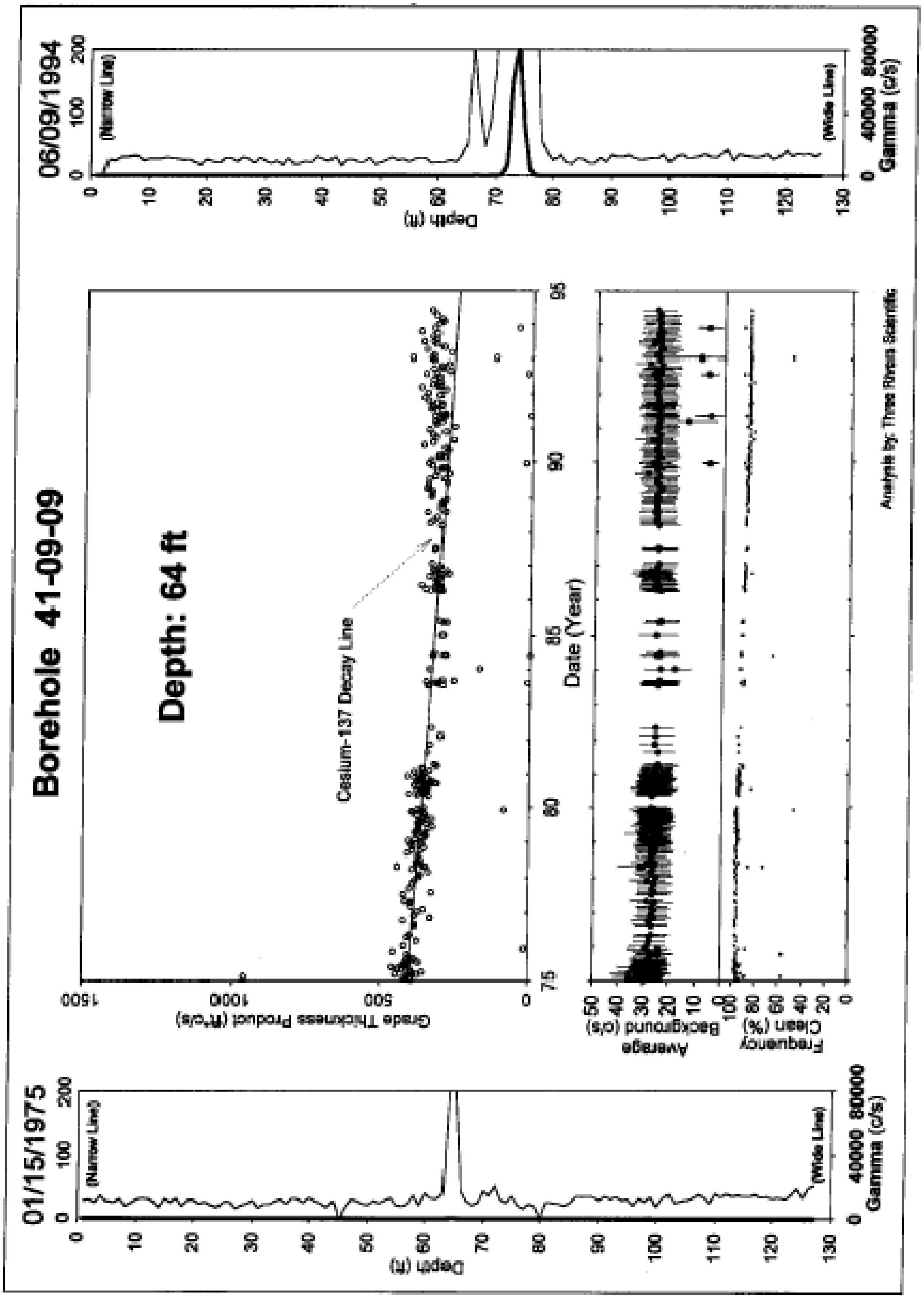
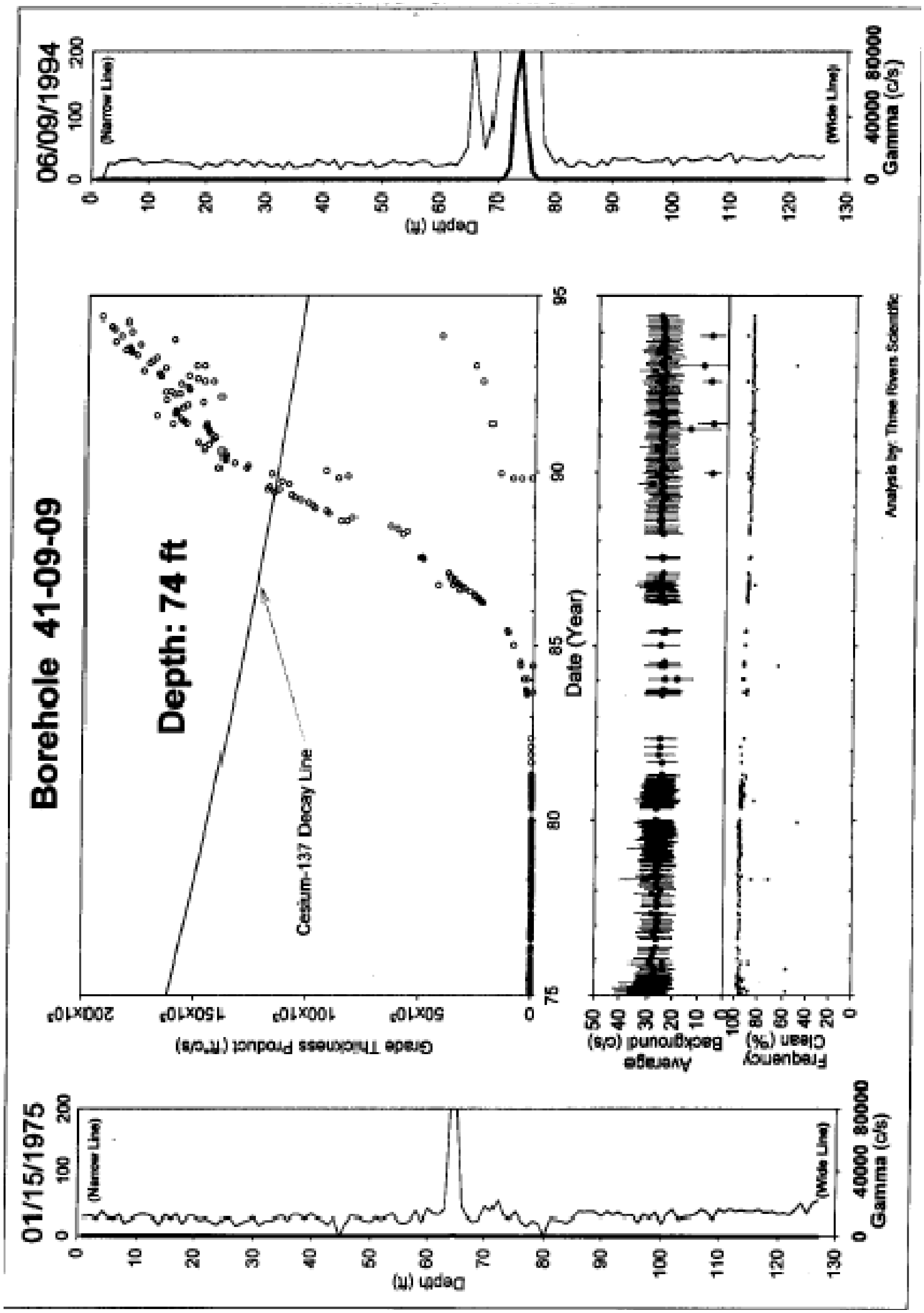


Figure 5.4-9. Drywell 41-09-09 Total Gamma (1975 to 1995) (2 of 2 sheets)



5.4.2.4 Kriging Analysis. An estimate of the waste loss from tank SX-109 was prepared based on a kriging analysis of the drywell gamma surveys and soil sample analyses for ^{137}Cs (RPP-7884 pages 3 through 22). This kriging analysis estimated that 2.67×10^3 Ci of ^{137}Cs (decay corrected to January 1, 1994) were leaked from tank SX-109 using the 95 percentile data (RPP-7884 page 3-26). The estimated waste loss from tank SX-109 is 989 gal based on the estimated average waste composition present in the tank at the time of the waste loss of 2.7 Ci/gal (RPP-7884 pages 3 through 18). The HDW model revision 4 was used to estimate the average waste composition in tank SX-109 for 1964 through 1969 (RPP-7884 Appendix C.3). This kriging analysis represents a defensible basis for establishing an estimated waste loss from tank SX-109. For additional discussion of the kriging analysis refer to Section 5.2 (Tank 241-SX-107).

5.4.3 Conclusions

The estimated ^{137}Cs inventory for the SX-109 tank leak was 2,300 Ci (decayed to January 1, 2001) based on vadose zone data and kriging analyses. The assumed ^{137}Cs concentration of the leak was 2.3 Ci/gal (decayed to January 1, 2001). This equates to a leak volume of 1,000 gal (2,300/2.3). The ^{137}Cs concentration at the time of the leak may have been smaller and the leak volume larger than that estimated with a cesium concentration of 2.3 Ci/gal. Also, unknown transfer line or water losses may have also been present resulting in a larger distribution of waste leaked to the soil. To calculate the inventory for other analytes multiply the ratio of the ^{137}Cs inventory (2,300 Ci) and the HDW/SIM ^{137}Cs inventory (2,400 Ci) to the SIM inventory for the selected analyte.

5.5 TANK 241-SX-110 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST SX-110. Tank SX-110 has three laterals (horizontal boreholes) installed about 10 ft under the tank and eight boreholes (41-10-01, 41-10-02, 41-10-03, 41-10-05, 41-10-06, 41-10-08, 41-10-10 and 41-10-11) located around tank SX-110 (see Figure 4-1).

5.5.1 Tank 241-SX-110 Waste Operations Summary

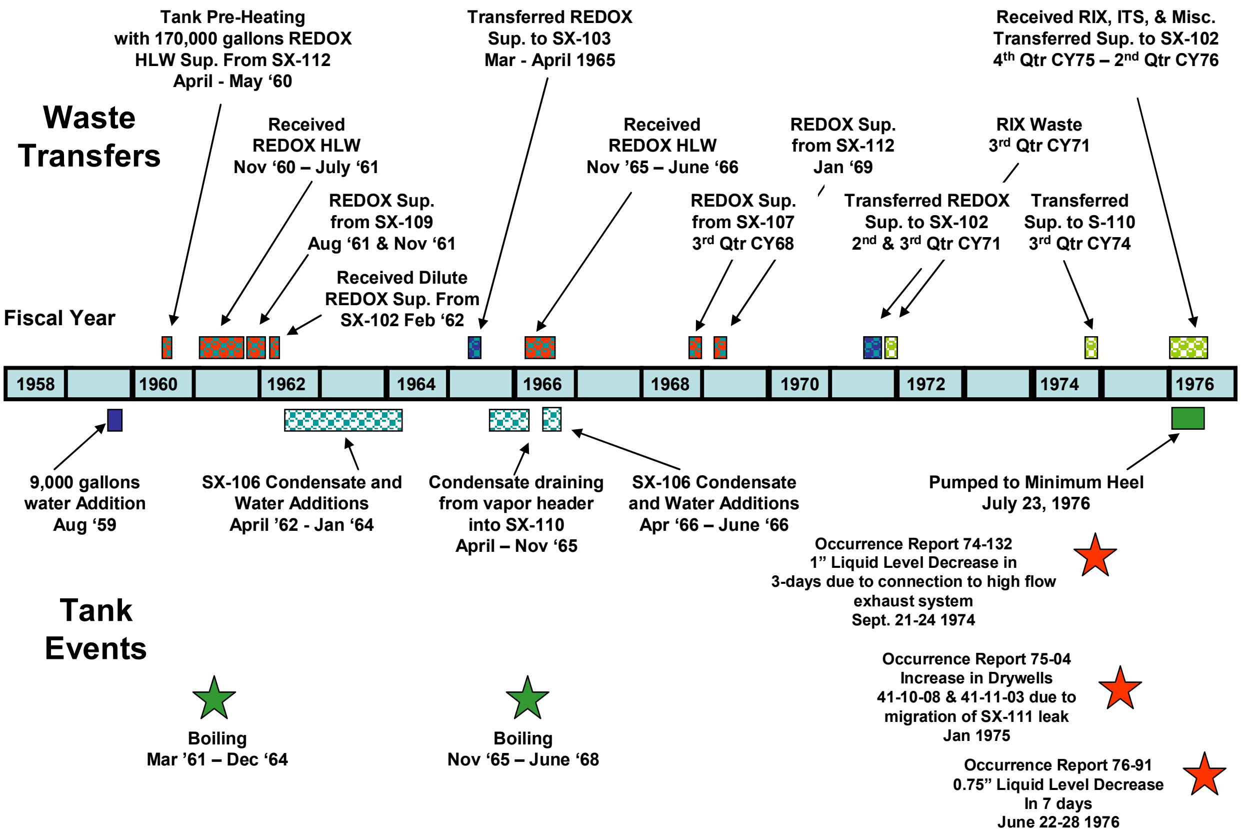
A tank history timeline is shown in Figure 5.5-1. The following subsections provide a brief discussion of the waste transfer history for tank SX-110.

5.5.1.1 Tank 241-SX-110 Waste History

REDOX High-Level Waste Storage (1960 to 1964)
Prior to receipt of waste, 9,000 gal of water were added to tank SX-110 in August 1959 (HW-61952, *Chemical Processing Department Waste Status Summary August 1, 1959 – August 31, 1959*, page 8). In April 1960, 33,000 gal of aged REDOX HLW supernate were transferred from tank SX-112 into tank SX-110 (HW-65272, *Chemical Processing Department Waste Status Summary April 1 – 30, 1960*, page 8). An additional 137,000 gal of SX-112 supernate were transferred into tank SX-110 in May 1960 (HW-65643, *Chemical Processing Department Waste Status Summary May 1 – 31, 1960*, page 8). These transfers were made to

pre-heat this tank prior to receipt of higher heat waste (RHO-R-39). The temperature of the waste in tank SX-110 was approximately 100 °F after the addition of the SX-112 supernate, as shown in Appendix A.

Figure 5.5-1. Tank 241-SX-110 Operating History (Fiscal Years 1959 to 1976)



Tank SX-110 started receiving HLW from the 202-S REDOX Plant in November 1960, receiving 24,000 gal of this waste (HW-68291, *Chemical Processing Department Waste Status Summary*, *November 1, 1960 – November 30, 1960*, page 8). Tank SX-110 continued to receive REDOX HLW, receiving ~105,000 gal in December 1960 (HW-68292, *Chemical Processing Department Waste Status Summary*, *December 1, 1960 – December 31, 1960*, page 8), 535,000 gal in January through June 1961 (HW-71610, *Chemical Processing Department Waste Status Summary January 1, 1961 Through June 30, 1961*, page 8), and 50,000 gal in July 1961 (HW-83906-E-RD page 4). The temperature of the waste in tank SX-110 was ~220 ± 10 °F following these transfers.

The next waste added into tank SX-110 was ~123,300 gal of aged REDOX HLW supernate transferred from tank SX-109 in August 1961, followed by 144,000 gal of aged REDOX HLW supernate transferred from tank SX-109 in November 1961 (HW-83906-E-RD pages 4 and 5). In February 1962, ~113,000 gal of dilute REDOX HLW supernate was transferred from tank SX-102 into tank SX-110 (HW-83906-E-RD page 14). The temperature of the waste in tank SX-110 was ~240 ± 10 °F following these transfers.

No additional waste transfers were made into tank SX-110 from March 1962 through October 1965. However from April 1962 through January 1964, ~335,400 gal of condensate from tank SX-106 and 55,000 gal of water were added to tank SX-110 (HW-83906-E-RD pages 13, 22, 23, 24, 31, 32, 33, 40, 41, 42, 48, 49 and 50). Condensate and water were added to tank SX-110 to aid in temperature control as well as to prevent over-concentration of the stored REDOX HLW.

Spare Tank for 241-SX Tank Farm (1965)
In March and April 1965 ~514,000 gal of REDOX HLW supernate were transferred from tank SX-110 into tank SX-103, leaving a heel of 114,000 gal of waste in tank SX-110 (HW-83906-E-RD page 62b and RL-SEP-297 page 87). These transfers were conducted to empty tank SX-110 to minimum waste level. Tanks SX-113 (see section 5.8.1.4) and SX-115 (see section 5.10.1.5) were confirmed as having leaked waste. Radioactivity in the laterals and drywells associated with tanks SX-107, SX-108 and SX-109 resulted in these tanks being suspected to be leaking waste in 1965. Tank SX-110 was designated as a spare tank in case tank failures were confirmed.

About 61,000 gal of condensate from the vapor header slowly drained into tank SX-110, filling the tank to 175,200 gal as of September 1, 1965 (RL-SEP-297 page 141). An additional 17,200 gal of condensate drained from the vapor header into tank SX-110 from September 2, 1965 through November 3, 1965, resulting in a total of 192,400 gal of waste stored in this tank (RL-SEP-297 page 168).

By early November 1965 tank SX-110 could no longer be held at minimum heel as spare capacity due to insufficient space available in other 241-SX tanks for storage of freshly generated REDOX HLW. Tank SX-110 was returned to normal service in November 1965.

Second Filling with REDOX HLW (1965 to 1971)
The routing of HLW from the 202-S REDOX Plant was switched from tank SX-111 to tank SX-110 on November 3, 1965 (RL-SEP-297 page 168). The second filling of this tank with REDOX HLW commenced with the tank receiving ~142,400 gal of waste in November 1965 and 131,200 gal in December 1965 (HW-83906-E-RD pages 75 and 76). In the first quarter of CY 1966 ~434,000 gal of REDOX HLW was added to tank SX-110 (ISO-226, *Chemical Processing Division Waste Status Summary January 1, 1966 Through March 31, 1966*, page 8). The waste in tank SX-110 began to boil and evaporate water after these waste transfers.

In the second quarter of CY 1966 (i.e., April through June), tank SX-110 received an additional 202,000 gal of REDOX HLW, ~151,800 gal of condensate from tank SX-106 and ~69,900 gal of water (HW-83906-E-RD page 83 and 84). An additional 310,000 gal of water were added to tank SX-110 in the third quarter of CY 1966 (ISO-538, *Chemical Processing Division Waste Status Summary July 1, 1966, Through September 30, 1966*, page 8) and 220,000 gal of water in the fourth quarter CY 1966 (ISO-674, *Chemical Processing Division Waste Status Summary October 1, 1966, Through December 31, 1966*, page 8). The total volume of waste in tank SX-110 was ~623,000 gal following these water additions. These water additions were made to control the waste temperature in tank SX-110 which had reached ~300 °F in May 1966 and remained at this temperature through June 1968.

No water additions to tank SX-110 are reported for CY 1967 through second quarter CY 1968 in the waste status summary reports. However, the volume of waste in this tank is reported for this period as between 620,000 and 640,000 gal. Since the waste temperature was ~300 °F, condensate or water must have been added to this tank to maintain the waste volume. Also, operation of the airlift circulators may have also contributed to expansion of the waste volume in this tank.

In the third quarter of CY 1968, 127,000 gal of REDOX HLW supernate were transferred from tank SX-107 into SX-110 (ARH-871, *Chemical Processing Division Waste Status Summary July 1, 1968 Through September 30, 1968*, page 9). Tank SX-107 was suspected of renewed waste leakage and this transfer was made to remove pumpable liquid from tank SX-107 to tanks SX-110, SX-111 and SX-112. Tank SX-110 was reported to contain 776,000 gal of waste at the end of third quarter CY 1968.

On January 23, 1969, tank SX-110 received 139,000 gal of REDOX HLW supernate from tank SX-112 (ARH-1200 A, *Chemical Processing Division Waste Status Summary January 1, 1969 through March 31, 1969*, page 10). Tank SX-112 was suspected of leaking waste and this transfer was made to remove remaining pumpable liquid from this tank (see section 5.7.1.3). Tank SX-110 was reported to contain 932,000 gal of waste after receiving the SX-112 tank waste transfer. No further waste additions were made to tank SX-110 for CY 1969 through first quarter CY 1971.

B Plant Ion Exchange and Miscellaneous Wastes (1971 to 1976)

In the second quarter of CY 1971, 663,000 gal of REDOX HLW supernate were transferred from tank SX-110 to tank SX-102 (ARH-2074 B, *Chemical Processing Division Waste Status Summary April 1, 1971 Through June 30, 1971*, page 10). An additional 116,000 gal of REDOX HLW supernate were transferred from tank SX-110 to tank SX-102 in the third quarter of CY 1971 (ARH-2074 C page 10). Following these transfers, tank SX-110 contained ~215,000 gal of REDOX HLW supernate and 32,000 gal of REDOX HLW sludge.

Tank SX-102 also received REDOX HLW supernates from other tanks in the 241-SX Tank Farm. The waste in tank SX-102 was diluted with water while transferring to tank BX-104 and then transferred to the 221-B Plant. In the 221-B Plant, the diluted REDOX HLW supernate was processed in the Cell 18 IX column to separate cesium, in particular $^{137}Cs/^{137m}Ba$ which are relatively high heat emitting radionuclides.

Following cesium IX processing, the diluted REDOX HLW supernate was designated as RIX waste. The RIX waste was transferred from 221-B Plant to tank BX-101, then to tank SX-105; from there, the RIX waste was transferred into other tanks within the 241-SX Tank Farm. In the third quarter of CY 1971, tank SX-110 received 734,000 gal of RIX waste from tank SX-105 (ARH-2074 C page 10). Tank SX-110 contained a total of 930,000 gal of waste following this transfer. No additional waste transfers into or out of tank SX-110 occurred until 1974.

In the third quarter of CY 1974, 516,000 gal of supernate were transferred from tank SX-110 to tank S-110 for staging as feed to the 242-S Evaporator, leaving 432,000 gal of waste in tank SX-110 (ARH-CD-133C, *Production and Waste Management Division Waste Status Summary July 1, 1974 through September 30, 1974*, page 8). An additional 221,000 gal of supernate were transferred from tank SX-110 to tank SX-102 in the third quarter of CY 1975, leaving ~183,000 gal of waste in tank SX-110 (ARH-CD-336 C page 8). This transfer was also conducted to stage waste in tank SX-102 for feed to the 242-S Evaporator.

From the fourth quarter of CY 1975 through second quarter CY 1976, tank SX-110 was used to receive dilute supernate wastes from the 200 East Area tank farms for staging to tank SX-102 and eventual processing in the 242-S Evaporator. Table 5.5-1 lists the waste volume, types, and source tanks for the dilute supernate wastes staged in tank SX-110 for processing in the 242-S Evaporator. Following these transfers, tank SX-110 was reported to contain ~336,400 gal of waste as of April 28, 1976 (ARHCO Occurrence Report 76-91, *Liquid Level Decrease Exceeding Criteria for Tank 110-SX*).

Table 5.5-1. Waste Staged in Tank 241-SX-110 for Feed to 242-S Evaporator

Quarter	CY	Volume Received (gallons)	Source Tanks	Volume Transferred to Tank 241-SX-102 (gallons)
Fourth	1975	669,000 603,000 283,000	B-103 (BIX, 224, misc.) BX-103 (BIX) BX-105 (BIX and ITS)	1,215,000[a]
First	1976	332,000	BX-103 (BIX) 241-BX-302B catch tank	778,000[b]
Second	1976	367,000 305,000	B-103 (BIX, 224, misc.) BX-103 (BIX)	442,000[c]

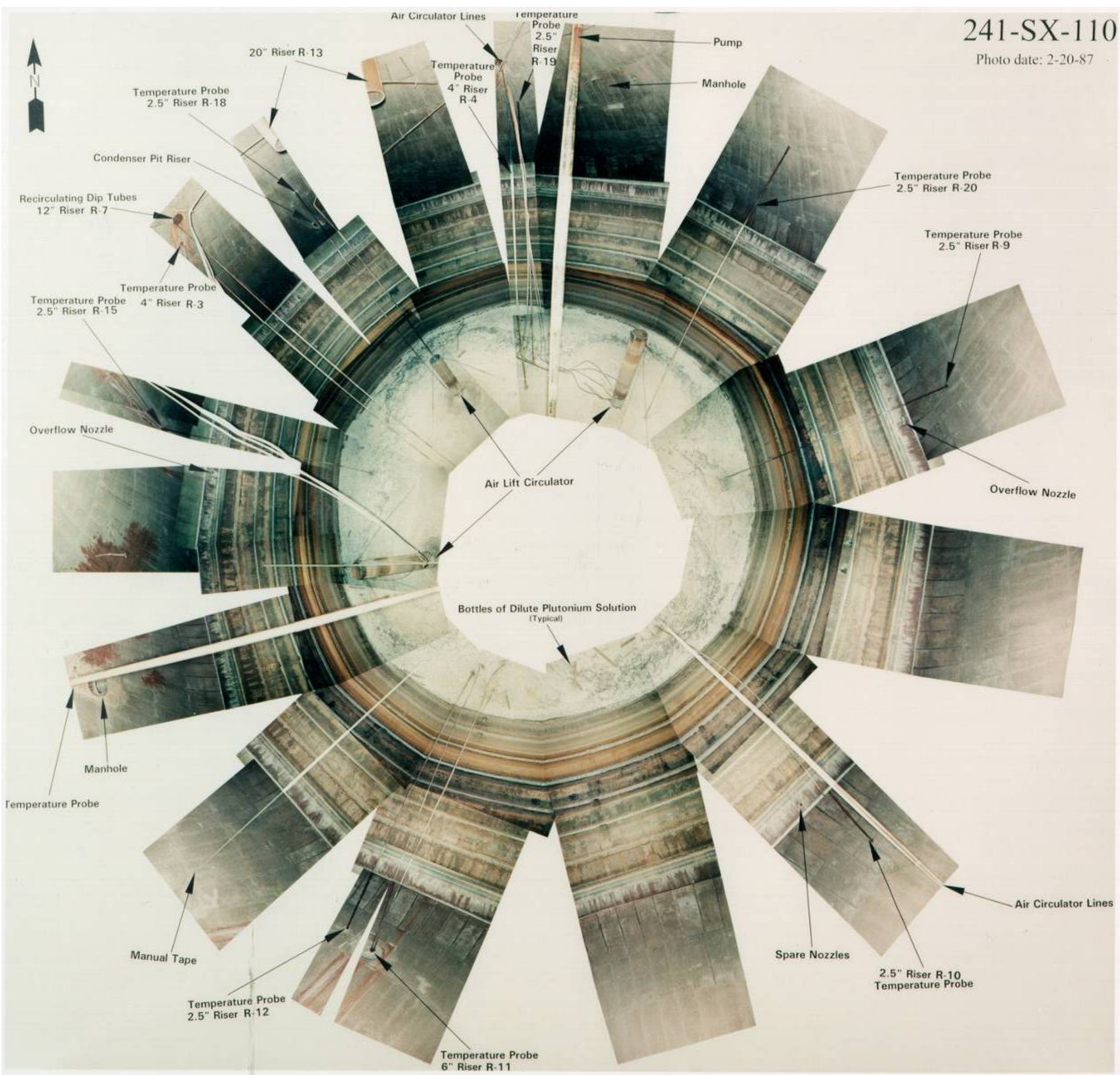
224 = 224-B Plutonium Concentration Building supernate from tanks B-201 through B-204
BIX = B plant Ion Exchange waste
CY = calendar year
ITS = In-Tank Solidification (evaporator bottoms)
[a]ARH-CD-336 D, 1976, *Production and Waste Management Division Waste Status Summary October 1, 1975* through *December 31, 1975*, page 8
[b]ARH-CD-702 A, 1976, *Production and Waste Management Division Waste Status Summary January 1, 1976 through March 31, 1976*, page 8
[c]ARH-CD-702 B, 1976, *Production and Waste Management Division Waste Status Summary April 1, 1976 through June 30, 1976*, page 8

5.5.1.2 Tank 241-SX-110 Integrity. Tank SX-110 was removed from service and identified as a potential leaker in July 1976 as a result of an apparent unexplained ~0.75-in. liquid level decline. The supernate in tank SX-110 was transferred to tank SX-102 in June 1976 (ARH-CD-702 B, *Production and Waste Management Division Waste Status Summary April 1, 1976 through June 30, 1976*, page 9).

5.5.1.3 Interim Stabilization (1979). After the supernate transfer to tank SX-102, tank SX-110 was connected to the 241-SX Tank Farm sludge cooler. The residual supernate and interstitial liquid contained in tank SX-110 evaporated. The waste surface in tank SX-110 was estimated to be 99% dry solids based on in-tank photographs obtained July 26, 1977 (HNF-SD-RE-TI-178 page 273). Based on these photographs, tank SX-110 was declared interim stabilized as of August 31, 1979.

5.5.1.4 Tank 241-SX-110 Current Status. Figure 5.5-2 depicts a mosaic of the waste surface in tank SX-110 as of February 1987, indicating no supernate is present in this tank. The tank is estimated to contain 49,000 gal of sludge and 7,000 gal of saltcake (HNF-EP-0182). Additionally, 16 plastic tubes which hold a total of 113 g of natural uranium, 52 g depleted uranium, 6 g enriched uranium, and 204 g of plutonium were added to tank SX-110 sometime before 1977 (RHO-CD-756, *Evaluation of Special Tanks 101-BX, 111-S, 107-SX, and 110-SX*, page 5). The plastic tubes are reported to be 3-in. diameter by 54 in. long (Internal letter 60412-78-014, "Heat Tracing for 200 Series Tanks" page 50).

Figure 5.5-2. Tank 241-SX-110 Waste Surface (February 1987)



5.5.1.5 Tank 241-SX-110 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-110 starts in May 1960 and continues through June 1968 (RHO-CD-1172). Temperature plots show tank SX-110 waste temperature reached a maximum of ~310 ± 10 °F in May 1966, staying at this temperature through June 1968. These relatively high tank waste temperatures are consistent with the operating practices for tanks that contained boiling REDOX HLW.

5.5.2 Data Review and Observations

5.5.2.1 Evaporation and Liquid Level Decreases. Tank SX-110 contained ~336,400 gal (129.5 in.) of waste as of April 28, 1976 following transfers made to stage waste for processing in the 242-S Evaporator. The tank liquid level was decreasing at a rate of approximately 0.25 in. per week as a result of evaporation from April 28 through June 22, 1976. The evaporation rate for tank SX-110 was within normal limits for this tank.

From June 22 through June 29, 1976, the liquid level in tank SX-110 decreased 0.75 in. (~2,000 gal), which exceeded normal expected evaporation rates for this tank. The manual tape used to measure liquid level in tank SX-110 had been flushed on June 28, 1976 and the liquid level increased from 127.5 to 127.75 in. However, the measured liquid level in tank SX-110 decreased to 127.25 in. on June 29, 1976. The liquid level in tank SX-110 was measured on June 30, 1976 and was reported as 127.25, 127.5, and 127.75; indicating erratic readings. An occurrence report was issued June 29, 1976 (ARHCO Occurrence Report 76-91) as a result of tank SX-110 liquid level decline exceeding normal limits.

The evaporation rate for the waste in tank SX-110 was measured as 0.3 in. per week in early June 1976 and 0.15 in. per week on June 30, 1976 (ARHCO Occurrence Report 76-91). The radioactivity detected in drywells and laterals associated with tank SX-110 for 1973 through 1976 are reported in ARHCO Occurrence Report 76-91 and summarized in Table 5.5-2.

5.5.2.2 Drywell and Lateral Data. There was no increase in the radioactivity detected in the drywells or laterals in June 1976 (see Table 5.5-2). The activity detected at the extreme end (or bottom) of lateral 44-10-01 is thought to be associated with the loss of waste from tank SX-107. The radioactivity detected in drywells 41-10-08 and 41-11-03 (see Table 5.5-2) was assumed to be associated with waste loss from tank SX-111 (ARHCO Occurrence Report 75-04, *Increasing Dry Well Radiation Levels Between Waste Tanks 110-SX and 111-SX*) which occurred in May 1974 (see Section 5.6).

The Energy Research and Development Administration (ERDA) issued Internal letter LET-072176, "241-SX-110 TANK" to the Atlantic Richfield Hanford Company (ARHCO) on July 21, 1976 to remove tank SX-110 from service due to questionable integrity (ERDA 1976). ERDA stated in this letter:

> "This decision is based on the fact that ARHCO's long-range tank use projection does not indicate a continued need for this tank, which obviously does not justify risking continued use with an apparent unexplained liquid level loss over the past two months in excess of one inch."

Table 5.5-2. Tank 241-SX-110 Drywells and Laterals Radioactivity Measurements

(From ARHCO Occurrence Report 76-91)

Counts per Second									
Drywells									
Date	**41-10-01**	**41-10-02**	**41-10-03**	**41-10-05**	**41-10-06**	**41-10-08**	**41-10-10**	**41-10-11**	**41-00-04**
9/13/73	300 @ 64 ft	<200		<200	<200	<200	<200	<200	<200
4/10/74	391 @ 67 ft	<200	<250	<200	<250	<250	<250	<250	<200
7/10/74	311 @ 67 ft					<250	<250	<250	<200
7/12/74	55 (1) @ 65					<50 (1)			
7/24/74		<150	<150	<200	<200				
7/31/74		<50 (1)	<100 (1)	<50 (1)					
8/9/74					<60 (1)				
9/25/74						53 @ 55 ft			
11/5/74						161 @ 57 ft			
11/26/74						328 @ 56 ft			
1/22/75	60 @ 68 ft	<50	<50	<50			<50 (1)	<60 (1)	<50 (1)
1/28/75					<50	212 @ 54 ft			
7/22/75	58 @ 66 ft	<50	<50	<50	<50	113 @ 56 ft	<50	<50	<50
4/5/76									<50
4/7/76	63 @ 66 ft	<50	<50	<50	<50	70 @ 55 ft	<50	<50	
6/2/76									<50
6/14/76						56 @ 58 ft	<50	<50	
6/16/76	60 @ 64 ft								
6/24/76		<50	<50	<50	<50				

Laterals			
Date	**44-10-01**	**44-10-02**	**44-10-03**
4/26/74	0	0	0
9/3/74	0	0	0
10/2/74	12 (at bottom) (1)	0 (1)	0 (1)
2/3/75	21 (at bottom)	0	0
7/7/75	20 (at bottom)	<2	<2
10/1/75	20 (at bottom)	<2	<2
3/2/76	15 (at bottom)	<2	<2
6/28/76	19 (at bottom)	<2	<2

(1) New monitoring equipment used on / after this date
(2) Blanks indicate no reading obtained on the date

Based on this letter of direction, ARHCO removed the tank SX-110 from service and transferred the remaining pumpable liquid to tank SX-102. Drywell total gamma data obtained between 1975 and 1995 is shown in Figures 5.5-3 to 5.5-5. SX-110 laterals were not re-logged in 2005 due to limited funding and lower priority.

5.5.2.3 1980 Assessment. Rockwell Hanford Operations (RHO) convened an independent panel to review the integrity of tank SX-110 in 1980 (RHO-CD-896, *Review of Classification of Nine Hanford Single-Shell "Questionable Integrity" Tanks*). This panel was comprised of representatives from Tank Farm Surveillance Group, Tank Farm Process Control Group, Effluent Controls Group, and the Chief Scientist. The RHO panel was tasked with reviewing tanks that had been classified as of questionable integrity to determine whether these tanks should be reclassified as confirmed leakers. This panel was not chartered to reclassify tanks as being sound integrity.

This panel reviewed the ARHCO Occurrence Report 76-91, drywell radiation readings, and the operational history of tank SX-110. The RHO tank integrity assessment panel noted that 300 counts per second (cps) was first detected in 1973 in drywell 41-10-01 (drilled in 1962) at ~64-ft level and had slowly decreased to 60 cps by 1980 (see Figure 5.5-3). Tank SX-107 was confirmed as leaking waste in 1964, which could be the source of activity detected in drywell 41-10-01. The RHO panel also reviewed the radioactivity detected in drywells 41-10-08 and 41-11-03.

The RHO panel also described possible corrosion of the steel liner in tank SX-110 between the 304- to 360-in. levels, based on photographs taken on October 15, 1975 (RHO-CD-896 page 58). The panel noted that the inside of tank SX-110 was not clear in these photographs. The conclusions of the RHO panel were as follows:

Surveillance Group:	"… Tank SX-110 did leak during 1974 at a high liquid level – probably above the 304-inch level, but most likely above the 340-inch level." "Tank 110-SX should be classified as a Confirmed Leaker."
Process Control Group:	"… The drywells are located on either side of a 4-inch diameter cascade line between Tank 110-SX and Tank 111-SX. This line is equipped with a cleanout facility, which could be subject to leakage." "Tank 110-SX should continue to be classified as of Questionable Integrity."
Effluents Control Group:	"Based upon liquid level decreases of 0.75 inch and no confirmation by dry well or lateral detection, it is considered that the evidence is insufficient to warrant reclassification of Tank 110-SX. "Adjacent known leaker tanks and their associated high dry well activity are considered to have an influence on activities of Dry Well 41-10-01 and, possibly Dry Wells 41-10-08 and 41-11-03." "It is recommended that Tank 110-SX remain classified as Questionable Integrity."

Figure 5.5-3. Drywell 41-10-01 Historical Radiation Readings

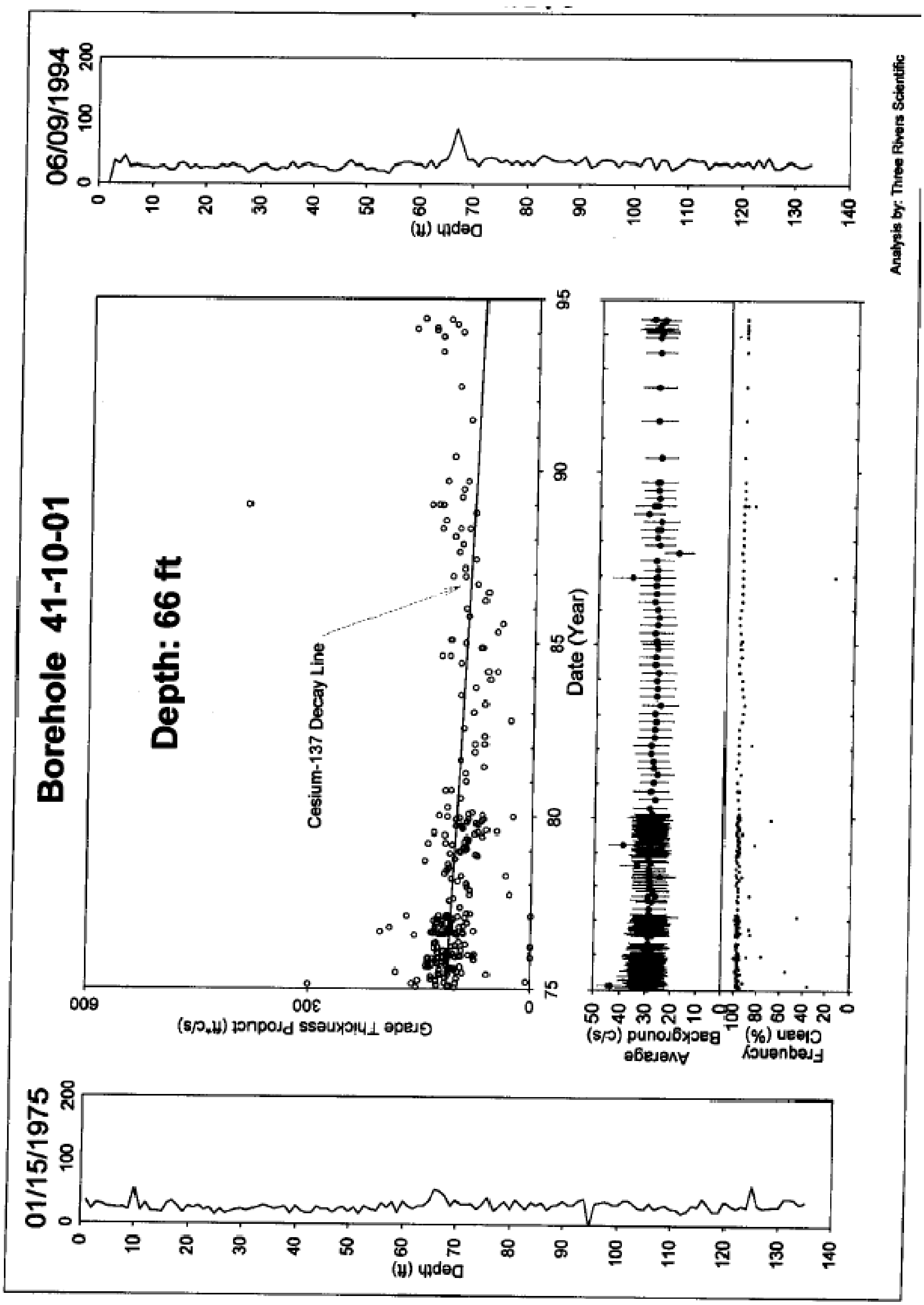


Figure 5.5-4. Drywell 41-10-08 Historical Radiation Readings

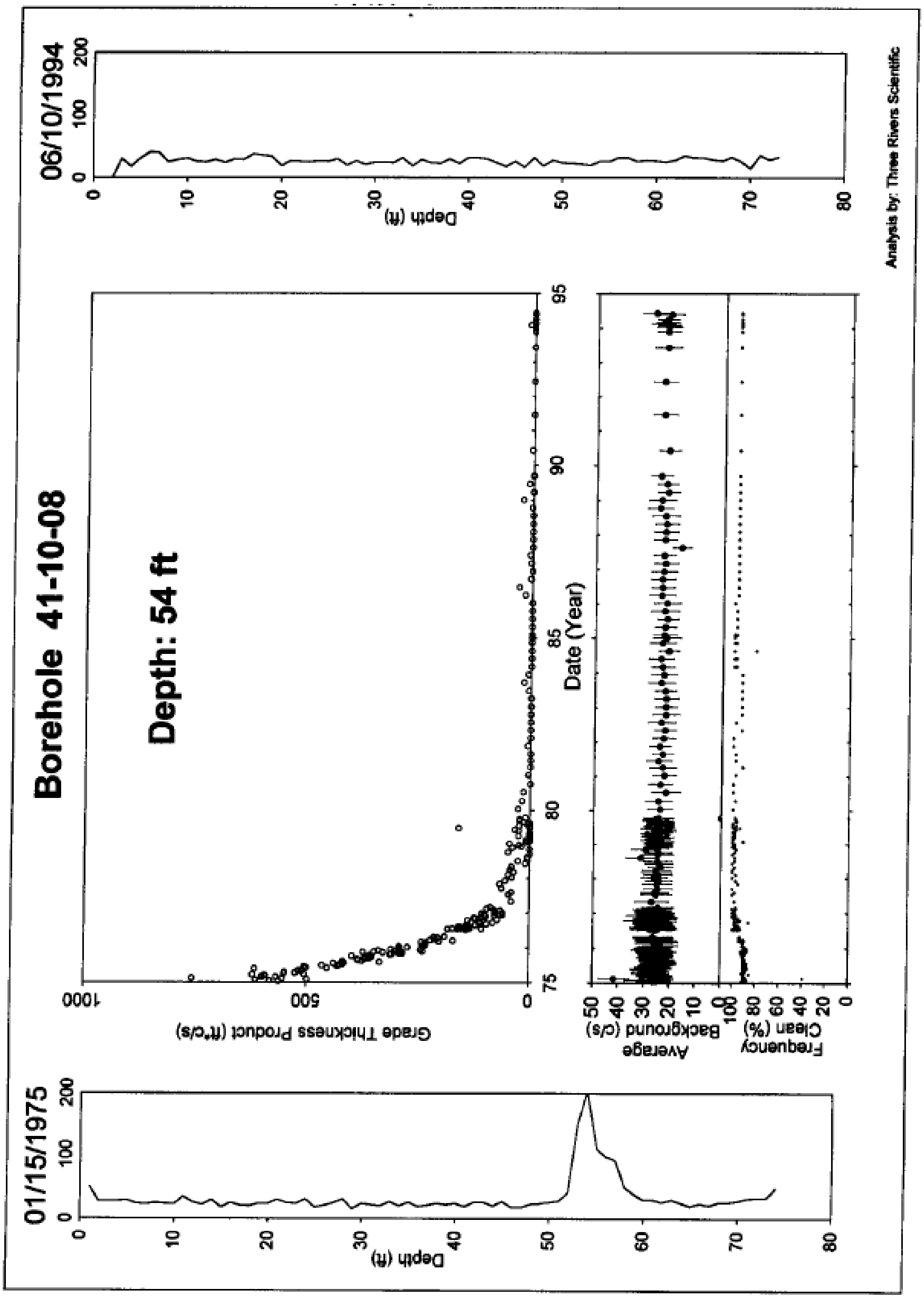
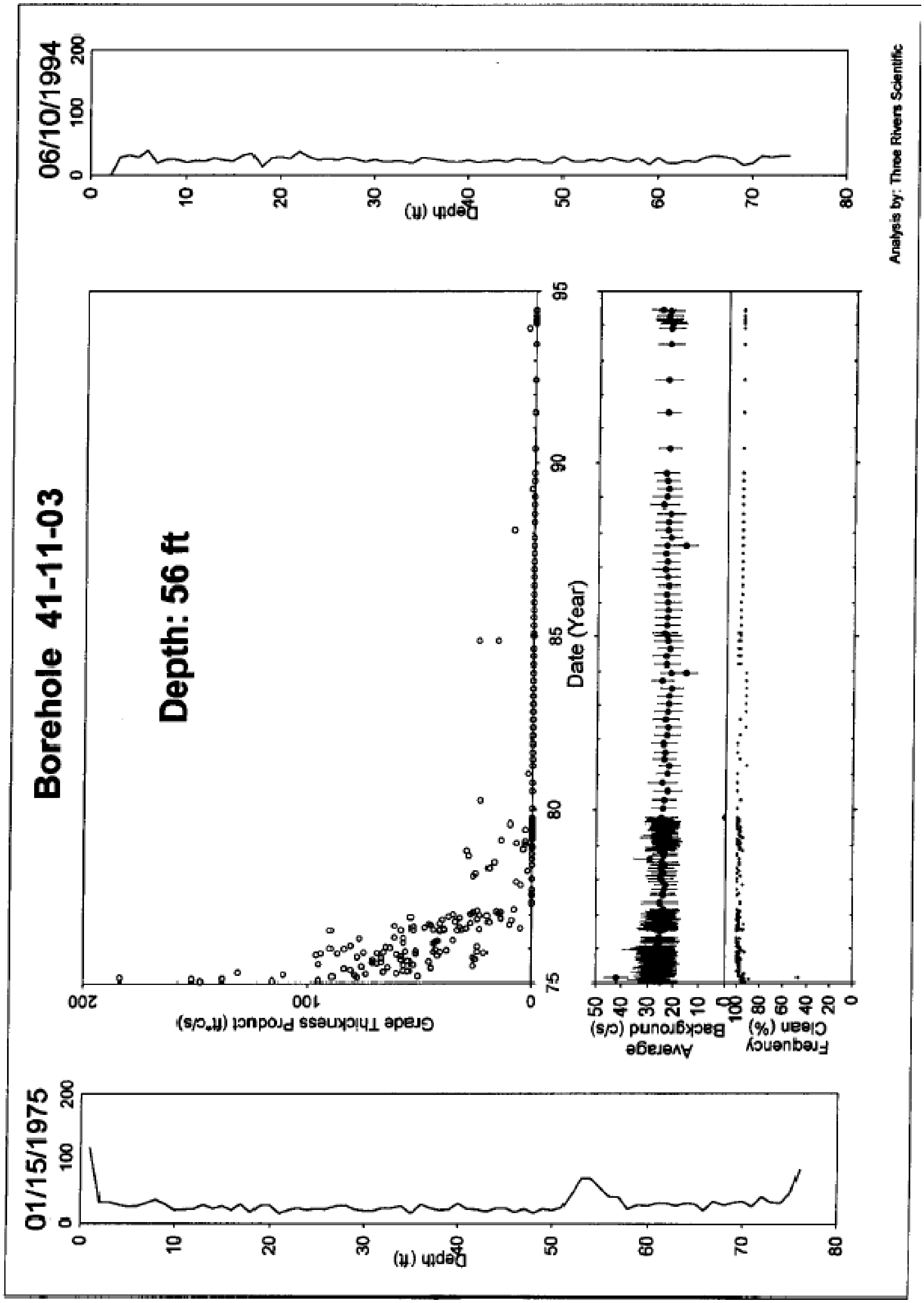


Figure 5.5-5. Drywell 41-11-03 Historical Radiation Readings



Chief Scientist: "… 95 percent of the available evidence certainty does not support the judgment that Tank 110-SX is a Confirmed Leaker." "Tank 110-SX should continue to be classified as of Questionable Integrity."

Consistent with the rules established, the RHO tank integrity assessment panel recommended that tank SX-110 continue to be classified as of Questionable Integrity, since at the 95% confidence level there was insufficient information to warrant reclassification of this tank as a confirmed leaker.

The RHO tank integrity assessment panel identified possible corrosion of the tank steel liner between 304- and 360-in. levels, based on unclear photographs taken on October 15, 1975. These photographs were not located. Clear photographs taken inside tank SX-110 on July 23, 1976 and February 20, 1987 were located and reviewed. The July 23, 1976 photographs are black and white images whereas the February 20, 1987 photographs are color images. There is streaking on the steel liner walls, but the 1976 photographs do not show any evidence of corrosion of the steel tank liner. The February 20, 1987 color photographs show different coloration (i.e., shades of yellow, orange and red) along the steel tank liner walls, possibly due to residual red lead paint used to protect the steel liner (HW-4957, *Specification for Waste Disposal Facility 241-SX*, page 34). An example of the color photographs taken on February 20, 1987 is shown in Figure 5.5-6.

5.5.3 Conclusions

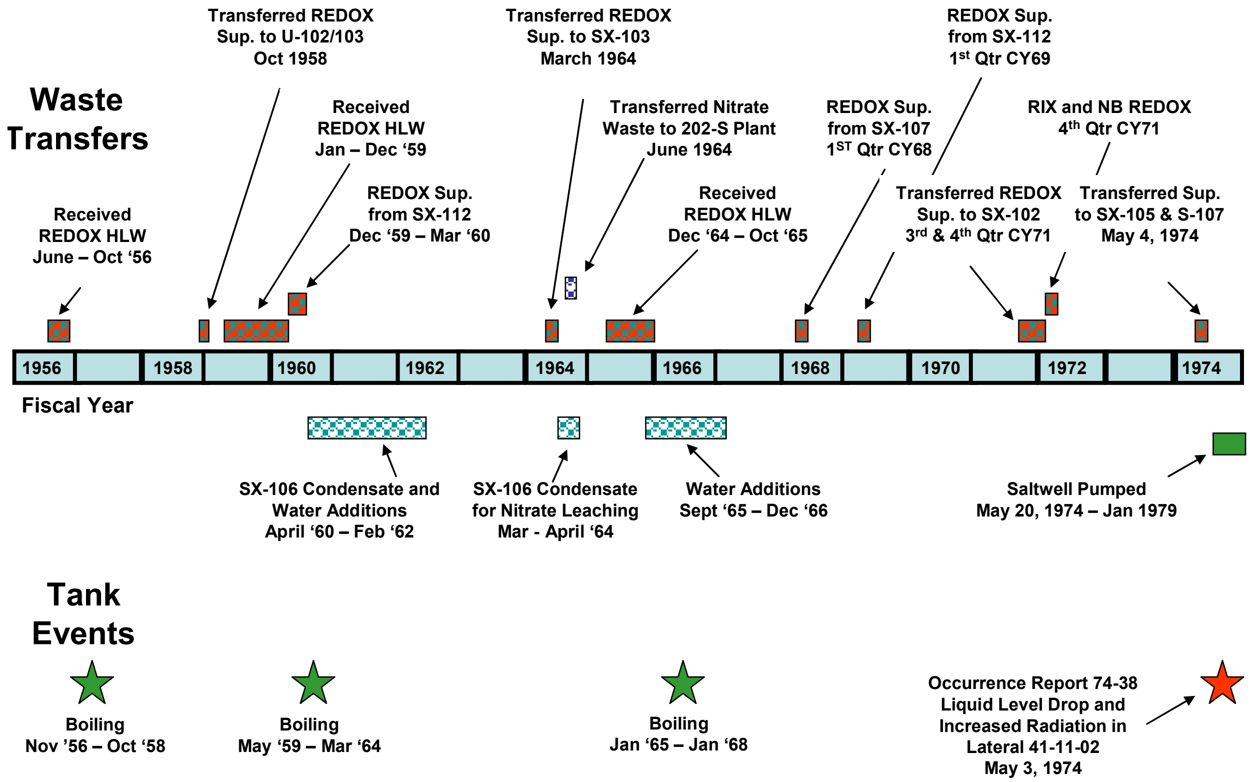
Tank SX-110 was removed from service and identified as a potential leaker in July 1976 as a result of an apparent unexplained ~0.75 in. liquid level decline. A gamma survey of the laterals beneath tank SX-110 conducted in 2005 indicates equivalent ^{137}Cs concentrations to be less than 10 pCi/g in each lateral (RPP-RPT-27605 pages B-30 through B-35). Based on the lack of drywell and lateral radiation readings, along with the lack of liner corrosion evidence, it seems likely that tank SX-110 did not leak waste. A formal integrity assessment should be conducted for tank SX-110 per procedure TFC-ENG-CHEM-D-42, "Tank Leak Assessment Process."

Figure 5.5-6. Tank 241-SX-110 Interior Wall (February 20, 1987)

5.6 TANK 241-SX-111 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST SX-111. Tank SX-111 has three laterals (horizontal boreholes) installed about 10 ft under the tank, as depicted in Figure 5.6-1. There are seven boreholes (41-11-02, 41-11-03, 41-11-05, 41-11-06, 41-11-08, 41-11-09 and 41-11-10) located around tank SX-111.

Figure 5.6-1. Tank 241-SX-111 Operating History (Fiscal Years 1956 to 1974)



5.6.1 Tank 241-SX-111 Waste Operations Summary

A tank history timeline is shown in Figure 5.6-1. Section 5.6.1.1 provides a brief discussion of the waste transfer history for tank SX-111.

5.6.1.1 Tank 241-SX-111 Waste History

REDOX High-Level Waste Storage (1956 to 1971)

Tank SX-111 was constructed from 1953 to 1954. The tank was not used until June 1956 (HW-43895, *Separations Section Waste Status Summary for June 1956*, page 8), when 123,000 gal of 202-S REDOX HLW was received. Tank SX-111 continued to receive REDOX HLW through October 1956. When the waste volume in tank SX-111 reached 994,000 gal, waste began to cascade into tank SX-112 on October 27, 1956 (HW-46382 page 8). No waste was added or removed from tank SX-111 from November 1956 through September 1958.

Self boiling and evaporation of waste from tank SX-111 was first reported to have started in November 1956 (HW-47052 page 2), consistent with the reported tank supernate temperature of ~260 °F (see Appendix A). The tank supernate temperature slowly decreased through CY 1957 and CY 1958 until reaching ~196 °F in October 1958 (HW-58201 page 8). A total of 392,000 gal of condensate was evaporated from tank SX-111 from November 1956 through September 1958, leaving 631,000 gal of waste in this tank (HW-57711, *Chemical Processing Department Waste Status Summary September 1, 1958 – September 30, 1958*, page 8).

In October 1958, 60,000 gal of the concentrated REDOX supernate was transferred from tank SX-111 to tank 241-U-102 (HW-58201 page 8). An additional 465,000 gal of waste were transferred from tank SX-111 into tanks 241-U-102 and 241-U-103 in November 1958 (HW-58579, *Chemical Processing Department Waste Status Summary November 1, 1958 – November 30, 1958*, page 8) and 1,000 gal to tank 241-U-103 in December 1958 (HW-58831, *Chemical Processing Department Waste Status Summary December 1, 1958 – December 31, 1958*, page 8). These transfers left an estimated 29,000 gal of sludge and 76,000 gal of supernate in tank SX-111.

Tank SX-111 received another 67,000 gal of REDOX HLW in January 1959 (HW-59204, *Chemical Processing Department Waste Status Summary January 1, 1959 – January 31, 1959*, page 8). The supernate temperature reached 211 °F in May 1959 with self boiling of the waste commencing (HW-60738, *Chemical Processing Department Waste Status Summary May 1, 1959 – May 31, 1959*, page 8) and continuing through March 1964 (HW-83906-E-RD page 50). Tank SX-111 continued to receive REDOX HLW through December 1959 and also received 145,000 gal of REDOX HLW supernate from tank SX-112 (HW-63559, *Chemical Processing Department Waste Status Summary December 1-31, 1959*, page 8). Approximately 233,000 gal of REDOX supernate were also transferred from tank SX-112 into tank SX-111 during January 1960 (HW-63896, *Chemical Processing Department Waste Status Summary January 1-31, 1960*, page 8), February 1960 (HW-64373, *Chemical Processing Department Waste Status Summary February 1-29, 1960*, page 8) and March 1960 (HW-64810, *Chemical Processing Department Waste Status Summary March 1-31, 1960*, page 8).

Approximately 21,000 gal of condensate were transferred from tank SX-106 into tank SX-111 in April 1960 (HW-65272 page 8), 45,000 gal in May 1960 (HW-65643 page 8), and 10,000 gal, along with 43,000 gal of water, in June 1960 (HW-66187, *Chemical Processing Department – Waste Status Summary*, *June 1, 1960 – June 30, 1960*, page 8). An additional 149,000 gal of water were added to tank SX-111 from July 1960 (HW-66557 page 8) through January 1961 (HW-83906-D-RD page 193). Approximately 91,000 gal of condensate were transferred from tank SX-106 into tank SX-111 in January and February 1962 (HW-83906-E-RD page 14). These additions of condensate and water were conducted to maintain the waste density and temperature within operating limits.

In March 1964, 484,000 gal of REDOX supernate (specific gravity 1.50) and ~52,000 gal of dilution water were transferred from tank SX-111 to tank SX-103, leaving ~108,000 gal of waste in tank SX-111 (HW-83906-E-RD page 50 and HW-80202, *REDOX Weekly Process Reports January through December, 1964*, no. 626). Then, 203,000 gal of condensate were transferred from tank SX-106 into tank SX-111 in March and April 1964 (HW-83906-E-RD page 49) to leach sodium nitrate from the REDOX sludge. Sodium nitrate was leached from REDOX sludges for reuse in the 202-S REDOX Plant to suppress hydrogen generation during fuel dissolution and to reduce the sludge mass in the storage tanks. Approximately 201,700 gal of REDOX nitrate waste[4] were transferred from tank SX-111 into tank SX-105 in June 1964,

[4] Nitrate waste was sodium nitrate leached from REDOX HLW sludge (RL-SEP-243, page 7).

leaving an estimated 123,000 gal of waste at a supernate specific gravity of 1.3 and ~170 °F in tank SX-111 (HW-83906-E-RD page 49 and HW-80202 no. 638).

Tank SX-111 began its third filling with REDOX HLW on December 23, 1964 having received ~89,000 gal by month end (HW-80202 no. 665 and HW-83906-E-RD pages 56a and 60). Tank SX-111 rapidly reached boiling conditions (200 °F supernate temperature) on January 2, 1965 (RL-SEP-297 no. 666). Tank SX-111 received a total of 1,127,800 gal of REDOX HLW from January 1965 through October 1965 (HW-83906-E-RD pages 62a, 62b, 62c, 68a, 68b and 75).

The supernate and sludge temperatures continued to increase, reaching 258 °F and 292 °F (respectively) on September 5 through 11, 1965, prompting air sparging of the tank contents all day on September 9, 1965 to aid in cooling (RL-SEP-297 no. 702). The specific gravity of the supernate in tank SX-111 was also reported to have reached 1.67 (RL-SEP-297 no. 702). This air sparging was in addition to the normal operation of four air spargers at 10-cfm each. Continuous water addition to tank SX-111 was started on September 19, 1965 (RL-SEP-297 no. 703) to further reduce the waste temperature. Water additions to this tank were as follows:

March 1965:	35,130 gallons condensate (HW-83906-E-RD page 62b)
September 1965:	~53,800 gallons (HW-83906-E-RD page 68b).
October through December 1965:	~274,200 gallons (HW-83906-E-RD pages 75 and 76)
April through June 1966:	123,000 gallons (HW-83906-E-RD page 83)
July through September 1966:	199,000 gallons (ISO-538 page 8)
October through December 1966:	179,000 gallons (ISO-674 page 8)

The waste temperatures remained elevated (313 °F in sludge and 252 °F in supernate) and temperature control was difficult (RL-SEP-297 no. 709). These water additions began to slowly lower the waste temperature in tank SX-111, reaching 297 °F in sludge and 250 °F in supernate by January 1, 1966 (RL-SEP-297 no. 718). However, the sludge temperature began to slowly increase in July 1966 (no data exists for supernate after January 1966), reaching ~320 °F by January 1968 (see Appendix A).

Tank SX-111 received 145,000 gal of REDOX HLW supernate from tank SX-107 in the third quarter of CY 1968 (ARH-871 page 9) and 111,000 from tank SX-112 in the first quarter of CY 1969 (ARH-1200 A page 10). These transfers were made as a result of suspected waste leakage from tanks SX-107 and SX-112. No further waste additions were made to tank SX-111 for the remainder of CY 1969 through the second quarter of CY 1971.

B Plant Ion Exchange and Non-Boiling REDOX Wastes (1971 to 1974)

In the third and fourth quarters of CY 1971, all of the REDOX HLW supernate was transferred from tank SX-111 to tank SX-102, leaving the REDOX HLW sludge in this tank (ARH-2074 C page 10 and ARH-2074 D page 10). The REDOX HLW supernate, along with dilution water and other REDOX HLW supernates, was then transferred to tank BX-104. These solutions were then processed in the 221-B Plant for separation of cesium using IX.

The REDOX HLW supernate, after dilution and cesium removal, was designated as RIX waste. The RIX waste was transferred from the 221-B Plant to tank BX-101 and then tank SX-105 for distribution to various tanks in the 241-SX Tank Farm. Tank BX-101 also received evaporator bottoms from the Cell 23 evaporator in the 221-B Plant, organic wash waste and coating removal waste from 241-C Farm tanks. While the organic wash waste and coating removal waste were transferred to tank SX-101, some heel of these wastes remained in tank BX-101 when the RIX waste was received.

Tank SX-111 received 790,000 gal of RIX waste from tank SX-105 and 170,000 gal of non-boiling REDOX HLW supernate from tank SX-106 in fourth quarter of CY 1971 (ARH-2074 D page 10). These transfers filled tank SX-111 to near capacity; the tank contained 867,000 gal of supernate and 77,000 gal of REDOX HLW sludge. No additional waste transfers were made into tank SX-111.

It appears tank SX-111 continued to evaporate waste after receiving the RIX and non-boiling REDOX HLW transfers. The liquid level in tank SX-111 continued to decline at an average of ~6,500 gal per quarter as shown in Table 5.6-1. On May 3, 1974, the temperatures of the supernate and sludge waste in tank SX-111 were reported to be 160 °F and 218 °F, respectively, indicating ongoing waste evaporation. More detailed information on the liquid level for tank SX-111 for June 13, 1973 through May 13, 1974 is provided in RL Occurrence Report 74-38, *Symptoms of leakage from an underground waste tank – 111-SX.*

On May 4, 1974, it was determined that tank SX-111 was leaking waste (see section 5.6.1.4) and the RIX and non-boiling REDOX HLW wastes were transferred to tanks S-107 (757,000 gal) and SX-105 (2,000 gal) (ARH-CD-133B, *Operations Division Waste Status Summary April 1, 1974 through June 30, 1974*, page 8).

The liquid in tank SX-111 was sampled and analyses reported in September 16, 1974 (Internal memo MEM-010274, "Analysis of Tank Farm Samples 01/02/74 Thru 12/26/74," page 60), as shown in Table 5.6-2. The concentrations of ^{137}Cs, ^{90}Sr and plutonium reported in this sample were 1.2 Ci/gal, 1.33×10^{-4} Ci/gal and less than 3.91×10^{-6} g/L respectively. Assuming the volume of waste leaked from tank SX-111 was 2,000 gal, the inventories of ^{137}Cs, ^{90}Sr and plutonium leaked in May 1974 are 2,400 Ci, 0.27 Ci, and 0.03 g. This is consistent with the estimated upper bound inventories for the loss of these radionuclides as reported by ARHCO to the U.S. Atomic Energy Commission, Richland Operations Office.

Table 5.6-1. Tank 241-SX-111 Supernate Level (December 1971 to March 1974)

Date	Supernate Volume (gallons)
December 1971[a]	867,000
March 1972[b]	862,000
June 1972[c]	867,000
September 1972[d]	843,000
December 1972[e]	831,000
March 1973[f]	847,000
June 1973[g]	836,000
September 1973[h]	828,000
December 1973[i]	818,000
March 1974[j]	808,000

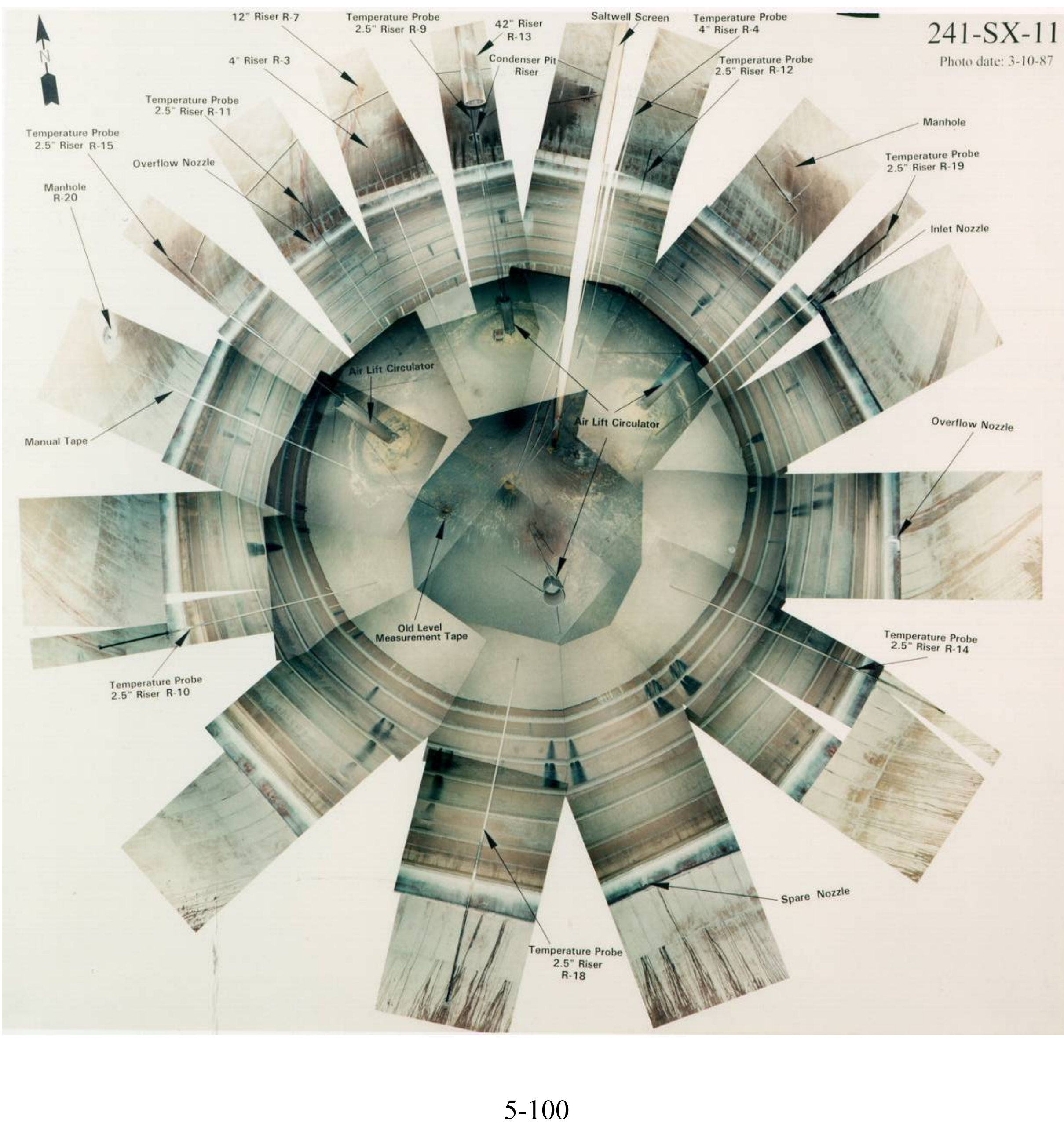
[a]ARH-2074 D, 1972, *Chemical Processing Division Waste Status Summary October 1, 1971 Through December 31, 1971*, page 10
[b]ARH-2456 A, 1972 *Chemical Processing Division Waste Status Summary January 1, 1972 Through March 31, 1972*, page 9
[c]ARH-2456 B, 1972, *Chemical Processing Division Waste Status Summary April 1, 1972 Through June 30, 1972*, page 9
[d]ARH-2456 C, 1972, *Chemical Processing Division Waste Status Summary July 1, 1972 Through September 30, 1972*, page 8
[e]ARH-2456 D, 1973, *Chemical Processing Division Waste Status Summary October 1, 1972 Through December 31, 1972*, page 8
[f]ARH-2794 A, 1973 *Chemical Processing Division Waste Status Summary, January 1, 1973 through March 31, 1973*, page 8
[g]ARH-2794 B, 1973, *Chemical Processing Division Waste Status Summary, April 1, 1973 through June 30, 1973*, page 8
[h]ARH-2794 C, 1973, *Chemical Processing Division Waste Status Summary, July 1, 1973 through September 30, 1973*, page 8
[i]ARH-2794 D, 1974, *Manufacturing and Waste Management Division Waste Status Summary, October 1, 1973 through December 31, 1973*, page 8
[j]ARH-CD-133A, 1974, *Operations Division Waste Status Summary, January 1, 1974 through March 31, 1974*, page 8

Table 5.6-2. Tank 241-SX-111 Supernate Analysis (September 1974)

Analyte	Result	Units
pH	> 13.2	
Sp.Gr.	1.4836	
OH	1.47	M
Al	0.805	M
Na	8.05	M
NO_2	0.836	M
NO_3	4.72	M
Pu	<3.91E-06	g/L
SO_4	6.01E-02	M
PO_4	5.74E-03	M
F	1.40E-02	M
CO_3	0.168	M
^{134}Cs	5.83E+03	µCi/gal
^{137}Cs	1.20E+06	µCi/gal
$^{80,90}Sr$	1.33E+02	µCi/gal

5.6.1.2 Interim Stabilization (1974 through 1979). A saltwell was installed in tank SX-111 on May 20, 1974 and ~1,300 gal of liquid were pumped from the tank before the pump lost suction (RL Occurrence Report 74-38). The tank was also connected to the sludge cooler in the 241-SX Tank Farm in the summer of 1974. Pumping of the interstitial liquid from the saltwell in this tank was periodically attempted until January 1979, when the tank was declared interim stabilized (Internal letter 65260-79-048, “Tank Status Change”). The waste surface in tank SX-111 was estimated to be 99% dry solids and to contain approximately 50 gal of supernate based on photographs taken on January 3, 1979 (65260-79-048 – Letter). Figure 5.6-2 depicts a mosaic of the waste surface in tank SX-111 as of March 1987, indicating no supernate was present in the tank at that time. As of 2007 the tank was estimated to contain 97,000 gal of sludge and 18,000 gal of saltcake, including 11,000 gal of drainable interstitial liquid (HNF-EP-0182).

Figure 5.6-2. Tank 241-SX-111 Waste Surface (March 1987)



5.6.1.3 Tank 241-SX-111 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-111 starts in August 1956 and continues through June 1968 (RHO-CD-1172 pages B-73 through B-114). Appendix A provides plots showing the maximum temperature (°F) of the waste stored in tank SX-111. The temperature plots for tank SX-111 are consistent with the waste history discussed in section 5.6.1. These temperature plots show tank SX-111 waste temperature reached a maximum of ~300 °F in June 1960 and February 1962 and was at ~310 ± 10 °F from November 1964 through June 1968. These relatively high tank waste temperatures are consistent with the operating practices for tanks that contained boiling REDOX HLW.

5.6.1.4 Basis for Leak Declaration. Tank SX-111 was declared an assumed leaker in May 1974 based on liquid level decline and an increase in radiation detected in lateral 44-11-02 during the period of April 19 through May 4, 1974 (RL Occurrence Report 74-38). No gamma activity was detected in laterals 44-11-01 or 44-11-03. The peak gross gamma activity detected using the Geiger Mueller probe in lateral 44-11-02 increased from 130 cpm on April 30, 1974 to 300 to 380 cpm on May 4, 1974. The peak gross gamma activity in lateral 44-11-02 increased after supernate removal from tank SX-111 was started on May 4, 1974, reaching 1,455 cpm on May 21, 1974 (RL Occurrence Report 74-38). Gross gamma activity detected in lateral 44-11-02 reached a maximum of 22,200 cpm (370 cps) on October 7, 1974, and then began to decline (SD-WM-TI-356 page 41-11-07). All peak gross gamma activity was detected at a distance of ~120 to 125 ft from the entrance of lateral 44-11-02.

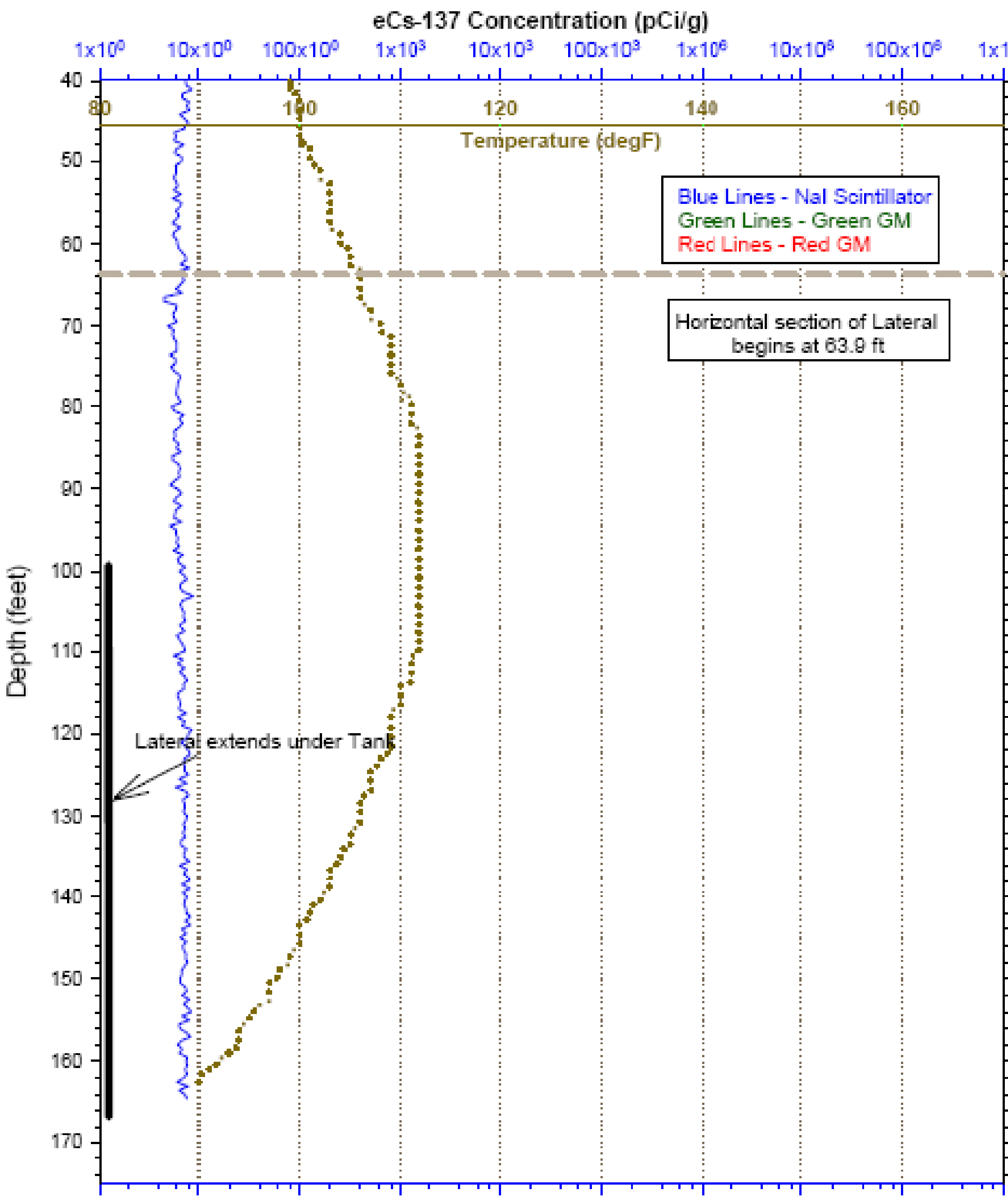
The Atlantic Richfield Hanford Company, tank farm contractor at the time of the tank leak, estimated 500 to 2,000 gal of waste was leaked from tank SX-111 based on radiation readings taken in May 1974 (Internal letters ARHC-051574, "111-SX Tank Leak" and ARHC-051474, "111-SX Lateral Readings"). This estimate assumed a drop shape for the leak area originating from the tank bottom and extending downward to lateral 44-11-02. The 25-ft distance along the lateral where elevated radiation was detected was assumed to be the base of the drop shape. The soil from the lateral to the tank bottom was assumed to have a void space of 0.3 and to be 50% saturated. ARHCO estimated that 500 to 2,000 gal leaked from tank SX-111 with a ^{137}Cs inventory of 600 to 2,400 Ci (Letter 001125, "Status of Tank 241-SX-111 Contract AT(45-1)-2130" pages 23 and 24).

5.6.2 Data Review and Observations

5.6.2.1 Liquid Level Decrease. In ARHC-051574 – Letter, ARHCO provided graphical information and calculations that demonstrate tank SX-111 experienced a liquid level decline averaging 73.2 gal per day from March 4 to April 4, 1974 (from 329 in. to 327.15 in.) due to evaporation. However, the average liquid level decline for tank SX-111 increased to 176.8 gal per day from April 7 to May 4, 1974 (from 327 in. to 325.2 in.). The liquid level decline increased by 103.6 gal per day during these 27 days, likely as a result of the tank leak. Using this information, the estimated volume of waste leaked from tank SX-111 is 2,800 gal (103.6 gal/day * 27 days = 2,797.2 gal). There is considerable scatter in the tank liquid level readings (as reported in ARHC-051574 – Letter and RL Occurrence Report 74-38), leading to uncertainty in the estimated volume of waste leaked.

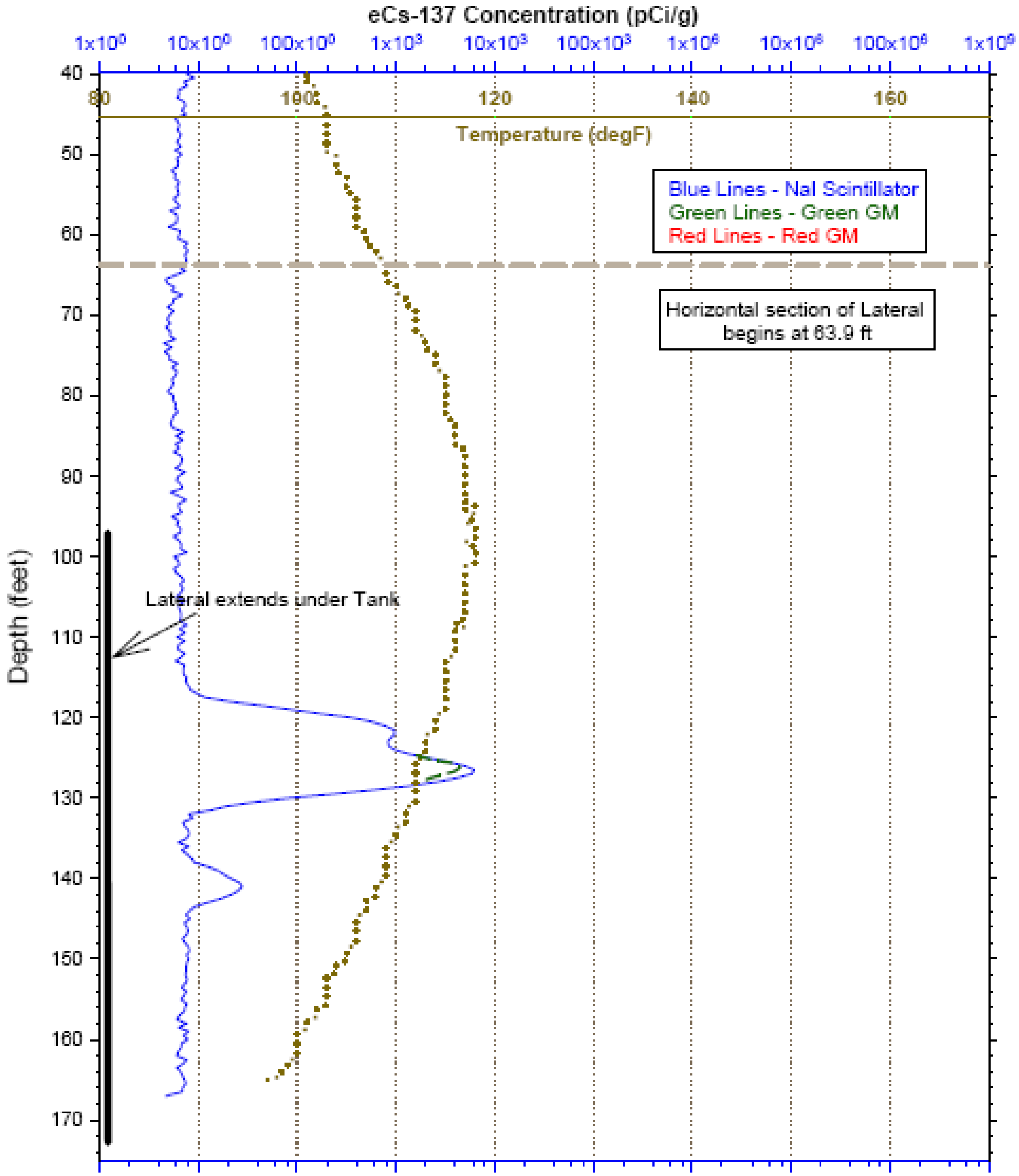
5.6.2.2 Drywell Gamma Logging. Gamma scans of laterals 44-11-01, 44-11-02 and 44-11-03 beneath tank SX-112 from May 2005 are shown in Figures 5.6-3, 5.6-4 and 5.6-5 (RPP-RPT-27605 pages B-36 through B-41). The ^{137}Cs concentration in laterals 44-11-01 and 44-11-03 was less than 10 pCi/g. The ^{137}Cs concentration in lateral 44-11-02 was a maximum of 8×10^3 pCi/g over a distance of about 14 ft, indicating a very small loss of ^{137}Cs from tank SX-111.

Figure 5.6-3. Gamma Survey for Lateral 44-11-01 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

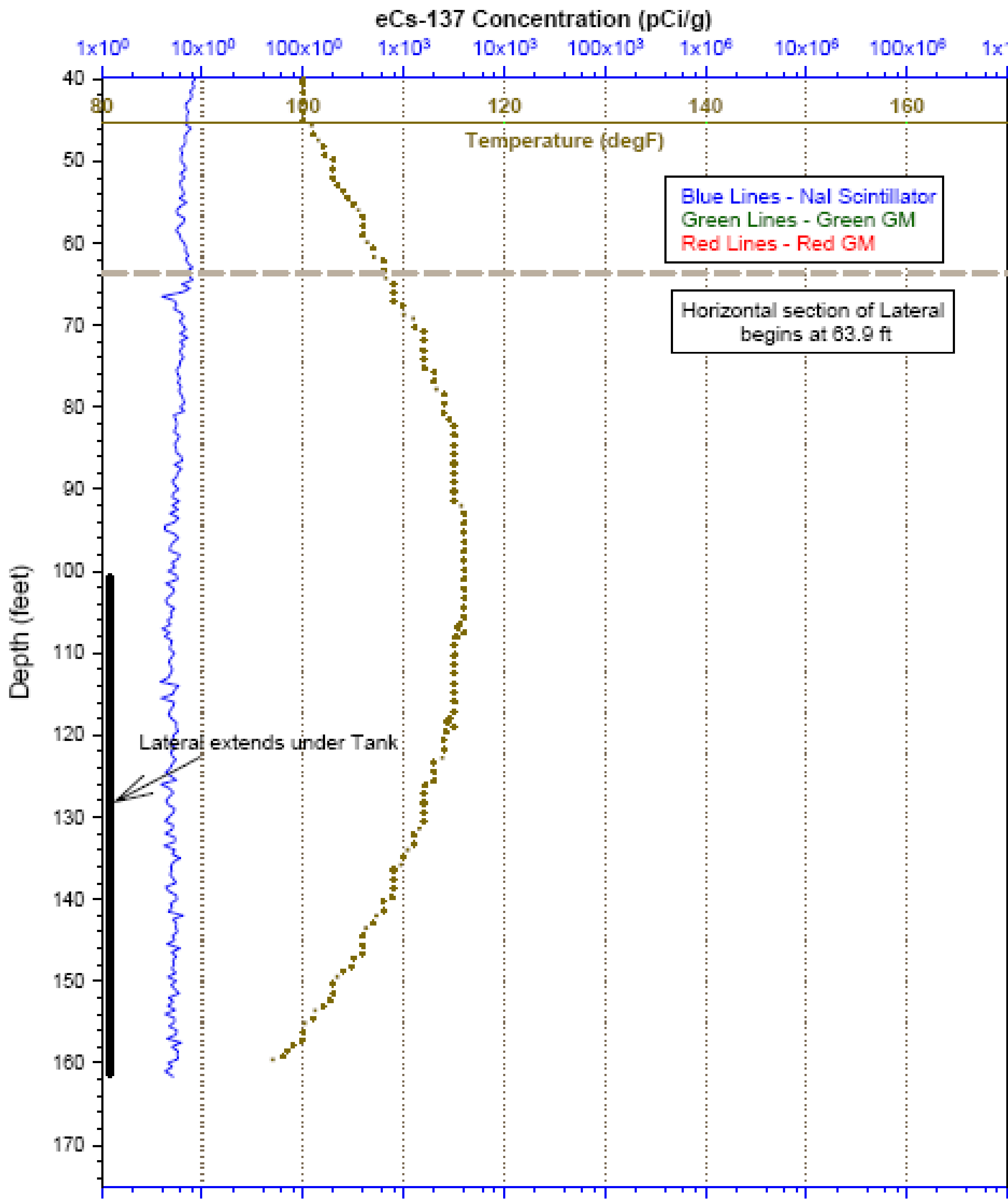
Figure 5.6-4. Gamma Survey for Lateral 44-11-02 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

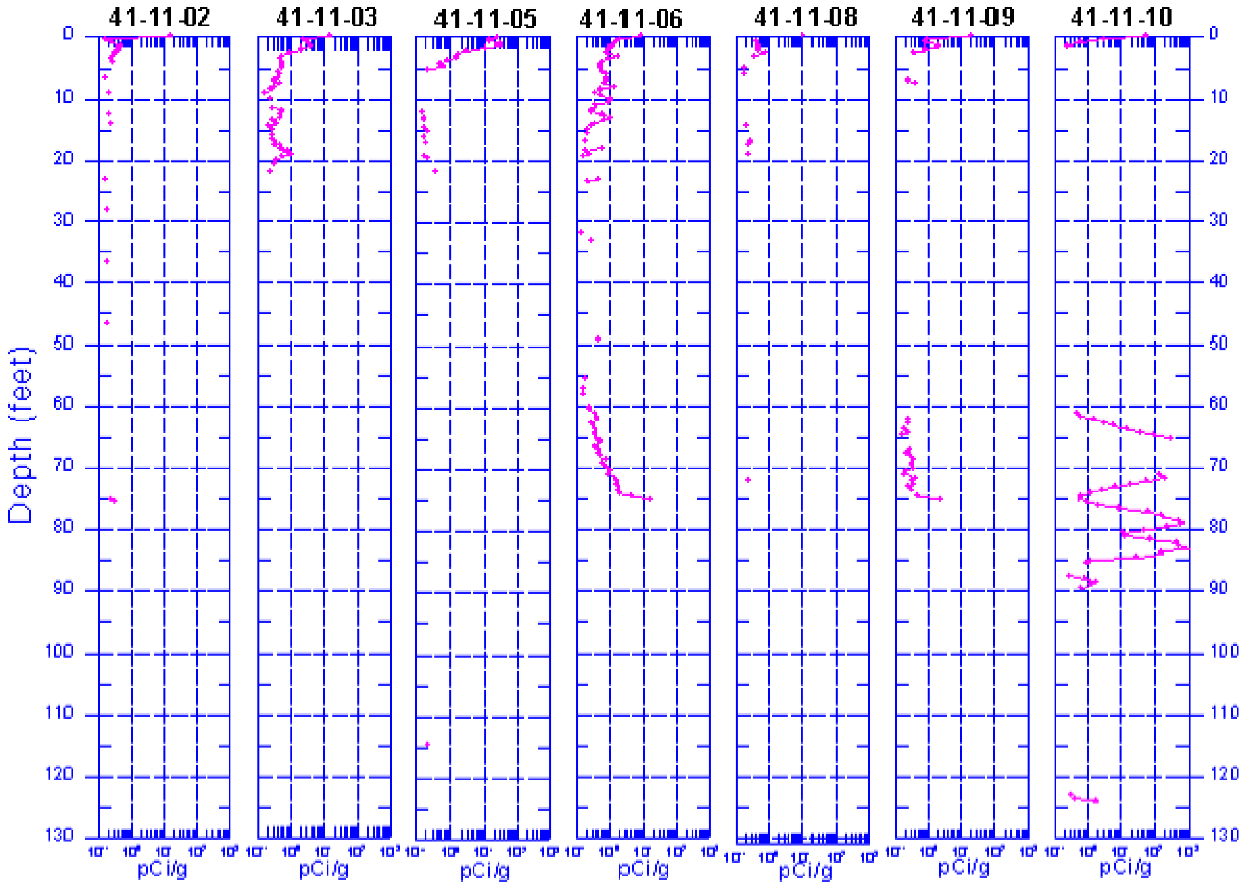
Gamma scans of drywells 41-11-02, 41-11-03, 41-11-05, 41-11-06, 41-11-08, 41-11-09 and 41-11-10 were most recently conducted in 1994 (GJ-HAN-13, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank SX-111*). Only boreholes 41-11-06, 41-11-09, and 41-11-10 have significant contamination below the upper 20 ft, as shown in Figure 5.6-6. The absence of contamination in the lower parts of borehole 41-11-08 indicates ^{137}Cs contamination is not continuous from 41-11-06 to 41-11-09 and might not be related. The source of the contamination for boreholes 41-11-09 and 41-11-10 is probably tank SX-108, SX-111 or SX-112. The origin of the contamination at borehole 41-11-06 might be a leak from tank SX-111 or SX-114.

Figure 5.6-5. Gamma Survey for Lateral 44-11-03 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

Figure 5.6-6. Gamma Scans for Drywells near Tank 241-SX-111 (1994)



5.6.3 Conclusions

Tank SX-111 leaked up to 2,800 gal of waste based on information presented in RL Occurrence Report 74-38. The composition of the waste leaked from tank SX-111 is provided in Table 5.6-2 and is a mixture of RIX and non-boiling REDOX HLW supernate. The location inside tank SX-111 where the waste leak occurred cannot be determined from available information. Based on the leak estimate and 1974 supernatant analyses, the ^{137}Cs inventory is estimated to be 1,830 Ci (decayed to January 1, 2001). Because SIM assumed a 1958 leak date versus 1974 and should have used the R-Saltcake waste type (RSLTCK) to calculate an inventory for other analytes, divide the sampled ^{137}Cs concentration (0.65 Ci/gal decayed to January 1, 2001) by the HDW RSLTCK ^{137}Cs waste concentration (1.2 Ci/gal decayed to January 1, 2001) for a ratio of 0.55. For a selected analyte, multiply this ratio by the HDW RSLTCK concentration for the analyte, then multiply by 2,800 gal to calculate an inventory (Example: ^{99}Tc HDW Concentration for RSLTCK = 4.4×10^{-4} Ci/gal, so ^{99}Tc = 4.4×10^{-4} * 0.55 * 2,800 = 0.88 Ci).

5.7 TANK 241-SX-112 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST SX-112. Tank SX-112 has three laterals (horizontal boreholes) installed about 10 ft under the tank, and there are seven boreholes (41-12-02, 41-12-03, 41-12-04, 41-12-06, 41-12-07, 41-12-09 and 41-12-10) located around the tank (see Figure 4-2).

5.7.1 Tank 241-SX-112 Waste Operations Summary

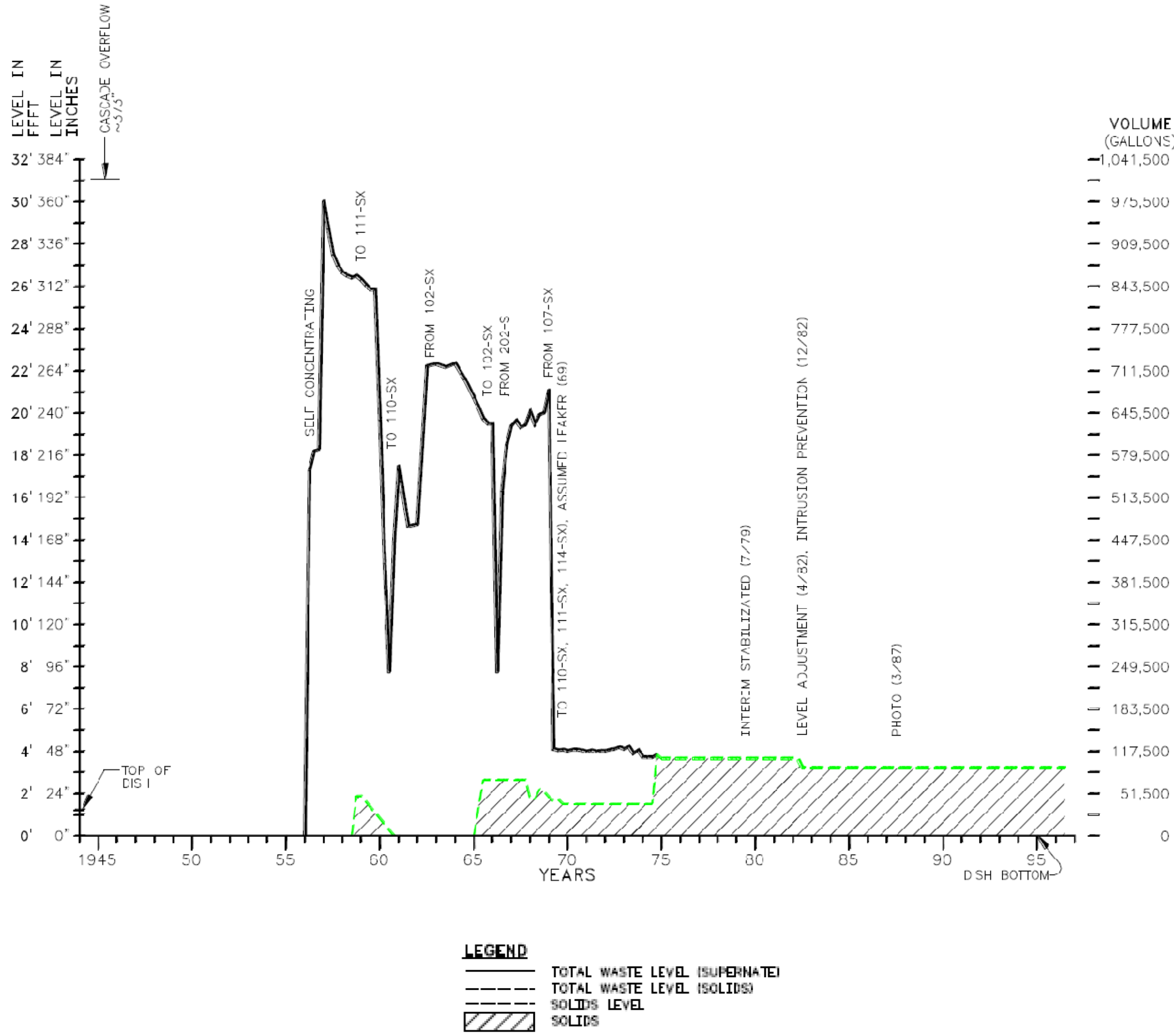
A tank surface-level diagram summarizing the waste transfer history is shown in Figure 5.7-1 (HNF-SD-WM-ER-352, *Historical Tank Content Estimate for the Southwest Quadrant of the Hanford 200 West Area*).

5.7.1.1 Tank 241-SX-112 Waste History. Tank SX-112 was constructed from 1953 to 1954. The tank was not used until February 13, 1956 (HW-41812 page 8), when 202-S REDOX HLW was received. Additional REDOX HLW was transferred into tank SX-112 in March 1956. The concentration of radionuclides present in the REDOX HLW received into tank SX-112 was sufficient to promote self boiling of this waste, which was observed in March 1956 (HW-42394, *Separations Section Waste – Status Summary for March 1956*, page 2). The evaporation rate was moderate, reported as 11,000, 6,000, 0, 1,000, and 0 gal for March, April, May, June and July 1956. No additional evaporation was reported until additional waste was added October 1956. The waste volume reported in tank SX-112 was 589,000 gal as of July 1956 (HW-44860, *Separations Section Waste – Status Summary for July 1956*, page 8).

In October and November 1956, REDOX HLW waste was cascaded from tank SX-111 into tank SX-112, filling tank SX-112 to ~977,000 gal (HW-46382 page 8, HW-47052 page 8 and HW-50216, *Current Status of REDOX Waste Self-Concentration*, page 6). The waste in tank SX-112 began to boil in December 1956 and continued to evaporate water through June 1959 (HW-61095, *Chemical Processing Department Waste Status Summary June 1, 1959 – June 30, 1959*, page 2). The waste volume in tank SX-112 was 838,000 gal in June 1959. From November 1959 through March 1960 ~426,400 gal of supernate were transferred from tank SX-112 to tank SX-111 (HW-83906-D-RD pages 84, 92, 100, 108, 115 and 122). An additional 170,100 gal of supernate were transferred from tank SX-112 into tank SX-110 in April and May 1960, leaving 244,000 gal of waste in tank SX-112 (HW-83906-D-RD pages 124 and 131).

From July 1960 through November 1960, tank SX-112 received ~368,800 gal of REDOX HLW (HW-83906-D-RD pages 147, 155, 163, 171 and 178). The waste in tank SX-112 began to boil in October 1960 (HW-67705, *Chemical Processing Department Waste Status Summary October 1, 1960 – October 31, 1960*, page 2). After evaporating sufficient water, tank SX-112 again received ~437,000 gal of REDOX HLW from July through December 1961 (HW-83906-E-RD pages 4 and 5).

Figure 5.7-1. Tank 241-SX-112 Surface Level History



In January 1962, ~275,600 gal of REDOX HLW supernate was transferred from tank SX-102 into tank SX-112 (HW-83906-E-RD page 15). Water was added to tank SX-112 from February through May 1962 in order to maintain the waste temperature within operating limits (HW-83906-E-RD pages 14 and 15). The waste in tank SX-112 was allowed to self-concentrate through boiling and evaporation, with periodic additions of water (or condensate from tank SX-106) and operation of airlift circulators, until the first quarter of CY 1966 at which time 388,000 gal of supernate were transferred to tank SX-102 (ISO-226 page 8). Tank SX-112 contained ~168,000 gal of supernate and 73,000 gal of sludge following this transfer.

In the second, third and fourth quarters of CY 1966, tank SX-112 received 638,000 gal of REDOX HLW from the 202-S Plant (ISO-404, *Chemical Processing Division Waste Status Summary April 1, 1966 Through June 30, 1966*, page 8, ISO-538 page 8 and ISO-674 page 8). The waste in tank SX-112 began to boil in the third quarter of CY 1966, evaporating 220,000 gal (average ~2,450 gal per day) and an additional 35,000 in the fourth quarter of CY 1966. 300,000 gal of water were added to tank SX-112 in the fourth quarter of CY 1966 for cooling. Evaporation of water from tank SX-112 continued through the second quarter of 1967 (ISO-967, *Chemical Processing Division Waste Status Summary April 1, 1967 Through June 30, 1967*, page 8).

No further additions of waste were made to tank SX-112 from the first quarter of CY 1967 through the third quarter of CY 1968. In the fourth quarter of CY 1968, 21,000 gal of REDOX HLW were transferred from tank SX-107 into tank SX-112, as result of a suspect leak in tank SX-107 (ARH-1061 page 10). After this transfer, tank SX-112 contained 636,000 gal of supernate and 46,000 gal of sludge.

In January 1969, a leak was detected in tank SX-112 and the supernate was transferred to tanks SX-110, SX-111 and SX-114, leaving an estimated 82,000 gal of supernate and 39,000 gal of sludge in this tank (ARH-1200 A page 10).

5.7.1.2 Interim Stabilization (1969 to 1979). Tank SX-112 was connected to the sludge cooler servicing other suspected leaking tanks within the 241-SX Tank Farm. Evaporation of water from the waste in tank SX-112 was allowed to occur as a result of the radiolytic decay heat generated from the sludge. By July 1979, no supernate remained and the tank was administratively stabilized (HNF-SD-RE-TI-178 page 275). Figure 5.7-2 depicts a mosaic of the waste surface in tank SX-112 as of March 1987. As of 2007 the tank was estimated to contain 75,000 gal of sludge, including 6,000 gal of drainable interstitial liquid (HNF-EP-0182).

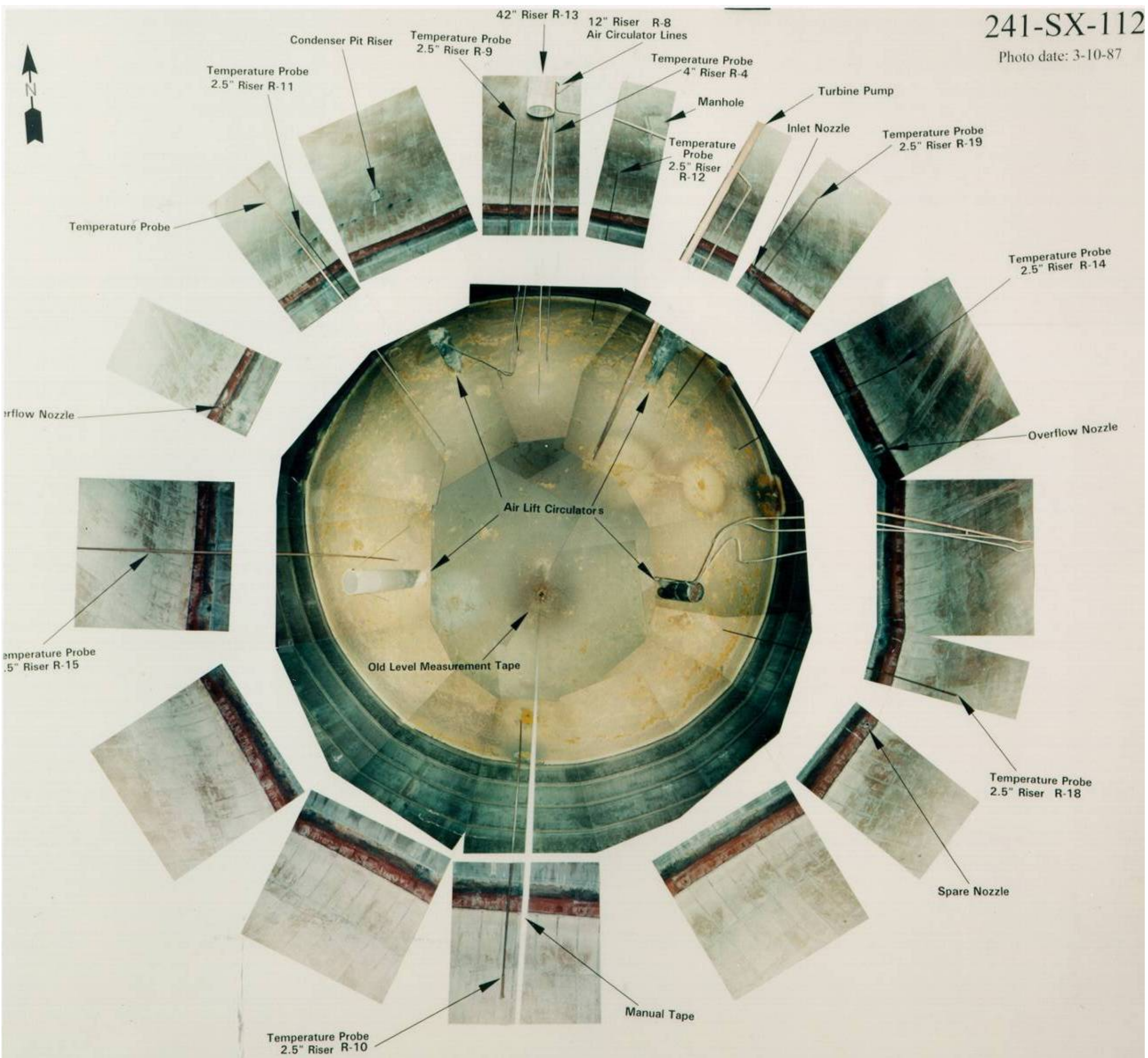
5.7.1.3 Tank 241-SX-112 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-112 starts in August 1956 and continues through June 1968 (RHO-CD-1172 pages B-73 through B-114). Appendix A provides plots showing the maximum temperature (°F) of the waste stored in tank SX-112. The temperature plots for tank SX-112 are consistent with the waste history discussed in section 5.7.1. These temperature plots show tank SX-112 waste temperature reached a maximum of ~310 °F in March 1962 and again in April 1967 as the tank contained boiling REDOX HLW.

5.7.1.4 Basis for Leak Declaration. Information from available references on the waste leak from tank SX-112 is summarized in Table 5.7-1. The verbatim text from the cited references is included in this table. These reference documents indicate that a liquid level decrease followed by increased radiation detected in laterals beneath tank SX-112 were the bases for declaring this tank a confirmed leaker. No gamma scans for laterals beneath tank SX-112 were located in available documentation when this leak was detected in January 1969.

5.7.2 Data Review and Observations

Photographs taken in January 1969 were reported to show twisted and broken pipes and equipment apparently resulting from a raised liner (ARH-1100-DEL, *200 Areas Operation Monthly Report January 1969*, page G-4). These photographs were not located. Additional photographs taken in July 1974 "… depicts an apparent crack in the sidewall of tank 241-SX-112 above the 4th stiffer ring (about 16 foot level)" (Internal memo ARHCO-072674, "Apparent Liner Crack in 112 SX"), as shown in Figure 5.7-3. These photographs do not show any other apparent breach in the tank liner.

Figure 5.7-2. Tank 241-SX-112 Waste Surface (March 1987)



5.7.2.1 Lateral and Drywell Gamma Logging. Gamma scans of laterals 44-12-01, 44-12-02 and 44-12-03 beneath tank SX-112 were performed in 2005, as shown in Figures 5.7-4, 5.7-5 and 5.7-6 (RPP-RPT-27605 pages B-42 through B-47). Extensive ^{137}Cs contamination, up to $\sim 1\times10^7$ pCi/g, was detected in lateral 44-12-02, with less than 2×10^3 pCi/g found in lateral 44-12-01 and less than 4×10^4 pCi/g found in lateral 44-12-03.

Table 5.7-1. Tank 241-SX-112 Leak Information (2 sheets)

Date	Event as Described in Reference
1/16/1969[a]	1/16/69, Page 21: Due to liquid level drop in 112-SX, decided to pump tank contents to 114-SX. Jumper changes made and started pumping at 2310 on 1/16/69. 1/19/69, Page 23: Transfer of some waste from 112 to 114-SX completed. 112 liquid level appears to be holding at 8 feet 4 inches. 1/20/69, Page 25: Liquid level holding at 8 feet. However, routing has been established to pump 112-SX to 110-SX should it become necessary. 1/21/69, 1/21/69: 112-SX Liquid level dropping slightly. 1/22/69, 1/22/69: 112-SX liquid level dropped slightly (about one inch). 1/23/69, Page 31: Pumping 112-SX to 110-SX. 1/26/69, Page 33: 112-SX Portable exhauster installed and pictures taken on 1/25/69. Some sludge exposed, but considered to be no problem. 1/27/69, Page 35: 112-SX Liquid level holding at four feet. 1/29/69, Page 39: 112-SX Liquid level holding at about 4 feet. 1/30/69, Page 41: 112-SX Liquid level holding at about 4 feet. 2/2/69, Page 43: 112-SX Liquid level holding at about 4 feet. 2/9/69, Page 67: 112-SX Liquid level holding at 4 feet. Took pictures in 107, 108, 112-SX.
1/1969[b]	Tank Leak, 241-SX-112 A gradual liquid level decrease in TK-112-SX, first observed in mid-January, indicated the existence of a leak in the tank even though no increase in leak detection laterals readings were observed. **Based on the liquid level measurements, up to 27,000 gallons of supernatant liquid containing about 40,000 curies of cesium-137 may have leaked from the tank**. The 112-SX liquid level was reduced from about 20 feet to about 8 feet by pumping to other boiling tanks in the SX Farm. During the following week the tank level held essentially constant, but the radiation readings in the leak detection laterals began rising sharply, apparently as a result of the migration of activity from the initial leak. The liquid level was further reduced to four feet above the normal bottom liner location. Photographs showed twisted and broken pipes and equipment apparently resulting from a raised liner. The extent of the bulge is being mapped to determine the sludge thickness from which the feasibility of air cooling can be determined.
2/1969[c]	After positive radiation readings were observed in the laterals beneath Tank 112-SX, **the maximum liquid level was reduced to four feet to maintain the hydrostatic head at a minimum without exposing any sludge.** The rate of rise of the radiation readings in the leak detection laterals has been drastically reduced, and an excellent material balance (condensate being added, compared to boiloff rate) indicates no additional leakage is occurring. Eight risers were installed through the dome, and the sludge surface has been mapped. A maximum sludge height variation of 30 inches was found, which is much less than that found in other SX farm tanks. Thermocouple trees have been installed in each of the eight risers. The forthcoming sludge temperature profiles and sludge thickness measurements will be analyzed to determine if air cooling can provide adequate heat removal for Tank 112-SX in the near future.

Table 5.7-1. Tank 241-SX-112 Leak Information (2 sheets)

Date	Event as Described in Reference
3/1969[d]	Sludge Removal, Tank 241-SX-112 - Mapping of the **bulged liner** and sludge depth indicates that Tank 112-SX sludge thickness varies from 0.0 to 3.1 feet. Heat transfer analyses indicate that the tank can be safely air cooled, and installation of necessary equipment is proceeding. The tank is being held at a reduced liquid level by recycling tank farm condensate to replace water evaporated by the decay heat.
7/1974[e]	Photograph depicts an apparent crack in the sidewall of tank 241-SX-112 above the 4th stiffer ring (about 16 foot level).

[a]ARH-1023-DEL, *Chemical Processing Division Daily Production Reports January, 1969 through March, 1969.*

[b]ARH-1100–DEL, *200 Areas Operation Monthly Report January 1969*, page G-4.

[c]PR-REPORT-FEB69-DEL, *Monthly Status and Progress Report February 1969*, page AIV-5.

[d]PR-REPORT-MAR69-DEL, *1969, Monthly Status and Progress Report March 1969*, page AIV-4.

[e]Internal memo ARHCO-072674, "Apparent Liner Crack in 112 SX;" see Figure 5.7-3.

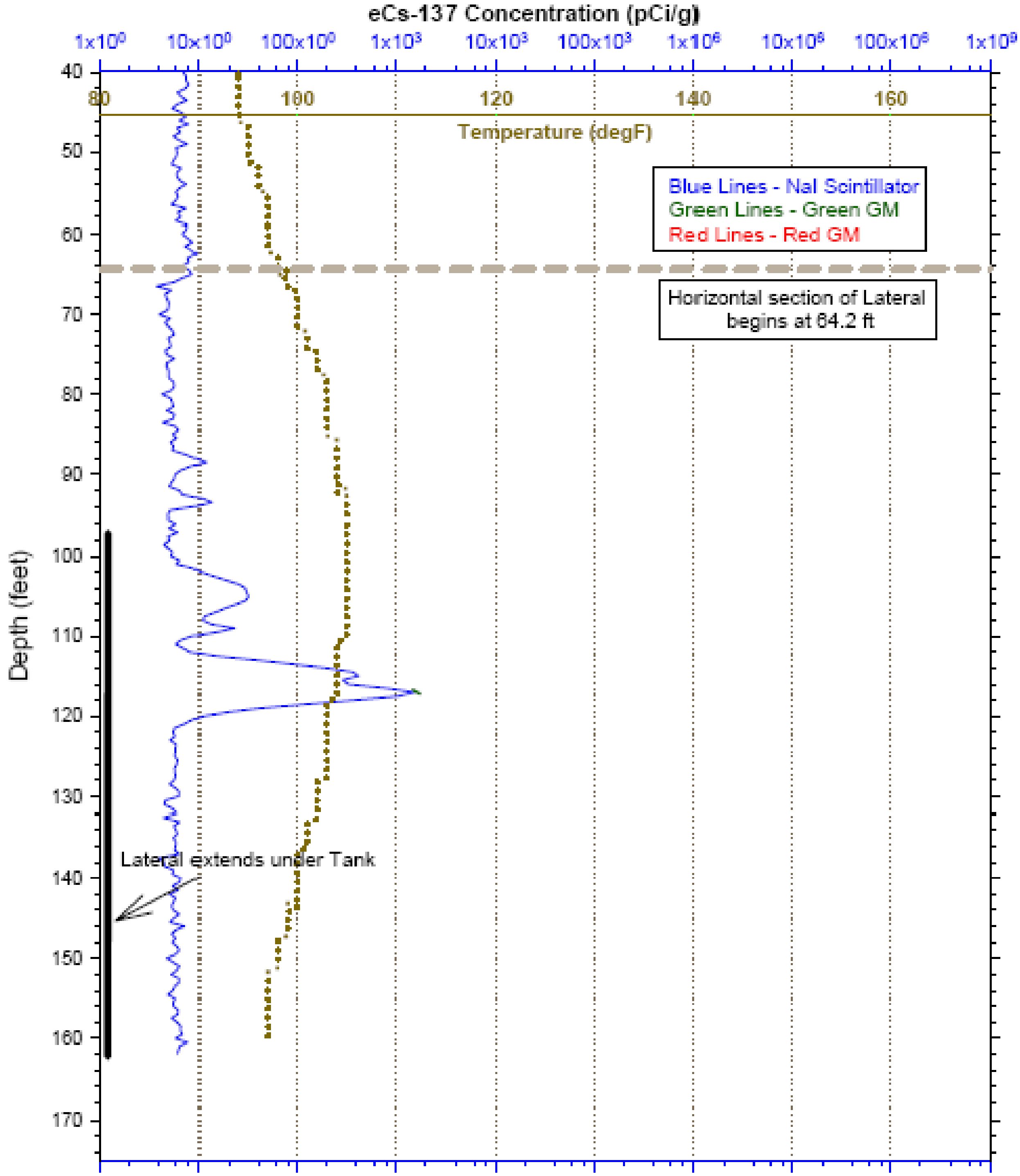
Gamma scans of drywells 41-12-04, 41-12-06, 41-12-07, 41-12-09 and 41-12-10 show only surface contamination of ^{137}Cs (GJ-HAN-14, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank SX-112*). However, drywells 41-12-02 and 41-12-03 indicated elevated ^{137}Cs contamination, as shown in Figure 5.7-7 (GJPO-HAN-4 Figure D-21). The ^{137}Cs contamination detected in drywell 41-12-02 was a maximum of ~1×10^8 pCi/g at ~72 ft bgs. Extensive contamination was detected from 72 to 120 ft bgs (maximum depth of drywell), with the ^{137}Cs contamination between 1×10^4 to 1×10^6 pCi/g. The maximum concentration of ^{137}Cs contamination detected in drywell 41-12-03 was ~1×10^5 pCi/g at 60 to 70 ft bgs. The activity detected in these drywells may be due to migration of waste that was leaked from tank SX-108 in August 1964 through December 1965 (WHC-MR-0300).

5.7.2.2 Tank 241-SX-112 Waste Loss Estimate. Tank SX-112 was declared a leaking tank in January 1969 due to liquid level decreases and increased activity in tank laterals. Documentation reported in Table 5.7-1 estimate that up to 27,000 gal of waste containing 40,000 Ci of ^{137}Cs (~1.48 Ci/gal) were leaked from tank SX-112 in January 1969. This equates to 16,160 Ci of ^{137}Cs (~0.6 Ci/gal) when decay corrected from January 1969 to May 2008. The supernatant waste type in tank SX-112 at the time of this leak was diluted supernate based on the amount of water and REDOX waste added from 1966 through 1968 (see section 5.7.1.1). The SIM (RPP-26744) assumes the waste type is RSLT (R2), REDOX salt waste with a mean supernatant ^{137}Cs concentration of 1.19 Ci/gal as of January 2004 or 1.08 Ci/gal decay corrected to May 2008. While the waste type for the tank SX-112 leak is correct, the concentrations of waste components in the RSLT (R2) waste type need to be corrected based on the ratio of the ^{137}Cs concentrations (i.e., 0.6 / 1.08) to adjust for waste dilution. In addition, prior to obtaining 2005 lateral data the previous SIM estimate assumed a leak volume of only 1,000 gal, attributing drywell contamination to a leak from SX-108. This is inconsistent with the information reported in available documentation (see Table 5.7-1), which states that up to 27,000 gal of waste was leaked from tank SX-112.

Figure 5.7-3. Crack in Tank 241-SX-112 Sidewall at ~16-ft Elevation

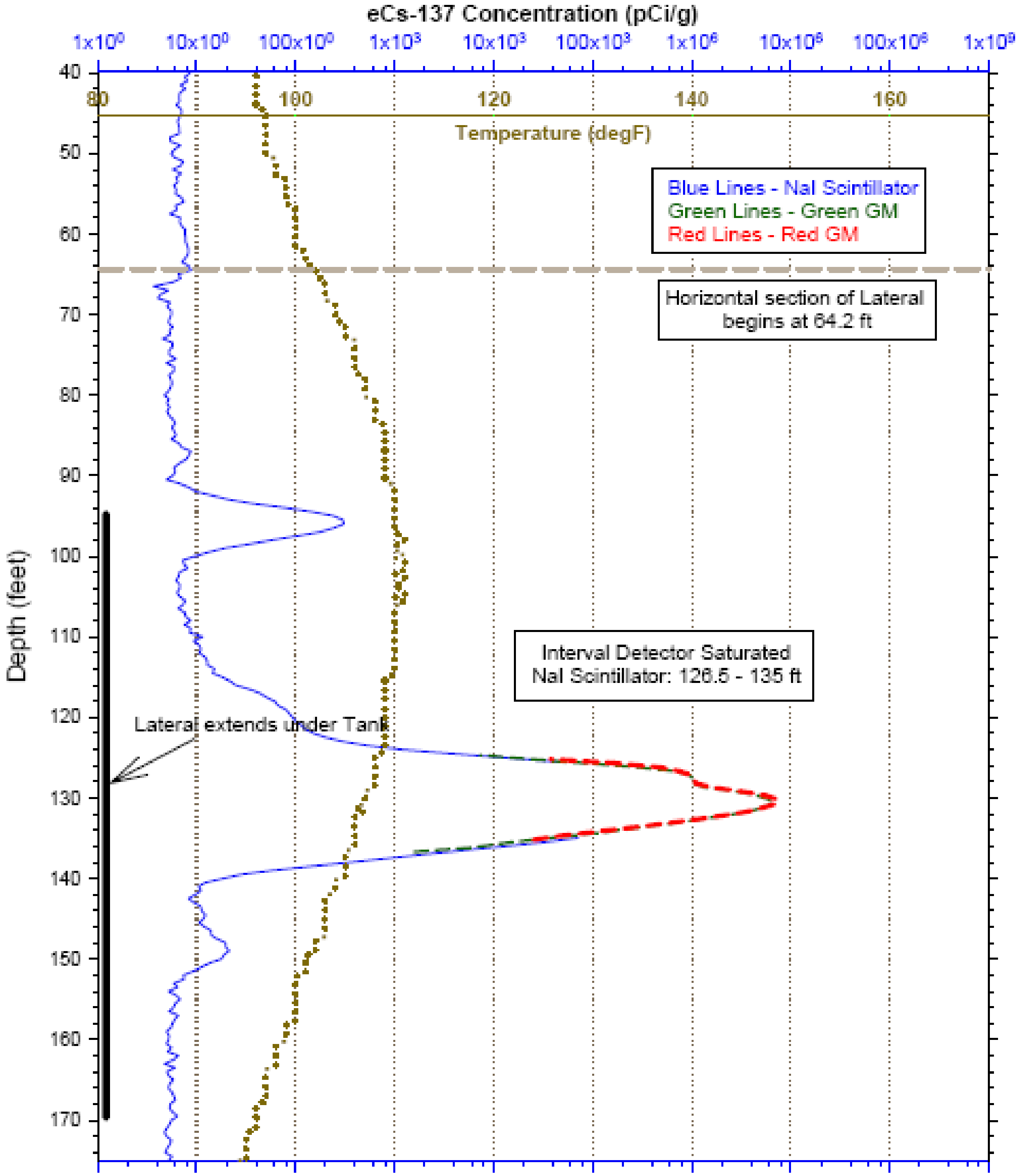
In an effort to verify the inventory of waste leaked from tank SX-112, two new conceptual models were devised to describe the leak. Tank SX-112 was assumed to have leaked over the areas where ^{137}Cs activity was detected in the three laterals beneath the tank, as shown in Figures 5.7-4, 5.7-5 and 5.7-6. The waste is assumed to have leaked from the tank to the laterals, a distance of 10 ft, and spread the same width as indicated by the ^{137}Cs activity for the three laterals.

Figure 5.7-4. Gamma Survey for Lateral 44-12-01 on Log Scale (May 2005)



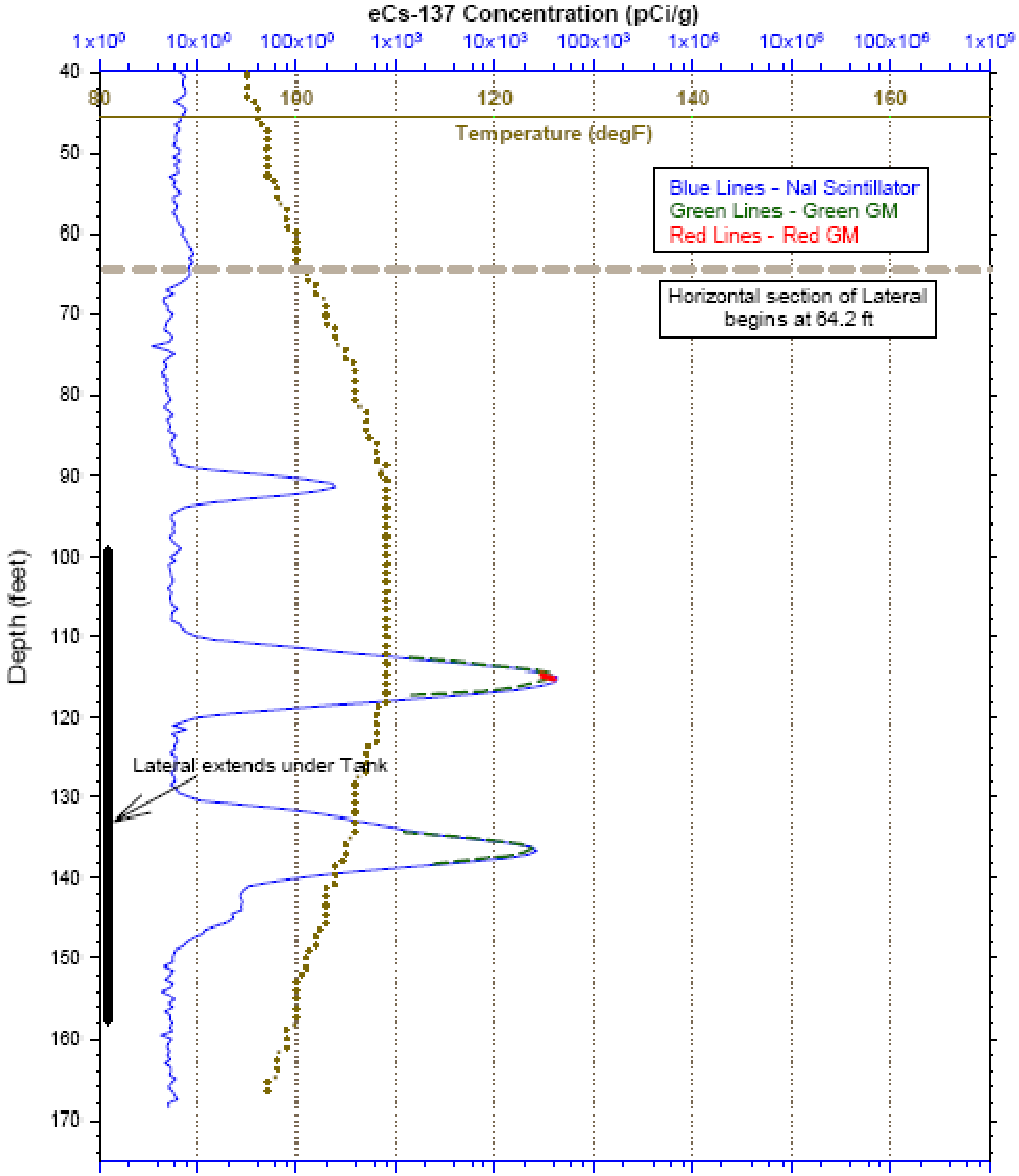
Log date: May 2005. Reference depth: ground level.

Figure 5.7-5. Gamma Survey for Lateral 44-12-02 on Log Scale (May 2005)



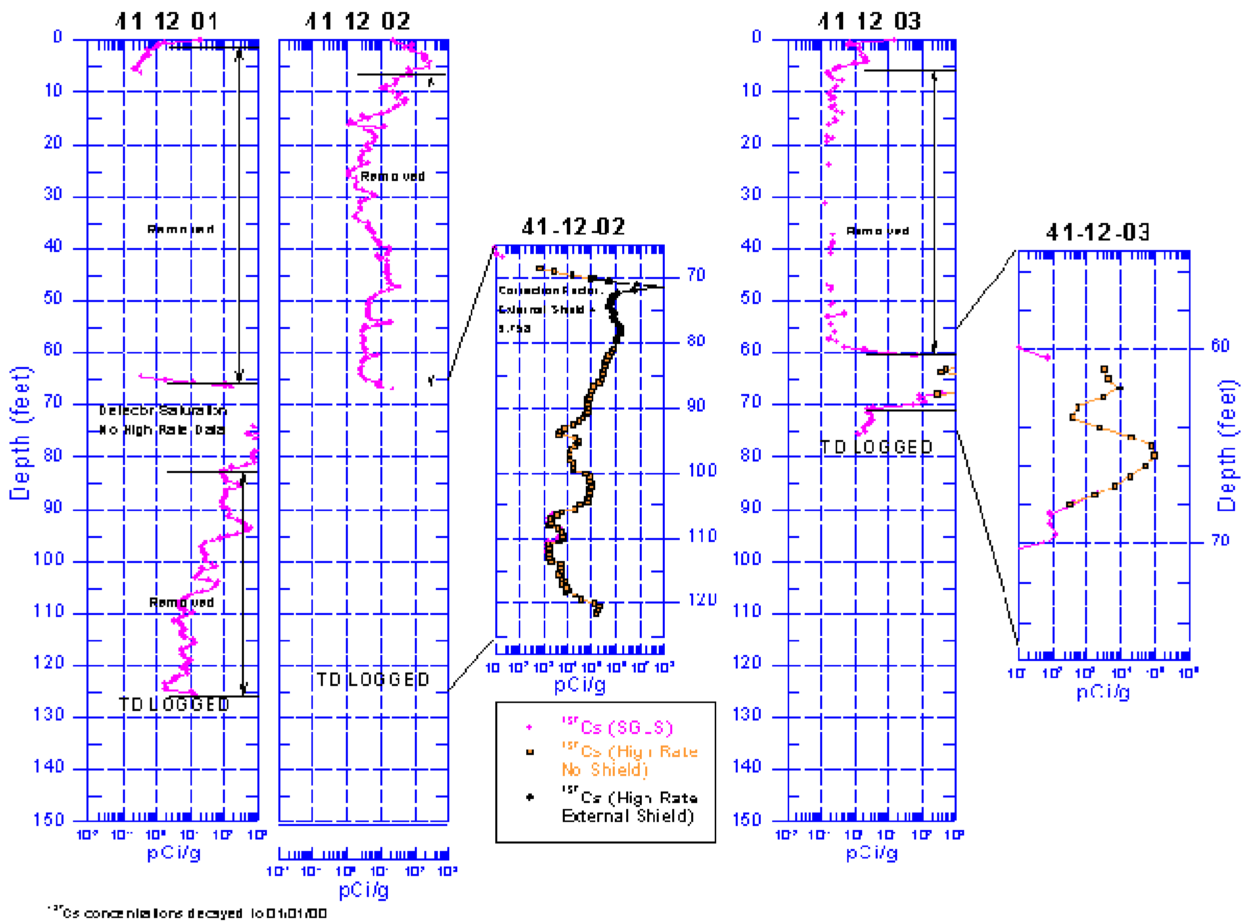
Log date: May 2005. Reference depth: ground level.

Figure 5.7-6. Gamma Survey for Lateral 44-12-03 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

Figure 5.7-7. Gamma Scan for Drywells 41-12-02 and 41-12-03 (1999)

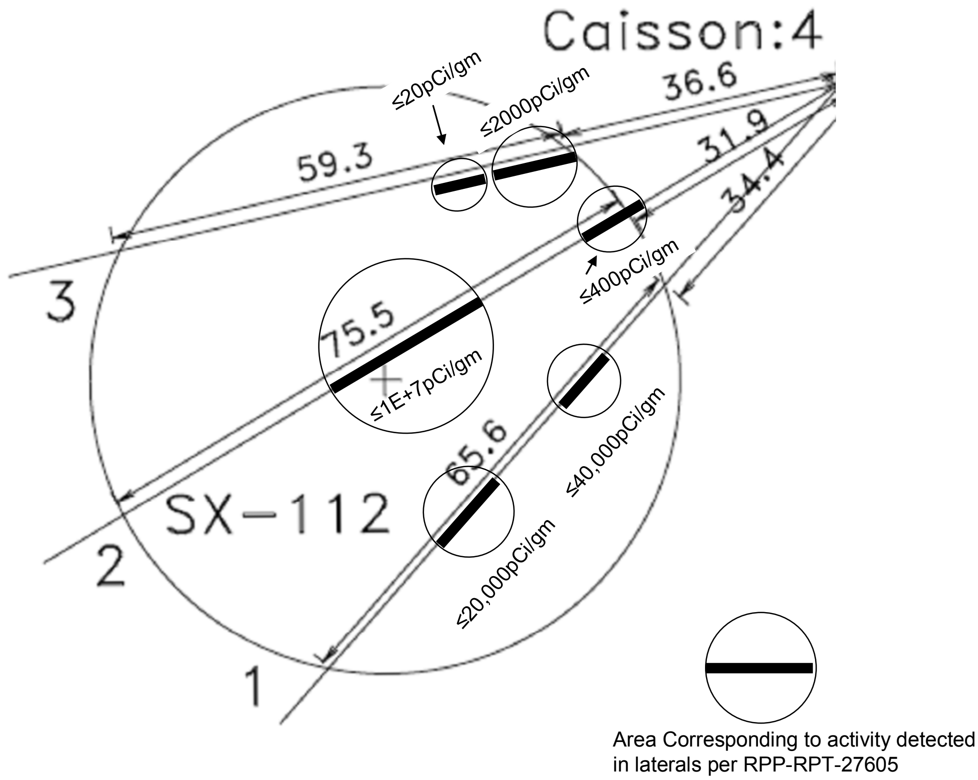


Conceptual Model #1
For the first conceptual model, the concentration of ^{137}Cs in the soil contacted by the leaked waste is assumed to be at the maximum ^{137}Cs activity shown for each lateral, as shown in Figure 5.7-8. The estimated ^{137}Cs loss was then calculated as follows:

Assumptions/Inputs:

- Soil density = 1.7 g/cc
- Distance to lateral below base of tank = 10 ft
- ^{137}Cs activity beneath lateral 44-12-01
  - $2{\times}10^3$ pCi/g at 112 to 120 ft
- ^{137}Cs activity beneath lateral 44-12-02
  - $1{\times}10^7$ pCi/g at 120 to 140 ft

Figure 5.7-8. Areas of Activity Detected Beneath Tank 241-SX-112 (May 2005)



- ^{137}Cs activity beneath lateral 44-12-03
    - 4×10^4 pCi/g at 112 to 120 ft
    - 2×10^4 pCi/g at 132 to 142 ft

- Assume waste does not extend below laterals based on Cs-Sorption chemistry.

- As a conservative estimate assume the waste spread as much as the distance of the ^{137}Cs activity detected in the laterals in a cylindrical distribution.

Calculation:

$$\text{Total Ci in soil} = \pi * [(4)^2 \text{ ft}^2 * 2E3 \text{ pCi/g} + (10)^2 \text{ ft}^2 * 1E7 \text{ pCi/g} + (4)^2 \text{ ft}^2 * 4E4 \text{ pCi/g} + (5)^2 \text{ ft}^2 * 2E4 \text{ pCi/g}] * 10 \text{ ft} * 1.7 \text{ g/cm}^3 * 1 \text{ Ci}/10^{12} \text{ pCi} * 28{,}320 \text{ cm}^3/\text{ft}^3$$

= 1,5,14 Ci ^{137}Cs as of May 2005
= 1,410 Ci ^{137}Cs as of May 2008

Conceptual Model #2
The second conceptual model assumes lateral 44-12-02 is closer to the waste leak source, and the activity detected in the other laterals is due to spreading of the waste or simply attenuation of a radiation source that is away from laterals 44-12-01 and 44-12-03. If this conceptual model of the waste leak is used and the soil is assumed to be saturated with ^{137}Cs from lateral 44-12-02 to the tank bottom, the quantity of leaked ^{137}Cs can be estimated as follows:

Assumptions/ Inputs:

- Soil density = 1.7 g/cc
- Distance to lateral below base of tank = 10 ft
- ^{137}Cs activity beneath lateral 44-12-02 is at 120 to 140 ft
- Assume waste does not extend below laterals based on Cs-Sorption chemistry.
- As a conservative estimate assume the waste spread as much as the distance of the ^{137}Cs activity detected in the laterals in a cylindrical distribution.
- Assume soil is saturated with ^{137}Cs at 1×10^8 pCi/g.

Calculation:

$$\text{Total Ci in soil} = \pi * (10)^2 \text{ ft}^2 * 1\text{E}8 \text{ pCi/g} * 10 \text{ ft} * 1.7 \text{ g/cm}^3 * 1 \text{ Ci}/10^{12} \text{ pCi} * 28{,}320 \text{ cm}^3/\text{ft}^3$$

$$= 15{,}100 \text{ Ci } ^{137}\text{Cs as of May 2005}$$
$$= 14{,}100 \text{ Ci } ^{137}\text{Cs as of May 2008}$$

The estimated inventory of ^{137}Cs leaked from tank SX-112 using the second conceptual model and the January 1969 loss estimate are within ± 15%. This may be a coincidence, or may indicate the ^{137}Cs leaked from tank SX-112 is actually retained in the soil extending from the tank bottom to lateral 44-12-02.

5.7.3 Conclusions

Tank SX-112 leaked up to 27,000 gal of waste with a ^{137}Cs inventory of 19,200 (decayed to January 1, 2001) based on liquid level decreases and ^{137}Cs inventory estimates reported in ARH-1100-DEL, page G-4. This estimate is consistent with inventory calculations based on 2005 lateral measurements. To calculate the inventory for other analytes, multiply the ratio of the ^{137}Cs inventory (19,200 Ci) and the HDW/SIM ^{137}Cs inventory (1,190 Ci) to the SIM inventory for a selected analyte.

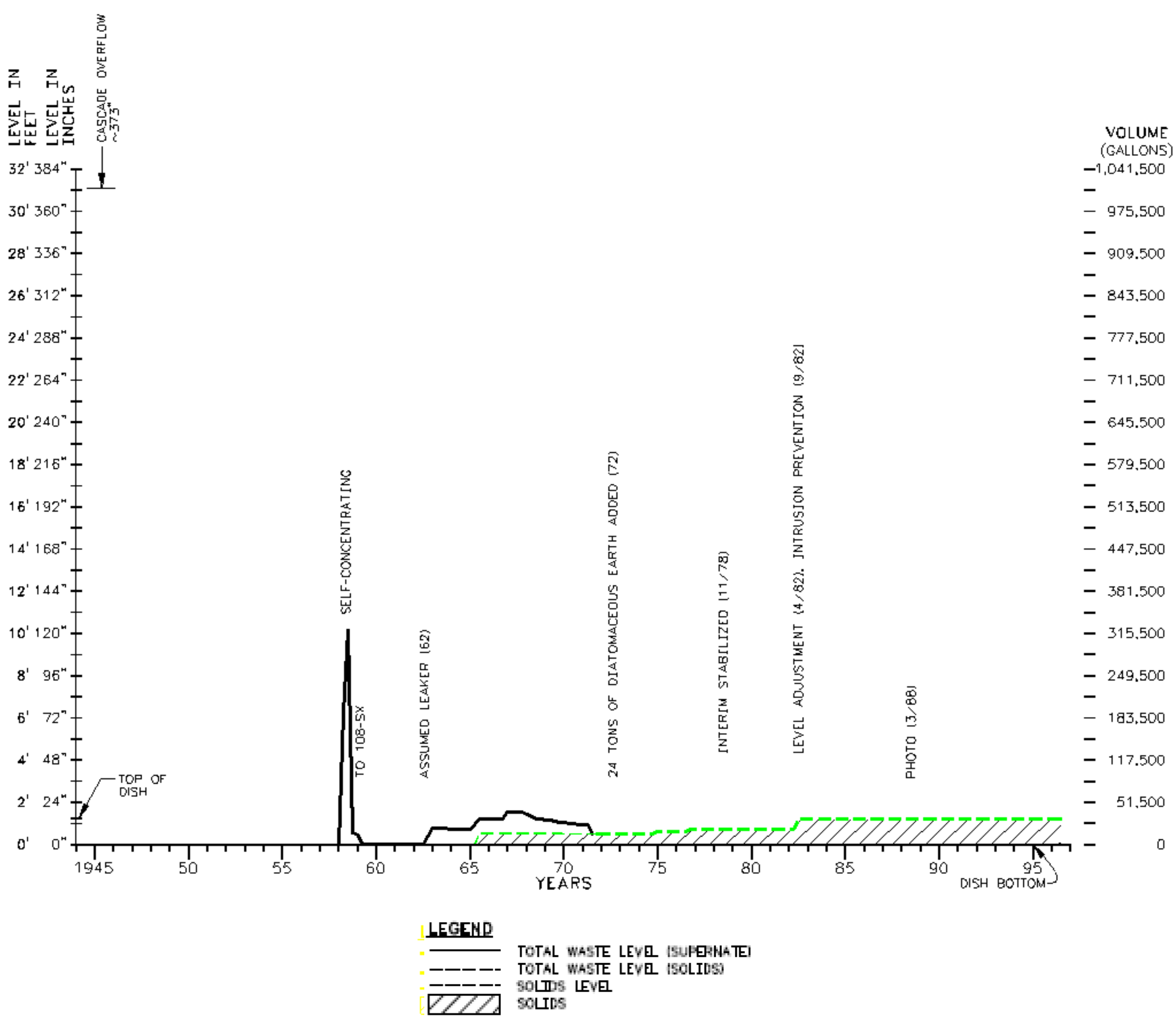
5.8 TANK 241-SX-113 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST SX-113. Tank SX-113 has five laterals (horizontal boreholes) installed about 10 ft under the tank in December 1958 (HW-58711-DEL, *Chemical Processing Department Monthly Report for December, 1958*, page D-3). There are only two drywells located nearby tank SX-113: 41-00-05 and 41-13-10 (see Figure 4-1).

5.8.1 Tank 241-SX-113 Waste Operations Summary

A tank surface-level diagram is shown in Figure 5.8-1 (HNF-SD-WM-ER-352). The following sections provide a brief discussion of waste operations for tank SX-113.

Figure 5.8-1. Tank 241-SX-113 Surface Level History



5.8.1.1 Tank 241-SX-113 Waste History. Tank SX-113 was constructed from 1953 to 1954. The tank was not used to receive any waste until February 20, 1958 (HW-57249, *Interim Report on Displacement of the REDOX 113-SX Waste Storage Tank Liner*, Appendix). On February 19, 1958, the 24-in. vapor header butterfly valve was opened to tank SX-113. On February 20, 1958, tank SX-113 began receiving 202-S REDOX HLW via diversion box 241-SX-151. There is no record that tank SX-113 contained any liquid waste or water prior to receiving REDOX HLW. This sequence of events is important because the tank was first connected to the exhaust ventilation system before receiving any waste. If the exhaust ventilation system exerted vacuum of 2.4-in. water gauge or higher, deflection of the tank bottom would occur since no liquid was present in the tank (OSD-T-151-00013, *Unclassified Operating Specifications for Single-Shell Waste Storage Tanks*, section 2.2).

Approximately 483,000 gal of REDOX HLW was received into tank SX-113 through June 2, 1958. The concentration of radionuclides present in the REDOX HLW received into tank SX-113 was sufficient to promote self boiling of this waste, with continuous boiling commencing about April 22, 1958 (HW-57249 page 4).

Operations personnel observed "… that the volume received in the tank exceeded slightly the volume sent, a condition not uncommon where interchange of water vapor is possible. Attempts, on May 28, 1958, to install an experimental, replaceable air-lift circulator in the newly activated 113-SX storage tank failed when the circulator encountered an obstruction. Subsequent soundings through several nearby openings in the tank", i.e., risers, "indicated the steel lining of the tank to be elevated to a height greater than four feet above its original position. Measurements in several other tanks in the SX farm revealed no similar abnormality. Routing of waste to the 113-SX tank was terminated on June 2, 1958. During a seven-day period starting June 11, 1958, the liner returned to its original position with an apparent net loss in volume of approximately 63,000 gallons. The volume remaining following the collapse of the liner, however, was in good agreement with the volume sent, indicating the liner was probably intact. Because of the stresses suffered by the liner, the tank contents were pumped to another SX farm tank", i.e., SX-108, "during a two-day period starting July 23, 1958" (HW-57249 page 2).

Additional information on the chronology of events for tank SX-113 was located in several of the operating contractor monthly reports for the Hanford Site and is summarized in Table 5.8-1.

Condensate from the self-boiling waste tanks in 241-SX Tank Farm was collected in tank SX-106. The condensate was either discharged to a crib or a portion returned to the self-boiling waste tanks in 241-SX Tank Farm to maintain the waste temperature below a maximum operating limit. The airlift circulators in tank SX-113 were operated from April 7, 1958 through July 22, 1958 to provide added waste cooling. The airlift circulators were shutoff on July 22, 1958 to enable removal of the tank contents to tank SX-108.

Table 5.8-1. Tank 241-SX-113 Leak Information (5 sheets)

Date	Event Described Verbatim from Reference
5-1958[a]	On 5-28-58 a prototype air-lift circulator was installed in the 113-SX pump pit. However, the assembly lacked approximately three feet of seating on the riser flange, indicating either an obstruction in the tank or that the tank bottom has buckled. Further checks are being made at month end to determine the exact trouble. An extensive leak check of the 113-SX tank has been started and plans to route the salt waste to another tank are currently being made
6-1958[b]	Page A-4: The steel liner in waste storage tank 113-SX was found to be bulged about four feet upwards of its normal position. Liquid between the concrete supporting structure and the steel liner appears to be the most plausible explanation for the observed condition. During the month, the liner returned to its normal position. The situation is under investigation with the objective of getting further data required to fully explain and understand the condition. Page B-2: Early in June a suspected bulge in the bottom of the 113-SX waste storage tank was confirmed. Waste was diverted to another storage tank and continuous soundings of the 113-SX tank were made. By the week of June 17, the tank bottom had returned to its normal position; however the integrity of the vessel was in doubt. Prior to the discovery of this condition, the contents of the vessel had been boiling for about 2 ½ months. Although monitoring of fourteen adjacent wells in SX tank farm showed no contamination, no conclusive evidence was found to assure that the tank was not leaking. Tentative plans have been made to transfer the waste in the 113-SX tank to another waste storage tank. Page D-3: As reported during May, unsuccessful attempt to install prototype removable circulators in the 113-SX tank led to the discovery that the tank bottom had buckled to a maximum height of approximately four feet above its normal position. Investigation by the Redox Technology Operation indicates the presence of liquid between the concrete shell and the liner to be the most likely cause of the displacement. Further investigation of this condition during June has revealed that the tank bottom has returned to essentially normal position in all quadrants of the tank. Extensive leak checks have been made, however, dry well checks have all been negative and tank electrode readings indicate no leakage. Well points were also driven to a depth of 50 feet on the northwest side of the tank and to a depth of 24 feet by the tank fill line. No evidence of ground contamination has been detected. However, as a precautionary measure, plans to route the salt waste to another tank are proceeding. Page H-7: An upward bulge of approximately four feet (3 feet above a horizontal plane) was detected in the Redox 113-SX tank when trying to install a prototype replaceable circulator through the riser in the pump pit. Additional reading indicated the bulge formed an approximate simple curve and each quadrant of the tank was raised about the same direction. The movement of the sidewalls, if any, was not detectable. There was about 460,000 gallons (electrode reading) of high level wastes at a maximum temperature of 236 °F in the tank at the time the bulge was discovered. Sometime during June 17 or 18, the east half of the tank bottom settled to about five inches above the original position of the bottom and the west half to about three inches above, with the sounding at the south 4-inch riser about ¾ of an inch lower than the original bottom position. No indications of a leak have been detected with present leak detection methods. It is planned to transfer the wastes from 113-SX to 103-SX to permit further evaluation of the tank. Page J-8: Unsuccessful attempts at the end of May to install prototype removable circulators in the 113-SX tank led to the discovery that the tank liner had been elevated to a maximum height of approximately 4 feet above its original position. Extensive evaluation of material balances and temperature data indicates the presence of liquid between the concrete shell and the liner to be the most likely cause of the displacement. The liner returned to essentially normal position during June with a corresponding decrease in the liquid level within the tank. Investigation of the liner movement is being investigated extensively.

Table 5.8-1. Tank 241-SX-113 Leak Information (5 sheets)

Date	Event Described Verbatim from Reference
7-1958[c]	The questionable integrity of Tank 113-SX remains unchanged. Attempts to sink well points near the tank met with only moderate success, 48 feet being the maximum depth attained. Monitoring at this level detected no contamination; however, it is doubtful that sufficient depth was reached to permit detection of activity, assuming it to be present. A second well point was successfully sunk to and slightly below the tank fill line for monitoring purposes, since if a leak had occurred, the fill line was a logical source. In view of the fact that contamination was not found at this site either, it seems safe to proceed with excavation as soon as the tank can be emptied. Pumping of the liquid to Tank 103-SX started July 23 and was expected to be completed before month-end.
7-1958[d]	The bulge in the bottom of the 241-SX-113 tank (Redox buried waste) collapsed during June, and as the bottom plate resumed its normal shape, the rate of apparent liquid loss observed during the collapse (12,000 – 15,000 gallons per day for approximately five days) dropped sharply to 3,000 – 3,500 gallons per day where it remained essentially constant until the tank was emptied by pump near the end of July. This rate of decrease represents normal boil-off, thus indicating that the steel liner was intact and that no liquid was escaping to the soil during this period. **However, the most painstaking calculations show that approximately 40,000 gallons of waste remained unaccounted for**. This is consistent with the theory that the bulge was caused by liquid (under the bottom of the liner) which subsequently escaped to the soil through a fault in the concrete, thus allowing the steel plate to resume its normal position. At the beginning of the final week of the month, approximately 270,000 gallons of the tank's contents were pumped to another tank, leaving a heel of approximately 20,000 gallons in 113-SX. This liquid level has continued to drop slowly but steadily at an evaporation rate of about 1,200 gallons per day, and will be permitted to continue until the tank is dry. At such time, inspection of the interior of the tank (by periscope or photographic techniques) can be started. Meanwhile excavation has been started for the purpose of exposing the influent line so that a postulated mechanism for the formation of the bulge can be investigated.
8-1958[e,1]	Page A-4: Waste tank 113-SX continued to exhibit bottom movement. Sixteen days after emptying, the bottom again started to rise, reaching 40 inches above normal within the next 15 days. This movement raised the sluice pump and caused it to become inoperable. Further inspection of this tank is delayed until the pump can be replaced and sluicing can be done. Page B-3: After completing the transfer of waste in 113-SX, the soil was excavated to the encasement. A hole was then drilled through the encasement to permit swabbing. Negative monitoring results indicated no leak at this point. During the week ending August 17, there were indications that the tank bottom bulged again to a height of approximately one foot. Liquid and/or sludge content of the tank was less than 5,000 gallons. Current plans are to install a periscope and inspect the tank interior before taking further action. Page D-3: The investigation for possible causes which may have resulted in the buckling of the tank bottom on the 113-SX salt waste storage tank (May 1958) was continued this month. Excavation of the fill line at the tank revealed that the line was in good repair and no traces of moisture or radiation, that would normally be expected to accompany a leak, were found. Further investigation of the tank bottom distortion will depend on the successful installation and use of a periscope in the 113-SX tank. Page J-8: Starting approximately 16 days after the 113-SX tank was emptied the liner again rose, over a 15-day period, to a height 40 inches above its original position. The temperature, as indicated by the mercury-filled thermometer, rose from an average of 218 °F to 224 °F about two days prior to the movement of the liner. The liner returned to approximately normal position near the month end several days after an apparent decrease in temperature. During the course of the second rise of the liner, it lifted the pump (used to empty the tank in July) about eight inches despite the fact that it was still attached to the discharge jumper. The pump had not been bolted down. Since the pump will not now run, it is presumed that the shaft was bent by the pressure, and thus it appears that a replacement pump will be necessary before sluicing and sludge removal can be started.

Table 5.8-1. Tank 241-SX-113 Leak Information (5 sheets)

Date	Event Described Verbatim from Reference
8-13-1958[f]	Summary During the initial filling of the 113-SX tank, started on February 20, 1958, it was observed that the volume received in the tank exceeded slightly the volume sent, a condition not uncommon where interchange of water vapor is possible. Attempts, on May 28, 1958, to install an experimental, replaceable air-lift circulator in the newly-activated 113-SX storage tank failed when the circulator encountered an obstruction. Subsequent soundings through several nearby openings in the tank indicated the steel lining of the tank to be elevated to a height greater than four feet above its original position. Measurements in several other tanks in the SX farm revealed no similar abnormality. Routing of waste to the 113-SX tank was terminated on June 2, 1958. During a seven-day period starting June 11, 1958, the liner returned to its original position with an apparent net loss in volume of approximately 63,000 gallons. The volume remaining following the collapse of the liner, however, was in good agreement with the volume sent, indicating the liner was probably intact. There were no subsequent indications of loss of waste from the tank. Because of the stresses suffered by the liner, the tank contents were pumped to another SX farm tank during a two-day period starting July 23, 1958. A chronological history of the 113-SX tank is presented in the appendix. As yet there is no conclusive evidence as to the cause of the displacement of the liner. The possibility that waste had been introduced below the liner, due to a fault in fabrication, was virtually eliminated when investigation revealed the most likely point of ingress to be free of radioactive contamination. Photographic inspection of the tank interior will be employed in the near future in a further effort to determine the cause of the displacement and the extent of the damage sustained. *…. [Comment: Report contains additional details on liner displacement, tank temperature, and material balance estimates.]*
9-1958[g]	Page B-3: Since efforts to inspect the empty 110-SX tank by periscope were unsuccessful, no attempt was made to inspect 113-SX. Present plans are to check the 113-SX tank for a leak by adding water periodically. A pump will be installed for transferring the liquid in the event a leak is detected. Further efforts to monitor soil at depth will be made upon completion of another monitoring well. The contractor is scheduled to start drilling 9-29-58, and the job should be completed in three to four days. The well will be located northwest of 113-SX, about ten feet from the tank.
10-1958[h]	Page B-3: Drilling of the 100 foot monitoring well immediately northwest of Tank 113-SX was completed 10-7-58 and subsequent monitoring of the soil showed negative results insofar as a leak in the tank is concerned. Further investigation of the tank condition is underway. Page D-2: Daily electrode checking of the 113-SX tank indicated that the tank bottom remained static during the month. The leak detection program started late in September is progressing satisfactorily. The test well drilled northwest of the 113-SX tank to determine the extent of ground contamination was completed without finding a trace of contamination. A caisson, twelve feet in diameter will be sunk at the same site as the test well with laterals radiating out under the tank from the bottom of the caisson.
12-1958[i]	Page A-4: The contractor has experienced considerable difficulty installing the five lateral pipe lines under the 113-SX waste storage tank. The fourth line was not completed beyond 100 feet as a result of damage to the augering equipment and cutting shoe on the pipe. The contractor is now preparing as-built data showing location of the lateral pipes. Page D-3: The 113-SX tank bottom remained static during the month. Drilling of the five horizontal laterals at an elevation of approximately 10 feet below the bottom of the tank was completed by Engineering Limited of Seattle. No soil contamination was encountered.

Table 5.8-1. Tank 241-SX-113 Leak Information (5 sheets)

Date	Event Described Verbatim from Reference
1-1959[j,2]	Page D-2: The 113-SX tank bottom remained static during the month. Radiation readings taken inside the five horizontal laterals, which were drilled ten feet below the tank bottom during December gave no indication of a leak in the tank bottom. The addition of water to the tank to verify the presence (or absence) of a leak has been delayed pending more favorable weather conditions. Page H-5: **Measurements were made of gamma radiation level in the lateral test holes under the 113-SX tank. At all five points it was less than 0.1-mr/hour.** Steps are being taken to provide greater sensitivity in the instrument for additional experimental testing.
2-1962[k]	A periscope and light-bar were installed in the 113 tank, 241-SX Tank Farm to assist the Waste Handling and Decontamination Operations in determining the extend of damages to the tank pump. The pump shaft housing is bent to such an extend that it cannot be withdrawn through the tank nozzle in the conventional manner. No conclusion had been reached at month-end as to how the problem will be resolved.
4-1962[l]	The Hayden Well Drilling Company completed drilling of 49 vertical monitoring wells within the SX Tank Farm. There were no radiation dose rates involved in this work nor was there any detectable contamination encountered. The demonstration lateral under the 110-SX waste tank, from the existing caisson at 113-SX, was completed this month. The work, which was done by the Boring and Tunneling Company, Houston, Texas, was completed per contract date despite the one-week exclusion from the 200-W Area as a result of the Z-Plant criticality incident. The lateral met project specifications.
5-1962[m]	A grossly contaminated 50-foot pump was removed from 113 tank at the 241-SX Tank Farm, and disposed of by burial in the conventional manner. Evidence indicated the pump had received irreparable damage when the bottom of the tank buckled.
7-1962[n]	The Bore-Tun Company completed drilling of the laterals under the 110 and 111-SX waste tanks and completed the first of three vertical caissons (located between 109 and 115-SX tanks) on July 26. To date no significant ground contamination has been detected. However, a surface dose rate of 5r/hr was detected on two condensate recycle lines which were uncovered at a depth of four feet in one of the caissons. An effort is currently being made to relocate the caissons.
8-1962[o]	**In preparation for a full-scale leak test of the 113-SX tank, Redox and Facilities Engineering personnel completed the monitoring of the laterals under the tank in 8-2-62. No radiation was detected**. The leak test is expected to begin next month with the transfer of recovered sodium nitrate solution from the 114-SX tank into 113-SX.
8-15-1962[p]	During 1958, shortly after waste capable of self-concentration was routed to the 113-SX tank, the tank liner bottom bulged. Although the bulge receded several days later, the boiling waste was pumped to another tank. The tank liner bottom bulged a second time after the contents were pumped out. This bulge also receded over a period of several days; however, the 113-SX tank has not been re-used or tested to determine whether it leaks. Currently, prototype facilities are being installed to route dissolved sludge, high in sodium nitrate, from the 114-SX tank to the Redox plant, for use as a hydrogen suppressant during aluminum jacket dissolution. If it can be determined that the 113-SX tank does not leak, its use for storage of the sodium nitrate solution in place of the 114-SX tank would be very desirable. Periscopic inspection, completed several months ago, found no visible damage to the 113-SX tank liner. The pump, which was damaged when the second bulge occurred, was removed without incident. **Monitoring of the five laterals under the tank in January 1959, and in August 1962, together with periodic monitoring of the test wells in the vicinity of the tank, has failed to detect any contamination indicative of a leak from this tank.** However, proof of the tank's integrity can only be obtained by adding liquid to the tank and measuring the liquid level over a reasonable period of time. The following program for leak testing the 113-SX tank is recommended: ….

Table 5.8-1. Tank 241-SX-113 Leak Information (5 sheets)

Date	Event Described Verbatim from Reference
10-1962[q]	Leak checking the 113-SX Tank began on October 10, when 63,000 gallons of wastes were transferred from 241-SX-114.
10-1962[r,3]	Leak testing of the 113-SX tank was started on October 10, 1962, and was terminated on November 13, 1962. A leak, indicated by liquid level measurements, was confirmed by monitoring the horizontal laterals under the tank. The 113-SX tank contents were returned to the 114-SX tank on November 14 and 15, 1962, except for a heel of 9-3/16 inches (approximately 10,000 gallons, corrected for the 2-inch sludge level). Calculations show that approximately 15,000 gallons of solution containing 7800 curies of gamma activity (>99% Cs-137) were lost to the ground. The 113-SX tank is therefore considered unusable. The major portion of the leakage occurred after November 2, 1962, at a rate of 1200 – 1400 gallons per day. The leak test also proved the efficacy of the horizontal lateral leak detection system in confirming the presence of a leak.
11-1962[s]	Leak checking of the previously deformed 113-SX waste storage tank was completed this month and the tank was found to be leaking.

Notes:
1. Periscope inspection of tank 113 SX was not conducted due to poor periscope visibility observed during testing in tank SX-110 (see HW 57640-DEL page B-3).
2. HW-60749 (June 1959) page 3 and 4 state a scintillation probe was used to scan the laterals beneath tank SX-113.
3. HW 75714 provides the composition of the supernatant added to tank 241-SX-113 for the leak check.

References cited:
[a]HW-56218-DEL, *Chemical Processing Department Monthly Report for May, 1958*, page D-4
[b]HW-56602-DEL, *Chemical Processing Department Monthly Report for June, 1958*
[c]HW-56972-DEL, *Chemical Processing Department Monthly Report for July, 1958*, page B-2
[d]HW-56972-DEL, page J-8
[e]HW-57328-DEL, 1958, *Chemical Processing Department Monthly Report for August, 1958*
[f]HW-57640-DEL, *Chemical Processing Department Monthly Report for September, 1958*
[g]HW-57249, *Interim Report on Displacement of the REDOX 113-SX Waste Storage Tank Liner*
[h]HW-58051-DEL, *Chemical Processing Department Monthly Report for October, 1958*
[i]HW-58711-DEL, *Chemical Processing Department Monthly Report for December, 1958*
[j]HW-59079-DEL, *Chemical Processing Department Monthly Report for January, 1959*
[k]HW-72890, *Chemical Processing Department Monthly Report February, 1962*, page E-3
[l]HW-73525, *Chemical Processing Department Monthly Report April, 1962*, page C-3
[m]HW-73884, *Chemical Processing Department Monthly Report May, 1962*, page E-2
[n]HW-74505, *Chemical Processing Department Monthly Report July, 1962*, page C-3
[o]HW-74804, *Chemical Processing Department Monthly Report August, 1962*, page C-4
[p]Internal letter LET-081562, "Leak Testing of the 113-SX Tank"
[q]HW-75470, *Chemical Processing Department Monthly Report October, 1962*, page F-5
[r]HW-75714, *Leak Testing of the 113-SX Tank*
[s]HW-75702, *Chemical Processing Department Monthly Report November, 1962*

Leak Test with Tank 241-SX-114 Salt Waste (1962)

Tank Farms operations personnel were uncertain as to the integrity of tank SX-113 following the events in 1958. Less than 0.1-mrem/h gamma radioactivity was detected in the laterals underneath tank SX-113 when first monitored in January 1959 (HW-59079-DEL, *Chemical Processing Department Monthly Report for January, 1959*, page H-5), indicating the tank integrity was intact. Additional monitoring of the laterals underneath tank SX-113 is reported on

August 2, 1962 and again indicated no radiation was detected (HW-748-4 page C-4). Furthermore as reported on August 15, 1962, a "Periscopic inspection, completed several months ago, found no visible damage to the 113-SX tank liner …" and "… Monitoring of the five laterals under the tank in January 1959, and in August 1962, together with periodic monitoring of the test wells in the vicinity of the tank, has failed to detect any contamination indicative of a leak from this tank (Internal letter LET-081562, "Leak Testing of the 113-SX Tank"). A leak test was conducted on tank SX-113 in October 1962 in order to confirm its integrity and the possibility of resuming its use.

As reported in HW-75714, *Leak Testing of the 113-SX Tank*, leak testing of the tank SX-113 was started on October 10, 1962, and was terminated on November 13, 1962. A total of 65,000 gal of salt waste solution at 168 °F was transferred from tank SX-114 into tank SX-113. Liquid level measurements in tank SX-113 conducted during the period of October 11, 1962 through October 29, 1962 indicated a volume decrease of ~2,800 gal. Proof that the tank did or did not leak was considered to be inconclusive since 1,100 to 1,200 gal of this waste volume loss was attributed to cooling the solution from 168 °F to 107 °F and the measured volume of waste in tank SX-113 was greater than that initially transferred from tank SX-114.

An additional 143,000 gal of waste was transferred from tank SX-114 into tank SX-113 from October 30, 1962 through November 2, 1962, filling tank SX-113 to the 80-in. level or 204,000 gal. The total volume of waste added from tank SX-114 to tank SX-113 was ~208,000 gal. A leak was indicated when the liquid level in tank SX-113 decreased 2 9/16 in. (7,000 gal) in five days (November 2, 1962 through November 7, 1962). Figure 5.8-2 depicts the liquid level data for tank SX-113 during this leak test. A pump was installed in tank SX-113 and the remaining liquid was transferred back to tank SX-114 on November 14 and 15, 1962, except for a heel of about 10,000 gal.

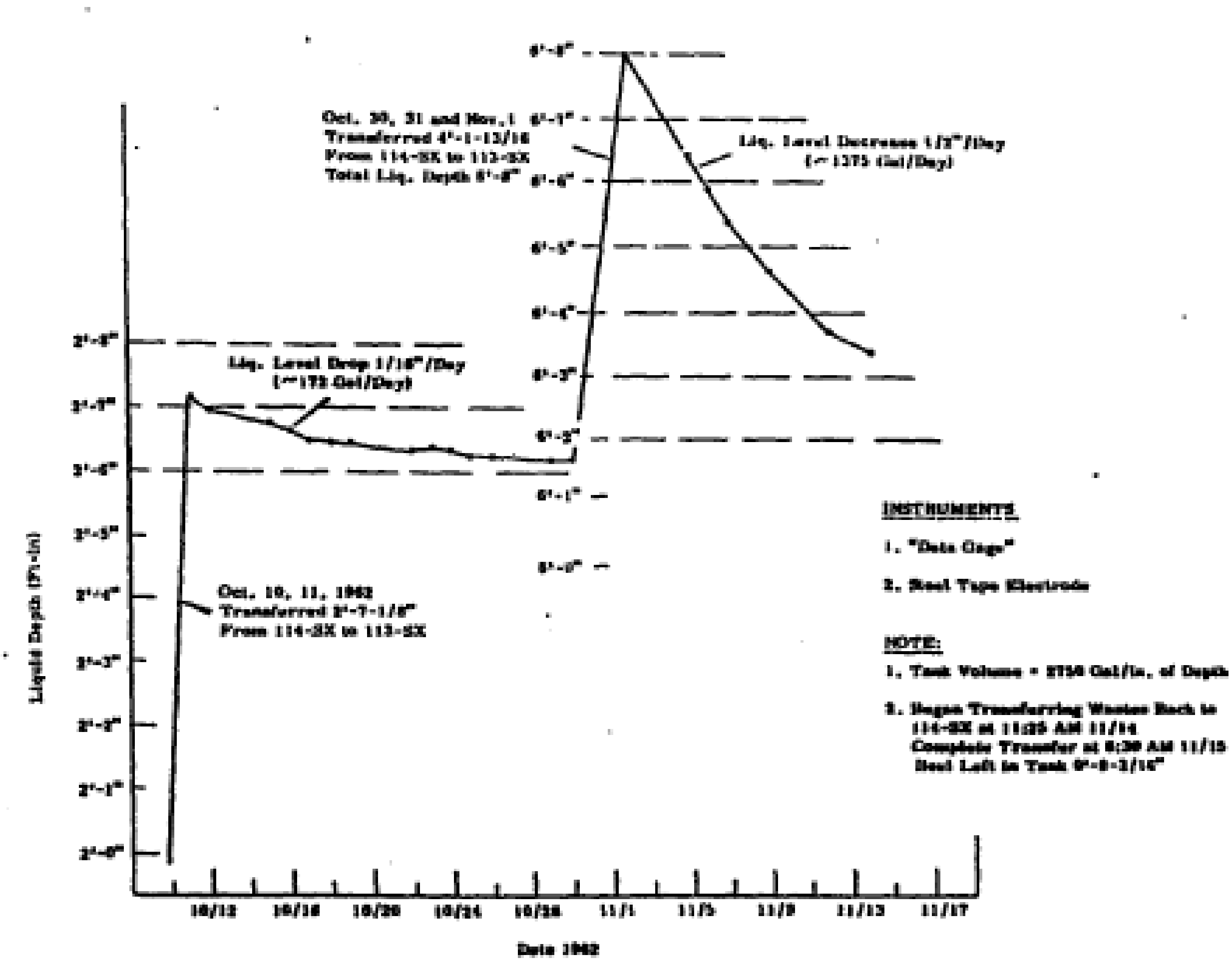
A leak, indicated by liquid level measurements, was confirmed by monitoring the horizontal laterals under the tank on November 13, 1962. The peak activity detected was ~7,500 cpm gamma in the central lateral no. 3 beneath tank SX-113 at a distance of 73 ft. 300 to 500 cpm gamma activity was also detected in lateral no. 2 at a distance of 73 to 76 ft. Gamma activity detected in lateral no. 1 was 50 to 150 cpm at a distance of 105 to 110 ft. Drywells W-23-72 (i.e., 41-13-10), W-23-69 (i.e., 41-14-04), W-23-3 (i.e., 41-00-05), and the 6-in. diameter 75-ft deep drywell at Hanford coordinates N35131, W75720 (i.e., 41-14-03) were monitored on November 14, 1962 and each had less than 50 cpm gamma activity (HW-75714 Figure 2).

Calculations show that ~15,000 gal of solution containing 7,800 Ci of gamma activity (>99% ^{137}Cs) were lost to the ground. The major portion of the leakage occurred after November 2, 1962, at a rate of 1,200 to 1,400 gal per day when the tank liquid level was increased from approximately 30 in. to 80 in.

Diatomaceous Earth Addition (1972)

Approximately 45 tons of diatomaceous earth were added to tank SX-113 in 1972 (ARH-CD-222, *Characterization of the Effects of Diatomaceous Earth Additions to Hanford Wastes*, page 4). The addition of the diatomaceous earth was conducted to adsorb and immobilize the liquid waste heel in tank SX-113 that could not be removed through pumping techniques available in 1972.

Figure 5.8-2. Tank 241-SX-113 Liquid Level Measurements (October to November 1962)

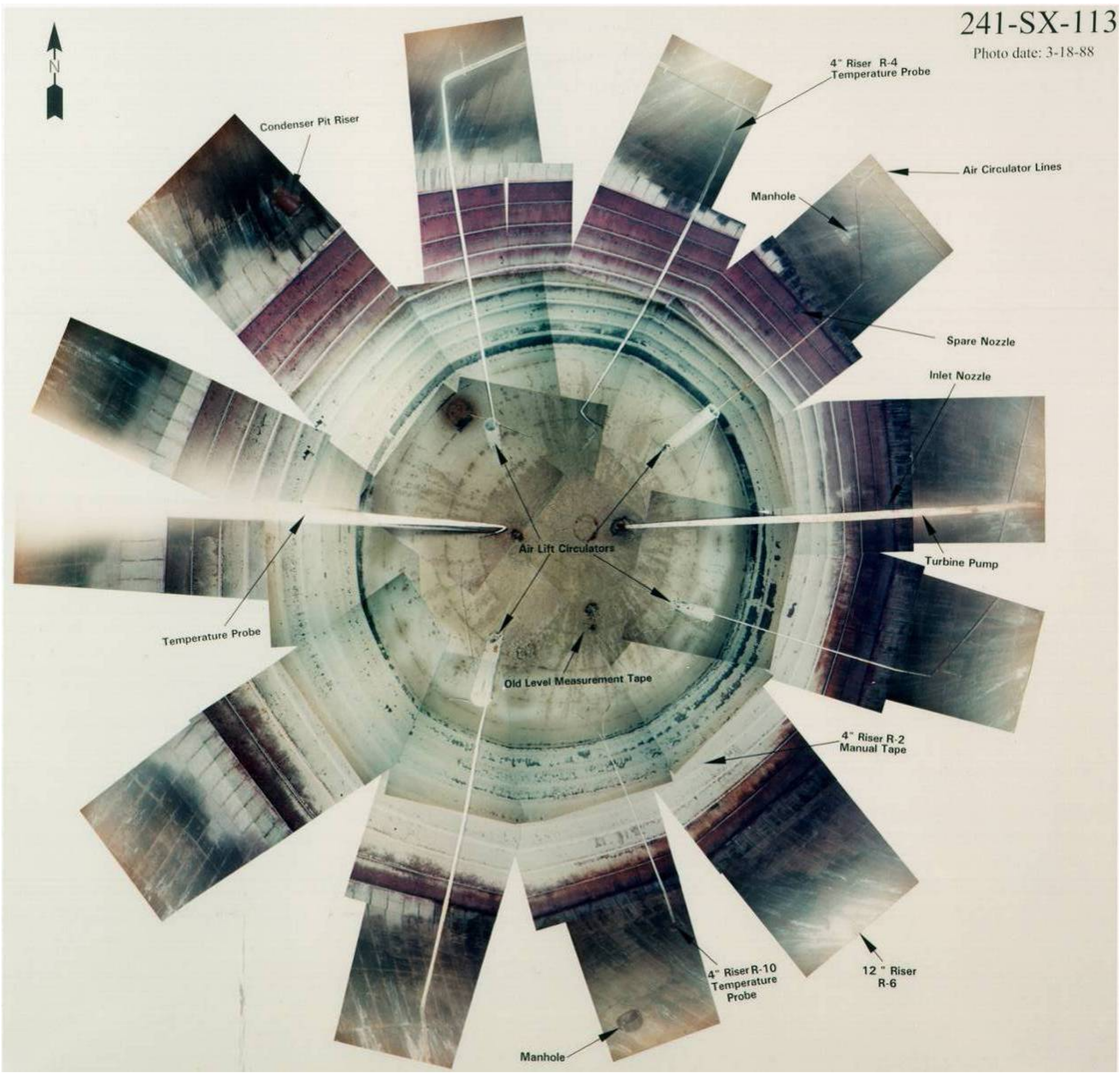


5.8.1.2 Interim Stabilization and Status. This tank was air cooled and declared interim stabilized / partially isolated in 1978. The photo evaluation indicated a dry cracked solids surface over the entire waste surface (HNF-SD-RE-TI-178).

As of 2007, SST SX-113 is estimated to contain 19,000 gal of sludge comprised of 2,000 gal of REDOX HLW sludge and 17,000 gal of diatomaceous earth with adsorbed supernate, equivalent to a depth of 15 in. No pumpable liquid remains in the tank (HNF-EP-0182). For inventory estimates, the sludge is designated as principally high-level REDOX process waste and the saltcake as precipitate from self-concentration in 241-SX Tank Farm (Tank Waste Information Network System). Figure 5.8-3 depicts a mosaic of the waste surface in tank SX-113 as of March 1988.

5.8.1.3 Tank 241-SX-113 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-113 starts in August 1958, when REDOX waste was first added and continued through June 1966 (RHO-CD-1172 pages B-75 through B-116). Appendix A provides plots showing the maximum temperature (°F) of the waste stored in tank SX-113 from 1958 through 1966. The temperature plots for tank SX-113 are consistent with the waste history discussed in section 5.8.1.

Figure 5.8-3. Tank 241-SX-113 Waste Surface (March 1988)



These temperature plots show a steady rise in tank SX-113 waste temperature from ~80 °F in early February 1958 to a peak of ~260 °F in early July 1958, as the tank was filled for the first time with REDOX HLW. The supernate was removed from tank SX-113 in July 1958 and the waste temperature beginning to decline.

5.8.1.4 Basis for Leak Declaration. Tank SX-113 was confirmed as leaking in 1962 based on the leak test described in Section 5.8.1.1 and gamma activity detected in laterals underneath the tank.

5.8.2 Data Review and Observations

Additional information on the chronology of events for tank SX-113 was located in several of the operating contractor monthly reports for the Hanford Site and is summarized in Table 5.8-1 (RPP-RPT-29191). The verbatim text from the cited references is provided in Table 5.8-1.

The July 1958 contractor's monthly report (HW-56972-DEL, *Chemical Processing Department Monthly Report for July, 1958*, page J-8) has generated considerable interest by stakeholders. This monthly report states:

> "The bulge in the bottom of the 241-SX-113 tank (Redox buried waste) collapsed during June, and as the bottom plate resumed its normal shape, the rate of apparent liquid loss observed during the collapse (12,000 – 15,000 gallons per day for approximately five days) dropped sharply to 3,000 – 3,500 gallons per day where it remained essentially constant until the tank was emptied by pump near the end of July. This rate of decrease represents normal boil-off, thus indicating that the steel liner was intact and that no liquid was escaping to the soil during this period. **However, the most painstaking calculations show that approximately 40,000 gallons of waste remained unaccounted for**. This is consistent with the theory that the bulge was caused by liquid (under the bottom of the liner) which subsequently escaped to the soil through a fault in the concrete, thus allowing the steel plate to resume its normal position. At the beginning of the final week of the month, approximately 270,000 gallons of the tank's contents were pumped to another tank, leaving a heel of approximately 20,000 gallons in 113-SX. This liquid level has continued to drop slowly but steadily at an evaporation rate of about 1,200 gallons per day, and will be permitted to continue until the tank is dry."

It has been suggested by some stakeholders that this monthly report is evidence that tank SX-113 actually leaked 40,000 gal of REDOX HLW in July 1958. However, a leak of this magnitude from tank SX-113 in July 1958 is highly unlikely, since no radioactivity was detected in the drywells or laterals beneath tank SX-113 until the October 1962 leak test (see Table 5.8-1).

It should be noted that the July 1958 contractor's monthly report does not represent the results from the completed investigation of events associated with tank SX-113. A detailed assessment of the tank condition, waste additions and condensate boil-off was published in August 1958 (HW-57249). This report states "…The volume remaining following the collapse of the liner, however, was in good agreement with the volume sent, indicating the liner was probably intact" and "… The possibility that waste had been introduced below the liner, due to a fault in fabrication, was virtually eliminated when investigation revealed the most likely point of ingress to be free of radioactive contamination" (HW-57249 page 2).

The bulged liner in tank SX-113 was likely the result of water contained in the grout and concrete tank shell that vaporized to steam as a result of the elevated waste temperatures in the tank. The steam would have needed to exert only a pressure of 0.1 psi for the tank SX-113 liner to deform as observed (HW-57249 page 3).

Testing of grout samples similar to the grout used beneath the steel liners in the 241-SX tanks was conducted in 1959 (HW-60556, *Portland Cement Grout Vapor Pressure – Temperature Test*). Grout samples were placed in a sealed container, heated to 240 °F and the vapor pressure measured within the sealed container. This testing demonstrated that if heated to 240 °F, the grout beneath the steel liners in the 241-SX tanks would evolve water vapor and develop pressures from 1.3 to 16 psig. At these pressures, the steel liner in tank SX-113 could deform. The waste in tank 241-SX-113 was reported to have exceeded 240 °F from May 20, 1958 through July 25, 1958 (HW-57249 Figure 2), indicating the tank temperature was sufficient to cause vaporization of the water in the grout beneath the steel liner. The pressure beneath the steel liner could possibly be relieved through: (1) cracking of the concrete tank shell without apparent damage to the steel liner, or (2) through damage of the steel liner and venting of the trapped gases into the tank.

5.8.2.1 Pipelines and Spare Inlet Nozzle. There are no known leaks associated with pipelines in the vicinity of tank SX-113 (Interoffice memorandum 7G410-MEJ-07-004, "Information on Process Pipeline Failures Due to Corrosion"). Therefore, it is unlikely that a waste loss from a pipeline could have contributed to contamination located nearby this tank.

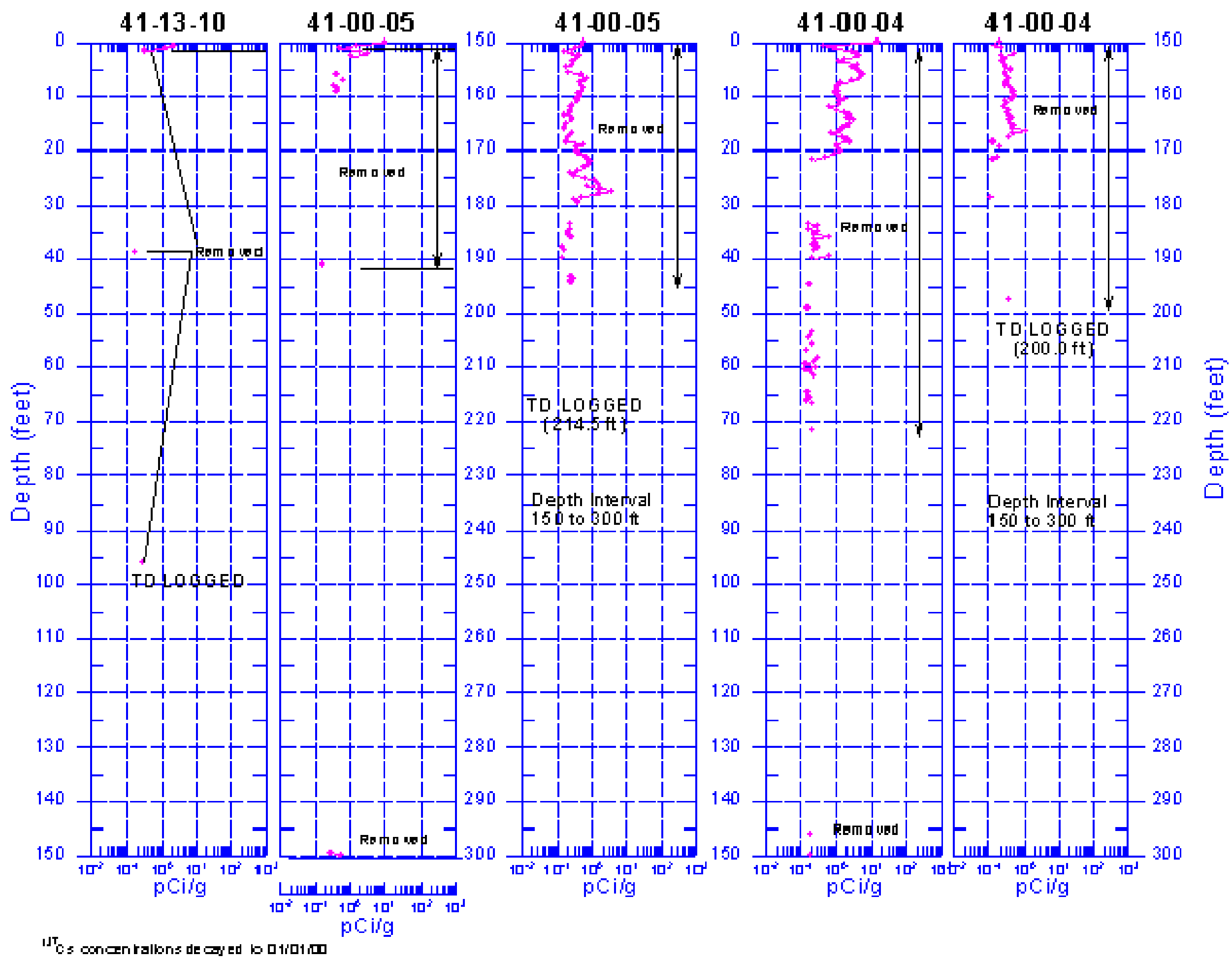
Pipeline L113 originates in the centrally located tank SX-113 pump pit and traverses at a 45-degree angle northeast (2 o'clock position) across the top of the tank, eventually terminating in diversion box 241-SX-152. The one spare inlet nozzle (N-1) for tank SX-113 is located 45-degrees counter-clockwise from pipeline V-592 (nozzle N-2) at the 3 o'clock position and is capped (H-2-39510, *Plan 75 FT. Tanks Waste Disposal Facility 241-SX TKs 101-115* and H-2-39517, *75 FT. Dia. Tank Nozzle Assemblies & Dtls. Waste Disposal Facility 241-SX*, detail 216). Pipeline V-592 is encased in an 8-in. diameter pipe; it is unlikely that waste could have leaked from these encased pipelines. Also, pipeline V-592 was cup and capped in 1970, as shown on drawings H-2-73215 and H-2-35590, *Waste Tank Isolation 241-SX-TK.113*.

A 3-in. steel pipeline with a gate valve attaches to riser R-7 atop tank SX-113 and was used to transfer condensate from tank SX-106 into tank SX-113. Tank SX-106 was used from 1954 through 1966 to collect condensate from the boiling waste tanks in the 241-SX Tank Farm. Condensate could be pumped from tank SX-106 through a buried steel pipeline equipped with gate valves to route condensate to any one of the boiling waste tanks. There is no record of this condensate return pipeline having leaked.

5.8.2.2 Drywell Gamma Logging. There are only two drywells located near tank SX-113: 41-00-05 and 41-13-10. Historical gross gamma logging data in drywells associated with tank SX-113 are reported in SD-WM-TI-356 and HNF-3136. No contamination was detected in these drywells as gross gamma activity was below survey detection limits (SD-WM-TI-356 page 41-13-03).

Drywell 41-00-05, located on the southeast side of tank SX-113, was not logged in 1996 because it was completed with double casings (GJ-HAN-15, *Vadose Zone Monitoring Project at the Hanford Tank Farms, Tank Summary Data Report for Tank SX-113*). The double casings significantly affect logging results because of the attenuating effects of the casings on gamma rays. However, drywells 41-13-10 and 41-00-05 were logged in 1999 and the logging results are presented in Figure 5.8-4 (GJPO-HAN-4 Figure D-23). While there is some ^{137}Cs detected near surface in drywells 41-13-10 and 41-00-05, there is no activity detected at the tank base (~53 ft bgs.). Drywell 41-00-05 does show some ^{137}Cs activity at a depth of 150 to 195 ft, but the concentration is generally less than 1 pCi/g. A much higher concentration of ^{137}Cs (generally $1{\times}10^6$ pCi/g or greater) is generally associated with tank waste leaks.

Figure 5.8-4. Tank 241-SX-113 Drywell Logging Results (1999)



5.8.3 Conclusions

The estimated volume of waste loss during the leak test was ~15,000 gal with composition as of October 1962 reported in Table 5.8-2 (HW-75714 page 4). Based on the waste composition in Table 5.8-2, ~7,800 curies of ^{137}Cs (October 1962) were lost to the soil. Decay correcting to January 1, 2001, the inventory of ^{137}Cs lost to the soil was ~4,100 curies.

Table 5.8-2. Composition of Salt Waste Added to Tank 241-SX-113 (October 1962)

Component	Concentration	Units
$NaNO_3$	4.2	M
$NaNO_2$	0.1	M
NaOH	0.4	M
$NaAlO_2$	0.4	M
Gamma (>99% ^{137}Cs)	0.52	Ci/gal
Plutonium	< 5E-07	g/gal
Uranium	< 2.3E-03	g/gal
Neptunium	< 3E-05	g/gal

5.9 TANK 241-SX-114 WASTE LOSS EVENT

This section provides information on the historical waste loss event associated with SST SX-114. Tank SX-114 has three laterals (horizontal boreholes) installed about 10 ft under the tank and eight drywells surrounding the tank (41-14-02, 41-14-03, 41-14-04, 41-14-06, 41-14-08, 41-14-09, 41-14-11 and 41-11-05) as depicted in Figure 4-1.

5.9.1 Tank 241-SX-114 Waste Operations Summary

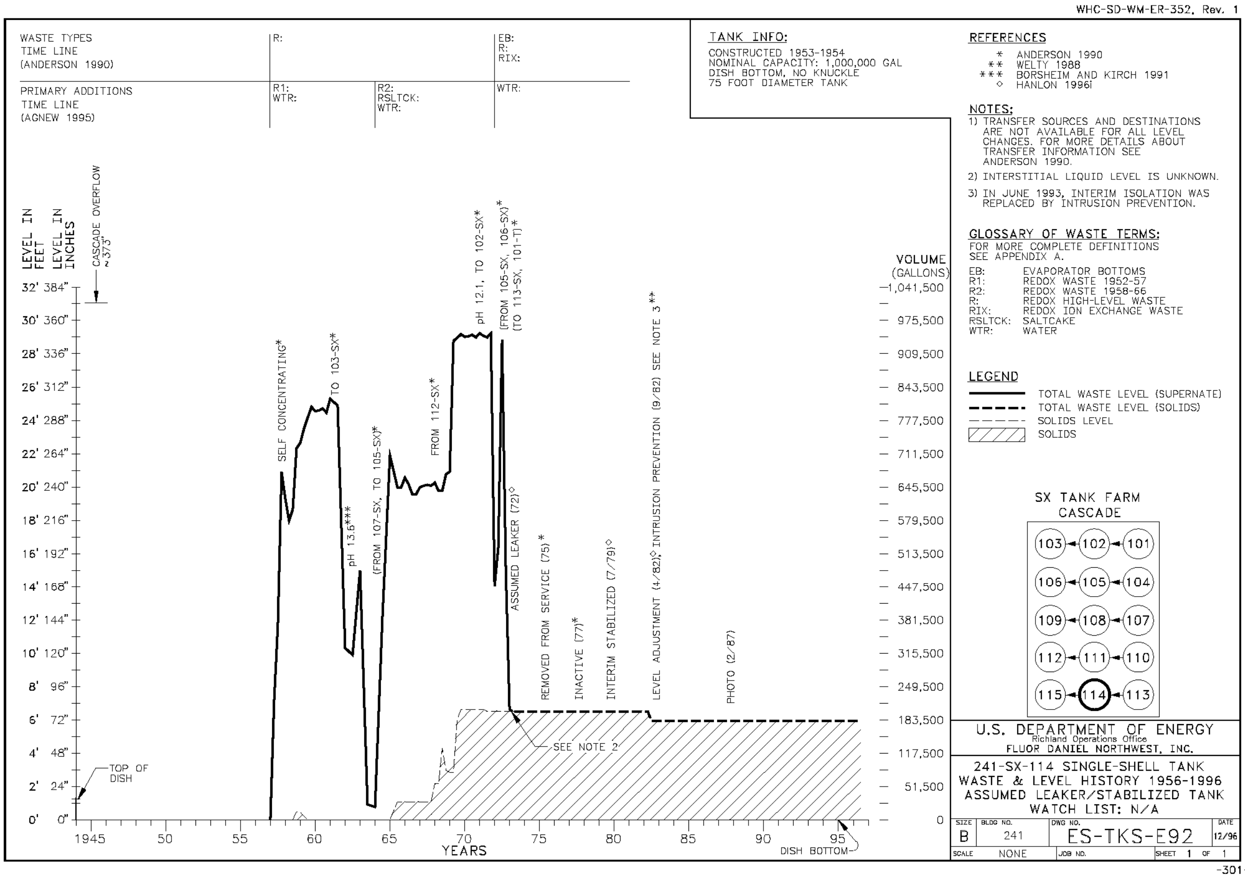
A tank surface-level diagram is shown in Figure 5.9-1 (HNF-SD-WM-ER-352). Sections 5.9.1.1 and 5.9.1.2 provide a brief discussion of the waste operations history for SST SX-114. A more detailed listing of the waste transfer histories is presented in LA-UR-96-3860, *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4* and the Chemical Processing Department Waste Status Summaries referenced in LA-UR-96-3860.

5.9.1.1 Tank 241-SX-114 Waste History

REDOX High-Level Waste Storage (1956 to 1972)
Tank SX-114 was constructed from 1953 to 1954. The tank was not used to receive any waste until the fall of 1956. Tank SX-114 began receiving 202-S REDOX HLW in the fall of 1956. The concentration of radionuclides present in the REDOX HLW received into tank SX-114 was sufficient to promote self boiling of this waste, which was first observed in April 1957.

Condensate from the self-boiling waste tanks in 241-SX Tank Farm was collected in tank SX-106. The condensate was either discharged to a crib or a portion returned to the self-boiling waste tanks in 241-SX Tank Farm to maintain the waste temperature below a maximum operating limit. The airlift circulators were operated in tank SX-114 to provide added waste cooling.

Figure 5.9-1. Tank 241-SX-114 Surface Level History



Periodic transfers of REDOX HLW into tank SX-114 continued to be made through August 1958, as space was made available by self evaporation of the waste. In August 1958, waste additions to the tank were halted due to a pressurization of the tank (WHC-MR-0135, *Radiation Occurrence – Spread of Contamination from a Radiation Zone*). Tank SX-114 contained ~676,000 gal (~21 ft.) of waste in August 1958. Over the next 3 years the tank was operated as a boiling waste tank with frequent additions of water or condensate from tank SX-106 to replace condensate losses.

In July 1961, tank SX-114 contained ~807,000 gal of waste, which corresponds to a waste height of ~24.9 ft (HW-71610 page 8). Approximately 724,000 gal of the aged REDOX HLW supernate were transferred from tank SX-114 to tank SX-103 in August and September 1961, leaving ~83,000 gal of waste in tank SX-114. Approximately 295,400 gal of condensate from tank SX-106 were added to the waste in tank SX-114 from September through December 1961, which continued to boil and evaporate waste.

Approximately 204,500 gal of REDOX nitrate waste[5] were transferred from tank SX-108 into tank SX-114 in July and August 1962. Approximately 57,000 gal of waste were transferred from

[5] Nitrate waste was sodium nitrate leached from REDOX HLW sludge (RL-SEP-243, page 7).

tank 241-SX-114 to tank SX-113 in November 1962 and then 180,000 gal of waste were transferred from tank SX-113 back to tank SX-114 in December 1962. These transfers were conducted as part of an integrity test of tank SX-113. As a result of these transfers, tank SX-114 contained ~480,000 gal (~15.1 ft) of waste as of December 31, 1962.

In January 1963, approximately 219,000 gal of nitrate waste were transferred from tank SX-107 into tank SX-114, resulting in the tank containing ~699,000 gal (~21.75 ft) of waste. During the next three months, a total of 57,100 gal of the nitrate waste in tank SX-114 were transferred to the REDOX Plant for re-use in the fuel cladding dissolution process. The remaining nitrate waste, 619,400 gal, was transferred from tank SX-114 to tank SX-105 in May 1963, leaving approximately 16,000 gal of waste in tank SX-114. No further waste transfers involving tank SX-114 were conducted in 1963.

In April through June 1964, tank SX-114 received 285,300 gal of HLW from the REDOX Plant, 104,000 gal of condensate from tank SX-106, and 33,000 gal of water. The condensate from tank SX-106 was added to tank SX-114 prior to addition of the REDOX HLW to avoid thermal shocking of the tank (HW-80202 page 74). Periodic additions of HLW from the REDOX Plant, condensate from tank SX-106, and water were made to tank SX-114 from July 1964 through 1965, as space became available from self evaporation of waste. No waste was added to tank SX-114 in 1966, although water was periodically added to maintain the tank level at ~650,000 gal (~20.3 ft). No waste or water additions are reported to have been made to tank SX-114 for 1967 through 1968.

In January 1969, tank SX-114 received 248,000 gal of REDOX HLW from tank SX-112, which was determined to be leaking (RPP-RPT-29191 page 45). The waste volume in tank SX-114 was reported as 935,000 gal (~28.9 ft) after this transfer. No waste or water additions are reported to have been made to tank SX-114 for the remainder of 1969 through November 1971, however, the waste volume was reported to have varied from 935,000 gal to 950,000 gal (~29.35 ft), the highest recorded waste volume (height) for this tank. Waste volume fluctuations could be due to thermal expansion of the waste and/or boiling conditions.

In December 1971, 492,000 gal of REDOX HLW were transferred from tank SX-114 to tank SX-102, leaving 249,000 gal of supernate and 200,000 gal of sludge in tank SX-114 (PPD-489-DEL, *Monthly Status and Progress Report December 1971*, page AIV-17 and ARH-2074 D). An additional 171,000 gal of REDOX HLW were transferred from tank SX-114 to tank SX-102 in January 1972 (PPD-493-1-DEL, *Monthly Status and Progress Report January 1972*, page AIV-15, PPD-493-2-DEL, *Monthly Status and Progress Report February 1972*, page AIV-14 and ARH-2456 A, *Chemical Processing Division Waste Status Summary January 1, 1972 Through March 31, 1972*). Tank SX-114 contained approximately 38,000 gal of REDOX HLW supernate and 200,000 gal of sludge following these transfers. The REDOX HLW transferred to tank SX-102 was subsequently transferred to the 221-B Plant for cesium IX processing.

The pipeline used to transfer waste from tank SX-114 to tank SX-102 was L114 from nozzle U-1 in the pump pit atop tank SX-114 to diversion box 241-SX-152 (H-2-35866, *REDOX Supernate Transfer Sys. Hydraulic Flow Diagram* and H-2-73216). This pipeline traverses northeast across the top of tank SX-114 (2 o'clock position) to an area between tanks SX-110, SX-111, SX-113 and SX-114 near drywell 41-14-02. Pipeline L114 does not traverse nearby drywell 41-14-06.

B Plant Cesium Ion Exchange Waste Storage (1972)
Following removal of the REDOX HLW supernate, tank SX-114 was used to receive waste from the cesium IX process (designated as RIX waste) conducted in 221-B Plant. Beginning in the first quarter of CY 1972 (ARH-2456 A), tank SX-114 began receiving RIX waste that was generated from processing REDOX HLW supernate in B Plant. The RIX waste was collected in tank BX-101 and then transferred to tank SX-105. After filling tank SX-105, the RIX waste was then transferred to tank SX-106, which pumped waste to tank SX-114. Tank SX-114 continued to receive RIX waste through April 1972 (PPD-493-4-DEL, *Monthly Status and Progress Report April 1972*, page AIV-18 and ARH-2456 B), by which time tank SX-114 contained 200,000 gal of sludge and 737,000 gal of supernate for a total waste volume of 937,000 gal (~29 ft). Pipeline V-591 connecting to the inlet nozzle N-3 on tank SX-114 is the only known pipeline that could have been used to transfer RIX waste into tank SX-114.

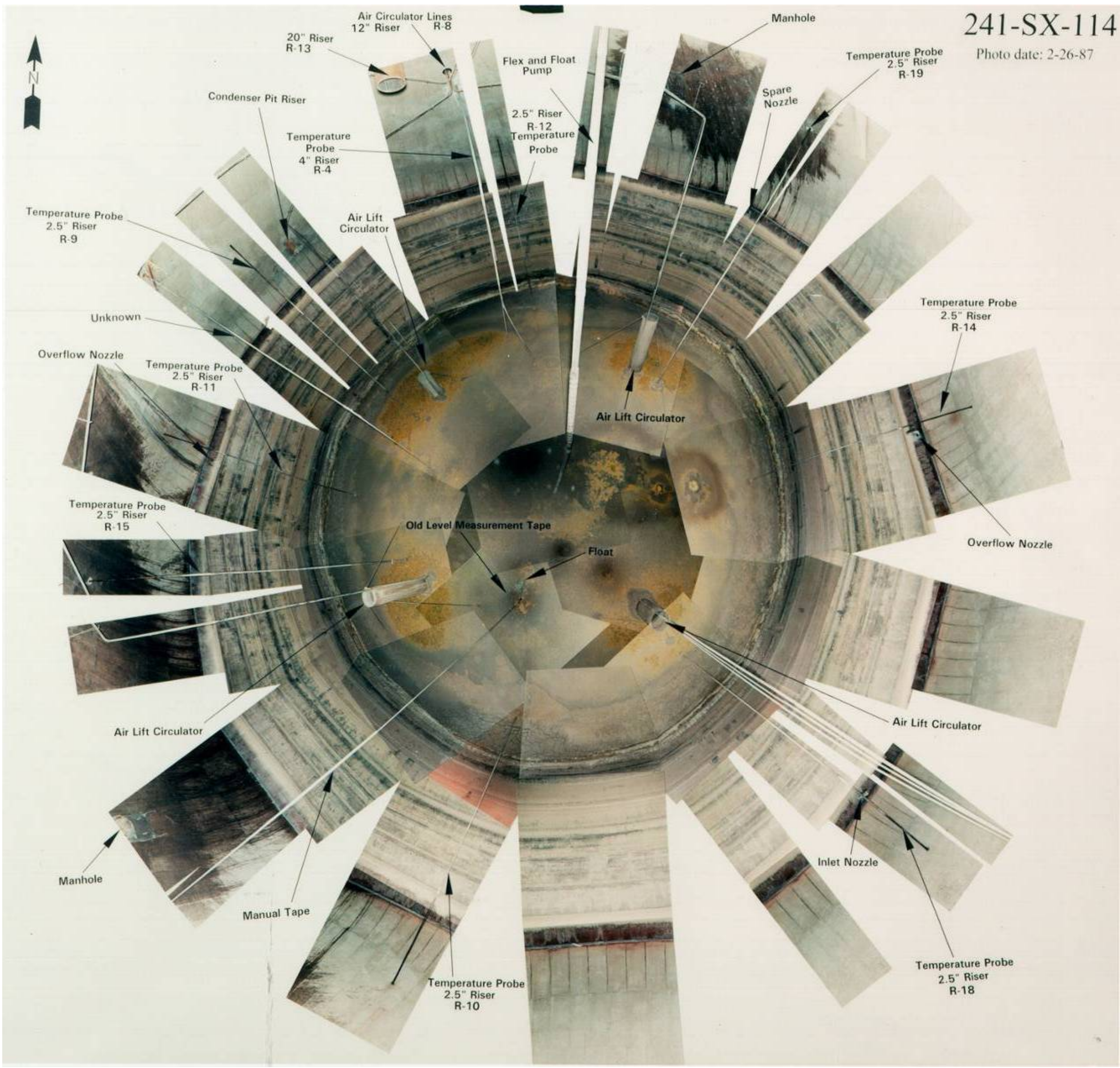
5.9.1.2 Interim Stabilization. Tank SX-114 was connected to a sludge cooler in the 241-SX Tank Farm to remove excess heat and water vapor. In January 1979 a photo of the tank contents was obtained showing no liquid remaining, and the tank was administratively stabilized (HNF-SD-RE-TI-178 page 279). As of January 1, 2008, SST SX-114 is estimated to contain 126,000 gal of sludge and 29,000 gal of saltcake or 155,000 gal total waste, equivalent to a 63.7-in. depth. The surface of the waste in tank SX-114 as of February 1987 is depicted in Figure 5.9-2.

5.9.1.3 241-SX-114 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-114 starts in November 1956, when REDOX waste was first added, and continues through June 1968 (RHO-CD-1172 pages B-75 through B-116). Appendix A provides plots showing the maximum temperature (°F) of the waste stored in tank SX-114 from 1956 through 1968. The temperature plots for tank SX-114 are consistent with the waste history discussed in section 5.9.1.

These temperature plots show a steady rise in tank SX-114 waste temperature from ~120 °F in November 1956 to a peak of ~305 °F in May 1958, as the tank was filled for the first time with REDOX HLW. As addition of REDOX HLW to tank SX-114 continued through August 1958, a temperature excursion to 357 °F occurred (see section 5.9.2.3). The waste temperature was moderated by operations of the airlift circulators and addition of water and/or condensate.

The tank continued to operate as a boiling waste tank through August 1961, as evident by the waste temperature being controlled between ~260 to 320 °F during this period. The waste temperature in tank SX-114 began to decline in October 1961 as the REDOX HLW supernate was removed and condensate was added to the tank, reaching approximately 160 °F in January 1962. The waste temperature remained at ~160 °F until May 1964, when tank SX-114 again received REDOX HLW. Over a period of approximately six months, the temperature of the waste in tank SX-114 steadily rose until reaching ~260 °F in October 1964, indicating the waste was again boiling in this tank. The tank SX-114 waste temperature continued to increase and then was controlled between ~300 to 320 °F from January 1965 through November 1967. In December 1967, the tank SX-114 waste temperature was reduced to ~270 °F and remained at this temperature until the temperature data ceased to be available in June 1968.

Figure 5.9-2. Tank 241-SX-114 Waste Surface (February 1987)



5.9.1.4 Basis for Leak Declaration. Tank SX-114 was classified a potentially leaking tank in 1972 based on gamma activity detected in drywell 41-14-06 (Internal letter LET-081072, "TK-114-SX Leak Status and Recommendations") and the tank was removed from service in 1975. A leak volume was not determined for this tank other than a rough volume estimate based on leak volumes for other tanks (HNF-EP-0182). The maximum gamma activity detected in drywell 41-14-06 was reported as 60,000 cpm (PPD-493-8-DEL, *Monthly Status and Progress*

Report August 1972, page AIV-17). The supernate in tank SX-114 was pumped to tanks 241-T-101 and 241-T-102 in August and September 1972 (PPD-493-8-DEL page AIV-17) leaving a minimum heel of 200,000 gal of solids.

5.9.2 Data Review and Observations

Contamination was observed in only one of the drywells (41-14-06) beginning in August 1972 and at the end of a nearby lateral 44-14-03 about 2 years later. Drywell 41-14-06 is located about 13 ft to the south of SST SX-114 on the south side of 241-SX Tank Farm, as depicted in Figure 4-2. No other tanks are adjacent drywell 41-14-06. Given the location of this drywell and the lack of similar contamination in drywells 41-14-04 and 41-14-08, tank SX-114, ancillary equipment or piping appear to be the only possible contamination sources.

5.9.2.1 Pipelines and Spare Inlet Nozzle. There are no known leaks associated with pipelines in the vicinity of tank SX-114 (7G410-MEJ-07-004 – Memorandum). Therefore, it is unlikely that a waste loss from a pipeline could have contributed to the gamma activity detected in drywell 41-14-06 in August 1972.

Two 3 1/2-in. pipelines (V-590 and V-591) that traverse nearby drywell 41-14-06 are the fill lines to tanks SX-115 and SX-114, respectively. Pipelines V-590 and V-591 are each encased in an 8-in. diameter pipe; it is unlikely that waste could have leaked from these encased pipelines.

Pipeline L114 originates in the centrally located tank SX-114 pump pit and traverses northeast (2 o'clock position) across the top of the tank, eventually terminating in diversion box 241-SX-152. This pipeline was used to remove the REDOX HLW supernate from tank SX-114. Pipeline L114 is not in the vicinity of drywell 41-14-06 and is an unlikely candidate to have contributed to the gamma activity detected in this drywell.

The one spare inlet nozzle (N-4) for tank SX-114 is located 90-degrees counter-clockwise from pipeline V-591 (nozzle N-3) at the 2 o'clock position and is capped (H-2-39510 and H-2-39517 detail 216). This spare inlet nozzle also is an unlikely source of the contamination detected in drywell 41-14-06.

A 3-in. steel pipeline with a gate valve attaches to riser R-7 atop tank SX-114 and was used to transfer condensate from tank SX-106 into tank SX-114. Tank SX-106 was used from 1954 through 1966 to collect condensate from the boiling waste tanks in the 241-SX Tank Farm. Condensate could be pumped from tank SX-106 through a buried steel pipeline equipped with gate valves to route condensate to any one of the boiling waste tanks. The main valve box for routing condensate to the 241-SX boiling waste tanks is located atop tank SX-112, with individual valves located atop each of the tanks. An estimated 25,000-gal leak of condensate, containing an estimated 80 to 100 Ci of ^{137}Cs, was reported to have occurred in the valve box atop tank SX-112 in November 1959 (RPP-RPT-29191 page 153). This demonstrates the condensate pipeline and valves were prone to failure. However, condensate was last added to tank SX-114 in 1965. It is unlikely a condensate leak atop tank SX-114 could have contributed to the gamma activity detected in drywell 41-14-06 in August 1972.

5.9.2.2 Evaporation from Vapor Header. The buried 24-in. vapor header atop tank SX-114 contained condensate as well as non-condensable vapors. This vapor header was welded, but included a butterfly valve to regulate airflow. The centerline of the butterfly valve is located ~4 ft below ground atop tank SX-114, at about the 8 o'clock position (H-2-39901, *Tanks 107-115 Manifold Facilities General Layout* and H-2-39909, *Tanks 107-115 Manifold Facilities Vapor Manifold Support Details*, detail 11).

Approximately 2.1 million gal of waste were reported to have been evaporated from tank SX-114 from 1956 through 1966, which does not include water that was added to the tank and subsequently evaporated (ISO-674 page 2). A small leak from this vapor header could possibly have gone unnoticed by tank farms personnel, since a material balance was difficult to perform for the boiling waste tanks.

5.9.2.3 Tank Structure. Tank SX-114 experienced a pressurization event in August 1958, which resulted in a maximum reported pressure of 71 in. of water (~2.6 psi) and steam escaping from two risers on tank SX-113 (WHC-MR-0135). The tank contained ~676,000 gal (~21 ft) of REDOX HLW at 357 °F when this pressurization occurred. While measures were taken at the time to reduce the tank temperature and pressure, damage to the concrete tank shell may have resulted. Structural failure of the concrete tank wall approximately 18 ft from the bottom is reported to occur if the pressure inside the tank exceeds 140 in. of water (5.2 psi) when the tank is full (Internal letter LET-121654, "Allowable Pressures and Vacuums in PUREX and 241-SX Tank Farms"). Complete failure of the concrete tank wall in August 1958 is unlikely to have occurred given that the tank pressure was only 50% of the maximum allowable, but cracks may have occurred in the concrete wall. Furthermore, the thermal coefficient of expansion for the carbon steel liner and concrete tank shell are different. Temperature excursions in the waste could lead to crushing and cracking of the concrete tank shell. This could result in a leak pathway out of the tank.

A caisson was sunk to the base of tank SX-108 in 1968 to expose the lower sidewall of the concrete shell, top of the footing, and the edge of the footing down to the footing bottom. Cracking of the concrete was encountered extending downward through the footing and some distance up the concrete shell sidewall (RPP-10435 page A-72). The cracking of the concrete shell and footing for tank SX-108 indicates that similar cracking is possible for tank SX-114.

Tank SX-114 was filled to 937,000 gal (~29 ft) with RIX waste from B Plant from February through April 1972. The gamma activity in drywell 41-14-06 was first detected in August 1972, shortly after tank SX-114 was filled with this waste. The gamma activity observed in drywell 41-14-06 is believed to be associated with the RIX waste and may be due to leakage from the tank structure. The RIX waste is known to have contained ^{106}Ru and ^{137}Cs.

5.9.2.4 Drywell Gamma Logging. On August 10, 1972, a radiation peak at 38 ft bgs (~16 ft above tank bottom) was detected using a scintillation probe in drywell 41-14-06. The actual radiation reading measured by the scintillation probe was not reported in the reference. Drywell 41-14-06 had been installed in 1962. No records were located that indicated radioactivity had been previously detected in this drywell. Tank SX-114 was postulated to have developed a leak above the 16 ft waste height (i.e., 508,600 gal). In an effort to prevent further waste loss, the waste level in tank SX-114 was lowered to ~15.1 ft above tank bottom (i.e., 480,000 gal) in August and September 1972 (PPD-493-8-DEL, page AIV-17 and PPD-493-9-DEL, *Monthly Status and Progress Report September 1972*, page AIV-17).

On August 21, 1972 a second radiation peak was detected using a scintillation probe in drywell 41-14-06 at ~51 ft bgs, about 3 ft above the tank bottom (Internal letter LET-082172, "TK-114-SX Leak Status and Recommendations"). The radiation peak observed in drywell 41-14-06 at ~51 ft bgs continued to increase through August 31, 1972 but did not reach the same activity level as the radiation peak 38 ft bgs (Internal letter LET-083172, "TK-114-SX Leak Status and Recommendations"). Again, the actual radiation readings measured by the scintillation probe were not reported in the references. All remaining supernate was transferred from tank SX-114 to tanks 241-T-101 and 241-T-102, lowering the waste height to that of the sludge (~6.8 ft. above tank bottom or 204,000 gal) in the fourth quarter of CY 1972.

Radioactivity was also subsequently detected in October 1972 in drywell 41-14-04 (installed in 1956) and in September 1973 in drywell 41-14-09 (installed in 1962). Gamma logging data prior to these dates is not reported in SD-WM-TI-356. The radiation peaks detected in drywells 41-04-04 and 41-14-09 were 3,250 cps detected at 57 ft bgs and 580 cps at 60 ft bgs (SD-WM-TI-356 pages 41-14-05 and 41-04-06) and have declined to background levels. The gamma activity detected in the other drywells around tank SX-114 – 41-04-02, 41-04-03, 41-04-08 and 41-04-11 – is less than the detection limit (200 cps) for the scintillation monitoring probe.

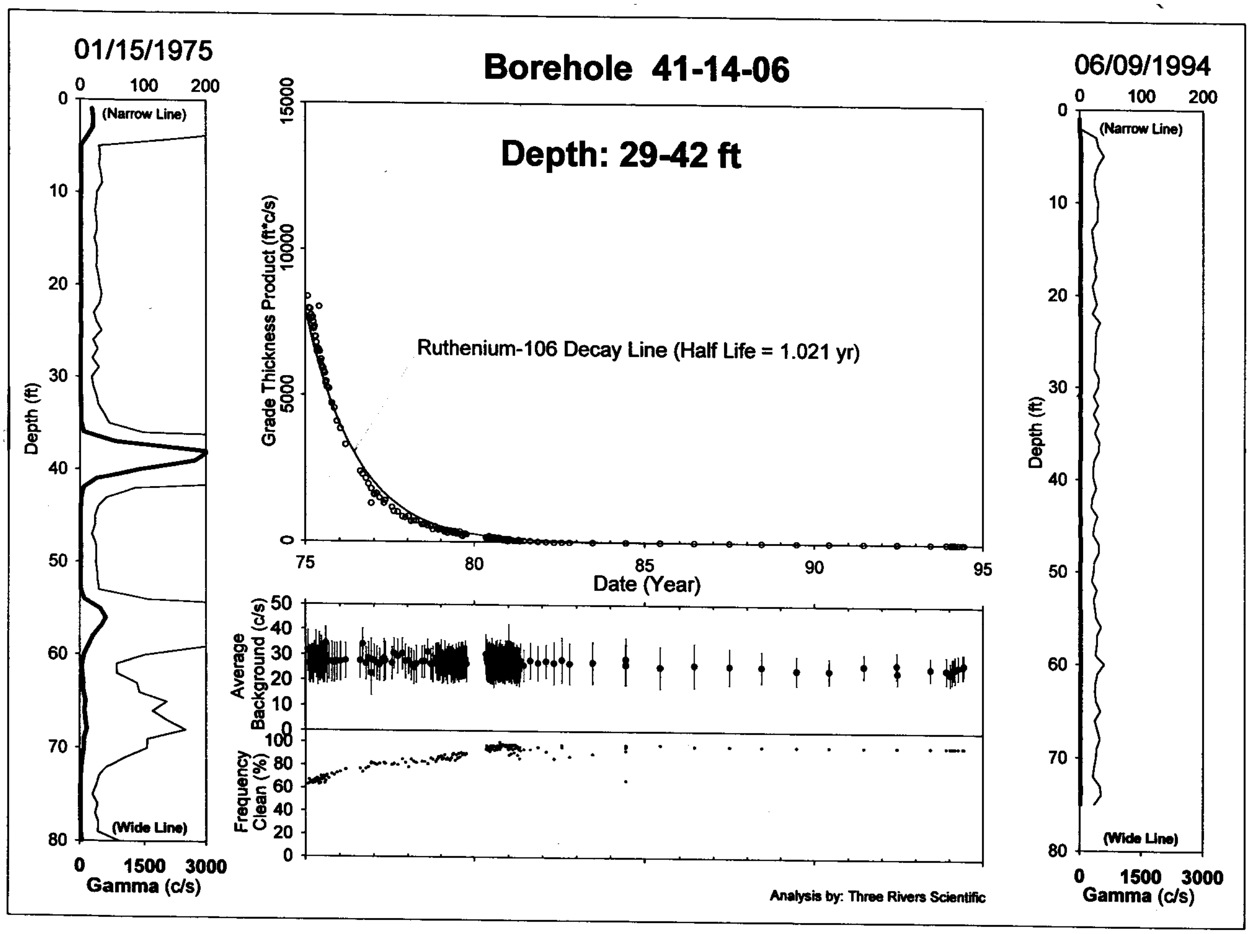
A summary of the historical gamma logging data from 1975 through 1994 for drywell 41-14-06 is provided in Figures 5.9-3, 5.9-4 and 5.9-5 (HNF-3136, pages B-329 to B-331). Note that the timeline in Figure 5.9-5 starts with the earliest date at beginning of the X-axis and the later date/information at the end. The historical gamma logging data shown in Figure 5.9-3 indicates the activity detected at 29 to 42 ft bgs in drywell 41-14-06 was consistent with the radioactive decay rate for ^{106}Ru. Activity detected at the 46 to 73 ft bgs in drywell 41-14-06, as shown in Figure 5.9-4, was less than activity detected at 29 to 42 ft bgs and also followed the radioactive decay rate for ^{106}Ru. As is apparent from Figure 5.9-5, the gamma activity detected in drywell 41-14-06 has decreased significantly from 1975 through 1995.

A gamma log of drywell 41-14-06 taken in July 1995 is provided in Figure 5.9-6. ^{137}Cs was detected at the ground surface and throughout the borehole at concentrations less than 1 pCi/g. ^{60}Co is encountered at 35 ft and from 60 ft to total depth at 76 ft. The maximum concentration is 0.53 pCi/g at 35 ft.

Between 1978 and 1999, tank surveillance data indicate a steady 1/3 in./yr surface-level drawdown that is typical of tank evaporation. These data do not indicate an active tank leak during this time period. Surface-level drawdown plots before 1978 were not located.

In February 1964, gamma activity was first reported in lateral 44-14-03: "No changes noted except for a 550 c/s reading detected in the South lateral under the 114-SX Tank. Daily checking revealed no change at the end of the month" (*Monthly Report Waste Handling and Decontamination Operation REDOX Operation February 1964*, Rough Draft [Harmon 1964b] page 2). At the time activity was detected in lateral 44-14-03, tank SX-114 contained a small waste heel of 16,000 gal (see section 5.9.1.1). No further information was located on activity detected in this lateral until 1974.

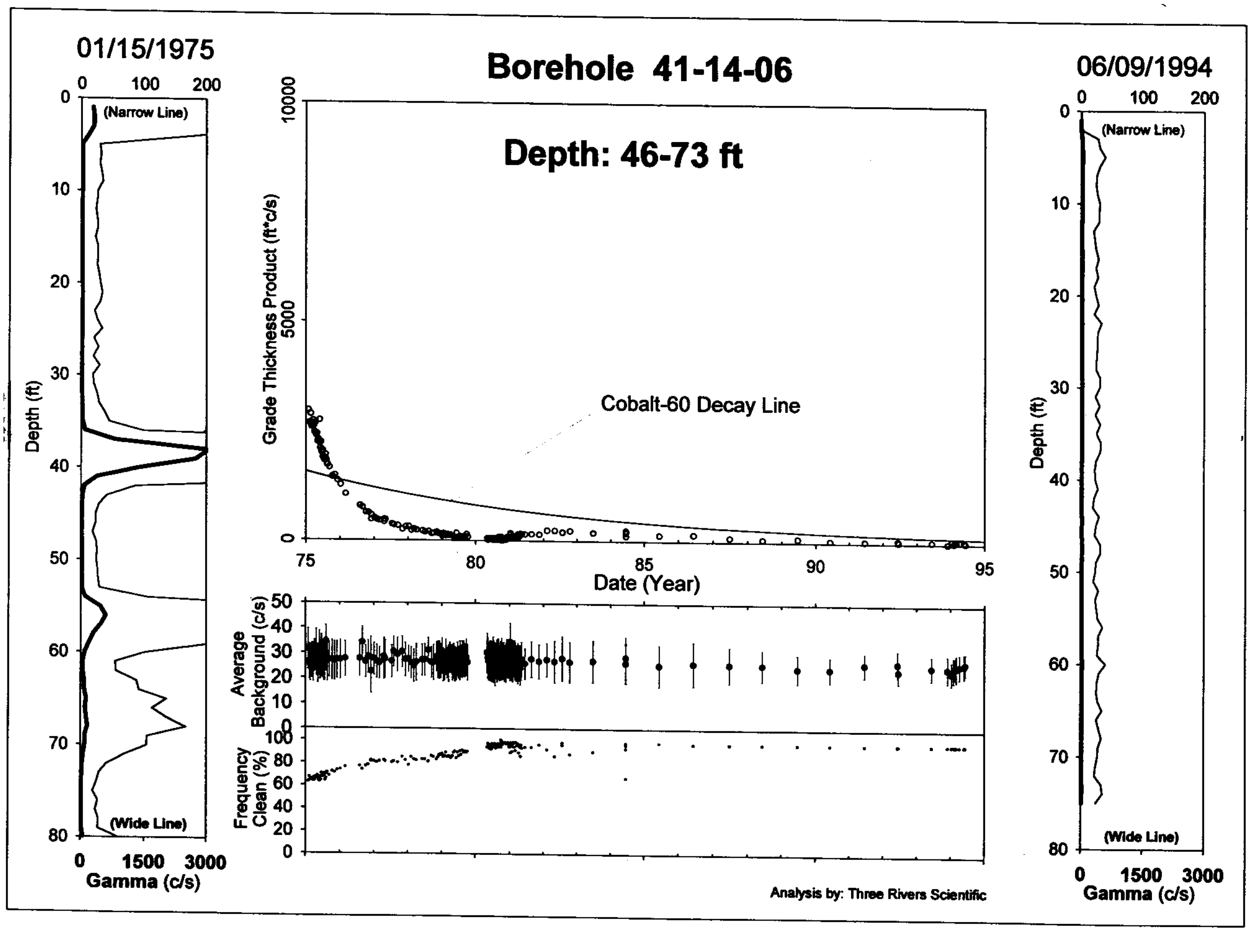
Figure 5.9-3. Drywell 41-14-06 Gamma Activity at 29 to 42 below Ground Surface



From 1974 to 1980, gamma activity was observed at the end of lateral 44-14-03 (SD-WM-TI-356 page 41-14-09). The gamma activity detected at the end of lateral 44-14-03 was a maximum of 19 cps on October 11, 1974 as measured using the green Geiger-Muller probe (GM) no. 1. This activity was not detected between 1973 and 1974, or between 1980 and 1987. No anomalous gamma activity was observed in the other laterals (44-14-01 and 44-14-02). The activity reported in lateral 44-14-03 occurs at the end of the lateral in the general vicinity of drywell 41-14-06 (GJ-HAN-16, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank SX-114*).

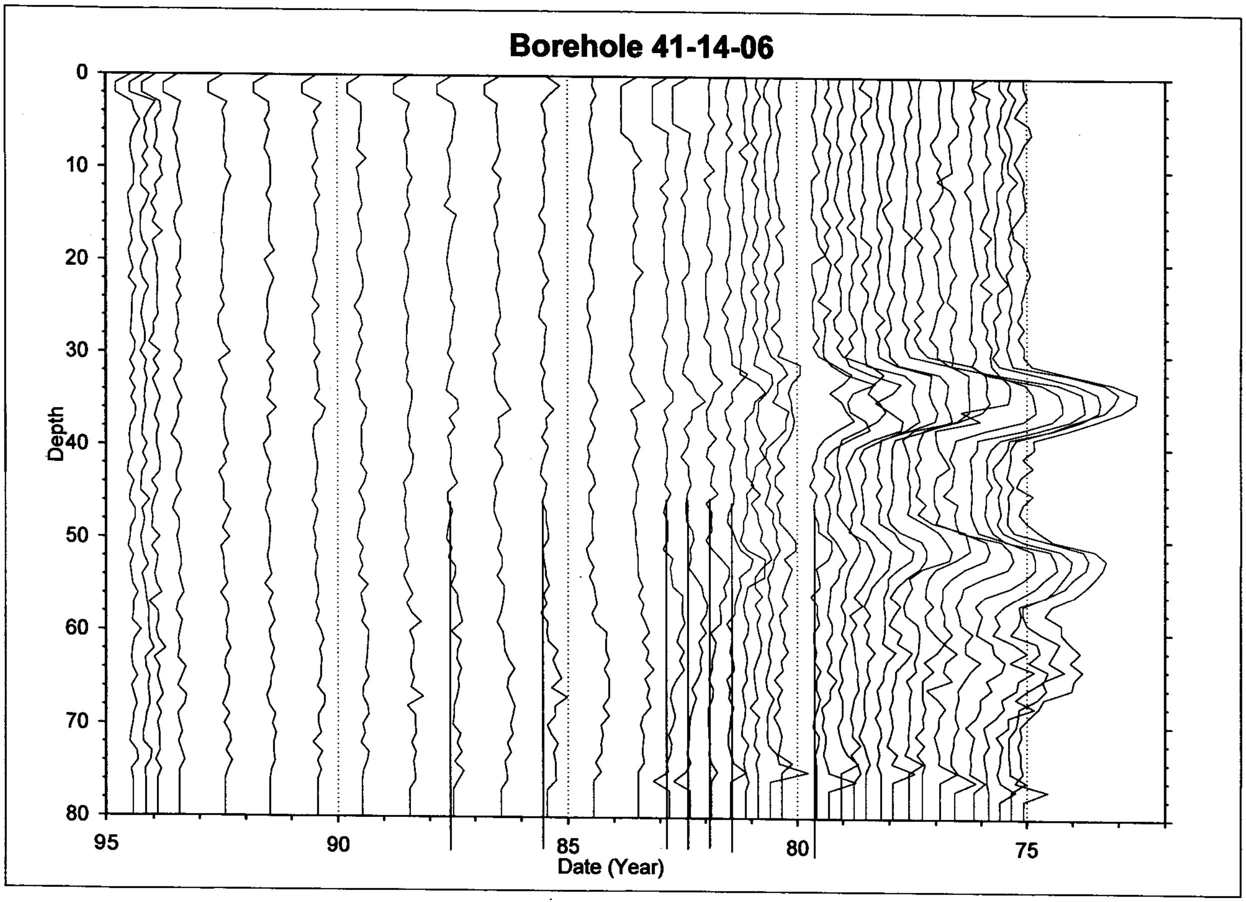
In mid-1981, a slight increase in gamma activity detected in drywell 41-14-06 occurred at 51 ft bgs. However, a separate tank leak or contamination source at the base of SX-114 (51 ft bgs) is not supported by the data because SST SX-114 contained little, if any, free liquid at that time. It is much more likely that the short-lived contamination observed at 51 ft was from the same source as that observed at 38 ft bgs. The lack of cesium at 38 ft bgs suggests that the actual source is some distance from drywell 41-14-06, and may be above the 38-ft level. Gamma activity observed in drywell 41-14-06 at 51 ft bgs probably represents contamination that accumulated at the base of the backfill in the tank farm excavation. The surface of the excavation would have been compacted to some degree by vehicles and heavy equipment during tank construction, and may act as a retarding layer for downward migration. The slight increase of contamination detected in drywell 41-14-06 at 51 ft bgs observed in 1981 is most likely the result of water infiltration and increased soil moisture causing migration of contamination from some other location toward drywell 41-14-06.

Figure 5.9-4. Drywell 41-14-06 Gamma Activity at 46 to 73 ft below Ground Surface



Contamination was first detected in 1972 in drywell 41-14-06 at approximately 29 to 42 ft bgs, with peak activity detected at 38 ft bgs. The height of waste in tank SX-114 corresponding to 38 ft bgs is 16 ft. Gravity and surface water would cause migration of contamination down through the soil column. Therefore, the contamination source detected in drywell 41-14-06 appears to have originated above the 16-ft level of waste in the tank (less than 38 ft bgs). Secondary gamma activity observed at the base of the tank (i.e., ~51 ft bgs) is most likely associated with surface water transporting radioactivity down through the soil column resulting in accumulation of soil moisture at the base of the tank farm excavation. Although it cannot be entirely ruled out, development of a second leak at 51 ft bgs within the same time frame as a leak at the higher elevation is considered unlikely. Ancillary equipment and pipelines in the vicinity of tank SX-114 do not appear to be the source of contamination detected in drywell 41-14-06.

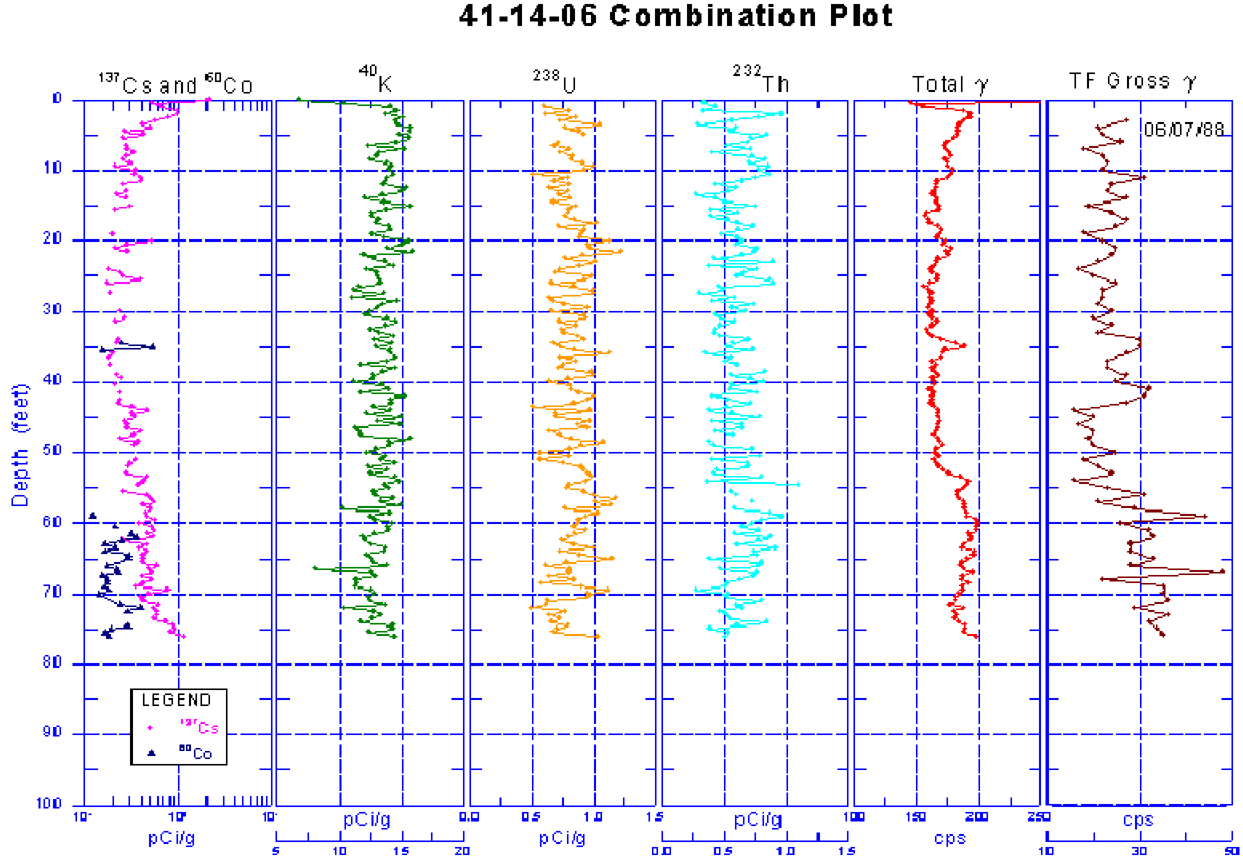
Figure 5.9-5. Drywell 41-14-06 Gamma Logging History



5.9.2.5 Tank 241-SX-114 Waste Loss Estimate. Since there was no measured liquid level decrease in tank SX-114 associated with the leak detection event (i.e., gamma activity detected in drywell 41-14-06), an estimate of the waste volume leaked from tank SX-114 cannot accurately be made. Based on the accuracy of the liquid level measurement system (see Appendix C), up to 2,000 gal of RIX waste could have leaked from the tank without being detected.

Tanks SX-110 and SX-111 also contained RIX waste from 1972 to 1974. As with tank SX-114, both tanks SX-110 and SX-111 also contained a heel of REDOX HLW sludge and supernate along with the RIX waste, albeit varying quantities of each waste type. The supernate wastes in tank SX-110 (MEM-010274 – Memo page 15) and SX-111 (MEM-010274 – Memo page 60) were sampled in 1974 in preparation for processing in the 242-S Evaporator and the results are presented in Table 5.9-1. The tank SX-110 and SX-111 supernate analyses provide an estimate of the range for the composition of the supernate in SX-114 at the time the RIX waste leak occurred.

Figure 5.9-6. Drywell 41-14-06 Gamma Log (July 1995)



In an attempt to better quantify the estimated volume of waste leaked from tank SX-114 in August 1972, a conceptual leak model was developed using the gamma activity detected in adjacent drywells. The gamma activity detected in adjacent drywells was reviewed by R. McCain, Stoller and Associates (e-mail from R. G. McCain to J. G. Field, "Conversion of Total Gamma Counts to equivalent Ru," [McCain, R.G., 2008-05-08]) and converted to an equivalent ^{106}Ru (e^{106}Ru) concentration in the soil. A conceptual model was then postulated for waste leakage into the soil from tank SX-114 to the drywell. This conceptual model was used to calculate the mass of soil contacted by the leaked waste, the inventory of ^{106}Ru present in the soil, and the volume of waste leaked. The calculations estimated that the measured gamma activity is roughly equivalent to 43 gal of waste leaked from tank SX-114.

It does not seem plausible that a leak of ~43 gal of RIX waste from tank SX-114 could have been detected in drywell 41-14-06. The conceptual model for estimating the volume of waste leaked from tank SX-114 using the e^{106}Ru concentration detected in drywell 41-14-06 seems at best to be a qualitative indication of a small unquantifiable leak volume. Calculations and assumptions are presented below.

<u>Gross Gamma Activity Related to e^{106}Ru</u>: For tank SX-114, the primary indications of contamination occur in drywell 41-14-06. Historical gross gamma scans (or logs) were collected with the scintillator (probe 4). Mr. McCain converted the gross gamma data files into an

MS Excel®[6] workbook. The gross gamma logs show three intervals of activity: 32 to 38 ft, 50 to 56 ft, and 59 to 67 ft. In the 32- to 38-ft interval, gamma activity is high with the first log in January 22, 1975 (3,331 cps) and falls off rapidly. Between 1975 and 1977, the rate of decay appears to be somewhat faster than the ^{106}Ru decay curve, suggesting that even shorter-lived radionuclides may be contributing to the observed activity or ^{106}Ru is being depleted in that depth interval because of its mobility. From 1977 to about 1980, the decay seems to follow ^{106}Ru (1.0238-yr half-life). From 1980 to about 1984, decay is more consistent with ^{60}Co (5.27-yr half-life). From 1984 to 1994, the decay rate is more consistent with ^{137}Cs (30.07-yr half-life). The gamma log in 1995 found low levels on ^{60}Co in this interval and intermittent ^{137}Cs over much of the borehole, as shown in Figure 5.9-6. The 41-14-06 drywell gross gamma activity detected at intervals 50 to 56 ft and 59 to 67 ft both follow the ^{106}Ru decay curve for 1975 to 1978. The maximum gross gamma activities detected in drywell 41-14-06 during the January 22, 1975 gross gamma scans were 594 cps and 146 cps.

Table 5.9-1. Tanks 241-SX-110 and 241-SX-111 Supernate Analyses

	SX-110 January 30, 1974	**SX-111 September 16, 1974**
pH	11.55	> 13.2
Sp.Gr.	1.42	1.48
Al	0.944 M	0.805 M
Na	8.72 M	8.05 M
OH	1.28 M	1.47 M
SO_4	2.09E-02 M	6.01E-02
NO_3	5.20 M	4.72 M
NO_2	0.501 M	0.836 M
F	2.38E-2 M	1.40E-02
CO_3	0.102 M	0.168 M
PO_4	1.89E-02 M	5.74E-03 M
Pu	3.34E-06 g/L	< 3.91E-06 g/L
^{137}Cs	0.66E+06 µCi/gal 1.74E+05 µCi/L	1.2E+06 µCi/gal 3.17E+05 µCi/L
^{134}Cs	4.7E+03 µCi/gal 1.24E+03 µCi/L	5.83E+03 µCi/gal 1.54E+03 µCi/L
$^{89/90}$Sr	Not requested	1.33E+02 µCi/gal

The maximum gross gamma activities detected in drywell 41-14-06 on January 22, 1975 at depth intervals of 39 to 49 ft and 57 to 58 ft were 58 cps and 85 cps, respectively. It is interesting that the gross gamma activity detected in drywell 41-14-06 on January 22, 1975 does not decline

[6] Excel® is a registered trademark of Microsoft Corporation, Redmond, Washington.

uniformly with depth; there does not seem to be an explanation for this phenomenon. There is a general downward migration of gamma activity from the 32- to 38-ft interval, as evident from the increase in gamma activity detected at lower elevations in drywell 41-14-06. There appears to be an increase in gamma activity measured in intervals 50 to 56 ft and 59 to 67 ft, beginning in mid-1980.

Calculations were performed by Mr. McCain to estimate the gamma dose rate at the borehole axis for a uniform distribution of ^{106}Ru. Using the decay gammas for the ^{106}Ru - ^{106}Rh - ^{106}Pd decay series and assuming a 6-in. diameter borehole with schedule-40 steel casing (0.28-in. wall thickness), the gamma dose rate is estimated to be about 1.92×10^{-4} mR/h for a uniformly distributed ^{106}Ru concentration of 1 pCi/g. From these estimates, the "conversion" from probe 4 cps to "equivalent ^{106}Ru" is estimated to be about (2.89×10^{-4} mR/h per cps) / (1.92×10^{-4} mR/h per pCi/g) or about 1.5 pCi/g e^{106}Ru per cps for probe 4.

If the gross gamma activity measured in drywell 41-14-06 on January 22, 1975 is assumed to be attributable to ^{106}Ru, an estimate can be made of the ^{106}Ru in the soil.

<u>Assumptions</u>:

1. Gross gamma activity measured in drywell 41-14-06 on January 22, 1975 is assumed to be attributable to ^{106}Ru.

2. Drywell 41-14-06 is located approximately 10 ft from tank SX-114.

3. The e^{106}Ru is assumed to have spread uniformly in all directions. A cylindrical area can be used to describe the area of soil, with the cylinder height matching the intervals in which gross gamma activity was detected in drywell 4-14-06 and the radius equivalent to the distance the drywell is away from tank SX-114.

4. Soil density is 1.7 g/cm^3.

5. No sample analyses were found for the RIX waste stored in tank SX-114 at the time the leak was detected in August 1972. Furthermore, the only ^{106}Ru analyses found for any of the REDOX HLW stored in the 241-SX tanks was for tank SX-108, where the ^{106}Ru concentration was reported as 12.5 Ci/gal as of December 15, 1965 (BNWL-CC-701 page 10). It is assumed that the tank SX-108 ^{106}Ru concentration is representative of other REDOX HLW stored in 241-SX tanks. The waste stored in tank SX-108 was REDOX HLW and not RIX waste. The sodium molarity in the REDOX HLW was reduced approximately in half for transfer to the 221-B Plant IX process. The ^{106}Ru concentration of the diluted REDOX HLW is assumed to not be reduced when processed through 221-B Plant. Therefore, it is assumed the ^{106}Ru concentration in RIX waste was ~6.25 Ci/gal as of December 15, 1965 or ~1.34×10^{-2} Ci/gal as of January 22, 1975.

Inputs:

1. Maximum gross gamma activity detected in drywell 41-14-06 on January 22, 1975:

   32 to 38 ft: Maximum 3,331 cps
   39 to 49 ft: Maximum 58 cps
   50 to 56 ft: Maximum 594 cps
   57 to 58 ft: Maximum 85 cps
   59 to 67 ft: Maximum 194 cps

Calculations:

1. Multiplying each of these maximum gross gamma activities by the $e^{106}Ru$ conversion factor developed by Mr. McCain (1.5 pCi/g $e^{106}Ru$ per cps) yields the following estimated $e^{106}Ru$ concentration for drywell 41-14-06:

   32 to 38 ft: Maximum 3,331 cps * 1.5 pCi/g $e^{106}Ru$ per cps ≈ 5,000 pCi/g
   39 to 49 ft: Maximum 58 cps * 1.5 pCi/g $e^{106}Ru$ per cps ≈ 90 pCi/g
   50 to 56 ft: Maximum 594 cps * 1.5 pCi/g $e^{106}Ru$ per cps ≈ 890 pCi/g
   57 to 58 ft: Maximum 85 cps * 1.5 pCi/g $e^{106}Ru$ per cps ≈ 130 pCi/g
   59 to 67 ft: Maximum 194 cps * 1.5 pCi/g $e^{106}Ru$ per cps ≈ 290 pCi/g

2. The mass of soil in each interval is as follows:

   Mass = $\pi * h * (r)^2 * 28{,}317\ cm^3/ft^3 * 1.7\ g/cm^3$

   Mass 32 to 38 ft = $\pi * 6 * (10)^2 * 28{,}317\ cm^3/ft^3 * 1.7\ g/cm^3$
   = 9.07E+07 g

   Mass 39 to 49 ft = $\pi * 10 * (10)^2 * 28{,}317\ cm^3/ft^3 * 1.7\ g/cm^3$
   = 1.51E+08 g

   Mass 50 to 56 ft = $\pi * 6 * (10)^2 * 28{,}317\ cm^3/ft^3 * 1.7\ g/cm^3$
   = 9.07E+07 g

   Mass 57 to 58 ft = $\pi * 1 * (10)^3 * 28{,}317\ cm^3/ft^3 * 1.7\ g/cm^3$
   = 1.51E+07 g

   Mass 59 to 67 ft = $\pi * 8 * (10)^3 * 28{,}317\ cm^3/ft^3 * 1.7\ g/cm^3$
   = 1.21E+08 g

3. The inventory of $e^{106}Ru$ in each interval is calculated by multiplying the results of (1) by (2):

   $e^{106}Ru$ Ci = Mass (grams) * $e^{106}Ru$ (pCi/g) * (1 Ci/1E+12 pCi)

e^{106}Ru Ci at 32 to 38 ft = 9.07E+07 g * 5,000 pCi/g * (1 Ci/1E+12 pCi)
= 0.45 Ci

e^{106}Ru Ci at 39 to 49 ft = 1.51E+08 g * 90 pCi/g * (1 Ci/1E+12 pCi)
= 0.014 Ci

e^{106}Ru Ci at 50 to 56 ft = 9.07E+07 g * 890 pCi/g * (1 Ci/1E+12 pCi)
= 0.081 Ci

e^{106}Ru Ci at 57 to 58 ft = 1.51E+07 g * 130 pCi/g * (1 Ci/1E+12 pCi)
= 0.002 Ci

e^{106}Ru Ci at 59 to 67 ft = 1.21E+08 g * 290 pCi/g * (1 Ci/1E+12 pCi)
= 0.035 Ci

4. The total e^{106}Ru inventory (as of January 22, 1975) estimated for the soil surrounding drywell 41-14-06 is the summation of the inventories calculated for each interval in (3); ≈ 0.58 Ci.

5. The estimated volume of waste leaked from tank SX-114 is:

   Estimated Volume of Leak = total e^{106}Ru Ci / 1.34E-02 Ci ^{106}Ru / gal
   = 0.58 Ci / 1.34E-02 Ci/gal
   ≈ 43 gal

5.9.3 Conclusions

The evaluation confirmed the designation of SX-114 as a leaking tank. No leak volume or inventory estimate for SX-114 was previously included in SIM. Because a liquid level decrease was not observed the leak is less than 2,000 gal. A rough calculation assuming that gamma detected in the drywells was ^{106}Ru indicated that the leak may have been much smaller, but the calculation provided only a "ball park" estimate. No samples of SX-114 waste were available. Because the waste types received by SX-114 were the same, it is assumed that the ^{137}Cs composition of the SX-114 tank leak was the same as the 1974 SX-111 sample. Multiplying by 2,000 gal the estimated ^{137}Cs inventory is less than 1,310 Ci. The inventory estimate for other analytes is the same as the SX-111 inventory for a selected analyte multiplied by a volume ratio of 2,000 over 2,800 (0.71).

5.10 TANK 241-SX-115 WASTE LOSS EVENT

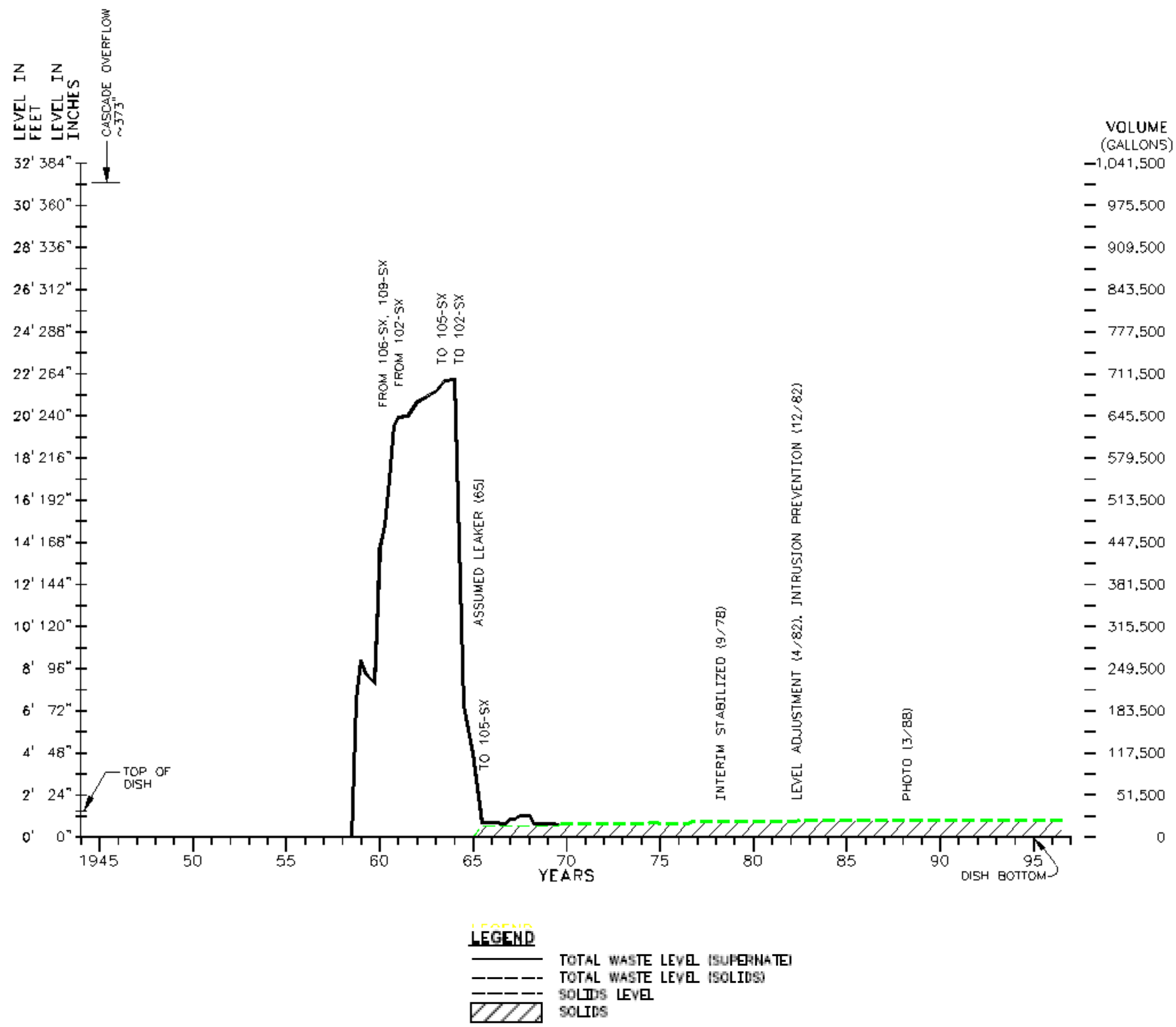
This section provides information on the historical waste loss event associated with SST SX-115. The information presented in this section is consistent with the information presented in WHC-MR-0302, *Tank 241-SX-115 Leak Assessment*.

5.10.1 Tank 241-SX-115 Waste Operations Summary

Tank SX-115 has three laterals (horizontal boreholes) installed about 10 ft under the tank in 1962 and seven drywells (41-15-02, 41-15-03, 41-15-05, 41-15-07, 41-15-09, 41-15-10 and 41-12-04) surrounding the tank, as depicted in Figure 4-1.

5.10.1.1 Tank 241-SX-115 Waste History. A tank surface-level diagram showing waste transfer history is shown in Figure 5.10-1 (HNF-SD-WM-ER-352).

Figure 5.10-1. Tank 241-SX-115 Surface Level History



REDOX High-Level Waste Storage (1958 to 1964)

Tank SX-115 was not used to receive any waste until August 1958 (HW-57550, *Chemical Processing Department Waste Status Summary August 1, 1958 – August 31, 1958*, page 8 and HW-83906-C-RD, *Chemical Processing Department 200 West Area Tank Farm Inventory and*

Waste Reports January 1957 Through December 1958, page 174). Waste transfer history for tank SX-115 is summarized in Table 5.10-1.

Table 5.10-1. Tank 241-SX-115 Waste Storage Summary (5 sheets)

Date	Total Waste Volume (Kgal)	Sludge Temperature (°F)[a]	Liquid Temperature (°F)[b]	Transfers / Comments	Reference
8-1958	53	92	not reported	6,327 gal D-8 and flush 18,209 gal raw water 33,069 gal condensate reflux from SX-106	HW-83906-C-RD page 174 HW-57550 page 8
9-1958	200	184	175	139,760 gal of REDOX salt waste 2,000-gal caustic flush	HW-83906-C-RD page 188 HW-57711 page 8
10-1958	288	207	191	88,000 gal water (per HW-58201 page 8; 90,277 gal per HW-83906-C-RD page 192)	HW-83906-C-RD page 192 HW-58201 page 8
11-1958	277	217	197	11,000-gal decrease. Air sparging and evaporation	HW-83906-C-RD page 194 HW-58579 page 8
12-1958	263	214	194	Latest electrode reading	HW-83906-C-RD page 202 HW-58831 page 8
1-1959	252	210	193	11,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 3 HW-59204 page 8
2-1959	245	201	185	7,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 12 HW-59586 page 8
3-1959	243	207	189	2,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 19 HW-60065 page 8
4-1959	238	187	188	5,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 28 HW-60419 page 8
5-1959	236	200	181	2,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 36 HW-60738 page 8
6-1959	234	194	176	2,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 43 HW-61095 page 8
7-1959	230	194	178	4,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 52 HW-61582 page 8
8-1959	230	188	172	None	HW-83906-D-RD page 60 HW-61952 page 8

Table 5.10-1. Tank 241-SX-115 Waste Storage Summary (5 sheets)

Date	Total Waste Volume (Kgal)	Sludge Temperature (°F)[a]	Liquid Temperature (°F)[b]	Transfers / Comments	Reference
9-1959	227	190	174	3,000-gal decrease. Air sparging and evaporation	HW-83906-D-RD page 68 HW-62421 page 8
10-1959	227	182	170	None	HW-83906-D-RD page 76 HW-62723 page 8
11-1959	313	212	184	86,000 gal REDOX salt waste (87,142-gal per HW-83906-D-RD page 84)	HW-83906-D-RD page 84 HW-63083 page 8
12-1959	439	231	210	126,000 gal REDOX salt waste (139,861 gal per HW-83906-D-RD page 92)[c]	HW-83906-D-RD page 92 HW-63559 page 8
1-1960	492	242	210	116,000 gal REDOX salt waste (116,339 gal per HW-83906-D-RD page 100) 63,000 gal evaporated	HW-83906-D-RD page 100 HW-63896 page 2 and 8
2-1960	486	244	213	59,000 gal REDOX salt waste (58,602 gal per HW-83906-D-RD page 108) 65,000 gal evaporated	HW-83906-D-RD page 108 HW-64373 page 2 and 8
3-1960	475	242	215	71,000 gal REDOX salt waste (71,166 gal per HW-83906-D-RD page 115) 82,000 gal evaporated	HW-83906-D-RD page 115 HW-64810 page 2 and 8
4-1960	493	254	226	101,000 gal REDOX salt waste (101,260 gal per HW-83906-D-RD page 124) 83,000 gal evaporated	HW-83906-D-RD page 124 HW-65272 page 2 and 8
5-1960	464	254	229	43,000 gal REDOX salt waste (43,102 gal per HW-83906-D-RD page 131) 74,000 gal evaporated	HW-83906-D-RD page 131 HW-65643 page 2 and 8
6-1960	547	257	232	166,000 gal REDOX salt waste (165,744 gal per HW-83906-D-RD page 139) 83,000 gal evaporated	HW-83906-D-RD page 139 HW-66187 page 2 and 8
7-1960	599	239	234	53,000 gal REDOX salt waste and 108,000 gal from SX-109 (53,144 gal and 107,461 gal per HW-83906-D-RD page 147) 109,000 gal evaporated	HW-83906-D-RD page 147 HW-66557 page 2 and 8

Table 5.10-1. Tank 241-SX-115 Waste Storage Summary (5 sheets)

Date	Total Waste Volume (Kgal)	Sludge Temperature (°F)[a]	Liquid Temperature (°F)[b]	Transfers / Comments	Reference
8-1960	612	not reported	not reported	102,000 gal from SX-109 (101,251 gal per HW-83906-D-RD page 155) 89,000 gal evaporated	HW-83906-D-RD page 155 HW-66827 page 2 and 8
9-1960	631	276	245	12,000 gal condensate from SX-106 and 74,000 gal from SX-109 (12,398 gal and 74,386 gal per HW-83906-D-RD page 163) 56,000 gal evaporated	HW-83906-D-RD page 163 HW-67696 page 2 and 8
10-1960	621	258	243	23,000 gal condensate from SX-106 and 30,000 gal water (23,418 gal and 30,147 gal per HW-83906-D-RD page 171) 10,000 gal evaporated[d]	HW-83906-D-RD page 171 HW-67705 page 2 and 8
11-1960	626	275	244	54,000 gal condensate from SX-106 (54,600 gal per HW-83906-D-RD page 178) 49,000 gal evaporated	HW-83906-D-RD page 178 HW-68291 page 8
12-1960	643	255	241	45,000 gal water (45,315 gal per HW-83906-D-RD page 185) 28,000 gal evaporated	HW-83906-D-RD page 185 HW-68292 page 8
6-1961	645	not reported	not reported	April 1961: 48,213 gal condensate from SX-106 May 1961: 23,418 gal condensate from SX-106 June 1961: 28,239 gal condensate from SX-106 Gallons evaporated not reported	HW-83906-D-RD pages 193 - 194 HW-71610 page 8
12-1961	667	250	not reported	August 1961: 37,885 gal condensate from SX-106 September 1961: 14,444 gal condensate from SX-106 December 1961: 90,230 gal dilute waste from SX-102 45,000 gal evaporated	HW-83906-E-RD pages 4, 5 and 10 HW-72625 page 2 and 8
6-1962	675	227	not reported	March 1962: 51,660 gal condensate from SX-106 June 1962: 35,819 gal condensate from SX-106 Gallons evaporated not reported	HW-83906-E-RD pages 13, 14 and 19 HW-74647 page 8

Table 5.10-1. Tank 241-SX-115 Waste Storage Summary (5 sheets)

Date	Total Waste Volume (Kgal)	Sludge Temperature (°F)[a]	Liquid Temperature (°F)[b]	Transfers / Comments	Reference
12-192	684	224	not reported	July 1962: 17,219 gal condensate from SX-106 August 1962: 23,418 gal condensate from SX-106 November 1962: 25,484 gal condensate from SX-106 Gallons evaporated not reported	HW-83906-E-RD pages 22 -24 HW-76223 page 8
6-1963	700	213	not reported	February 1963: 15,153 gal condensate from SX-106 April 1963: 35,815 gal condensate from SX-106 Gallons evaporated not reported	HW-83906-E-RD pages 31 -33 HW-78279 page 8
12-1963	702	not reported	206	July 1963: 22,729 gal condensate from SX-106 Gallons evaporated not reported	HW-83906-E-RD pages 40 - 42 HW-80379 page 8
6-1964	192	not reported	170	June 1964: Transferred 573,797 gal of waste and 75,082 gal of dilution water to SX-102 June 1964: 77,837 gal condensate from SX-106	HW-83906-E-RD pages 49 - 50 HW-83308 page 8
12-1964	117	175	not reported	July 1964: 137,766 gal condensate from SX-106 September 1964: Transferred 215,603 gal of sodium nitrate waste[e] to SX-105	HW-83906-E-RD pages 56a – 56c and 60 RL-SEP-260 page 8
6-1965	8 (3 Kgal sludge)	142	not reported	February-March 1965: Waste lost to ground as a results of SX-115 tank failure is 50,976 gal, tank leaks March 1965: 52,349 gal of sodium nitrate waste to SX-105	HW-83906-E-RD pages 62a – 62c and 66 RL-SEP-659 page 8
9-1965	8 (3 Kgal sludge)	138	not reported	Tank leaks	HW-83906-E-RD pages 68a – 68b and 72 RL-SEP-821 page 8

[a]Measured approximately 3-inches off the tank bottom

[b]Measured approximately 5-ft off the tank bottom

[c]Discrepancy in volumes transferred into tank SX-115 likely due to unreported waste evaporation.

[d]Evaporated waste volumes are as reported in reference and do NOT include water or condensate from tank SX 106 that were evaporated.

[e]Sodium nitrate waste results from leaching REDOX HLW sludge with condensate or water. The leachate, containing sodium nitrate, was collected in tank SX-105 and transferred to the 202-S REDOX Plant for use in the dissolution of irradiated nuclear fuel.

Table 5.10-1. Tank 241-SX-115 Waste Storage Summary (5 sheets)

Date	Total Waste Volume (Kgal)	Sludge Temperature (°F)[a]	Liquid Temperature (°F)[b]	Transfers / Comments	Reference

References cited:
HW-57550, *Chemical Processing Department Waste Status Summary August 1, 1958 – August 31, 1958*
HW-57711, *Chemical Processing Department Waste Status Summary September 1, 1958 – September 30, 1958*
HW-58201, *Chemical Processing Department Waste Status Summary October 1, 1958 – October 31, 1958*
HW-58579, *Chemical Processing Department Waste Status Summary November 1, 1958 – November 30, 1958*
HW-58831, *Chemical Processing Department Waste Status Summary December 1, 1958 – December 31, 1958*
HW-59204, *Chemical Processing Department Waste Status Summary January 1, 1959 – January 31, 1959*
HW-59586, *Chemical Processing Department Waste Status Summary February 1, 1959 – February 28, 1959*
HW-60065, *Chemical Processing Department Waste Status Summary March 1, 1959 – March 31, 1959*
HW-60419, *Chemical Processing Department Waste Status Summary April 1, 1959 – April 30, 1959*
HW-60738, *Chemical Processing Department Waste Status Summary May 1, 1959 – May 31, 1959*
HW-61095, *Chemical Processing Department Waste Status Summary June 1, 1959 – June 30, 1959*
HW-61582, *Chemical Processing Department Waste Status Summary July 1, 1959 – July 31, 1959*
HW-61952, *Chemical Processing Department Waste Status Summary August 1, 1959 – August 31, 1959*
HW-62421, *Chemical Processing Department Waste Status Summary September 1, 1959 – September 30, 1959*
HW-62723, *Chemical Processing Department Waste Status Summary October 1-31, 1959*
HW-63083, *Chemical Processing Department Waste Status Summary November 1-30, 1959*
HW-63559, *Chemical Processing Department Waste Status Summary December 1-31, 1959*
HW-63896, *Chemical Processing Department Waste Status Summary January 1-31, 1960*
HW-64373, *Chemical Processing Department Waste Status Summary February 1-29, 1960*
HW-64810, *Chemical Processing Department Waste Status Summary March 1-31, 1960*
HW-65272, *Chemical Processing Department Waste Status Summary April 1 – 30, 1960*
HW-65643, *Chemical Processing Department Waste Status Summary May 1 – 31, 1960*
HW-66187, *Chemical Processing Department – Waste Status Summary*, *June 1, 1960 – June 30, 1960*
HW-66557, *Chemical Processing Department Waste Status Summary*, *July 1, 1960 – July 31, 1960*
HW-66827, *Chemical Processing Department – Waste Status Summary*, *August 1960*
HW-67696, *Chemical Processing Department Waste Status Summary*, *September 1, 1960 – September 30, 1960*
HW-67705, *Chemical Processing Department Waste Status Summary October 1, 1960 – October 31, 1960*
HW-68291, *Chemical Processing Department Waste Status Summary*, *November 1, 1960 – November 30, 1960*
HW-68292, *Chemical Processing Department Waste Status Summary*, *December 1, 1960 – December 31, 1960*
HW-71610, *Chemical Processing Department Waste Status Summary January 1, 1961 Through June 30, 1961*
HW-72625, *Chemical Processing Department – Waste Status Summary*, *July – December 1961*
HW-74647, *Chemical Processing Department – Waste Status Summary*, *Planning and Scheduling Production Operation, January – June 1962*
HW-76223, *Chemical Processing Department – Waste Status Summary*, *Planning and Scheduling Production Operation, July – December 1962*
HW-78279, *Chemical Processing Department Waste Status Summary*, *January 1, 1963 through June 30, 1963*
HW-80379, *Chemical Processing Department Waste Status Summary*, *July 1, 1963 through December 31, 1963*
HW-83308, *Chemical Processing Department Waste Status Summary January 1, 1964 Through June 30, 1964*
HW-83906-C-RD, 1964, *Chemical Processing Department 200 West Area Tank Farm Inventory and Waste Reports January 1957 Through December 1958*
HW-83906-D-RD, 1964, *Chemical Processing Department 200 West Area Tank Farm Inventory and Waste Reports January 1959 Through June 1961*
HW-83906-E-RD, 1964, *Chemical Processing Department 200 West Area Tank Farm Inventory and Waste Reports July 1961 Through 1966*
RL-SEP-260, *Chemical Processing Department Waste Status Summary, July 1, 1964 Through December 31, 1964*
RL-SEP-659, *Chemical Processing Department Waste Status Summary January 1, 1965 Through June 30, 1965*
RL-SEP-821, *Chemical Processing Department Waste Status Summary July 1, 1965 through September 30, 1965*

In August 1958, tank SX-115 received ~18,200 gal of raw water, 33,000 gal of condensate from tank SX-106, and 6,300 gal of 202-S REDOX HLW from tank D-8 along with a flush of the transfer pipeline. In September 1958, tank SX-115 received ~140,000 gal of REDOX HLW and a 2,000-gal caustic flush of the pipeline. As shown in Table 5.10-1, tank SX-115 began to boil and evaporate waste beginning in October 1958, prompting addition of water and air sparging to cool the waste. Air sparging and waste evaporation from tank SX-115 continued through October 1959.

REDOX HLW waste was again added to tank SX-115 from November 1959 through June 1960, along with aged REDOX HLW supernate from tank SX-109 in July, August and September 1960. Condensate from tank SX-106 and water were periodically added to tank SX-115 from November 1960 through July 1963 to maintain the waste temperature below 300 °F and prevent further concentration of the waste. In June 1964, all of the pumpable REDOX HLW supernate was transferred from tank SX-115 to tank SX-102 to prepare for leaching the sludge within tank SX-115. Tank SX-115 contained ~192,000 gal of waste as of June 30, 1964 (HW-83308, *Chemical Processing Department Waste Status Summary January 1, 1964 Through June 30, 1964*, page 8).

Sodium Nitrate Waste Storage (1964 to 1965)
Condensate from tank SX-106 was transferred into tank SX-115 in June and July 1964 to leach sodium nitrate from the REDOX HLW sludge. The leached sodium nitrate solution was transferred to tank SX-105 in September 1964 and then to the 202-S REDOX Plant for use in suppressing hydrogen gas evolution during dissolution of irradiated nuclear fuel. An analysis of the sodium nitrate waste in tank SX-115 is provided in Table 5.10-2 (BNWL-CC-701 page 10).

Table 5.10-2. Tank 241-SX-115 Sodium Nitrate Waste Analysis (September 1964)

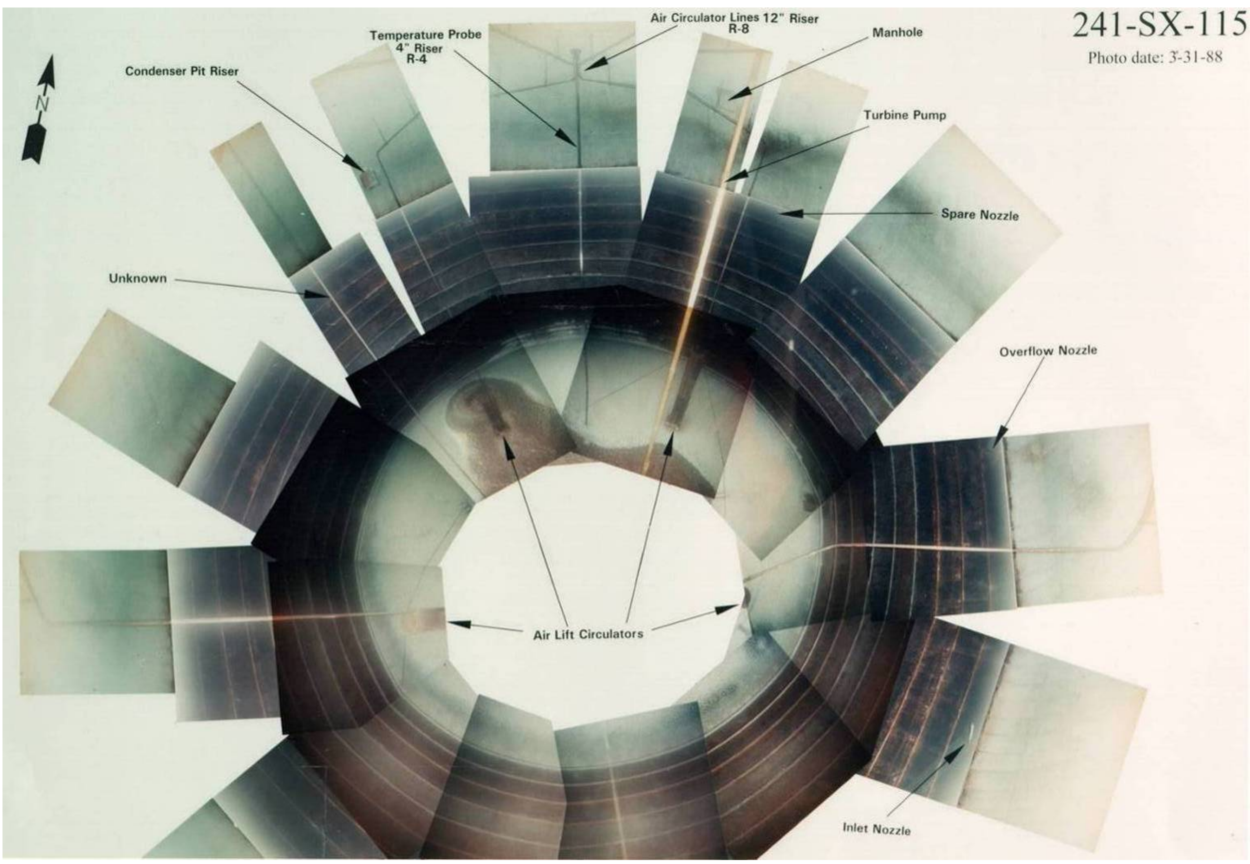
Component	Concentration	Units
NaOH	1.28	M
Cr^{+6}	1.42	g/L
^{137}Cs	0.763	Ci/gal
^{134}Cs	0.0092	Ci/gal

Tank SX-115 was determined to be leaking sodium nitrate waste to the ground between February 24 and March 3, 1965. Tank SX-115 contained ~111,000 gal (~47.7 in.) of waste at the time this leak was discovered. The remaining pumpable sodium nitrate waste was transferred to tank SX-105 by March 3, 1965 (BNWL-CC-701 page 3).

5.10.1.2 Concrete Core Drilling. One unique feature of tank SX-115 is that a 2.7-in. diameter core of the concrete was extracted in 1981 from the top haunch, sidewall, and tank footing (RHO-CD-1538, *Waste Tank 241-SX-115 Core Drilling Results* and H-2-91959, *Tank 241-SX-115 Caisson Location Plan, Section & Details*). The core was extracted in support of SST structural integrity evaluations and was tested to determine elasticity and strength properties. An 8-ft diameter by 13-ft 8-in. length corrugated galvanized steel pipe with cover was placed in an excavation on tank SX-115. A concrete pad with 3-in. by 3-in. curbing was poured at the base of the corrugated galvanized steel pipe. Core drilling of the tank concrete shell was conducted from within this corrugated galvanized steel pipe. No contamination was encountered in the ~6-ft-long core segments removed from tank SX-115 concrete shell until the last segment was drilled. The core drilling was stopped 8 in. short of the bottom when contamination was encountered. The last 6 ft of concrete core segment removed during drilling had a beta radiation reading of 1,600-mR at the bottom of the segment. Also, the drilling water was slightly contaminated, reading 3,800 cpm when drilling this last segment.

5.10.1.3 Interim Stabilization. This tank was declared interim stabilized in October 1978 based on photograph evaluation (HNF-SD-RE-TI-178 page 280). As of January 1, 2008, SST SX-115 is estimated to contain 4,000 gal of sludge. No pumpable liquid remains in the tank (HNF-EP-0182). The sludge is designated as REDOX HLW type R2 generated from 1958 to 1968 (Tank Waste Information Network System). Figure 5.10-2 depicts a mosaic of the waste surface in tank SX-115 as of March 1988.

Figure 5.10-2. Tank 241-SX-115 Waste Surface (March 1988)



5.10.1.4 Tank 241-SX-115 Temperature History. Available thermal histories for SSTs are summarized in RHO-CD-1172. The thermal history for tank SX-115 starts in August 1958 when REDOX waste was first added, and continues through January 1968 (RHO-CD-1172 pages B-87 through B-109). Appendix A provides plots showing the maximum temperature (°F) of the waste stored in tank SX-115. The temperature plots for tank SX-115 are consistent with the waste history discussed in section 5.10.1.1.

5.10.1.4 Basis for Leak Declaration. Tank SX-115 was confirmed as a leaking tank based on an observed liquid level decrease of about 16 in. from February 24 through March 3, 1965, and gamma activity detected in the laterals beneath this tank.

5.10.2 Data Review and Observations

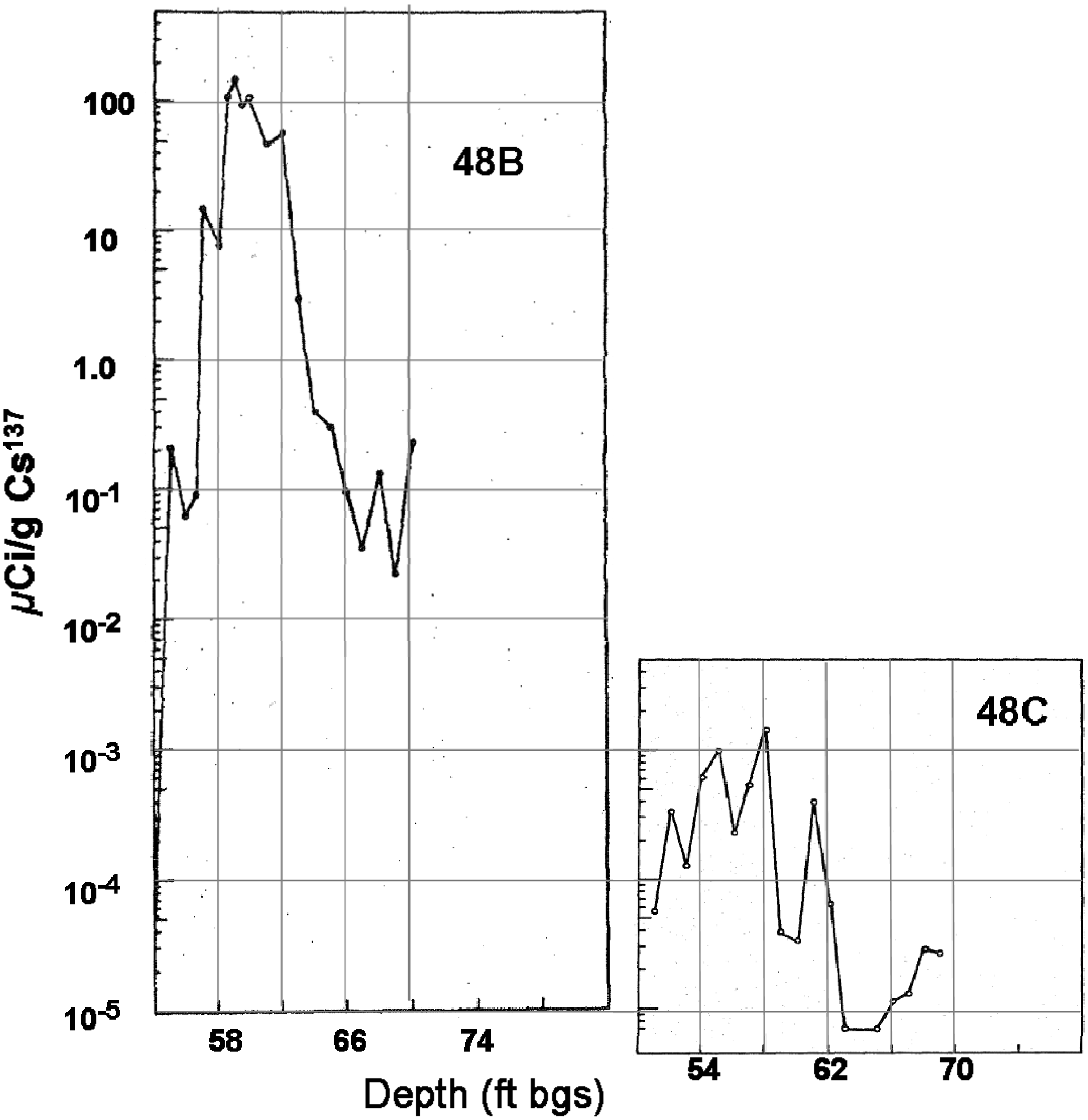
5.10.2.1 Previous Assessments. A vadose zone characterization effort was completed in 1966 after the release occurred to better determine the nature of subsurface contamination near the tank (BNWL-CC-701). Ten boreholes were drilled near the perimeter of the tank and sediments were collected between 50 and 80 ft bgs and analyzed for gamma emitting radionuclides.

^{137}Cs profiles (concentration data as a function of depth) from two boreholes (48C and 48B) on the southwest side of the tank and from two boreholes (45B and 17A) on the northeast side of the tank were shown in the documentation. The largest ^{137}Cs concentration occurred in borehole 48B (see Figure 5.10-3) on the southwest portion of the tank perimeter close to lateral 44-15-02. From 58 to 62 ft bgs, concentrations ranged between 50 and 110 µCi/g. The ^{137}Cs profile at borehole 48C just 10 ft southwest of borehole 48B is significantly less contaminated, with maximum ^{137}Cs concentrations of $\sim 1\times10^{-3}$ µCi/g between 60 and 65 ft bgs. These data suggest that the point of waste entry into the subsurface is near borehole 48B and that insufficient ^{137}Cs was available to extend outward to the borehole 48C location. On the northeast side of the tank, ^{137}Cs concentrations in both boreholes 45B and 17A (see Figure 5.10-4) show maximum values of ~10 µCi/g between 60 and 65 ft bgs. These data suggest that both borehole locations are roughly the same distance from the point of entry. The common observation among the four boreholes of maximum concentrations around 60 ft bgs suggests a local sediment layer through which fluid flow occurred preferentially. Data from other boreholes was not provided and it is assumed that ^{137}Cs contamination was not measured in the sediment samples.

From these data and available gross gamma measurements in the laterals, a set of ^{137}Cs contours were drawn as shown in Figure 5.10-5. Unfortunately laterals data was only described for one location along the middle lateral (44-15-02) in the northeast quadrant. Although not stated, it is assumed that the contours were meant to represent contamination across a horizontal plane determined by the laterals about 60 ft bgs. Using these contours, three zones of contamination were extrapolated. Total ^{137}Cs content was then estimated by assuming roughly concentric cylinders of soil contaminated at the indicated ^{137}Cs concentrations. Cylinder areas were determined from the Figure 5.10-5 map view; contours and cylinder heights were determined from borehole data. The total estimated ^{137}Cs inventory in the vadose zone using this approach was 23,730 Ci versus ~40,000 Ci determined from volume loss based on liquid level drops in the tank between February and March, 1965 and one prior ^{137}Cs concentration measurement from a tank fluid sample.

Additional information on the chronology of events for tank SX-115 was located in several of the operating contractor monthly reports for the Hanford Site. Verbatim text from the cited references is provided in Table 5.10-3 (RPP-RPT-29191).

Figure 5.10-3. Cesium-137 Concentration Profiles in Boreholes 48B and 48C (modified from BNWL-CC-701)

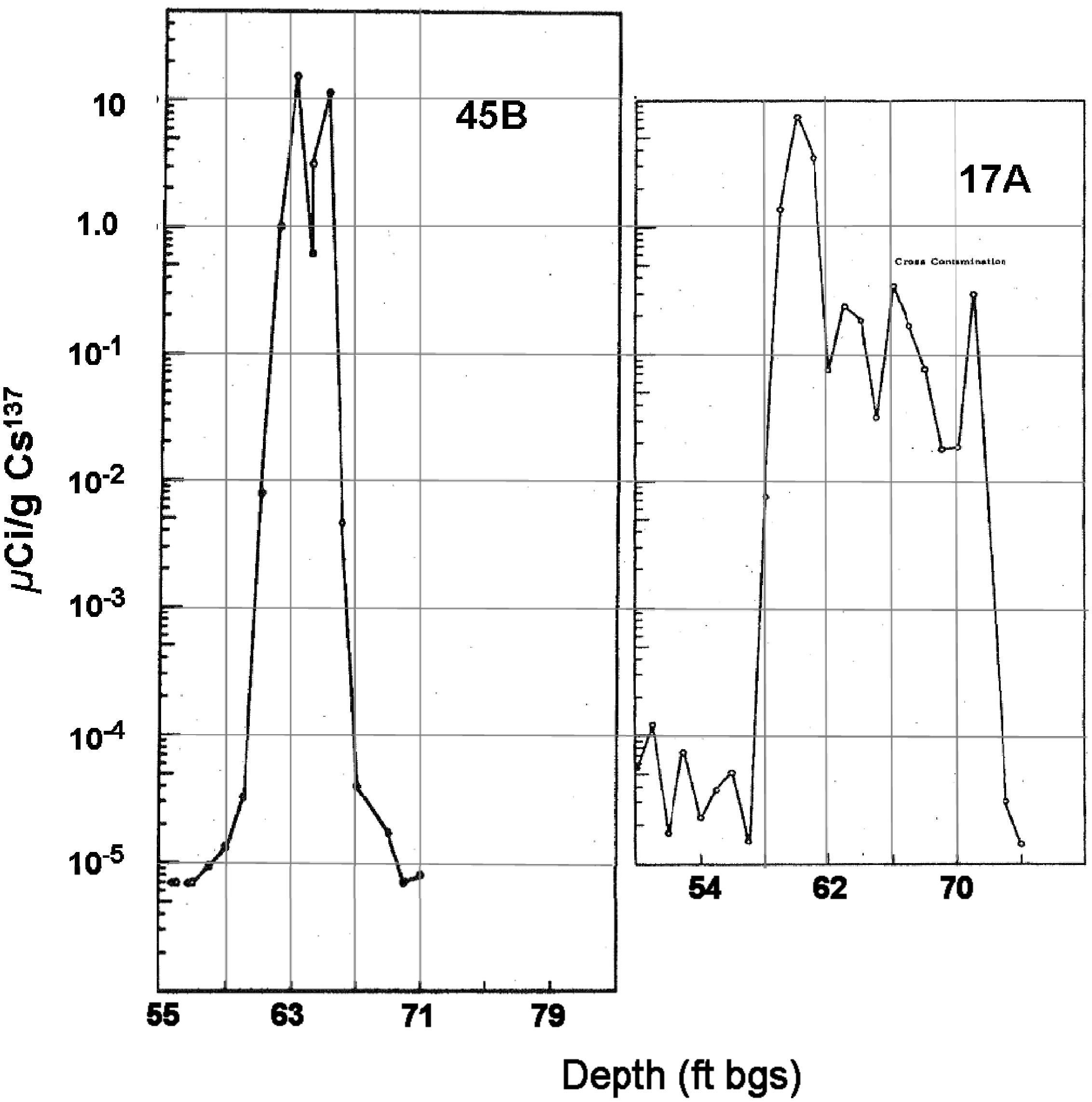


Reference: BNWL-CC-701, *Characterization of Subsurface Contamination in the SX Tank Farm*

5.10.2.2 Pipelines and Spare Inlet Nozzle. There are no known leaks associated with pipelines in the vicinity of tank SX-115 (7G410-MEJ-07-004 – Memorandum). Therefore, it is unlikely that a waste loss from a pipeline could have contributed to contamination located near this tank.

Pipeline L115 originates in the centrally located tank SX-115 pump pit and traverses at a 45-degree angle northeast (2 o'clock position) across the top of the tank, eventually terminating in diversion box 241-SX-152. The one spare inlet nozzle (N-1) for tank SX-115 is located 45-degrees clockwise from north. Pipeline V-590 (nozzle N-4), at about the 5 o'clock position, was capped as it exits the concrete encasement and plugged in diversion box 241-SX-151 in 1970 (H-2-35591, *Waste Tank Isolation 241-SX-TK.115*). Pipeline V-590 is encased in an 8-in. diameter pipe; it is unlikely that waste leaked from these encased pipelines.

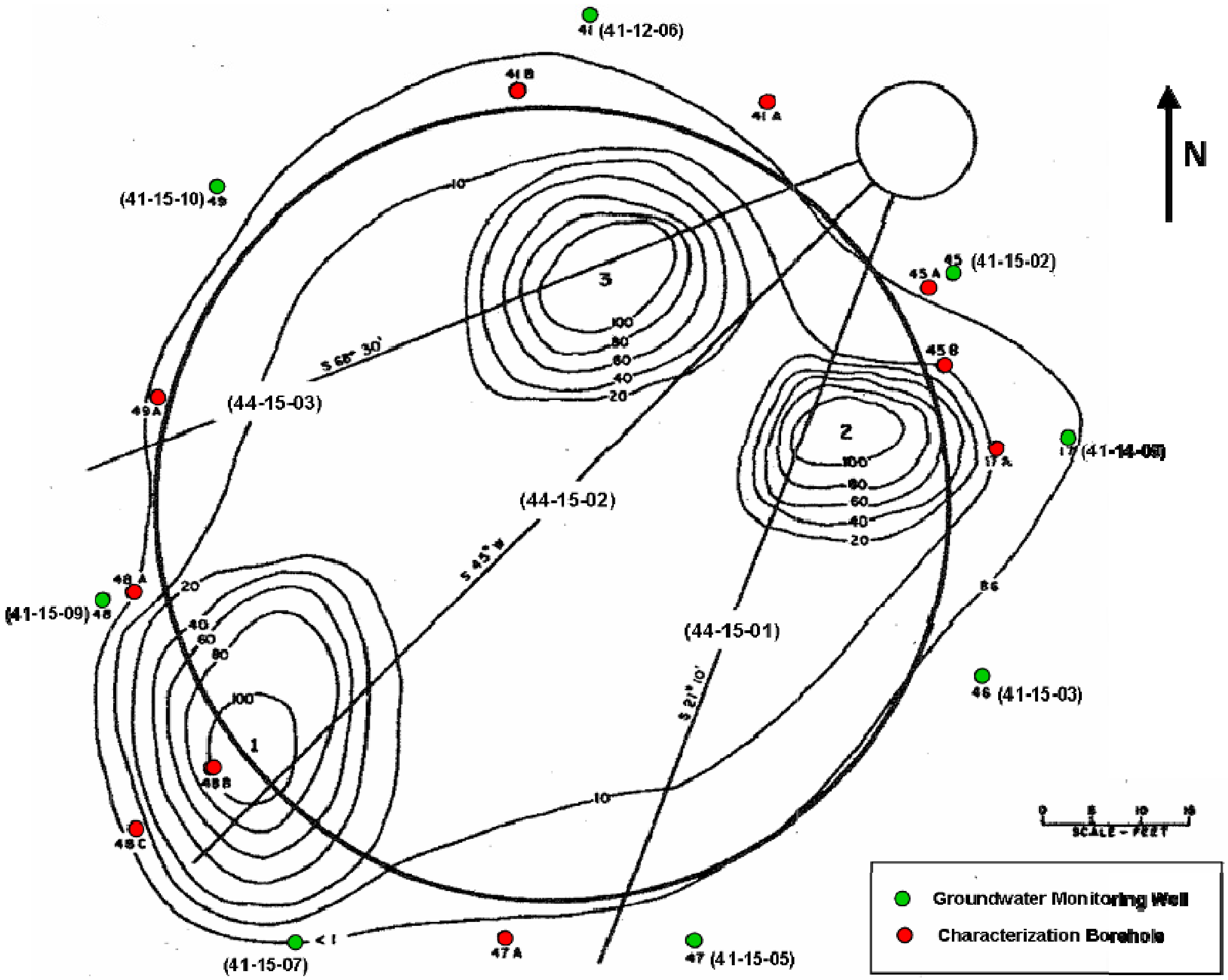
Figure 5.10-4. Cesium-137 Concentration Profiles in Boreholes 45B and 17A (modified from BNWL-CC-701)



Reference: BNWL-CC-701, *Characterization of Subsurface Contamination in the SX Tank Farm*

A 3-in. steel pipeline with a gate valve was attached to riser R-6 atop tank SX-115 and was used to transfer condensate from tank SX-106 into tank SX-115. This gate valve was blanked in 1970 (H-2-35590). Tank SX-106 was used from 1954 through 1966 to collect condensate from the boiling waste tanks in the 241-SX Tank Farm. Condensate could be pumped from tank SX-106 through a buried steel pipeline equipped with gate valves to route condensate to any one of the boiling waste tanks. There is no record of this condensate return pipeline having leaked.

Figure 5.10-5. Tank 241-SX-115 Subsurface Cesium-137 Concentration Contour Estimates (Contour value × 10^6, pCi/g) (modified from BNWL-CC-701 1966)



Reference: BNWL-CC-701, *Characterization of Subsurface Contamination in the SX Tank Farm*

5.10.2.3 Drywell and Lateral Gamma Logging. There are seven drywells located nearby tank SX-115 – 41-15-02, 41-15-03, 41-15-05, 41-15-06, 41-15-07, 41-15-09 and 41-15-10 – as well as groundwater monitoring well 299-W23-19. Historical gross gamma logging data in drywells associated with tank SX-115 are reported in SD-WM-TI-356 and HNF-3136. No contamination was detected in drywells 41-15-02, 41-15-03, 41-15-05 or 41-15-10 or in well 299-W23-19, as shown in Figure 5.10-6 and Figure 5.10-7 (GJPO-HAN-4 figures D-26 and D-27). However, as shown in Figure 5.10-6, ^{137}Cs contamination has been detected in drywell 41-15-07 at 55 to 60 ft bgs (HNF-3136 page B-351), which is slightly beneath the base of tank SX-115. Drywell 41-15-07 is located nearby lateral 44-15-03 in which the highest gamma activity has been detected beneath tank SX-115. Furthermore, high gross gamma activity has been detected in laterals 44-15-01, 44-15-02 and 44-15-03 beneath tank SX-115, as reported in SD-WM-TI-356 pages 41-15-06 and 41-15-07.

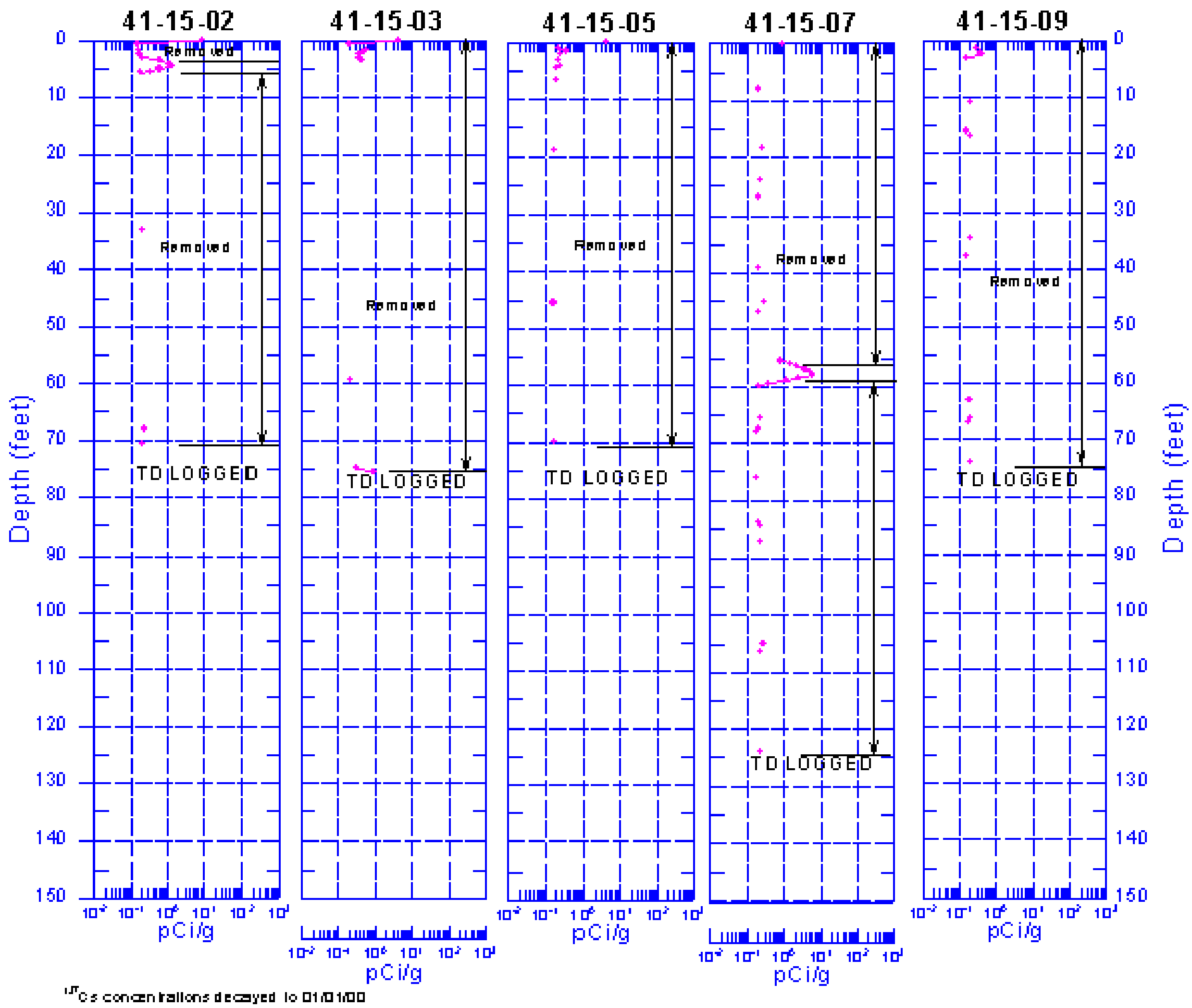
Table 5.10-3. Tank 241-SX-115 Leak Information

Date	Event as Described in Reference
10-1958[a]	Settling of sludge in the 115-SX tank, currently being heated up for active service, caused the temperature measured at the one-inch level to rise approximately 15°F above the temperature at the four-inch level and about 30°F higher than the average liquid temperature. When minor variations in liquid level were observed on October 13, a sounding of the tank bottom was made which indicated **the liner to be raised three inches above its original elevation which had been confirmed by soundings made as late as October 2**. The injection of approximately 90,000 gallons of water into the tank reduced the average solution temperature 38°F but lowered the sludge temperature only 10°F, despite the agitation provided by two circulators. Concurrently the tank liner returned to within a half-inch of its original position and remained there throughout the report period in spite of a 30°F increase in the average solution temperature.
7-26 – 8-1-64[b]	The sludge level of the 115-SX tank was reduced from 13 inches to 4 inches by 7-31-64. Sodium nitrate dissolution from this tank is nearly complete.
3-1965[c]	Tank farm tank leakage continues to be an area of major concern. The 115-SX tank, which contained approximately four feet of dissolved sodium nitrate salt and was being held as a reserve waste tank, suddenly developed a large leak and 16 inches of solution was lost to ground. The balance of the material was pumped to the 105-SX tank and as soon as the steam and vapor in the tank clear up, inspection and photographs of the tank interior will be done in an effort to obtain additional information relative to the leak.
8-1965[d]	Page C-3: Test wells are being drilled to depths of up to 70 feet around the 115-SX tank which leaked approximately 16 inches of dissolved sodium nitrate salt solution to the ground during March 1965. Two wells have been drilled to date, which show the deepest penetration of radiation activity to be 9 feet below the tank bottom. Maximum beta-gamma activity encountered in soil samples brought to the surface from this depth to date is 6,000 c/m. Page G-3: Test holes are being drilled to depths of up to 70 feet around Tank 115-SX. This tank failed earlier this year and leaked **approximately 50,000 gallons of dilute waste into the ground**. Two holes have been drilled thus far and show the deepest penetration of contaminations to be 9 feet below the tank bottom.
12-1965[e]	Drilling of the ten test wells around the 115-SX waste storage tank, which leaked approximately 16 inches of sludge leach solution into the ground during pumping operations during March, was completed this month. Contamination up to a maximum of 5-rads/hr was detected in three distinct areas, indicating the possibility of multiple leaks. The activity, primarily radiocesium, appeared to have penetrated no more than 15 feet below the tank bottom.

Comment:
For detailed discussion on waste leakage from this tank, see WHC-MR-0302, *Tank 241-SX-115 Tank Leak Assessment*.
[a]HW-58051-DEL, *Chemical Processing Department Monthly Report for October, 1958*, page J-8
[b]HW-80202, *REDOX Weekly Process Reports January through December, 1964*, page 41
[c]RL-SEP-405-DEL, *Chemical Processing Department Monthly Report for March, 1965*, page C-3
[d]RL-SEP-706-DEL, *Chemical Processing Department Monthly Report for August, 1965*, page C-3 and G-3
[e]RL-SEP-913-DEL, *Chemical Processing Department Monthly Report for December, 1965*, page C-3 and G-3

Additional gamma scans of laterals 44-15-01, 44-15-02 and 44-15-03 beneath tank SX-115 were performed in 2005, as shown in Figures 5.10-8, 5.10-9 and 5.10-10 (RPP-RPT-27605 pages B-48 through B-53). Gamma measurements along these laterals are represented as equivalent ^{137}Cs concentrations. ^{137}Cs is considered the current major gamma dose contributor given what is known about the waste fluid composition from operational records, but other contaminants (e.g., ^{90}Sr) may also be present. Measurements of gamma activity along the laterals were consistent with the general vicinity of specific highly contaminated areas and the likelihood of multiple points of entry into the vadose zone indicated in Figure 5.10-5. However, comparisons of the 2005 lateral data with the ^{137}Cs contours in Figure 5.10-5 show several differences.

Figure 5.10-6. Drywells 41-15-02 through 41-15-09 Spectral Gamma Analyses (1999)



- Equivalent high ^{137}Cs concentrations (1×10^8 pCi/g) are shown for each lateral in Figure 5.10-5 in discrete locations. Conversely, the recent gamma measurements show large differences in gamma radiation levels among the three laterals. Maximum concentrations of 1×10^7, 1×10^2 and 1×10^5 pCi/g occur in laterals 44-15-03, 44-15-02 and 44-15-01, respectively. Some of the differences may be attributed to improved detection capabilities.

- In lateral 44-15-03 (Figure 5.10-10) the maximum gamma level ($>1\times10^7$ pCi/g) occurs under the tank perimeter 86 ft along the lateral, and lower but still elevated concentrations (1×10^5 µCi/g or more) extend to 105 ft along the lateral. In Figure 5.10-5, the reverse trend is shown. Maximum ^{137}Cs concentrations are projected at 105 ft (100 µCi/g) and decrease away from the tank center to about 10 µCi/g directly underneath the tank perimeter along the lateral.

- In lateral 44-15-02 (Figure 5.10-9) two gamma peaks (100 pCi/g) occur near the two locations where the lateral crosses the hypothetical extensions of the tank wall at about 88 and 148 ft along the lateral. Figure 5.10-5 indicates contamination in the same locations but greatly different ^{137}Cs concentrations; a maximum of ~100 µCi/g at 148 ft along the lateral and no distinct peak at 88 ft.

- In lateral 44-15-01 (Figure 5.10-8), maximum gamma concentrations up to 1×10^5 pCi/g occur between 84 and 99 ft along the lateral. These measurements correspond reasonably well with the zone two projection in Figure 5.10-5. However, a secondary peak (about 1000 pCi/g) occurs at 130 ft along the lateral which has no corollary in Figure 5.10-5.

The reasons for these differences are not clear. One plausible explanation is the presence of other short-lived and perhaps more dominant gamma emitters contributing to the measurements at the time of the leak event. In particular, ^{106}Ru was a significant component in waste fluids at the time of the leak and being chemically more mobile than ^{137}Cs would be expected to distribute differently in the subsurface. If so, the concentration contours attributed to ^{137}Cs distribution in the 1966 report (see Figure 5.10-5) might contain ^{106}Ru also. The 2005 measurements would not detect ^{106}Ru because by then it would have decayed to insignificant levels. The lateral data used to construct the 1966 contours is not presented in the BNWL-CC-701 report; consequently it is not possible to determine how ^{137}Cs contours were calculated. Some scaling assumptions may have been made to convert laterals readings to ^{137}Cs contours. Because of these questions and differences the ^{137}Cs inventory estimates in BNWL-CC-701 are uncertain.

5.10.2.4 Tank 241-SX-115 Waste Loss Estimate. A leak from tank SX-115 may have occurred as early as 1963 based on a scan of lateral no. 2 (44-15-02) taken on December 12, 1963. The December 12, 1963 scan of lateral no. 2 indicated "*… background readings between 40 and 60 c/m and radiation peaks between 60 and 98 c/m. These readings were taken by a probe that is no longer used, and they* [i.e., these readings] *cannot be compared with readings cited elsewhere in this report* [i.e., BNWL-CC-701]. *Insufficient data are available to estimate the amount leaked, but it was minor compared with the 1965 leak. Using the same probe, the 1965 leak generated readings exceeding 2,000,000 c/m (off scale)*" (WHC-MR-0302 page 9). There was no reported liquid level decline associated with the activity detected in lateral no. 2 in 1963; therefore, no estimate of the waste loss can be made. Given the low levels of gamma activity detected, any waste loss in 1963 is likely to have been small.

The type of waste leaked from tank SX-115 in March 1965 is a sodium nitrate solution derived from leaching the REDOX HLW sludge. The SIM (RPP-26744 page A-118) incorrectly identifies the waste leaked from tank SX-115 as R1 and R2 types. Therefore, the SIM incorrectly identifies the quantities of analytes and radionuclides leaked from tank SX-115 and will need to be corrected.

Figure 5.10-7. Drywell 41-15-10 and Groundwater Monitoring Well 299-W23-19 Spectral Gamma Analyses (1999)

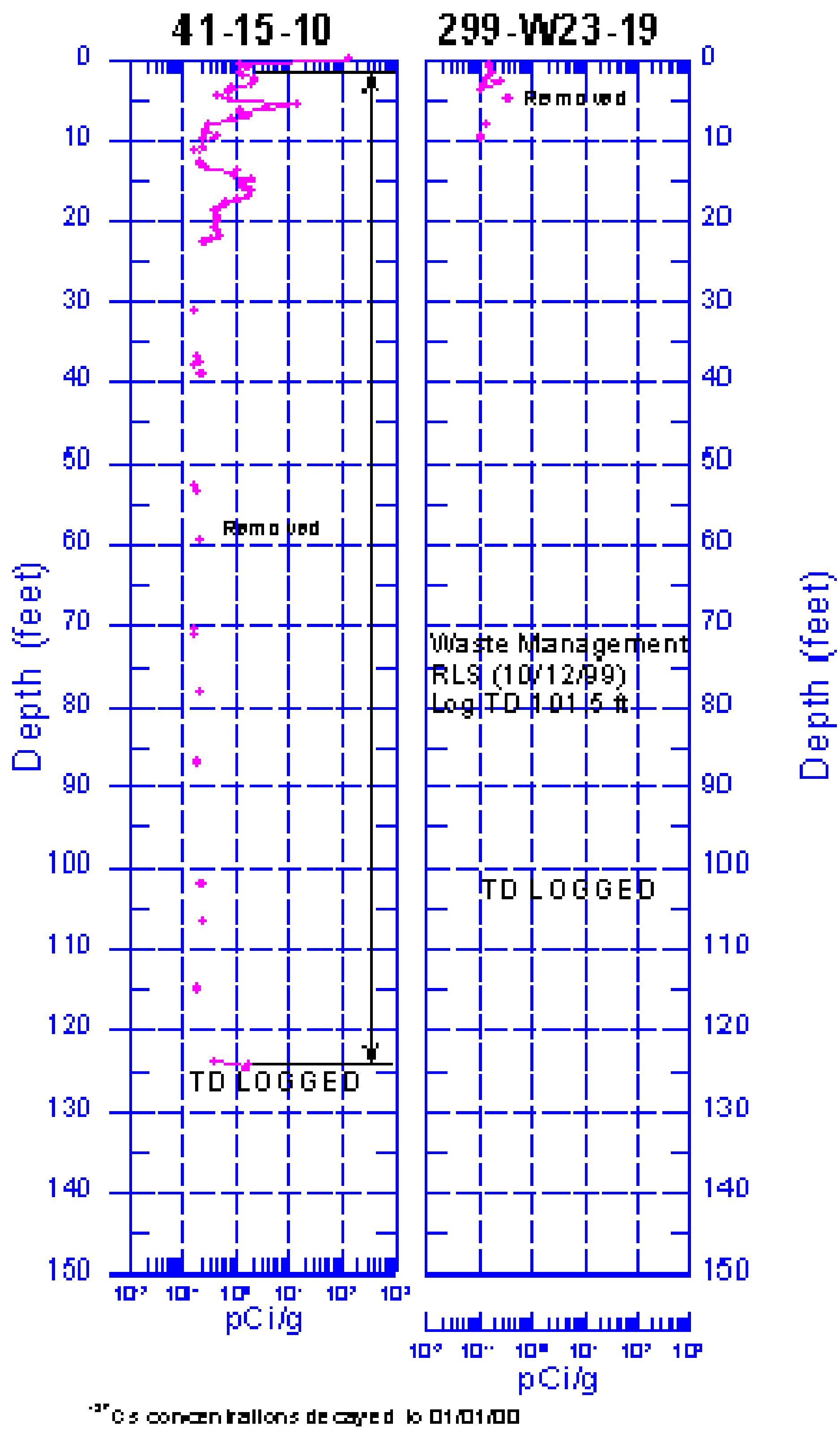
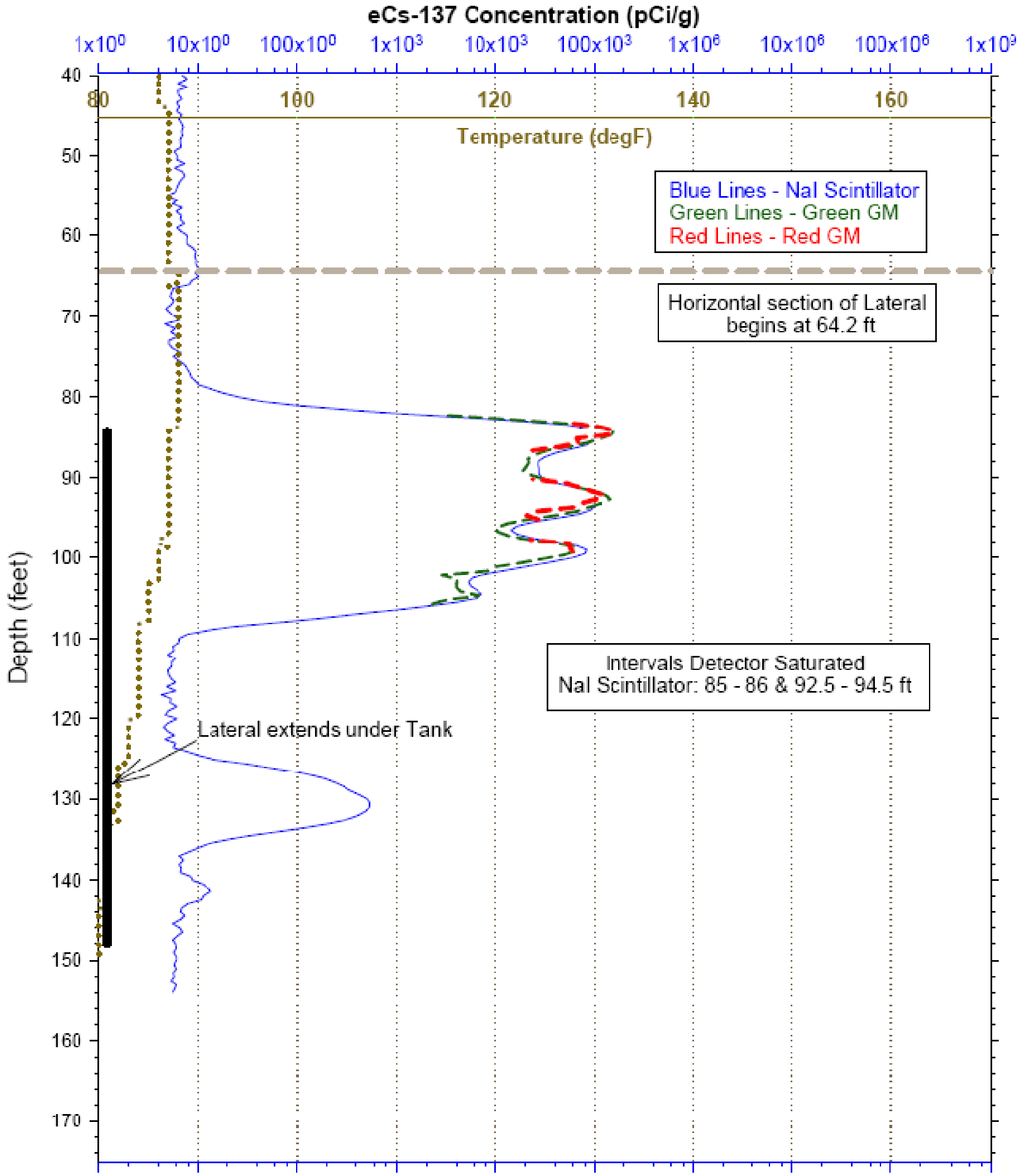
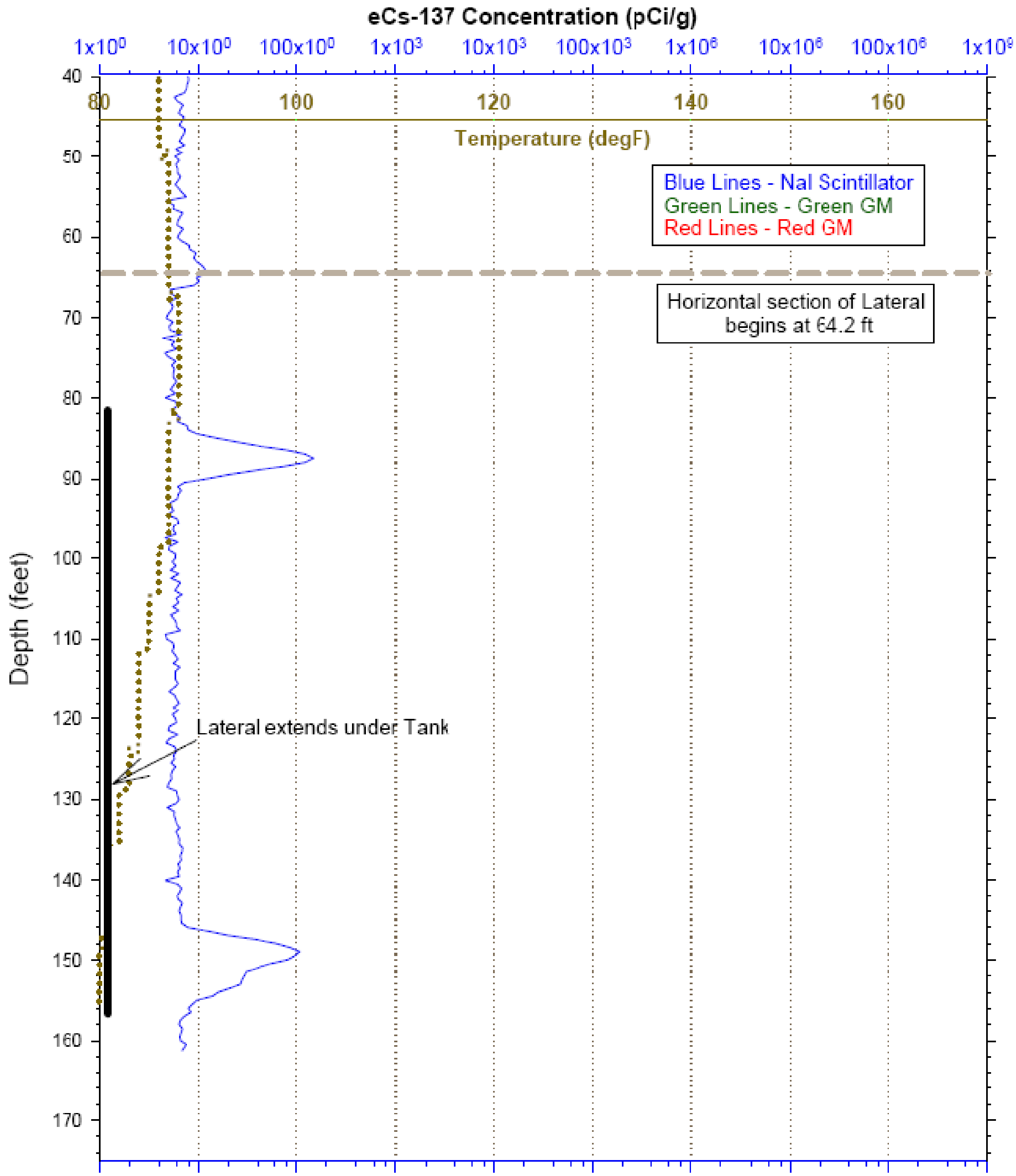


Figure 5.10-8. Gamma Survey for Lateral 44-15-01 on Log Scale (May 2005)



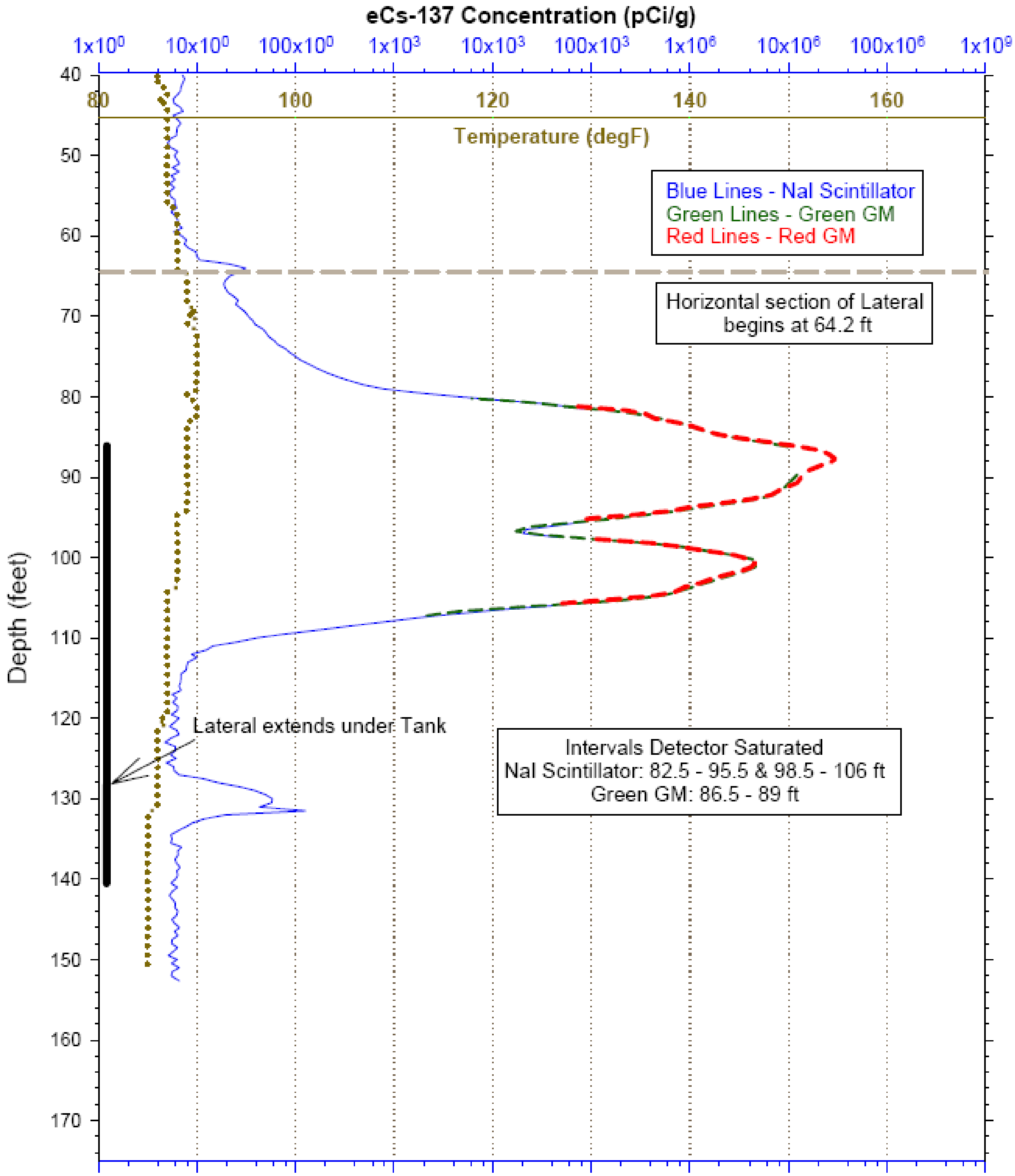
Log date: May 2005. Reference depth: ground level.

Figure 5.10-9. Gamma Survey for Lateral 44-15-02 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

Figure 5.10-10. Gamma Survey for Lateral 44-15-03 on Log Scale (May 2005)



Log date: May 2005. Reference depth: ground level.

The estimated volume of waste loss from tank SX-115 was 50,000 to 50,976 gal (HW-83906-E-RD page 62c) with composition as of September 1964 reported in Table 5.10-2. This waste loss estimate is based on a liquid level decline of ~18 in. in tank SX-115 which had a static liquid level at the time (i.e., the tank was no longer self boiling). The SIM lists a leak volume of 50,000 gal, which is consistent with information contained in this report. Based on the waste composition in Table 5.10-2, ~38,150 to 38,900 curies of ^{137}Cs (September 1964) were lost to the soil. Decay correcting to January 2001, the inventory of ^{137}Cs in the soil is 16,800 Ci.

In an effort to verify the inventory of waste leaked from tank SX-115, a new conceptual model was devised to describe the leak. Tank SX-115 was assumed to have leaked over the areas where ^{137}Cs activity was detected in the three laterals beneath the tank, as shown in Figures 5.10-8, 5.10-9 and 5.10-10. The waste is assumed to have leaked from the tank to the laterals, a distance of 10 ft, and spread the same width as indicated by the ^{137}Cs activity for the three laterals. The concentration of ^{137}Cs in the soil contacted by the leaked waste is assumed to be at the maximum ^{137}Cs activity shown for each lateral. Figure 5.10-11 shows the approximate area of the ^{137}Cs activity detected in the laterals beneath tank SX-115 during the May 2005 survey, superimposed on the estimated leak area by Raymond and Shdo (BNWL-CC-701 page 17). The May 2005 gamma survey of the laterals and the leak area estimated by Raymond and Shdo in 1966 do not align exactly. As noted previously, this difference could be due to Raymond and Shdo detecting gamma emitting radionuclides with short half-lives, which have subsequently decayed and were not detected in the May 2005 lateral survey.

The estimated ^{137}Cs loss was then calculated as follows:

Assumptions/ Inputs:

- Soil density = 1.7 g/cc
- Distance to lateral below base of tank = 10 ft
- ^{137}Cs activity beneath lateral 44-15-01
  - 2×10^5 pCi/g at 82 to 108 ft
  - 5×10^2 pCi/g at 124 to 136 ft
- ^{137}Cs activity beneath lateral 44-15-02
  - 2×10^2 pCi/g at 84 to 90 ft
  - 1×10^2 pCi/g at 146 to 156 ft
- ^{137}Cs activity beneath lateral 44-15-03
  - 3×10^7 pCi/g at 80 to 108 ft
  - 2×10^2 pCi/g at 126 to 132 ft
- Assume waste does not extend below laterals based on Cs-Sorption chemistry.
- As a conservative estimate assume the waste spread to the distance of the ^{137}Cs activity detected in the laterals in a cylindrical distribution, as shown in Figure 5.10-11.

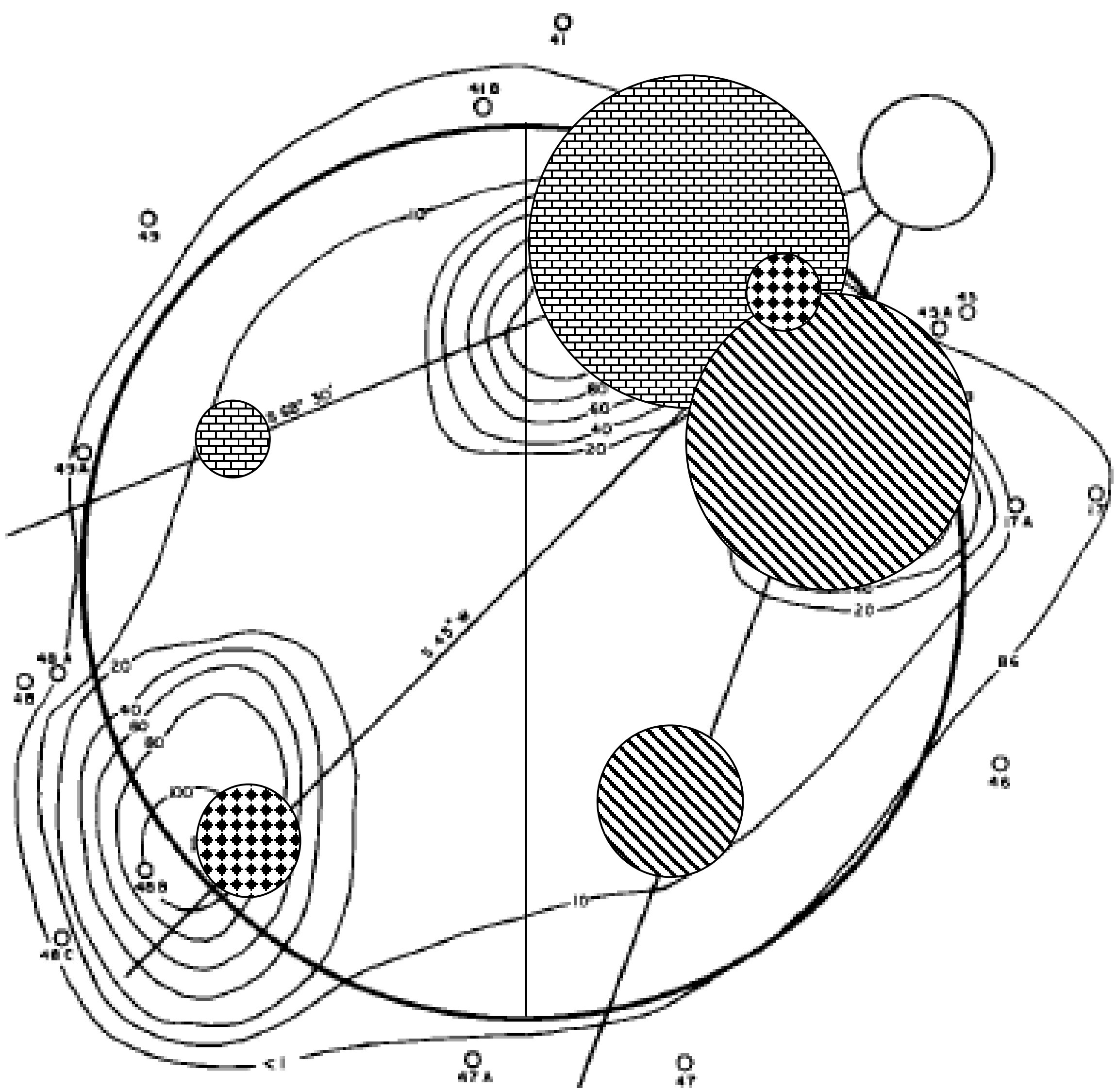
Although there is some overlay of ^{137}Cs activity zones between laterals, this will provide a conservative estimate of the ^{137}Cs loss beneath tank SX-115.

Calculation:

Total Ci in soil = π * [$(13)^2$ ft^2 * 2E5 pCi/g + $(6)^2$ ft^2 * 5E2 pCi/g + $(3)^2$ ft^2 * 2E2 pCi/g + $(5)^2$ ft^2 * 1E2 pCi/g + $(14)^2$ ft^2 * 3E7 pCi/g + $(3)^2$ ft^2 * 2E2 pCi/g] * 10 ft * 1.7 g/cm^3 * 1 Ci/10^{12} pCi * 28,320 cm^3/ft^3

= 8,940 Ci ^{137}Cs as of May 2005

Figure 5.10-11. Conceptual Model of Cesium-137 Contamination beneath Tank 241-SX-115



Note: Shaded areas correspond to width of ^{137}Cs activity detected in each lateral beneath tank 241-SX-115.

This conceptual model accounts for only about 60% of the estimated ^{137}Cs loss based on the liquid level decline and the September 1964 tank waste sample analysis. Raymond and Shdo estimated the ^{137}Cs inventory loss from tank SX-115 was 23,730 Ci (or ~9,000 Ci decay corrected to May 2008), based on their conceptual leak model and interpretation of drywell and lateral gamma scans (BNWL-CC-701 page 18). Coincidentally, the new conceptual leak loss model using the 2005 lateral surveys results in approximately the same ^{137}Cs inventory loss estimated by Raymond and Shdo. However, neither of the conceptual models agree with the ^{137}Cs inventory loss from tank SX-115 based on liquid level decline and the September 1964 supernate sample analysis. This discrepancy may be due to the waste having leaked beneath the tank in an area not covered by the laterals, the waste having leaked to an unknown depth beneath the laterals, or concentration differences in the waste leaked from the September 1964 sample analysis.

5.10.3 Conclusions

Based on measured liquid level decreases, tank SX-115 leaked up to 51,000 gal in 1965. The leak was a sodium nitrate solution derived from leaching the REDOX HLW sludge (HW-83906-E-RD page 62c) with a ^{137}Cs inventory of 16,800 Ci, based on September 1964 tank samples. To calculate inventories for other analytes, SIM inventories should be multiplied by a ratio of 1.13 accounting for volume and sample differences from current SIM estimates.

5.11 POTENTIAL PIPELINE FAILURES AND OTHER UNPLANNED RELEASES

DOE/RL-88-30, *Hanford Site Waste Management Units Report*, contains the official listing of UPRs identified at the Hanford Site. The operational history for the 241-SX Tank Farm was reviewed to determine if additional information exists for the UPRs within the 241-SX Tank Farm not associated with tank waste loss events. No significant new information was located for these UPRs. However, pipeline failures and near-surface releases not currently listed as UPRs and summarized in Table 5.11-1 were identified through review of the operational histories for the 241-SX Tank Farm. Insufficient information was available to estimate a leak volume or inventory for the identified pipeline failures.

Cascade line overflows are potential sources of near-surface contamination observed in other farms. However, the waste surface levels summarized in waste status transaction records and tank waste summary reports did not reach the height of the cascade overflow pipe for any of the SX-Farm tanks.

Table 5.11-1. Potential Pipeline Failures and Other Unplanned Waste Releases (3 sheets)

Date	Event	Comments
	Diversion box work in January and February 1953 resulted in extensive ground contamination. An area around the box of approximately 1,000 ft^2 was covered with 6 in. of clean gravel. This is roped off and posted with radiation zone signs.[a]	
7-1954[a]	The REDOX stack was flushed and approximately 20,000 gal of flush water drained into a pit 20 ft wide, 90 ft long and 10 ft deep situated in the NE corner of the REDOX exclusion area. An estimated 5 Ci of beta particle emitters and 2-3 Ci of gamma particle emitters, predominantly Ru and Zr-Nb, were disposed of here and covered with several feet of clean soil.	
9-1955[b]	Airlift circulator for tank 241-SX-101 waste loss to ground: The 104-SX air lift is continuing to function satisfactorily with an air flow of 4 to 5 cfm. However, the air lift on 101-SX was taken out of service following the release of contamination at grade level. The tank is being agitated with the mechanical auger which is apparently giving satisfactory results.	
6-1957[c]	241-SX Tank Farm: The nine air-cooled condensers which extend above the waste tanks in the 241-SX tank farms developed leaks around the base gaskets. Sealing was accomplished by pouring additional concrete around the condenser bases in sufficient quantity to cover the flanged areas.	Surface contamination within confines of tank farm site 200-W-96
7-1958[d]	On July 22, 1958 the ground between the 241-SX-111 and 241-SX-113 tanks was contaminated with levels up to 6 rads/h. This UPR is a 5,000 ft^2 area found outside the SE corner of SX-Farm on July 31, 1958 with dose readings of 150 millirads/h and a single spot of 10 rad/h attributed to wind spread of the in-farm contamination.	Surface contamination. UPR-200-W-49
9-1958[a]	A contamination spread from 241-S-151 diversion box. This oval shaped area up to 300 ft wide covers ground immediately south of the box toward 10th Street in the 200 West Area and includes the 207 basin at the South end. The soil was saturated with water and turned over with a bull dozer. Beta/gamma readings 50 millirad/h w/I 100 ft of diversion box and ~ 1 rad/h at the box.	UPR-200-W-51, UPR-200-W-20
10-1958[e]	Plugged line and Pipeline leak in 241-SX and 241-TX Tank Farm: Of the two available lines for pumping non-boiling waste from the 241-SX to the 241-TX Tank Farm, one was found to be plugged, the other to have a leak. This situation made necessary an alternative program consisting of pumping the waste to the 101, 102, and 103 tanks in the 241-U farm. The pump out of the 111-SX tank will make this tank available for raw salt waste from the 202-S Building.	**Identified in RPP-25113 as a failed line.**

Table 5.11-1. Potential Pipeline Failures and Other Unplanned Waste Releases (3 sheets)

Date	Event	Comments
11-1959[f]	Diversion valve located nearby Tank 241-SX-112: On 11-12-59 a significant leak was detected in a diversion valve located in the valve pit near the 112-SX boiling waste tank. Condensate from waste storage tanks 101-SX through 105-SX, is collected in the 106-SX de-entrainment tank and then pumped, as directed by the Redox Process Technology Operation, to any one of the boiling waste tanks 107-SX through 115-SX. Direction of flow is controlled through valving located in the valve pit near the 112-SX tank. Since the valve pit has no catch tank, any liquid losses are diverted to the immediate ground area. From inventory losses observed over the past four months, during condensate transfers from the 106-SX tank, it is **estimated that a maximum of 25,000 gallons of condensate containing 80 to 100 curies of cesium have been discharged to ground** via the leaking diversion valve and the valve pit. However, dry-well readings in the 241-SX Tank Farm Area have indicated no increase in activity, continuing to remain within the normal level of less than 100 cpm.	HW-63706-DEL, pages C-2 and E-2 indicates 8 inches of magnetite ore and 12 inches of concrete were placed atop the earth floor in the valve pit to reduce the radiation dose rate. The leaking condensate valve was replaced. Included in UPR-200-W-144 and UPR-W-200-94 (Contaminated soil at 241-S/SX/SY Tank Farms).
7-11-1961	SX pump and elephant trunk removed for burial. All but last 3 or 4 ft fabrifilmed and whole assembly placed in plastic bag as pulled out of pump pit. 10 x 20 ft area around pump pit contaminated to 5 rads/h including 3 r/h 3 ft above the ground. 100 yards of the road to burial ground with spots reading up to 40 mr/hr. Small area around waste trench read 1,000,000 dpm.	Historical occurrence reports
12-3-1962[g]	Failed pipeline valve Tank 241-SX-101 and 241-SX-102: 241-SX Condensate Return System A bad leak developed at the isolation valve between the 101 and 102-SX Tank, in the condensate return system. Excavated and attempted to replace the faulty valve; however, the opposing flanges did not line up. It was necessary to blank this line on both flanges. This will not affect the operation of this system, as pumping can be attained in either direction.	
03-19-1965[h]	Tank 241-SX-103: A higher concentration of suspected leaker tanks continues in an effort to help seal the leaks. Pumped part of 103-SX to 101-TX; then while transferring 103-SX to 101-TX, the flush riser valve failed on 3-19-1965. While pumping 103-SX to 101-TX, a leak was discovered outside the pump pit. Tried to replace the valve but found out it so "hot" maintenance couldn't get to it, so a new line was installed from 102-SX pump pit into 103-SX pump pit. To pump into or out of 103-SX pump pit, the 102-SX routing must be used.	
11-18-1965[i,j]	Tank 241-SX-102: 102-SX to 105-TX was pumped for 3 days (520,225 gal pumped out of 102-SX) when a leak developed at the 102-SX transfer valve. **Approximately 4,000 gal of radioactive wastes were lost to the ground.** Contamination controls were initiated and no spread nor exposure to personnel were in evidence.	Contaminated soil in the vicinity of tanks 241-SX-102 and 241-SX-103 pump pits was removed in September through November 1972 per ARH-2348 RD, pages 25 and 55.

Table 5.11-1. Potential Pipeline Failures and Other Unplanned Waste Releases (3 sheets)

Date	Event	Comments
5-1966[j]	Tanks 241-SX-102 and 241-SX-103: The 102 – 103-SX transfer valves have been leaking. The leakage has caused the surrounding dirt to harden and become highly radioactive, making excavation of the valves most difficult. Excavation has been carried out by working from behind a radiation shield and loosening the dirt with a jack-hammer equipped with a twenty-foot extension. The loose dirt is then removed with a "clam bucket" and placed in a "sluff trench". A sample of dirt has been sent to Al Case to see if a way can be found to soften the dirt and make the excavation less difficult.	Surface contamination within confines of tank farm site 200-W-96

dpm = disintegrations per minute
cpm = counts per minute

[a]HW-60807, *Unconfined Underground Radioactive Waste and Contamination in the 200 Areas – 1959*

[b]HAN-62372-DEL, *200 Area Monthly Reports for 1955*, page 4

[c]HW-51211, *Chemical Processing Department Monthly Report for June 1957*, page F-3

[d]PNL-6456, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford*

[e]HW-58051, *Chemical Processing Department Monthly Report for October, 1958*, page D-3

[f]HW-62864-DEL, *Chemical Processing Department Monthly Report for November, 1959*, page D-3

[g]*Monthly Report Waste Handling and Decontamination Operation REDOX Operation November 1962*, Rough Draft (Harmon 1962), page 2

[h]RL-SEP-297, *REDOX Weekly Process Reports January through December, 1965*, page 77

[i]RL-SEP-297, page 174

[j]ISO-75 RD, *Fission Products Process Engineering Monthly Reports January – December, 1966*, page 79

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APPENDIX A

THERMAL HISTORY FOR 241-SX TANKS
(From RHO-CD-1172)

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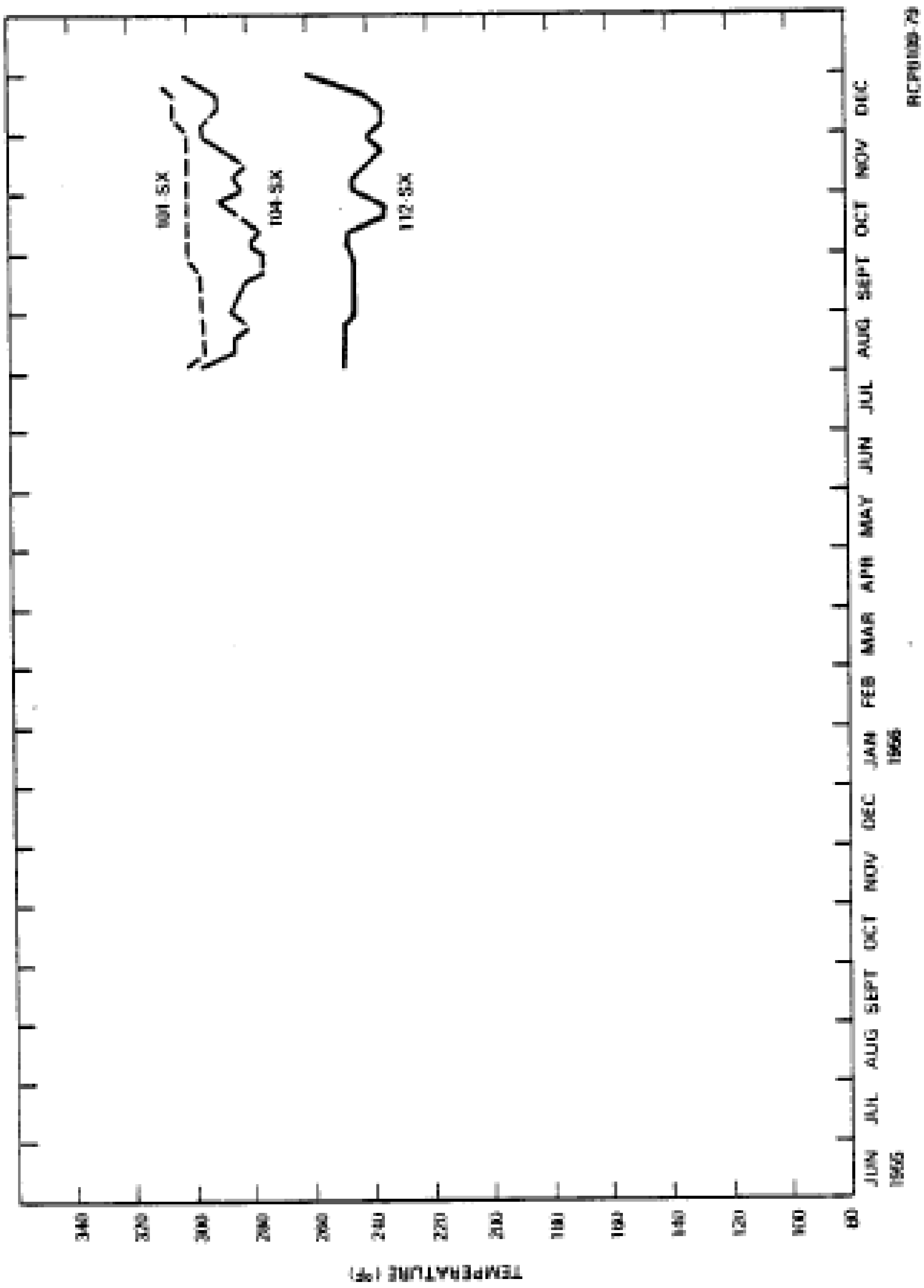

FIGURE B-73. 241-SX-101, -104, -112 (Bulb Temp.)
August 1956 - December 1956

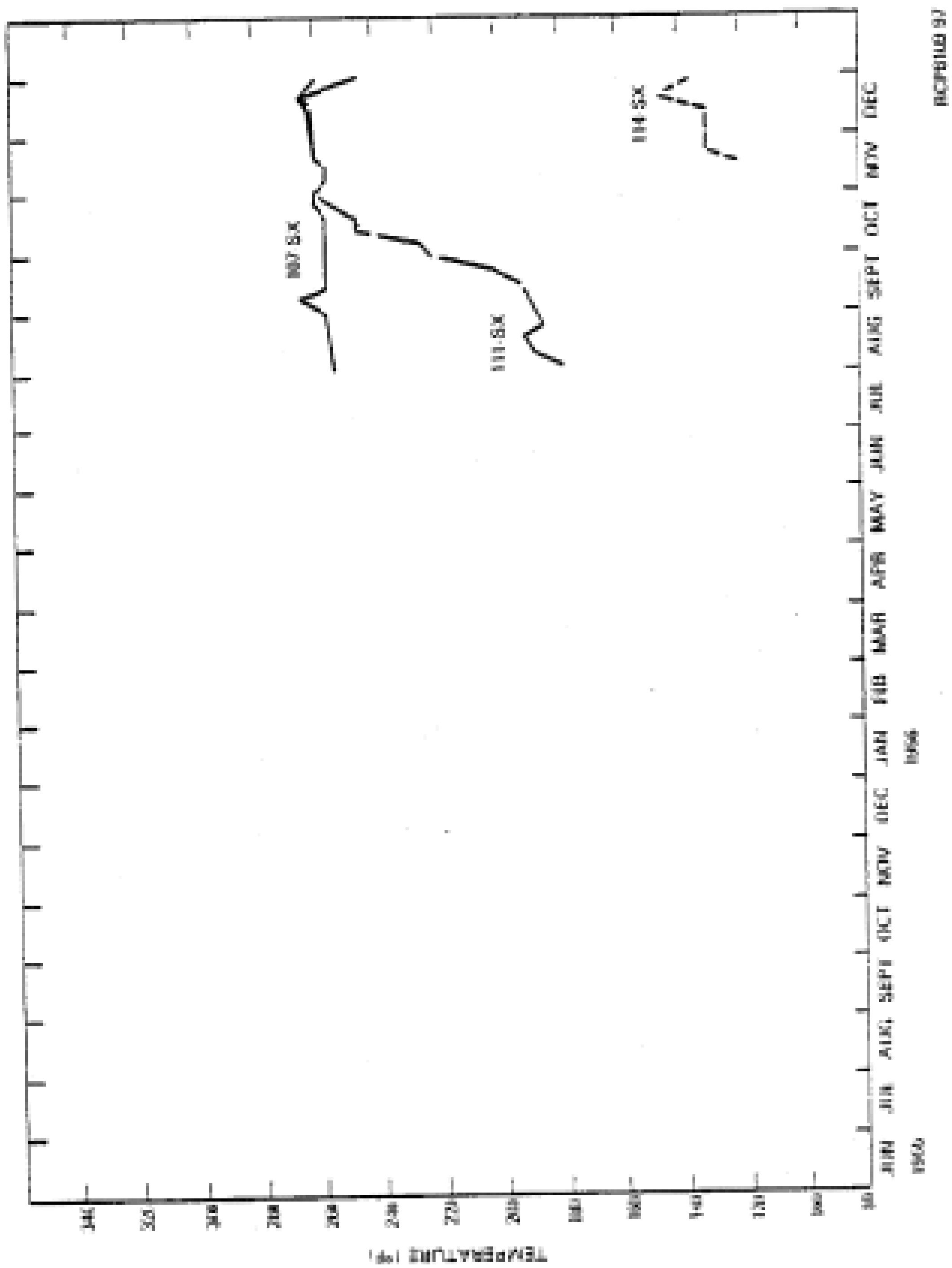

FIGURE B-75. 241-SX-107, -111, and -114 (Bulb Temp.)
August 1956 thru December 1956

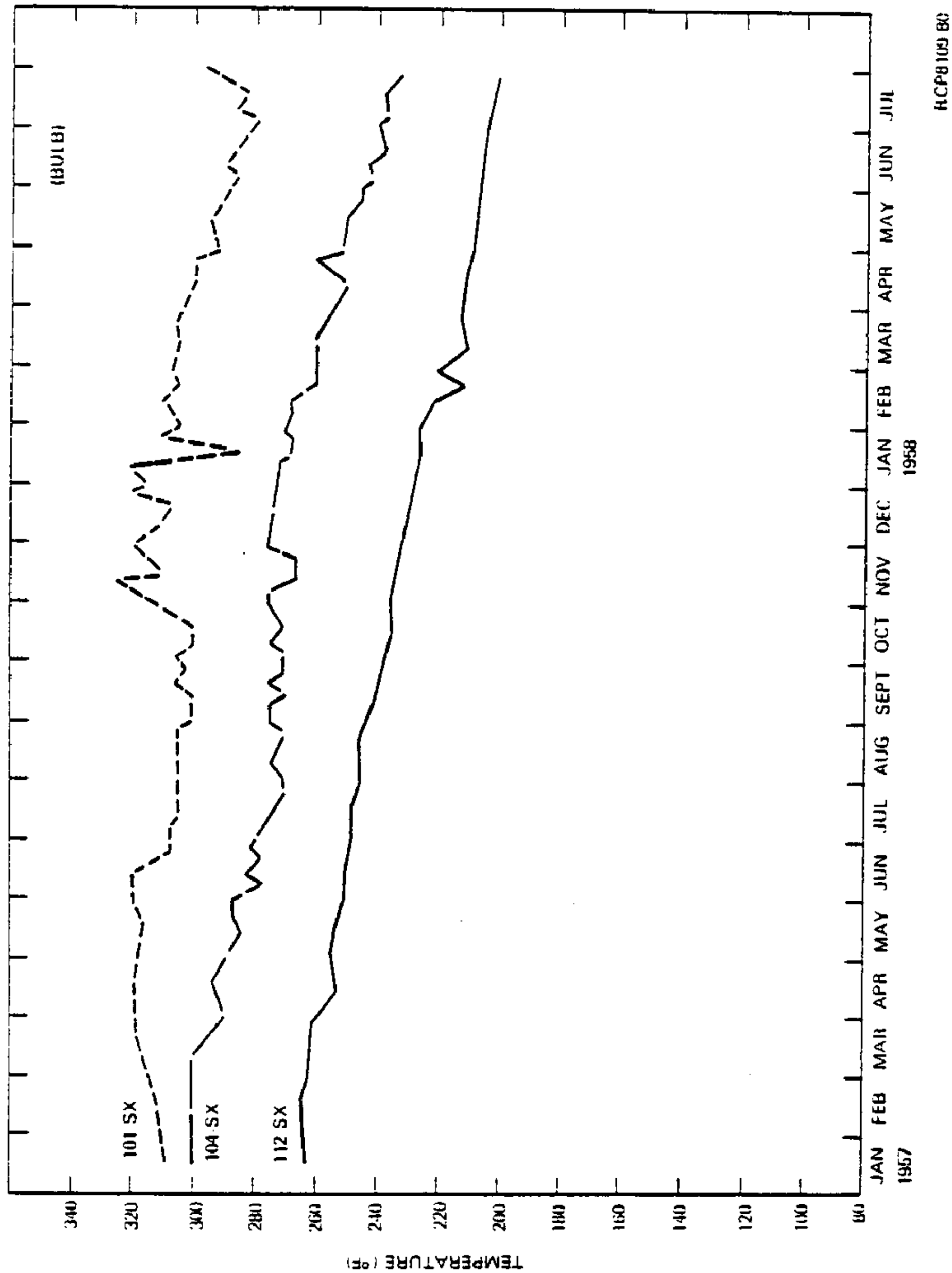

FIGURE B-78. 241-SX-101, -104, and -112 (Bulb Temp.) January 1957 thru July 1958

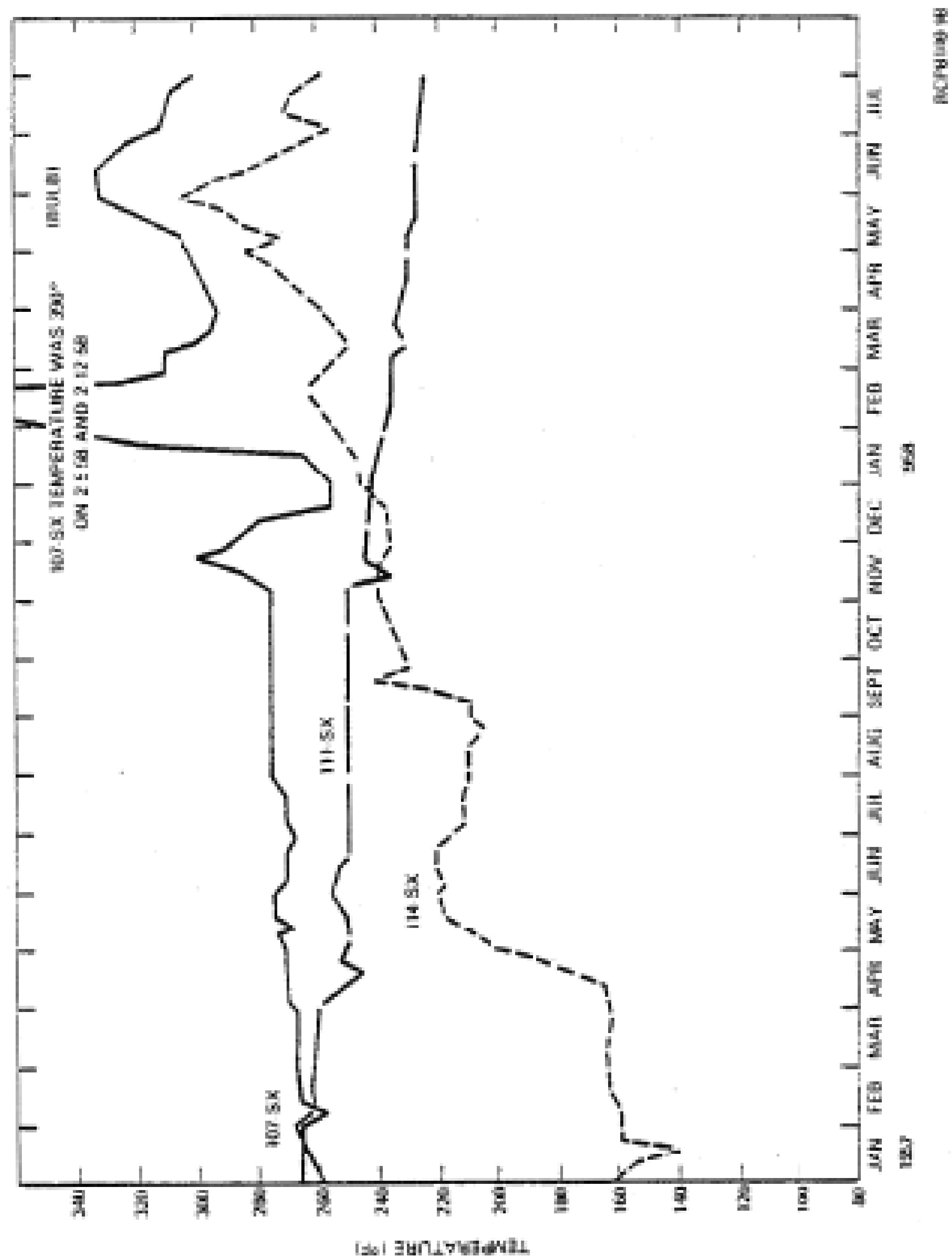

FIGURE B-80. 241-SX-107, -111, and -114 (Bulb Temp.)
January 1957 thru July 1958

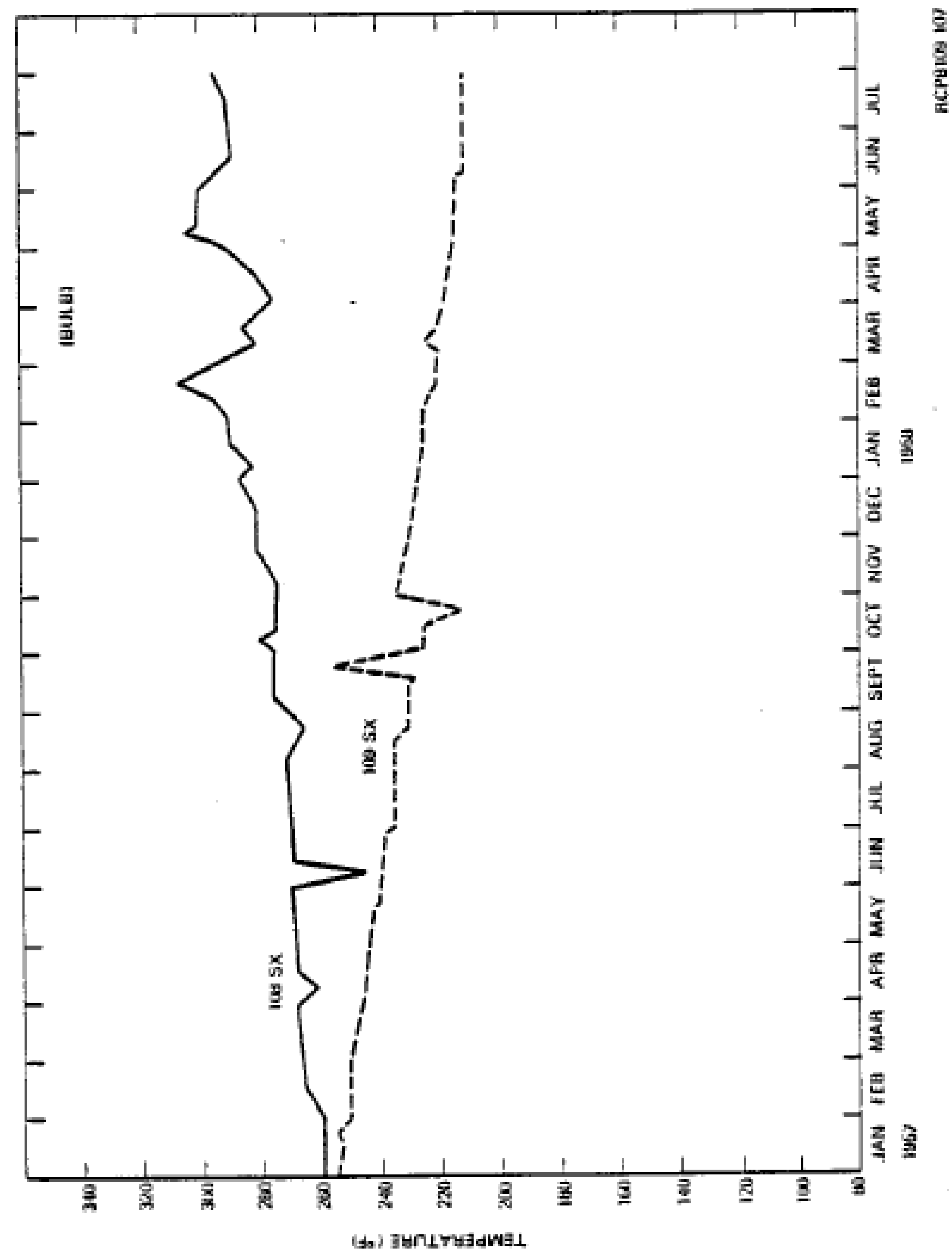

FIGURE B-81. 241-SX-108 and -109 (Bulb Temp.) January 1957 thru July 1958

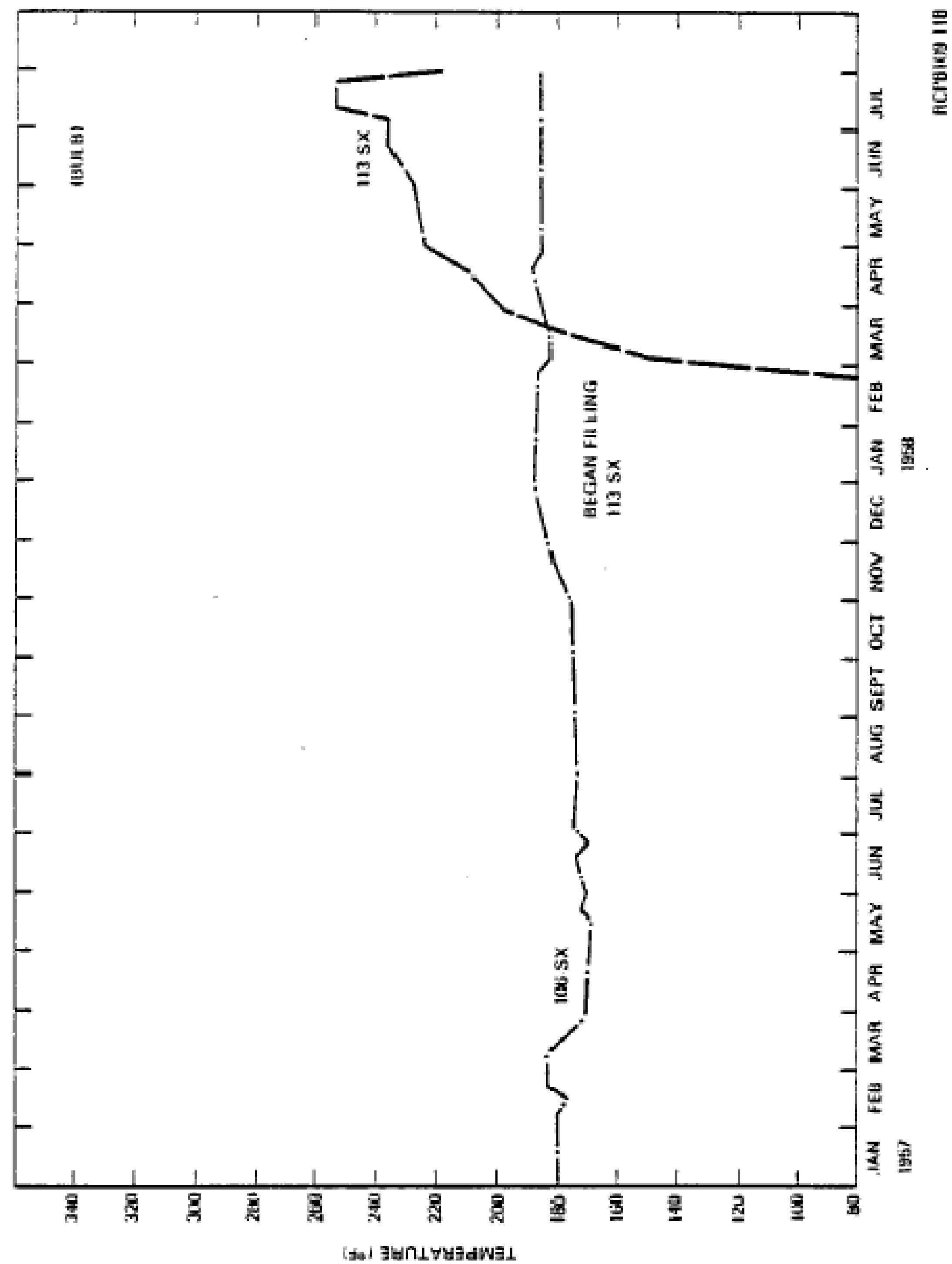

FIGURE B-82. 241-SX-106 and -113 (Bulb Temp.)
January 1957 thru July 1958

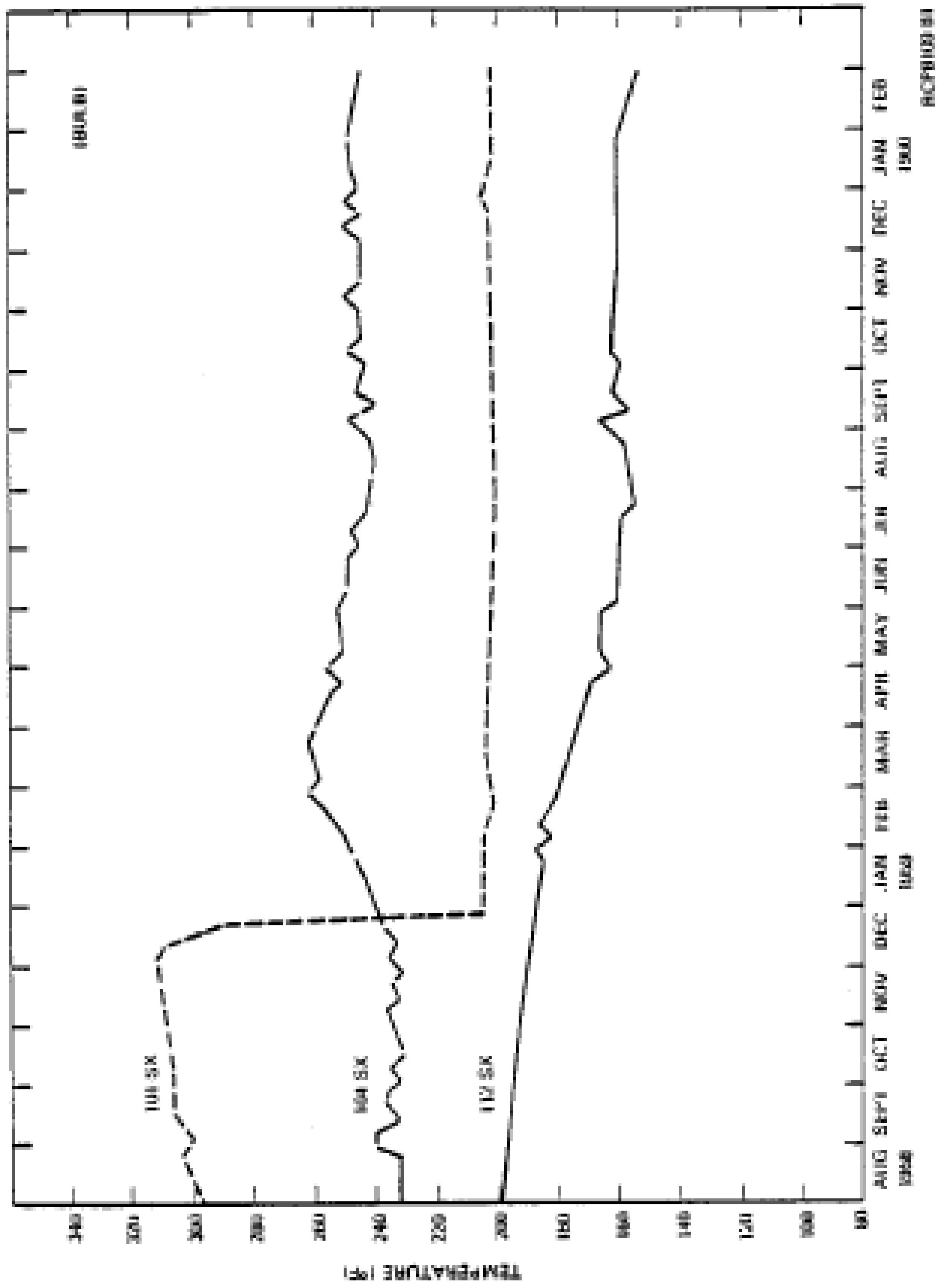

FIGURE B-83. 241-SX-101, -104, and -112 (Bulb Temp.) August 1958 thru February 1960

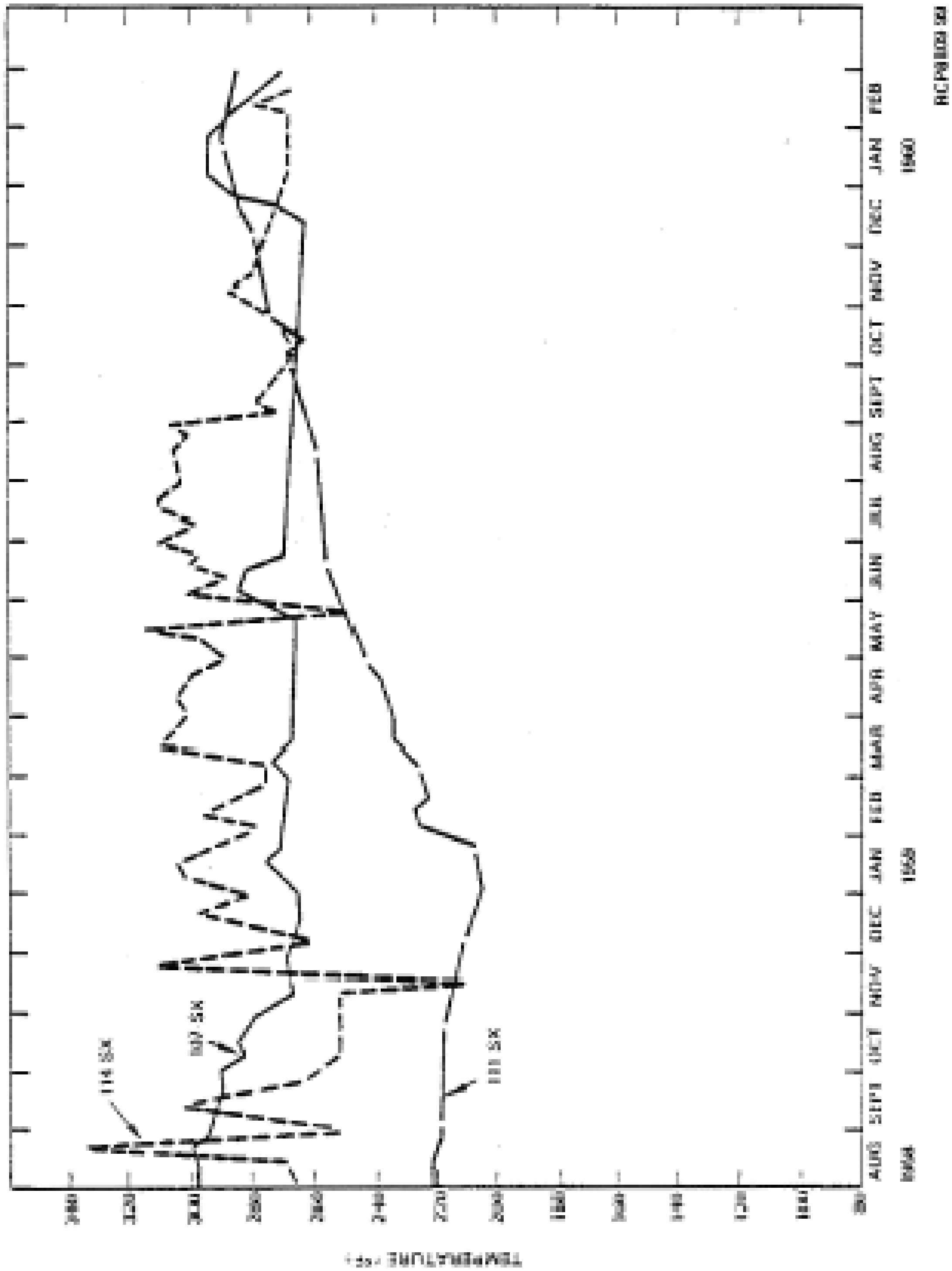

FIGURE B-85. 241-SX-107, -111, and -114 (Bulb Temp.) August 1958 thru February 1960

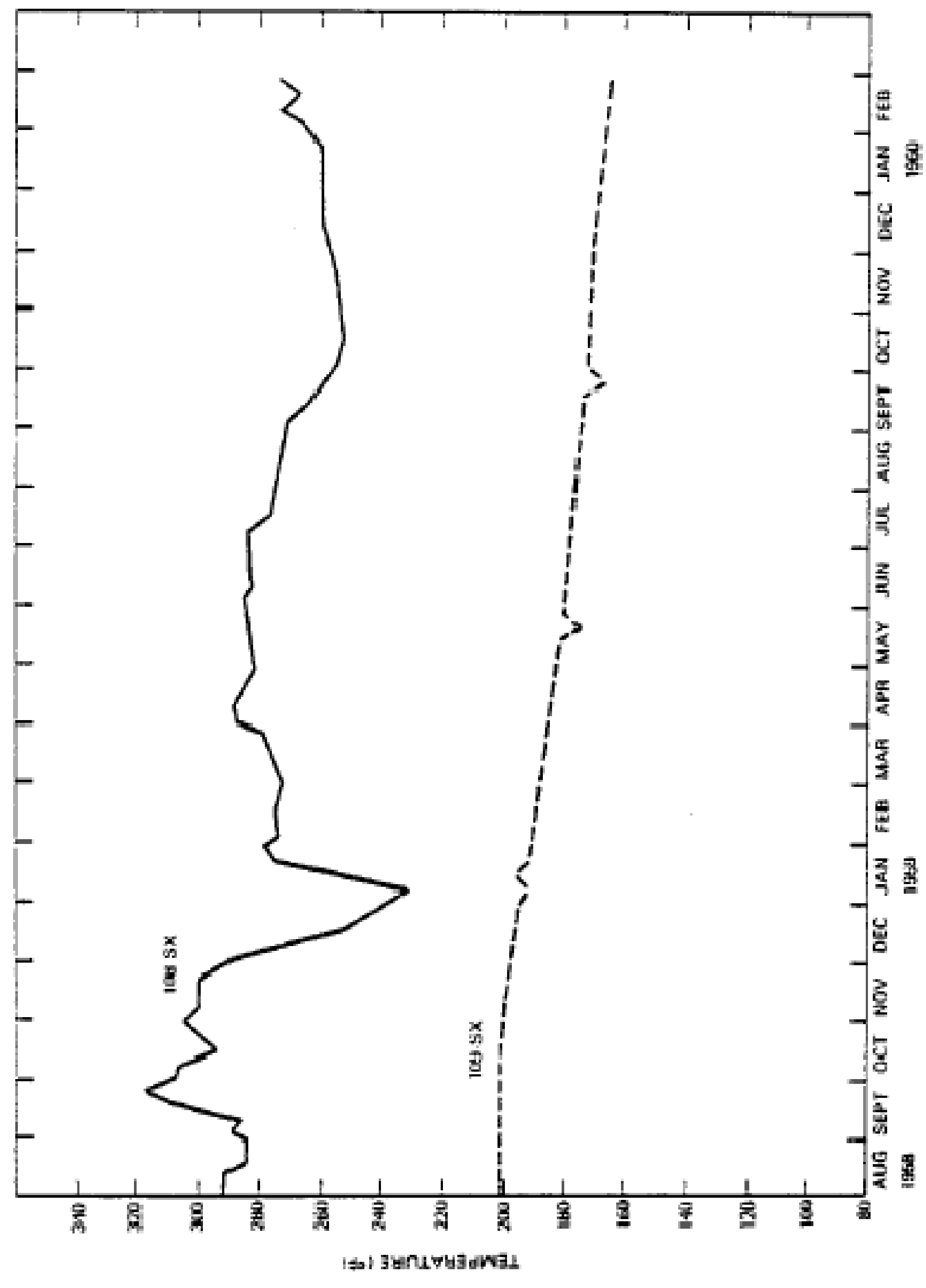

FIGURE B-86. 241-SX-108 and -109 (Bulb Temp.)
August 1958 thru February 1960

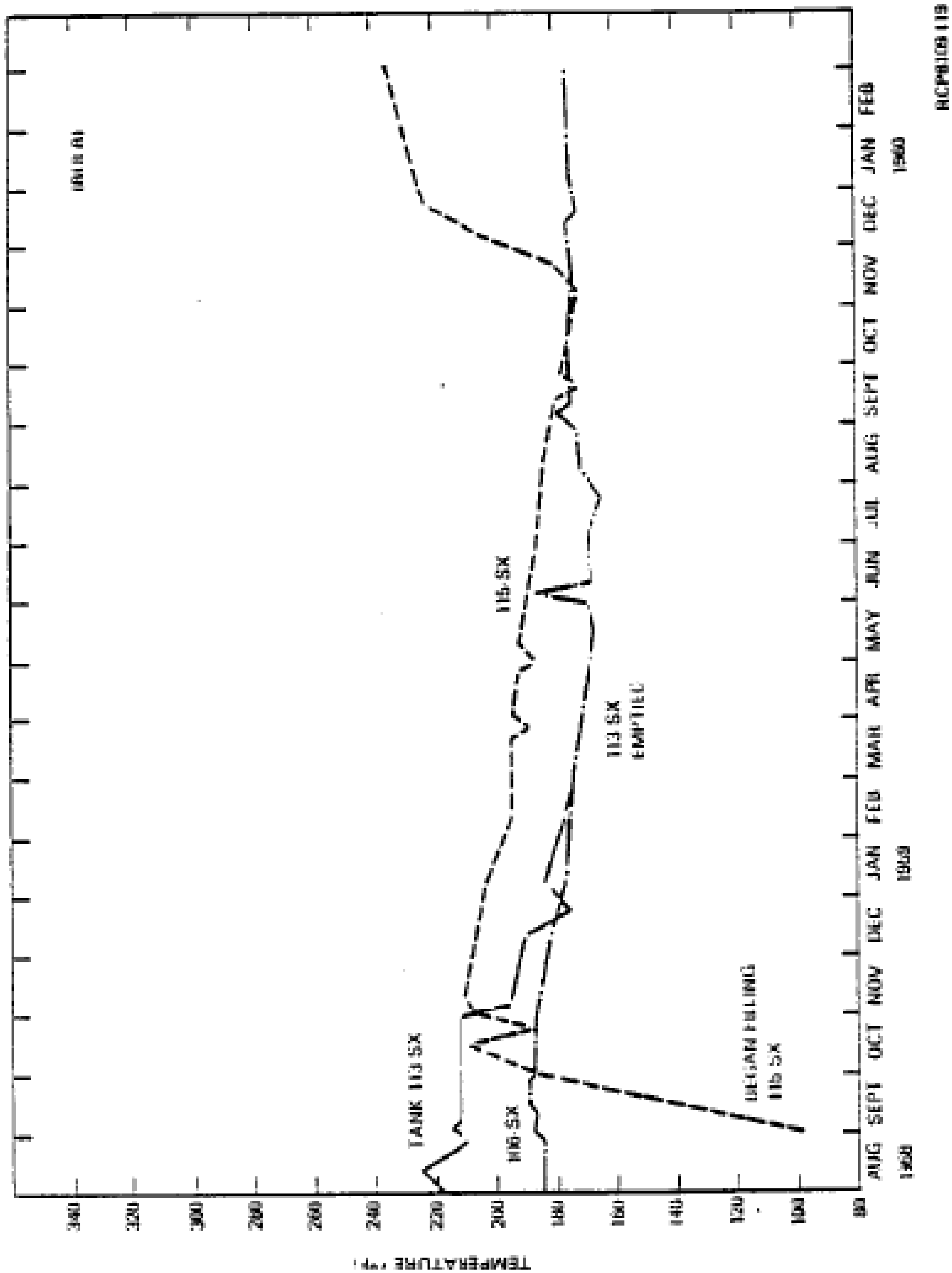

FIGURE B-87. 241-SX-105, -113, and -115 (Bulb Temp.) August 1958 thru February 1960

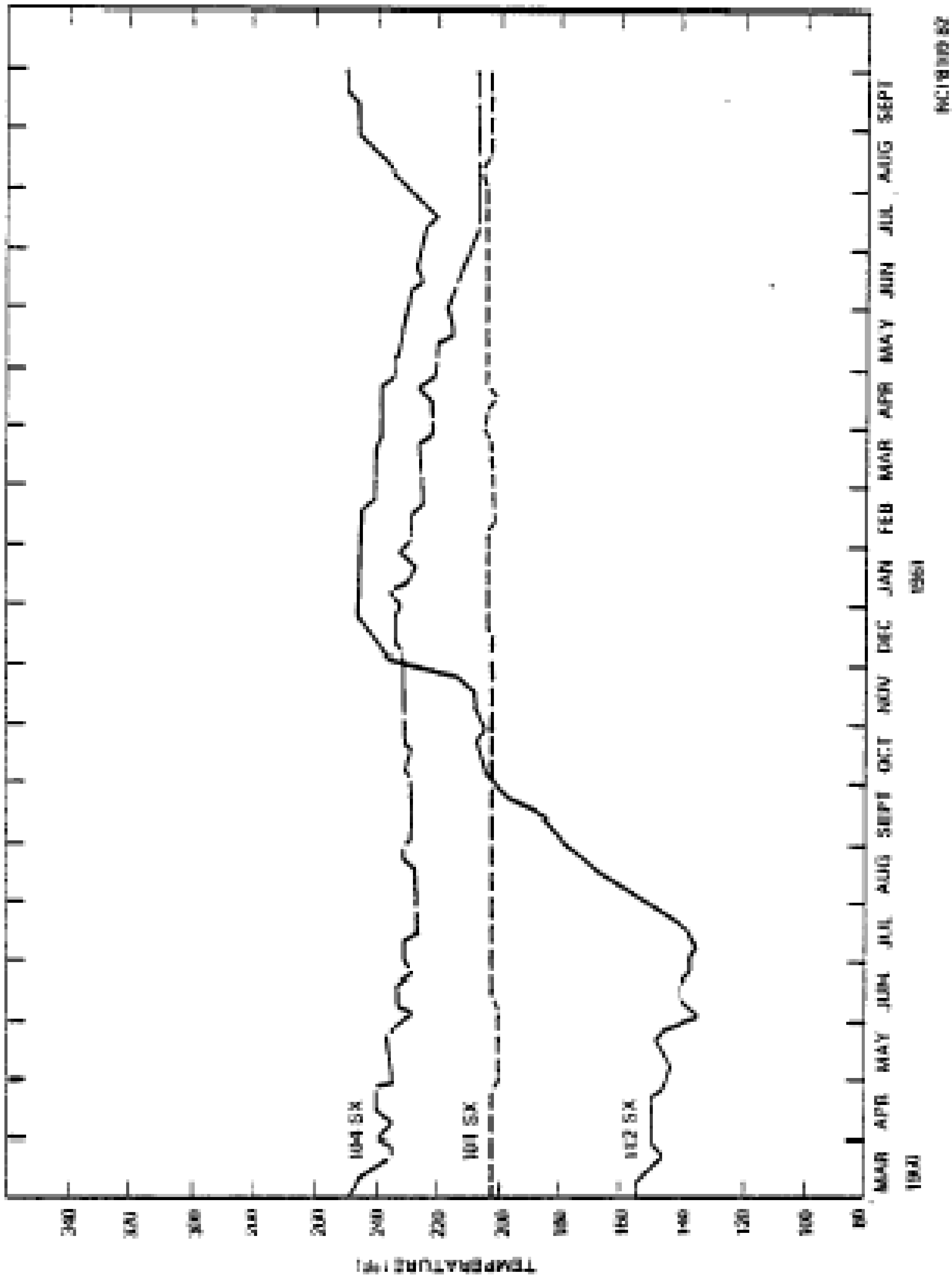

FIGURE B-88. 241-SX-101, -104, and -112 (Bulb Temp.)
March 1960 thru September 1961

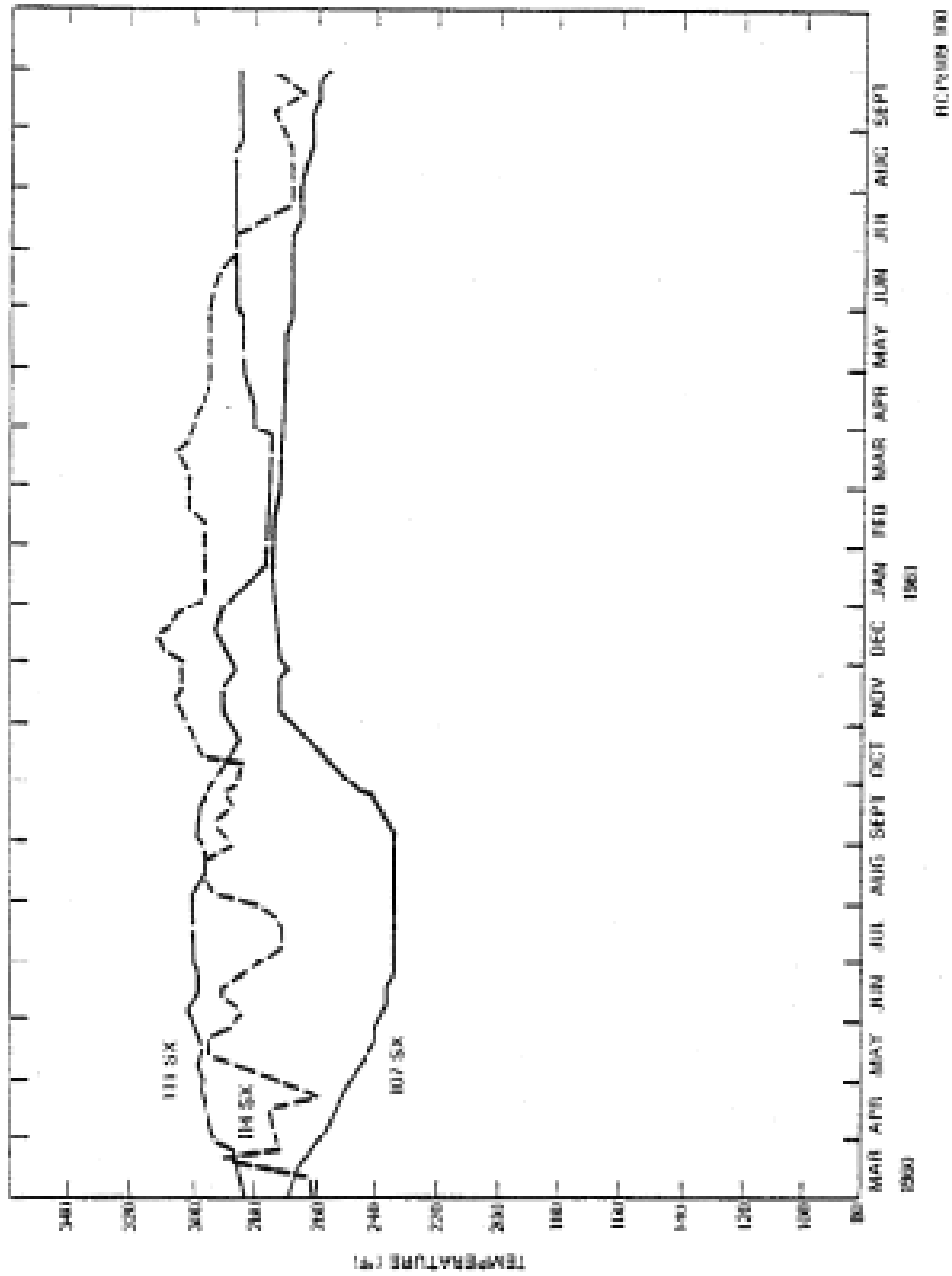

FIGURE B-9D. 241-SX-107, -111, and -114 (Bulb Temp.) March 1960 thru September 1961

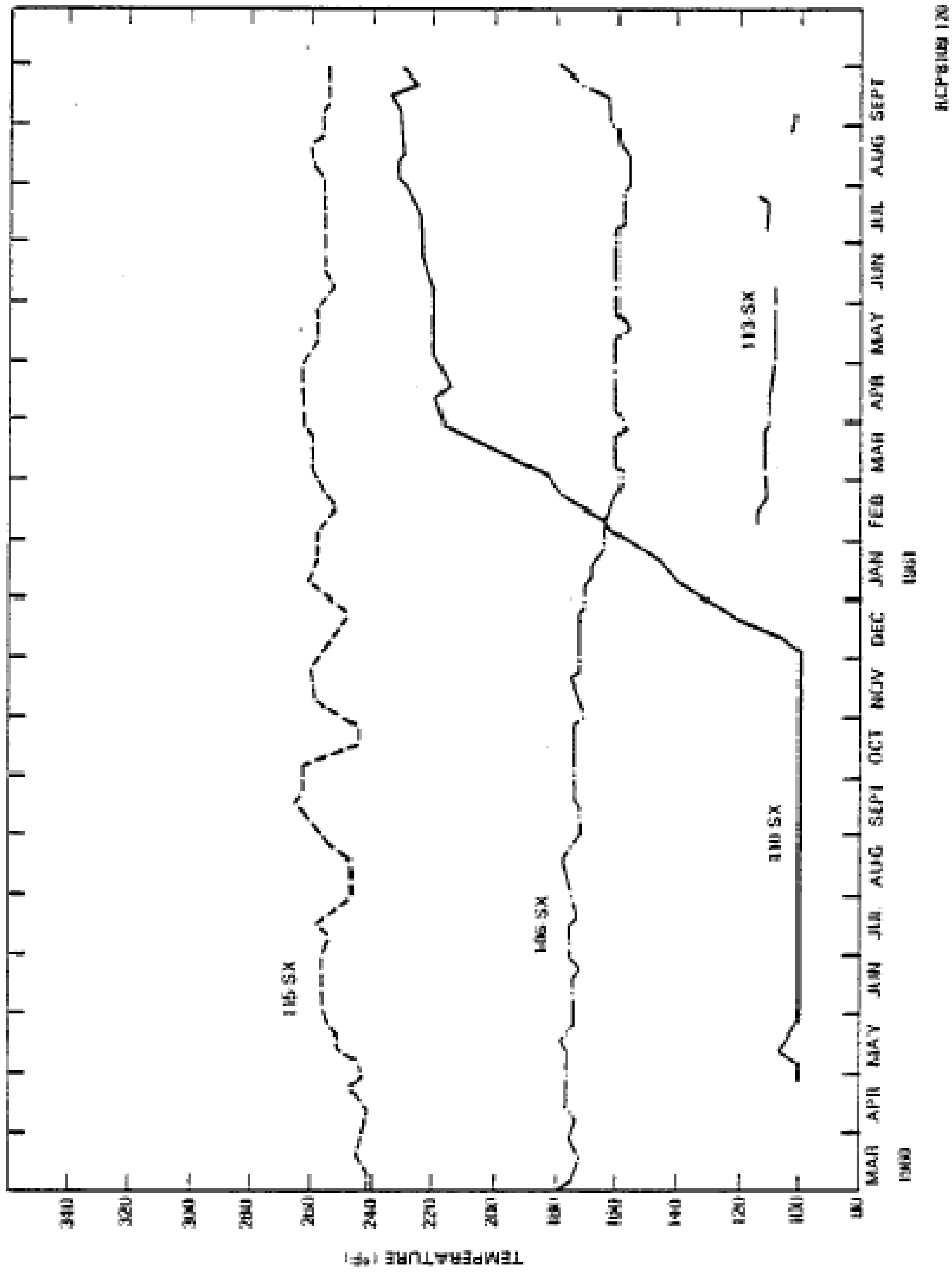

FIGURE B-91. 241-SX-106, -110, -113, and -115 (Bulb Temp.)
March 1960 thru September 1961

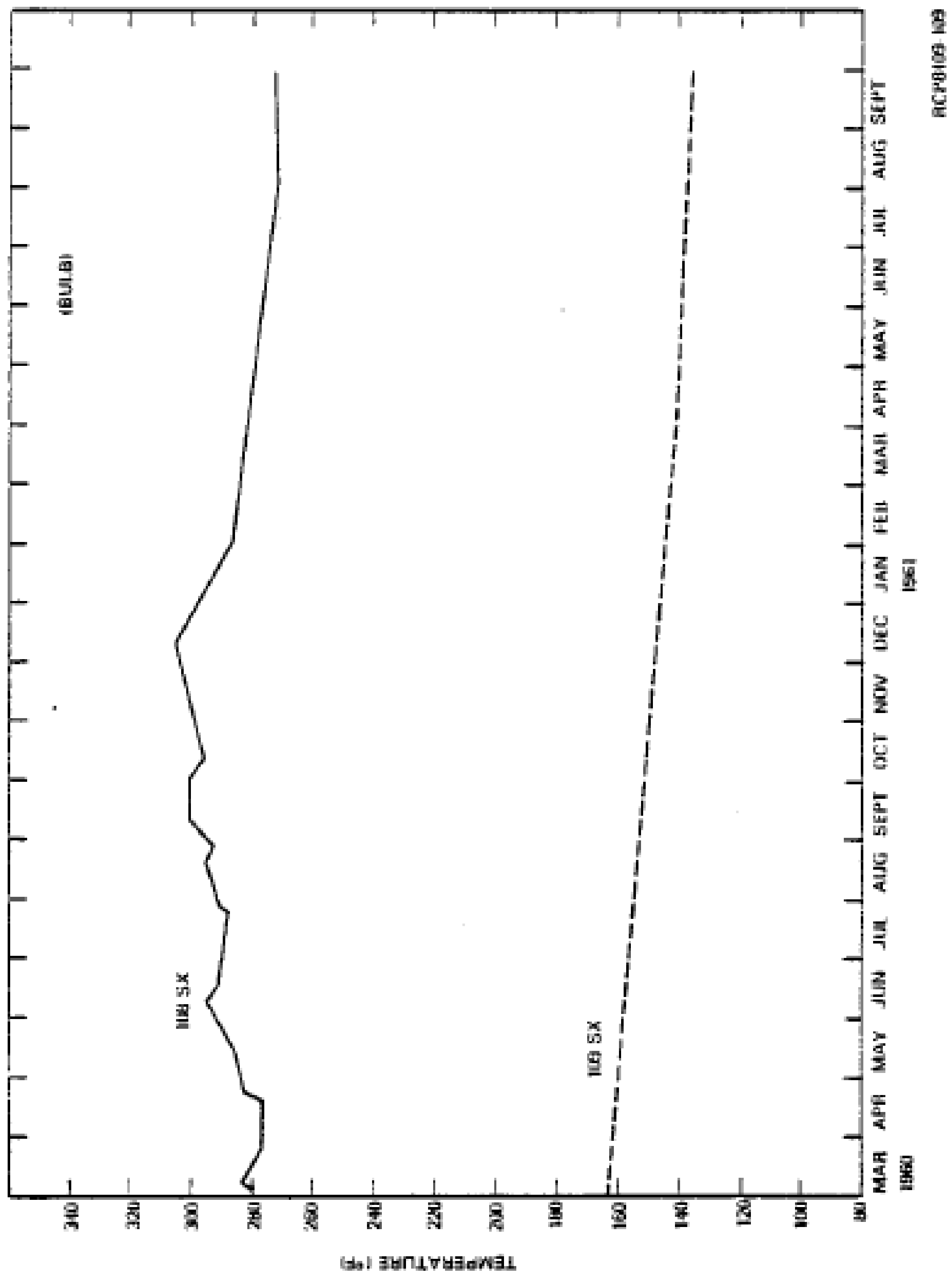

FIGURE B-92. 241-SX-108 and -109 (Bulb Temp.)
March 1960 thru September 1961

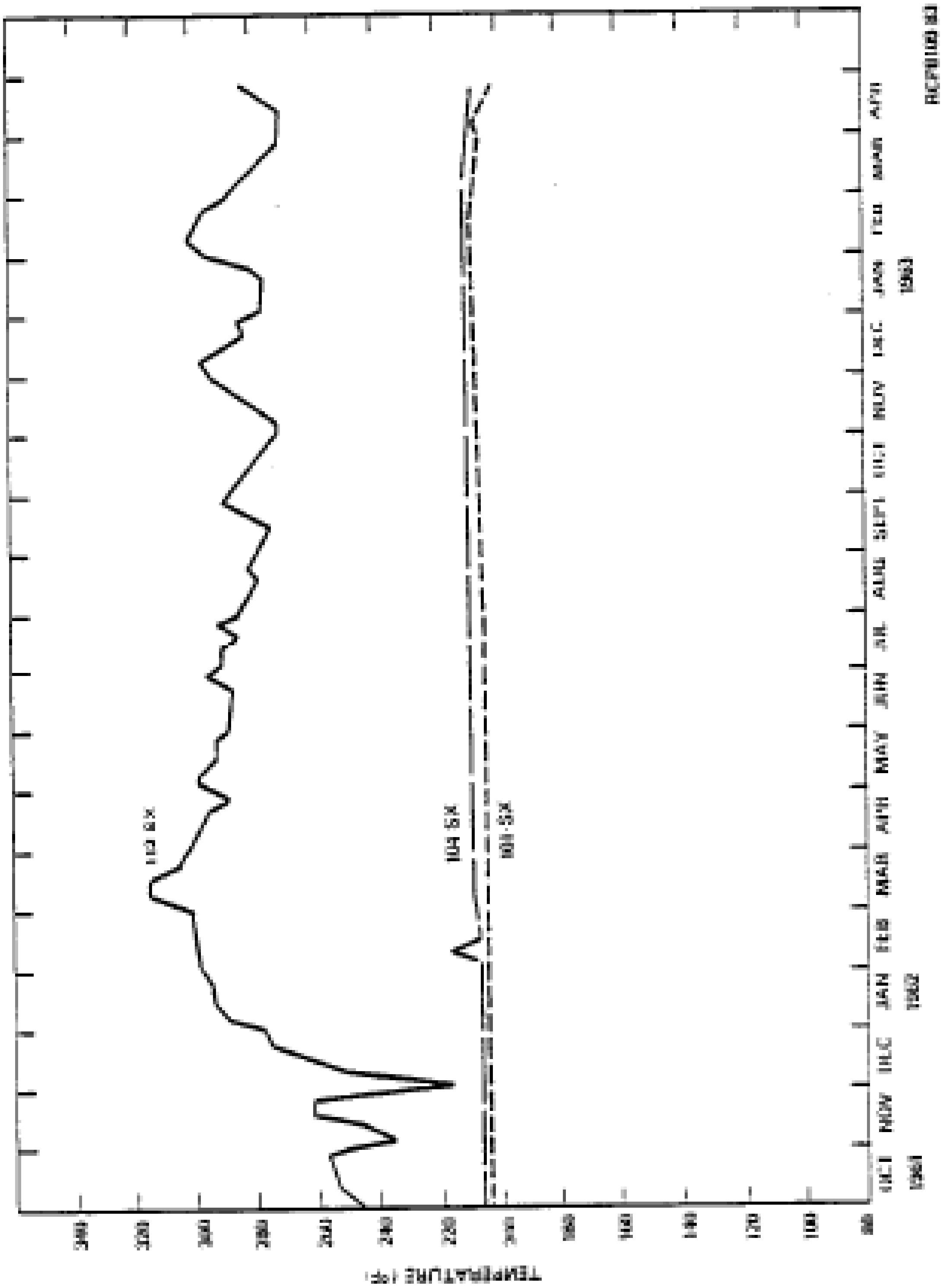

FIGURE B-93. 241-SX-101, -104, and -112 (Bulb Temp.) October 1961 thru April 1963

B-93

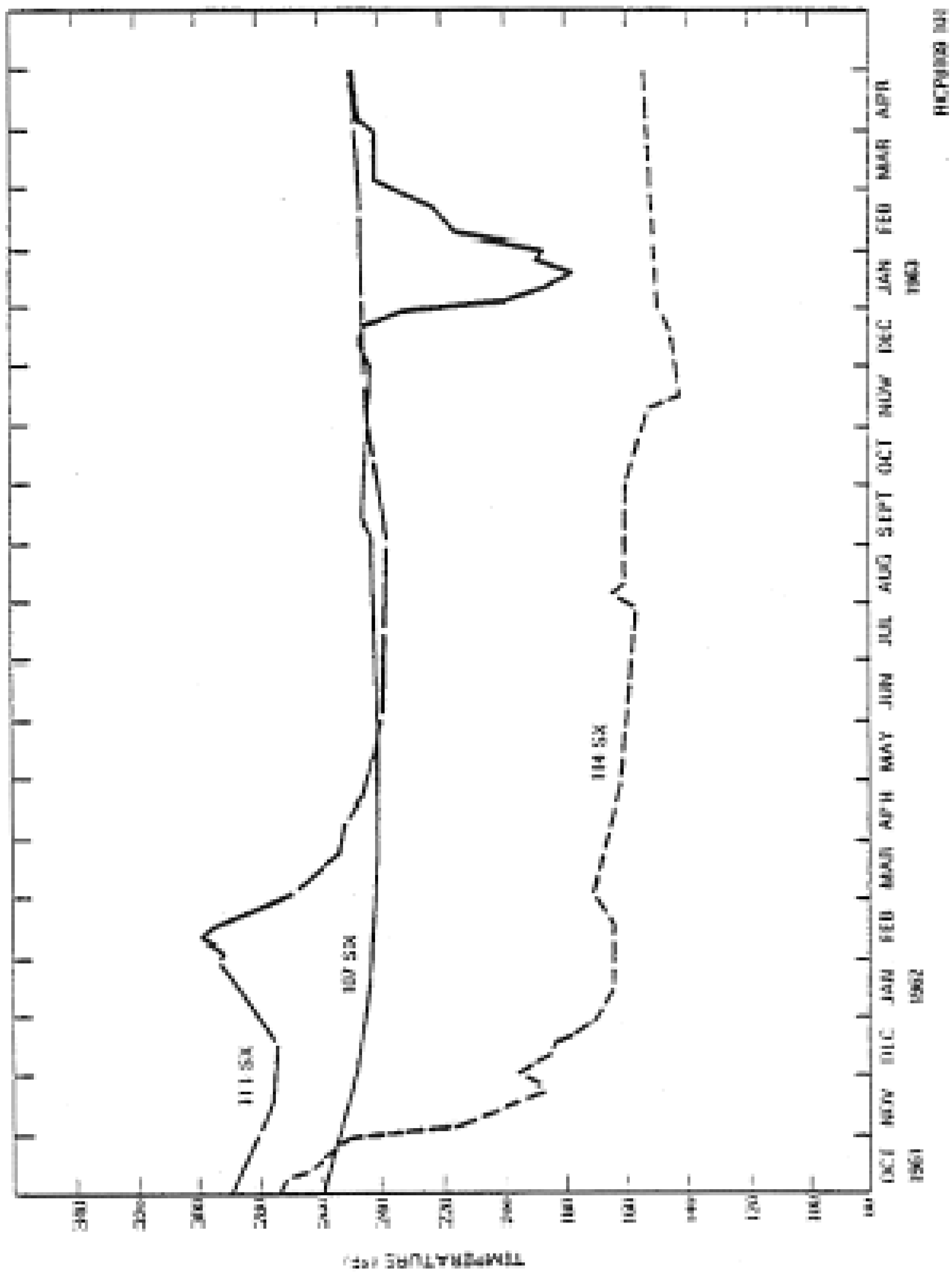

FIGURE B-95. 241-SX-107, -111, and -114 (Bulb Temp.) October 1961 thru April 1963

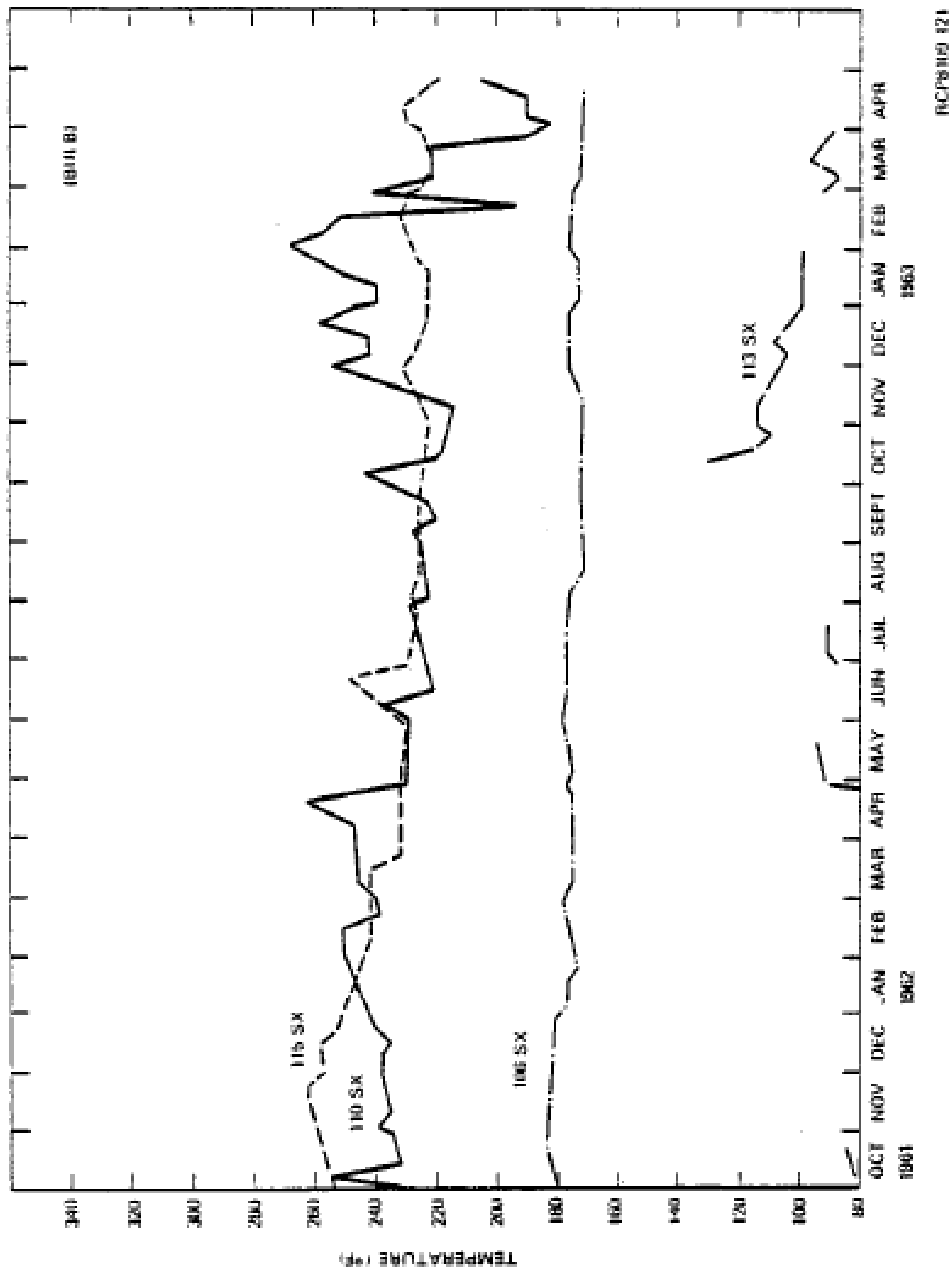

FIGURE B-96. 241-SX-106, -110, -113, and -115 (Bulb Temp.) October 1961 thru April 1963

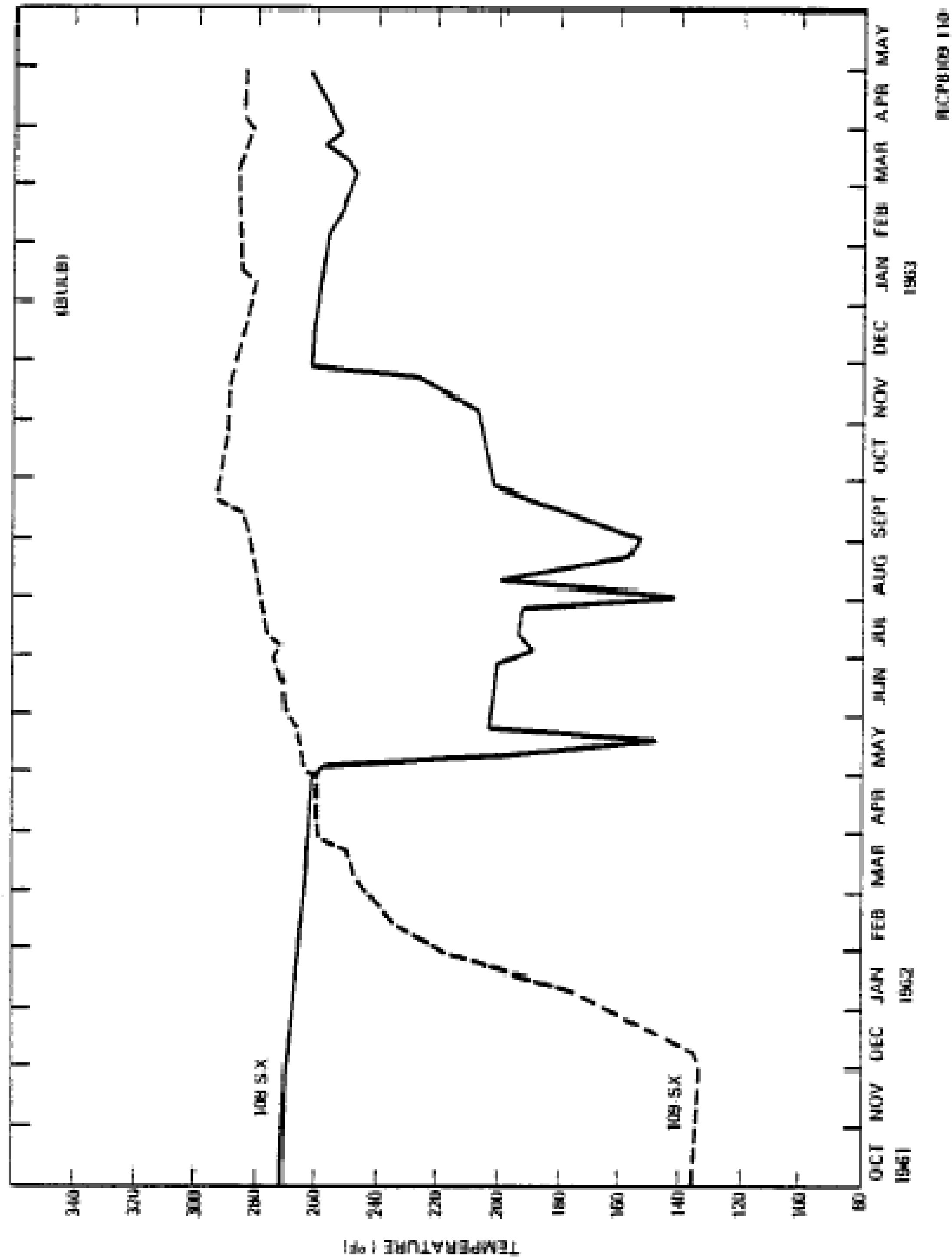

FIGURE B-97. 241-SX-108 and -109 (Bulb Temp.)
October 1961 thru May 1963

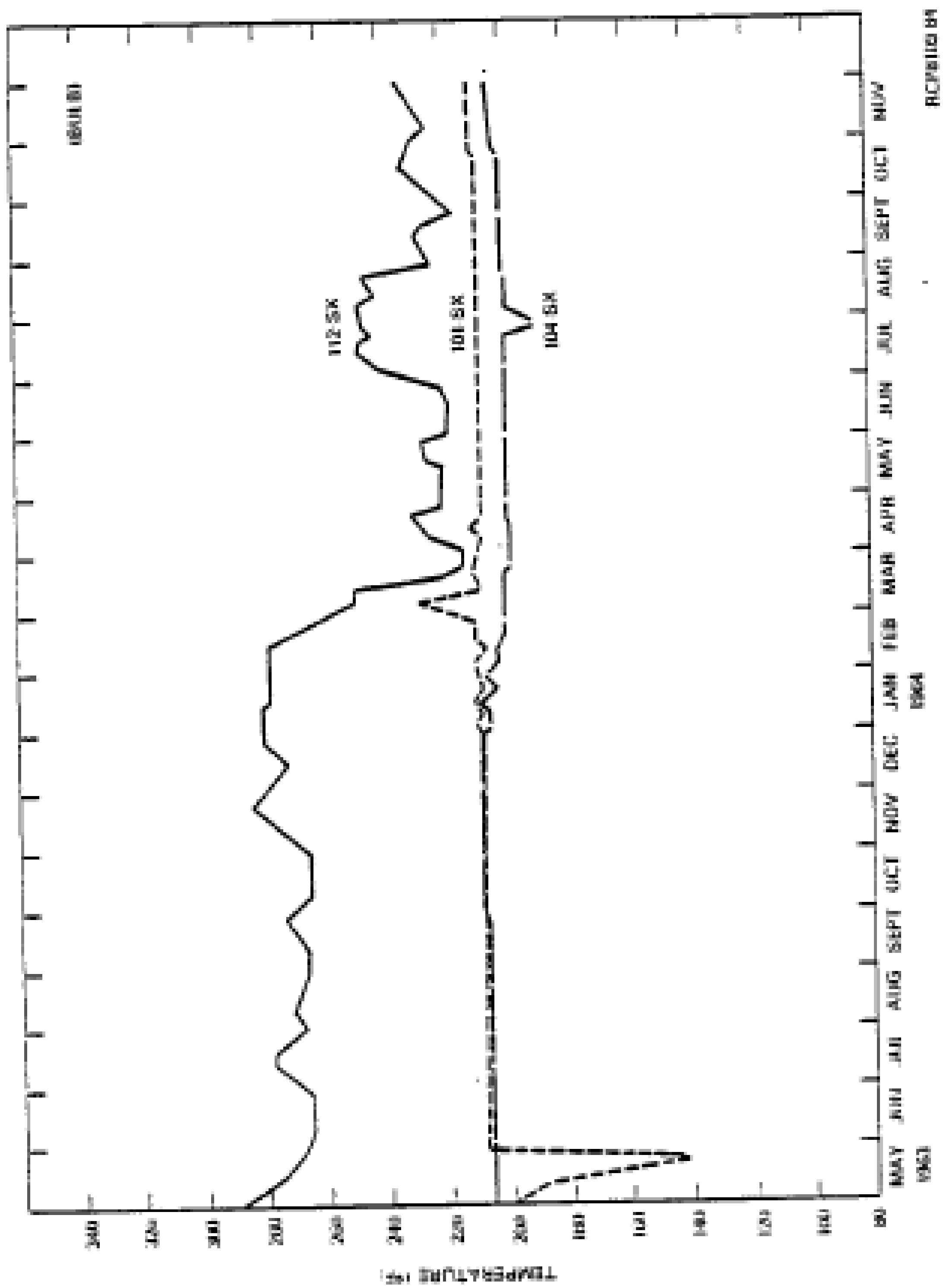

FIGURE B-98. 241-SX-101, -104, and -112 (Bulb Temp.) May 1963 thru November 1964

B-98

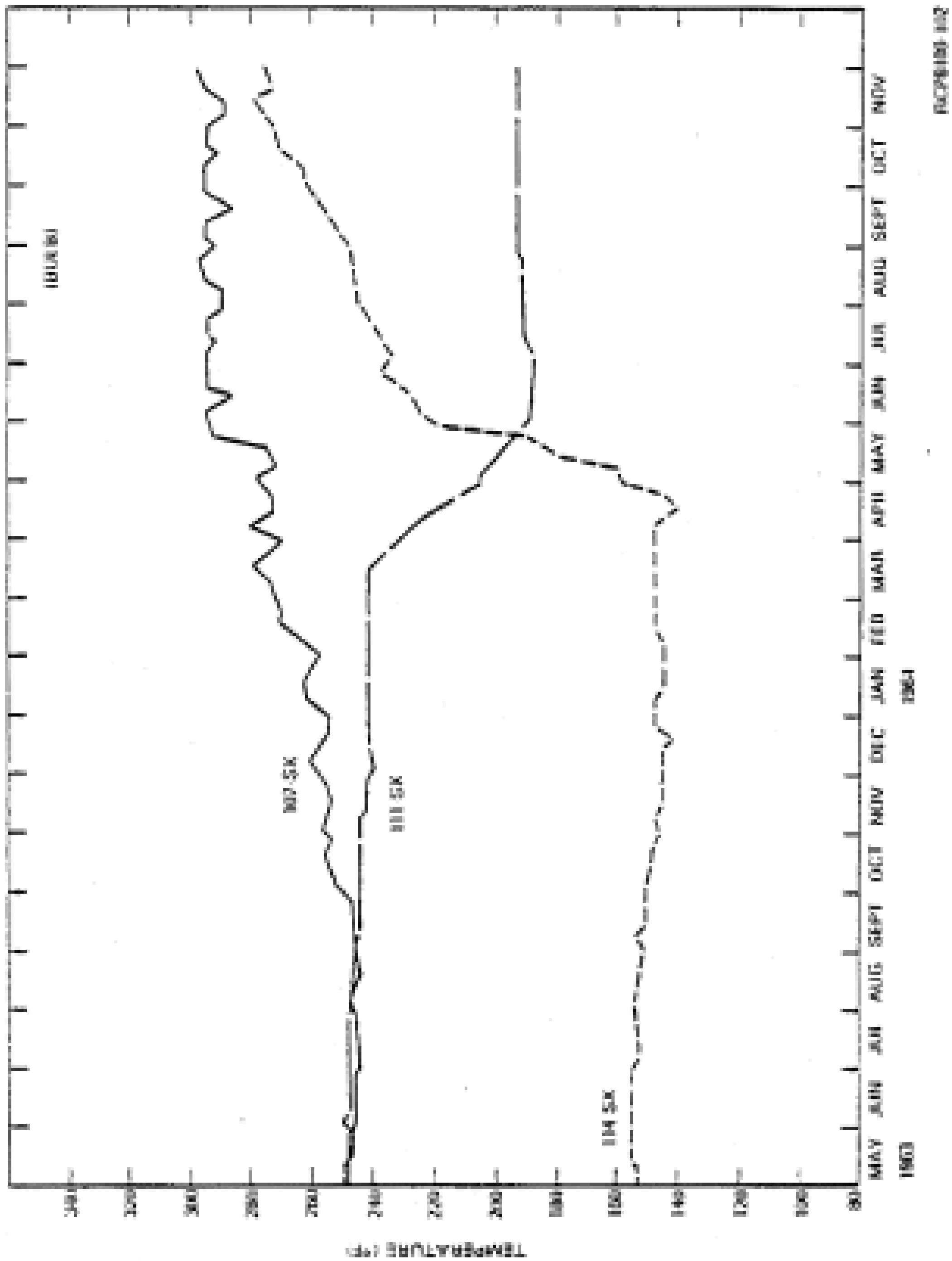

FIGURE B-100. 241-SX-107, -111, and -114 (Bulb Temp.) May 1963 thru November 1964

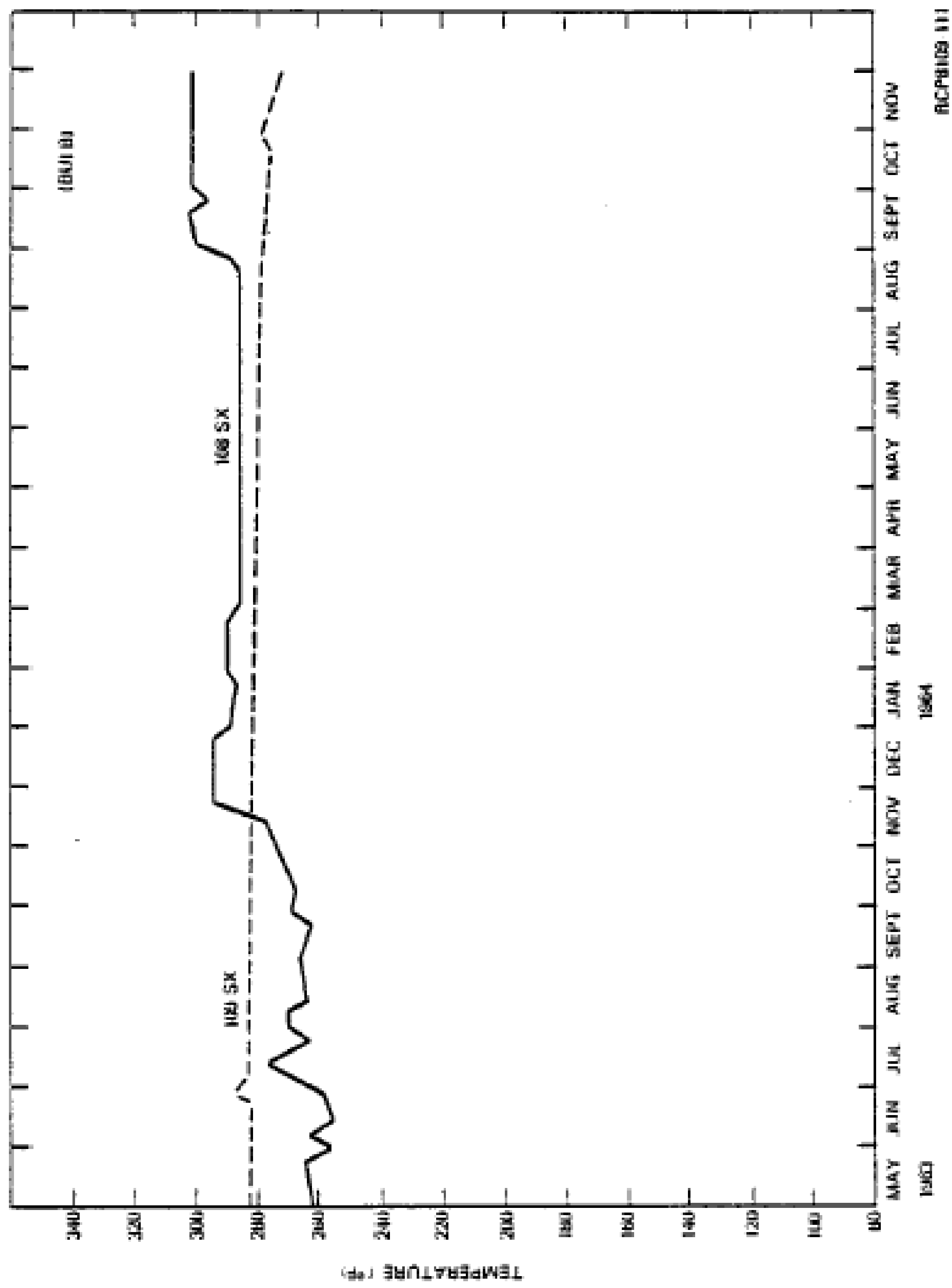

FIGURE B-101. 241-SX-108 and -109 (Bulb Temp.)
May 1963 thru November 1964

RHO-CD-1172

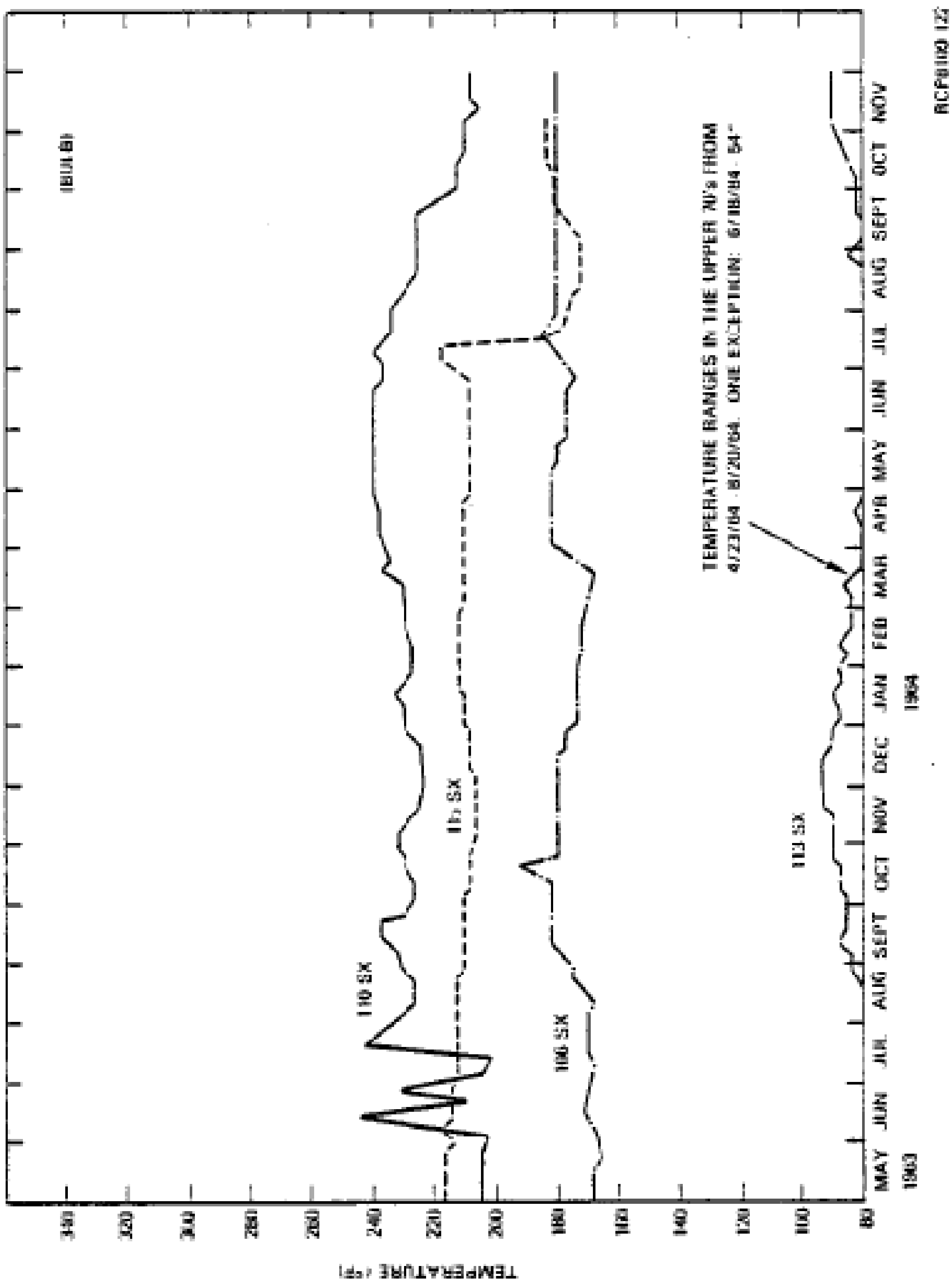

FIGURE B-102. 241-SX-106, -110, -113, and -115 (Bulb Temp.) May 1963 thru November 1964

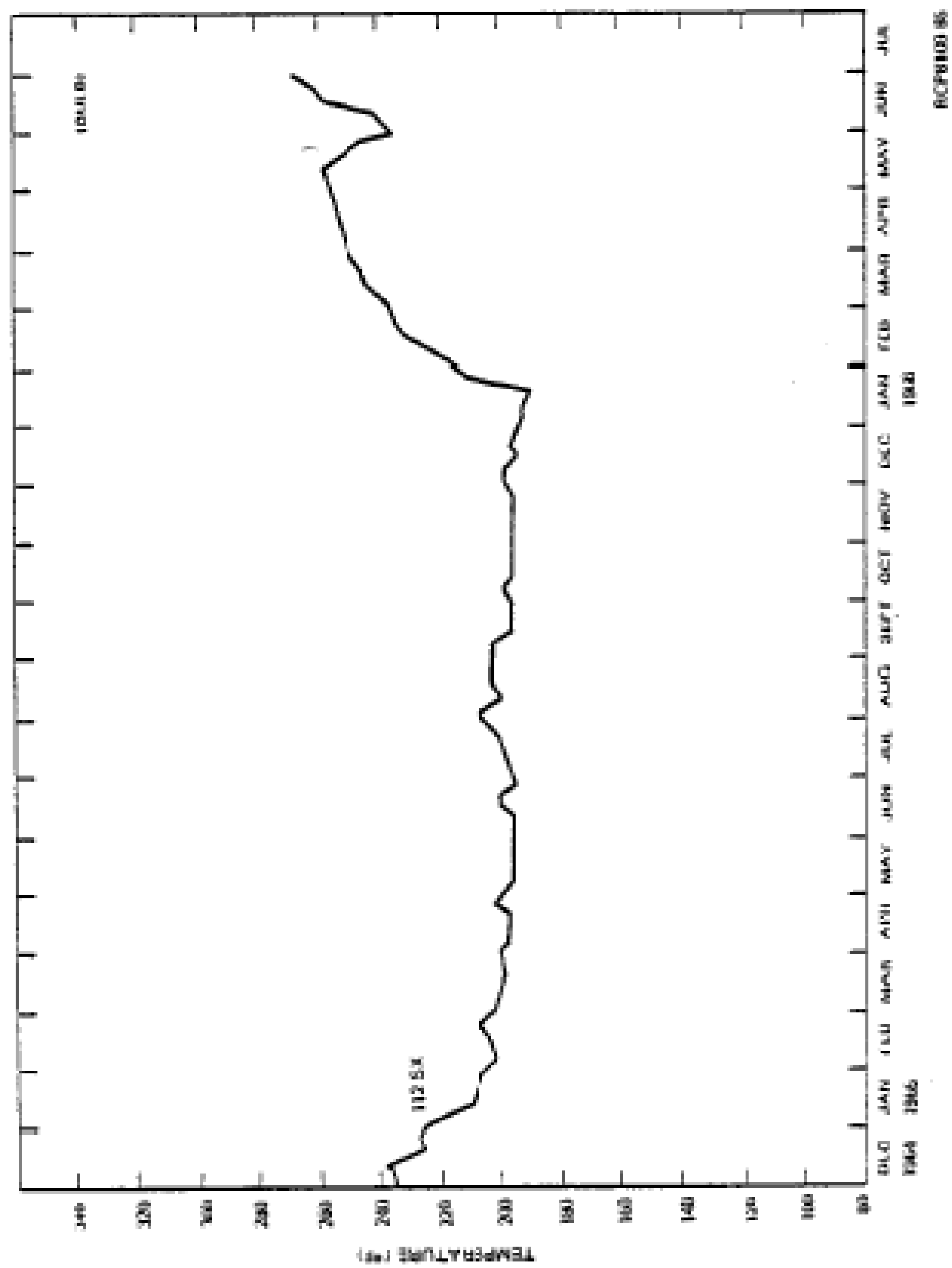

FIGURE B-103. 241-SX-112 (Bulb Temp.)
December 1964 thru July 1966

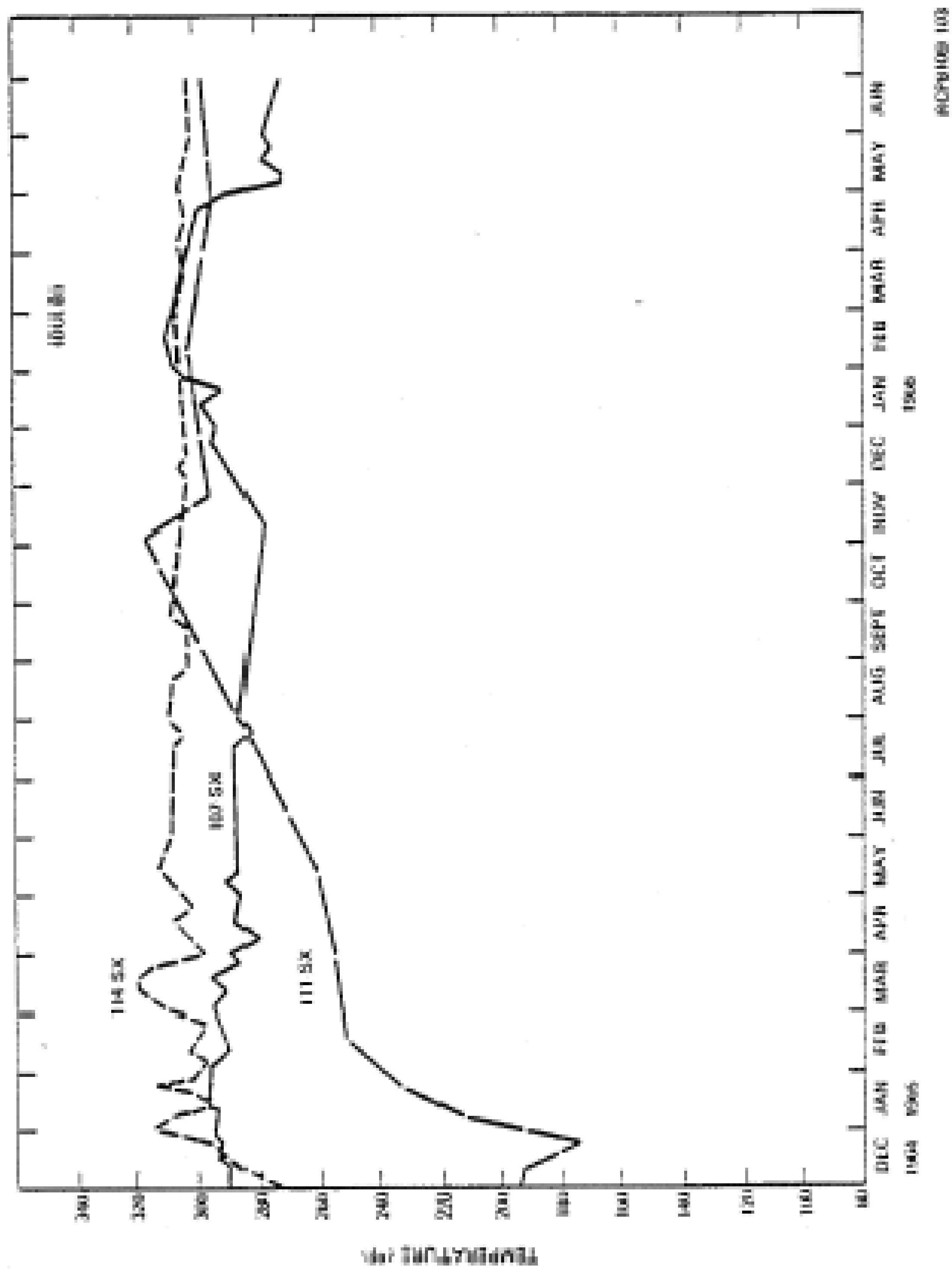

FIGURE B-105. 241-SX-107, -111, and -114 (Bulb Temp.) December 1964 thru June 1966

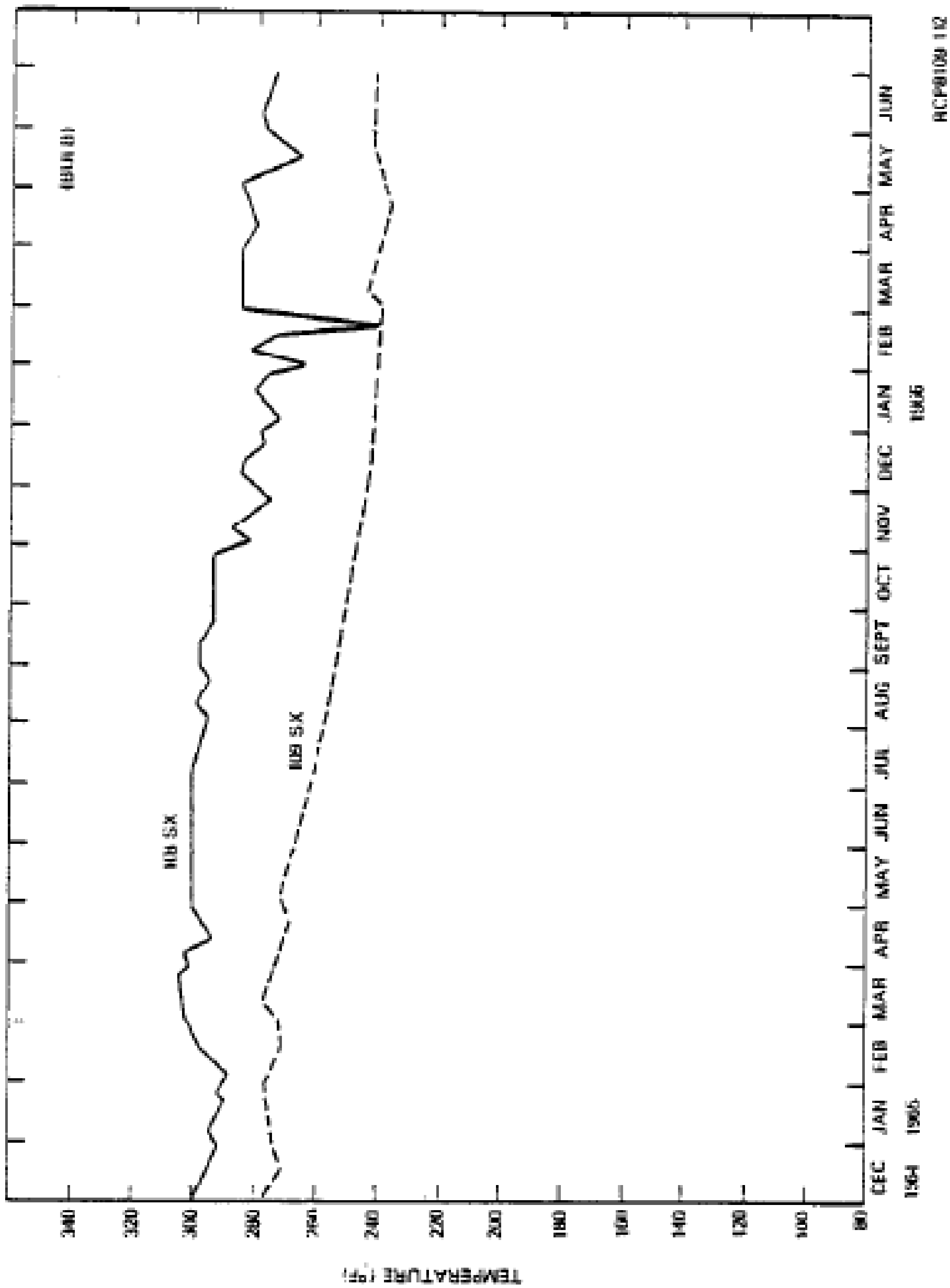

FIGURE B-106. 241-SX-108 and -109 (Bulb Temp.) December 1964 thru June 1966

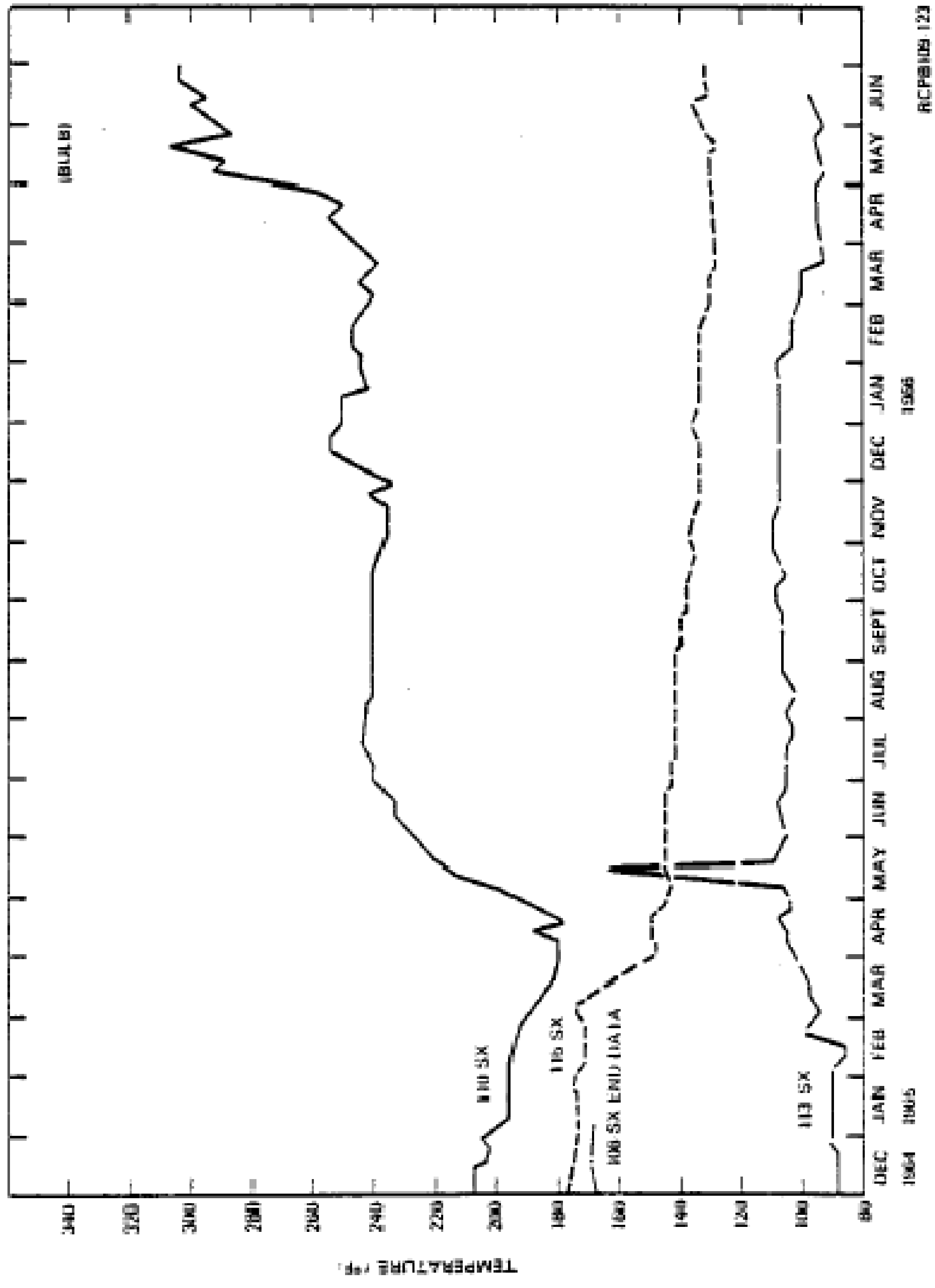

FIGURE B-107. 241-SX-106, -110, -113, and -115 (Bulb Temp.) December 1964 thru June 1966

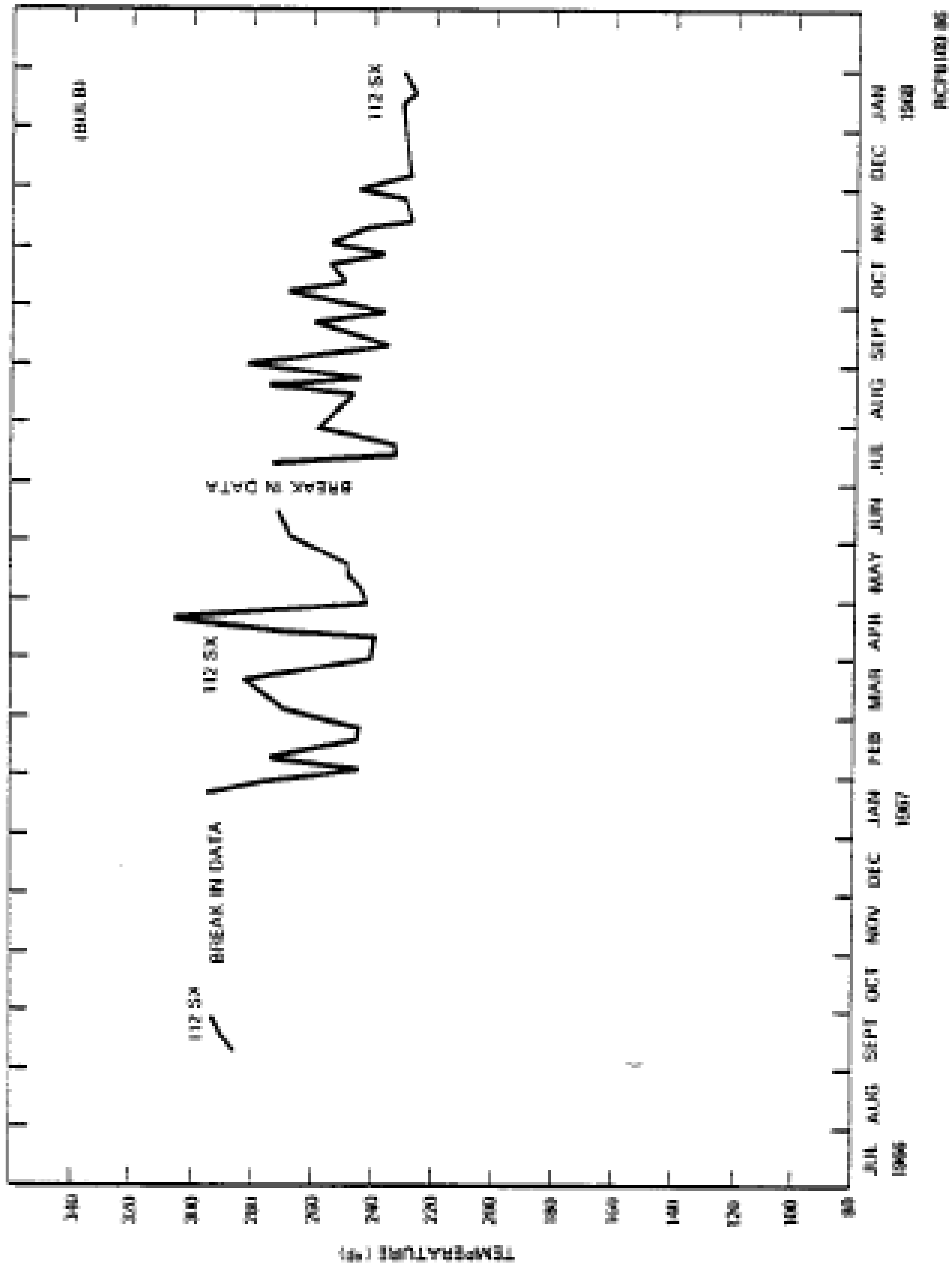

FIGURE B-108. 241-SX-112 (Bulb Temp.)
July 1966 thru January 1968

B-108

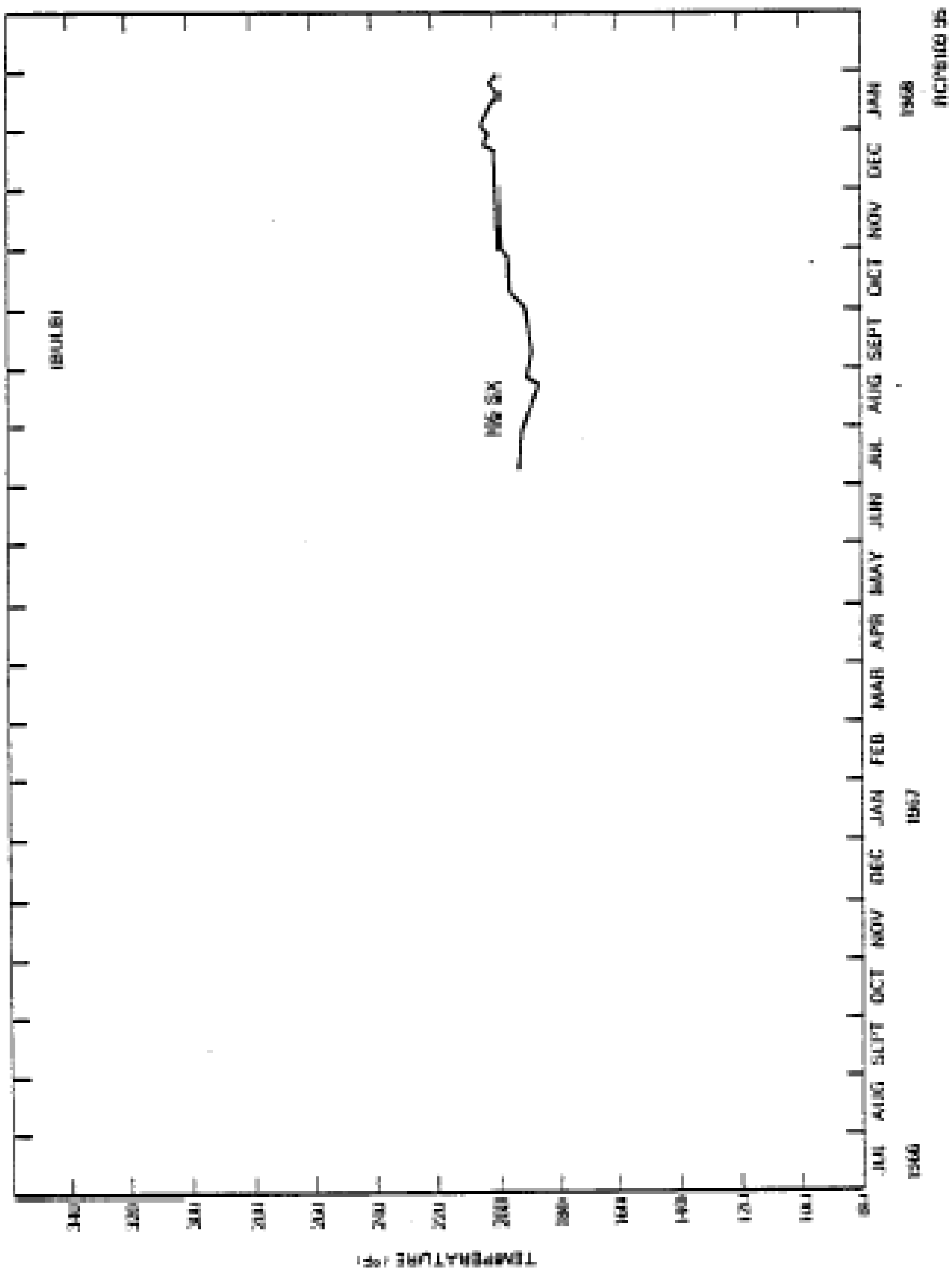

FIGURE B-109. 241-SX-115 (Bulb Temp.) July 1967 - January 1968

B-109

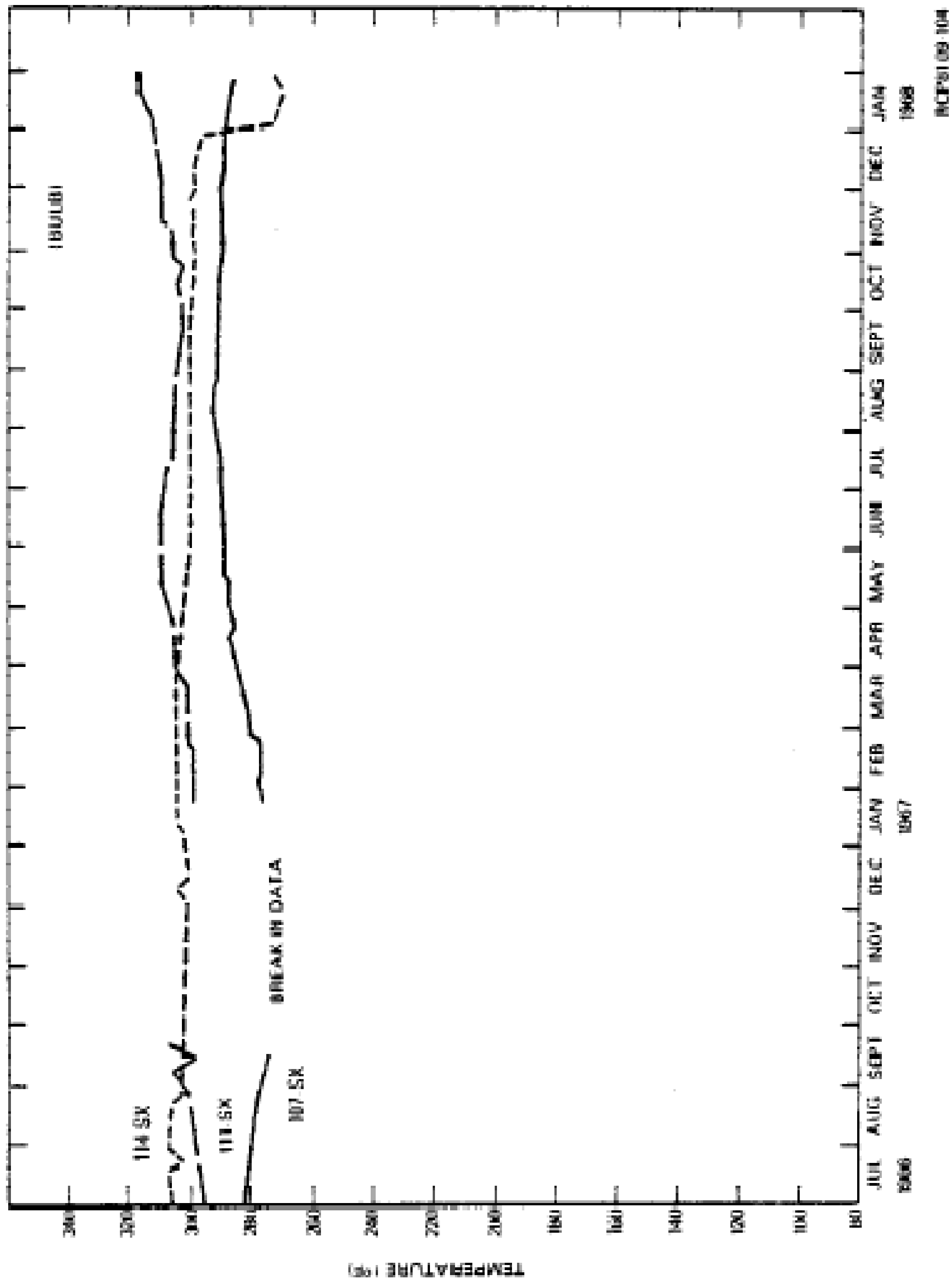

FIGURE B-110. 241-SX-107, -111, and -114 (Bulb Temp.)
July 1966 - January 1968

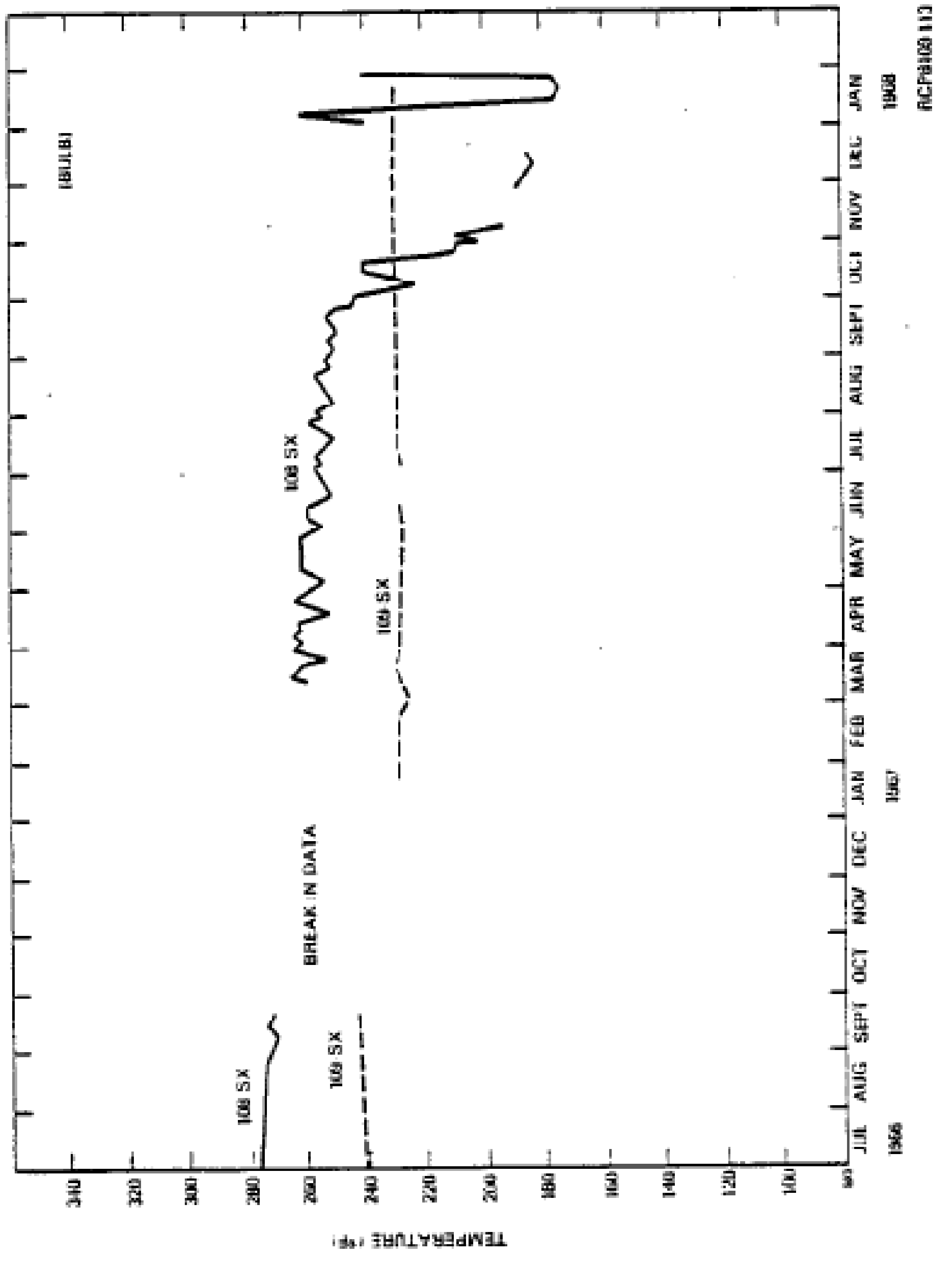

FIGURE B-111. 241-SX-108 and -109 (Bulb Temp.) July 1966 thru January 1968

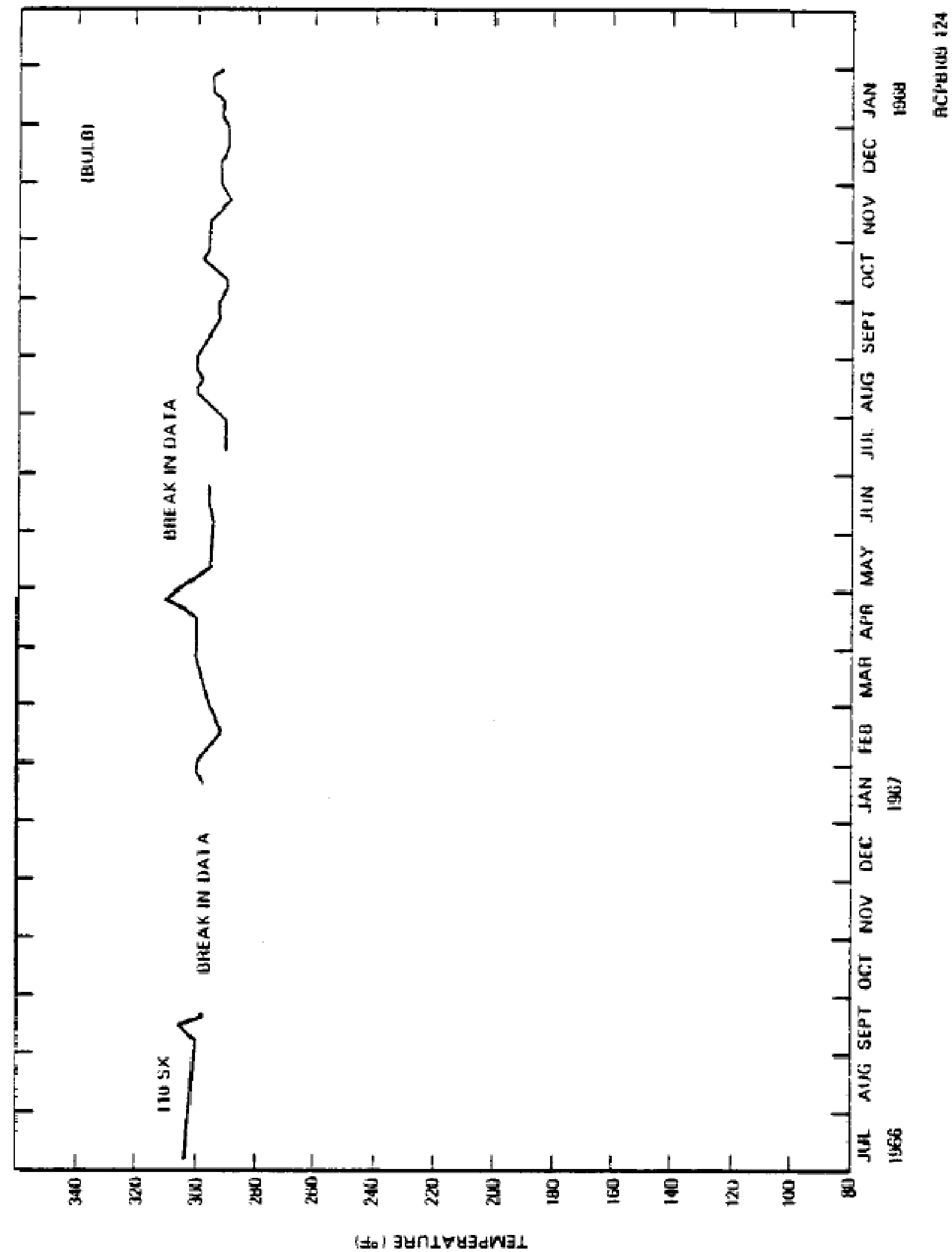

FIGURE B-112. 241-SX-110 (Bulb Temp.)
July 1966 - January 1968

B-112

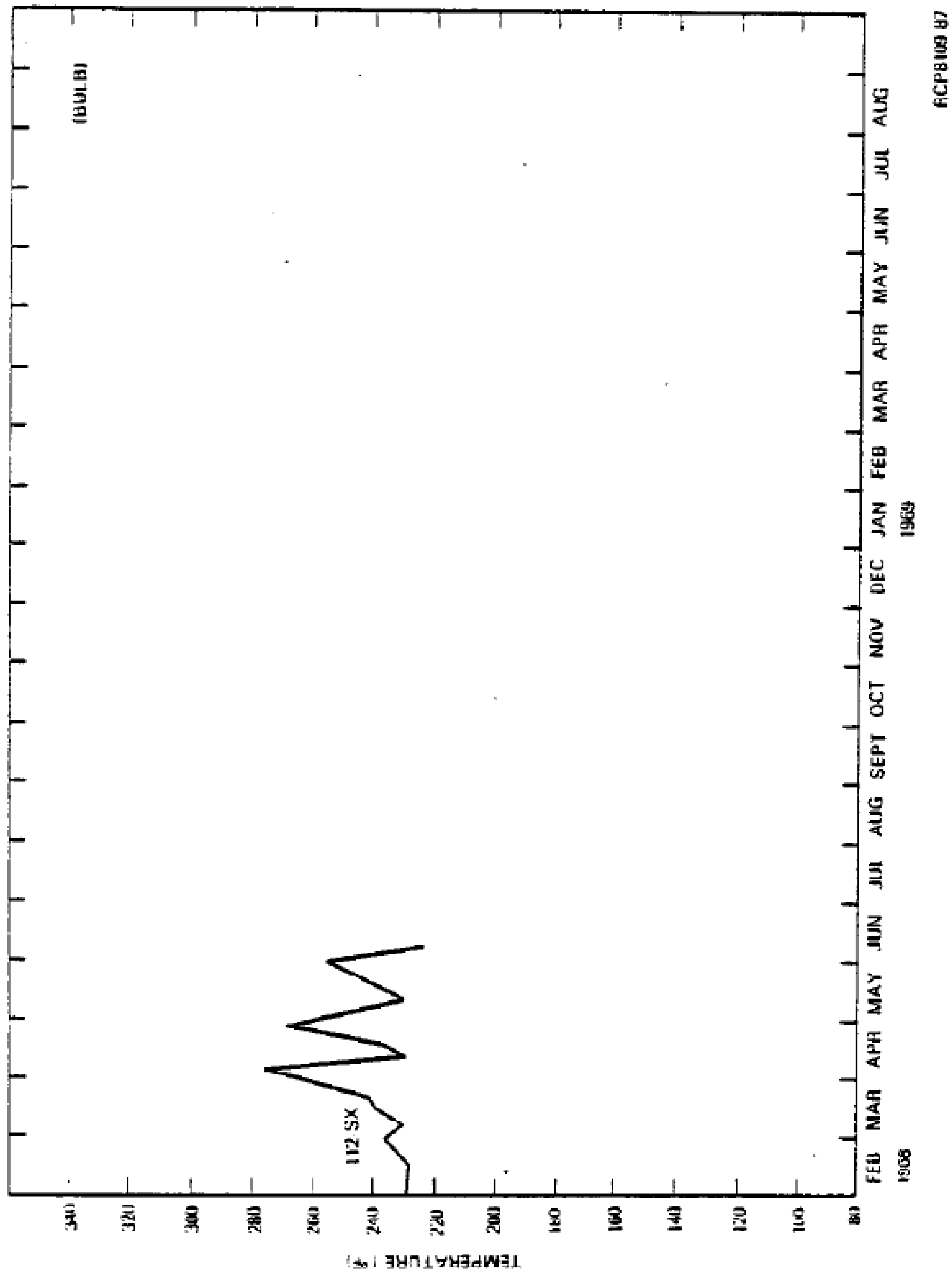

FIGURE B-114. 241-SX-112 (Bulb Temp.) February 1968 - June 1968

B-114

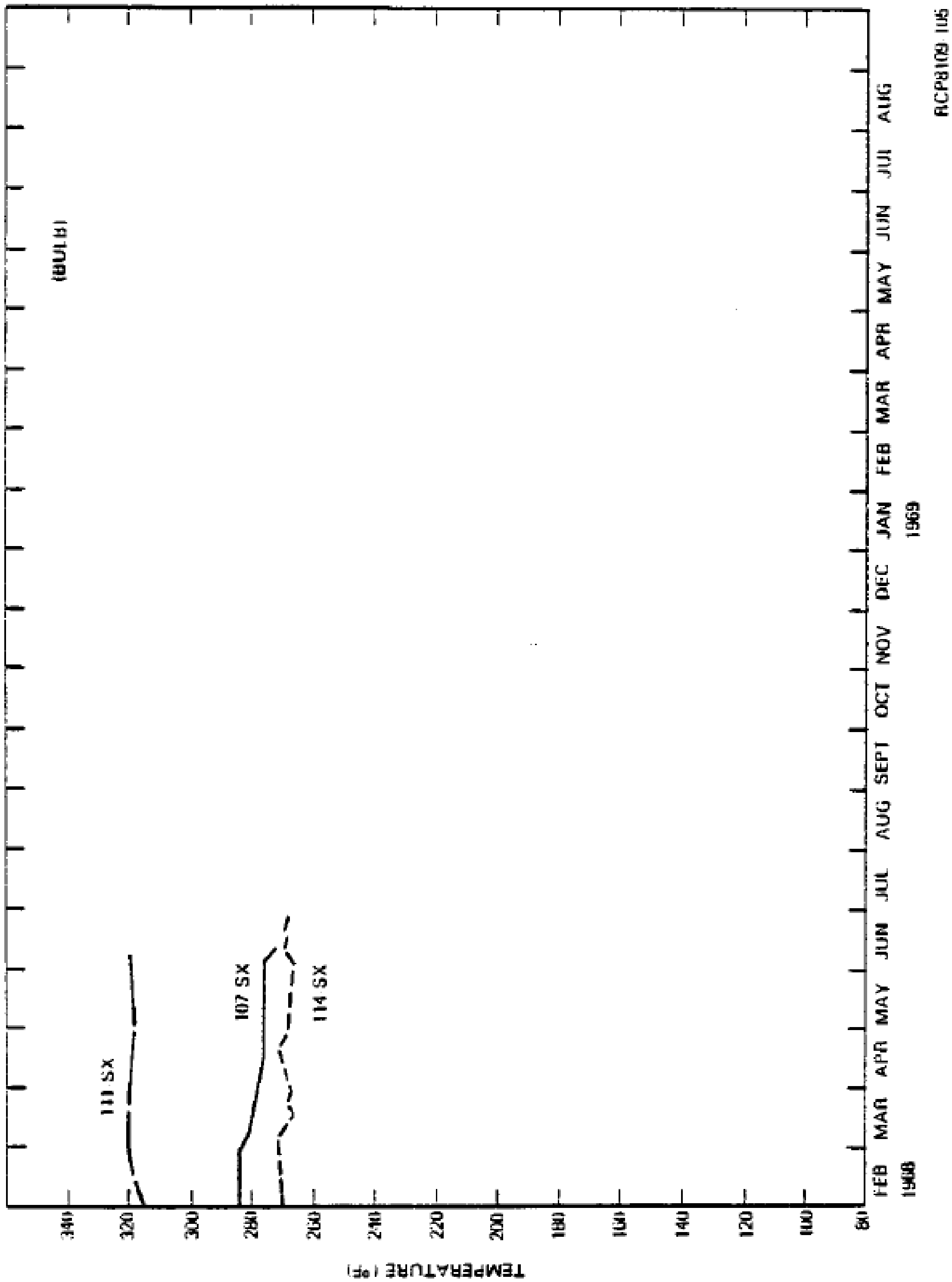

FIGURE B-116. 241-SX-107, -111, and -114 (Bulb Temp.) February 1968 thru June 1968

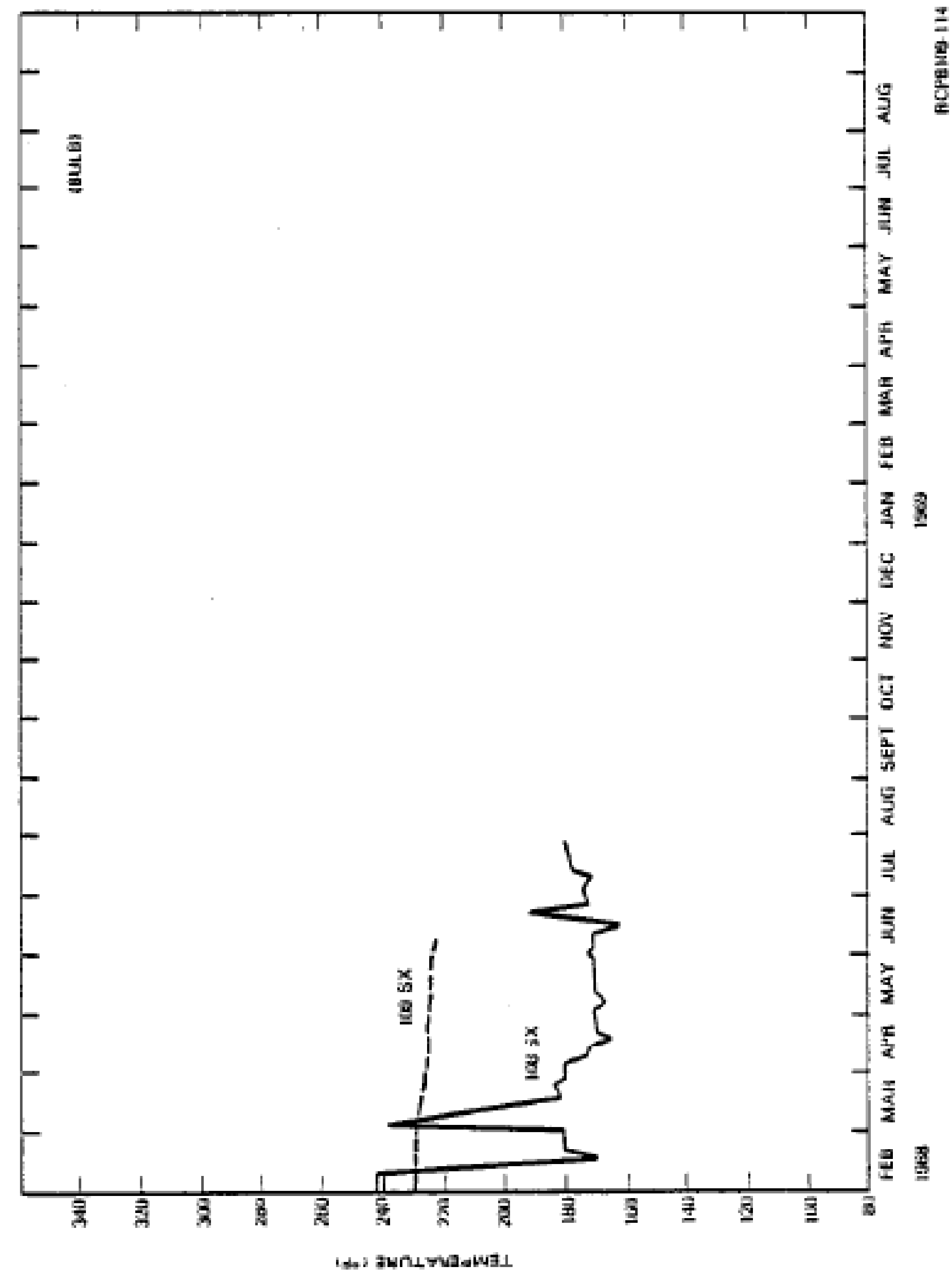

FIGURE 117. 241-SX-108 and -109 (Bulb Temp.)
February 1968 - July 1968

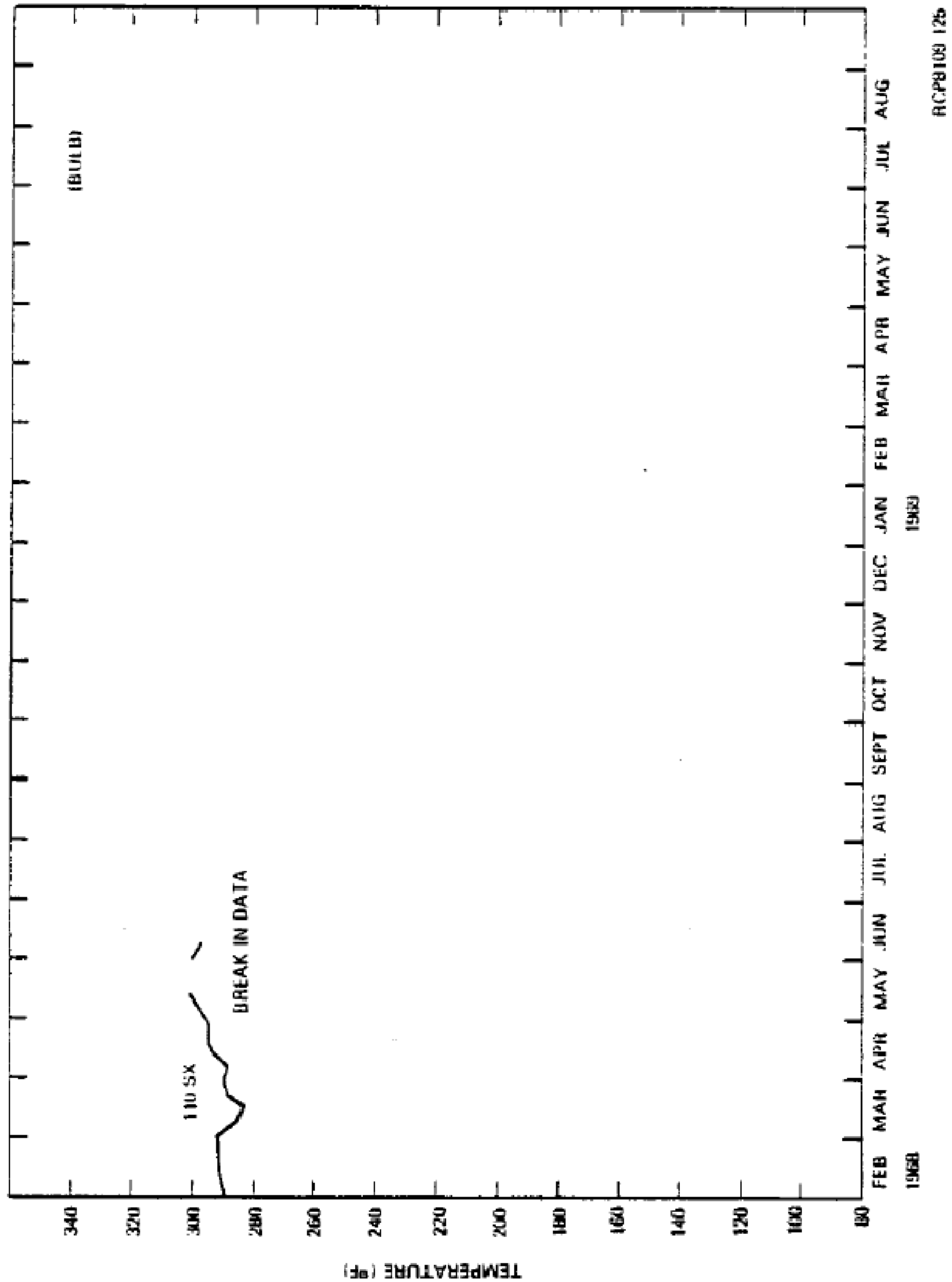

FIGURE B-118. 241-SX-110 (Bulb Temp.)
February 1968 - June 1968

B-118

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APPENDIX B

SX-FARM TANK LEAK ASSESSMENT MEETING SUMMARIES

CH2MHILL
Hanford Group, Inc.

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MEETING SUMMARY

From:	J. G. Field, CH2M HILL Hanford Group, Inc
Phone:	376-3753
Location:	Ecology Office,
Date:	April 15, 2008
Subject:	Tank Farm Leak Evaluation
To:	Distribution/Attendees
Distribution:	Joe Caggiano, ECOLOGY Jim Field, CH2M HILL Les Fort, ECOLOGY Paul Henwood, S. M. STOLLER Michael Johnson, CH2M HILL Beth Rochette, ECOLOGY Marcus Wood, FLUOR

PURPOSE:
Begin SX-Farm leak assessments

Review of Previous Meeting Summary:
The April 1, 2008 meeting summary was reviewed and approved with changes.

Additional Discussion of A/AX-Farm UPRs
Emphasis was added that the inventory for UPRs in A/AX –Farm could not be determined. Although some UPRs are listed as "cleaned up" in WIDS. The criteria for considering the sites cleaned up at the time are unknown, as is the detection limit for any instruments used to make this judgment. Typically in the past sites were cleaned enough to eliminate smearable contamination and to allow workers into the location.

Assessment of SX-114
Information regarding tank transfers, operating conditions and contamination observed near SX-114 was presented by Mike Johnson. Multiple unique aspects of SX-Farm were identified. Presentation details will be in the assessment report.

SX-114 was classified as an assumed leaker based on gamma activity (60,000 cpm) in drywell 41-04-06 observed measured in 8/10/72 at 38 ft below ground surface (bgs), about 16 ft above the tank base. On 8/21/72 contamination was observed at 51 ft bgs. No liquid level loss has been observed and no leak inventory assigned in the past. However, there are no known pipeline leaks around SX-114 and a structural failure was a typical cause of leaks for tanks with temperature and waste type histories similar to SX-114.

Based on the gamma level and decay the drywell activity appears to be Ru-106 and/or Co-60. The waste type in the tank at the time was REDOX Ion Exchange waste. In this waste type, Cs-137 was extracted from REDOX high level waste. An action was assigned to look closer at the records to determine the percent of Cs extracted in the process and the ratio of Cs to Ru waste following extraction. This may enable a rough calculation to estimate an upper bound leak inventory. Lacking that, no leak volume estimate could be determined.

Because no Cs was observed and Ru-106 has decayed, future characterization near drywell 41-04-06 would target chemical constituents. This leak appears to be minor compared to other SX-Farm releases and additional characterization may not be warranted.

NEXT MEETING AGENDA

Continue SX-Farm leak assessments (SX-113 and 115)

ACTIONS:

1. J. Field: Prepare and distribute April 15, 2008 Draft Meeting Summary.
2. M. Johnson: Look for information showing the Cs-137 concentration after the Cs extraction process and the Cs/Ru ratio for the waste.

(Finding: The HDW rev. 5 Model does not contain a separate defined waste type for REDOX ion exchange waste and no sample analyses of this waste type were located. Therefore an estimate of the waste loss inventory can not be made at this time using the Ru-106 concentration and assumed leak geometry.)

3. M. Johnson: Prepare additional SX-Farm information for discussion.

NEXT MEETING:

Date: April 29, 2008
Time: 3:00-4:30
Location: ECOLOGY Office room 3B

CH2MHILL
Hanford Group, Inc.

MEETING SUMMARY

From: J. G. Field, CH2M HILL Hanford Group, Inc
Phone: 376-3753
Location: Ecology Office,
Date: April 29, 2008
Subject: Tank Farm Leak Evaluation

To: Distribution/Attendees
Distribution: Joe Caggiano, ECOLOGY
Jim Field, CH2M HILL
Les Fort, ECOLOGY
Paul Henwood, S. M. STOLLER
Michael Johnson, CH2M HILL
Beth Rochette, ECOLOGY

PURPOSE:
Continue SX-114 assessment and begin to discuss SX-113.

Review of Previous Meeting Summary:
The April 15, 2008 meeting summary was reviewed and approved with minor changes. Red-line comments received were incorporated to the final meeting summary reviewed.

Assessment of SX-114
Additional information to perform a rough inventory estimate for the SX-114 leak was requested. Given that there was no liquid level decrease observed in SX-114 it can be assumed that the leak is less than 2,000 gallons. As noted in the last meeting, it appears that activity observed in drywell 41-04-06 was Ru-106 because of the rate of decay measured. Because no Ru-106 data or model estimates are available specifically for SX-114 at the time of the leak, a rough calculation will be performed using the Ru-106 concentration ratio for IX waste and the ratio of Ru-106 to Cs-137 for that waste type. This approach has a high uncertainty but will provide a rough, order of magnitude, estimate.

Discussion of Probe Types
Paul Henwood of Stoller presented calibration curves developed for different probe types. There is a clear difference in the measured activity level depending on the probe type used. These calibration curves will be included in the appendix for the A/AX and SX assessment reports.

Assessment of SX-113
The SX-113 fill and leak history, sent to participants following the April 15 meeting, was discussed. This history will be included in the SX assessment report. Currently HNF-EP-0182 and RPP-23405 indicate a 15 kgal waste leak occurred in October 1962 based on a measured liquid level decrease and tank leak test. This leak is well documented and appears to be consistent with logging data from SX-113 laterals. The composition for the October 1962 leak is reported in HW-75714, page 4. Based on this composition, approximately 7,800 curies of ^{137}Cs (10/1962) were lost to the soil. There was no reason or basis to question these prior estimates.

The Soil Inventory Model (RPP-26744 page A-118) incorrectly identifies the waste leaked from tank SX-113 as R1 type. Therefore, the Soil Inventory Model will need to be corrected to identify the waste composition and type.

In addition to the 15 kgal leak, a 40 kgal discrepancy in REDOX high level waste observed in July 1958 was discussed. This discrepancy is explained in HW-57249 and is attributed to a bulge in the tank liner during that time frame. A 40 kgal REDOX HLW leak is inconsistent with lateral data as the activity levels in the laterals were not observed before 1962 and would be expected to be much higher and distributed more widely if such a leak occurred. There was also no observed liquid level decrease in SX-113 before 1962.

Before concluding the SX-113 assessment an action was taken to investigate if any more sensitive measurements (GM tube) are available.

NEXT MEETING AGENDA

Continue SX-Farm leak assessments (SX-113 and SX-115)

ACTIONS:

1. J. Field: Prepare and distribute April 29, 2008 Draft Meeting Summary.
2. M. Johnson: Develop rough inventory calculation for S-114 based on drywell data, and Cs/Ru ratios for IX waste in tanks SX-110/111.
3. M. Johnson: Prepare additional SX-Farm information for discussion.
4. P. Henwood: Send lateral figure for SX-113
5. P. Henwood: Look for SX-113 GM tube measurements

<u>NEXT MEETING:</u>

Date:	May 20, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office room 3B

CH2MHILL
Hanford Group, Inc.

MEETING SUMMARY

From: J. G. Field, CH2M HILL Hanford Group, Inc
Phone: 376-3753
Location: Ecology Office,
Date: May 27, 2008
Subject: Tank Farm Leak Evaluation

To: Distribution/Attendees

Distribution: Joe Caggiano, ECOLOGY
Jim Field, CH2M HILL
Les Fort, ECOLOGY
Paul Henwood, S. M. STOLLER
Michael Johnson, CH2M HILL

PURPOSE:
Assess leak losses from Tank 241-SX-115.

Review of Previous Meeting Summary:
The April 29, 2008 meeting summary was reviewed and approved by attendees.

Assessment of SX-114 (Continued)
A rough conversion from counts per minute measurements to pCi/g of Ru-106 was developed by Stoller. This information will be used in an effort to further approximate the size of the SX-114 leak.

Assessment of SX-115
Mike Johnson reviewed SX-115 tank waste history and the basis for current leak inventory estimates. This write-up will be included in the assessment report. The estimated waste loss from tank SX-115 was 50,000 to 50,976 gallons of sodium nitrate waste in March 1965 (HW-83906-E-RD page 62-b) with approximately 38,150 to 38,900 curies of ^{137}Cs lost to the soil (Based on 1964 analytical data). Decay correcting to May 2008, the inventory of ^{137}Cs lost to the soil is about 14,000 curies.

Marc Wood further discussed the gamma logging surveys of drywells and laterals following the leak. The May 2005 gamma survey of the laterals (RPP-27605) and the leak area estimated by Raymond and Shdo in 1966 (BNWL-CC-701) do not align exactly. This difference could be due to Raymond and Shdo drywell measurements detecting gamma emitting radionuclides with short half-lives, which have subsequently decayed and were not detected in the May 2005 lateral survey. Also, the gamma surveys appear to indicate a smaller leak inventory compared to leak loss inventory estimates from the 1964 tank data. A rough calculation based on vadose measurements indicates a ^{137}Cs inventory of about 5,000 Ci at the time of the leak, suggesting that the 1964 analysis of sodium nitrate waste in the tank may not be representative of the composition of the waste leaked or waste loss occurred in areas not accessed by the laterals.

Vadose zone measurement based calculations will be prepared and included in the assessment report and a range of leak inventory estimates will be included with a low based on vadose observations and high assuming the measured sample inventory. The volume of the leak for both high and low inventory estimates is the measured liquid level decrease of 51,000 gallons (increase of 1,000 gallons compared to current volume in the Waste Tank Summary Report (HNF-EP-0182)).

Lateral #2 data suggests a possible leak in 1963. However, gamma readings were low (peaks between 60 and 98 cpm) and there was no reported liquid level decrease at that time. Therefore any waste loss is likely to have been small.

The Soil Inventory Model (SIM) incorrectly assigns an R1 and R2 waste type to SX-115 leak. This will need to be corrected for future inventory estimates.

NEXT MEETING AGENDA
Continue SX-Farm leak assessments (SX-112, followed by SX-111 and SX-110)

ACTIONS:

1. J. Field: Prepare and distribute May 27, 2008 Draft Meeting Summary.
2. M. Johnson: Develop rough inventory calculation for SX-114 based on drywell data, and Ru for IX waste in tank SX-108. (This was done following the meeting: The result was an estimate of about 44 gallons. This value appears low, but suggests that the SX-114 leak may have been significantly smaller than 2,000 gallons).
3. M. Johnson: Prepare SX-112 information for discussion.

NEXT MEETING:

Date:	June 24, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office room 3B

CH2MHILL
Hanford Group, Inc.

MEETING SUMMARY

From: J. G. Field, CH2M HILL Hanford Group, Inc
Phone: 376-3753
Location: Ecology Office,
Date: June 24, 2008
Subject: Tank Farm Leak Evaluation

To: Distribution/Attendees

Distribution: Joe Caggiano, ECOLOGY
Jim Field, CH2M HILL
Les Fort, ECOLOGY
Michael Johnson, CH2M HILL
Beth Rochette, ECOLOGY
Marcus Wood, Fluor

PURPOSE:
Assess leak losses from Tank 241-SX-112.

Review of Previous Meeting Summary:
The May 27, 2008 meeting summary was reviewed and approved by attendees.

Assessment of Tank 241-SX-112
Mike Johnson reviewed the SX-112 tank waste history and the basis for current leak inventory estimates. This write-up will be included in the assessment report. The current estimated waste loss from tank SX-112 is up to 27,000 gallons of dilute REDOX HLW supernatant were leaked in January 1969 and contained about 40,000 Ci of ^{137}Cs (ARH-1100). The monthly waste tank summary report shows a leak volume of 30,000 gallons. A crack is observed in tank photos at about 16 feet above the base of the tank and a bulge in the bottom of the tank liner was also reported.

No gamma scans for laterals beneath tank SX-112 were available when the leak was detected in January 1969 and drywell data appeared inconsistent with a 30,000 gallon leak from this tank. Spectral gamma scans of laterals beneath tank SX-112 were performed in 2005. The scans show up to ~1E+07pCi/gm ^{137}Cs contamination in lateral 44-12-02. Activity levels were orders of magnitude lower in the other two laterals.

Based on a rough calculation of a worst case leak volume and ^{137}Cs activity, after decay correction the lateral data appear to be reasonably consistent with the earlier 27,000 gallon leak volume estimate. It was noted that the leak is probably smaller, but insufficient data is available to verify it. The "worst case" calculations based on the lateral activity assumed the following:

1. Leak did not extend below the laterals because this is not a high sodium waste and activity levels observed at the lateral were below ^{137}Cs saturation capacity (1E+8 pCi/g).
2. The width of the leak is based on the width observed at the lateral (~ 20 ft).

3. Assume a soil density of 1.7 g/cc
4. Assume the plume width is constant from the tank to the laterals.
5. Assume a plume concentration at ^{137}Cs saturation capacity 1E+8 pCi/g

An alternate calculation will be performed using the actual activity levels measured at the laterals and both calculations will be included in the assessment report.

After the leak was detected in 1969, the liquid level was reduced to four feet above the bottom of the tank and no further decline in liquid level or increase in lateral radioactivity beneath tank SX-112 was observed. This indicates that the leak may have occurred on the side walls at greater than four feet above the tank bottom. However, because lateral data shows high contamination extending under the tank, a leak at the tank bottom is also plausible.

A picture of the plume measurements at the lateral (similar to the sketch for A-105) will be prepared for the assessment report to enhance visualization of the lateral data.

An action was taken for next meeting to provide data for team members to better understand and to attempt to quantify sodium/cesium mobility factors and relationships.

Additional Discussions
On June 20 the A-AX assessment report was distributed for review. The requested review date was extended two weeks to July 17, 2008.

At the conclusion of the meeting it was pointed out that, due to budget issues, Stoller likely would not be participating in future assessments in FY 08. The need to continue assessments now was also discussed. ECOLOGY expressed a desire to continue with the assessments because they may support ongoing structural integrity reviews. The team agreed that it would be good to have Stoller support on the team, but M. Wood could provide sufficient dry well and vadose expertise to continue. It was also noted that the continued assessments are needed to help guide tank farm vadose zone characterization in support of corrective actions.

NEXT MEETING AGENDA
Continue SX-Farm leak assessments (SX-111 followed by SX-110)

ACTIONS:
1. J. Field: Prepare and distribute June 25, 2008 Draft Meeting Summary.
2. M. Johnson: Continue preparation of SX Farm assessment report. Include a visual of lateral results and conceptual plume distribution for SX-112.
3. M. Johnson: Prepare SX-111 information for discussion next meeting.
4. M. Wood: Prepare information to discuss sodium impact on ^{137}Cs mobility and K_D factors.

NEXT MEETING:

Date:	July 15, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office room 3B

CH2MHILL
Hanford Group, Inc.

MEETING SUMMARY

From:	J. G. Field, CH2M HILL Hanford Group, Inc
Phone:	376-3753
Location:	Ecology Office,
Date:	July 15, 2008
Subject:	Tank Farm Leak Evaluation
To:	Distribution/Attendees
Attendees:	Joe Caggiano, ECOLOGY Jim Field, CH2M HILL Les Fort, ECOLOGY Michael Johnson, CH2M HILL Linda Lehman, CH2M HILL Marcus Wood, Fluor

PURPOSE:
Assess leak losses from Tank 241-SX-111.

Review of Previous Meeting Summary:
The June 24, 2008 meeting summary was reviewed and approved by attendees.
The A/AX assessment report review will be extended to the August meeting due to conflicting priorities.

Cesium Mobility
Marc Wood presented correlations between ^{137}Cs mobility (Kd factors) and sodium concentration. PNNL evaluations, documented in the S/SX Field Investigation Report looked at several different analytes and concluded that sodium concentration was the largest factor for ^{137}Cs mobility. Observed differences in SX-Farm laterals illustrating ^{137}Cs patterns for high sodium waste (SX-108) vs. lower sodium waste were discussed.

Assessment of Tank 241-SX-111
Mike Johnson reviewed the SX-111 tank waste history and the basis for current leak inventory estimates. This write-up will be included in the assessment report. The current estimated waste loss from tank SX-111 is up to 500 to 2000 gallons of REDOX-IX waste. Based on discussion and information presented participants concluded that Tank SX-111 leaked up to 2,800 gallons of waste based on information presented in ARHCO Occurrence Report 74-38. The composition of the waste leaked from tank SX-111 is provided in the following table and is a mixture of RIX and non-boiling REDOX HLW supernate.

Tank SX-111 Supernate Analysis (Sept. 1974)

Analyte	Result	Units
pH	> 13.2	
Sp.Gr.	1.4836	
OH	1.47	M
Al	0.805	M
Na	8.05	M
NO_2	0.836	M
NO_3	4.72	M
Pu	<3.91E-06	gm/L
SO_4	6.01E-02	M
PO_4	5.74E-03	M
F	1.40E-02	M
CO_3	0.168	M
Cs^{134}	5.83E+03	μCi/gal
137Cs	1.20E+06	μCi/gal
$Sr^{89,90}$	1.33E+02	μCi/gal

It was noted that the current template for REDOX-IX waste should not be used directly. Measured sample values in the table should be used and template values for other analytes should be ratioed to the measured ^{137}Cs value (1.2 Ci/gal).

NEXT MEETING AGENDA
Assess Tank 241-SX-110

ACTIONS:
1. J. Field: Prepare and distribute July 15, 2008 Draft Meeting Summary.
2. M. Johnson: Continue preparation of SX Farm assessment report.
3. M. Johnson: Prepare SX-110 information for discussion next meeting.

NEXT MEETING:
Date: August 12, 2008
Time: 3:00-4:30
Location: ECOLOGY Office room 3B

CH2MHILL
Hanford Group, Inc.

MEETING SUMMARY

From:	J. G. Field, CH2M HILL Hanford Group, Inc
Phone:	376-3753
Location:	Ecology Office,
Date:	August 12, 2008
Subject:	Tank Farm Leak Evaluation
To:	Distribution/Attendees
Attendees:	Joe Caggiano, ECOLOGY Jim Field, CH2M HILL Les Fort, ECOLOGY Michael Johnson, CH2M HILL Linda Lehman, CH2M HILL Marcus Wood, Fluor

PURPOSE:
Assess leak losses from Tank 241-SX-110.

Review of Previous Meeting Summary:
The July 15, 2008 meeting summary was reviewed and approved by attendees.
The A/AX assessment report review will be extended to the next meeting.
The group agreed that no further review of tank SX-111 is needed.

Assessment of Tank 241-SX-110
Mike Johnson reviewed the SX-110 tank waste history and the basis for current leak inventory estimates. This write-up will be included in the assessment report. The current estimated waste loss from tank SX-110 is 5,500 gallons of REDOX/RIX supernatant.

Summary of Leak Basis and Past Assessments
Liquid level changes (both decreases and increases) were observed during June 1976 and an occurrence report was issued as a result of tank SX-110 liquid level decline exceeding normal limits. However, there was no increase in the radioactivity detected in the drywells or laterals at that time and drywell activity observed in wells near SX-110 is attributed to other tanks. The occurrence report concluded that the tank was sound.

In July, 1976 the Energy Research and Development Administration (ERDA) issued a letter to remove tank SX-110 from service based on the fact that, "ARHCO's long-range tank use projection does not indicate a continued need for this tank, which obviously does not justify risking continued use with an apparent unexplained liquid level loss over the past two months in excess of one inch."

A tank integrity assessment was conducted in 1980 (RHO-CD-896) which concluded that there was insufficient evidence to confirm the tank as a leaker and recommended that the tank remained classified as questionable integrity.

Current Panel Assessment
Participants noted that a classification of "questionable integrity" does not mean a tank is a leaking tank and there is no real evidence that tank SX-110 leaked. Based on the BBI for this tank, the current heat load is about 36,000 Btu/hr as of 1-1-2008. In June 1976, the heat load for tank SX-110 would have been about 77,100 Btu/hr. Heat load and temperature data (RHO-CD-1172) presented shows that the liquid level decreases can be explained by evaporation. The changes can also be explained by manual tape error. It appears that the current leak volume estimate of 5,500 gal ignores evaporation and is based on a potential manual tape error of 2 inches (2750 gal/inch).

It was noted that a high concentration of ^{90}Sr would be expected due to evaporative losses. However, tank SX-110 has not been previously sampled.

Based on discussion and information presented, participants concluded that there is no basis for a leak volume or inventory for Tank SX-110 and recommended a leak status re-assessment per (TFC-ENG-CHEM-D-42) for this tank.

NEXT MEETING AGENDA
Assess Tank 241-SX-109

ACTIONS:
1. J. Field: Prepare and distribute August 12, 2008 Draft Meeting Summary.
2. M. Johnson: Continue preparation of SX Farm assessment report.
3. M. Johnson: Prepare SX-109 information for discussion next meeting.

NEXT MEETING:

Date:	August 26, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

CH2MHILL
Hanford Group, Inc.

MEETING SUMMARY

From: J. G. Field, CH2M HILL Hanford Group, Inc
Phone: 376-3753
Location: Ecology Office,
Date: September 9, 2008
Subject: Tank Farm Leak Evaluation

To: Distribution/Attendees

Attendees: Joe Caggiano, ECOLOGY
Jim Field, CH2M HILL
Les Fort, ECOLOGY
Linda Lehman, CH2M HILL
Beth Rochette, ECOLOGY
Marcus Wood, Fluor

PURPOSE:
Assess leak losses from Tank 241-SX-109.

Review of Previous Meeting Summary:
The August 12, 2008 meeting summary was reviewed and approved by attendees.
Attendees agreed that no further evaluation of SX-110 is needed.

Assessment of Tank 241-SX-109
Jim Field and Marc Wood reviewed the SX-109 tank waste history prepared by Mike Johnson and the basis for current leak inventory estimates. This write-up will be included in the assessment report. The current estimated waste loss from tank SX-109 is < 10,000 gallons of REDOX HLW supernatant.

Summary of Leak Basis and Past Assessments
Tank SX-109 was determined to be leaking based on radioactivity first detected in lateral no. 3 beneath this tank in January 1965. Radioactivity was subsequently detected in the other laterals beneath tank SX-109 in March and April 1965.

In September 1972 significant increases in radiation below the tank bottom were reported in four dry wells adjacent to Tank SX-109. The drywells were not identified and no drywell data was located for September 1972. Later tank farm contractors determined that waste leaked from tank SX-109 may have spread from 1980 through 1988 based on increased radioactivity detected in drywells. In 1992, a review of SX-109 was conducted. The review concluded that the volume of waste leaked from tank SX-109 was unknown, but was likely less than 10,000-gallons based on comparison of the contaminated area under tank SX-109 with that under tank SX-108. (WHC-MR-0301).

Another estimate of the waste loss from tank SX-109 was prepared based on a mathematical model or (kriging analysis) of the drywell gamma surveys and soil sample analyses for ^{137}Cs (RPP-7884). This kriging analysis estimated 2,670 Ci of ^{137}Cs (decay corrected to 1-1-1994) were leaked from tank SX-109. The estimated waste loss from tank SX-109 is 989 gallons (~1,000 gal) based on the estimated average waste composition present in the tank at the time of the waste loss. The Hanford Defined Waste model, revision 4 was used to estimate the average waste composition in tank SX-109 from 1964 – 1969.

Current Panel Assessment
Participants concluded that the lateral and drywell data clearly indicates that tank SX-109 leaked. However, the previous leak volume estimate of < than 10,000 gallons has no technical basis. The kriging analysis was discussed and participants concluded that, lacking additional data, this provided a more defensible basis for the ^{137}Cs leak inventory estimate. A higher leak volume is possible if the waste was diluted.

Both mass and volume are important for risk assessments and to assess remediation needs and potential extent of contamination. It was noted that re-logging laterals under tank SX-109 to obtain ^{137}Cs concentration estimates vs. only total gamma C/S indicators would be useful if a more precise volume or inventory is needed for remediation decisions. SX-109 laterals were not re-logged in 2005 due to schedule and resource priority limitations. A decision whether to re-log laterals will be deferred to considerations in an SX-Farm DQO in support of Corrective Measures Studies.

In the interim, the leak estimate is assumed to be 1,000 gal with a concentration of 3,000 Ci of ^{137}Cs. As noted, the leak volume may be larger, but there is no technical basis for a statistical range for this volume or inventory.

NEXT MEETING AGENDA
Assess Tank 241-SX-108

ACTIONS:
1. J. Field: Prepare and distribute September 9, 2008 Draft Meeting Summary.
2. M. Johnson: Continue preparation of SX Farm assessment report.
3. J. Field: Prepare SX-108 information for discussion next meeting.

<u>NEXT MEETING:</u>

Date:	September 23, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

CH2MHILL
Hanford Group, Inc.

MEETING SUMMARY

From: J. G. Field, CH2M HILL Hanford Group, Inc
Phone: 376-3753
Location: Ecology Office,
Date: September 23, 2008
Subject: Tank Farm Leak Evaluation

To: Distribution/Attendees

Attendees: Joe Caggiano, ECOLOGY
Jim Field, CH2M HILL
Les Fort, ECOLOGY
Beth Rochette, ECOLOGY
Marcus Wood, Fluor

PURPOSE:
Assess leak losses from Tank 241-SX-108.

Review of Previous Meeting Summary:
The September 9, 2008 meeting summary was reviewed and approved by attendees.
Attendees agreed that no further evaluation of SX-109 is needed.

Assessment of Tank 241-SX-108
Jim Field and Marc Wood reviewed the SX-108 tank waste history and the basis for current leak inventory estimates. The SX-108 write-up and additional information discussed will be included in the assessment report. The current estimated waste loss from tank SX-108 is 2,400 to 35,000 gallons of REDOX HLW supernatant.

Summary of Leak Basis and Past Assessments
Tank SX-108 was determined to be leaking based on radioactivity detected in laterals beneath this tank in August 1964. Activity in the laterals continued to increase through June 1966. Drywell logging and samples also showed high ^{137}Cs activity. An assessment report prepared by Raymond and Shdo (BNWL-CC-701) documented leak inventory estimates of 2,400 gal and 17,400 Ci of ^{137}Cs for contamination found through mid-1965. Another evaluation published in May 1992 documents additional contamination and leak losses observed between March 1967 and August 1968 estimates an additional 0 to 33,000 gallons of REDOX HLW waste that may have been lost during this period. The upper value is based on a 24 inch level change observed in the tank from November 1965 after a condenser was installed. The range is due to the uncertainty in evaporation and porosity estimates. WHC-MR-0300 notes “some leakage must have occurred since early 1967, because of increased radioactivity observed under the tank.

Johnson reviewed weekly reports and found that the WHC-MR-0300 assessment did not account for all water added to the tank or a potential 24 inch liquid level decrease based on information presented. An estimated 18,000 gallon decrease may have been due to water evaporation and discharge to the tank exhaust ventilation system, but there is no evidence of water evaporative loss to the tank exhaust ventilation system. Therefore an additional 48,000 to 66,000 gallons, not accounted for by WHC-MR-0300, may have leaked from the tank between December 1965 and February 1967 (DA01801448).

Vertical and slant borehole samples provided additional data to assess the SX-108 tank leak. Results will be further discussed next meeting. Based on the available data a mathematical model or (krieging analysis) to estimate total ^{137}Cs mass leaked from SX-108 was conducted (RPP-7884). This krieging analysis estimated 78,000 Ci of ^{137}Cs at the time of the leak or 11,000 gal of waste based on a 137Cs concentration of 7.22 Ci/gal. This appears to be the best current estimate for total ^{137}Cs mass. However, because large volumes of water were added to the tank the leak concentration was likely below 7.22 Ci/gal. Estimates by Johnson indicate that the tank may have leaked 50,000 to 101,000 gallons.

Current Panel Assessment

The panel requested additional time to read through and consider the information presented on the Tank SX-108 leak. Discussion of leak inventory estimates for this tank will continue in the next meeting.

NEXT MEETING AGENDA

Continue discussion of Tank 241-SX-108

ACTIONS:

1. J. Field: Prepare and distribute September 23, 2008 Meeting Summary.
2. J. Field: Prepare SX-107 information for discussion next meeting.

NEXT MEETING:

Date:	October 7, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

MEETING SUMMARY

washington river protection solutions

From: J. G. Field, Washington River Protection Solutions
Phone: 376-3753
Location: Ecology Office,
Date: October 7, 2008
Subject: Tank Farm Leak Evaluation

To: Distribution/Attendees

Attendees: Joe Caggiano, ECOLOGY
Jim Field, WRPS
Les Fort, ECOLOGY
Beth Rochette, ECOLOGY

PURPOSE:
Continue discussion of leak losses from Tank 241-SX-108.

Review of Previous Meeting Summary:
The September 23, 2008 meeting summary was reviewed and approved by attendees.

Tank 241-SX-108 Discussion
Participants discussed the 2005 lateral data and borehole data and the distribution of contamination shown by the data. Ecology requested additional time to review the SX-108 write-up and a more detailed discussion of borehole data results by Marc Wood in the next meeting.

Changes to the SX-108 write-up for the assessment report were discussed. The changes incorporate comments from the previous meeting. Surface geophysics exploration (SGE) resistivity results for SX farm were recently completed and a figure and summary of results will be added to the assessment report.

The group also discussed participants for future tank farm leak evaluations. A representative from S.M Stoller will be added for the next meeting. Additional support from a process engineer is also needed to replace Mike Johnson. Jim Field will look into possible replacements suggested by Ecology. Ecology also asked about DOE involvement. DOE has not attended meetings, but is invited to all meetings, receives draft and final meeting summaries, and receives leak assessment reports for review.

NEXT MEETING AGENDA
Continue discussion of Tank 241-SX-108

ACTIONS:

1. J. Field: Prepare and distribute October 7, 2008 Meeting Summary.
2. J. Field: Prepare SX-107 information for discussion next meeting.
3. J. Field: Find process engineering representative for the assessment team

NEXT MEETING:

Date:	October 21, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

MEETING SUMMARY

From:	J. G. Field, Washington River Protection Solutions
Phone:	376-3753
Location:	Ecology Office,
Date:	October 21, 2008
Subject:	Tank Farm Leak Evaluation
To:	Distribution/Attendees

Attendees: Joe Caggiano, ECOLOGY
Jim Field, WRPS
Les Fort, ECOLOGY
Paul Henwood, S. M. Stoller
Beth Rochette, ECOLOGY

PURPOSE:
Continue discussion of leak losses from Tank 241-SX-108.

Review of Previous Meeting Summary:
The October 07, 2008 meeting summary was reviewed and approved by attendees.

Tank 241-SX-108 Discussion
Participants discussed the vertical and slant borehole data results showing the effects of the high sodium concentrations on other chemicals and radionuclides. The data shows that the high sodium resulted in a more mobile waste form and demonstrated that a single K_D factor is not representative of the ^{137}Cs mobility for the SX-108 tank leak. Participants again discussed leak mass and volume. The mass will vary depending on how much the waste was diluted. However, participants agreed that a 100 kgal leak was unlikely because the activity did not spread to other wells like the T-106 leak. Kriging was identified as the best current basis for estimating Cs mass. However, there was some question as to whether the kriging analysis used the correct dry well data set. Because kriging analyses are key to estimates for tanks SX-107, 108 and 109, the kriging process will be further reviewed and presented in future meetings. The next tanks to be reviewed will be tanks SX-107 and SX-104. A write-up of the SX-107 waste history and leak basis was distributed to participants.

NEXT MEETING AGENDA
Discuss Tank 241-SX-107

ACTIONS:
1. J. Field: Prepare and distribute October 21, 2008 Meeting Summary.
2. J. Field: Prepare SX-107, SX-104 information for discussion next meeting.
3. P. Henwood: Review MSU and Sullivan kriging analyses inputs and prepare ^{137}Cs mass (Ci) estimates for tanks SX-107, 108 and 109 to compare with Kriging results.
4. J. Field: Request Mike Connelly present kriging analysis data and results for SX-Farm.

NEXT MEETING:

Date:	November 25, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

MEETING SUMMARY

From:	J. G. Field
Phone:	376-3753
Location:	Ecology Office,
Date:	November 25, 2008
Subject:	Tank Farm Leak Evaluation
To:	Distribution/Attendees
Attendees:	Joe Caggiano, ECOLOGY
	Jim Field, WRPS
	Les Fort, ECOLOGY
	Paul Henwood, S. M. Stoller
	Beth Rochette, ECOLOGY
	Marcus Wood, CHPRC

PURPOSE:
Discuss leak losses from Tank 241-SX-107.

Review of Previous Meeting Summary:
The October 21, 2008 meeting summary was reviewed and approved by attendees.

Tank 241-SX-107 Discussion
Jim Field presented information for discussion of past releases from Tank 241-SX-107. The tank was identified as a suspect leaker in 1967 based on dry well and lateral activity and was removed from service. The current leak volume estimate for tank SX-107 is less than 5,000 gallons. However, no technical basis was found for this estimate. Activity was first observed in lateral #1 in 1964 which stabilized and began to decay by 1968. The highest levels of activity were observed in lateral #2 in 1968 and later in drywell 41-07-07 suggesting two separate leak events had occurred. Data from re-logging of the laterals in 2005 was presented and discussed. Lateral and drywell data show total gamma concentrations as high as 10^8 pCi/g in lateral #2 and drywell 41-07-07. The waste is a high sodium REDOX waste similar to SX-108; therefore, even for a small leak (ie. <5,000 gallons), ^{137}Cs may have a larger vertical and horizontal distribution compared to low sodium waste.

Groundwater data in the SX-Farm was also discussed. A specific source for groundwater contaminants can not be determined. However, the data strongly indicates the presence of SX-Tank farm contaminants in the groundwater. A summary discussion of groundwater data will be included in the SX-Farm leak assessment report.

After reviewing the available vadose zone data, the kriging analysis for SX-107 of 33,000 Ci of ^{137}Cs (decayed to 1964) appears to provide a defensible estimate for the ^{137}Cs inventory for the leak. The kriging process results and inputs for tanks SX-107, 108 and 109 and comparisons with available data will be further discussed in the next meeting. The only tank samples for

SX-107 were taken well after the leak events and may not be representative of waste in the tank at the time. Therefore, the average, model based, REDOX waste concentration used in previous SIM estimates should be used to estimate a leak volume.

Participants also discussed future assessments. Ecology inquired about a separate process for "questionable integrity (QI)" tanks that had been mentioned. A preference and request was expressed to continue to use the existing RPP-32681 process to assess the QI tanks with Ecology.

A benefit of continuing to assess tanks and UPRs by farm to observe potential impacts of one release on another and to see a "bigger picture" was recognized. If random tanks are reviewed some of the potential interactions within a farm could be missed. Future farms considered were: S-Farm (has only one known tank leak and few UPRs and would complete review for the S-SX WMA), TY-Farm (needed for barrier evaluations and finding interesting new direct push results indicating a larger plume than thought and high ^{99}Tc just above the cold creek formation), and BX-Farm (needed to support groundwater planning and of interest to tribes and stakeholders, particularly BX-102). Ecology deferred to DOE and WRPS to select the next tanks to review.

NEXT MEETING AGENDA
Discuss Kriging analyses, and possibly Tank 241-SX-104

ACTIONS:
1. J. Field: Prepare and distribute November 25, 2008 Meeting Summary.
2. J. Field: Prepare SX-104 information for discussion next meeting.
4. Mike Connelly: present kriging analysis data and results for SX-Farm.

NEXT MEETING:

Date:	December 16, 2008
Time:	3:30-4:30
Location:	ECOLOGY Office

MEETING SUMMARY

From: J. G. Field
Phone: 376-3753
Location: Ecology Office,
Date: December 16, 2008
Subject: Tank Farm Leak Evaluation
To: Distribution/Attendees

Attendees: Joe Caggiano, ECOLOGY
Mike Connelly, WRPS
Jim Field, WRPS
Les Fort, ECOLOGY
Paul Henwood, S. M. Stoller
Marcus Wood, CHPRC

PURPOSE:
Discuss SX-Farm tank leak estimates based on heat load and discuss kriging analyses for tanks SX-107, SX-108 and SX-109.

Review of Previous Meeting Summary:
The November 25, 2008 meeting summary was reviewed and approved with changes. Tank SX-104 information was distributed to the team before the meeting.

Discussion of Tank Leak Estimates based on Heat Load
During the week questions were received from Stan Sobjek (Nez Perce Tribe) regarding the leak assessment process and in particular suggesting that the Heat load based leak estimates (HNF-3233) should be used as an upper limit for SX-Farm tank leaks. A draft section to be included in the SX-Farm report was distributed for discussion. Previous evaluations and review of the heat load assessments concluded that heat load estimates are inconsistent with previous assessments such as WHC-MR-0300 and vadose and tank data. The discussion of heat load estimates will be expanded in the report to include a description of the heat load approach and to discuss why leak volume estimates based on this approach appear to be unreasonably high or to include revised heat load estimates.

SX-Farm Report Review Process
The SX-Farm assessment report will be released during the first quarter of 2009 as Draft Rev. 0 after peer review by the assessment team and review by WRPS and ORP. Draft Rev. 0 will state that it is being released for public review. After release, Draft Rev. 0 can be sent for public review to obtain input from tribes and stakeholders. Rev. 0 of the report will incorporate comments as dispositioned.

Kriging Analysis
Mike Connelly reviewed the kriging analysis process and presented figures showing that the kriging results for individual tanks generally show higher ^{137}Cs inventory estimates compared to 2005 lateral data. Paul Henwood discussed graphics, also showing that kriging analyses generally provided high leak volume estimates. There was still question as to whether the kriging for SX-108 accurately accounted for the level of gamma activity in drywells 41-09-04 and 41-08-07 and how far to the Southwest the plume extended, also whether activity in these wells was from SX-108 or SX-109 or another source. There is apparent co-mingling of plumes from two or more tank leaks and a combined kriging estimate for co-mingled plumes may be more representative than individual tank leak estimates. Given that SX-107, 108 and 109 are known leakers, there is no apparent need for tank specific leak estimates and a co-mingled estimate for multiple tanks is acceptable. Discussion of the kriging analysis approach and evaluation will be included in the SX-Farm assessment report.

NEXT MEETING AGENDA
Discuss Tank 241-SX-104 leak information

ACTIONS:
1. All: Review meeting summaries and SX-104 information.
2. J. Field: Prepare and distribute December 16, 2008 Meeting Summary.
3. J. Field: Prepare SX-Farm assessment report and UPR information.
4. M. Wood: Prepare SX-Farm groundwater discussion for report.
5. M. Connelly: Prepare kriging analysis input to report.
6. P. Henwood: Prepare review of other SX-Farm drywell data for discussion (eg. SX-102)

NEXT MEETING:

Date:	January 13, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

DRAFT MEETING SUMMARY

From: J. G. Field
Phone: 376-3753
Location: Ecology Office,
Date: January 13, 2008
Subject: Tank Farm Leak Evaluation
To: Distribution/Attendees

Attendees: Jim Field, WRPS
Les Fort, ECOLOGY
Paul Henwood, S. M. Stoller
Marcus Wood, CHPRC

PURPOSE:
Discuss SX-Farm tank leak estimates for tank 241-SX-104.

Review of Previous Meeting Summary:
The December 16, 2008 meeting summary was reviewed and approved with changes.

SX-104 Assessment
Jim Field reviewed SX-104 tank waste history and the basis for current leak inventory estimates. SX-104 is the only tank that was declared a leaker based on liquid observation well (LOW) decreases. Assessments of LOW decreases were conducted in 1988, 1998 and 2008 as a result of separate events. The 1998 and 2008 assessments concluded that the LOW decreases in 1997 and 2008 were not caused by a tank leak. The 1988 assessment concluded that that there was no proof the tank was leaking and the LOW decrease was probably due to evaporation. However, because the LOW decrease could not be explained with 95% certainty three of five panel members classified the tank as an assumed leaker.

After review of previous assessments and available date the team concluded that tank SX-104 probably did not leak and there was no evidence of a leak. The only indication of a potential leak, the LOW, was not a reliable indicator for several reasons; the 1988 LOW failed and was replaced by two other LOWs in different locations in the tank; SX-104 has a tank crust with multiple waste layers that make the LOW difficult to interpret; and the tank waste is highly porous with high hydrogen gas content and several gas release events that likely contributed to the LOW changes as well as evaporation. Therefore no leak inventory should be assigned for this tank.

SX-102 Discussion
Paul Henwood (S.M. Stoller) then discussed additional logging data observations in SX-Farm to determine if other tanks should be assessed for leaks. No indication of a leak was observed in the logging data for any of the tanks currently “assumed sound” except SX-102.

Occurrence reports due to liquid level decreases in SX-102 were filed in 10/75, 1/77 and 6/80. Previous tank leak assessments concluded that the tank was sound because the liquid level decrease was consistent with evaporation rates and gamma data did not indicate a tank leak. The logging data presented shows 100 pCi.g of ^{137}Cs at about 2 ft and 30 pCi/g from 30 to 70 ft. Drywell 41-10-01 also shows near surface contamination and a peak to 10 pCi/g at 66 ft. The gamma data for 41-02-02 shows a gradual increase from 300 to 600 c/s in a peak observed at 50 ft bgs between 1975 and 1990. These levels appear to be insignificant levels, but the increasing gamma activity from 1975 to 1990 raises questions and SX-102 will be further discussed in the next meeting.

Near Surface Contamination

Near surface contamination of ~100 pCi/g ^{137}Cs was observed in the top 5-10 ft bgs in gamma logs and in surface radiation surveys throughout the SX-Farm. There are no records to quantify this contamination and the contamination has not been identified as an unplanned release. Estimates for near surface contamination and unplanned releases other than tank leaks will be discussed in the next meeting.

NEXT MEETING AGENDA

Discuss Tank 241-SX-102 and near surface releases in SX-Farm

ACTIONS:

1. All: Review meeting summary
2. J. Field: Prepare and distribute January 13, 2008 Meeting Summary.
3. J. Field: Prepare SX-Farm assessment report and UPR information.
4. M. Wood: Prepare SX-Farm groundwater discussion for report.

<u>NEXT MEETING:</u>

Date:	January 28, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

MEETING SUMMARY

From: J. G. Field
Phone: 376-3753
Location: Ecology Office,
Date: January 28, 2008
Subject: Tank Farm Leak Evaluation

To: Distribution/Attendees

Attendees: Joe Caggiano, ECOLOGY
Jim Field, WRPS
Les Fort, ECOLOGY
Paul Henwood, S. M. Stoller
Beth Rochette, ECOLOGY
Marcus Wood, CHPRC

PURPOSE:
Discuss Tank 241-SX-102 and near surface releases in SX-Farm

Review of Previous Meeting Summary:
The January 13, 2008 meeting summary as modified by Paul Henwood before the meeting was reviewed and approved. Based on the conclusion from the previous meeting that Tank 241-SX-104 probably did not leak, a formal leak integrity assessment per TFC-ENG-CHEM-D-42 was recommended.

SX-102 Assessment
Discussion of tank SX-102 continued. Studies were presented showing that liquid level decreases were explained by evaporation. A likely source of the low levels of radioactivity (<30 pCi/g) in drywell 41-02-08 is a 4,000 gallon leak at the SX-102 transfer valve on the SX-102 to SX-105 transfer line (ISO-75 p. 79). A 1962 failed isolation valve resulting in a “bad leak” between tanks SX-101 and SX-102 on the condensate return system (IDMS D19602553 p. 2) could be the source of the low levels of radioactivity in drywell 41-02-02. Both drywells show surface contamination suggesting a shallow leak source. In addition, while pumping waste from SX-103 to SX-101 the flush valve failed on 3-19-1965 and a leak was discovered outside the pump pit (RL-SEP-297). An action was taken to review drawings in an attempt to verify the location of the leaking valves. It was concluded that there is not enough definitive evidence for a leak from tank SX-102 and there is no new information to overrule a prior designation of "sound" for this tank.

Near Surface Contamination

Radiation survey data and dry well plots were presented that show near surface contamination across the farm. A list of SX-Farm Occurrence Reports and leak sites identified in RHO-CD-673 and a list of potential pipeline failures and other unplanned releases in SX-Farm (RPP-RPT-29191) (see Attachment 1) were discussed. These included the near surface sites in the Waste Information Data System (WIDS). However, it was observed that many of the releases are not currently in WIDS and it was recommended that these sites be added. The SX-Farm assessment report will identify each of the surface contamination sites discussed. A surface contamination inventory will be developed in the future after additional characterization is performed. The surface release sites identified should be considered as locations for future characterization.

NEXT MEETING AGENDA

Wrap up near surface contamination discussion including a review of SX-Farm pipelines and discuss SX-Farm groundwater results.

ACTIONS:

1. All: Review meeting summary
2. J. Field: Prepare and distribute January 13, 2008 Meeting Summary.
3. J. Field: Prepare SX-Farm assessment report and UPR information.
4. M. Wood: Prepare SX-Farm groundwater discussion for report.

NEXT MEETING:

Date:	January 28, 2008
Time:	3:00-4:30
Location:	ECOLOGY Office

APPENDIX C

KRIGING ANALYSES DESCRIPTION
Modified From RPP-8209

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C1. SUMMARY OF KRIGING APPROACH

To estimate the volume and concentration of contaminated soil a geostatistical approach is used. This approach incorporates a conceptual model (a three-dimensional grid which represents the Tank Farm and surrounding soil), sample data, the statistical or trend information (derived from the sample data), and geophysical and other site information (soil type, hydrogeologic conditions, historical record) . The site geology and history, along with the spatial distribution of the data, are used to develop the conceptual model. The conceptual model is comprised of a three-dimensional grid that represents the tanks and volume of soil around tanks.

The method of kriging is used to make estimates of contaminant concentration values at locations where there are no samples within the conceptual model domain. It should be noted that the actual sample values are used and respected during the interpolation process.

The analysis is performed in four tasks, as shown in Table C-1: preliminary evaluation, spatial trend analysis, interpolation, and inventory estimation. Each of the subsequent tasks is dependent on the previous tasks. During the preliminary evaluation the raw data is analyzed to determine continuity and data density. Any transformation or data quantity issues are detected and addressed in this task. The next task is to perform a spatial trend analysis. In this task the spatial statistical trends or structure of the sampled data are described. The parameters that describe the spatial trends are used during the interpolation task. During the interpolation task ordinary and trend kriging are used to interpolate ^{137}Cs point and confidence estimates for regions below and around the waste storage tanks. The final task is to use ^{137}Cs estimates to generate inventory and activity level estimates for the Tank Farm.

Table C-1. Task Summary

Task	Preliminary Evaluation	Spatial Trend Analysis	Interpolation	Inventory Estimation
Activity	Analysis of: Data continuity Data normality Data density Other physical processes	Correlation determination: Vertical Horizontal Anisotropy search	Use method of kriging to make ^{137}Cs activity estimates	Integration of the estimated ^{137}Cs activity field
Result	Site conceptual model Data transform Data compression or filter	Variogram parameters Variogram model Range (X,Y,Z) Sill Nugget	^{137}Cs and variance of error estimates for all locations around and below tanks	Estimation of: Gross ^{137}Cs activity levels Contaminated soil volume

C2. PRELIMINARY EVALUATION

This task is the first step in the activity and volume estimation process. In this task the site conceptual model is developed and a number of topics are addressed so that a geostatistical approach may be used to make defensible activity and volume estimates. These issues pertain to the spatial and statistical distribution of the data. The spatial distribution and density of data are evaluated at a qualitative level to determine if a geostatistical approach is warranted or possible.

The statistical distribution of the data is quantitatively evaluated in order to satisfy assumptions inherent in the geostatistical interpolation process (kriging).

C2.1 Site Conceptual Model

The site conceptual model appraises the spatial distribution of data at the site, and establishes regions and sub-regions. It incorporates the physical description, such as the locations of the waste storage tanks, the extent of the volume covered by the sample data, and the site geology. The conceptual model indicates the manner in which the estimation process is performed. For instance, the approach will delineate and associate the areas around the waste storage tanks that are used in the final activity and soil volume estimates. The sub-regions are also used to segregate the sample data, as described in section C2.2. The development of the conceptual model is partially influenced by the project objectives, namely to evaluate inventory on a tank-by-tank basis. This will require the model to be divided into sub-regions that are specific to the individual waste storage tanks.

At the 241-SX Tank Farm the conceptual model consists of a rectangular cube that encompasses waste storage tanks SX-101 through SX-115, 23,785 gamma readings (^{137}Cs) from 142 lateral and vertical dry wells, and the soil adjacent to the waste storage tanks. The dimensions of the conceptual model are 105 m east-west by 165 m north-south by 60 m deep. The site conceptual model is shown in two dimensions in Figure C-1 and in three dimensions in Figure C-2.

Figure C-1. Two-Dimensional View Site Conceptual Model

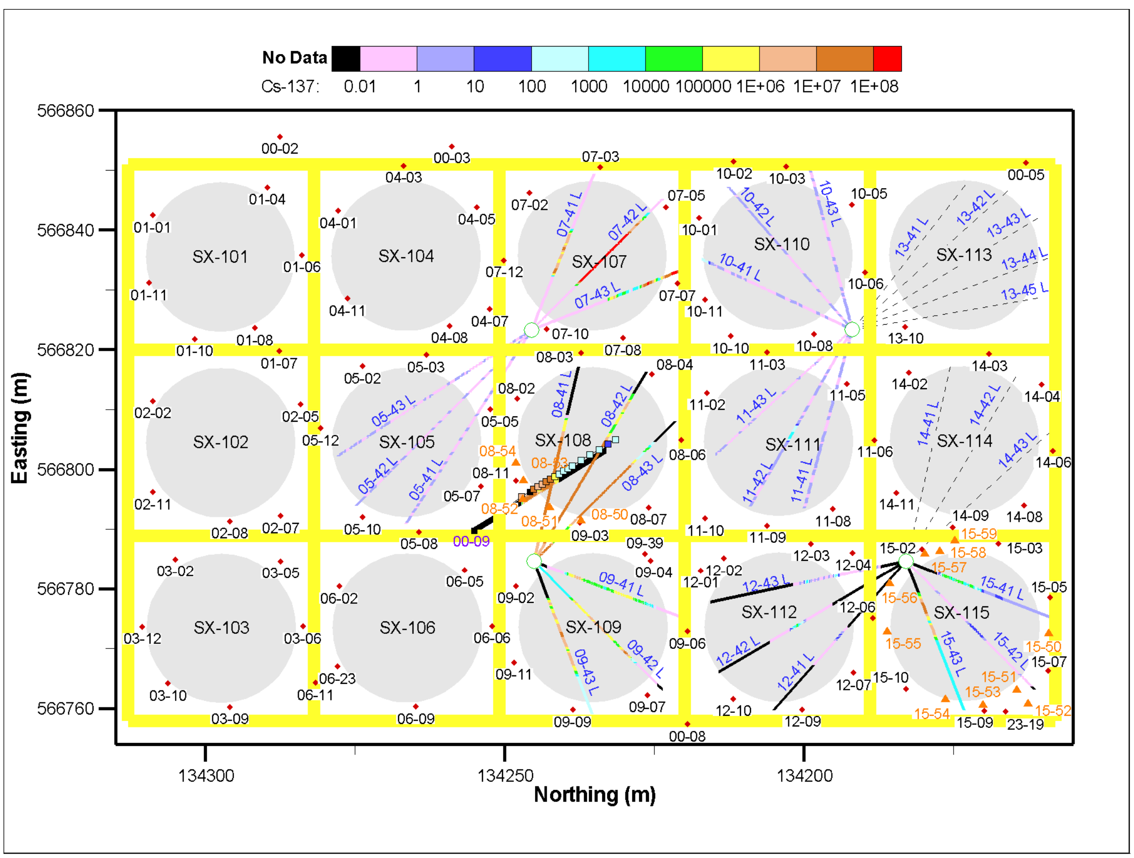
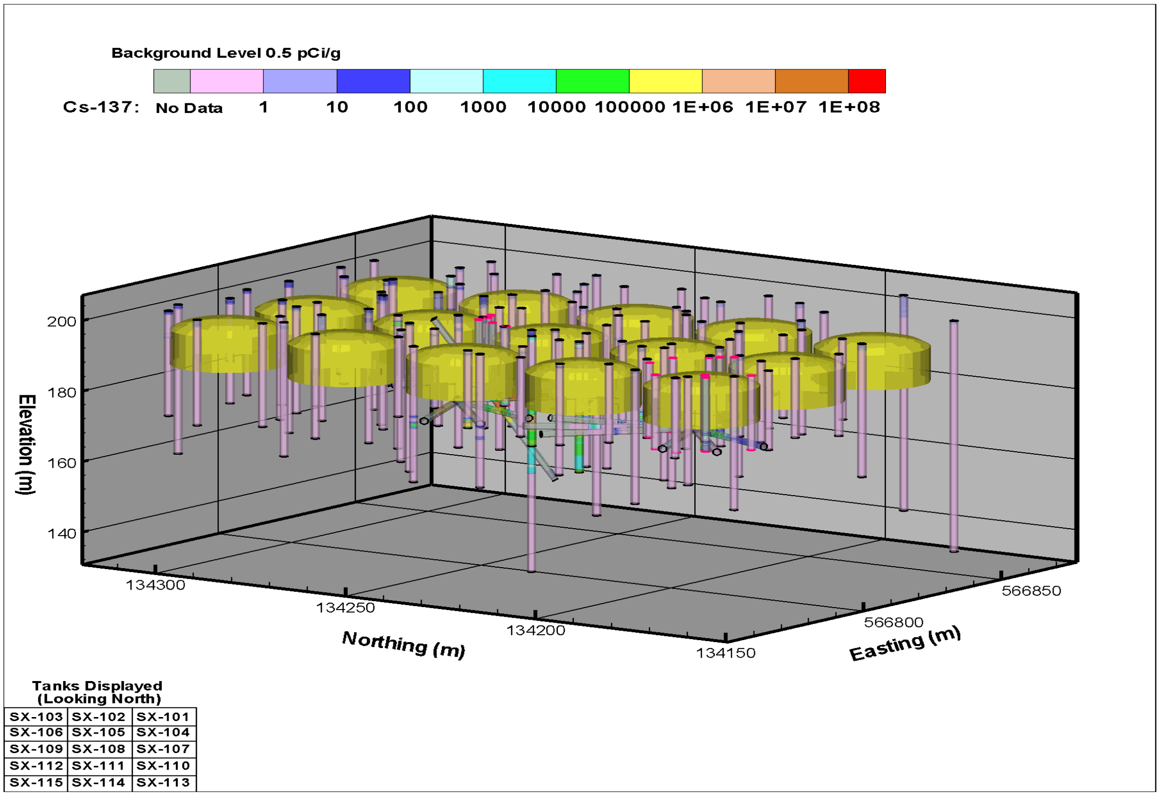


Figure C-2. Three-Dimensional View of Site Conceptual Model



As previously stated, the estimates of ^{137}Cs activities and contaminated soil volumes are reported in a tank-by-tank basis; therefore, the conceptual model is divided into fifteen sub-regions. The yellow grid in Figure C-1 indicates the sub-regions. The sub-regions are also used to segregate the sample data. The segregation of the sample data is discussed in section C2.2.

Data Density

All Hanford Tank Farms have had monitoring boreholes installed around the tanks to detect leaks from the tanks. Additionally, in the 241-SX Tank Farm, caissons were hand-dug to install horizontal boreholes (laterals) underneath tank SX-105 and tanks SX-107 to SX-115. All these tanks except SX-113 had three laterals placed underneath them (Figure C-1); tank SX-113 had five laterals. The total number of data points used in this analysis was 23,785. The sources for this data are listed below.

- MACTEC-ERS Spectral Gamma Measurements for ^{137}Cs. This consisted of Spectral Gamma Logging of 101 dry boreholes which resulted in 20,578 data points of ^{137}Cs (GJPO-HAN-4, 2000, *Hanford Tank Farms Vadose Zone Addendum to the SX Tank Farm Report*).

- Lateral Gross Gamma Logging. Goodman (HNF-5782, *Estimation of SX-Farm Vadose Zone Cs-137 Inventories from Geostatistical Analysis of Drywell and Soil Core Data*) reviewed the historical gross gamma logging of the laterals underneath the tank and correlated the gross gamma measurements to ^{137}Cs concentration. This assumes the short-lived gamma emitters have decayed away and that ^{137}Cs is the principal source for the gamma. The laterals had 2,497 data points.

- Chemical analysis of vadose zone sediments for ^{137}Cs around tanks SX-108 and SX-115 (orange boreholes on Figure C-1) by Raymond and Shdo (BNWL-CC-701) yielded 172 data points above background. Further, Goodman (HNF-5782) fixed background values for another 425 data points in boreholes which Raymond and Shdo sampled, but did not find ^{137}Cs.

- Chemical analysis of the slant borehole (41-00-09) vadose zone samples by Pacific Northwest National Laboratory (PNNL-13757-4, *Characterization of Vadose Zone Sediment: Slant Borehole SX-108 in the S-SX Waste Management Area*) yielded 16 data points

- Spectral gamma logging of the slant borehole (41-00-09) by MACTEC-ERS (GJPO-HAN-4) yielded 97 data points.

The density of sample data affects the ability to estimate ^{137}Cs activity levels in two ways. First, the level of confidence in the activity level estimate is inversely proportional to distance between the interpolation point and the sample data. In other words, estimates can only be made in regions within a correlation length of sample data. This is initially done with a qualitative evaluation of the sample data locations in the conceptual model (see Figure C-1). The site conceptual model is examined to ensure that all regions are populated with samples. No estimates will be made in regions where there are no samples. This analysis is quantitatively substantiated after correlation lengths are determined in section C3.1. Based on the spatial distribution of the sample data, as shown in Figures C-2 and C-3, there are adequate data to continue with the geostatistical analysis.

The second factor pertaining to data density is the number of samples to be used in the interpolation process. At 241-SX Tank Farm there are 23,785 ^{137}Cs samples from 142 lateral, vertical and diagonal dry wells. During the kriging process the variability between these samples are represented in the covariance matrix. To solve the kriging equations requires the inversion of the $n \times n$ covariance matrix, where n is the number of samples. The computational demand for this process is proportional to n^3 and is the process-limiting step in the geostatistical approach.

Two approaches are employed to address the limitation caused by computational demands of so large a sample data set. The first is to divide the data into regional sub-groups and the second is to compress the data by filtering.

C2.2 Sub-Region Data Grouping

The sub-regions outlined in the site conceptual model provide a quick segregation of the sample data. All data within an individual tank sub-region are associated with that sub-region. For instance, the data within sub-region SX-101 would sample data from the following dry wells: 00-02, 01-01, 01-04, 01-06, 01-08, 01-10 and 01-11. The associations of each sub-region are summarized in Table C-2.

Table C-2. Summary of Dry Well Membership in Sub-Regions

Sub-Region	Dry Wells in Sub-Region	Adjacent Sub-Regions
SX-101	00-02, 01-04, 01-06, 01-08, 01-10	SX-102, SX-104, SX-105
SX-102	01-07, 02-02, 02-05, 02-07, 02-08, 02-11	SX-101, SX-103, SX-104, SX-105, SX-106
SX-103	03-02, 03-05, 03-06, 03-09, 03-10, 03-12	SX-102, SX-105, SX-106
SX-104	00-03, 04-01, 04-03, 04-05, 04-07, 04-08, 04-11	SX-101, SX-102, SX-105, SX-107, SX-108
SX-105	00-09, 05-02, 05-03, 05-05, 05-07, 05-08, 05-10, 05-12, 05-41L, 05-42L, 05-43L *	SX-101, SX-102, SX-103, SX-104, SX-106, SX-107, SX-108, SX-109
SX-106	06-02, 06-05, 06-06, 06-09, 06-11, 06-23	SX-102, SX-103, SX-105, SX-108, SX-109
SX-107	07-02, 07-03, 07-05, 07-07, 07-08, 07-10, 07-12, 07-41L, 07-42L, 07-43L	SX-104, SX-105, SX-108, SX-110, SX-111
SX-108	00-09, 08-02, 08-03, 08-04, 08-06, 08-07, 08-11, 08-41L, 08-42L, 08-43L, 08-50, 08-51, 08-52, 08-53, 08-54 *	SX-104, SX-105, SX-106, SX-107, SX-109, SX-110, SX-111, SX-112
SX-109	09-02, 09-03, 09-39, 09-04, 09-06, 09-07, 09-09, 09-11, 09-41L, 09-41L, 09-43L	SX-105, SX-106, SX-108, SX-111, SX-112
SX-110	10-01, 10-02, 10-03, 10-05, 10-06, 10-08, 10-10, 10-11, 10-41L, 10-42L, 10-43L	SX-107, SX-108, SX-111, SX-113, SX-114
SX-111	11-01, 11-03, 11-05, 11-06, 11-08, 11-09, 11-10, 11-41L, 11-42L, 11-43L	SX-107, SX-108, SX-109, SX-110, SX-112
SX-112	12-01, 12-02, 12-03, 12-04, 12-06, 12-07, 12-09, 12-10, 12-41L, 12-42L, 12-43L	SX-108, SX-109, SX-111, SX-114, SX-115
SX-113	00-05, 13-10	SX-110, SX-111, SX-114
SX-114	14-02, 14-03, 14-04, 14-06, 14-08, 14-09, 14-11,	SX-110, SX-111, SX-112, SX-113, SX-115
SX-115	15-02, 15-03, 15-05, 15-07, 15-09, 05-10, 23-19, 15-50, 15-51, 15-52, 15-53, 15-54, 15-55, 15-56, 15-57, 15-58, 15-59, 15-41L 15-42L, 15-43L	SX-111, SX-112, SX-114

* indicates bore holes that have data in more than one sub-region

During the interpolation phase each sub-region of the site is estimated separately. Only sample data from the current and adjacent sub-regions are used for the estimation. In addition to decreasing the local sample size, this approach allows for a more robust estimation because the estimates are not biased by samples that are from regions beyond a correlation distance away. In terms of the global kriging estimate, the use of local sub-regions allows for a local mean that may vary from region to region. This is one way to address the stationarity assumptions inherent in the kriging algorithms.

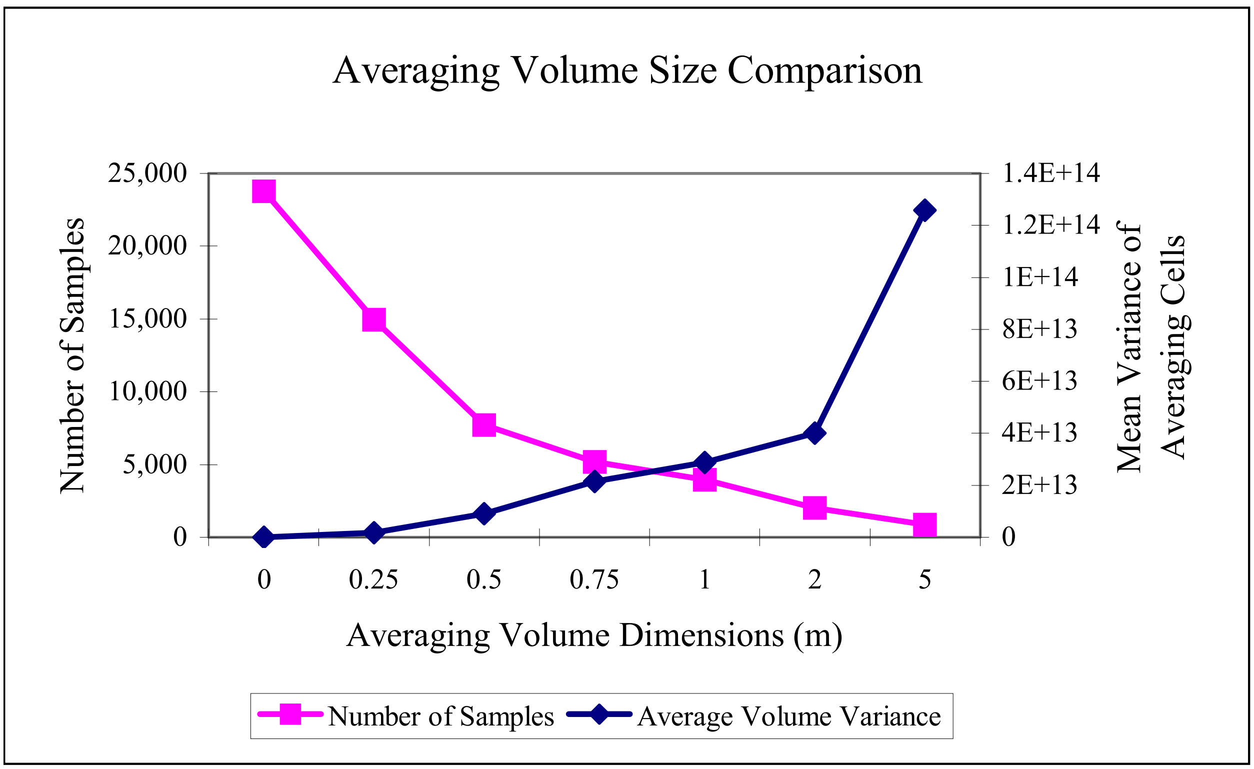
C2.3 Data Compression / Filtering

Ideally all of the sample data should be used and compressing or filtering the data may add uncertainty and bias to the process. However, even with the efficiencies gained by segregating the data into sub-regions the amount of data is problem-limiting due to computational burden; in particular, in the center sub-regions where there is a great deal of sample data, such as sub-regions SX-108 and SX-111. To reduce the size of the sample data set the data are spatially averaged. The amount of bias and uncertainty introduced in the filtering process is dependent on the scale or size of averaging volume and the type of averaging performed.

C2.3.1 Averaging Volume Size

In the case of the averaging volume size, the uncertainty introduced may be expressed by the variance within each averaged volume. This uncertainty is propagated through the interpolation phase by using block kriging. Block kriging is identical in structure to Ordinary and Trend kriging in the method of solving the system of equations and making estimates. The difference is in how the covariance matrix is created. In block kriging each data point within a block (averaging volume) has an associated variance that comes from the variance between the samples within the averaging volume or block. There is a trade-off between averaging size and uncertainty. The larger the averaging volume size, the greater the compression and the smaller the data set; however, the uncertainty also increases. The optimal averaging volume is the smallest volume possible that produces a sample size that can be inverted during the interpolation phase. Figure C-3 shows the trade-off between averaging volume size and uncertainty (variance).

Figure C-3. Trade-off Between Averaging Cell Size and Uncertainty



The kriging process is limited by the size of the covariance matrix, which is related to the number of samples ($n \times n$). The size of the covariance matrix poses a technological limit to the size of the sample set. In the case of the 241-SX Tank Farm, the largest sample set that can be implemented is between 7,000 and 9,000 points. Conversely, there is a limit on the maximum amount of point variance (this is expressed as the mean variance of the averaging cell or volume) that can be incorporated into the kriging process before it dominates the solution. At the 241-SX Tank Farm the upward bound on the averaging volume occurs around 2 m. This yields a range of averaging volume dimensions of 0.5 to 2 m. An averaging volume dimension of 0.75 m was used for this investigation.

C2.3.2 Averaging Volume Filtering

Another factor in the data compression process that affects the interpolation results is the method of filtering within the averaging volume. A single value or statistic represents all of the samples within an averaging volume. The possible methods for calculating the representative statistics are: minimum value, maximum value, arithmetic mean, or geometric (logarithmic) mean. Each method has advantages and disadvantages.

The use of the minimum value is not a likely candidate because it produces a non-conservative estimate and it introduces a large bias towards the lower sample values. The estimation of activity level is greatly influenced by the peak values in the data set, and by using the minimum value in the filtering process, peak values may be removed. Therefore, no investigation was performed to determine the impacts of using the minimum value and it is only mentioned here for completeness.

The maximum value filter adds bias to the estimation process in the opposite direction of the minimum value. This approach favors the peak values and produces a conservative estimate. Since the estimation of activity levels may be dominated by peak values, the use of the maximum value filter produces a "worst case" scenario.

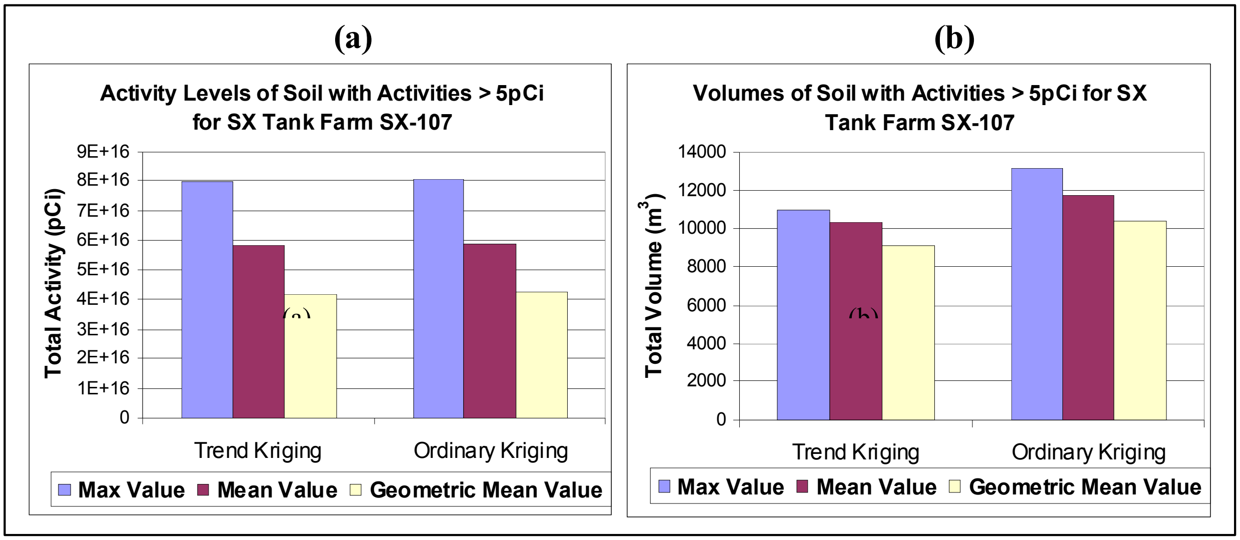
The use of the arithmetic mean filter provides a less conservative estimate than the maximum value, but it more closely represents the initial sample set. A weakness of the arithmetic mean filter is the introduction of bias, in either direction, when there is a large variance in the initial sample population. This is illustrated by situations where the higher values are several orders of magnitude greater than the lower values and the mean value is dominated by non-detect or background level measurements, as is the case with much of the ^{137}Cs data.

The properties of the geometric mean filter are similar to the arithmetic mean filter with a higher degree of bias towards the lower values due to the log compression of the higher values.

The impact of the filter method is also dependant on the value distribution of the actual data set. To assess the impact of each filter type on the estimation process the predicted inventories obtained with each filter type are compared. This comparison test is performed at tank SX-107. The estimated activity levels and contaminated soil volumes are compared in Figure C-4 (a) and (b), respectively.

In evaluating the results of the test, as shown in Figure C-4, it is seen that the most conservative estimate is obtained using the maximum value filter with the arithmetic mean and geometric mean respectively less conservative. It is important to note that activity level estimates show a greater variation than do the volume estimates. The difference between the most and least conservative activity level estimates differ by nearly 50% while the volume estimates differ by only 20%. This means that the choice of a data compression filter will have a greater impact on the inventory estimate than on the volume estimate. This examination of the data compression filters does not indicate which filter is best for the analysis, as that is policy decision, but rather, it illustrates the trade-offs of each method.

Figure C-4. (a) Estimated Activity Levels and (b) Estimated Contaminated Soil Volume Using Maximum, Arithmetic Mean, and Geometric Mean Sample Data Filtering for Tank 241-SX-107



Normality Check of Data

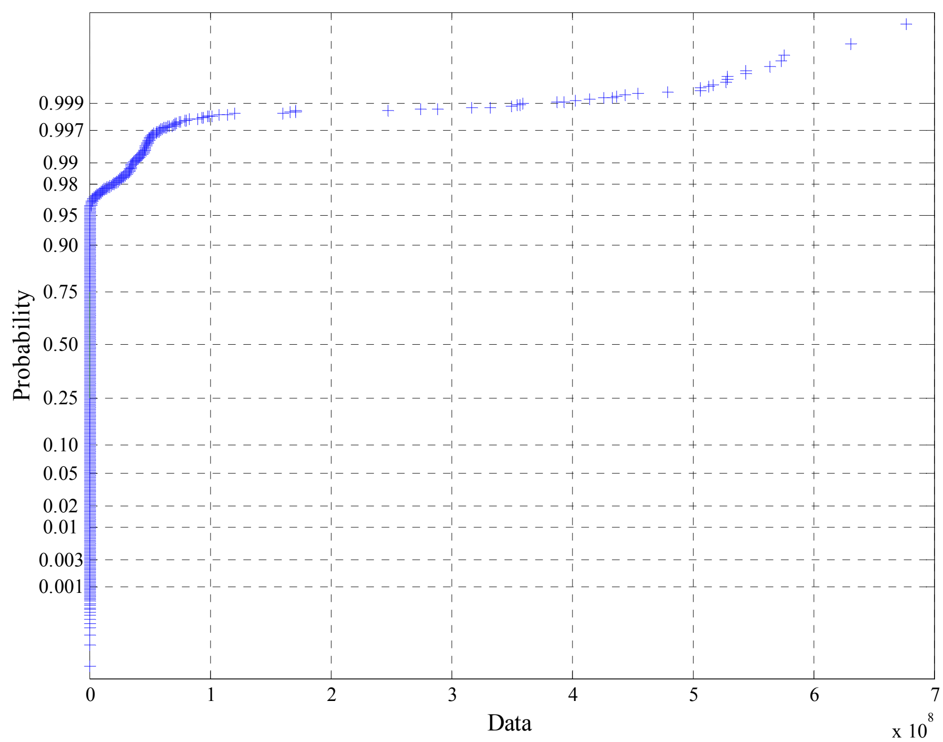
In this step of the analysis the normality of the sample data is examined. The possibilities of data distribution conditions and associated data manipulation are summarized below in Table C-3. There is a two-fold reason for determining the normality of the data. First, the normal or Gaussian distribution has properties that are used in the theoretical derivation of geostatistical parameter estimation methods (kriging); mainly, the fact that there is a succinct mathematical description of the Gaussian distribution. Second, it is has been found that environmental concentration data tend to be normally or lognormally distributed (*Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities – Addendum to Interim Final Guidance* [EPA 1992]). It should be noted that although geostatistical estimation tools work better if the data is normally or lognormally distributed, normality is not a mandatory requirement for the applicability of geostatistical methods.

Although there are number of methods for determining normality of data, probability plots of the sample data are the preferred method. The normal and lognormal probability plots of the ^{137}Cs activity level data are shown in Figures C-5 and C-6, respectively.

Table C-3. Summary of Normality Types of Data and Action

Condition of Data	Action	Comment
Data is normally distributed	No transformation needed	Use of geostatistics is appropriate
Data is lognormally distributed	Use log transformation of data	Use of geostatistics is appropriate
Data is partially normally or lognormally distributed	Use log transformation if necessary. Filter for outliers and background.	Use of geostatistics is appropriate
Data is not normally or lognormally distributed	NA	Use of geostatistics is NOT appropriate

Figure C-5. Normal Probability Plot of ^{137}Cs Data from 241-SX Tank Farm



From Figures C-5 and C-6 it is seen that the data are lognormally distributed in the central tendency. There is, however, a larger deviation at the tails of the probability plot. The near vertical portion at the low end is due to the large amount of sample data that are at or near the background levels. The deviation at the top end of the plot is due to the extreme values that are several orders of magnitude greater than the mean values. Upon investigation the hump and upturning trend are related to the extreme values (~6.0×10^8 pCi/g) from borehole 41-07-42. The lognormality of the data is further verified by lognormal probability of the sample data without measurements below the background level, as shown in Figure C-7.

Figure C-6. Lognormal Probability Plot of ^{137}Cs Data from 241-SX Tank Farm

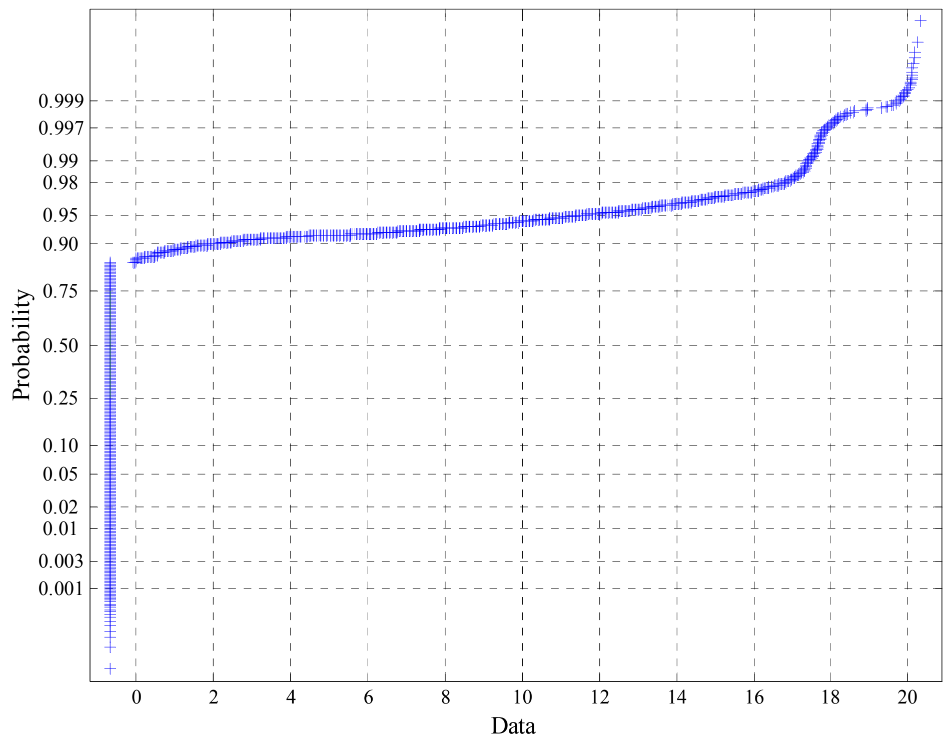
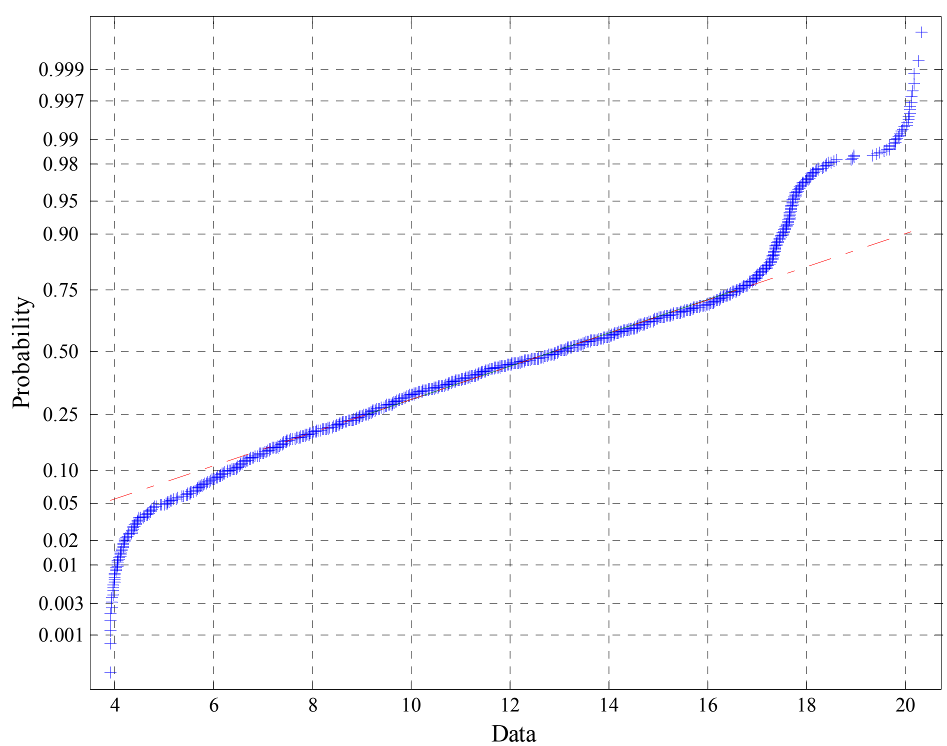


Figure C-7. Lognormal Probability Plot of ^{137}Cs Data from 241-SX Tank Farm Without Samples Below Background



C3. Interpolation with Ordinary Kriging

The development of the conceptual model and the preliminary statistics dictate the strategy for applying the interpolation method (kriging). Namely the sub-regions and sub-data sets have been delineated, any data compression or preprocessing has been performed, and the statistical requirements of the interpolation method have been satisfied. The conceptual model kriging grid is populated one tank grid at a time. Only the sample values within the tank grid's neighborhood are used to determine the variogram parameters and make estimates. This allows for local means to influence the interpolation process and avoid biasing the estimates by the large amounts of non-detect or background data. In order to perform the interpolation, however, the trends in the variability of data need to be determined. This variability in the sample data is modeled by a variogram. The variogram model is in turn described by parameters: nugget, ranges and sill (described in section C3.2). The variogram parameters and sample data are used in the kriging process to make estimates of the contaminant at all interpolation grid locations. Therefore, the determination of the spatial trends in the data (variogram analysis) occurs prior to the kriging process. However, a background of the kriging process and how the variogram parameters are employed is essential in the understanding of the overall process. A thorough review of the method of kriging is covered in Appendix A of RPP-8209, *Geostatistical Analysis of Gamma-Emitting Radionuclides in the SX Tank Farm Vadose Zone*.

C3.1 <u>Spatial Trend Analysis</u>

In this section determination of the underlying geostatistical trends is discussed. The underlying trends in the variability of the data must be identified in order to estimate parameter values at locations without samples. The following topics with their respective outcomes are discussed in this section.

Topics	Outcomes
Effects of sample values at or below background	Background samples are removed from trend analysis
Trends associated with background versus ^{137}Cs samples	Compare variograms and correlation lengths determined with both sample populations
Determination of vertical correlation length and the vertical filter	Vertical filter size and correlation length
Determination of horizontal correlation lengths – Anisotropy in the plan	Horizontal (northing and easting) correlation lengths

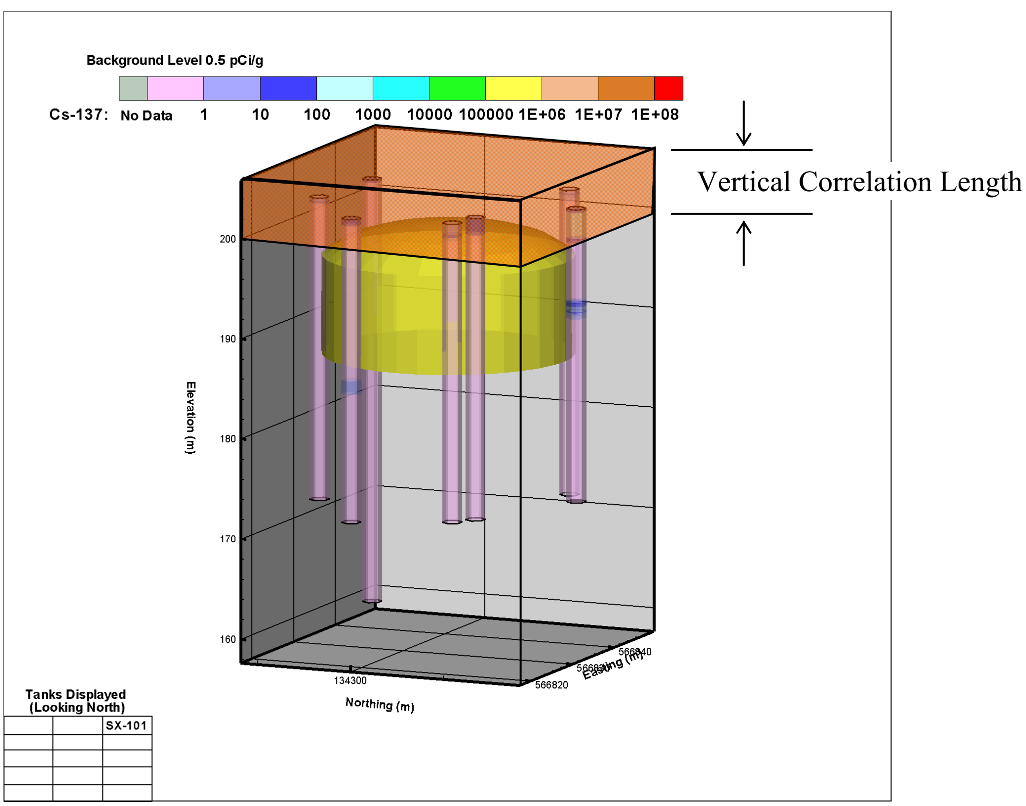
A variogram analysis is performed to establish these trends. The variogram is a statistical model that relates the variability of sample value pairs with their separation distance. The variogram model is used in the kriging process to estimate the contaminant value based on sample values and how far the sample locations are from the interpolation point.

Due to the spatial distribution of the sample data and the site geology the search for correlation lengths of the sample variability is performed in two steps: depth or vertical, and horizontal correlation search. This is done because there are different scales in the distribution of data. The distance between data gathered from individual boreholes is very small, around 15 cm, compared to the distance between data gathered in separate boreholes, meters to tens of meters. It is also known, from the site geology, that the sub-surface geology supports different scales in the physical properties. The depth-wise correlation length search is performed first. The depth-wise correlation length for a sub-region is then used to filter the sub-region data during the horizontal correlation length search.

The vertical correlation lengths are determined for the boreholes separately and then an average vertical correlation length is determined for the site. Special attention is given to the boreholes that are in the regions where ^{137}Cs waste is known to have leaked.

When calculating the horizontal correlation lengths for the sub-regions, only the variance of data that is within the average vertical correlation lengths is considered. In Figure C-8 a sub-region is shown with a tank and seven vertical boreholes. The vertical correlation length of the individual boreholes is used to determine the average vertical correlation length. This correlation length is the vertical dimension of the data filter box shown as the orange box in Figure C-8. Only the variances between the data within the filter box are used in the horizontal correlation search. The filter box is "moved" down the sub-region to compile variances between data points that are within the average vertical correlation length. The filter ensures that the horizontal correlation length search is not biased by the variances between data that are from vastly different depths.

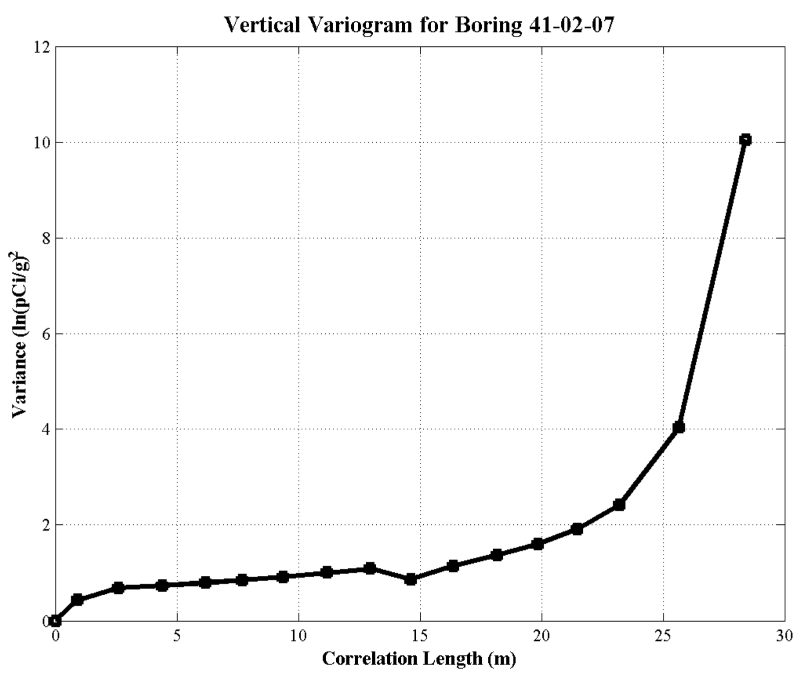
Figure C-8. Data Locations for Vertical Filter Example

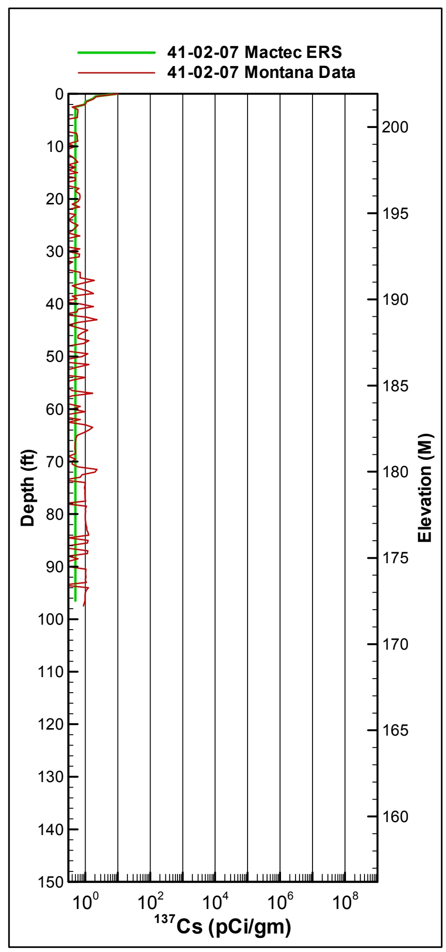


C3.2 Determine Depth-Wise Correlation Length

In performing the vertical correlation length search several phenomena were observed. Several of the tank sub-regions exhibited small amounts of variation. These were sub-regions where there was little to no leaking from the waste storage tanks, such as tanks SX-101, SX-102, SX-103, SX-104, SX-105, SX-106, SX-110, SX-111, SX-113 and SX-114. For these tank sub-regions very large vertical correlation lengths were found. An example of a boring log and its associated variogram is shown in Figure C-9. The variogram demonstrates two key features. First, there is a strong correlation, as seen by a variance of 0.5 $\ln(\text{pCi/g})^2$, for up to 20 m. A variance of 0.5 $\ln(\text{pCi/g})^2$ translates to an uncertainty of ± ~2.0 pCi/g at 20 m. Secondly there is an exponential increase in the variance after 20 m. Upon examination of the gamma boring log data it is observed that there is a low degree variability, with most of the measurements near background levels. This indicates that there is very little variation in this borehole, as seen in Figure C-9. The variogram in Figure C-9 allows the prediction, with kriging, with low uncertainty. In the gamma log there is a small increase in the values at the surface, which causes the variance to increase at larger distances, as seen in the exponential tail of the variogram.

Figure C-9. Variogram and Gamma Log for Borehole 41-02-07





However, it is clear that the phenomena being represented in this variogram, and thus the ability to predict, are the natural variation in background measurements. It is the distribution of ^{137}Cs in the soil and not background levels that are the focus of this analysis. Therefore, to examine the variability of ^{137}Cs in the soil, only measurements above background are used in the variogram analysis. This will bias the analysis towards regions of the site that have larger amounts of contamination, primarily sub-regions: SX-107, SX-108, SX-109 and SX-115. The boreholes in the above listed sub-regions have the highest percentage of data above background.

Next the impact of removing samples at or below background levels is assessed. The boreholes that are examined are from sub-regions SX-108 and SX-109 and most importantly the diagonal borehole (41-00-09) in SX-108. The diagonal borehole gives the best information about the activity levels because it transects the area directly below a leaking tank, as opposed to the vertical boreholes that are adjacent to the tanks. Figure C-10 shows the gamma boring logs for drywells 41-00-09, 41-08-07 and 41-09-39, and Figures C-11 through C-13 depict their associated variograms with and without background data removed. As seen in Figure C-11, the variogram of the data for diagonal borehole 41-00-09, the effect of filtering out the background data has little influence on the variogram because there are very few points that are below background levels. This borehole more thoroughly captures the feature of the leaking waste because it transects the area below the leaking tank. Both variograms in Figure C-11 of borehole 41-00-09 show a steady increase with a plateau around 15 to 18 m.

Figure C-10. Gamma Logs for Boreholes 41-00-09, 41-08-07 and 41-09-39

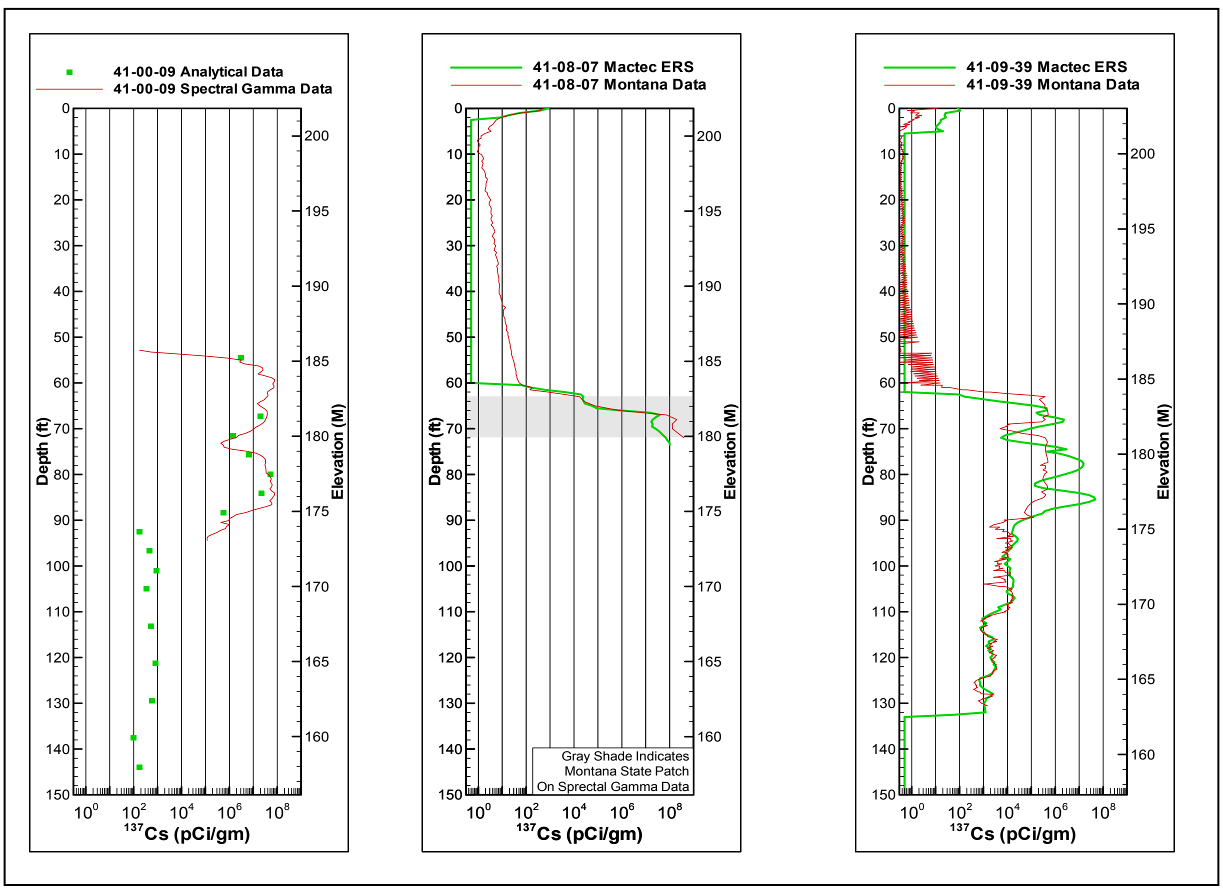


Figure C-11. Variogram of Gamma Log Data from Borehole 41-00-09

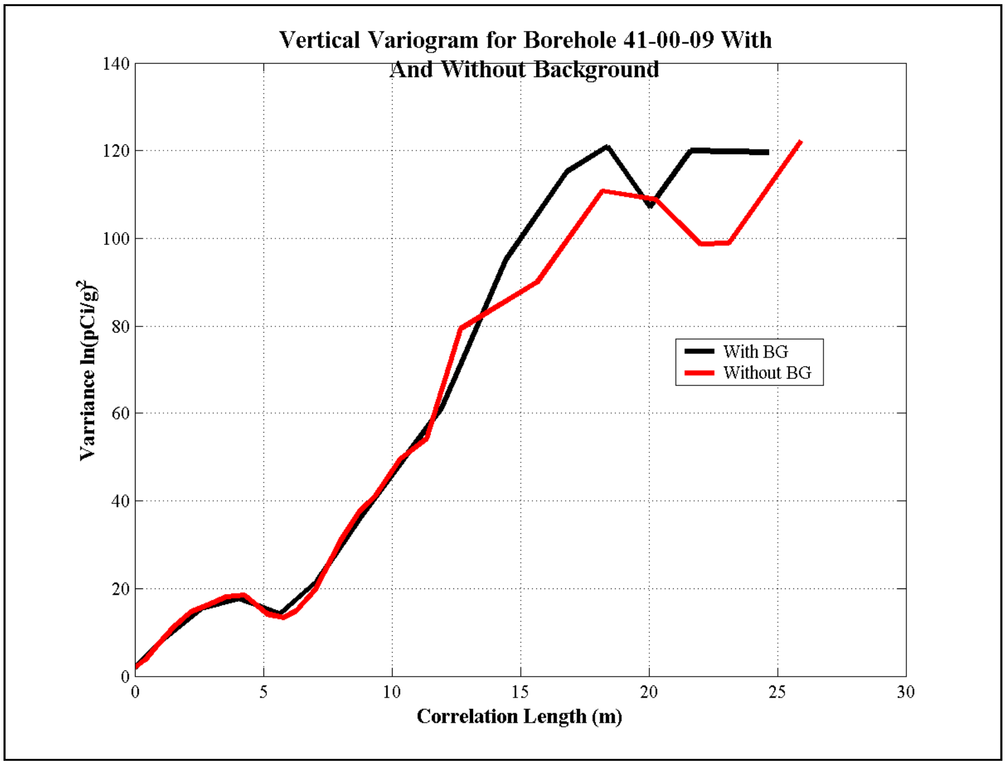


Figure C-12. Variogram of Gamma Log Data from Borehole 41-08-07

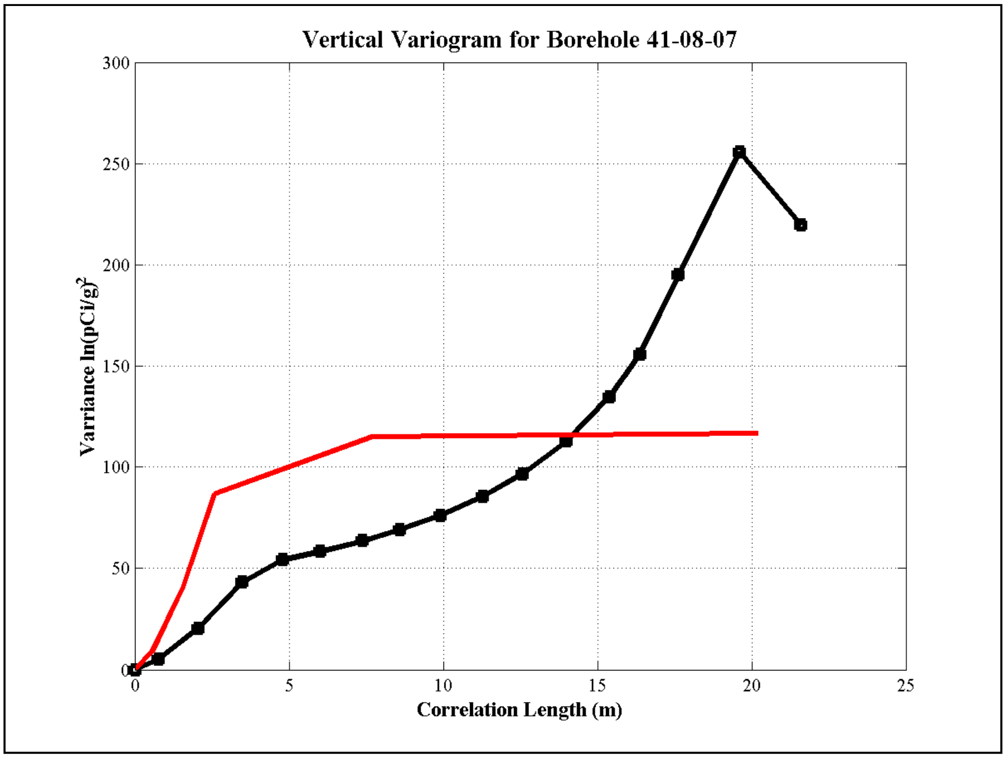
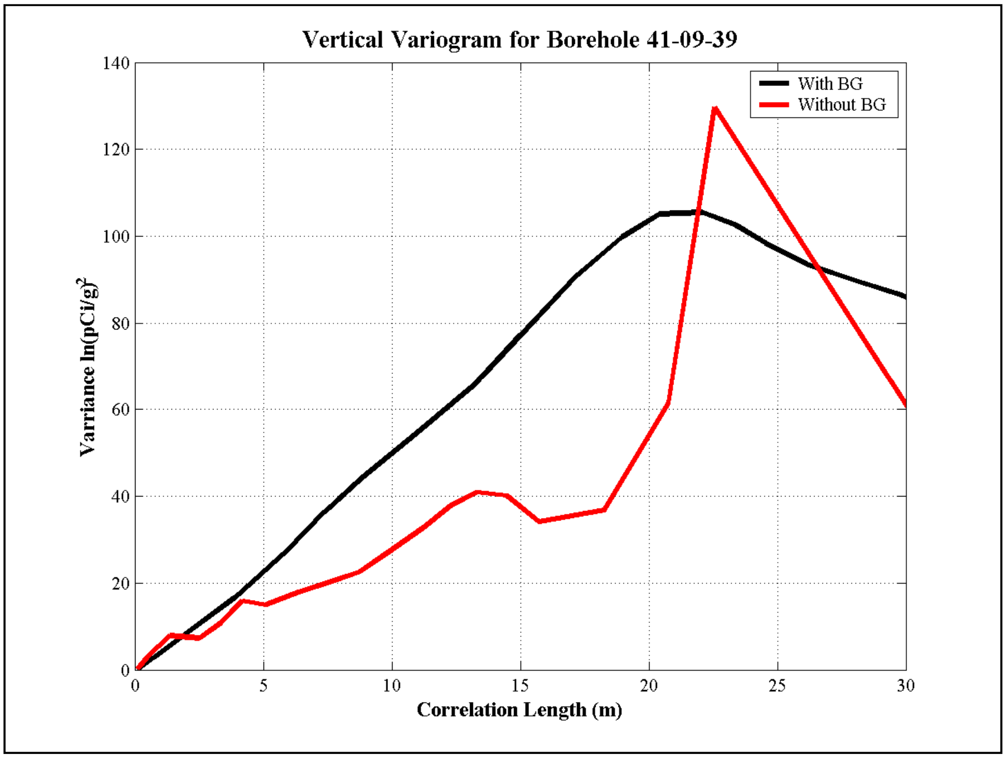


Figure C-13. Variogram of Gamma Log Data from Borehole 41-09-39



The variograms in Figures C-12 and C-13 both show an increase in correlation length and decrease in variance due to the removal of the sample data below background. The variogram shown in Figure C-13 from borehole 41-09-39 has two distinct regions after data below background have been removed. The two regions are indicative of sample data that is bi-modally distributed. The bi-modal distribution of the sample data can be seen in the gamma-boring log in Figure C-10. The sample values from 185 to 175 m range from 1.0×10^5 to 1.0×10^6 while the sample values from 175 to 163 m range from 10×10^3 to 10×10^4. This causes a large spike in both the filtered and unfiltered variogram between 20 and 25 m of separation. After filtering, however, there is a smooth rise to near 12 m and then a plateau between 12 and 17 m, after which the variance sharply increases. This indicates that a feature exists with a vertical correlation between 12 and 17 m.

An average vertical correlation length is determined from the average correlation length of all borehole data with an emphasis on the boreholes that have readings above background. Particular emphasis is given to the diagonal borehole (41-00-09) and others that show higher levels of activities. This is done because the feature that is being modeled is the leaked ^{137}Cs waste and not the background activity levels.

C3.3 Determine Plane Correlation Length – Anisotropy Search

The determination of the plane correlation length is accomplished using a variogram analysis in a manner similar to the determination of the vertical correlation length. However, where the vertical correlation length was determined with a one-dimensional (vertical) variogram, the plane correlation length is determined using a two-dimensional (horizontal) variogram. The variogram search is constrained in two ways. First, the search is performed for each sub-region separately and second, only on variance pairs that are within a vertical correlation length (as determined in the previous section). The sample data that is used for each sub-region include data from all boreholes in and adjacent to the sub-region. The samples used for each sub-region are summarized in section C2.2 in Table C-2.

The anisotropy analysis yields information about whether anisotropy exists and the variogram parameters used in the kriging interpolation process. The anisotropy and variogram parameters include: anisotropy angle, anisotropy ratio, correlation length (range) and the sill. The anisotropy orientation is the angle that yields the extreme (maximum and minimum) correlation length.

During the anisotropy analysis, two types of anisotropy behavior were observed, anisotropy and no anisotropy. An example of the analysis of a sub-region that demonstrated anisotropy is shown in Figure C-14 for sub-region SX-108. Although separate statistics were generated for each sub-region, a higher importance was given to sub-region SX-108 because of its large data set and the information from the diagonal borehole. As stated earlier, the diagonal borehole transects the plume directly below a leaking waste storage tank. Figure C-15 shows a trace plot for sub-region SX-101 that does not show evidence of anisotropy.

Figure C-14. Anisotropy Trace Plot for SX-108 Sub-Region

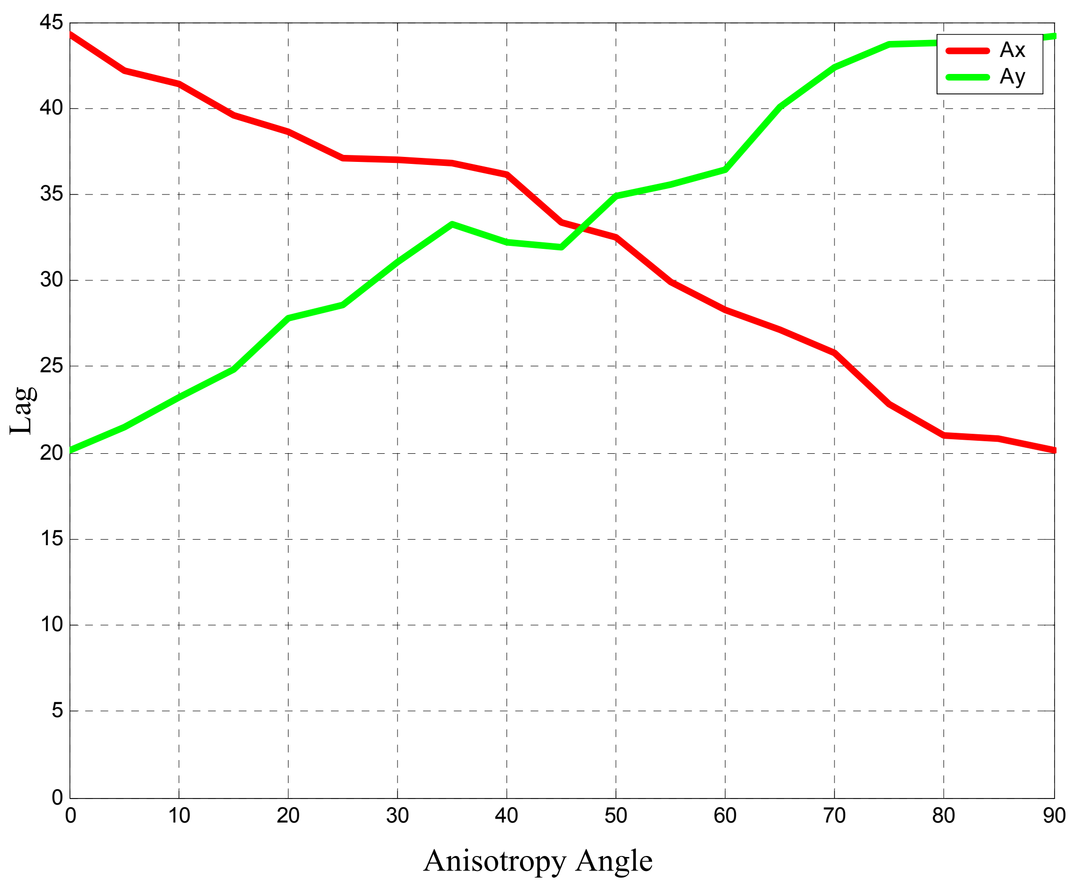
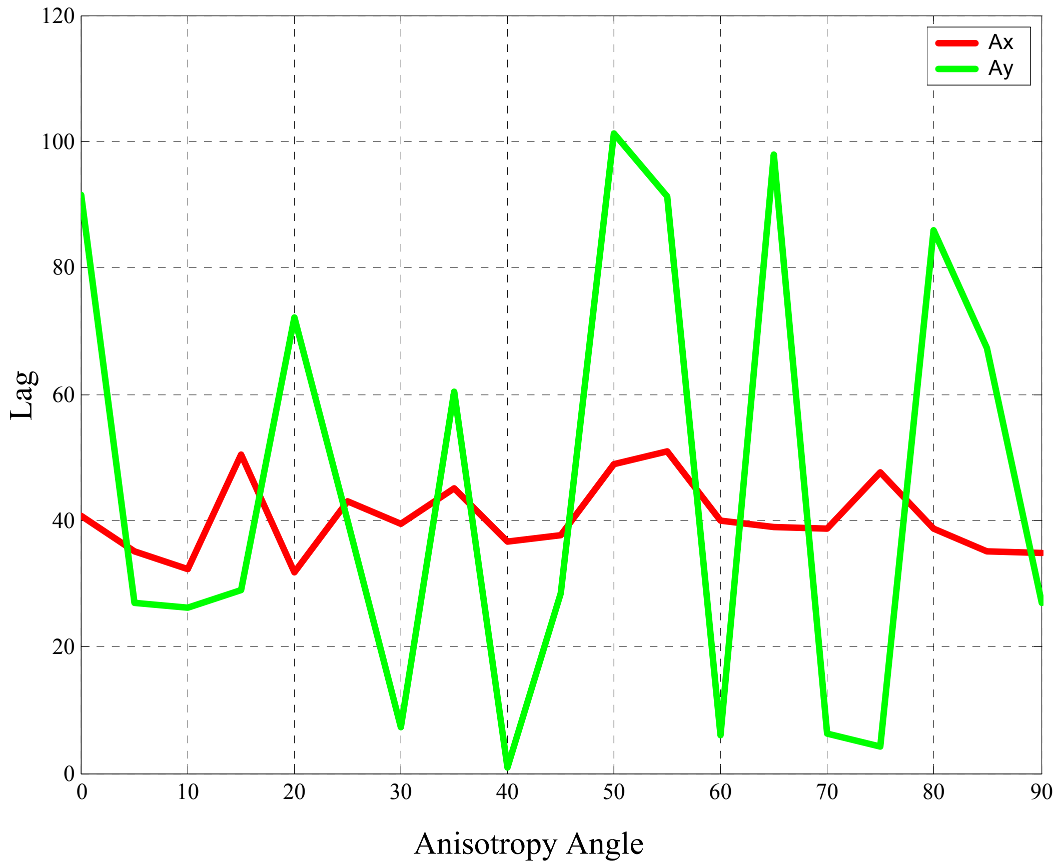


Figure C-15. Anisotropy Trace Plot for SX-101 Sub-Region



It should be noted that all sub-regions that showed anisotropy had a larger amount of sample data above background levels. Conversely, sub-regions with very few samples above background demonstrated inconclusive anisotropy evidence and a high degree of uncertainty. These sub-regions also had a high degree of variability in the kriging parameters with large residuals from the parameter-fitting process. This indicates that the parameters for sub-regions with few sample values above background have a higher degree of uncertainty. However, this uncertainty has little impact on the overall inventory estimation because, since there are few data points above background, there are only a few regions that would be impacted and the impacted regions are at a low activity level.

The anisotropy search analysis was performed for each sub-region and the results are summarized in Table C-4. The kriging parameters in this table were used during the kriging process.

Table C-4. Summary of Anisotropy Search and Plane Correlation Lengths

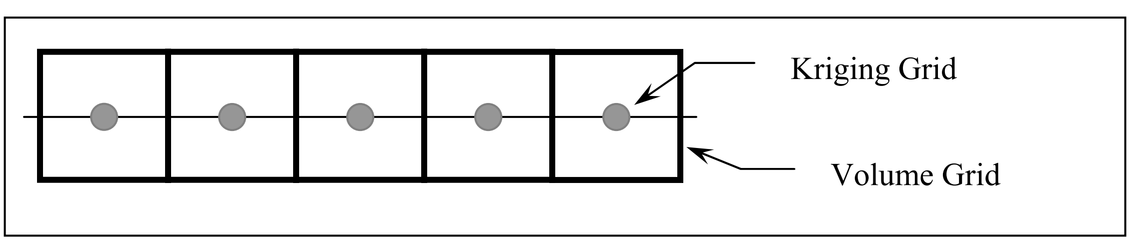
Sub-Region	# Samples	Range	Anisotropy	Angle	Ratio
SX-101	6449	38	None	NA	NA
SX-102	9067	44	None	NA	NA
SX-103	5960	40	None	NA	NA
SX-104	9666	12	None	NA	NA
SX-105	14054	28	None	NA	NA
SX-106	9592	11	None	NA	NA
SX-107	10257	24	Yes	50° - 70°	35%
SX-108	15295	42	Yes	275° - 5°	42%
SX-109	10447	20	Yes	65° - 75°	35%
SX-110	8491	12	Yes	65° - 75°	12%
SX-111	10240	15	Yes	45° - 60°	7.5%
SX-112	10501	14	Yes	55° - 70°	7.5%
SX-113	5274	25	None	NA	NA
SX-114	9330	12	None	NA	NA
SX-115	6869	14	Yes	65° - 80°	7.5%

C4. Volume and Inventory Calculations (integration)

To make the activity level and volume estimates, the kriging grid and associated volume grid are used. The kriging grid is a collection of points in the areas of interest (i.e., sub-regions) where estimates of contaminant concentration or activity values are made using the sample data and the method of kriging. Point estimations of ^{137}Cs pCi/g were made at 1 m × 1 m spacing in the plane and 0.5 m spacing in depth.

The dimensions of the kriging grid determine the size of the volume grid blocks. The volume grid block boundaries bisect the distance between the kriging grid points and are centered on the points of the kriging grid. An example of both grids is shown in Figure C-16.

Figure C-16. Two-Dimensional Example of Kriging and Volume Grid



Once the conceptual model kriging grid is populated with estimates, the results are used to determine quantity of gamma emitting radionuclides from the volume and concentration of contaminated soil. The estimated concentration value, in pCi/g, at a kriging grid point is assigned to its associated volume grid block. The total or bulk activity for a given volume block is calculated by taking the product of the block concentration (pCi/g), block volume (cm^3), and the bulk density of the soil (g/cm^3). A bulk density of 1.8 g/cm^3 was used. The total contaminated soil volumes are calculated for specified action levels by summing the volumes of grid blocks that have activity levels greater than the specified action level. All action levels used are in pCi/g and levels used are 5×10^0, 5×10^1, 5×10^2, 5×10^3, 5×10^4, 5×10^5, 5×10^6, 5×10^7 and 5×10^8. It is important to note that the specified action levels are activity levels relative to mass (i.e., in pCi/g) and not the bulk activity for a volume. The populated kriging grid is also used to generate three-dimensional graphical depictions of the contained soil.

C5. Results

The results of the geostatistical inventory analysis are presented in total and tank-by-tank format. The total ^{137}Cs activity and associated volume estimates are shown in tabular and graphical format. Table C-5 provides a brief summary of where the ^{137}Cs inventory was found for each tank. Included in the table is the relative percentage ^{137}Cs inventory of the total tank farm for that tank. Table C-6 provides the results of the inventory and volume calculations for the following activity threshold values: 5-, 50-, 500-, 5,000-, 50,000-, 500,000-, 5×10^6-, and 5×10^7-pCi/g using the geometric mean values for the data compression. For comparison purposes, Table C-6 provides the inventory and volume calculations for the same threshold values using the maximum value for data compression. Figures C-17 through C-23 provide three-dimensional perspective views of the isoshells for all of these threshold values except the 5 pCi/g. The three-dimensional perspectives have three different views of the isoshells; the first view is looking down from above the tank farm (upper left), the second view is looking from the south to the north (upper right), while the third view is looking from the west to the east. Figure C-24 is a vertical bar chart showing the total inventory for the tank farm by tank. Figure C-25 is a vertical bar chart showing the relative inventory for each tank compared to the total inventory for the tank farm.

Table C-5. Summary of ^{137}Cs Found in the Vadose for Each Tank Sub-Region

Tank Sub-Region	Absolute Inventory PCi	Relative Inventory*	Summary of the Location of ^{137}Cs Within Tank Sub-Region
SX-101	2.30E+10	0.0000%	Low levels of inventory exist in this tank sub-region. Inventory at this tank sub-region is mainly due to surficial contamination picked up at close to ground surface in boreholes 41-01-06, 41-01-07, and 41-01-08. Extends to a depth of approximately 20 ft below ground surface (bgs) or between elevations 199 to 205 m above mean sea level (MSL).
SX-102	1.53E+10	0.0000%	Low levels of inventory exist in this tank sub-region. Inventory at this tank sub-region is mainly due to surficial contamination picked up at close to ground surface in boreholes 41-02-02, 41-02-05, 41-02-08, and 41-02-11. Extends to a depth of approximately 20 ft bgs or between elevations 199 to 205 m above MSL.
SX-103	2.12E+10	0.0000%	Low levels of inventory exist in this tank sub-region. Inventory at this tank sub-region is mainly due to surficial contamination picked up at close to ground surface in boreholes 41-03-02, 41-03-05, 41-02-10, and 41-02-12. Extends to a depth of approximately 15 ft bgs or between elevations 201 to 205 m above MSL. Additional contamination at low levels is picked up at depth at borehole 41-03-02 at an elevation of 182 m above MSL or 60 ft bgs.
SX-104	7.75E+09	0.0000%	Low levels of inventory exist in this tank sub-region. Inventory at this tank sub-region is mainly due to surficial contamination picked up at close to ground surface in boreholes 41-04-11. Extends to a depth of approximately 15 ft bgs or between elevations 199 to 205 m above MSL.
SX-105	1.33E+10	0.0000%	Low levels of inventory exist in this tank sub-region. Inventory at this tank sub-region is mainly due to surficial contamination picked up at close to ground surface in boreholes 41-05-02, 41-05-03, 41-05-7, 41-05-8, 41-05-10, and 41-05-12. Of these, borehole 41-05-8 has the highest concentration levels. Extends to a depth of approximately 23 ft bgs or between elevations 198 to 205 m above MSL. Additionally, some contamination at low levels is found at depth in the middle lateral running horizontally underneath the tank. However, the lateral only shows low levels of contamination.
SX-106	5.90E+09	0.0000%	Low levels of inventory exist in this tank sub-region. Inventory at this tank sub-region is mainly due to surficial contamination picked up at close to ground surface in boreholes 41-05-02, 41-05-03, 41-05-7, 41-05-8, 41-05-10, and 41-05-12. Of these, borehole 41-05-8 has the highest concentration levels. Extends to a depth of approximately 23 ft bgs or between elevations 198 to 205 m above MSL. Additionally, some contamination at low levels is found at depth in the middle lateral running horizontally underneath the tank. However, the lateral only shows low levels of contamination.

Table C-5. Summary of ^{137}Cs Found in the Vadose for Each Tank Sub-Region

Tank Sub-Region	Absolute Inventory PCi	Relative Inventory*	Summary of the Location of ^{137}Cs Within Tank Sub-Region
SX-107	4.22E+16	50.8366%	High levels of inventory exist in this tank sub-region and this sub-region is responsible for over half the inventory in the vadose zone under the 241-SX Tank Farm. Inventory at this tank sub-region is mainly due to the very high ^{137}Cs concentration found along the middle lateral running underneath the tank (Figure C-1). On this lateral there is a ~10m section that has over 1E+8 pCi/g of ^{137}Cs. This middle lateral accounts for much of the inventory found in this tank sub-region. Additionally, at the far end of the 3rd lateral (41-07-43) there are high concentrations of ^{137}Cs. Well (41-07-07) located near the end of the lateral also has high levels of ^{137}Cs. There are no deep wells in this tank sub-region and almost all of the inventory is located near the laterals at an elevation between 179 to 186 m above MSL or 65 to 90 ft bgs. Lower concentrations are extrapolated deeper, but that is due to the vertical correlation length used in the kriging analysis. Minor surficial contamination occurs at an elevation of 203 m (borehole 41-07-12).
SX-108	3.91E+16	47.1022%	High levels of inventory exist in this tank sub-region and this sub-region is responsible for little under half the inventory in the vadose zone under the 241-SX Tank Farm. Inventory at this tank sub-region is mainly due to the high ^{137}Cs concentration found along the laterals running underneath the tank (Figure C-1). All three laterals contain contaminated sections having over 1E+7 pCi/g of ^{137}Cs. These highly contaminated sections are between 10 and 20 m in length. Additionally, the slant borehole (41-00-09, Figure C-10) indicates that these levels of ^{137}Cs contamination occur to an elevation of 175 m, which is approximately 6 m below the tank laterals. Additionally a number of the other boreholes show contamination at depth (41-08-02, 41-08-07, 41-08-11, 41-08-50, 41-08-51, 41-08-52, 41-08-53, 41-08-54). Boreholes that end with a number greater than 50 are from the sampling of Raymond and Shdo in the 1960s. Almost the entire inventory is located near the laterals at an elevation between 175 to 186 m above MSL or 65 to 100 ft bgs. Lower concentrations are observed deeper in the slant borehole. Minor surficial contamination occurs at an elevation of 203 m (boreholes 41-08-04, 41-08-06, 41-08-07).

Table C-5. Summary of ^{137}Cs Found in the Vadose for Each Tank Sub-Region

Tank Sub-Region	Absolute Inventory PCi	Relative Inventory*	Summary of the Location of ^{137}Cs Within Tank Sub-Region
SX-109	1.56E+15	1.8793%	High levels of contamination exist in this tank sub-region, but this sub-region is only responsible for approximately 2% of the total inventory in the vadose zone under the 241-SX Tank Farm. Inventory at this tank sub-region is mainly due to the ^{137}Cs concentration found along the laterals running underneath the tank (Figure C-1). All three laterals contain contaminated sections having over 1E+6 pCi/g of ^{137}Cs. These highly contaminated sections are usually short, < 5 m in length. Additionally, four boreholes (41-09-04, 41-09-07, 41-09-09 and 41-09-39 - see Figure C-1) show contamination at depth. These boreholes indicate that these levels of ^{137}Cs contamination occur to an elevation of 170 m, which is approximately 10 m below the tank laterals. Almost the entire inventory in this sub-region is located near the laterals at an elevation between 175 to 185 m above MSL or 65 to 100 ft bgs. Minor surficial contamination occurs at an elevation ranging from 199 to 205 m (boreholes 41-09-04, 41-09-39).
SX-110	7.51E+12	0.0090%	Low levels of inventory exist in this tank sub-region. Inventory at this tank sub-region is mainly due to ^{137}Cs contamination spilling over from the SX-107 tank sub-region. Minor contamination is found at depth (~183 m above MSL) at the end of tank lateral 41-10-41 (Figure C-1). Surficial contamination occurs at tops of all boreholes in this sub-region.
SX-111	2.26E+11	0.0003%	Minor ^{137}Cs inventory at this tank sub-region is due to ^{137}Cs contamination in the middle of the middle tank lateral and at borehole 41-11-10 at depth. Levels are on the order of ~5,000 pCi/g for the lateral and ~50,000 pCi/g in the borehole. Surficial contamination occurs at tops of all boreholes in this sub-region.
SX-112	2.92E+13	0.0352%	Minor ^{137}Cs inventory at this tank sub-region is due to ^{137}Cs contamination in the laterals and at boreholes 41-02-01 and 41-12-02 at depth. Levels are on the order of ~5,000 pCi/g for the lateral and up to 5E-7 in borehole 41-12-02. Nearby boreholes to 41-12-02 do not contain ^{137}Cs levels this high. The high levels surrounding this borehole are clearly seen in the three-dimensional perspective views (Figures C-18 through C-21) as a cloud of contamination around this borehole. Surficial contamination occurs at tops of all boreholes in this sub-region.
SX-113	6.41E+07	0.0000%	All ^{137}Cs inventory at this tank sub-region is due to surficial contamination.
SX-114	1.90E+08	0.0000%	All ^{137}Cs inventory at this tank sub-region is due to spillover from tank SX-115 sub-region.
SX-115	1.14E+14	0.1373%	^{137}Cs inventory at this tank sub-region is due to contamination found at depth within the laterals and in the Raymond and Shdo wells (41-15-53, 41-15-52, 41-15-58, 41-15-59).

*Relative inventory = (Inventory per Tank Region)/(Inventory for SX-Tank Farm)
bgs = below ground surface
MSL = mean sea level

Table C-6. Summary of Activity and Volume Estimates by Tank and Activity Threshold with Geometric Mean Filtering

Tank	Activity/ volume	5 (pCi/g)	50 (pCi/g)	500 (pCi/g)	5,000 (pCi/g)	50,000 (pCi/g)	500,000 (pCi/g)	5E+06 (pCi/g)	5E+07 (pCi/g)
SX-101	Activity (pCi)	2.30E+10	4.11E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	1.10E+03	2.05E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-102	Activity (pCi)	1.53E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	1.14E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-103	Activity (pCi)	2.12E+10	2.24E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	1.31E+03	2.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-104	Activity (pCi)	7.75E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	5.23E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-105	Activity (pCi)	1.33E+10	7.62E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	1.03E+03	3.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-106	Activity (pCi)	5.90E+09	3.35E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	4.93E+02	2.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-107	Activity (pCi)	4.22E+16	4.22E+16	4.22E+16	4.22E+16	4.22E+16	4.20E+16	4.06E+16	3.32E+16
	Volume (m^3)	7.82E+03	4.33E+03	2.90E+03	2.00E+03	1.36E+03	8.05E+02	3.57E+02	1.18E+02
SX-108	Activity (pCi)	3.91E+16	3.91E+16	3.91E+16	3.91E+16	3.90E+16	3.86E+16	3.55E+16	6.20E+15
	Volume (m^3)	1.83E+04	1.07E+04	7.02E+03	4.69E+03	3.06E+03	1.82E+03	9.02E+02	5.35E+01
SX-109	Activity (pCi)	1.56E+15	1.56E+15	1.56E+15	1.55E+15	1.48E+15	1.13E+15	2.20E+14	0.00E+00
	Volume (m^3)	1.74E+04	1.04E+04	6.58E+03	3.69E+03	1.58E+03	3.81E+02	1.55E+01	0.00E+00
SX-110	Activity (pCi)	7.51E+12	7.50E+12	7.47E+12	7.30E+12	6.63E+12	3.88E+12	0.00E+00	0.00E+00
	Volume (m^3)	5.15E+02	2.05E+02	9.10E+01	3.50E+01	1.20E+01	3.00E+00	0.00E+00	0.00E+00
SX-111	Activity (pCi)	2.26E+11	1.91E+11	1.07E+11	2.97E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	1.72E+03	3.42E+02	4.90E+01	1.50E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-112	Activity (pCi)	2.92E+13	2.91E+13	2.87E+13	2.67E+13	2.05E+13	7.45E+12	0.00E+00	0.00E+00
	Volume (m^3)	7.14E+03	2.27E+03	9.53E+02	2.82E+02	5.35E+01	6.00E+00	0.00E+00	0.00E+00
SX-113	Activity (pCi)	6.41E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	6.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-114	Activity (pCi)	1.90E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	1.25E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-115	Activity (pCi)	1.14E+14	1.14E+14	1.14E+14	1.13E+14	1.07E+14	9.27E+13	5.50E+13	0.00E+00
	Volume (m^3)	4.24E+03	1.46E+03	6.12E+02	2.46E+02	6.70E+01	1.70E+01	3.00E+00	0.00E+00
Sum	Activity (pCi)	8.3011E+16	8.3011E+16	8.3011E+16	8.2997E+16	8.2814E+16	8.1834E+16	7.6375E+16	3.940E+16
Sum	Volume (m^3)	62,750	29,375	18,205	10,945	6,133	3,032	1,278	172

Table C-7. Summary of Activity and Volume Estimates by Tank and Activity Threshold with Maximum Value Filtering

Tank	Activity/ Volume	5 (pCi/g)	50 (pCi/g)	500 (pCi/g)	5,000 (pCi/g)	50,000 (pCi/g)	500,000 (pCi/g)	5E+06 (pCi/g)	5E+07 (pCi/g)
SX-101	Activity (pCi)	6.29E+10	1.54E+10	1.96E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	2.56E+03	7.55E+01	1.50E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-102	Activity (pCi)	5.62E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	3.19E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-103	Activity (pCi)	7.60E+10	9.26E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	3.50E+03	6.80E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-104	Activity (pCi)	3.61E+10	1.53E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	1.74E+03	1.30E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-105	Activity (pCi)	7.03E+10	1.19E+10	9.85E+09	4.77E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	3.66E+03	1.25E+01	2.50E+00	5.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-106	Activity (pCi)	5.71E+10	5.78E+09	4.03E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	3.09E+03	1.05E+01	2.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-107	Activity (pCi)	8.08E+16	8.08E+16	8.08E+16	8.08E+16	8.08E+16	8.05E+16	7.86E+16	6.44E+16
	Volume (m^3)	9.94E+03	5.22E+03	3.54E+03	2.52E+03	1.79E+03	1.19E+03	6.38E+02	2.12E+02
SX-108	Activity (pCi)	5.02E+16	5.02E+16	5.02E+16	5.02E+16	5.01E+16	4.96E+16	4.60E+16	9.84E+15
	Volume (m^3)	2.27E+04	1.16E+04	7.60E+03	5.24E+03	3.51E+03	2.14E+03	1.08E+03	8.15E+01
SX-109	Activity (pCi)	3.77E+15	3.77E+15	3.77E+15	3.76E+15	3.67E+15	3.06E+15	9.61E+14	0.00E+00
	Volume (m^3)	2.19E+04	1.26E+04	8.33E+03	5.20E+03	2.68E+03	8.49E+02	6.60E+01	0.00E+00
SX-110	Activity (pCi)	1.11E+14	1.11E+14	1.11E+14	1.10E+14	1.09E+14	1.04E+14	8.35E+13	0.00E+00
	Volume (m^3)	1.50E+03	2.83E+02	1.37E+02	6.50E+01	3.00E+01	1.15E+01	4.00E+00	0.00E+00
SX-111	Activity (pCi)	1.16E+12	1.08E+12	9.70E+11	4.52E+11	1.11E+11	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	4.16E+03	5.92E+02	1.79E+02	1.65E+01	5.00E-01	0.00E+00	0.00E+00	0.00E+00
SX-112	Activity (pCi)	6.16E+13	6.14E+13	6.07E+13	5.82E+13	4.82E+13	2.76E+13	0.00E+00	0.00E+00
	Volume (m^3)	1.21E+04	3.50E+03	1.26E+03	4.57E+02	8.90E+01	1.30E+01	0.00E+00	0.00E+00
SX-113	Activity (pCi)	8.42E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	7.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-114	Activity (pCi)	6.16E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Volume (m^3)	4.64E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SX-115	Activity (pCi)	2.69E+14	2.69E+14	2.69E+14	2.68E+14	2.60E+14	2.27E+14	1.46E+14	0.00E+00
	Volume (m^3)	5.30E+03	1.82E+03	8.27E+02	3.97E+02	1.54E+02	3.80E+01	6.00E+00	0.00E+00
Sum	Activity (pCi)	1.35E+17	1.35E+17	1.35E+17	1.35E+17	1.35E+17	1.34E+17	1.26E+17	7.43E+16
Sum	Volume (m^3)	95,867	35,735	21,873	13,894	8,260	4,232	1,795	294

Figure C-17. Three-Dimensional Perspective of ^{137}Cs Contaminated Soil Above 5E1 pCi/g

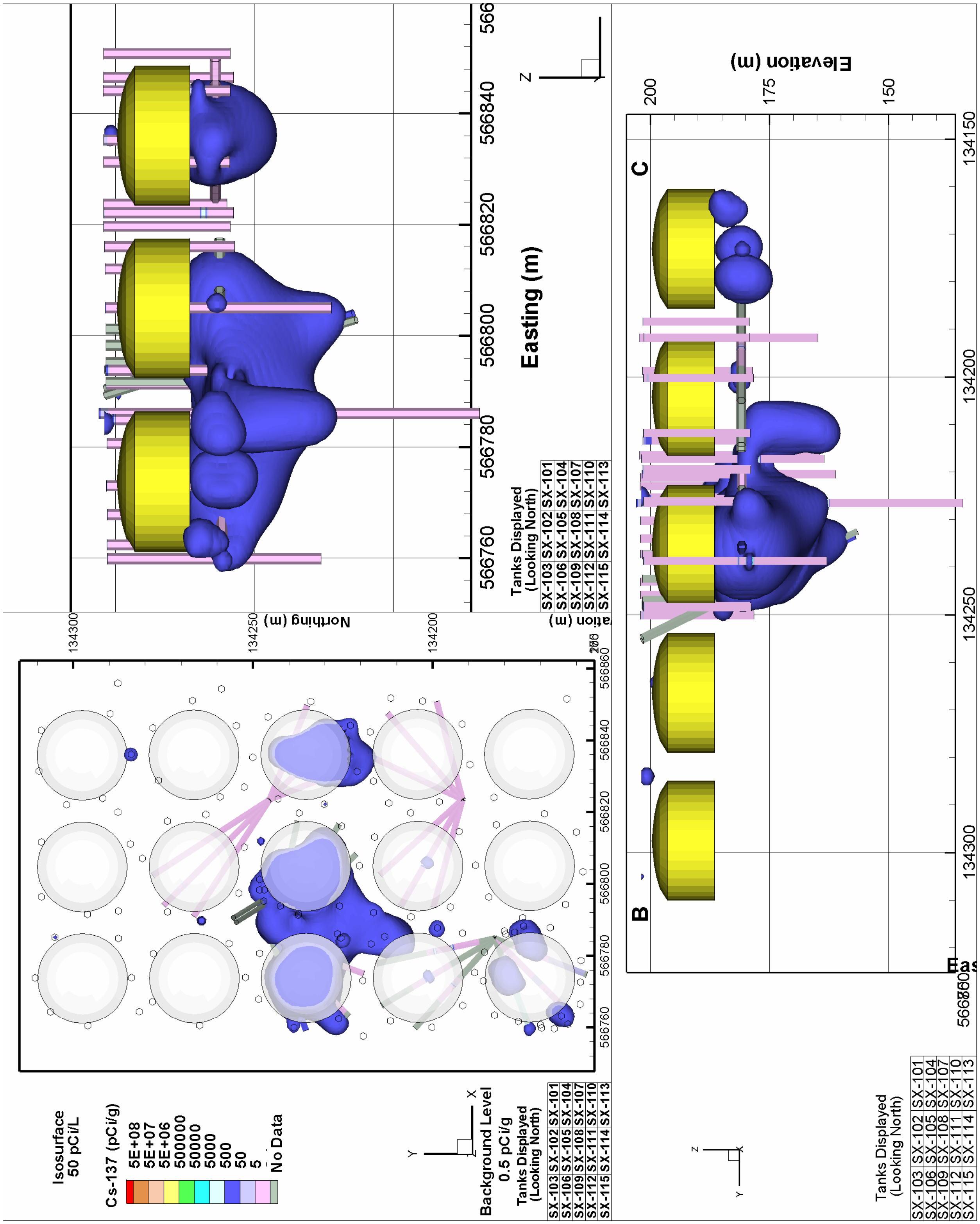


Figure C-18. Three-Dimensional Perspective of ^{137}Cs Contaminated Soil Above 5E2 pCi/g

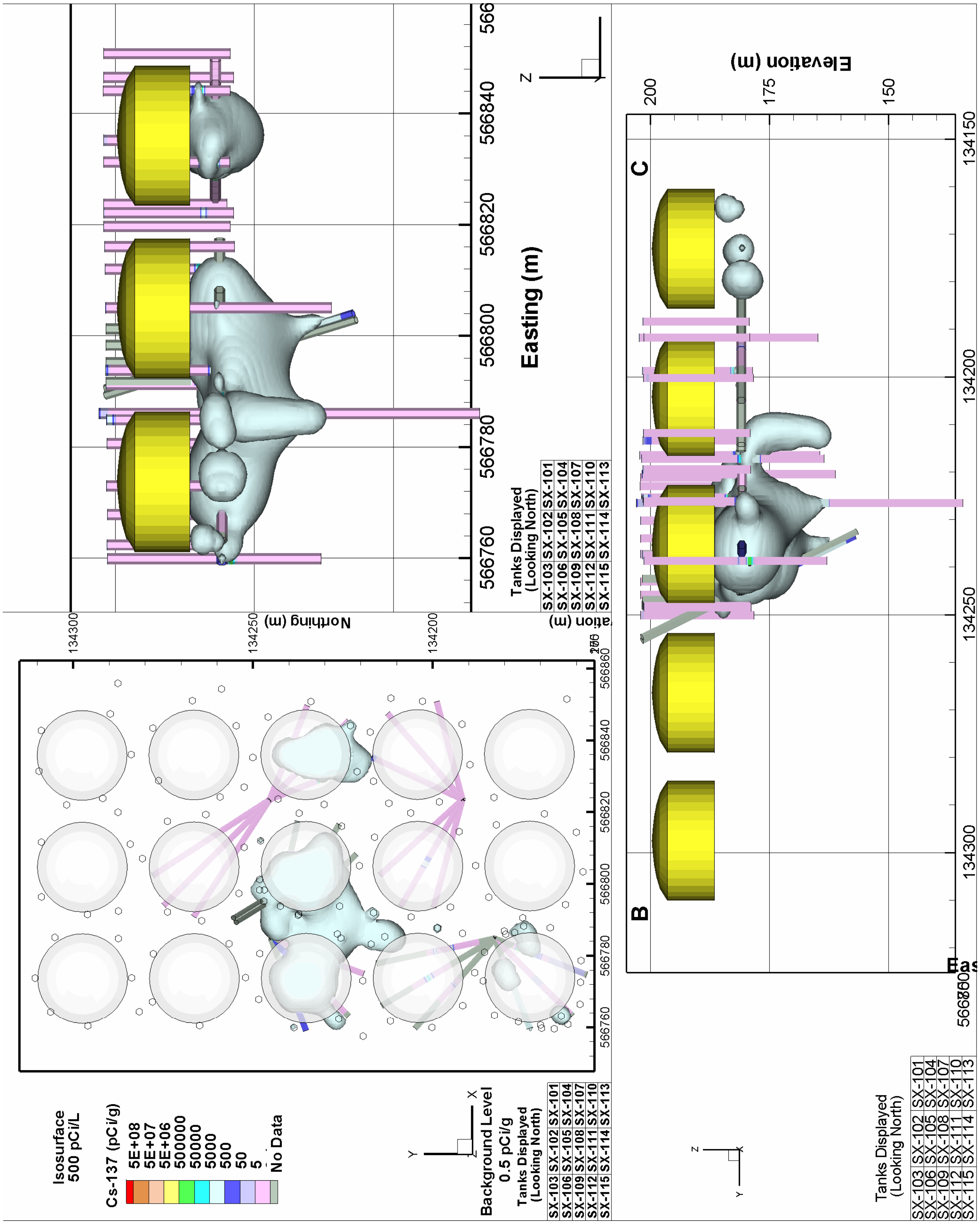


Figure C-19. Three-Dimensional Perspective of ^{137}Cs Contaminated Soil Above 5E3 pCi/g

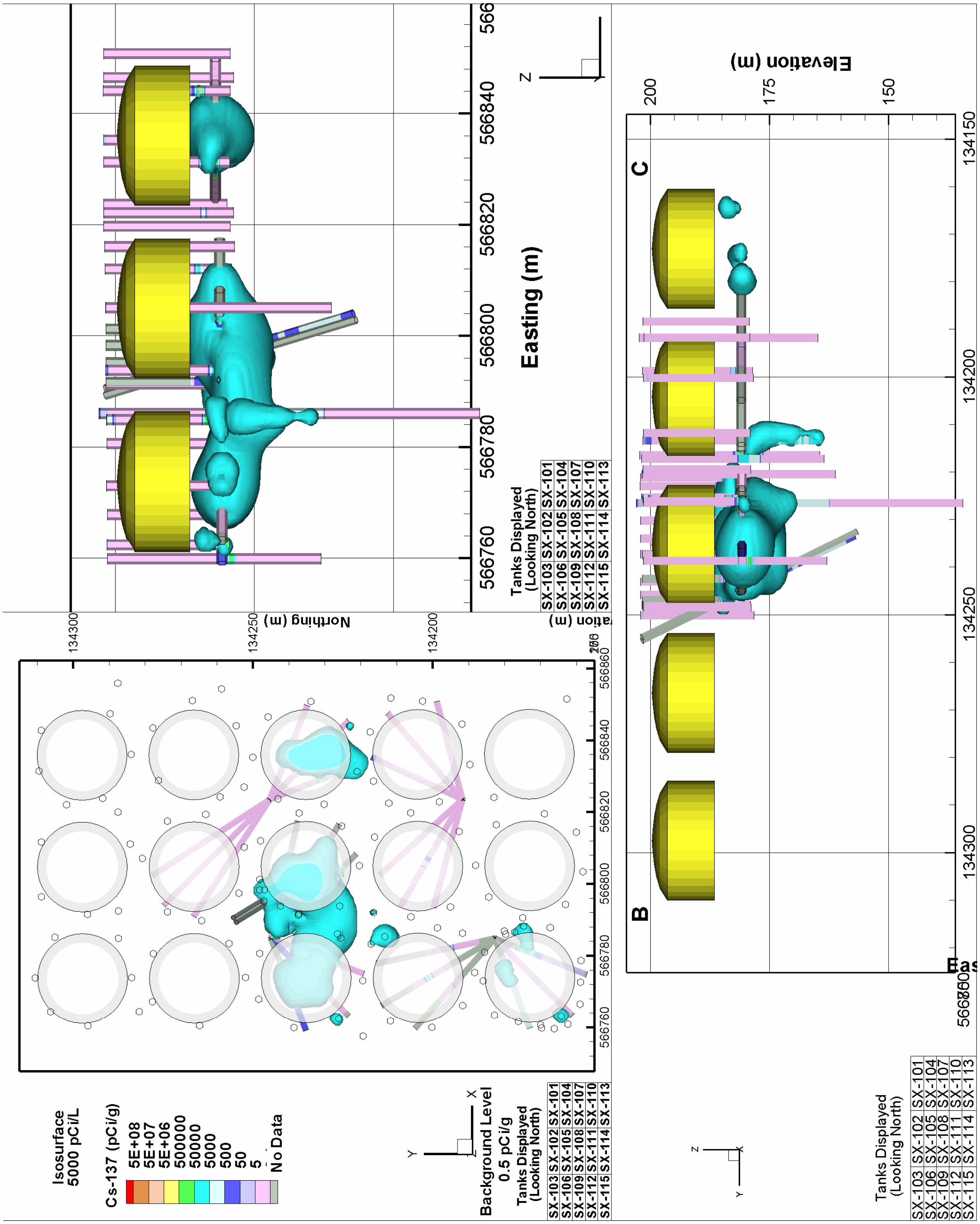


Figure C-20. Three-Dimensional Perspective of ^{137}Cs Contaminated Soil Above 5E4 pCi/g

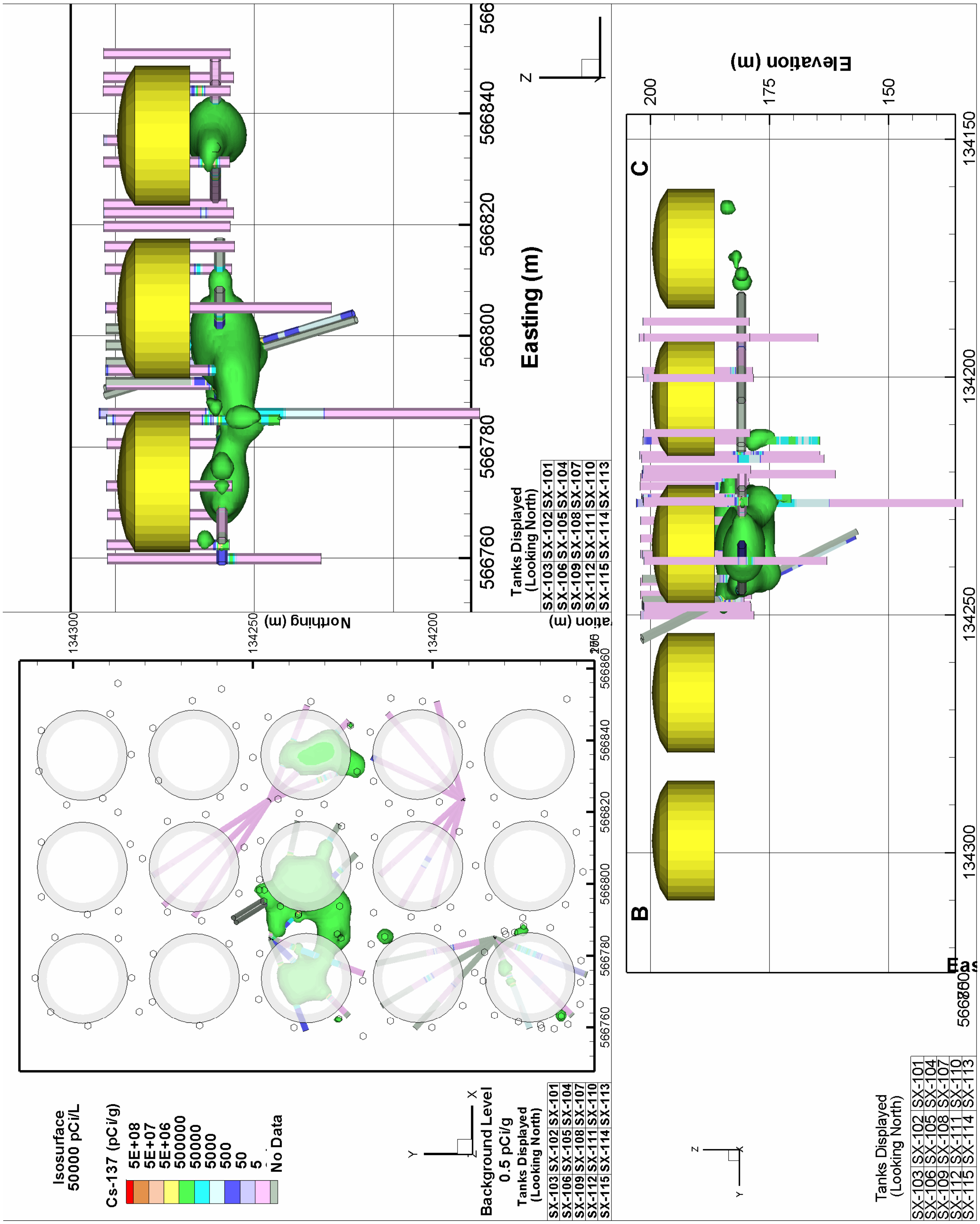


Figure C-21. Three-Dimensional Perspective of ^{137}Cs Contaminated Soil Above 5E5 pCi/g

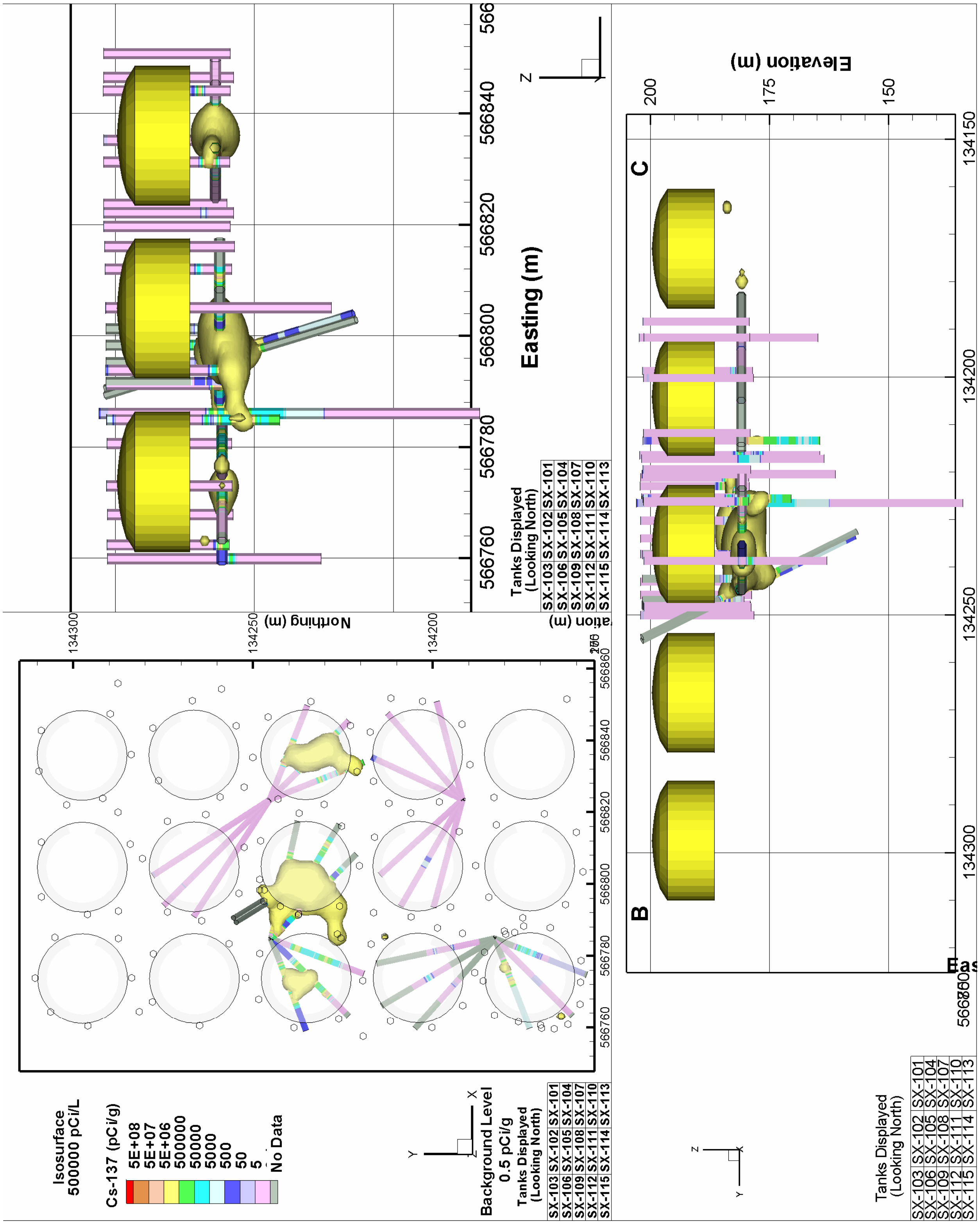


Figure C-22. Three-Dimensional Perspective of ^{137}Cs Contaminated Soil Above 5E6 pCi/g

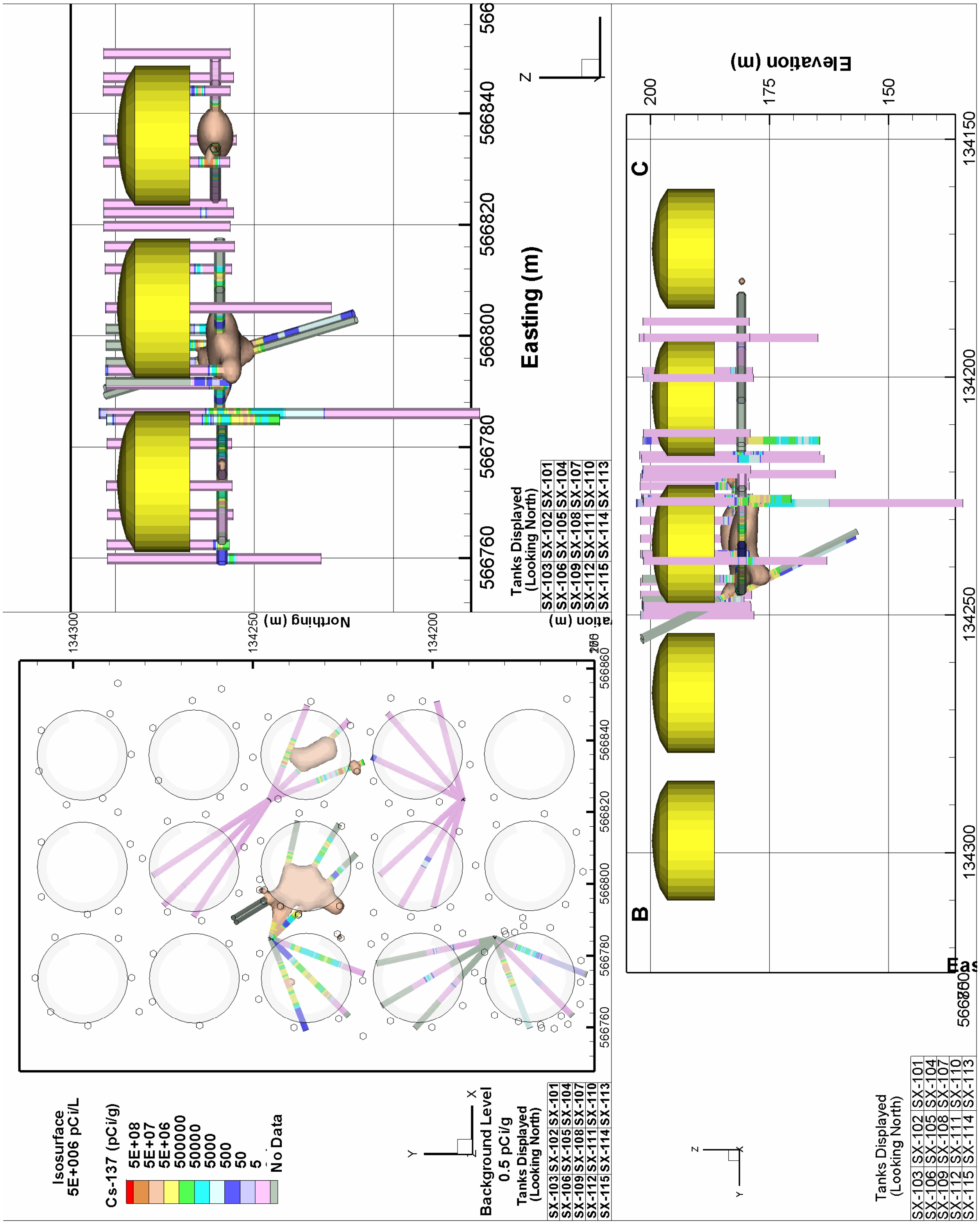


Figure C-23. Three-Dimensional Perspective of ^{137}Cs Contaminated Soil Above 5E7 pCi/g

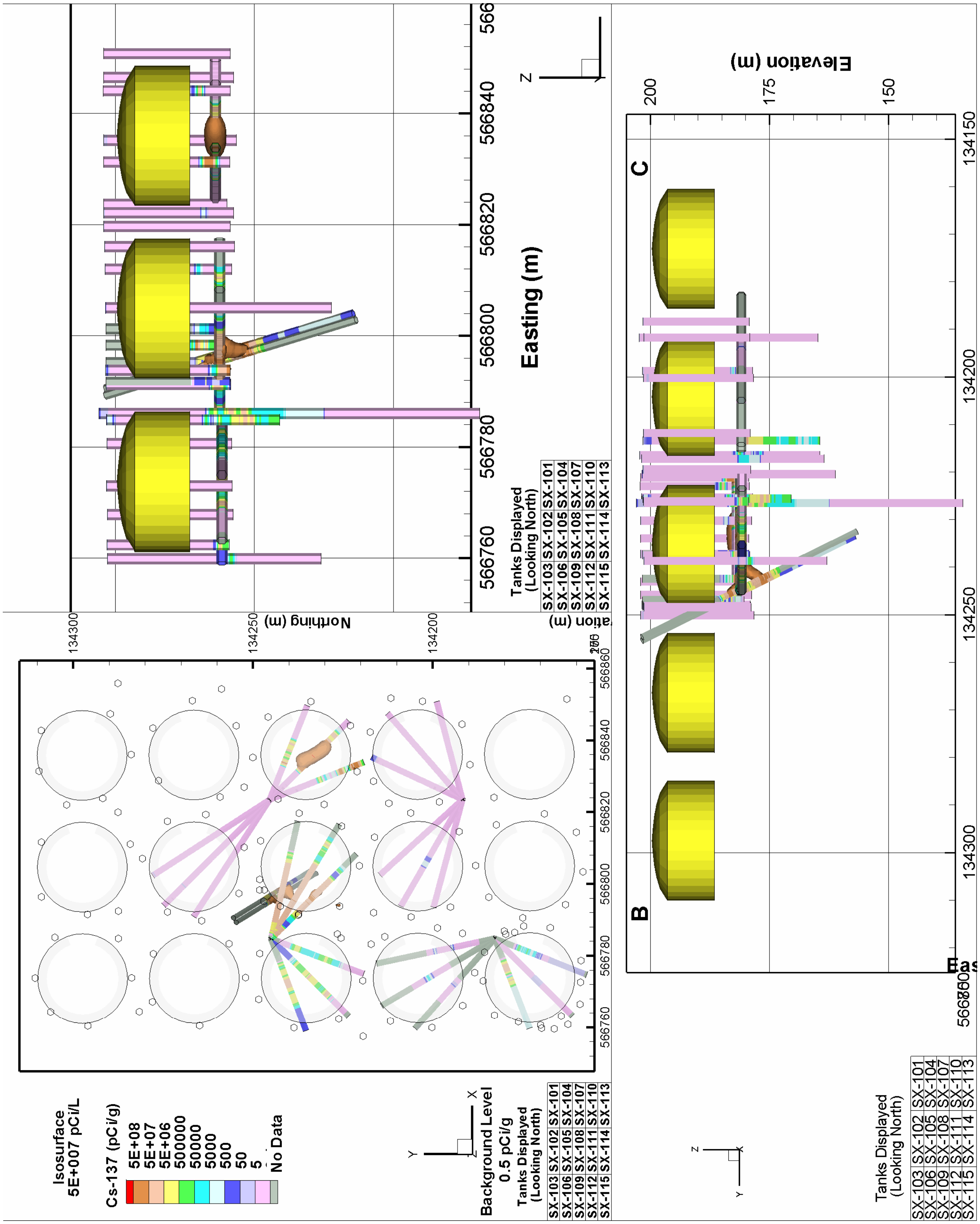


Figure C-24. Total pCi of ^{137}Cs Inventory by Tank

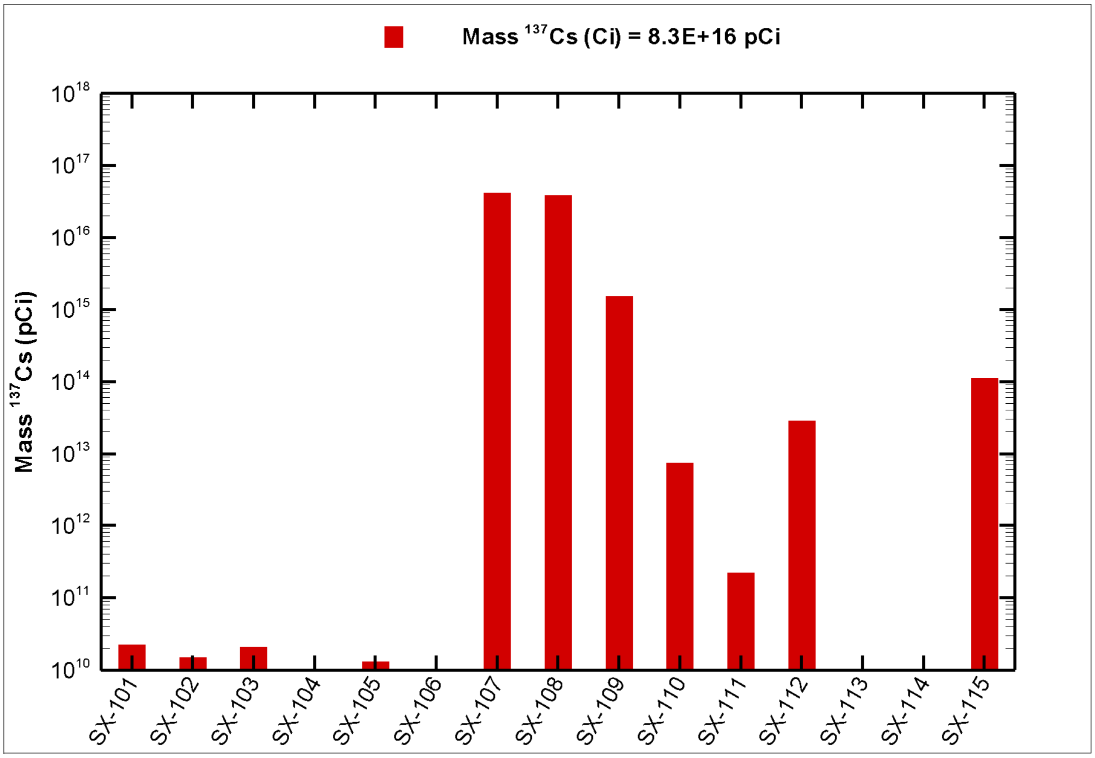
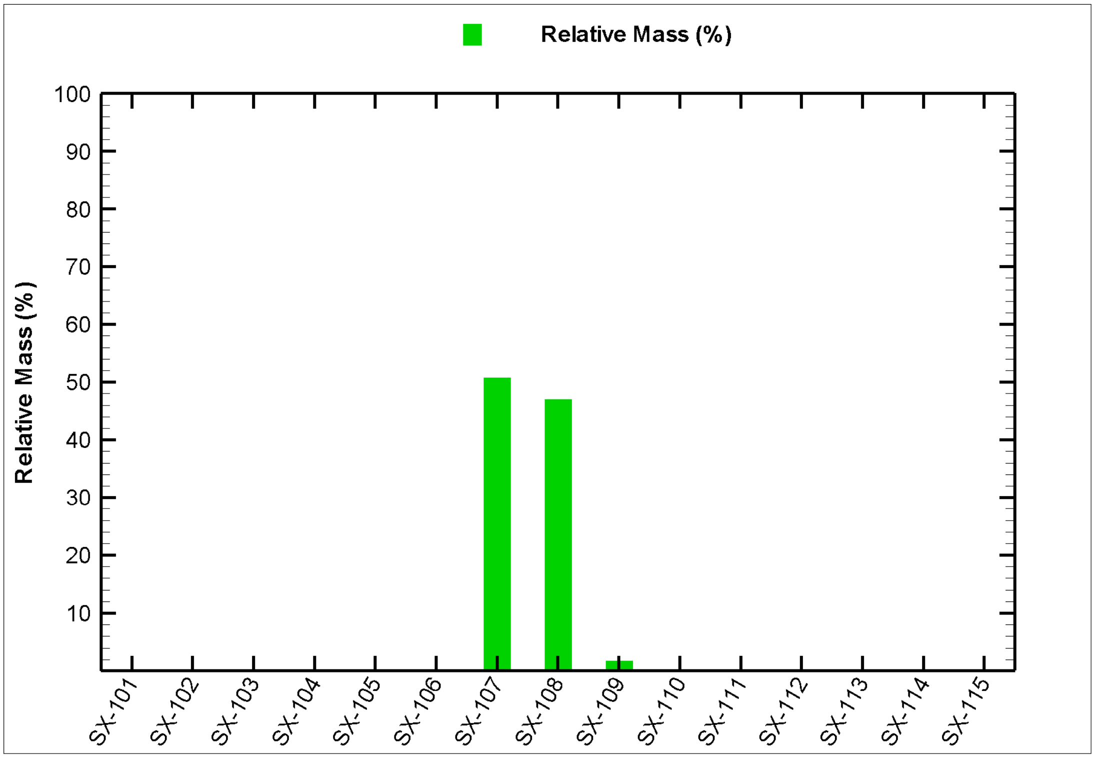


Figure C-25. Percent of Total pCi of ^{137}Cs Inventory by Tank



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