

Hanford Single-Shell Tank Leak Causes and Locations - 241-U Farm

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Abstract: This document identifies 241-U Tank Farm (U Farm) leak causes and locations for the 100 series leaking tanks (241-U-104, 241-U-110, and 241-U-112) identified in RPP-RPT-50097, Rev. 0, Hanford 241-U Farm Leak Inventory Assessment Report. This document satisfies the U Farm portion of the target (T04) in the Hanford Federal Facility Agreement and Consent Order milestone M-045-91F.

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EXECUTIVE SUMMARY

This document identifies 241-U Tank Farm (U Farm) leak causes and locations for the 100-series leaking tanks in U Farm. The leak causes and locations report for all of the 100-series single-shell leaking tanks is one of the targets, M-045-91-T04 (T04), in the Hanford Federal Facility Agreement and Consent Order milestone M-045-91F. The T04 target requires that the DOE provide to State of Washington, Department of Ecology (Ecology) a report on the 100-series single-shell tanks which have been or will be identified as having leaked in RPP-32681, Rev. 0 (Rev. 1), *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*, leak assessment reports.

The leak assessment report for U Farm, RPP-RPT-50097, Rev. 0, *Hanford 241-U Farm Leak Inventory Assessment Report*, identified three 100-series leaking tanks in U Farm, 241-U-104 (U-104), 241-U-110 (U-110), and 241-U-112 (U-112). All of the other nine 100-series tanks in U Farm are classified as “sound” or are identified in RPP-RPT-50097 as requiring re-assessment of their classification per TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*. The TFC-ENG-CHEM-D-42 assessments are not part of the M-045-91-T04 target.

This U Farm leak causes and locations document is part of a series of tank farm reports that identify leak causes and locations for 100-series leaking tanks. A summary and conclusions document will be issued, RPP-RPT-54909, *Hanford Single-Shell Tank Leak Causes and Locations – Summary*, that compiles the results from all of the leak causes and locations tank farm reports when they have been issued which will fulfill the T04 target requirements.

The identification of U Farm tank leak locations focused on the possible vertical indication of a liner leak from liquid level decreases, radial transport in the soil indicated by radiation detected in drywells, and other factors such as liner bulging. All three leaking U Farm tanks experienced leaking liners at or near the base of the tanks. The tank U-104 five foot bottom liner bulge and the depth of radioactivity detected in tank U-104, U-110, and tank U-112 drywells all point to a liner leak near the bottom of the tank.

Tank U-104 experienced a five foot bulge in the bottom liner which was detected while completing sluicing of the second batch of metal waste (MW). The liner bulge was probably the result of temperature rate of rise especially during the second filling of the tank with MW. This could have set up a situation where vapor pressure under the bottom liner was greater than the hydrostatic pressure. The bulge probably weakened the bottom liner to the point of failure which was confirmed by subsequent leak testing and drywell radioactivity.

Both tank U-110 and U-112 experienced liner failures that were detected by a liquid level decrease and subsequently confirmed by the detection of drywell radioactivity in one of the drywells surrounding each of the tanks. Corrosion may have been a factor in each case as both tank U-110 and U-112 stored REDOX waste which is conducive to pitting and stress corrosion cracking (SCC). Tank U-110 also stored several hundred thousand gallons of unknown laboratory waste which may have influenced corrosion. Tank U-112 may have experienced deformation of the bottom liner during construction which may have resulted in stressing and weakening of the plates and welds.

There appears to be very little contribution from tank design and construction temperatures. However, some or all of the factors can act serially or together to contribute to tank failure.

Basic information on the leaking and sound U Farm tanks was reviewed to try and identify any differences between leaking and sound tanks related to liner failure. A number of the sound tanks contained REDOX waste which was thought to have caused the corrosion that resulted in the tank U-110 and tank U-112 liner leaks. However, some other unknown factor influencing corrosion rate or other condition may have prevented a liner leak in the sound tanks.

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Acronyms and Abbreviations

221-B	B Plant
221-T	T Plant
241-U	U Farm
ALC	air lift circulator
BGS	below grade surface
BiPO ₄	bismuth phosphate
cpm	counts per minute
c/s, cps	counts per second
DE	diatomaceous earth
DST(s)	double-shell tank(s)
ECOLOGY	State of Washington, Department of Ecology
ENRAF	Pg 3-7
FIC	Food Instrument Corporation
GM	Geiger-Mueller probe
LL	liquid level
MT	manual tape
NaI	sodium-iodide
NO ₂ ⁻	nitrite
NO ₃ ⁻	nitrate
OCP	open circuit potential
OH ⁻	hydroxide
ORP	Office of River Protection
PCSACS	PC Surveillance Analysis Computer System
QI	questionable integrity
REDOX	Reduction Oxidation Plant
SCC	stress corrosion cracking
SGLS	Spectral Gamma Logging System
SP	scintillation probe
SST(s)	single-shell tank(s)
WRPS	Washington River Protection Solutions, LLC

Units

°C	degrees Centigrade
Ci	curie
°F	degrees Fahrenheit
ft	feet
gal	gallon
K	1000
kgal	kilogallon (10 ³ gallons)
in	inches
M	moles per liter
mm	millimeter
mR/hr	milliRoentgen Per Hour
pCi	picocurie (10 ⁻¹² curies)

pCi/g	picocurie per gram
ppm	parts per million
yr	year

Waste Type Abbreviations

1C	first cycle decontamination waste (from fuels reprocessing plant)
CPLX	complexed waste
CW	coating waste
DW	decontamination waste
EB	Evaporator Bottoms
Evap	Evaporator feed (post 1976)
HLW	high-level waste
LW	222-S Laboratory waste
MW	Metal waste
NCPLX	non-complexed waste
PNF	partial neutralization feed
R	REDOX HLW
Resid	Residual evaporator liquor
TBP	Tri-butyl phosphate waste

1.0 INTRODUCTION

The Hanford Federal Facility Agreement and Consent Order target M-045-91F-T04 indicated that part of the RPP-32681, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*, reporting would include leak causes and locations reports for all of the 100-series single-shell leaking tanks. This document is part of a series of documents that identifies leak causes and locations of 100-series single-shell leaking tanks that have been identified in the individual RPP-32681 tank farm leak assessments. An overall leak causes and locations summary and conclusions document will be prepared along with background and common tank farm information when all of the 100-series single-shell leaking tanks have been addressed (RPP-RPT-54909, *Hanford Single-Shell Tank Leak Causes and Locations - Summary and Conclusion*, to be issued). The information from RPP-RPT-54909 will be incorporated into the summary conclusions report on leak integrity for the Hanford Federal Facility Agreement and Consent Order milestone M-045-91F.

The 241-U Tank Farm (U Farm) tanks with a leak loss are addressed in this document. The U Farm assessment in RPP-RPT-50097, Rev. 0, *Hanford 241-U Farm Leak Inventory Assessment Report*, reported a leak loss for tanks 241-U-104 (U-104), 241-U-110 (U-110), and 241-U-112 (U-112) and recommended that tank 241-U-101 (U-101) be further assessed using TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*. The TFC-ENG-CHEM-D-42 assessments are not part of the M-045-91-T04 target.

The identification of U Farm tank leak locations focused on the first indication of radiation detected in drywells as well as liquid level decreases as appropriate. Leak detection laterals were not installed underneath the U Farm tanks.

The U Farm leak causes were identified as chemistry-corrosion and in the case of tank U-104, thermal conditions which likely resulted in the liner bulging upward. There appears to be very little contribution from tank design and construction temperatures. However, some or all of the factors can act serially or together to contribute to tank failure.

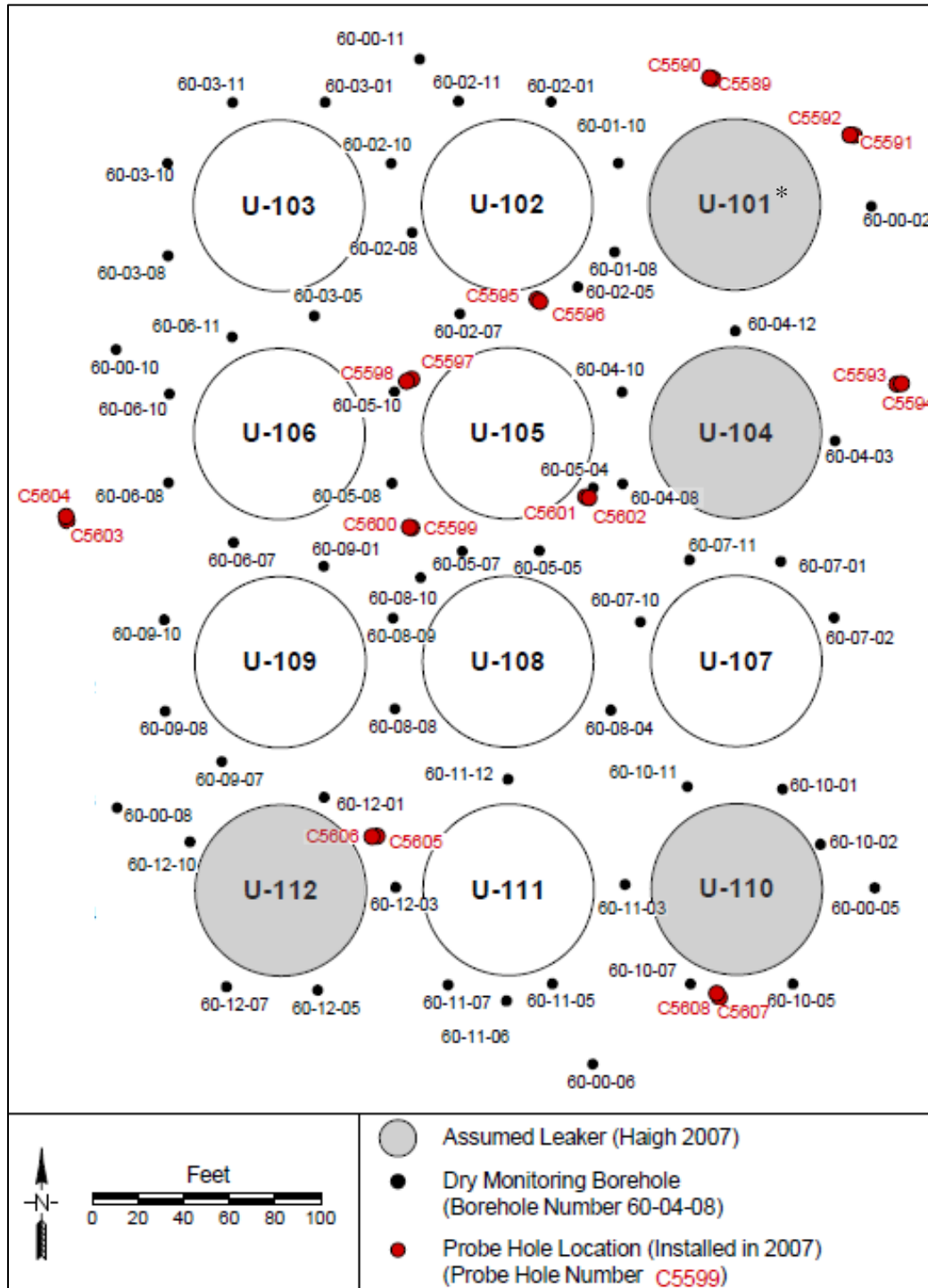
Three meetings were held to review status of tanks U-104, U-110, and U-112 with the Office of River Protection (ORP) and the State of Washington, Department of Ecology (Ecology) personnel. A review on June 25, 2013, covered the information that had been generated on the location of the tank U-104 leak and supporting data. A second meeting on August 6, 2013, provided a review of the tank U-110 leak causes and locations document. A third meeting on September 10, 2013, provided a review of the tank U-112 leak causes and locations document along with a comparison of the available information on the other U Farm tanks. Comments were received, responses developed, and additions/revisions were made to the document (see Appendix A).

2.0 U FARM BACKGROUND

The U Farm was constructed between 1943 and 1944 and is located west of Camden Avenue and north of 14th Street in the 200 West Area. The farm includes twelve 100-series dish bottom design SSTs. The tanks are 75-ft in diameter with an operating capacity of 530,000 gallons (WHC-SD-WM-ER-325, Rev. 1, *Supporting Document for the Historical Tank Content Estimate for U-Tank Farm*). A typical 100 series tank in U Farm contains 10 to 12 risers ranging in size from 4-in to 42-in in diameter that provide grade-level access to the underground tank. Normally, there is one riser in the center of the tank dome and four or five each on opposite sides of the dome. The tanks are arranged in four rows of three tanks forming a cascade. The cascade overflow height is ~15.9-ft from the tank knuckle bottom and 2.0-ft below the top of the steel liner.

Figure 2-1 shows a schematic of the U Farm tanks with location of the drywells.

**Figure 2-1. U Farm 100-Series Tanks and Associated Drywells
(RPP-35485, Rev. 0)**



* Tank U-101 was recommended to be assessed using the TFC-ENG-CHEM-D-42 procedure as identified in RPP- RPT-50097. Therefore, tank U-101 was not evaluated in this document.

Tanks U-104, U-110, and U-112 contained various waste types throughout operation which are listed in Table 2-1. The following sections describe some of the important common tank features and conditions that could affect tank leak causes and locations. This is followed by the individual tank analyses of the possible leak locations and causes and a comparison of leaking and non-leaking tanks in the conclusion section. The sections contain excerpts from RPP-RPT-50097, Rev. 0.

Table 2-1. Leaking U Farm Tanks with Waste Type

Tank	Waste Type¹
U-104	MW, water
U-110	1C, CW, R, LW
U-112	1C, CW, R

Note: Waste types are listed in the List of Terms

3.0 U FARM COMMONALITIES

3.1 TANK DESIGN/CONSTRUCTION

3.1.1 Tank Design

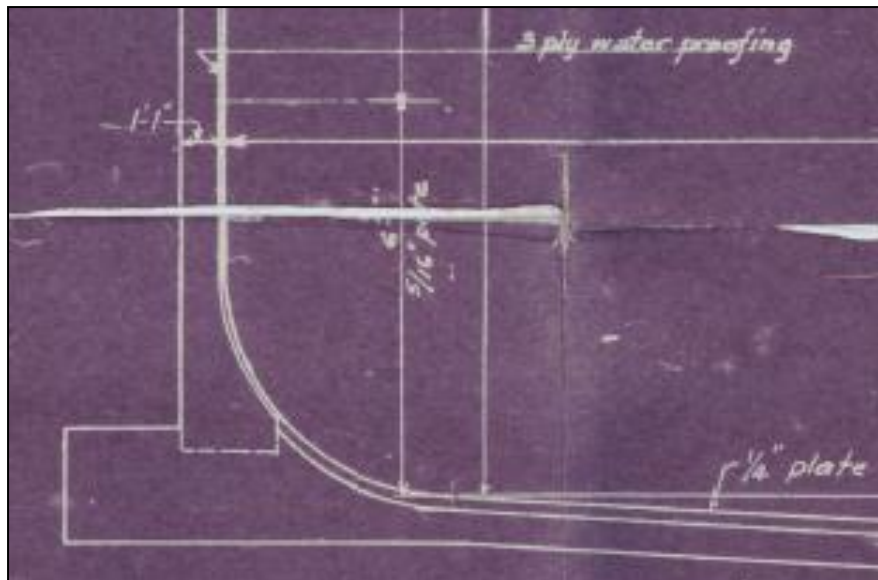
The U Farm SSTs are constructed of 1-ft thick reinforced concrete with a 0.25-in thick mild carbon steel liner (ASTM A7-39) on the bottom and sides with knuckle plates 0.3125-in thick and a 1.25-ft thick domed concrete top. The tanks have a dished bottom with a 4-ft radius knuckle.

The tanks are set on a reinforced concrete foundation. A three-ply waterproofing was applied over the foundation and then coated with a 2-in thick layer of grout reinforced with wire mesh. A three-ply waterproof membrane was applied directly to the outside of the steel surface up the sidewalls. Four coats of primer paint were sprayed on all exposed interior tank surfaces. Tank ceiling domes were covered with three applications of magnesium zincfluorosilicate wash. Lead flashing was used to protect the joint where the steel liner meets the concrete dome. Asbestos gaskets were used to seal the access holes in the tank dome. Each tank was covered with ~5.6 to 7.2-ft of overburden.

The tanks have four process spare inlet nozzles located ~16.5-ft from the tank knuckle bottom, ~0.6-ft above the cascade overflow line and 1.4-ft below the top of the steel liner. The steel bottom of the U Farm tanks intersects the sidewall on a 4-ft radius (BPF-73550, Drawings D-2 and D-3, *Specification for Construction of Composite Storage Tanks (B, C, T, and U Tank Farms)*).

Figure 3-1 shows the detail of the knuckle liner to the grout, and three-ply asphaltic waterproof membranes between the bottom and sidewall intersection (BPF-73550, Sheet D5).

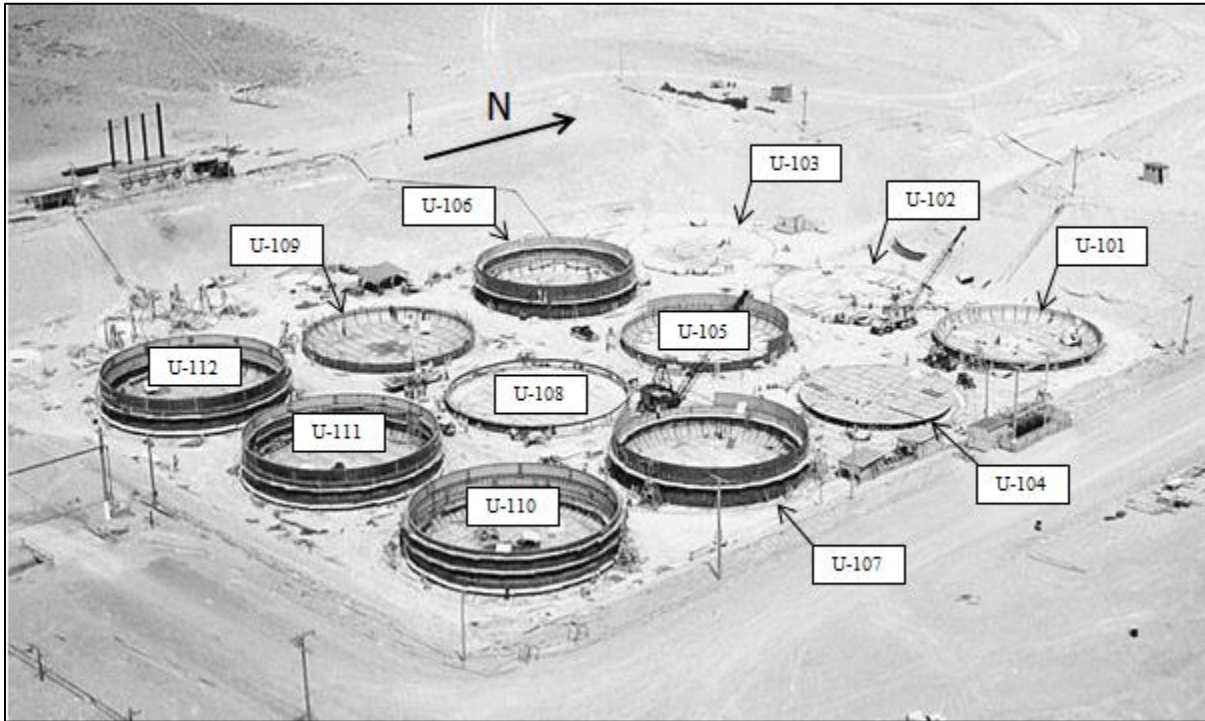
Figure 3-1. B C T U Tank Farm Knuckle Configuration with Three-Ply Waterproofing (BPF-73550, Sheet D5)



3.1.2 Tank Construction Conditions

The U Farm construction temperatures were examined to determine if the tank liner fabrication occurred at or below the metal ductile-to-brittle temperature transition. The photograph in Figure 3-2 shows the U Farm under construction on June 24, 1944.

**Figure 3-2. U Farm Construction Photograph June 24, 1944
(P3496 N1585573)**



The metallurgical factors that limited carbon steel's ability to resist impact at low temperature were perhaps not well understood when U Farm was constructed and were not specified for the 0.25-in thick ASTM A7-39, *American Society for Testing and Materials, Standard Specifications for Steel for Bridges and Buildings*, mild carbon steel liner at the time. Current standards for construction of pressure vessels, ASME Boiler & Pressure Vessel Code (B&PVC), Section VIII, *Rules for Construction of Pressure Vessels*, provide requirements for vessels constructed of carbon and low alloy steels with respect to minimum design metal temperatures. That standard does not identify ASTM A7-39, as a material type but it does identify ASTM A283, *Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates*. Early versions of ASTM A283 were similar to ASTM A7-39 because they identified the same chemical composition requirements as ASTM A7-39, and ASTM A283 steel plate and ASTM A7-39 steel plate had the same required tensile strength range, minimum yield point, and bending properties. Current B&PVC Section VIII requirements specify, for ASTM A283 material of nominal thickness ≤ 10 -mm (0.394-in), a minimum design metal temperature of 18°F. For the purposes of this report, it will be assumed that the 18°F design temperature is applicable to the fabrication of ASTM A7-39 carbon steel.

Boxes from the list of Vendor Information Reports for U Farm were searched for any Chemical and Physical Test Reports for the tank steel plates used in the farm but none were found. No other construction information for U Farm was found during the search.

A review of toughness and the ductile-to-brittle transition temperature for carbon steels (designated as “impact transition temperature”) in Mark’s Standard Handbook for Mechanical Engineers, Tenth Edition, indicates that carbon content can have a significant effect. Decreased carbon content not only raises the propagation energy needed for crack growth but also lowers the temperature for transition from ductile-to-brittle behavior (reference Fig 6.2.11 in Marks), suggesting that the B&PVC Section VIII low temperature service limit may be lower than what could be expected for steel of the vintage used in U Farm construction. The concentrations of carbon and trace impurities and their effect on this property are not specifically known, and low temperature impact resistance could only be determined reliably by impact testing of actual tank specimens.

Below the transition temperature, the metal loses its ability to absorb forces such as induced loads, or the impact of falling objects without fracturing. In this circumstance it is possible for micro-fissures or hairline cracks to be created. Later, when the metal is subjected to high stress, it might be possible for the cracks to propagate through the metal, or possibly subject the weakened areas to increased corrosion.

Any low temperatures experienced during construction at or less than the 18°F allowable temperature where impact loading (e.g. a dropped tool or piece of equipment from scaffolding) had the potential for creating micro-fissures may have triggered fissures in the steel liner (see Sections 4.3.2, 5.3.2, and 6.3.2).

Design, fabrication, and erection of the tank steel lining were required to be in accordance with current “Standards Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs” as promulgated by the “American Water Works Association” (BPF-73550). Welding and inspection requirements were to conform to the American Welding Society’s “Code for Arc and Gas Welding in Building Construction”, Section 4.

The possible variability of liner steel from either different runs from the same supplier, or because of multiple suppliers could affect the resistance to low temperatures.

3.2 IN-TANK DATA FOR LEAKING U FARM TANKS

The general information in this section is further developed and applied to the leaking tanks in Sections 4.4, 5.4, and 6.4 for tanks U-104, U-110, and U-112, respectively, to understand implications of the conditions that could affect liner leaks and identify possible liner leak locations.

3.2.1 Liquid Level

The following is an excerpt from RPP-ENV-39658 (*Hanford SX-Farm Leak Assessments Report*):

“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”.

It was stated in RPP-RPT-43704 (*Hanford BY-Farm Leak Assessments Report*) that the accuracy for the manual tape can vary from 0.25-in to 2-in for different tanks depending on surface conditions (liquid/solids), boiling, air lift circulator (ALC) operation, and conductivity.

The in-tank repeatability limits for FIC liquid level gauges are ± 0.25 -in (Letter 72730-80-097, “Review of Classification of Six Hanford Single-Shell “Questionable Integrity (QI)” Tanks”).

Transfer discrepancies of greater than 1.5-in (4,125 gal) measured at the first hour and every two hours thereafter with an FIC, manual tape, or flowmeter required an orderly and immediate shutdown, investigation, and notification. The 1.5-in discrepancy requirement was a specification limit in ARH-1601, Section D, *Specifications and Standards for the Operation of Radioactive Waste Tank Farms and Associated Facilities*.

Liquid level measured by manual tape (MT) is calculated for B, C, T, and U Farm tanks with the formula: volume = (MT Reading X 2750 gal/in) + 12,500 gal (LET-082172, H.N. Raymond to C.J. Francis, August 21, 1972, *Maximum Operating Levels and Cascade Levels in 200-West area Tank Farms* [IDMS Accession D196208887]). Even though the letter title indicates only west area, the above formula for the B, C, T, and U Farm tanks is found on the last page of the letter. The formula was confirmed to have been used as late as 1980 in RHO-CD-896, *Review of Classification of Nine Hanford Single-Shell “Questionable Integrity” Tanks*, page 76, for the then current tank T-111 volume (488,000 gal) and MT reading (173-in) which verified use of the formula. All half yearly and quarterly report ending volumes in this document were calculated with this formula. Original MT readings and the MT readings in PCSACS are all measured from the lower knuckle of the above tanks which is 12-in above the bottom inside center of the tanks. The ENRAF liquid level readings in PCSACS have been converted to read from the bottom inside center of the tank. Therefore, for the same reported liquid level the ENRAF reading is 12-in greater than the MT reading.

3.2.2 Temperature

Limited temperature data is available for the U Farm tanks until the 1970s. Available waste temperatures starting in the 1970s can be found in WHC-SD-WM-ER-325, Rev. 0, RHO-CD-1172, *Survey of the Single-Shell Tank Thermal Histories*, and in PCSACS. Historical documents in the following two paragraphs can be used to infer probable tank temperatures for the storage of waste in the U Farm tanks (see Sections 4.4.2, 5.4.2, and 6.4.2 for individual tank waste temperature).

The U Farm tank construction specifications indicated the temperature of the liquid contents would be (up to) 220°F (HW-1946, *Specifications for Composite Storage Tanks – Buildings #241 at Hanford Engineering Works*). The condensers on the B, C, T, and U Farm tanks 101 through 106 were reported to be adequate for the waste temperatures and vapor loads for the original operations at approximately 180°F for supernatant and sludge (WHC-MR-0132, *A History of the 200 Area Tank Farms*).

The earliest operation limitations found for U Farm are addressed in ARH-951, *Limitations for Use of Underground Waste Tanks*. The ARH-951 document was issued December 18, 1969 and indicated that tank temperatures should be held below 230°F with a 5°F per day rise for liquid temperatures below 180°F and a 3°F per day rise for liquid temperatures above 180°F during waste addition to the tank.

3.2.3 Liner Observations

A bulge, typically caused by rapid vaporization of moisture under the tank liner, may result in the direct failure of the liner or cause enough stress or thinning on the steel liner plates and welds that they become more susceptible to the effects of corrosion without producing a permanent bulge. Experience indicates that bulging tends to be a dynamic phenomenon, and it is possible that a tank with no measured bulge at one point in time may actually have had a displaced liner that was not detected at another time.

3.2.4 Chemistry

The types of corrosion that may occur in the Hanford Site SSTs include uniform corrosion, stress corrosion cracking (SCC), pitting, crevice, and liquid-air interface corrosion which were identified in PNNL-13571, *Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension*.

Uniform corrosion rates for SSTs are reported to be generally less than 1 mil/year (HNF-3018, Rev. 0, *Single-Shell Tank Sluicing History and Failure Frequency*) for the SSTs. Carbon steel exposed to alkaline solutions has a low general corrosion rate (PNL-5488, *Prediction Equations for Corrosion Rates of A-537 and A-516 Steels in Double Shell Slurry*). However, the presence of the nitrate ion may induce various forms of localized attack (i.e., SCC, pitting, etc.).

Nitrate Ion-Induced Stress Corrosion Cracking

Stress corrosion cracking is the growth of cracks in a corrosive environment. It can lead to unexpected sudden failure of normally ductile metals subjected to a tensile stress, especially at elevated temperatures. Stress corrosion cracking is highly chemically specific in that certain alloys are likely to undergo SCC only when exposed to a small number of chemical environments. The chemical environment that causes SCC for a given alloy is often one which is only mildly corrosive to the metal otherwise.

Nitrate ion-induced SCC is the predominant threat to the integrity of the steel liners in the SSTs and DSTs at the Hanford Site and many investigations have been performed to establish the parameters under which the tanks can be protected from this threat. This work, together with the

efforts of many others, led to the adoption of the waste chemistry control limits for SCC prevention in 1983 (OSD-T-151-00017, *Operating Specifications for the Aging Waste Operations in Tank Farms 241-AY and 241-AZ*).

The factors governing the rates of nitrate ion-induced SCC cracking by Hanford Site DST wastes were recently reviewed (RPP-RPT-47337, *Specifications for the Minimization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes*). In brief, the test results led to the conclusion that the rates of nitrate ion-induced SCC depended on the properties of the steel, the applied potential versus the open circuit potential (OCP), the temperature and the concentrations of aggressive substances such as nitrate ion, and the potential inhibitors such as hydroxide and nitrite ion.

The technical work has shown that SCC is promoted by high temperatures, high nitrate ion concentrations, low hydroxide ion concentrations, low nitrite ion concentrations, and low nitrite ion/nitrate ion concentration ratios. Tanks with maximum temperatures less than 122°F would not be expected to experience significant SCC damage regardless of waste types (HNF-3018, Rev. 0). Tanks with the maximum temperatures above 122°F and a ratio of nitrate concentration to the sum of nitrite and hydroxide concentrations greater than 2.5 would be expected to suffer SCC-related damage (HNF-3018, Rev. 0). The concentration of nitrate and temperature are parameters that have the most effect on SCC. However, the pH (hydroxide) and nitrite can inhibit SCC. The current double-shell tank operating specifications for chemistry are reported in OSD-T-151-00007, Rev. 10, *Operating Specifications for the Double-Shell Storage Tanks*. While the chemistry specifications stated in this document were prepared for the DSTs, corrosion mechanisms and corrosion protection mechanisms applicable to DST primary tank metal liners are equally applicable to the older SST metal liners.

Localized Corrosion: Crevice, Pitting, and Liquid-Air Interface Corrosion

Crevice corrosion can occur in regions where a small volume of solution cannot readily mix with the bulk solution such as under deposits, between metal flanges, and other confined areas. Once initiated, crevice corrosion proceeds by the same mechanism as pitting corrosion (RPP-RPT-33306, *IQRPE Integrity Assessment Report for the 242-A Evaporator Tank System*).

Pitting corrosion is the localized corrosion of a metal surface confined to a point or small area that takes the form of cavities. Pitting corrosion in dilute solutions ($\text{NO}_3^- < 1\text{M}$) of waste has been studied at the Savannah River Site (SRS). Pitting has been determined to not be a problem at hydroxide concentrations greater than 1M for any of the diluted waste solutions tested (WSRC-TR-90-512, *Effect of Temperature on the Nitrite Requirement to Inhibit Washed Sludge*; Oblath and Congdon 1987, *Inhibiting Localized Corrosion during Storage of Dilute Waste*). Nitrate ion was determined to be the usual controlling aggressive species when its concentrations ranged between 0.01M and 1M (WSRC-TR-90-512). The presence of hydroxide ion and nitrite ion has shown to inhibit pitting corrosion due to the aggressive nitrate ion. This work led to the conservative recommendation that the concentration of nitrite ion be greater than 0.033M for the avoidance of pitting in dilute solutions of nitrate ion at pH 10 and 40°C (104°F) (RPP-ASMT-53793, Rev. 0, *Tank 241-AY-102 Leak Assessment Report*).

The chemical compositions required for prevention of pitting corrosion can also be applied as limits for prevention of liquid-air interface corrosion at the surface of the supernatant.

Crevice, pitting, and liquid-air interface corrosion are types of localized corrosion possible in the SSTs; however, historically SCC is the more predominant type of corrosion of concern.

Historical Corrosion Control

The earliest chemical specifications for SSTs addressing pH, nitrite, nitrate, and hydroxide are listed in Table 3-1 (ARH-1601, Section D).

Table 3-1. ARH-1601 Specifications 1973

Waste Tank Farms and Associated Facilities Specifications	
Variable	Specification
pH	Minimum 8.0
NO ₂ ⁻	500 ppm
NO ₃ ⁻	< 6M
OH ⁻	< 7M

There was no similar specification found that addressed all of these parameters during the operation of U Farm prior to 1973. However, if the ARH-1601 specifications were in effect during prior U Farm waste storage, the storage of undesirable concentrations of NO₂⁻, NO₃⁻, and OH⁻ could result in vulnerability to SCC and/or localized corrosion.

Historical waste sample data as well as temperatures are typically not available for the SSTs and none were recovered for tanks U-104, U-110, and U-112. Thus, the concentrations of NO₂⁻, NO₃⁻, and OH⁻ listed in Sections 4.4.4, 5.4.4, and 6.4.4 are typical concentrations that were found in reports and other sources for the waste types listed. The reports may be based on limited data and/or values or were obtained from process flowsheets. Therefore, waste chemistry concentrations may not reflect the actual conditions when specific tank sample and temperature data is unavailable especially when multiple waste types are present in the tank. Individual tank sections provide information on the waste types stored in the tank.

3.2.5 Photographs

Available photographs of the U Farm leaking tanks U-104, U-110, and U-112 were reviewed. Photographs were reviewed to identify beachlines possibly indicating previous operations of overfilling the tank, damaged equipment, possible liner bulges, and any other anomalies that could be indicative of a tank liner leak, and/or possible leak location. See Sections 4.4.5, 5.4.5, and 6.4.5 for details for tanks U-104, U-110, and U-112, respectively. The photographs do not indicate a liner bulge for tanks U-110 and U-112. The 5-ft bulge reported in tank U-104 was visible in available photographs. The tank U-112 photographs show a pattern of solids below the liquid surface that appears to follow plate weld lines on the bottom tank liner (see Section 6.4.5).

3.3 EX-TANK DATA FOR LEAKING U FARM TANKS

The general information in this section is further developed and applied to the leaking tanks in Sections 4.5, 5.5, and 6.5 for tanks U-104, U-110, and U-112, respectively, to understand implications of the conditions that could affect liner leaks and identify possible liner leak locations.

3.3.1 Laterals

Leak detection laterals were installed approximately 10-ft underneath some of the tanks containing self-boiling waste in 241-A and 241-SX Farms. Each lateral is a 3-in pneumatic stainless steel tubing enclosed in 4-in carbon steel pipe. Probes were driven to the end of the lateral with compressed air then slowly withdrawn to gather a radiation profile below the bottom of the tank. Lateral leak detection systems were not installed under the U Farm tanks.

3.3.2 Drywells

Six drywells are located around tanks U-104 and U-112 and seven drywells are located around tank U-110. The earliest tank specific drywells were installed in 1970 through 1976; later four direct pushes were installed in 2007. All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted. Drywells were drilled vertically from the surface and drywell coordinates and detailed drywell information, e.g., pipe dimensions and configuration, for tanks U-104, U-110, and U-112 are addressed in references cited in the individual tank segments. Drywells will not be useful to detect releases that enter the soil from the tank unless the volume released is sufficiently large to facilitate lateral transport to a drywell typically to within ~1-ft of the drywell. The vertical height of a tank liner leak may not be directly related to the point of detection in the drywell. This is especially true for small leaks that may flow downward some distance before encountering a drywell.

The “00” series drywells (drywell 60-00-05, U Farm) were installed shortly after tank construction, usually around the periphery of the farm and most extend to 150-ft below grade surface (BGS). Others with tank numbers embedded in the drywell number (60-04-01, tank U-104) were constructed later, sometimes after tank operations had ceased and generally to 100-ft BGS, with a few deeper than 100-ft BGS. The usual number of drywells surrounding a tank is one to four. If there are more, then there likely was some concern regarding a release which was being investigated. The last number corresponds to the clocked position of the drywell with respect to due north.

Four gamma ray probe types were used to monitor gamma in drywells to detect leaks (RPP-8321, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm 200 East Area*). The most widely used probe was the unshielded gross gamma sodium-iodide (NaI) probe (or probe 04; the shielded NaI probe was referred to as probe 14). The NaI probe (04) is very sensitive and able to record gamma ray activity from 30 counts per second (cps) up to about 40,000 cps (15mR/hr) before the data becomes unreliable (RHO-RE-EV-4P, *Supporting Information for the Scientific Basis for Establishing Dry Well Monitoring Frequencies*). The next most commonly used probe was the Red-GM (or probe 02) which is less sensitive but can reliably record gross gamma at much higher levels of activity (up to ~500R/hr).

Operation of these and other probes are discussed in HNF-3136, *Analysis Techniques and Monitoring Results, 241-SX Drywell Surveillance Logs*. A scintillation probe (SP) was also used to measure low levels of radiation in the drywells. Leak location identification is primarily focused on the first indication of a leak and is therefore typically concerned with the lower levels of gross gamma detection and initial migration.

Drywell sections (see Sections 4.5.1, 5.5.1, and 6.5.1) contain gross gamma figures taken from RPP-7729, *Analysis and Summary Report of Historical Drywell Gamma Logs for 241-U Tank Farm – 200 West*, showing continuing or new contamination in the drywells based on BGS depth from 1975 to 1994. Some of these gross gamma figures show anomalous data that appear to be unexplained detections that do not reflect radioactivity in the soil. In 1996, a baseline characterization of the gamma-ray-emitting radionuclides distributed in the vadose zone sediments beneath and around U Farm was performed using spectral gamma logs (SGLS) and documented in GJO-HAN-8, *Vadose Zone Characterization Project at the Hanford Tank Farms U Tank Farm Report*. Individual vadose zone characterization summary data reports were issued in 1996 for the U Farm tanks with results reported in the leaking tank segments. The gross gamma and the SGLS can detect equivalent Cs-137 at concentrations down to ~10 pCi/g and ~0.1 pCi/g respectively. Therefore, radioactivity ≤ 10 pCi/g does not appear on the gross gamma figures (GJO-HAN-8). SGLS logging can confirm both Cs-137 and/or Co-60 radioactivity which can assist in the leak location analysis, and the SGLS data is weighted more heavily on interpreting drywells. SGLS documents refer to processed U-235/U-238 which refers to irradiated isotopic distribution versus naturally occurring uranium found in the soil. The criteria for drywell monitoring are defined in RHO-ST-34, *A Scientific Basis for Establishing Drywell-Monitoring Frequencies*, with the monitoring frequency found in SD-WM-TI-356, *Waste Storage Tank Status and Leak Detection Criteria*.

All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted and are from the Red-GM probe unless otherwise indicated. The individual tank segments report the available drywell data in the drywell section and in some cases the more recent direct pushes installed to locate detailed soil radioactivity. The drywell summary section provides the analyses of the associated drywells and any direct pushes with the tank that is of concern.

3.4 LINER LEAK LOCATIONS

Drywell radioactivity when first detected can indicate a radial or depth location of a tank leak, migration of the tank leak, or the possible migration of an adjacent tank leak. The radial drywell radioactivity is also dependent on any possible flow paths from the actual tank liner leak location to the drywell itself as well as the waste viscosity and distance to the drywell. Drywells can also indicate the tank liner sidewall leak vertical location but the indication needs to be analyzed relative to non-tank liner leaks associated with pipe lines or other sources.

Liquid level decreases can be used for sidewall as well as bottom liner leaks but need to be analyzed in relationship with the vertical level of the tank drywell radioactivity, evaporation, and drywell contamination from pipe line leaks and other non-tank sources.

A liner leak may have penetrated the waterproof membrane at any location and followed concrete cracks or construction joints to a different location including the top of the tank footing. Therefore, the point of waste egress from the tank liner may not be the point of entry of the leaking waste to the soil. Later indications of radioactivity in the drywells with improved detector capabilities could indicate additional leakage but the location of the leak could not be pinpointed without some additional information.

The lack of radioactivity above background in a drywell indicates that if there was a liner leak it either occurred at another location, the leak flow was insufficient to reach the effective radius of the probes used in the drywell, or was not able to adequately detect the specific radioisotope with the gamma probe. When there is no radioactivity detected in a drywell or no recoverable data for a drywell it is not included as part of the leak location analysis.

3.5 POSSIBLE LINER LEAK CAUSE(S)

Analysis of the U Farm commonalities which centered on tank design/construction, in-tank data, and ex-tank data indicates that there was essentially one condition, chemistry-corrosion, that was the most likely to have contributed to a possible tank failed liner for tanks U-110 and U-112. In the case of tank U-104, waste thermal conditions likely resulted in the reported liner bulge. There appears to be very little contribution from tank design (no inherent flaws have been documented in the literature reviewed), construction temperatures, and waste thermal conditions. However, some or all of the factors can act serially or together to contribute to tank liner failure. The following sections provide a tank U-101, U-110, and U-112 review of these conditions as they relate to liner leak causes.

Other general tank construction factors such as the quality of materials and fabrication could also contribute to tank liner failure. Because no evidence has been found to substantiate quality defects, these are not included as a leak cause.

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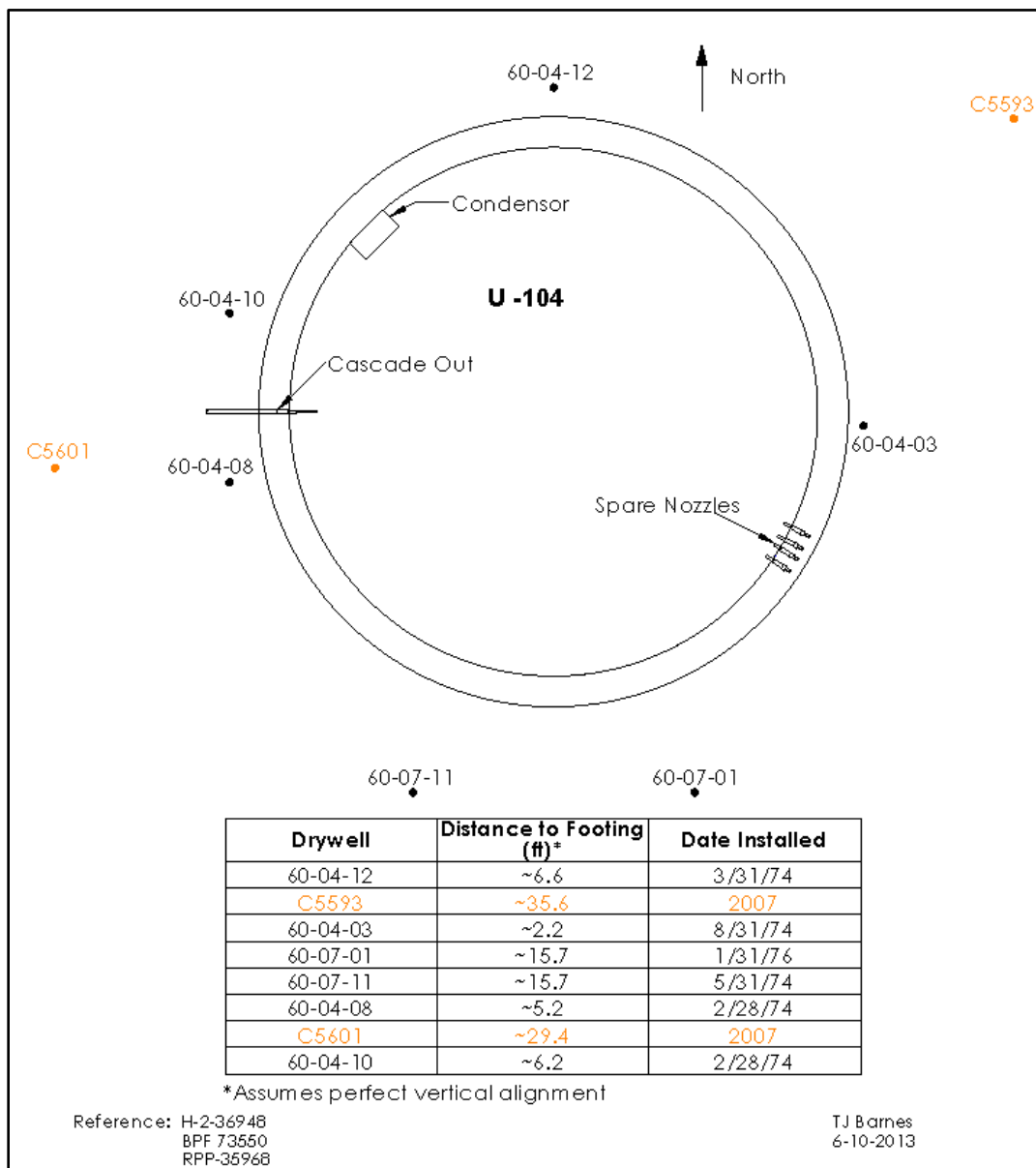
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4.1 TANK U-104 BACKGROUND HISTORY

This section provides information on the historical waste loss event associated with Single-Shell Tank (SST) 241-U-104 (U-104). There are six drywells located around tank U-104 with specified distances from the drywell to the tank footing shown in Figure 4-1: 60-04-03, 60-07-11, 60-04-08, 60-04-10, and 60-04-12, installed in 1974, and 60-07-01, installed in 1976. Two nearby direct pushes were installed in 2007.

The bottom of the tank footing is ~38-ft 4-in Below Grade Surface (BGS) with ~6.5-ft soil cover over the dome (WHC-SD-WM-TI-665, *Soil Load above Hanford Waste Storage Tanks*; BPF-73550).

Figure 4-1. Tank U-104 Associated Drywells
Tank inner ring is steel liner; outer ring is outer edge of tank footing



4.2 TANK U-104 OPERATIONS SUMMARY

Tank U-104 was placed into service in the third quarter of 1947 and began receiving metal waste (MW) from 221-T Plant (T Plant) in July 1947 (HW-7283-DEL, *Hanford Engineer Works Monthly Report July 1947*). The tank was declared full by the end of December 1947 and waste began to cascade to tank U-105 (HW-8438-DEL, *Hanford Works Monthly Report December 1947*). Metal waste cascaded into tank U-105 and tank U-106 through September 1948 when the three tank cascade was full (HW-11226-DEL, *Hanford Works Monthly Report September 1948*). No transfers occurred until supernatant was pumped to tank U-101 in the fourth quarter of 1952. The MW was sluiced out of the tank beginning in late January 1953 and the tank was empty by June 1953 (SD-WM-TI-302, *Hanford Waste Tank Sluicing History*).

The tank was refilled with MW from T Plant October 8, 1954 (HW-33544, *Separations Section, Waste-Status Summary for October 1954*) and the tank was full by the next monthly report (HW-33904, *Separations Section, Waste-Status Summary for November 1954*). The supernatant was pumped out of the tank beginning in January 1956 to prepare for sluicing (Internal memorandum EM-TF-040.9a, "Inspection of Waste Storage Tank 241-U-104"). Sluicing of tank U-104 was initiated on July 5, 1956 (HW-44024-RD, *TBP Plant and Tank Farm Weekly Summary – Process Unit – 6-29-56 thru 8-31-56*). Shortly after, sluicing was discontinued due to a pipe leak in the 151-UR diversion box. Normal sluicing was resumed on July 10, 1956 for tank U-104 but only for a couple days as a leak from tank U-104 was suspected by July 20, 1956. During sluicing operations when it was time to install the heel jet through the pit at the center of the tank, it was discovered that the center of the tank bottom was higher than normal and installation could not be accomplished. Internal memorandum EM-TF-040.9a states, "By means of electrode measurement the tank farm group determined that the center of the tank bottom was approximately five feet higher than normal." The methods of this measurement remain unknown. The tank contained 1,000 gal of sluicing liquid and 1,000 gal of MW sludge at the completion of sluicing (HW-44860, *Separations Section, Waste – Status Summary July 1956*).

Following this observation, a periscope was installed on July 26, 1956 to try to confirm suspicion of a bulge. The next week, as reported in HW-44024-RD, *TBP Plant and Tank Farm Weekly Summary – Process Unit – 6-29-56 thru 8-31-56*, "a definite bulge in the center of the tank and what appeared to be a meandering split in the steel plates of the bulged portion" was confirmed and on August 15, 1956 photographs were taken inside tank U-104. It was reported in HW-44024-RD that these photographs confirmed the bulge (see Section 4.4.3 for additional details). Tank U-104 is the only known non-boiling waste SST that experienced a tank bottom bulge.

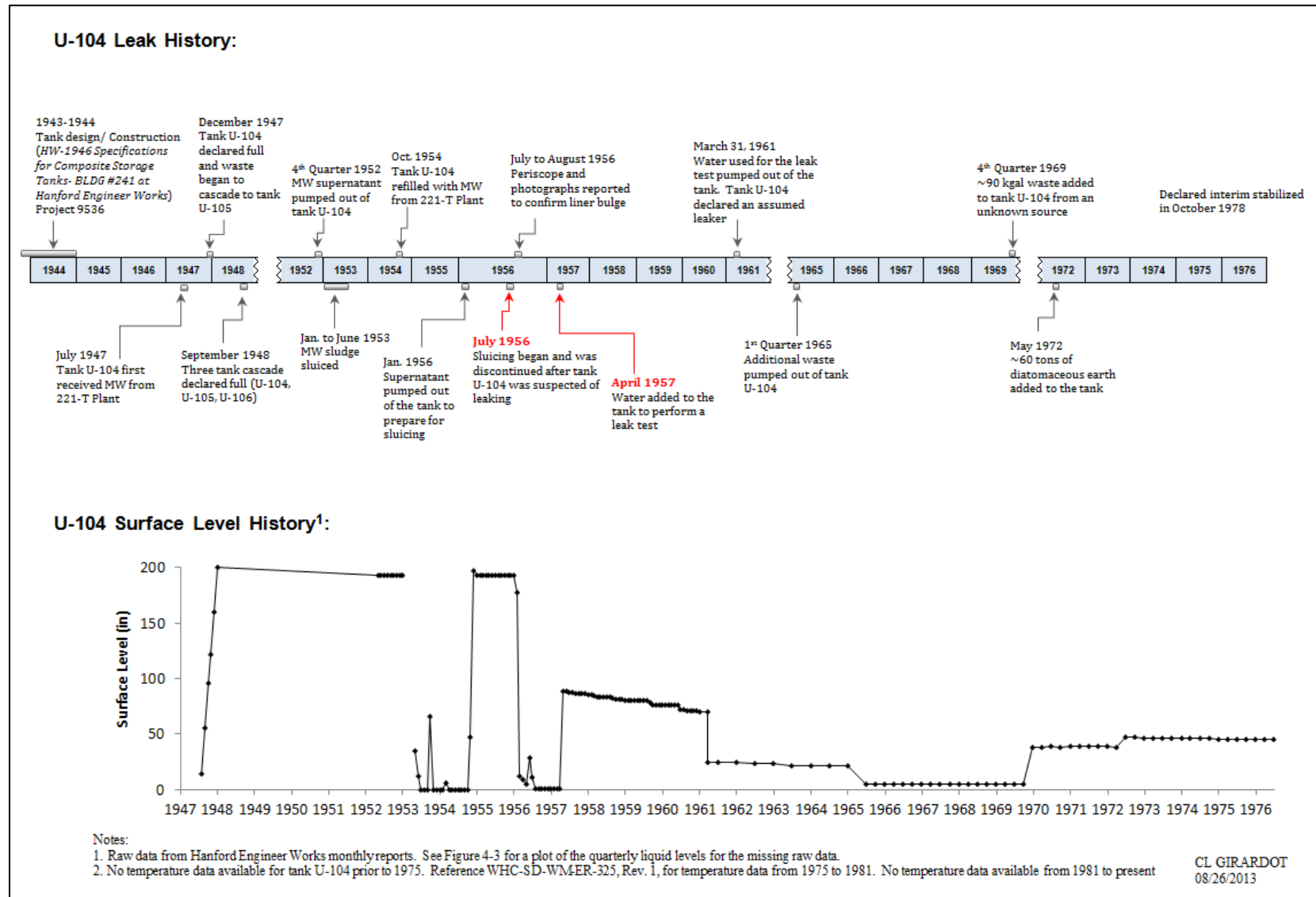
Water was added to the tank in April 1957 to test for a leak and the monthly liquid level readings indicate the level was decreasing; however, this water was not removed until March 31, 1961 (DSI 1961, "104-U Tank"). The tank was declared an assumed leaker in 1961. A significant volume of this water remained in the tank due to a bulged bottom which interfered with removal of the liquid heel until it was again pumped in the first quarter of 1965. In the fourth quarter of 1969 waste was added to the tank from an unknown source, increasing the waste volume to 106 kgal with 40 kgal solids. Process records list the tank waste type as R (REDOX) waste. However, it appears this was a mistake as the waste type was changed from MW to R on the process records without any transfers occurring. Therefore, the source of the 1969 transfer remains unknown.

In May 1972, ~60 tons of diatomaceous earth (DE) was added to tank U-104 to absorb any remaining free liquids (ARH-CD-222, *Characterization of the Effects of Diatomaceous Earth Additions to Hanford Wastes*).

Tank U-104 was declared administratively interim stabilized in October 1978. As of February 28, 2013, tank U-104 contains 54 kgal of sludge (HNF-EP-0182). The estimated volume is equivalent to approximately 31.6-in referenced to the tank center bottom.

The operational history of tank U-104 leak related details including liquid level is charted in Figure 4-2.

Figure 4-2. Operational Leak History of Tank U-104



4.3 TANK DESIGN/CONSTRUCTION

4.3.1 Tank Design

The steel bottoms of the U Farm tanks intersect the sidewall on a 4-ft radius knuckle transition (BPF-73550, Drawings D-2 and D-3). The rounded knuckle transition, the three-ply asphaltic membrane waterproofing between the liner and the concrete, a notched footing construction joint, and the concrete shell are features common to all U Farm tanks (see Section 3.1.1).

4.3.2 Tank Construction Conditions

The U Farm tanks were constructed between February 1944 and October 1944. Temperatures are not available for 1944 between May 18 and December 1. From the start of U Farm tank construction through May 18, 1944 there were two minimum temperatures of 12°F with daytime temperatures of 44°F and 57°F, one at 18°F, and four at 20°F with day time temperatures between 41°F and 56°F.

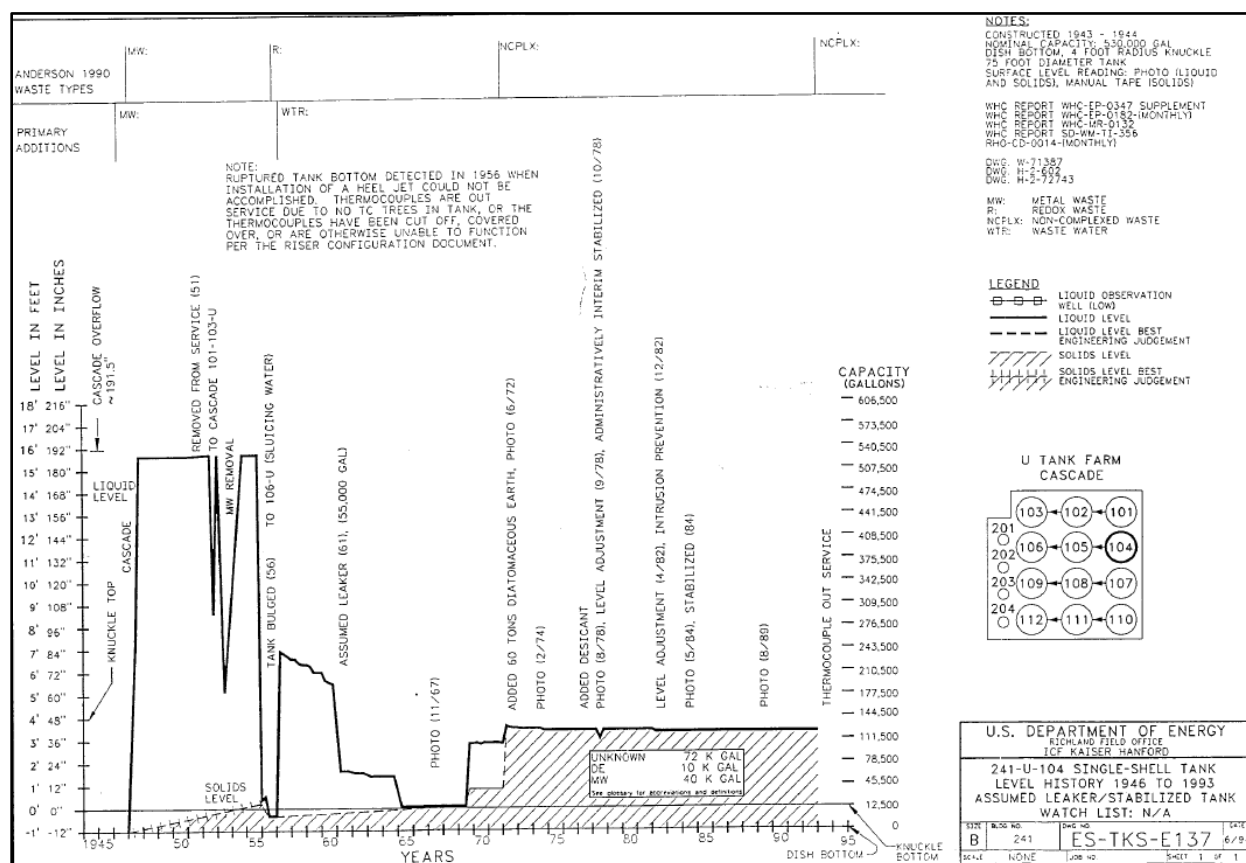
As described in Section 3.1.2, cold weather affects the ductile-to-brittle steel transition temperature, with 18°F being the assumed design temperature for the carbon steel liner, which could result in a fracture upon impact. However, in general, the temperatures during the U Farm construction time frame were much milder than those experienced during 241-SX Farm construction where ductile-to-brittle steel transition temperatures were exceeded.

Design, fabrication, and erection of the tank steel lining were required to be in accordance with current “Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs” as promulgated by the “American Water Works Association” (BPF 73550). Welding requirements were required to conform to the American Welding Society’s “Code for Arc and Gas Welding in Building Construction”, Section 4.

4.4 TANK U-104 IN-TANK DATA

4.4.1 Liquid Level

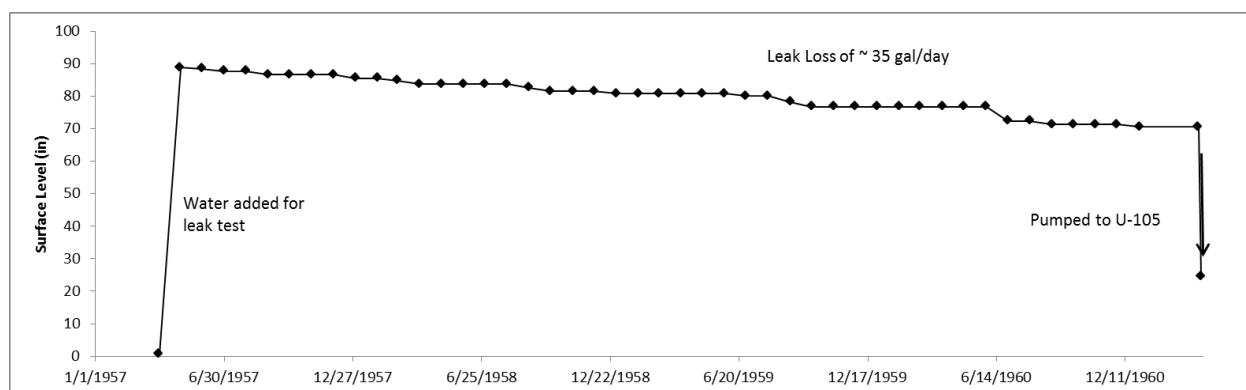
The liquid level plot in Figure 4-3 indicates the transfer activity into and out of tank U-104. The liquid levels are end of quarter levels so this figure may not reflect all transfers into and out of the tank that occurred during the operational history. See Figure 4-2 for historical monthly liquid level readings.

Figure 4-3. Tank U-104 End of Quarter Surface Level

WHC-SD-WM-ER-325, Rev. 0, 1994, Supporting Document for the SW Quadrant Historical Tank Content Estimate for U-Tank Farm.

Tank U-104 was first suspected of leaking during sluicing operations of the MW sludge in July 1956 (HW-44024-RD). During this time there were no reports indicating an unknown decrease in the liquid level; however, a tank liner bulge was suspected. In-tank photographs and a periscope confirmed a liner bulge in tank U-104 (see Section 4.4.3).

In April 1957, approximately 242 kgal of water was added to the tank (on top of the 2 kgal of waste) to perform a leak test. The liquid level decreased from 244 kgal reported at the end of April 1957 to 194 kgal reported on March 23, 1961 (DSI 1961) a potential loss of 50 kgal at a leak rate of approximately 35 gal/day over the four year span. No recorded liquid level decrease observations were recovered between the report of the liner bulge in July 1956 and the addition of the water for a leak test in April 1957. It remains unknown why the leak test lasted for a period of about four years and why the tank contents were not pumped out as the liquid level was decreasing. However, there are several periods where the liquid level remained unchanged for several months as shown in Figure 4-4. Tank U-104 was the first tank suspected of leaking and the first suspected of having a bulged liner (ARH-R-43, Rev. 2, *Management of Radioactive Wastes Stored in Underground Tanks at Hanford*).

Figure 4-4. Tank U-104 Liquid Level April 1957 through March 1961

4.4.2 Temperature

No temperature data were recovered for tank U-104 from July 1947 when the tank was first put into service until June 1975. Tank U-104 waste temperature plots from 1975 to 1981 can be found in WHC-SD-WM-ER-325, however all of the plots (thermocouples 1 through 11) are identical and range between ~55°F and ~85°F. The plots carry a footnote that the data was obtained from SACS (PCSACS); however, a query of PCSACS indicates that tank U-104 is not listed as available in the tank dropdown. Therefore, there does not appear to be any tank U-104 data available.

Condensers on the B, C, T, and U Farm tanks were reported to be adequate for the waste temperatures and vapor loads for the original operations at approximately 180°F for supernatant and sludge (WHC-MR-0132).

Five temperature data points between 1946 and November 1947 were found for Tank T-101 (HW-14946, *A Survey of Corrosion Data and Construction Details, 200 Area Waste Storage Tanks*). Tank T-101 contained MW from 221-T Plant two and a half years before tank U-104 began receiving MW from 221-T Plant. This provides a point of comparison to infer similar tank waste temperatures in tank U-104. The first temperature found for tank T-101 was recorded on May 29, 1946 of 174°F which was taken eight months after the tank began cascading to tank T-102. On that date as a point of comparison the waste temperature in tank T-102 was 126°F which accounts for cooling in the second cascade tank. Subsequent temperatures for tank T-101 ranged between 149°F and 153°F between November 1946 and November 1947. The tank U-104 temperature for MW storage and sluicing, which would be similar to tank T-101, does not appear to have exceeded 180°F prior to the tank leak. Similar temperatures were experienced in tank B-101 the first tank in the cascade which first received MW from 221-B Plant.

The rate of temperature rise can result in increased vapor pressure under the bottom tank liner from moisture in the underlying grout and vapor from the asphalt membrane below the grout. The initial MW fill period occurred over ~6 months. Temperatures are not available so an actual rate of temperature rise is not available. It seems improbable that the rate of rise for this initial period would have caused a scenario that resulted in a bulge either during the storage period taking into account the hydrostatic head or at the end of the storage period when the hydrostatic head essentially was reduced to zero. The latter would have required trapping the vapor pressure

under the liner for the more than 5 year storage period. There were no reports of bulging at the end of sluicing the initial MW when a heel jet would have been installed in the center riser to decrease the waste to the 2,000 gal volume. The second MW fill period occurred over less than two months which could have resulted in a higher temperature rate of rise, considering cooling of the empty tank over the preceding year when the tank was empty. There may have been some mechanism where small fissures in the liner allowed moisture to collect below the liner, somehow trapping the vapor during the yearlong storage period resulting in bulging the bottom liner when the tank was emptied, July 1956.

4.4.3 Liner Observations

A bulge in a tank liner may result in the direct failure of the liner or cause enough stress or thinning on the steel liner plates and welds that they become more susceptible to the effects of corrosion. Experience indicates that bulging tends to be a dynamic phenomenon, and it is possible that a tank with no measured bulge at one point in time may actually have had a displaced liner that was not detected at another time.

The tank U-104 MW sludge sluicing was halted after a failed installation of the heel jet through the pit at the center of the tank. It was determined by measurement that the center of the tank bottom was approximately 5-ft higher than normal (HW-45115 H, *Separations Technology Section Monthly Report – August, 1956*, page Fc-15) and thus, tank U-104 was suspected of leaking. A periscope was installed in the tank on July 26, 1956 for inspection which confirmed a liner bulge (HW-44024-RD; EM-TF-040.9a). A light assembly was installed in the tank the following week to permit better visibility and HW-44024-RD reported, “Subsequent inspections of the tank revealed a definite bulge in the center of the tank and what appeared to be a split in the steel plates of the bulged portion.” Tank U-104 was the only known non-boiling waste SST that experienced a tank bottom bulge during this time (see Appendix A1).

Photographs were reported to be taken of the interior of tank U-104 on August 15, 1956 (HW-44024-RD), and photographs confirmed the liner bulge (HW-45115 H, page Fc-15). However, the photographs did not indicate rupture of the liner although about half of the tank surface was covered with liquid (see Section 4.4.5). One of the retrieved photographs, Figure 4-5, seems to show the 5-ft bulged bottom liner with waste around upper quadrant.

**Figure 4-5. Tank U-104 Bulged Bottom Liner August 15, 1956
(Photograph 5BN1D0021185)**



4.4.4 Chemistry-Corrosion

Tank U-104 began receiving waste in July 1947 and test water as shown in Table 4-1. The typical concentration for nitrite, nitrate, and hydroxide for MW waste is shown in Table 4-2. Nitrite and hydroxide are known as nitrate induced SCC inhibitors. One key characteristic for inhibiting SCC is to maintain a high nitrite concentration to nitrate concentration ratio (see Section 3.2.4).

Table 4-1. Tank U-104 Waste Storage Chronology

Date	Waste Type	Length of Storage
July 1947 to July 1956	MW	~ 8 years
April 1957 to March 1961	Water	~ 4 years

Table 4-2. Waste Chemistries for Waste Types Stored in Tank U-104

Waste Type	[NO ₃ ⁻]	[NO ₂ ⁻]	[OH ⁻]	Meets Current DST Specification ²
MW ¹	0.59	Not reported	1.16	Yes ³

1. Reference WHC-EP-0449, 1991, *The Sort on Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Characteristic Groups*.
2. Reference OSD-T-151-00007, Rev. 12, 2013, *Operating Specification for the Double-Shell Storage Tanks*.
3. Even with no reported value for nitrite, the ratio of nitrate to nitrite and hydroxide would still be less than 2.5 as stated in the current DST specification.

Metal waste should not be a concern for either pitting or SCC under the tank U-104 conditions.

4.4.5 Photographs

Photographs were reported to be taken of the interior of tank U-104 on August 15, 1956 that confirmed a liner bulge (see Section 4.4.3). One of the retrieved photographs seems to show the bulged bottom liner. The next set of available photographs for tank U-104 was dated November 14, 1967. These photographs focused on the tank sidewall so a view of the waste surface was not available. These were the only sets of photographs taken prior to the addition of diatomaceous earth in May 1972 that could be located. No other anomalies were indicated from a review of available tank U-104 photographs.

4.5 TANK U-104 EX-TANK DATA

4.5.1 Drywells

There are six drywells located around tank U-104: 60-04-03, 60-07-11, 60-04-08, 60-04-10, and 60-04-12, installed in 1974, and 60-07-01, installed in 1976 in addition to two direct pushes installed in 2007. All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted (see Section 3.3.2). The following subsections report the available drywell information and the drywell summary section provides the analyses of the associated drywells with tank U-104.

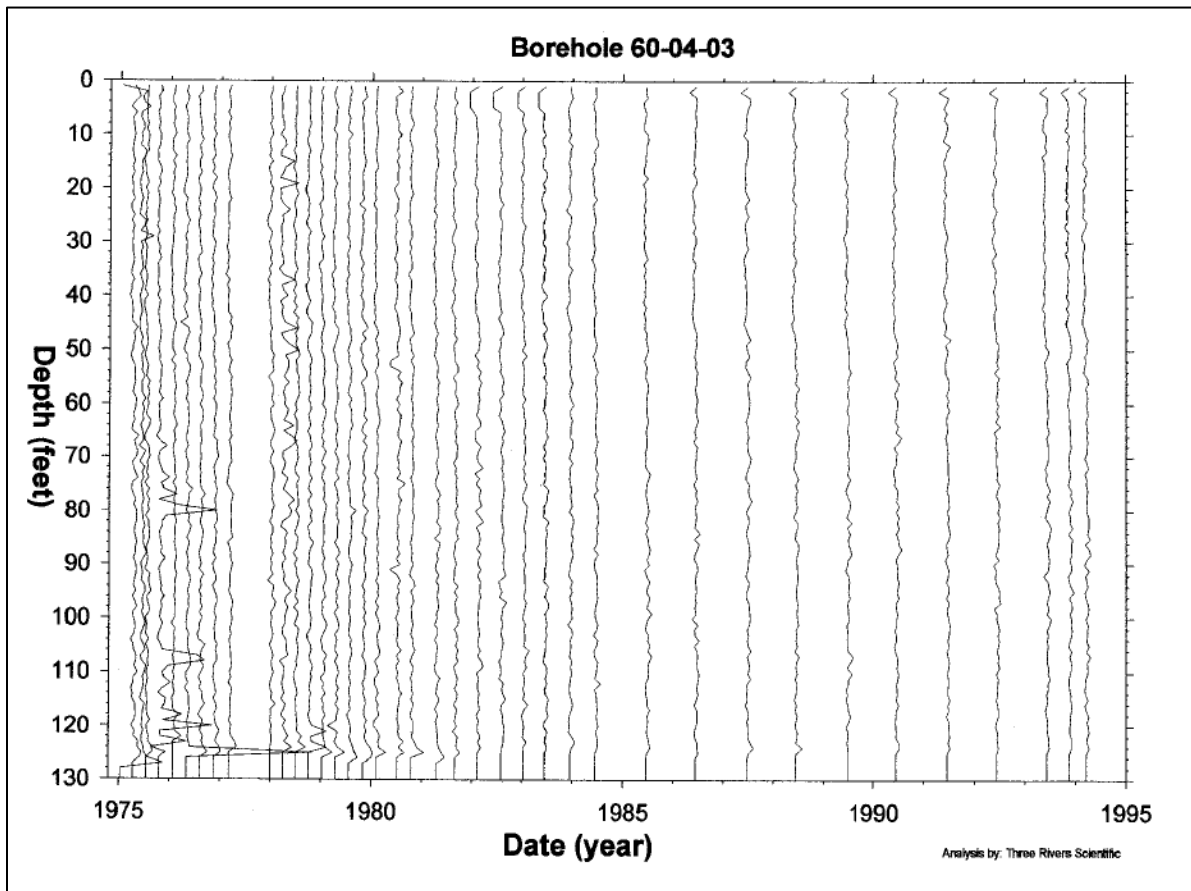
4.5.1.1 Drywell 60-04-03

Drywell 60-04-03 is located approximately 2.2-ft from the tank U-104 footing. Drywell 60-04-03 was drilled in 1974 with the first recoverable reading on October 4, 1974 reported as less than values (see Appendix B1). Readings continued to be reported as less than values through June 1986.

In July 1996, Cs-137 was the only man-made radionuclide detected in this drywell (GJ-HAN-33, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank U-104*). From the ground surface to 10-ft BGS, Cs-137 was detected continuously, intermittently from 10 to 15-ft BGS, at a few isolated locations, and at the bottom of the drywell. The maximum Cs-137 concentration was approximately 0.8 pCi/g at 3-ft BGS. Document GJ-HAN-33 reports, "The Cs-137 contamination resulted from a surface spill or leak from ancillary piping that migrated downward."

Since historical radioactivity in this drywell is very low, and GJ-HAN-33 reported low levels of radioactivity, drywell 60-04-03 is not being included as part of the leak location for tank U-104. Figure 4-6 shows the depths of radioactivity from 1975 to 1995 (RPP-7729, *Analysis & Summary Report of Historical Drywell Gamma Logs for 241-U Tank Farm - 200 West*).

Figure 4-6. Tank U-104 Drywell 60-04-03 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft 4-in BGS

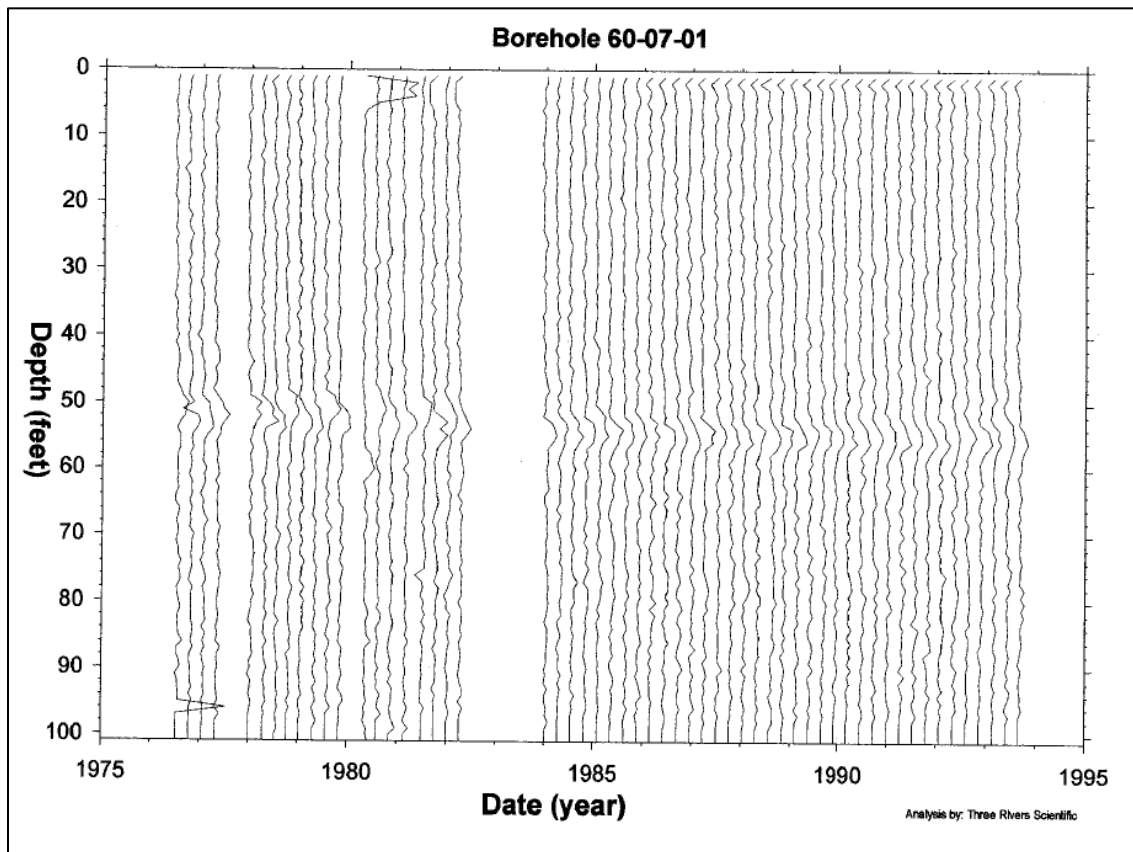
4.5.1.2 Drywell 60-07-01

Drywell 60-07-01 is located approximately 15.7-ft from the tank U-104 footing. Drywell 60-07-01 was drilled in 1976 with the first recoverable reading on May 12, 1976 with a peak 13-ft below the bottom base of the tank of 4K cpm at 51-ft BGS (see Appendix B1). Radioactivity levels remained relatively stable at this BGS depth through November 1986.

In July 1996, Cs-137 and processed U-235 and U-238 (or from waste associated with processed uranium fuel materials) were the only man-made radionuclides detected in drywell 60-07-01 (GJ-HAN-33). From the ground surface to 14-ft BGS, Cs-137 contamination was detected intermittently. The maximum concentration of 9 pCi/g was reported at 0.5-ft BGS which was the result of a surface spill or leak from ancillary piping (GJ-HAN-33).

Processed U-235 was detected continuously from 52 to 57-ft BGS, 73 to 77-ft BGS, intermittently between these two zones, and slightly below the lower zone. The maximum concentration of 9 pCi/g was measured at a depth of 55-ft BGS, 17-ft below the base of the tank. Processed U-238 was measured between 52 and 56-ft BGS at concentrations ranging between 100 and 200 pCi/g. Document GJ-HAN-33 states, "The processed U-235 and U-238 contamination most likely resulted from leakage from tank U-104." Figure 4-7 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 4-7. Tank U-104 Drywell 60-07-01 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft 4-in BGS

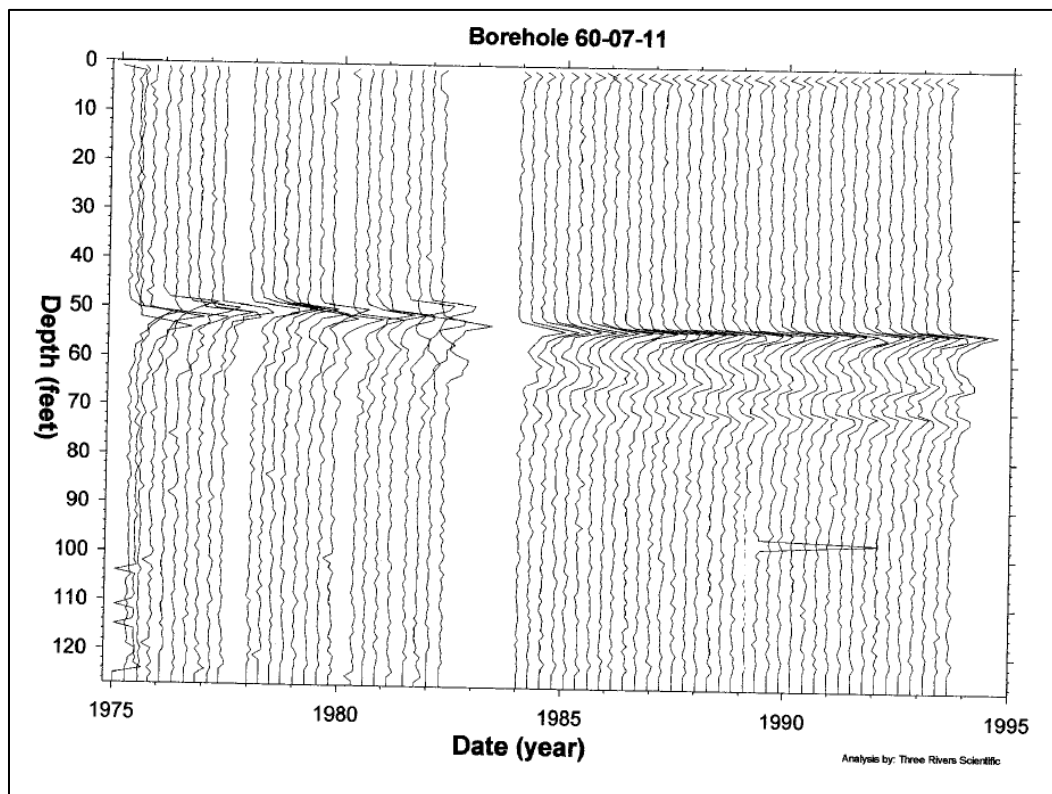
4.5.1.3 Drywell 60-07-11

Drywell 60-07-11 is located approximately 15.7-ft from the tank U-104 footing. Drywell 60-07-11 was drilled in 1974 with the first recoverable readings reported on June 4, 1974 with a peak 12-ft below the bottom base of the tank of 73.8K cpm at 50-ft BGS (see Appendix B1). The next recoverable reading on July 18, 1974 reported a peak at 15.2K cpm at 53-ft BGS. Readings remained relatively stable through November 1986 at this BGS depth.

In July 1996, Cs-137 and processed U-235 and U-238 were the only man-made radionuclides detected in drywell 60-07-11 (GJ-HAN-33). Cs-137 was detected continuously from the ground surface to 8-ft BGS, from 13 to 17-ft BGS, at a few isolated locations, and at the bottom of the drywell. The maximum Cs-137 concentration of approximately 20 pCi/g was detected at 1-ft BGS which resulted from a surface or near-surface spill, leak from piping that migrated downward, and/or was carried down when the drywell was drilled (GJ-HAN-33). Processed U-235 was detected from 52 to 82-ft BGS and from 83 to 93-ft BGS with the maximum concentration of 80 pCi/g measured at 53-ft BGS, 15-ft below the base of the tank.

Processed U-238 was detected at depths from 52 to 69-ft, from 70 to 82-ft, and from 83 to 93-ft BGS. The maximum U-238 concentration of more than 1,000 pCi/g was measured at 53-ft BGS. Document GJ-HAN-33 reported, "The processed U-235 and U-238 contamination most likely resulted from leakage from tank U-104." Figure 4-8 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 4-8. Tank U-104 Drywell 60-07-11 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft 4-in BGS

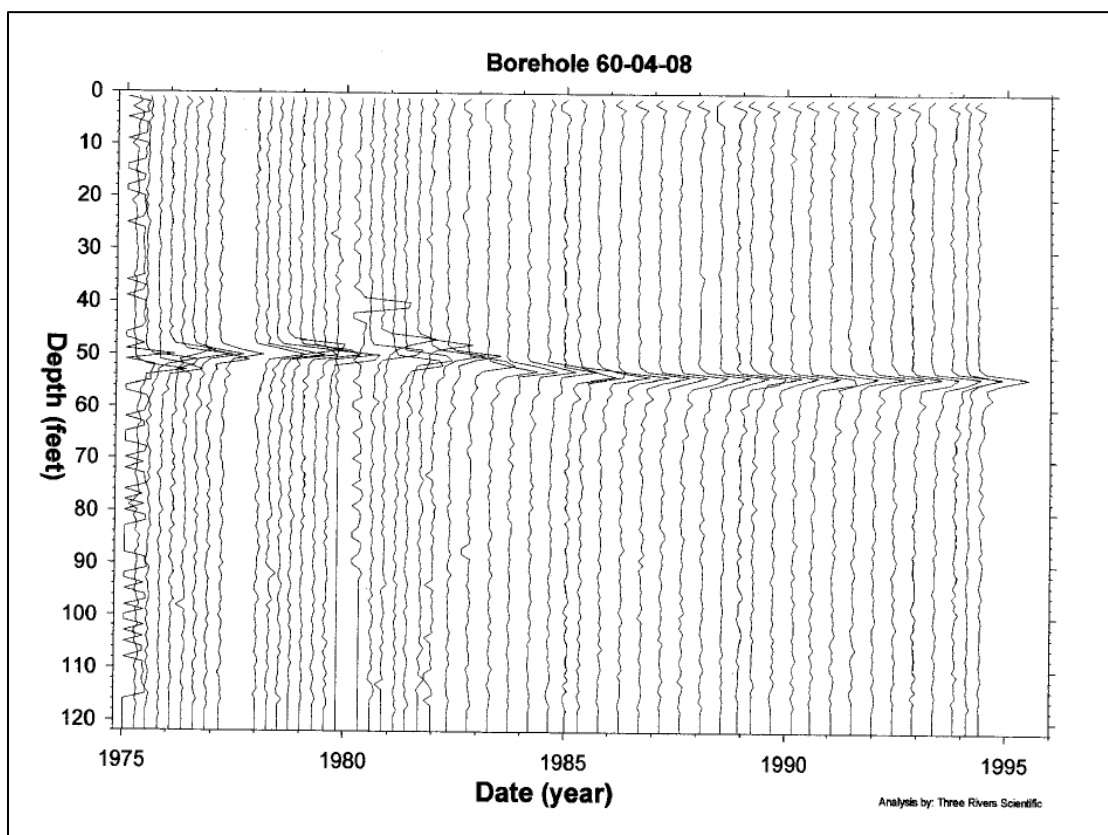
4.5.1.4 Drywell 60-04-08

Drywell 60-04-08 is located approximately 5.2-ft from the tank U-104 footing. Drywell 60-04-08 was drilled in 1974 with the first recoverable reading on June 4, 1974 with a peak 15-ft below the bottom base of the tank of 70.8K cpm at 53-ft BGS (see Appendix B1). The next reading reported on July 1, 1974 reported the peak at 17.8K cpm at 49-ft BGS. Radioactivity remained relatively stable at this BGS depth through September 1986.

In July 1996, Cs-137 and processed U-235 and U-238 were the only man-made radionuclides detected in drywell 60-04-08 (GJ-HAN-33). Continuous Cs-137 contamination was detected from the ground surface to 22-ft BGS with the maximum concentration of 8 pCi/g measured at 2-ft BGS which resulted from a surface or near-surface spill, leak from piping that migrated downward, and/or was carried down when the drywell was drilled (GJ-HAN-33).

Processed U-235 was detected from 53 to 65-ft BGS and from 70 to 76-ft BGS with the maximum U-235 concentration of approximately 20 pCi/g reported at 53-ft BGS. Processed U-238 was detected from 53 to 65-ft BGS, from 68 to 78-ft BGS, and at a few isolated locations. The maximum U-238 concentration of 500 pCi/g was measured at 53-ft BGS, 15-ft below the base of the tank. Document GJ-HAN-33 reports, "The processed U-235 and U-238 contamination most likely resulted from leakage from tank U-104." Figure 4-9 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 4-9. Tank U-104 Drywell 60-04-08 (RPP-7729)



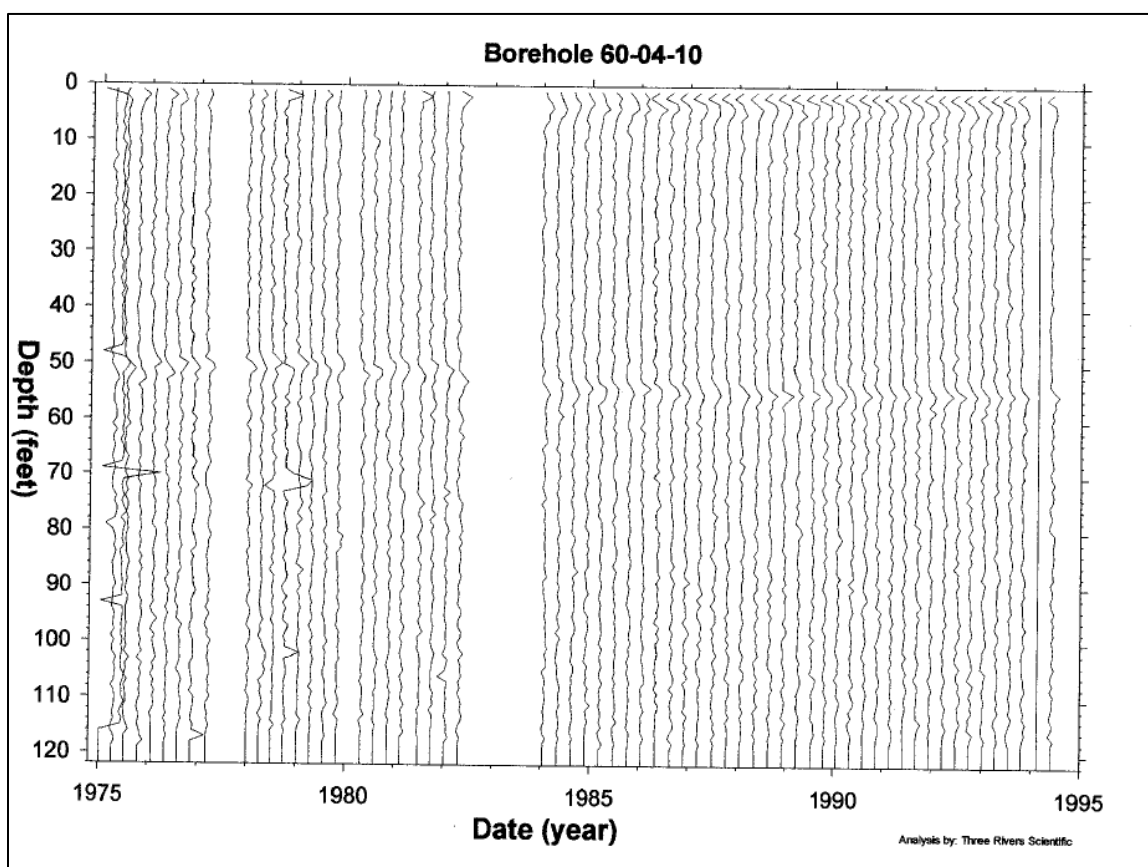
Note: Bottom of the tank footing is ~38-ft 4-in BGS

4.5.1.5 Drywell 60-04-10

Drywell 60-04-10 is located approximately 6.2-ft from the tank U-104 footing. Drywell 60-04-10 was drilled on 1974 with the first recoverable reading on April 18, 1974 with a peak of 15.6K cpm at 56-ft BGS (see Appendix B1). The next recorded reading on June 4, 1974 reported a peak 15-ft below the bottom base of the tank of 13.8K cpm at 53-ft BGS. Four days later, the radioactivity peak at 49-ft BGS was reported at approximately 3K cpm. Radioactivity remained relatively stable through November 1986 at this BGS depth.

In July 1996, Cs-137 and processed U-235 and U-238 were the only man-made radionuclides detected in drywell 60-04-10 (GJ-HAN-33). Cs-137 was detected continuously from the ground surface to 5-ft BGS and at a few intermittent locations. The maximum Cs-137 concentration of approximately 6 pCi/g was detected at 1-ft BGS which was the result from a surface or near-surface spill or leak from piping that migrated downward (GJ-HAN-33). Processed U-235 was detected from 53 to 55-ft BGS, 66 to 67-ft BGS, and at a few isolated locations with the maximum concentration of 10 pCi/g measured at 54-ft BGS. Processed U-238 was detected from 53 to 56-ft BGS and from 65 to 67-ft BGS with the maximum concentration of 150 pCi/g measured at 54-ft BGS. Document GJ-HAN-33 reported, "The processed U-235 and U-238 contamination most likely resulted from leakage from tank U-104." Figure 4-10 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 4-10. Tank U-104 Drywell 60-04-10 (RPP-7729)



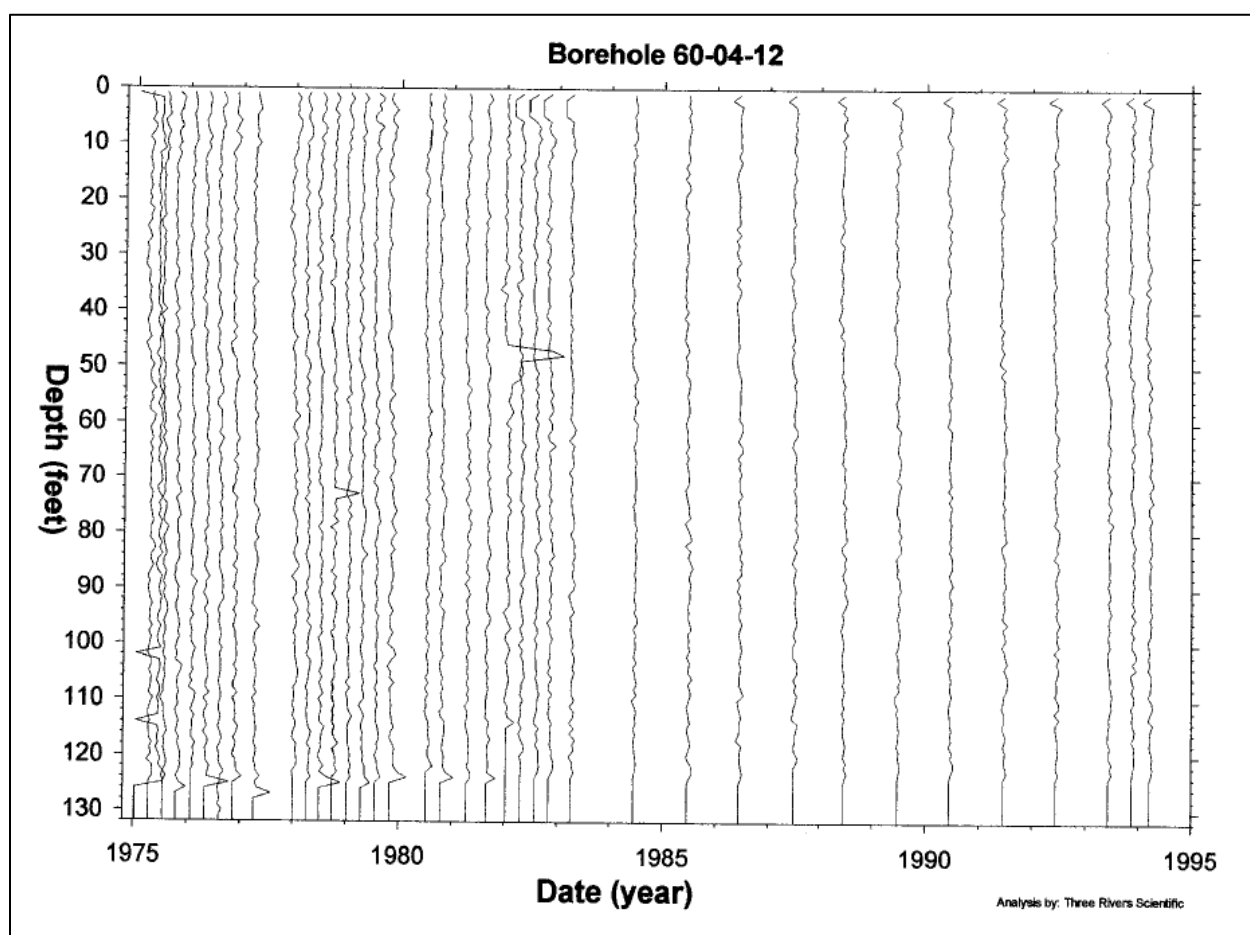
Note: Bottom of the tank footing is ~38-ft 4-in BGS

4.5.1.6 Drywell 60-04-12

Drywell 60-04-12 is located approximately 6.6-ft from the tank U-104 footing. Drywell 60-04-12 was drilled in 1974 with the first recoverable reading on April 18, 1974 reported as less than values (see Appendix B1). Readings continued to be reported as less than values through June 1986.

In July 1996, Cs-137 was the only man-made radionuclides detected in drywell 60-04-12 (GJ-HAN-33). Cs-137 was detected continuously from the ground surface to 18-ft BGS, intermittently from 24 to 31-ft BGS, at a few isolated locations, and at the bottom of the drywell. The maximum Cs-137 concentration of 4 pCi/g was detected at a depth of 9-ft BGS. Document GJ-HAN-33 reports, "This contamination resulted from a surface or near-surface spill or leak that migrated downward." Since historical radioactivity in this drywell is very low, and the 1996 SGLS report low levels of radioactivity, drywell 60-04-12 is not being included as part of the leak location for tank U-104. Figure 4-11 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 4-11. Tank U-104 Drywell 60-04-12 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft 4-in BGS

4.5.1.7 2007 Direct Pushes

In 2007, two direct pushes (C5593 and C5601) were installed near tank U-104 for spectral gamma logging (see Figure 4-1).

Results identified Cs-137 as the dominant gamma emitting radionuclide in direct push C5593 with a maximum equivalent Cs-137 concentration of 150 pCi/g detected at 24-ft BGS (RPP-36007, Rev. 0, *Small Diameter Geophysical Logging in the 241-U Tank Farm*). This appears to be a separate unrelated leak site from the earlier drywell data due to timing and depth and may be associated with a pipeline leak. The source does not appear to be from tank U-104 as only low-level radioactivity was detected in nearby drywells 60-04-12 and 60-04-03. However, a tank U-104 leak cannot be ruled out.

The maximum Cs-137 concentration detected in direct push C5601 was 24 pCi/g at 52-ft BGS (RPP-36007, Rev. 0). Radioactivity detected in this direct push appears to be related to the drywell radioactivity detected in the southern portion of the tank in 1974 due to the similar depths where maximum concentrations were recorded.

4.5.1.8 Drywell Summary

Tank U-104 was first suspected of leaking during sluicing operations in July 1956 (see Section 4.4.1). Drywells were not installed near tank U-104 until 1974.

Tank U-104 drywells 60-04-03 and 60-04-12 do not indicate any radioactivity associated with a tank U-104 leak. Therefore, these drywells are not included in the leak location for tank U-104.

The first recoverable readings in 1974-1976 for drywells 60-04-08, 60-04-10, 60-07-01, and 60-07-11 indicate radioactivity. A peak was reported in drywells 60-07-11 and 60-04-08 at around the same intensity (~70K cpm) and similar depths (~50-ft BGS). Radioactivity peaks of much lower intensity was reported in drywell 60-07-01 (4K cpm at 51-ft BGS) and drywell 60-04-10 (15.6K cpm at 56-ft BGS). Uranium reported in these four drywells (GJ-HAN-33) appears to be associated with a tank U-104 leak. Direct push C5601, installed in 2007, reports Cs-137 at a similar depth (52-ft BGS). It appears the source of the uranium detected in these four drywells and possibly the Cs-137 detected in direct push C5601 is from tank U-104.

Direct push C5593, installed in 2007, reports maximum radioactivity (150 pCi/g equivalent Cs-137) detected at 24-ft BGS. The source does not appear to be from tank U-104 as very little radioactivity was reported in nearby drywells 60-04-03 and 60-04-12 and may be associated with a pipeline leak. In addition the radioactive profile doesn't fit the profile of the radioactivity in the other drywells, however, a tank U-104 leak source cannot be ruled out. No laterals were installed near tank U-104.

4.6 POSSIBLE TANK U-104 LINER LEAK LOCATION(S)

A liner leak may have penetrated the waterproof membrane at any location or pooled on the waterproof membrane and followed concrete cracks or construction joints to a different location for egress to the soil, including the top of the tank footing.

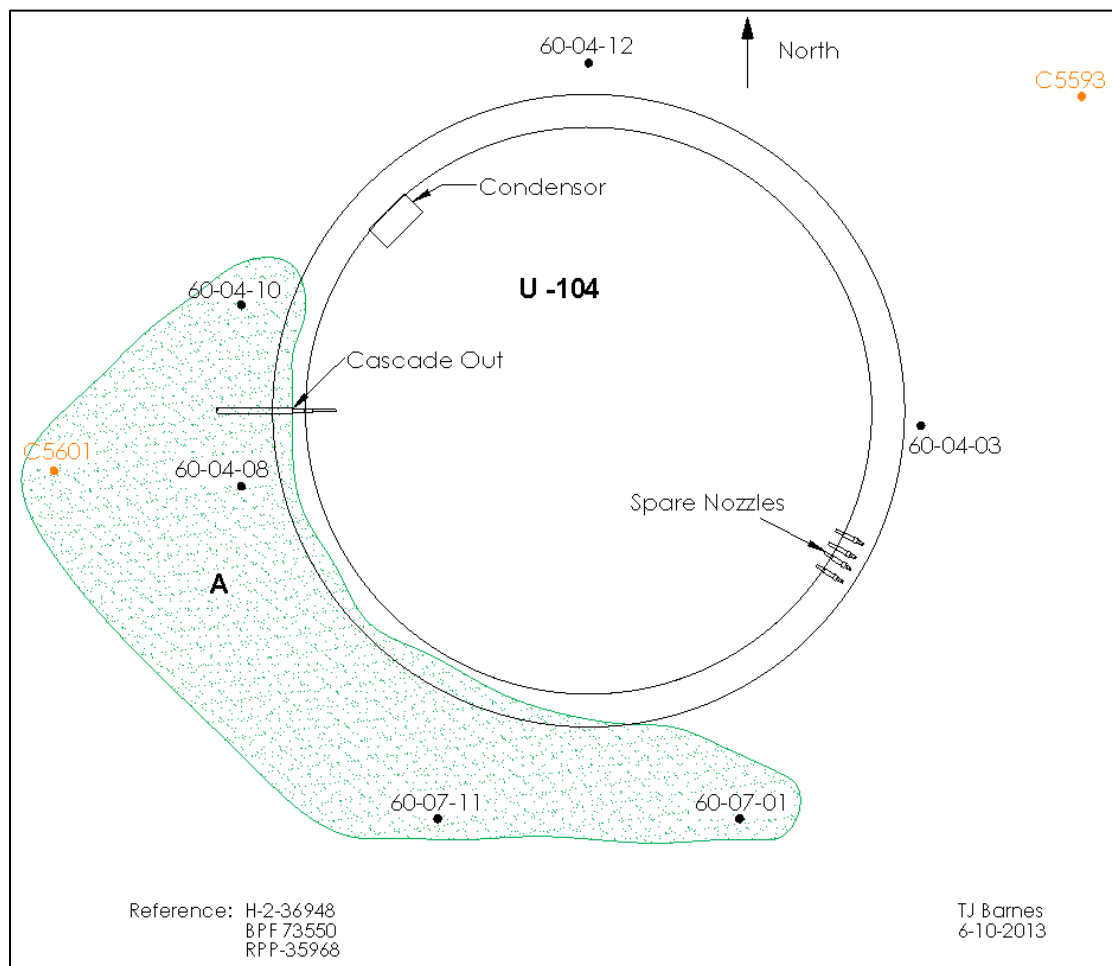
Tank U-104 was first suspected of leaking at the end of sluicing operations in July 1956 when the tank bulge was detected during the installation of a jet pump in the center riser. A subsequent leak test was performed between April 1957 and March 1961 confirmed a liner leak. Drywells were installed 1974 and two direct pushes in 2007. Tank U-104 had at least one liner leak site based on radioactivity detected in four drywells and two direct pushes, likely at or near the bottom of the tank.

4.6.1 Leak Detected in 1974-1976

Tank U-104 was first suspected of leaking during sluicing operations in July 1956 (see Section 4.4.1). Drywells were not installed near tank U-104 until 1974.

The first recoverable readings in 1974-1976 for drywells 60-04-08, 60-04-10, 60-07-01, and 60-07-11 indicate radioactivity. A peak was reported in drywells 60-07-11 and 60-04-08 at around the same intensity (~70K cpm) and similar depths (~50-ft BGS). Radioactivity at much lower intensity was reported in drywells 60-07-01 and 60-04-10 at similar BGS depths. The uranium detected in these four drywells appears to be associated with a tank U-104 leak. Direct push C5601, installed in 2007, reported radioactivity at a similar depth (52-ft BGS). The peak uranium detected in these drywells at approximately the 50-ft BGS level is roughly 12-ft lower than the bottom of the tank footing indicating some sort of transport mechanism during the 18-yr period when the leak was first suspected to the first drywell data. It appears the source of the radioactivity detected in these four drywells and direct push C5601 are related and indicate a tank U-104 leak in the southwestern portion of the tank (see Figure 4-12).

Figure 4-12. Tank U-104 Possible Leak Location (1974-1976)
 Tank inner ring is steel liner; outer ring is outer edge of tank footing

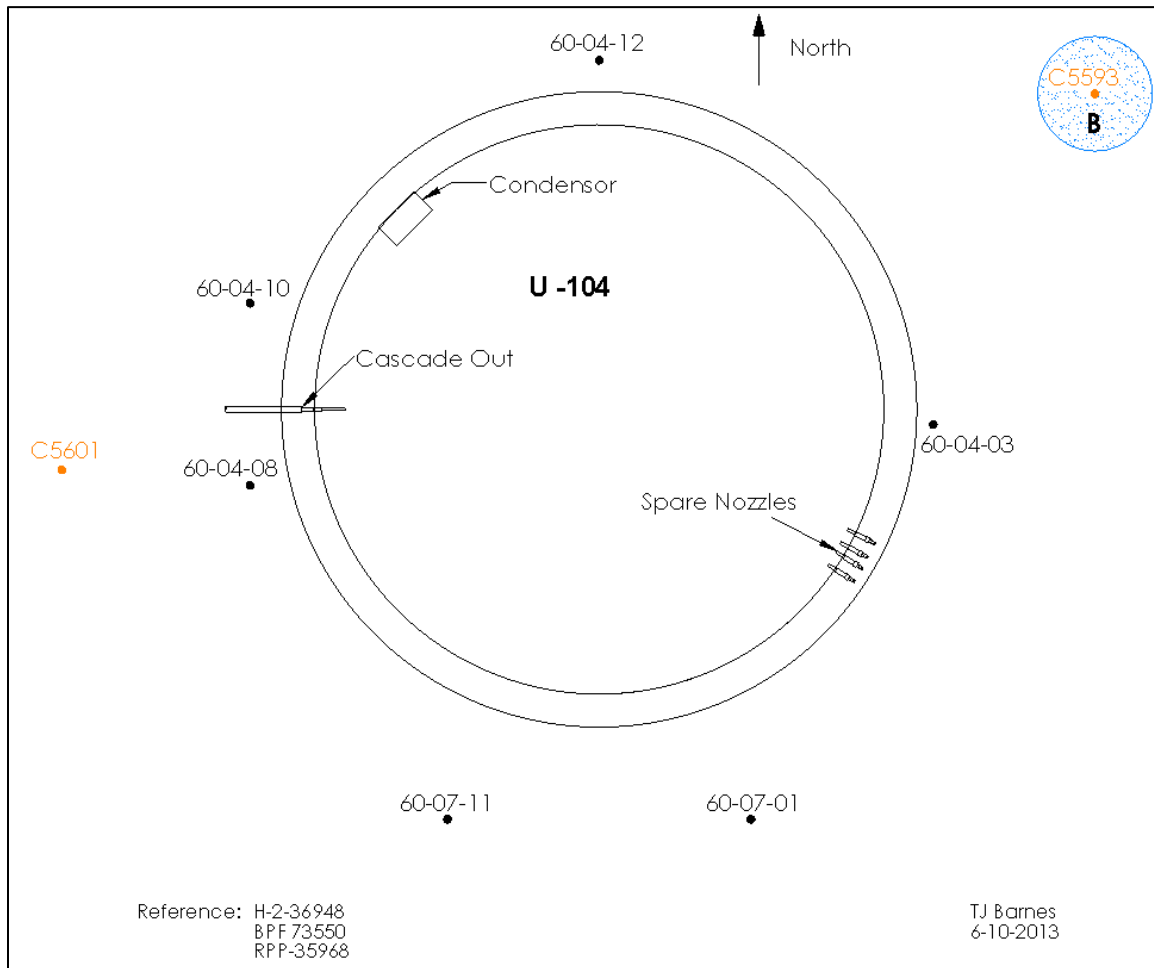


Tank U-104 was first suspected of leaking during sluicing operations in July 1956 (see Section 4.4.1).
 Drywells were not installed near tank U-104 until 1974.

4.6.2 Leak Detected in 2007

Direct push C5593, installed in 2007, reports maximum radioactivity (150 pCi/g equivalent Cs-137) detected at 24-ft BGS (see Figure 4-13). The source may be associated with a pipeline leak as it does not appear to be from tank U-104 since very little radioactivity was reported in nearby drywells 60-04-03 and 60-04-12 and radioactivity reported in this direct push was located at a much higher BGS level compared to site A in Figure 4-12. The source of this radioactivity remains unknown; however, a tank U-104 leak source cannot be ruled out.

Figure 4-13. Tank U-104 Possible Leak Location (2007)
Tank inner ring is steel liner; outer ring is outer edge of tank footing



Tank U-104 was first suspected of leaking during sluicing operations in July 1956 (see Section 4.4.1).
Drywells were not installed near tank U-104 until 1974.

4.6.3 Leak Location Summary

Tank U-104 was first suspected of leaking during sluicing operations in July 1956. A leak test was conducted from April 1957 through March 1961 where a volume of approximately 50 kgal was lost (see Section 4.4.1). During this time, no drywells were installed around tank U-104 to confirm a liner leak.

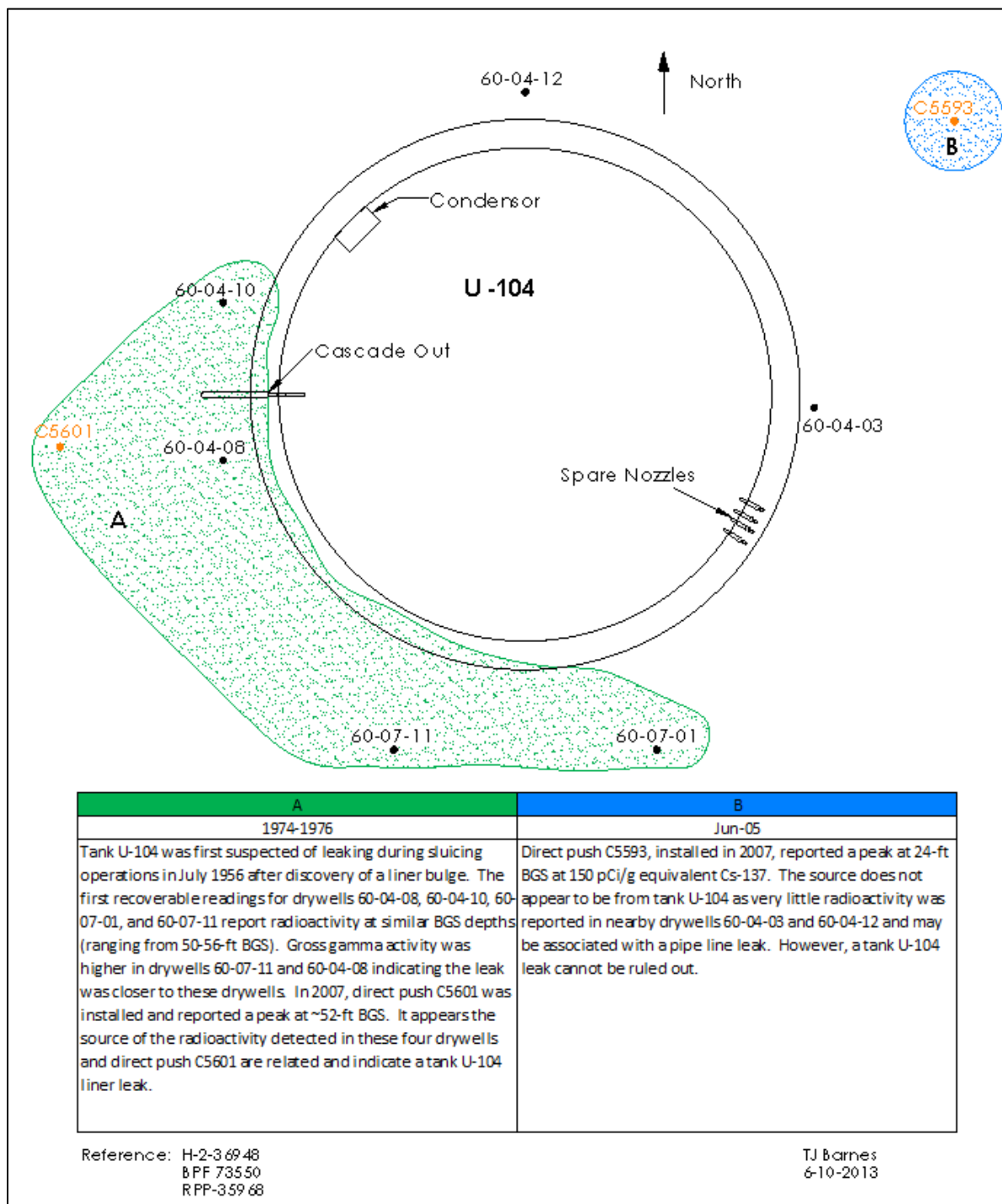
The first recoverable readings in 1974-1976 for drywells 60-04-08, 60-04-10, 60-07-01, and 60-07-11 indicate radioactivity at a depth ranging from 50-56-ft BGS. Gross gamma activity was higher in drywells 60-07-11 and 60-04-08 indicating the leak was closer to these drywells. Direct push C5601, installed in 2007, reports radioactivity at a similar depth (52-ft BGS). The peak uranium detected in these drywells starting at approximately the 50-ft BGS level is roughly 12-ft lower than the bottom of the tank footing indicating some sort of transport mechanism during the 18-yr period when the leak was first suspected to the first drywell data. It appears the source of the radioactivity detected in these four drywells and direct push C5601 are related and indicate a tank U-104 leak in the southwestern portion of the tank (see site A in Figure 4-14).

Direct push C5593, installed in 2007, reports maximum radioactivity (150 pCi/g equivalent Cs-137) detected at 24-ft BGS (see site B in Figure 4-14). The source may be associated with a pipeline leak as it does not appear to be from tank U-104 since very little radioactivity was reported in nearby drywells 60-04-03 and 60-04-12. The source of this radioactivity is unknown, therefore a tank U-104 leak source cannot be ruled out.

Leak locations in Figure 4-14 are based on peak readings and are a representation of possible initial boundaries of radioactivity.

Tank U-104 was reported to have bulged after a failed installation of the heel jet through the pit at the center of the tank during sluicing operations in July 1956. It was determined that the center of the tank bottom was ~5-ft higher than normal (see Section 4-11). Photographs were taken of the interior of tank U-104 on August 15, 1956 which confirmed the liner bulge (see Section 4.4.5).

Figure 4-14. Tank U-104 Possible Radial Leak Locations
 Tank inner ring is steel liner, outer ring is outer edge of tank footing



4.7 POSSIBLE TANK U-104 LINER LEAK CAUSE(S)

Tank U-104 was evaluated for five conditions known to contribute to a failed liner.

4.7.1 Tank Design

The U Farm tank design does not appear to be a factor contributing to a failed liner (see Section 3.1.1).

4.7.2 Thermal Conditions

No temperature data are available for tank U-104, however, tank U-104 held only non-boiling waste. Thermal shock creates stress both from rapid temperature rise as well as waste-induced high temperatures. Since no records are available, it is uncertain what the maximum temperature was in tank U-104 during operation as well as the rate of temperature rise when waste was added. The thermal attributes of the waste and other information (see Section 4.4.2) would indicate that thermal stresses were likely minimal and should not have challenged the tank storage limits. However, the rate of temperature rise could have resulted in vapor pressure under the liner overcoming the hydrostatic pressure.

Temperature requirements in ARH-951 issued December 18, 1969 indicated that tank temperatures should be held below 230°F.

4.7.3 Chemistry-Corrosion

Tank U-104 stored MW for ~8 years before the liner leak. Metal waste should not have resulted in pitting or SCC under tank U-104 conditions.

4.7.4 Liner Observations

Tank U-104 was the first SST reported to have a liner bulge (July 1956) after a failed attempt to install a heel jet through the pit at the center of the tank during sluicing operations. Confirmation of the possible 5-ft liner bulge was reported in multiple documents (see Sections 4.4.3 and 4.4.5). A review of available photographs appears to confirm liner bulging reports. The tank had stored and sluiced MW twice up to a total of eight years prior to the discovery of the bulge.

Liner bulging coupled with other tank conditions could affect tank liner integrity, however, by itself bulging induces stresses that can cause breaching of the tank liner (see Section 3.2.3).

4.7.5 Tank Construction Temperature

The U Farm tank liners were constructed between February 1944 and October 1944. Only isolated minimum temperatures were experienced during tank construction at or below 18°F with day time temperatures between 44°F and 57°F (see Section 4.3.2). Impact occurrences could have occurred during cold temperatures that may have triggered fissures in the steel liner; however, the possibility seems much less than that which might have occurred during construction in other tank farms.

4.8 TANK U-104 CONCLUSIONS

A 5-ft bulge in the tank U-104 bottom liner was discovered while completing the second sluicing of the full tank of MW in July 1956. The bulge with probable failure of the tank bottom liner resulted in a leak of waste to the soil under the tank towards the southwest. The cause of the bulge is not clear although there is a likely possibility related to rate of temperature rise which under the right conditions can cause vapor pressure under the liner to overcome hydrostatic pressure resulting in a bottom liner bulge. Subsequent leak testing with water confirmed the presence of a leak in the liner as well as detection of drywell radioactivity.

There are several liner leak cause conditions that were examined but the most likely cause of the tank U-104 liner leak was a 5-ft bulge in the bottom of the tank resulting from tank waste thermal conditions. The MW process waste is not conducive to pitting and SCC and there appears to be very little contribution from tank design and construction temperatures. Some or all of the factors can act serially or together to contribute to tank liner failure.

APPENDIX A1

TANK U-104 NON-BOILING WASTE OPERATIONAL HISTORY

Table A1-1. ARH-R-43 Waste Tank Leak Experience Table

TABLE 3. Underground Waste Storage Tank Leak Experience

<u>Tank</u>	<u>Built</u>	<u>First Used</u>	<u>Type of Waste Stored</u>	<u>Service</u>	<u>Leak First Suspected</u>	<u>Reason for Suspicion</u>	<u>Leak Confirmed by</u>	<u>Bulge Found</u>	<u>Estimated Volume of Leak, gal</u>	<u>Associated Cs-137, kCi</u>
104-U	1943-44	1947	Bismuth phosphate waste Uranium recovery waste	Nonboiling	1956	Bulged liner	Refill with water (1961)	Yes	55,000*	0.09
113-SX	1953-54	1958	Redox waste	Boiling	1958	Bulged liner	Refill with salt solution (1962)	Yes	15,000**	8
106-TY	1951-52	1953	TBP waste	Nonboiling	1959	Liquid level measurements	Soil radiation readings (1959)		20,000	2
101-U	1943-44	1946	Bismuth phosphate waste Uranium recovery waste Redox waste	Nonboiling	1959	Liquid level measurements	Liquid level measurements		30,000	23
105-TY	1951-52	1953	TBP waste	Nonboiling	1960	Liquid level measurements	Liquid level measurements		35,000	4
108-SX	1953-54	1955	Redox waste	Boiling	1962	Soil radi- ation readings	Liquid level measurements	Yes	3,400	17
105-A	1954-55	1963	Purex waste	Boiling	1963	Soil radi- ation readings	Soil radiation readings	Yes	Small	
107-SX	1953-54	1956	Redox waste	Boiling	1964	Soil radi- ation readings	Soil radiation readings	Yes	Small	
109-SX	1953-54	1955	Redox waste	Boiling	1965	Soil radi- ation readings	No further evidence	No	Small	
115-SX	1953-54	1958	Redox waste	Boiling	1965	Liquid level measurements	Soil radiation readings		50,000***	40
112-SX	1953-54	1956	Redox waste	Boiling	1969	Liquid level measurements	Soil radiation readings	Yes	30,000	45

* Contained water at time of leak.
 ** Contained NaNO_3 solution at time of leak, also some residual supernatant solution.
 *** Contained NaNO_3 solution at time of leak.

APPENDIX B1

TANK U-104 GROSS GAMMA DRYWELL DATA

**Table B1-1. Tank U-104 Drywell Radioactivity (K counts per minute) (April 1974 through November 1986)
(SD-WM-TI-356)**

60-04-03		60-07-01			60-07-11			60-04-08			60-04-10			60-04-12	
Date	Peak (K cpm)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)
N/A ¹		N/A ¹			N/A ¹			N/A ¹			4/18/1974	15.6	56	4/18/1974	< 12
N/A ¹		N/A ¹			6/4/1974	73.8	50	6/4/1974	70.8	53	6/4/1974	13.8	53	7/1/1974	< 3
10/4/1974	< 3	N/A ¹			7/18/1974	15.2	53	7/1/1974	17.8	49	6/8/1974	3.1	49	N/A ¹	
2/11/1975	< 3	N/A ¹			1/24/1975	16	50	2/8/1975	15.0	52	1/31/1975	3.4	52	1/30/1975	< 3
8/6/1975	< 3	N/A ¹			8/6/1975	19	53	8/11/1975	14.5	53	8/11/1975	3.2	51	8/6/1975	< 3
12/30/1975	< 3	N/A ¹			N/A ¹			12/30/1975	13.3	52	12/30/1975	2.9	53	12/30/1975	< 3
N/A ¹		N/A ¹			1/7/1976	17	53	N/A ¹			N/A ¹			N/A ¹	
5/12/1976	< 3	5/12/1976	4.0	51	5/5/1976	16	52	5/12/1976	14.2	50	5/12/1976	3.1	51	5/12/1976	< 3
N/A ¹		6/30/1976	3.9	53	11/10/1976	17	51	9/1/1976	13.7	50	11/28/1976	3.5	50	N/A ¹	
N/A ¹		1/26/1977	3.5	53	N/A ¹			1/19/1977	13.9	51	N/A ¹			1/5/1977	< 3
N/A ¹		6/1/1977	4.0	53	5/10/1977	17	51	6/1/1977	13.4	50	5/18/1977	3.2	51	N/A ¹	
11/15/1977	< 3	11/22/1977	4.5	54	11/22/1977	13	51	11/22/1977	14.7	51	11/22/1977	3.3	51	11/2/1977	< 3
N/A ¹		N/A ¹			N/A ¹			2/28/1978	21.4	50	N/A ¹			N/A ¹	
N/A ¹		5/5/1978	3.7	53	5/3/1978	17	50	5/31/1978	31.4	50	5/3/1978	3.6	50	11/17/1978	< 3
11/16/1978	< 3	11/15/1978	3.9	54	11/15/1978	18	52	12/1/1978	30.5	50	11/17/1978	3.8	50	N/A ¹	
N/A ¹		N/A ¹			N/A ¹			6/14/1979	21.9	50	8/23/1979	3.1	50	N/A ¹	
N/A ¹		10/31/1979	3.6	54	10/31/1979	16	52	10/5/1979	19.0	51	N/A ¹			N/A ¹	
11/1/1979	< 3	N/A ¹			N/A ¹			11/1/1979	16.5	50	11/1/1979	2.8	50	11/1/1979	< 3
10/16/1980	< 3	11/6/1980	3.4	53	11/13/1980	16	53	11/26/1980	17.6	51	11/13/1980	3.0	50	10/16/1980	< 3
11/19/1981	< 3	11/18/1981	3.8	53	11/19/1981	14	50	11/11/1981	11.6	52	11/11/1981	3.5	52	11/19/1981	< 3
10/20/1982	< 3	11/3/1982	3.2	54	11/3/1982	17.2	52	10/20/1982	13.6	52	11/3/1982	2.9	53	11/3/1982	< 3
6/15/1983	< 3	11/22/1983	3.7	54	11/22/1983	14.9	52	9/21/1983	15.0	53	11/16/1983	3.3	54	6/15/1983	< 3
6/13/1984	< 3	10/25/1984	3.7	53	10/25/1984	12.3	53	8/22/1984	14.6	53	10/17/1984	2.9	54	6/13/1984	< 3
6/19/1985	< 3	11/20/1985	3.5	55	11/20/1985	14.4	54	10/15/1985	16.2	54	10/30/1985	< 3	N/A ¹	6/19/1985	< 3
6/10/1986	< 3	11/6/1986	4.0	54	11/6/1986	14.6	54	9/17/1986	16.0	54	11/12/1986	3.1	55	6/10/1986	< 3

Note: ¹N/A: Data not available

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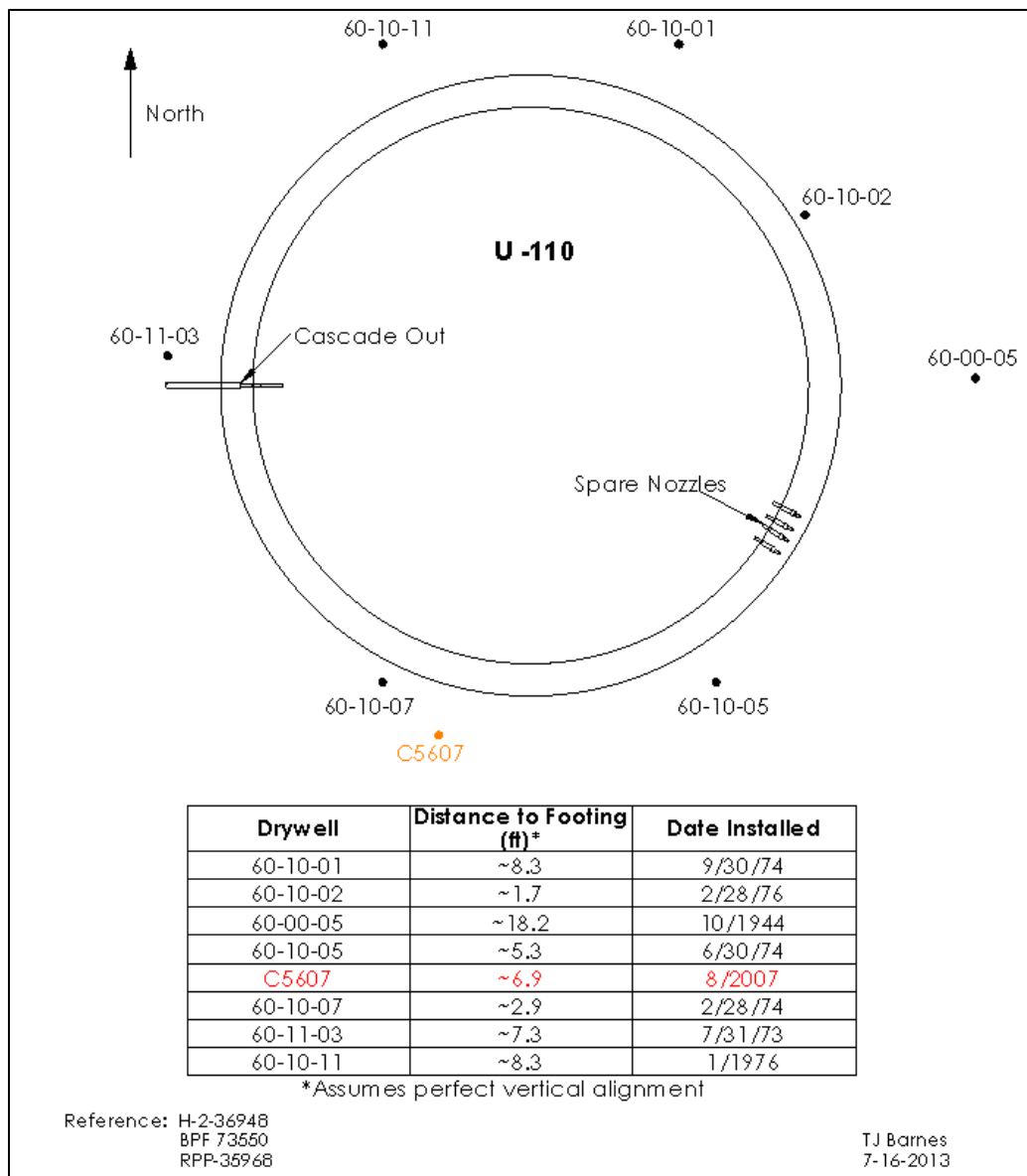
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5.1 TANK U-110 BACKGROUND HISTORY

This section provides information on the historical waste loss event associated with Single-Shell Tank (SST) 241-U-110 (U-110). There are seven drywells located around tank U-110 with specified distances from the drywell to the tank footing shown in Figure 5-1: 60-00-05 installed in 1944, 60-11-03 installed in 1973, 60-10-01, 60-10-05, 60-10-07, installed in 1974, and 60-10-11 and 60-10-02, installed in 1976. One nearby direct push was installed in 2007.

The bottom of the tank footing is ~39-ft 1-in Below Grade Surface (BGS) with ~7.2-ft soil cover over the dome (WHC-SD-WM-TI-665).

Figure 5-1. Tank U-110 Associated Drywells
Tank inner ring is steel liner; outer ring is outer edge of tank footing



5.2 TANK U-110 OPERATIONS SUMMARY

Tank U-110 first began receiving 221-T Plant (T Plant) first cycle waste (1C) typically neutralized with coating waste (CW) on July 22, 1946 (HW-7-4542-DEL, *Hanford Engineer Works Monthly Report July 1946*). The tank was declared full and 1C waste began to cascade to tank U-111 after April 1947 (HW-7-6184-DEL, *Hanford Works Monthly Report April 1947*). First cycle waste cascaded into tank U-111 and tank U-112 through May 1948 when the three tank cascade was declared full (HW-10166-DEL, *Hanford Works Monthly Report May 1948*) and no other transfers occurred through July 1951. No record of tank transfers was available between August 1951 and March 1952. Beginning in April 1952, supernatant was pumped out of tank U-110 to the sludge level leaving a volume reported at 336 kgal (HW-27838, *Waste Status Summary Period: April, May, and June 1952*). No waste transactions were reported until January 1954.

Beginning on January 13, 1954, tank U-110 started receiving REDOX concentrated salt waste (HW-30851, *Waste Status Summary January 1954*). The REDOX waste level decreased through self-evaporation from June 1954 through August 1955. Beginning in September 1955 through July 1957, periodic transfers of REDOX coating waste occurred into and out of tank U-110. No other transfers occurred until July 1958 when 39 kgal of water was added to the tank. No waste transfers into or out of the tank occurred from August 1958 until the second quarter in 1969.

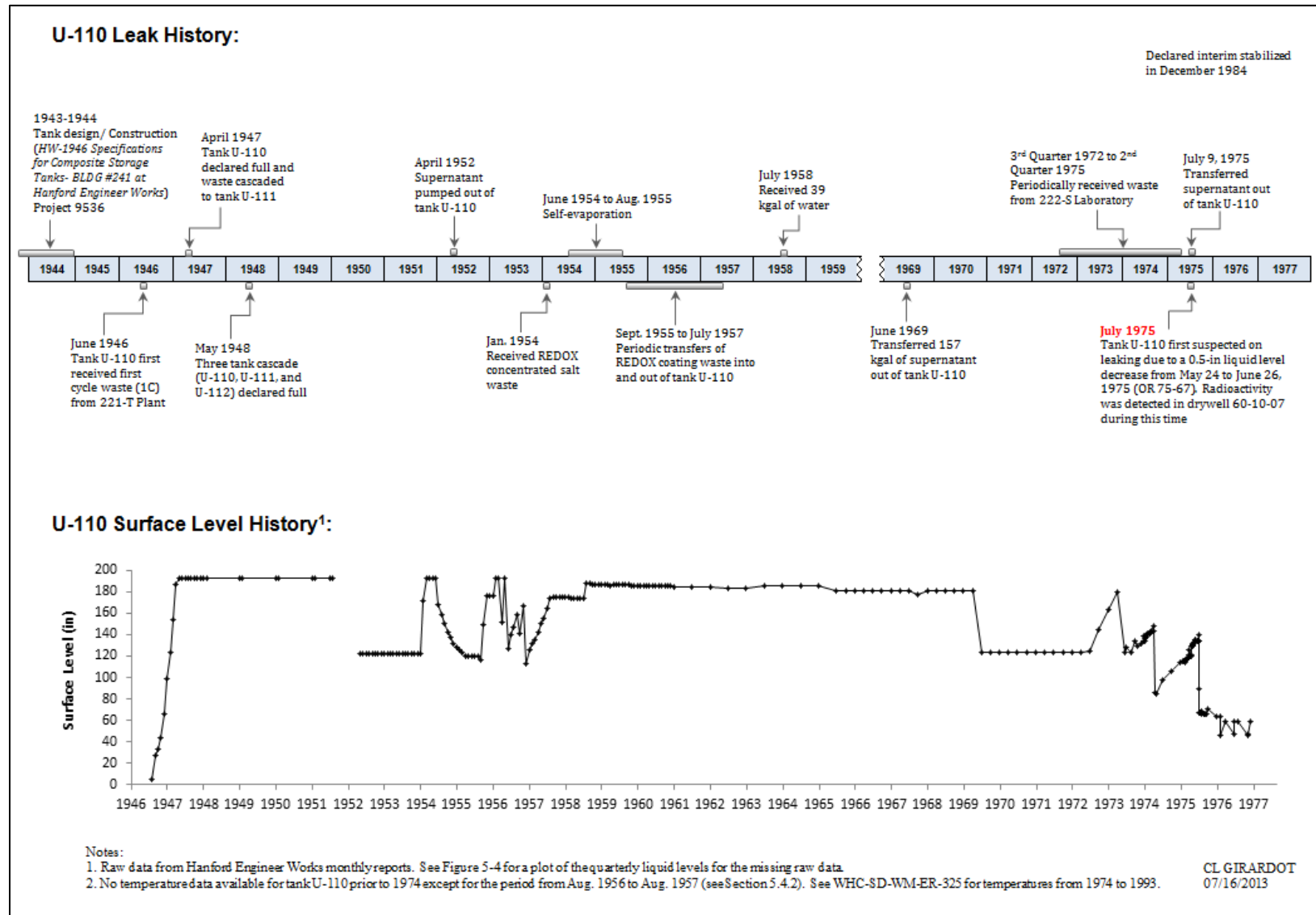
The next waste transfer occurred in June 1969 when 157 kgal of supernatant was transferred to tank TX-118. The solids content was subsequently adjusted downward 47-in to 284 kgal. No additional transfers were made until the third quarter of 1972 through the second quarter of 1975 when tank U-110 periodically received a total of 316 kgal of waste from 222-S Laboratory.

Tank U-110 was first reported to be leaking on July 9, 1975 after a 0.5-in liquid level decrease was observed. The 0.5-in liquid level decrease was reported between May 24, 1975 to June 26, 1975 (OR 75-67, *Liquid Level Decrease in Tank 110-U*). Beginning on July 9, 1975, 225 kgal supernatant was transferred out of tank U-110 to tank U-111 leaving approximately 161 kgal of sludge (ARH-CD-336C, *Production and Waste Management Division Waste Status Summary July 1, 1975 through September 30, 1975*).

Tank U-110 was declared administratively interim stabilized in December 1984 with 16 kgal of drainable liquid remaining (HNF-EP-0182). The estimated leak volume ranges from 5 to 8.1 kgal.

The operational history of tank U-110 leak related details including liquid level is charted in Figure 5-2.

Figure 5-2. Operational Leak History of Tank U-110



5.3 TANK DESIGN/CONSTRUCTION

5.3.1 Tank Design

The steel bottoms of the U Farm tanks intersect the sidewall on a 4-ft radius knuckle transition (BPF-73550, Drawings D-2 and D-3). The rounded knuckle transition, the three-ply asphaltic membrane waterproofing between the liner and the concrete, a notched footing construction joint, and the concrete shell are features common to all U Farm tanks (see Section 3.1.1).

5.3.2 Tank Construction Conditions

The U Farm tanks were constructed between February 1944 and October 1944. Temperatures are not available for 1944 between May 18 and December 1. From the start of U Farm tank construction through May 18, 1944 there were two minimum temperatures of 12°F with daytime temperatures of 44°F and 57°F, one at 18°F, and four at 20°F with day time temperatures between 41°F and 56°F.

As described in Section 3.1.2, cold weather affects the ductile-to-brittle steel transition temperature, with 18°F being the assumed design temperature for the carbon steel liner, which could result in a fracture upon impact. However, in general, the temperatures during the U Farm construction time frame were much milder than those experienced during 241-SX Farm construction where ductile-to-brittle steel transition temperatures were exceeded.

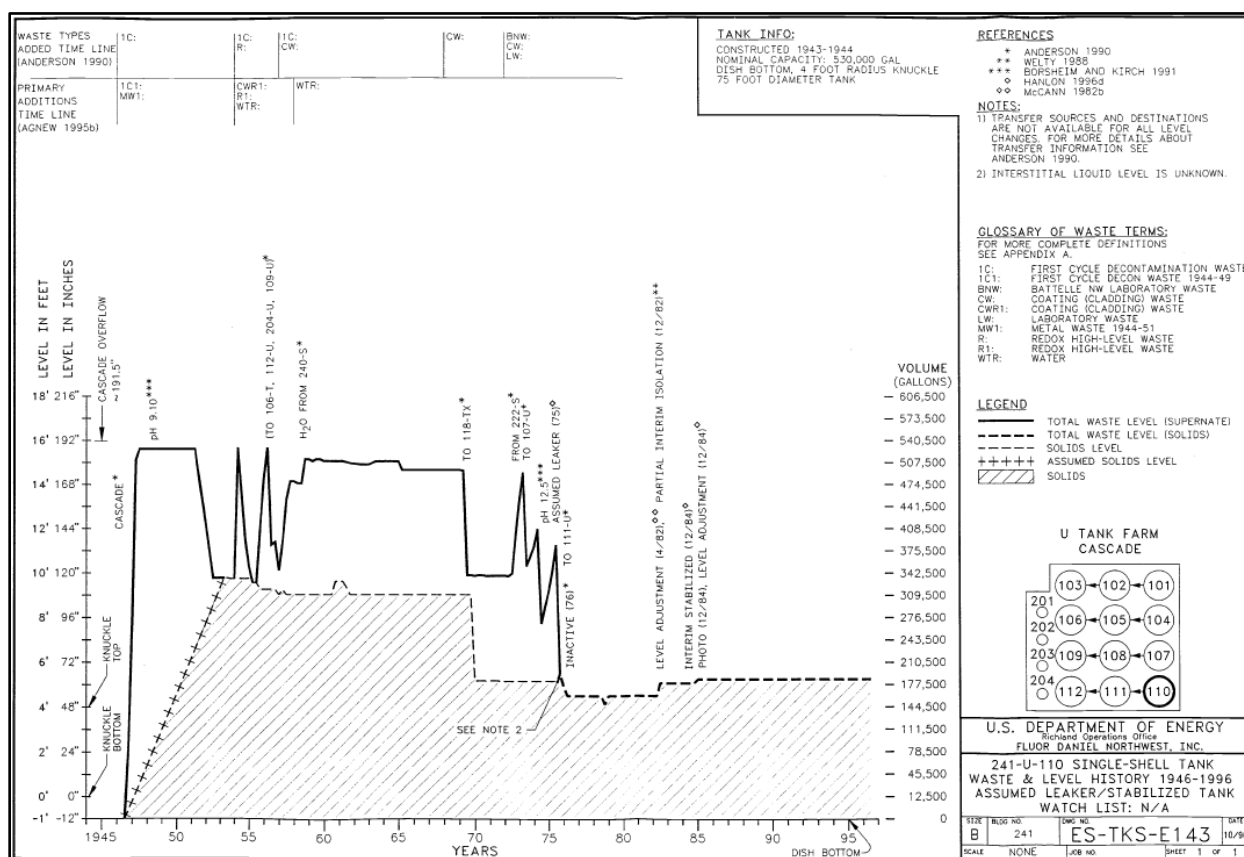
Design, fabrication, and erection of the tank steel lining were required to be in accordance with current “Standards Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs” as promulgated by the “American Water Works Association” (BPF 73550). Welding requirements were required to conform to the American Welding Society’s “Code for Arc and Gas Welding in Building Construction”, Section 4.

5.4 TANK U-110 IN-TANK DATA

5.4.1 Liquid Level

The liquid level plot in Figure 5-3 indicates the transfer activity into and out of tank U-110. The liquid levels are end of quarter levels so this figure may not reflect all transfers into and out of the tank that occurred during the operational history. See Figure 5-2 for historical monthly liquid level readings.

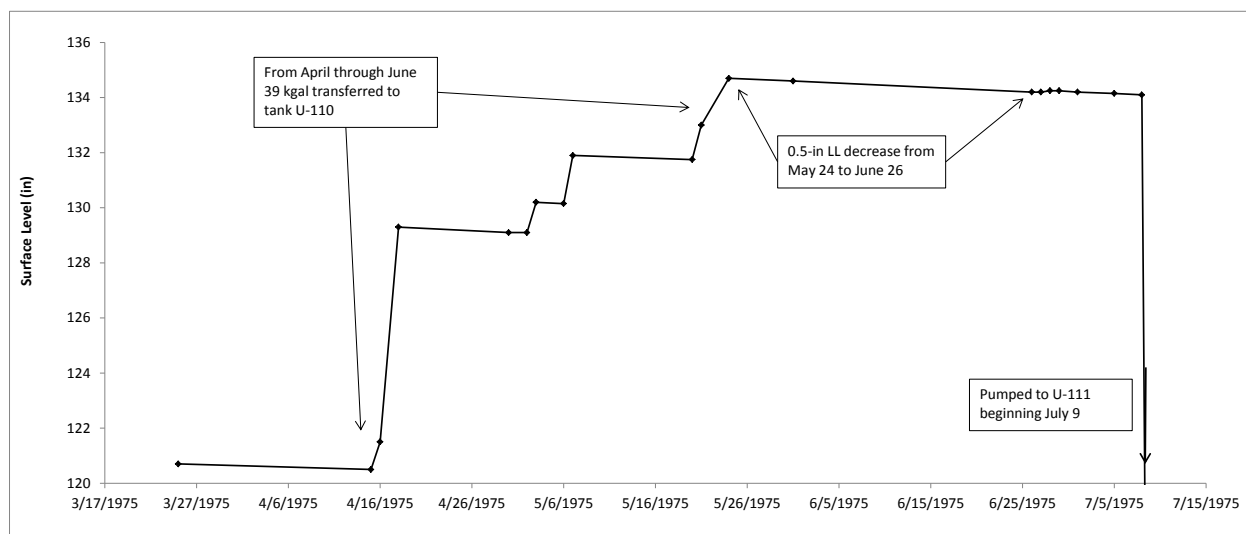
Figure 5-3. Tank U-110 End of Quarter Surface Level



WHC-SD-WM-ER-325, Rev. 0, 1994, Supporting Document for the SW Quadrant Historical Tank Content Estimate for U-Tank Farm.

Tank U-110 was first suspected of leaking due to a 0.5-in liquid level decrease that was reported between May 24, 1975 and June 26, 1975 (OR 75-67). The last transfer before this unexplained liquid level decrease occurred in the second quarter of 1975 and a total of 39 kgal was transferred to tank U-110 (ARH-CD-336B, *Production and Waste Management Division Waste Status Summary April 1, 1975 through June 30, 1975*). The liquid level was reported to be 134.7-in on May 24, 1975 and down to 134.2-in by June 26 (see Figure 5-4). Psychometric data taken June 11, 1975, gave no assistance in explaining the liquid level drop. Photographs taken on June 26, 1975, were reported to give no additional information on the cause of the liquid level drop.

The liquid level then appeared to stabilize through July 4, 1975. On July 8, 1975, the liquid level dropped an additional 0.1-in. During this time, radioactivity in drywell 60-10-07 was also increasing. Tank U-110 was classified as a leaker on July 9, 1975 (OR 75-67). By July 19, 1975, a salt well pump was in operation but apparently was not functioning properly. Photographs indicated the pump suction was hung up on an island of sludge with a considerable volume of liquid still evident. Thus, on July 28, 1975 a well casing and pump were installed in the center riser. Photographs taken August 5 and September 12, 1975 reported successful removal of the surface pools of liquid.

Figure 5-4. Tank U-110 Liquid Level March 25, 1975 to July 9, 1975

5.4.2 Temperature

Seven tanks in the B, C, T, and U Farms that contained metal waste (MW) ranged in temperature from 84°F to 174°F between 1945 and 1947 (HW-14946). The only U Farm tank (tank U-101) contained MW waste which was found to range from 84°F to 138°F between 1945 and 1947 (HW-14946). Document HW-20742, *Loss of Depleted Metal Waste Supernatant to Soil*, reports MW was cascaded into a 241-BX Farm series of tanks with temperatures recorded in the first tank of ~180°F, which contains the bulk of the uranium and fission products, and ~70°F in the last tank of the cascade. The MW contains approximately 90% of the fission products from the Bismuth Phosphate (BiPO₄) process at both 221-U Plant and 221-B Plant. Tank U-110, the first tank in the tank U-110 through tank U-112 cascade, which contained a mixture of 1C/CW waste, would have experienced much lower temperatures as the fission product content was much lower than MW. The 1C/CW waste contained approximately 10% of the BiPO₄ process fission products with approximately 90% in the MW.

No temperature data were recovered for tank U-110 from May 1946 when the tank was first put into service until 1974 except for a one year period from August 1956 to August 1957. Sludge temperature plots for the one year period between August 1956 and August 1957 (RHO-CD-1172) indicated a gradual decreasing temperature from ~140°F to ~115°F. These temperatures were during a period of REDOX coating waste transfers into the tank after the storage of REDOX concentrated salt waste. There had been a gradual decrease in liquid level during storage of REDOX concentrated salt waste indicating the temperature may have been higher at that time as the liquid level decrease had been attributed to evaporation.

Tank U-110 waste temperatures from 1974 to 1993 which ranged from ~105°F to 65°F can be found in WHC-SD-WM-ER-325. REDOX coating waste supernatant was transferred out of tank U-110 in 1969 and laboratory waste was transferred into the tank from 1972 until it was pumped in 1975.

5.4.3 Liner Observations

No liner observations relating to a tank U-110 leak have been found.

5.4.4 Chemistry-Corrosion

Tank U-110 began receiving waste in July 1946 and received various waste types throughout operation as shown in Table 5-1. The typical concentration for nitrite, nitrate, and hydroxide for waste is shown in Table 5-2. Nitrite and hydroxide are known as nitrate induced SCC inhibitors. One key characteristic for inhibiting SCC is to maintain a high nitrite concentration to nitrate concentration ratio (see Section 3.2.4).

Table 5-1. Tank U-110 Waste Storage Chronology

Date	Waste Type	Length of Storage
July 1946 to December 1953	1C/CW	~ 7 years
January 1954 to August 1955	R	~1.5 years
September 1955 to June 1972	CW	~3 years
July 1972 to September 1975	LW	~3 years

Table 5-2. Waste Chemistries for Waste Types Stored in Tank U-110

Waste Type	[NO ₃ ⁻]	[NO ₂ ⁻]	[OH ⁻]	Meets Current DST Specification ²
1C ¹	1.54	0.26	0.28	No ³
CW ¹	0.6	0.9	1.0	Yes
R ⁴	4.83	0.74		No ⁵
LW	Unknown ⁶			

- Reference WHC-EP-0449, 1991, *The Sort on Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Characteristic Groups*.
- Reference OSD-T-151-00007, Rev. 12, 2013, *Operating Specification for the Double-Shell Storage Tanks*.
- Waste type 1C does not meet the current DST specification for waste chemistry; however, 1C was mixed with CW prior to adding to the tank. Depending on this ratio, the resulting waste may have met the DST specification.
- Reference WHC-EP-0772, 1994, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single Shell Tanks*.
- Does not meet the current DST specification since the hydroxide and nitrite concentrations are not greater than or equal to 1.2M.
- The chemical content of the total of 316 kgal of laboratory waste transferred to tank U-110 has not been found.

Tank U-110 stored REDOX concentrated salt waste for ~1.5 years. REDOX concentrated salt waste could be a concern for either pitting or SCC under the tank U-110 conditions especially at elevated temperatures that were high enough to cause evaporation of the waste.

The chemical content of the 222-S laboratory waste (LW) could not be recovered and normally would be diluted; however, the quantity of 361 kgal that tank U-110 was reported to have received over three years leads to some uncertainty as one would not expect that much LW over three years.

The other waste types stored in tank U-110 should not have resulted in pitting or SCC. The waste type 1C/CW was combination of the acidic 1C waste from T Plant neutralized with the basic CW waste in T Plant. The combination would have resulted in a $[\text{NO}_3^-]/([\text{OH}^-] + [\text{NO}_2^-])$ ratio of < 2.5 , OSD-T-151-0007 specification for waste chemistry. The CW waste by itself met the OSD-T-151-0007 specification for waste chemistry.

5.4.5 Photographs

Photographs of tank U-110 taken before and after pumping the tank in 1975 were reviewed and no anomalies were indicated that relate to a liner failure.

5.5 TANK U-110 EX-TANK DATA

5.5.1 Drywells

There are seven drywells located around tank U-110: 60-00-05 installed in 1944, 60-11-03 installed in 1973, 60-10-01, 60-10-05, 60-10-07, installed in 1974, and 60-10-11 and 60-10-02, installed in 1976. One nearby direct push was installed in 2007. All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted (see Section 3.3.2). The following subsections report the available drywell information and the drywell summary section provides the analyses of the associated drywells with tank U-110.

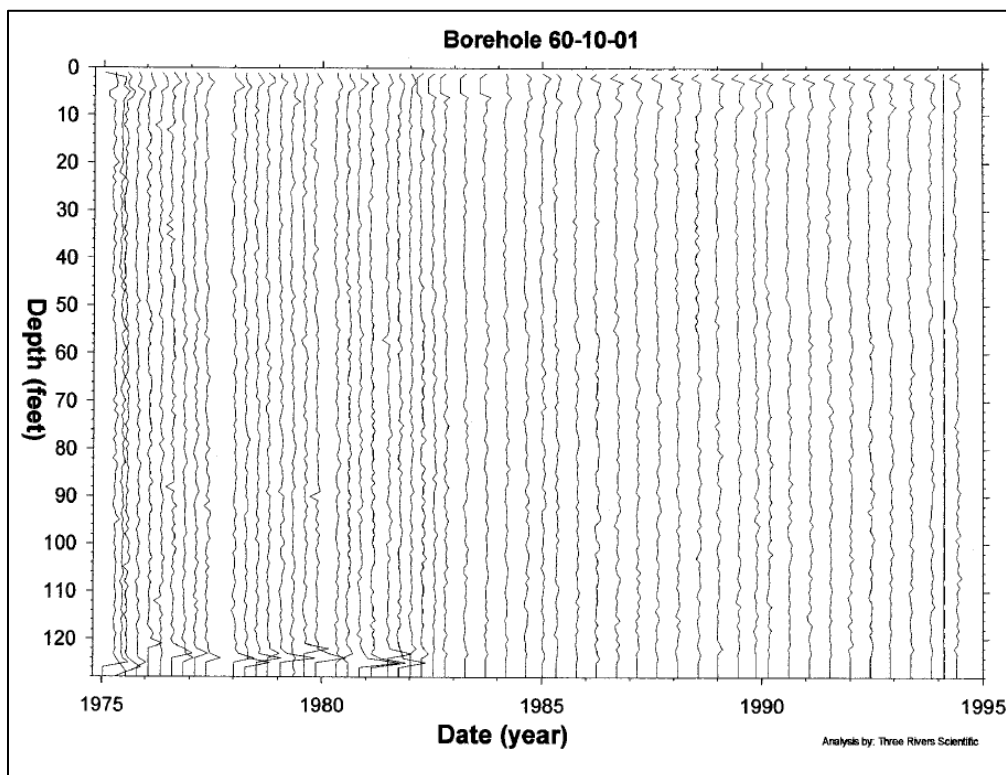
5.5.1.1 Drywell 60-10-01

In August 1996, drywell 60-10-01 is located approximately 12.5-ft from the north-northeast side of tank U-110. Drywell 60-10-01 was drilled in 1974 with the first recoverable reading on September 27, 1974 reported as a less than value (see Appendix A2). Readings continued to be reported as less than values through September 1986.

Cs-137 was detected continuously from ground surface to a depth of about 28-ft BGS and intermittently at greater depths (GJ-HAN-39, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank U-110*). Indications of Cs-137 were noted at 33-ft, 35-ft, from 40.5 to 41-ft, 78-ft BGS, and at the bottom of the drywell. The Cs-137 concentrations in the continuous zone ranged between 0.2 and about 9 pCi/g. The maximum Cs-137 concentration of about 9 pCi/g was measured at a depth of 6.5-ft BGS; a concentration of approximately 6 pCi/g was observed at a depth of 1.5-ft BGS. Document GJ-HAN-39 reports, "These two zones of Cs-137 contamination most likely resulted from a surface or near-surface spill from piping or transfer lines that migrated downward."

Since historical radioactivity in this drywell is very low, and the GJ-HAN-39 report indicated low levels of radioactivity below the surface level, drywell 60-10-01 is not being included as part of the leak location for tank U-110. Figure 5-5 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 5-5. Tank U-110 Drywell 60-10-01 (RPP-7729)



Note: Bottom of the tank footing is ~39-ft 1-in BGS

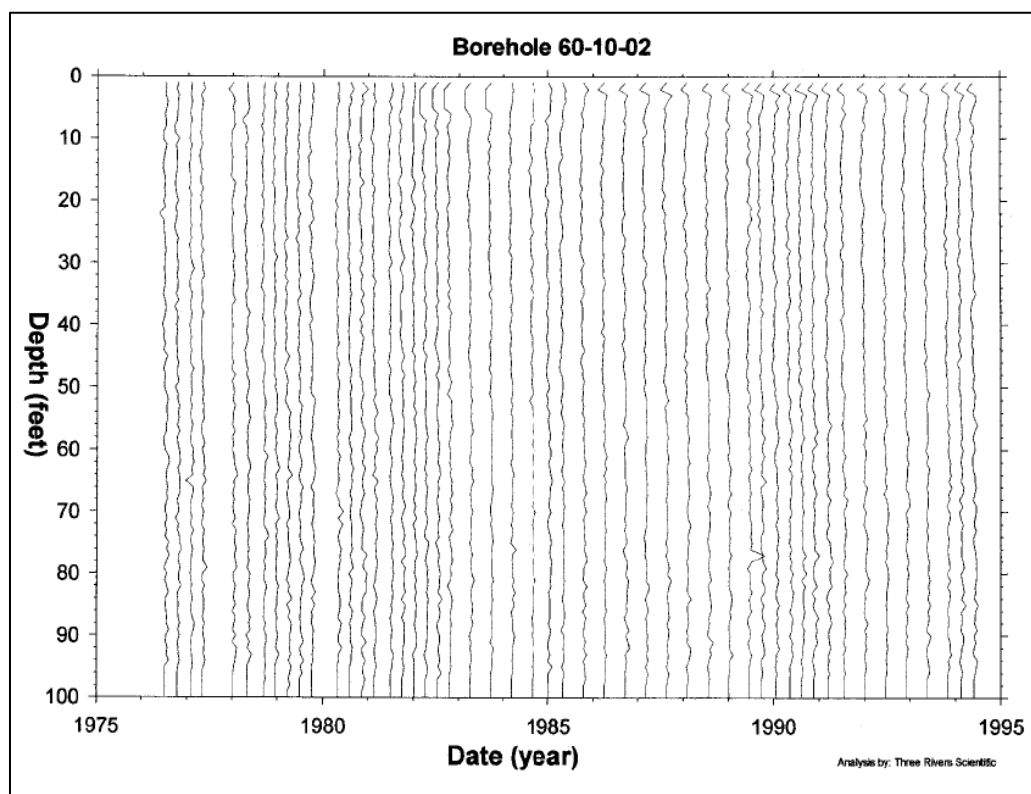
5.5.1.2 Drywell 60-10-02

Drywell 60-10-02 is located approximately 5-ft from the northeast side of tank U-110. Drywell 60-10-02 was drilled in 1976 with the first recoverable reading on May 12, 1976 reported as a less than value (see Appendix A2). Readings continued to be reported as less than values through September 1986.

In August 1996, Cs-137 was detected from ground surface to a depth of 9-ft, at 10.5-ft, and 13-ft BGS. Concentrations of Cs-137 ranged between 0.2 and 4 pCi/g (GJ-HAN-39). The highest contamination levels (3.72 pCi/g) were observed at a depth of 1.5-ft BGS. Cs-137 contamination of approximately 3 pCi/g was observed at a depth of 7.5-ft BGS. The near-surface contamination probably resulted from the migration of a surface or near-surface spill or leak. Some of the contamination may have migrated down the casing to a depth of 13-ft BGS. Document GJ-HAN-39 reports, "No Cs-137 contamination was observed below the 13-ft depth."

Since historical radioactivity in this drywell is very low, and GJ-HAN-39 report indicated low levels of radioactivity, drywell 60-10-02 is not being included as part of the leak location for tank U-110. Figure 5-6 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 5-6. Tank U-110 Drywell 60-10-02 (RPP-7729)



Note: Bottom of the tank footing is ~39-ft 1-in BGS

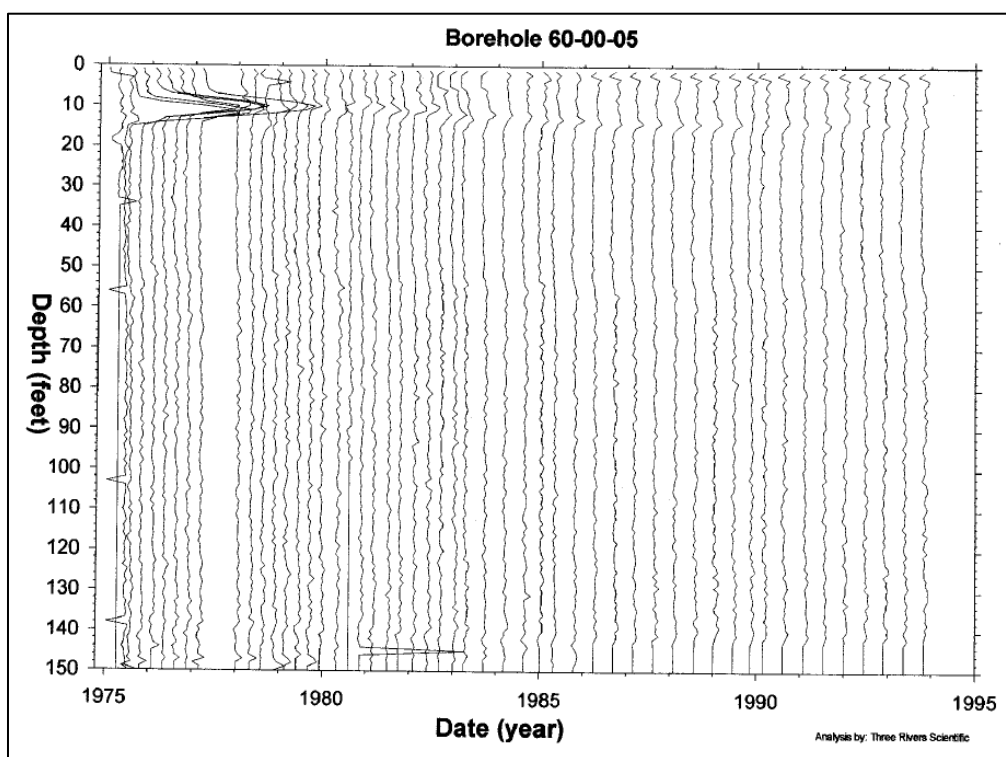
5.5.1.3 Drywell 60-00-05

Drywell 60-00-05 is located approximately 23-ft from the east side of tank U-110. Drywell 60-00-05 was drilled in 1944 with the first recoverable readings reported on August 23, 1973 as a less than value (see Appendix A2). Readings continued to be reported as less than values through September 1986.

In August 1996, contamination in the form of Cs-137 was detected in this drywell continuously from near the ground surface to a depth of 16.5-ft BGS and intermittently throughout the length of the drywell. Indications of Cs-137 contamination were observed in the depth intervals between 49 and 50-ft, 53 and 62-ft, 68 and 69-ft, at 76, 77, 83, 92, 99, 111, 117, 120.5-ft BGS, and at the bottom of the drywell (GJ-HAN-39). Concentrations ranged between 0.2 and slightly more than 6 pCi/g. Document GJ-HAN-39 reports, "The near-surface Cs-137 contamination apparently migrated from a spill or leak site to the drywell position on the surface or within the upper layer of the soil. The contamination observed below the 49-ft depth may have originated from the surface, traveled along the outer casing, entered the inner casing through the perforations, and from there migrated along the inner casing to the various locations where it has been observed."

Since historical radioactivity in this drywell is very low, and the GJ-HAN-39 report indicated low levels of radioactivity below the surface level, drywell 60-00-05 is not being included as part of the leak location for tank U-110. Figure 5-7 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 5-7. Tank U-110 Drywell 60-00-05 (RPP-7729)



Note: Bottom of the tank footing is ~39-ft 1-in BGS

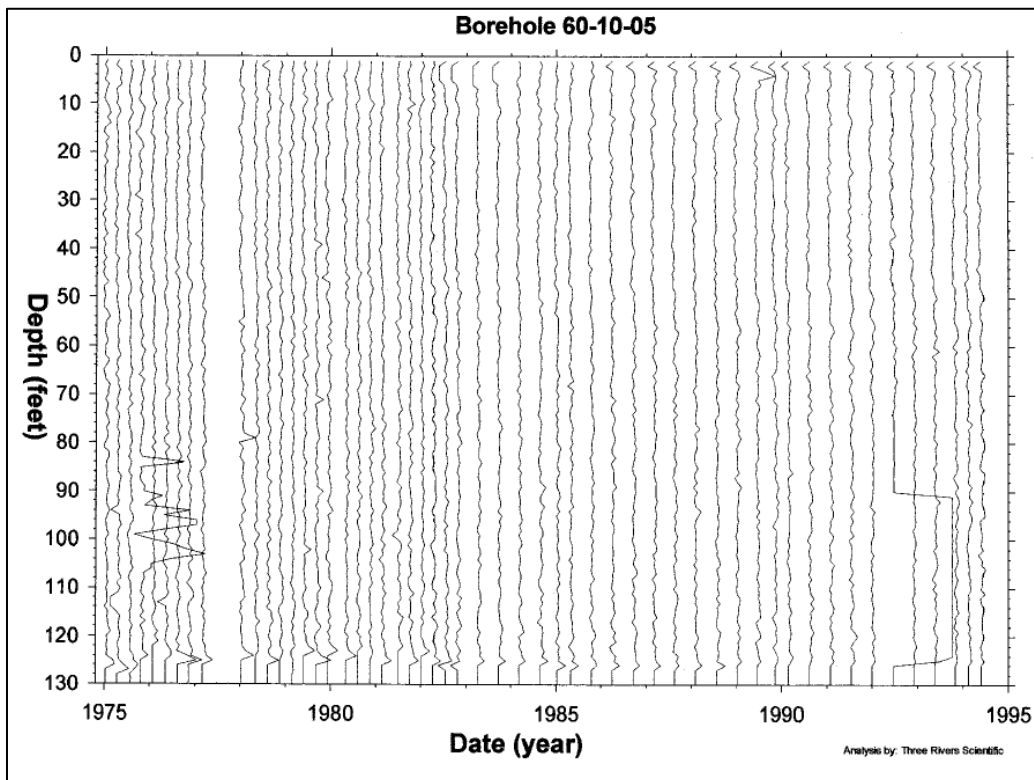
5.5.1.4 Drywell 60-10-05

Drywell 60-10-05 is located approximately 9-ft from the southeast side of tank U-110. Drywell 60-10-05 was drilled in 1974 with the first recoverable reading on July 19, 1974 reported as a less than value (see Appendix A2). Readings continued to be reported as less than values through September 1986.

In August 1996, Cs-137 was detected intermittently in this drywell (GJ-HAN-39). It was observed from the ground surface to a depth of about 6-ft, between 11 and 16-ft, from 20 to 26-ft BGS, and at the bottom of the drywell. The Cs-137 concentrations in the three zones noted within the upper 25-ft of the drywell ranged between 0.2 and about 6 pCi/g. The highest concentration (5.6 pCi/g) was measured at a depth of 12.5-ft BGS. In addition, Cs-137 contamination of about 5 pCi/g was observed at the mouth of the drywell.

Historical radioactivity in this drywell is very low, and the GJ-HAN-39 report indicated low levels of radioactivity, drywell 60-10-05 is therefore not being included as part of the leak location for tank U-110. Figure 5-8 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 5-8. Tank U-110 Drywell 60-10-05 (RPP-7729)



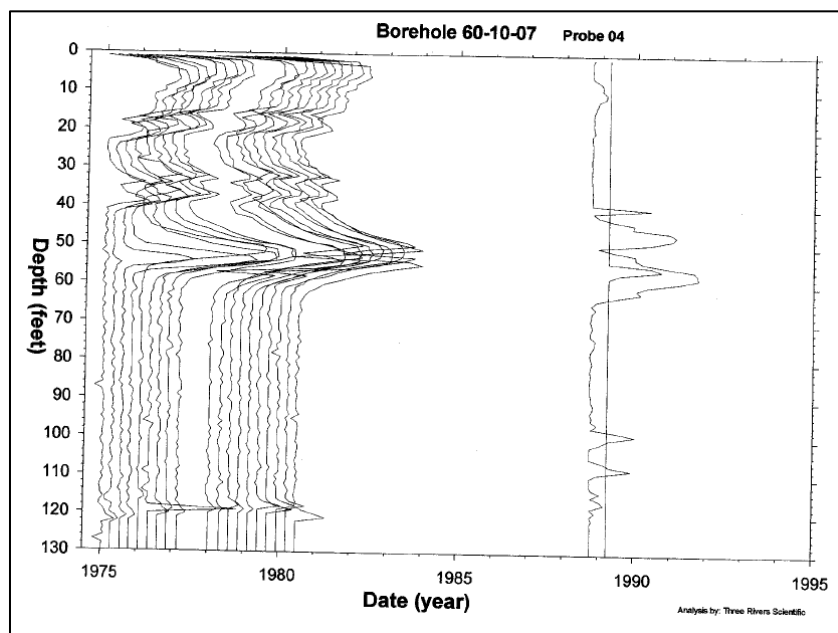
Note: Bottom of the tank footing is ~39-ft 1-in BGS

5.5.1.5 Drywell 60-10-07

Drywell 60-10-07 is located approximately 7-ft from the south southwest side of tank U-110. Drywell 60-10-07 was drilled on 1974 with the first recoverable reading on April 12, 1974 with a peak of 6.96K cpm at 33-ft BGS (see Appendix A2). The early measurements were made immediately following completion of the drywell and indicate that the contamination at this depth occurred before the detected liquid level decrease in 1975. In June 1975 radioactivity began to be detected at ~53-ft BGS and peaked near this level with increasing radioactivity even after pumping the tank.

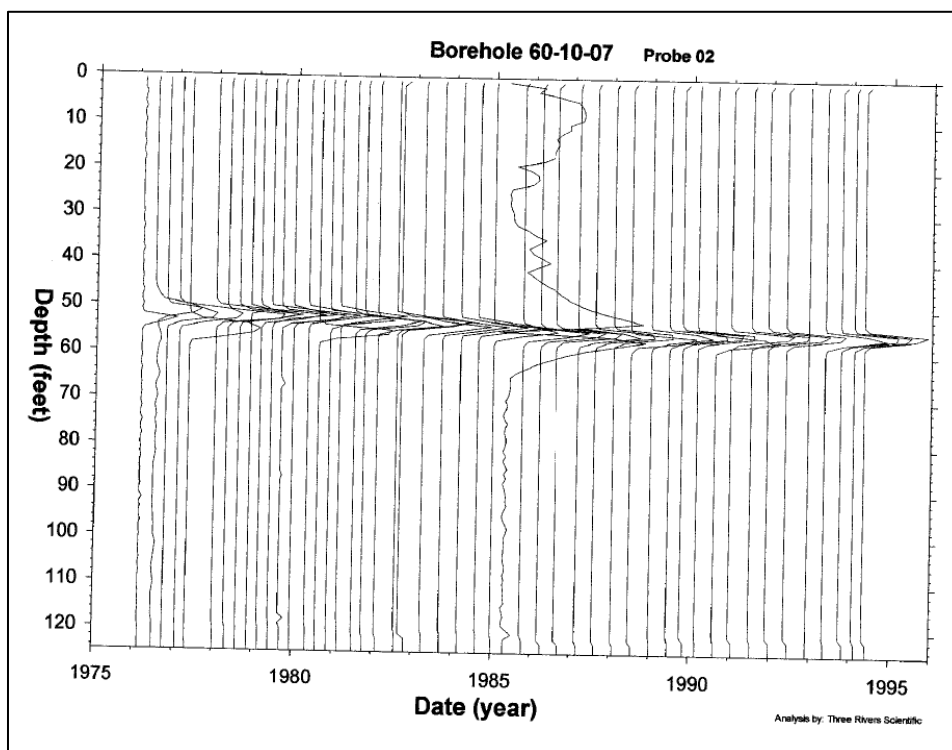
Drywell 60-10-07 was examined with the Green-GM probe (01), Red-GM probe (02), and the NaI probe (04) to monitor the large Cs-137 gamma variations in this drywell (see Figure 5-9, Figure 5-10, and Figure 5-12). The NaI probe is the most sensitive and was able to obtain data until about 1980 when the probe became saturated with high levels of radioactivity, making the data unreliable. The NaI probe shows the early influx of radioactivity. There is some conflict in the variability of the grade thickness product, used to eliminate variable sampling effects for a given zone, between the Green-GM probe, Figure 5-13, and the less sensitive Red probe, Figure 5-11. However, both the Green-GM probe and the Red probe indicate radioactivity Cs-137 below 50-ft BGS.

Figure 5-9. Tank U-110 Drywell 60-10-07 NaI Probe (RPP-7729)



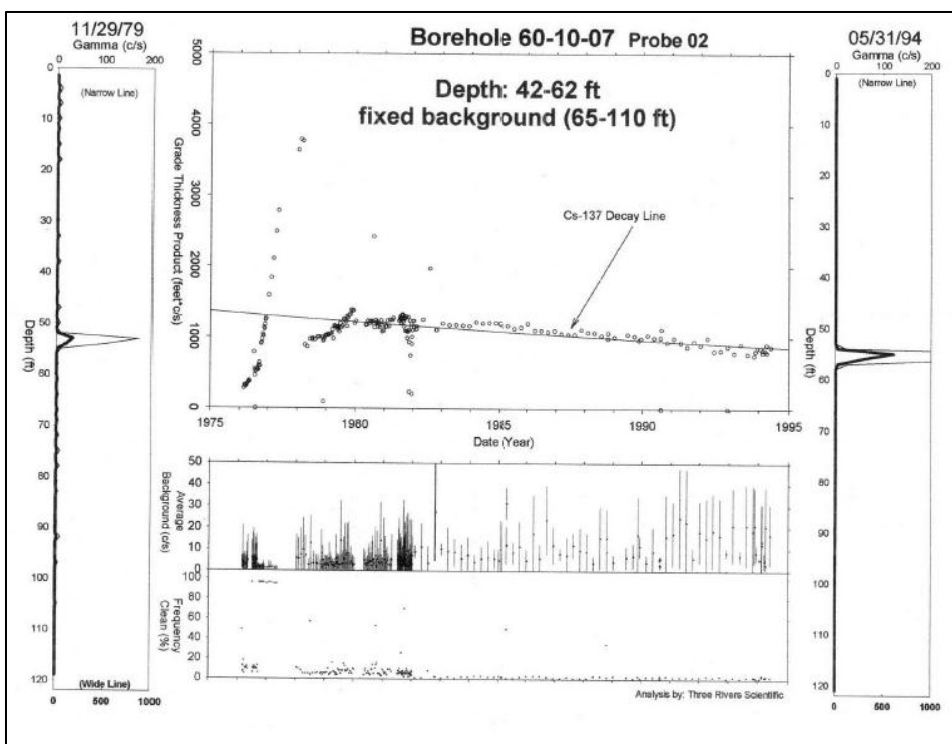
Note: Bottom of the tank footing is ~39-ft 1-in BGS

Figure 5-10. Tank U-110 Drywell Red GM Probe (RPP-7729)



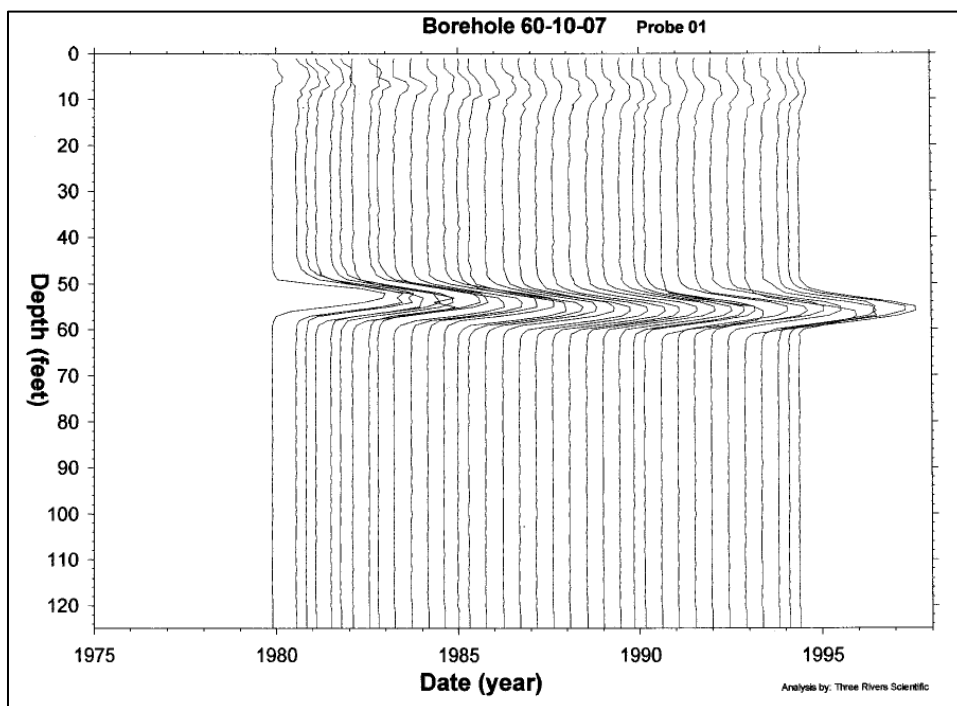
Note: Bottom of the tank footing is ~39-ft 1-in BGS

**Figure 5-11. Tank U-110 Drywell Red GM Probe (RPP-7729)
Grade Thickness Product**



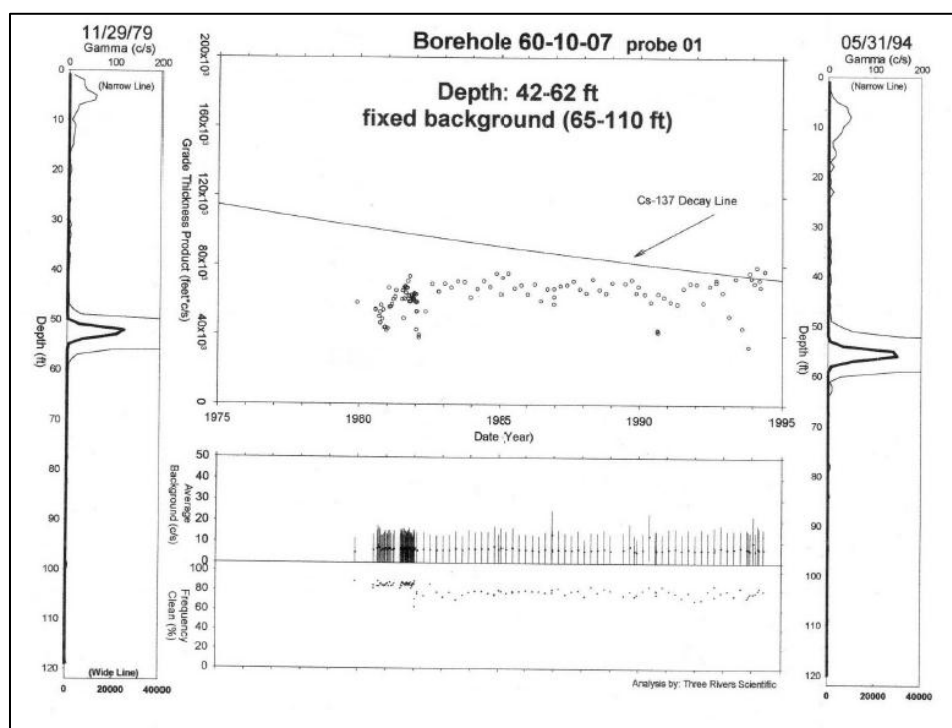
Note: Bottom of the tank footing is ~39-ft 1-in BGS

Figure 5-12. Tank U-110 Drywell 60-10-07 Green GM Probe (RPP-7729)



Note: Bottom of the tank footing is ~39-ft 1-in BGS

**Figure 5-13. Tank U-110 Drywell 60-10-07 Green GM Probe (RPP-7729)
Grade thickness Product**



Note: Bottom of the tank footing is ~39-ft 1-in BGS

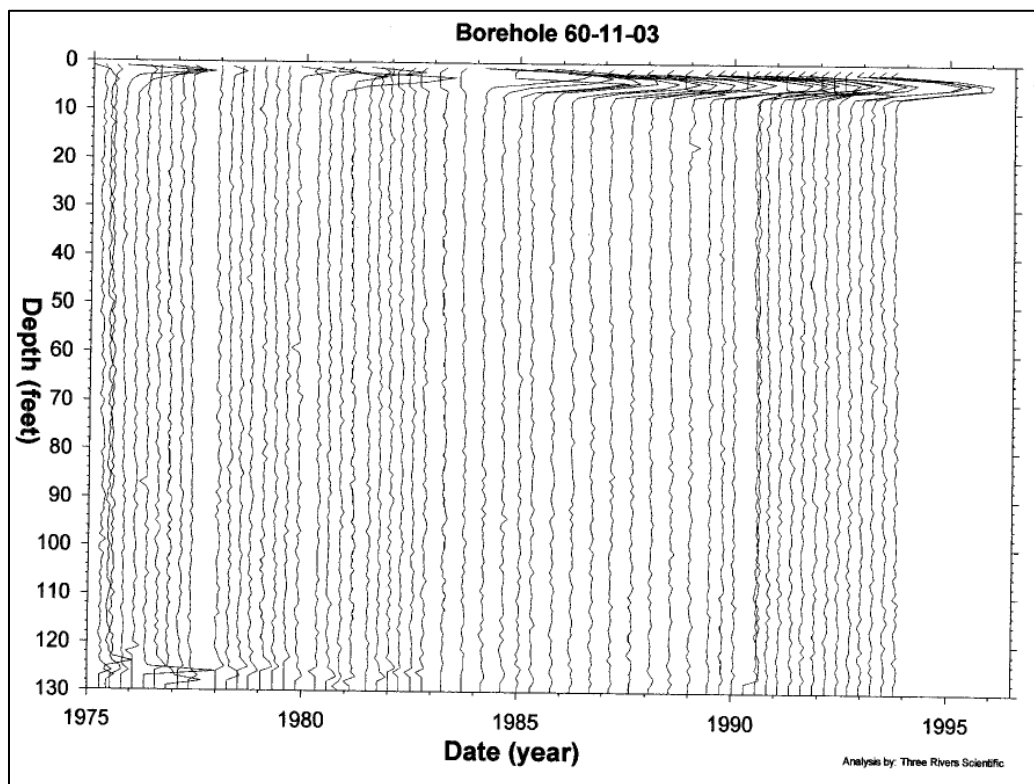
In August 1996, significant Cs-137 contamination was observed in this drywell continuously from the ground surface to a depth of 64.5-ft BGS and intermittently at greater depths to bottom of the drywell (GJ-HAN-39). The Cs-137 concentrations in the upper 9-ft of the drywell ranged up to 655 pCi/g. Even higher concentrations of Cs-137 projected to be above 1,000 pCi/g were indicated at depths between 52 and 59-ft BGS; the highest measured concentration in this region of the drywell was 462 pCi/g. However, because of high dead time, the SGLS system could not record the data in this region of the drywell (total gamma count rate greater than 500,000 cps).

5.5.1.6 Drywell 60-11-03

Drywell 60-11-03 is located approximately 12-ft west of tank U-110. Drywell 60-11-03 was drilled in 1973 with the first recoverable reading on September 21, 1973 reported as a less than value (see Appendix A2). Readings continued to be reported as less than values through June 1986.

In August 1996, significant Cs-137 contamination was detected in this borehole near the ground surface (GJ-HAN-39). The zone of contamination extends from the surface to a depth of 11-ft BGS. Concentrations of Cs-137 in this interval ranged between 0.7 and 525 pCi/g. Detectable Cs-137 contamination (between 0.2 and 1.0 pCi/g) was noted between depths of 16.5 and 21.5-ft BGS and at the bottom of the drywell. Detectable quantities of Co-60 (approximately 11 pCi/g) and Eu-154 (approximately 100 pCi/g) were also noted in the near-surface zone where the Cs-137 contamination occurs. Document GJ-HAN-39 reports, "The near-surface contamination is probably contained within a transfer line or its concrete encasement."

Since historical radioactivity in this drywell is very low, and the GJ-HAN-39 report indicated low levels of radioactivity below the surface level, drywell 60-11-03 is not being included as part of the leak location for tank U-110. Figure 5-14 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 5-14. Tank U-110 Drywell 60-11-03 (RPP-7729)

Note: Bottom of the tank footing is ~39-ft 1-in BGS

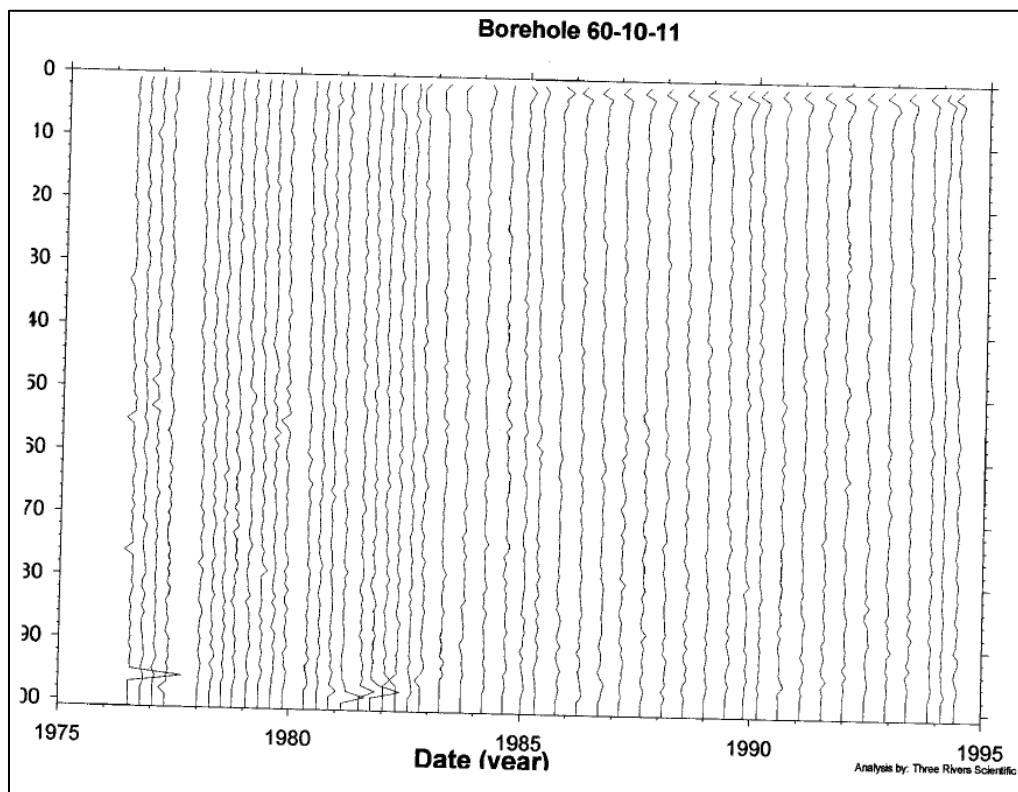
5.5.1.7 Drywell 60-10-11

Drywell 60-10-11 is located approximately 12-ft north northwest of tank U-110. Drywell 60-10-11 was drilled in 1976 with the first recoverable reading on May 12, 1976 reported as a less than value (see Appendix A2). Readings continued to be reported as less than values through June 1986.

In August 1996, Cs-137 was observed from the ground surface to a depth of about 14.5-ft, at 23-ft BGS, and at the bottom of the drywell (GJ-HAN-39). The Cs-137 concentrations in the near-surface zones ranged between 0.2 and slightly less than 6 pCi/g. The highest concentration of 5.91 pCi/g was measured at a depth of 1.5-ft BGS.

Since historical radioactivity in this drywell is very low, and the GJ-HAN-39 report indicated low levels of radioactivity below the surface level, drywell 60-10-11 is not being included as part of the leak location for tank U-110. Figure 5-15 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 5-15. Tank U-110 Drywell 60-10-11 (RPP-7729)



Note: Bottom of the tank footing is ~39-ft 1-in BGS

5.5.1.8 2007 Direct Push

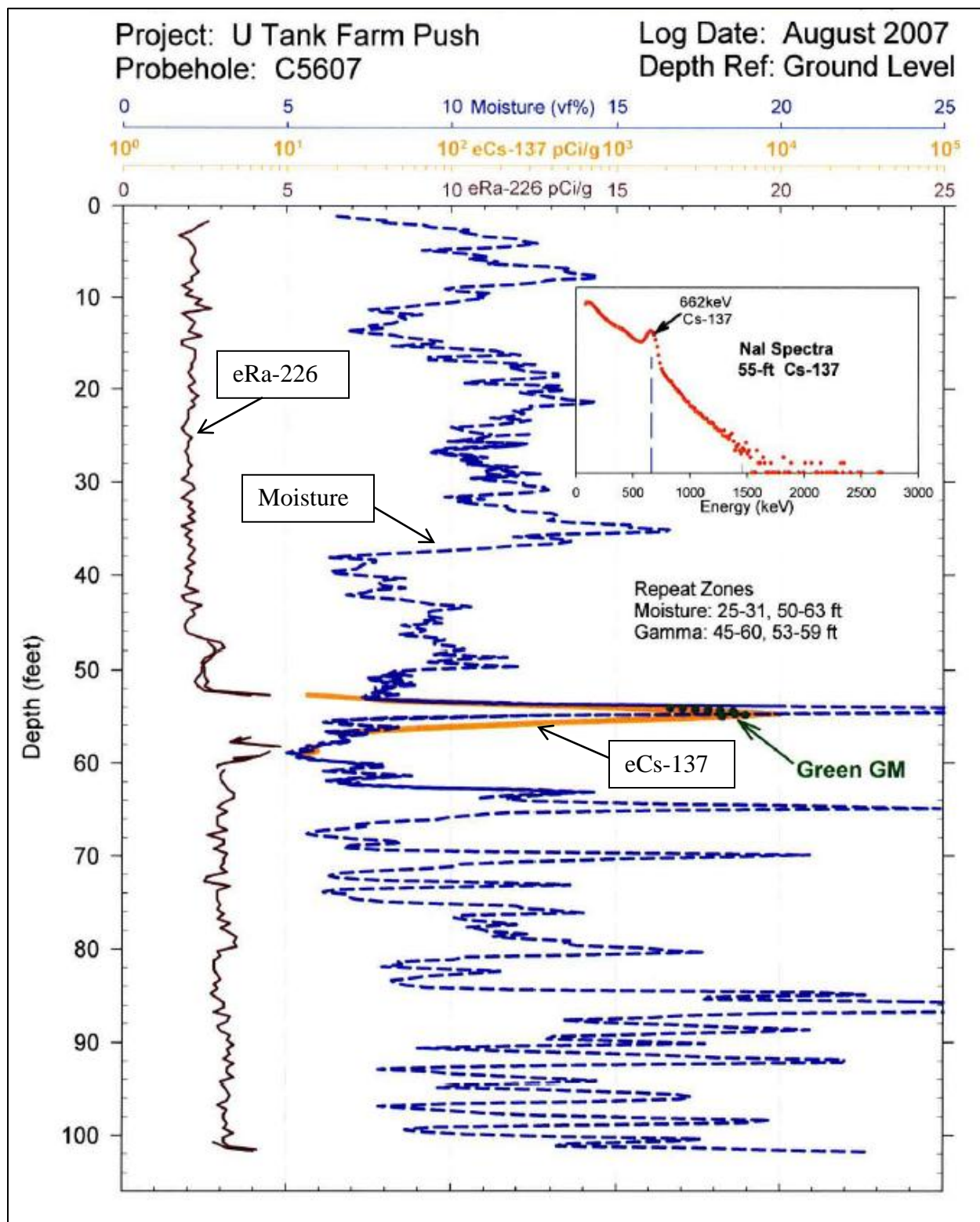
In 2007, one direct push (C5607) was installed near tank U-110 for spectral gamma logging (see Figure 5-16). The C5607 direct push, located about 14-ft from drywell 60-10-07, was logged for moisture and gamma properties (RPP-36007). A peak Cs-137 activity of 9,950 pCi/g was found at about the same 55-ft BGS depth as drywell 60-10-07.

The gross gamma survey data for the Gross Gamma and Moisture Survey Plot (see Figure 5-16) were dead-time corrected and the results were converted to two calibration units.

1. Equivalent Ra-226 for natural radionuclides (brown line). Hanford sediments have concentrations less than 5 pCi/g eRa-226. The plot scale for eRa-226 is 0-25 pCi/g (black scale).
2. Equivalent Cs-137 for contamination zones (orange/yellow line) is shown for concentrations greater than 4 pCi/g of eCs-137. The plot scale for eCs-137 (orange/yellow line) is displayed a logarithmic scale (10^0 to 10^5).

The green GM is displayed as a green dotted line with the logarithmic eCs-137 pCi/g scale. The neutron moisture survey data are shown as the blue dashed line. The moisture plot scale is 0-25 (%vf) Cs-137 was identified as the dominant gamma emitting radionuclide, energy (keV) plot insert.

Figure 5-16. Gamma and Moisture Log for C5607 (RPP-36007)



5.5.1.9 Drywell Summary

Tank U-110 was first reported to be leaking on July 9, 1975 after a 0.5-in liquid level decrease was observed. The 0.5-in liquid level decrease was reported between May 24, 1975 to June 26, 1975 (OR 75-67).

Tank U-110 drywells 60-10-01, 60-10-02, 60-10-05, 60-00-05, 60-10-11, and 60-11-03 do not indicate any radioactivity associated with a tank U-110 leak. Therefore, these drywells are not included in the leak location for tank U-110.

Peak radioactivity in drywell 60-10-07 was reported near 34-ft BGS when the well was drilled in April 1974 and increased in intensity spreading to ~54-ft BGS in June-July 1975. The increased radioactivity coincided with the 0.5-in liquid level decrease. Earlier decreases in liquid level may have occurred, but these decreases would have been masked by tank pumping and transfer operations. A direct push (C5607), installed in 2007, reported a peak radioactivity at approximately the same level BGS as drywell 60-10-07.

5.6 POSSIBLE TANK U-110 LINER LEAK LOCATION(S)

A liner leak may have penetrated the waterproof membrane at any location or pooled on the waterproof membrane and followed concrete cracks or construction joints to a different location for egress to the soil, including the top of the tank footing.

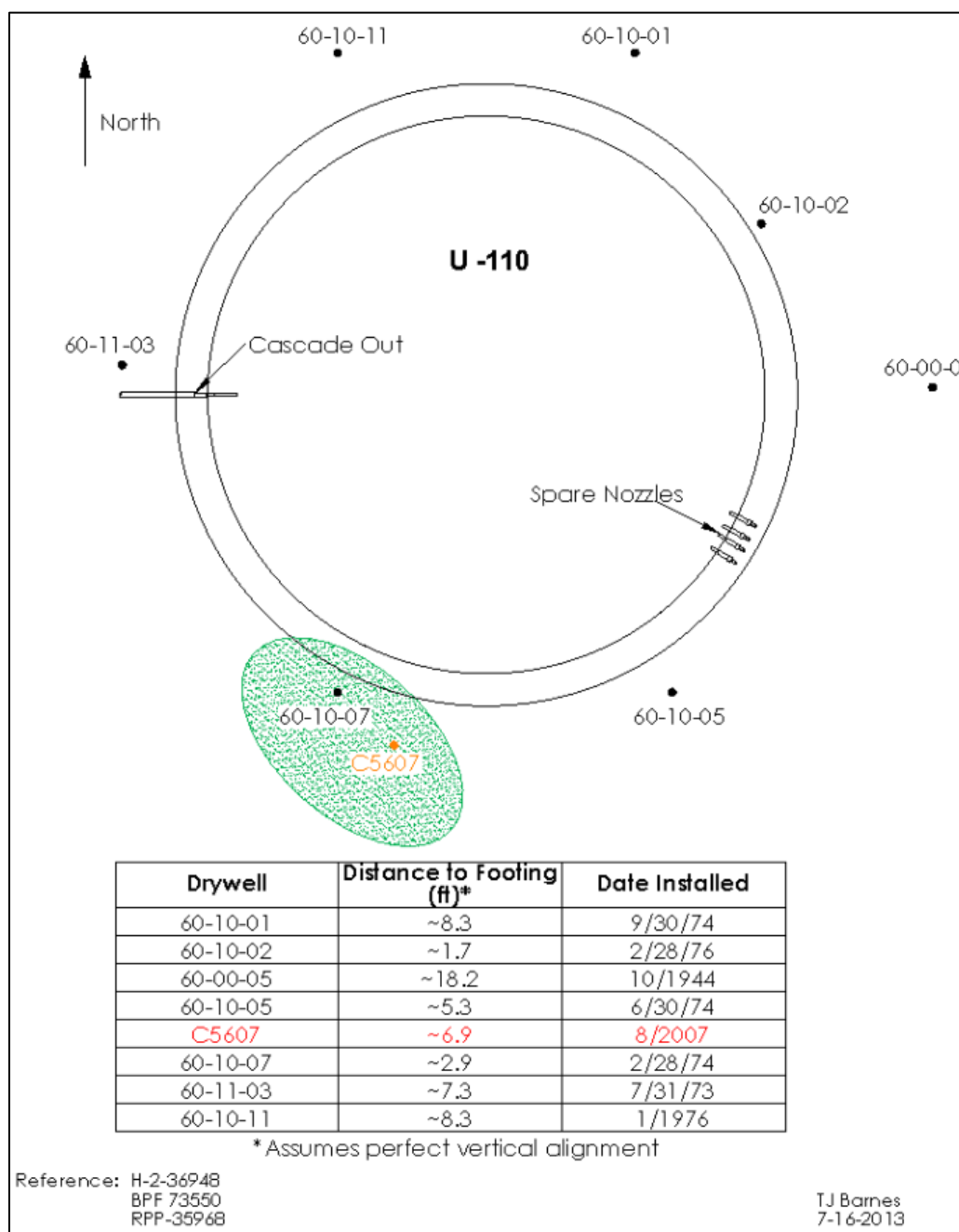
Tank U-110 had at least one leak site which is likely at or near the bottom of the tank based on liquid level decrease and drywell radioactivity.

5.6.1 Leak Detected in 1974-1975

Tank U-110 was first suspected of leaking on July 9, 1975 after a 0.5-in liquid level decrease was observed. A drywell installed in 1974 (60-10-07) and a direct push installed in 2007 (C5607) both indicated a liner leak with radioactivity detected in the south southwest portion of the tank likely at or near the bottom of the tank (see Figure 5-17). The drywell 60-10-07 radioactivity detected in 1974 may have been an early indication of a liner leak but a liquid level decrease during that time was probably masked by tank pumping and transfer operations.

Figure 5-17. Tank U-110 Possible Leak Location (1974-1975)

Tank inner ring is steel liner; outer ring is outer edge of tank footing



Tank U-110 was first suspected of leaking due to a 0.5-in liquid level decrease from May 24 to June 26, 1975, radioactivity increased in drywell 60-10-07 during this time.

5.7 POSSIBLE TANK U-110 LINER LEAK CAUSE(S)

Tank U-110 was evaluated for five conditions known to contribute to a failed liner.

5.7.1 Tank Design

The U Farm tank design should not have been a factor contributing to a failed liner in spite of the tank U-104 experience (see Section 3.1.1).

5.7.2 Thermal Conditions

Limited temperature data are available for tank U-110 and no temperature data are available during the storage of REDOX concentrated salt waste. The temperature during REDOX waste storage resulted in a gradual decrease in liquid level indicating the temperature may have been higher at that time as the liquid level decrease was attributed to evaporation. Temperatures after storage of REDOX waste gradually decreased from ~140°F to ~115°F over a period of a year.

Thermal shock creates stress both from rapid temperature rise as well as waste-induced high temperatures. Since no records are available during a period of evaporation, it is uncertain what the maximum temperature was in tank U-110 during operation as well as the rate of temperature rise when waste was added. The thermal attributes of the waste and other information (see Section 5.4.2) would indicate that thermal stresses were likely minimal and should not have challenged the tank storage limits.

Temperature requirements in ARH-951 (*Limitations for Use of Underground Waste Tanks*) issued December 18, 1969 indicated that tank temperatures should be held below 230°F.

5.7.3 Chemistry-Corrosion

Tank U-110 stored REDOX concentrated salt waste for ~1.5 years at elevated temperatures ~19 years before the liner leak. REDOX waste under high heat conditions could have resulted in pitting or SCC under tank U-110 conditions. The chemical content of the laboratory waste could not be recovered and normally would be diluted; however, the quantity of 361 kgal over three years leads to some uncertainty. Other waste types stored in tank U-110 should not have resulted in pitting or SCC.

5.7.4 Liner Observations

A review of the available photographs for tank U-110 does not contain any evidence pointing to a tank leak. There is no documentation available indicating a liner bulge was present in the tank.

5.7.5 Tank Construction Temperature

The U Farm tank liners were constructed between February 1944 and October 1944. Only isolated minimum temperature were experienced during tank construction at or below 18°F with day time temperatures between 44°F and 57°F (see Section 5.3.2). Impact occurrences could have occurred during cold temperatures that may have triggered fissures in the steel liner;

however, the possibility seems much less than that which might have occurred during construction in other tank farms.

5.8 TANK U-110 CONCLUSIONS

Liquid level evidence and drywell radioactivity indicate that the tank U-110 liner leaked in at least one location in the south southwest portion of the tank at or near the tank base.

There are several liner leak cause conditions that were examined and the likely one that might have caused the tank U-110 liner leak was pitting and SCC from the storage of REDOX concentrated salt waste or possible laboratory waste. However, the length of time from storage of REDOX waste at elevated temperatures to evidence of a tank liner leak was ~19 years. The unknown laboratory waste chemicals contained in the 316 kgal transferred to tank U-110, 3 years prior to detecting the liner leak, may have had a corrosive influence.

There appears to be very little contribution from other wastes as well as from tank design and construction temperatures. However, some or all of the factors can act serially or together to contribute to tank liner failure.

APPENDIX A2

TANK U-110 GROSS GAMMA DRYWELL DATA

Table A2-1. Tank U-110 Drywell Radioactivity (K counts per minute) (August 1973 through September 1986)
(SD-WM-TI-356) (2 pages)

60-11-03		60-10-01		60-10-02		60-00-05		60-10-05		60-10-07			60-10-11	
Drilled 7/31/73		Drilled 9/30/74		Drilled 2/28/76		Drilled 10/1944		Drilled 6/30/74		Drilled 2/28/74			Drilled 01/1976	
Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)
9/21/1973	< 12	N/A ¹		N/A ¹		8/23/1973	< 12	N/A ¹		N/A ¹			N/A ¹	
6/7/1974	< 12	N/A ¹		N/A ¹		4/18/1974	< 12	N/A ¹		4/12/1974	6.96	33	N/A ¹	
8/29/1974	< 3	9/27/1974	< 3	N/A ¹		7/18/1974	< 3	7/19/1974	< 3	8/1/1974	13.5	34	N/A ¹	
2/8/1975	< 3	1/30/1975	< 3	N/A ¹		1/30/1975	< 3	2/5/1975	< 3	2/13/1975	13.74	35	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		5/14/1975	13.98	38	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹			3.3	54	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		6/23/1975	14.64	38	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹			8.1	53	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		6/30/1975	15.6	53	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		7/9/1975	27	55	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		7/15/1975	48.24	54	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		7/23/1975	106.08	54	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		7/29/1975	12	39	N/A ¹	
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹			155.88	55	N/A ¹	
8/11/1975	< 3	8/6/1975	< 3	N/A ¹		8/5/1975	< 3	8/6/1975	< 3	8/6/1975	242.4	53	N/A ¹	
12/30/1975	< 3	12/30/1975	< 3	N/A ¹		12/30/1975	< 3	12/30/1975	< 3	12/30/1975	1367.1	54	N/A ¹	
5/5/1976	< 3	5/5/1976	< 3	5/12/1976	< 3	5/12/1976	< 3	5/5/1976	< 3	5/11/1976	16.38	52	5/12/1976	< 3
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹			6/30/1976	< 3
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		8/3/1976	15.6	52	8/10/1976	< 3
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		11/2/1976	25.2	52	N/A ¹	
1/5/1977	< 3	1/14/1977	< 3	1/5/1977	< 3	1/5/1977	< 3	1/5/1977	< 3	4/5/1977	61.68	52	1/5/1977	< 3
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		8/2/1977	85.5	52	N/A ¹	
11/23/1977	< 3	11/22/1977	< 3	11/1/1977	< 3	11/1/1977	< 3	11/1/1977	< 3	11/1/1977	138.36	52	11/1/1977	< 3
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		3/7/1978	155.16	50	11/15/1978	< 3

RPP-RPT-54914, Rev. 0

60-11-03		60-10-01		60-10-02		60-00-05		60-10-05		60-10-07			60-10-11	
Drilled 7/31/73		Drilled 9/30/74		Drilled 2/28/76		Drilled 10/1944		Drilled 6/30/74		Drilled 2/28/74			Drilled 01/1976	
Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)
N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹		4/4/1978	27.18	52	N/A ¹	
11/15/1978	< 3	11/15/1978	< 3	11/15/1978	< 3	11/15/1978	< 3	11/15/1978	< 3	11/6/1978	37.44	52	N/A ¹	
11/1/1979	< 3	11/1/1979	< 3	11/1/1979	< 3	10/31/1979	< 3	11/1/1979	< 3	10/22/1979	49.26	51	11/1/1979	< 3
11/13/1980	< 3	11/13/1980	< 3	11/13/1980	< 3	11/13/1980	< 3	11/13/1980	< 3	11/17/1980	47.22	53	11/13/1980	< 3
11/19/1981	< 3	11/19/1981	< 3	11/19/1981	< 3	11/11/1981	< 3	11/19/1981	< 3	11/16/1981	44.04	54	11/19/1981	< 3
11/3/1982	< 3	11/3/1982	< 3	11/3/1982	< 3	10/12/1982	< 3	11/3/1982	< 3	10/20/1982	52.5	53	11/3/1982	< 3
9/21/1983	< 3	9/21/1983	< 3	9/21/1983	< 3	9/21/1983	< 3	9/21/1983	< 3	9/20/1983	52.5	54	9/21/1983	< 3
8/23/1984	< 3	8/22/1984	< 3	8/22/1984	< 3	8/23/1984	< 3	8/22/1984	< 3	8/20/1984	53.58	54	8/22/1984	< 3
10/15/1985	< 3	10/15/1985	< 3	10/15/1985	< 3	10/15/1985	< 3	10/15/1985	< 3	10/14/1985	51.9	55	10/15/1985	< 3
9/17/1986	< 3	9/17/1986	< 3	9/17/1986	< 3	9/17/1986	< 3	9/17/1986	< 3	9/17/1986	38.88	55	9/17/1986	< 3

Note: ¹N/A: Data not available

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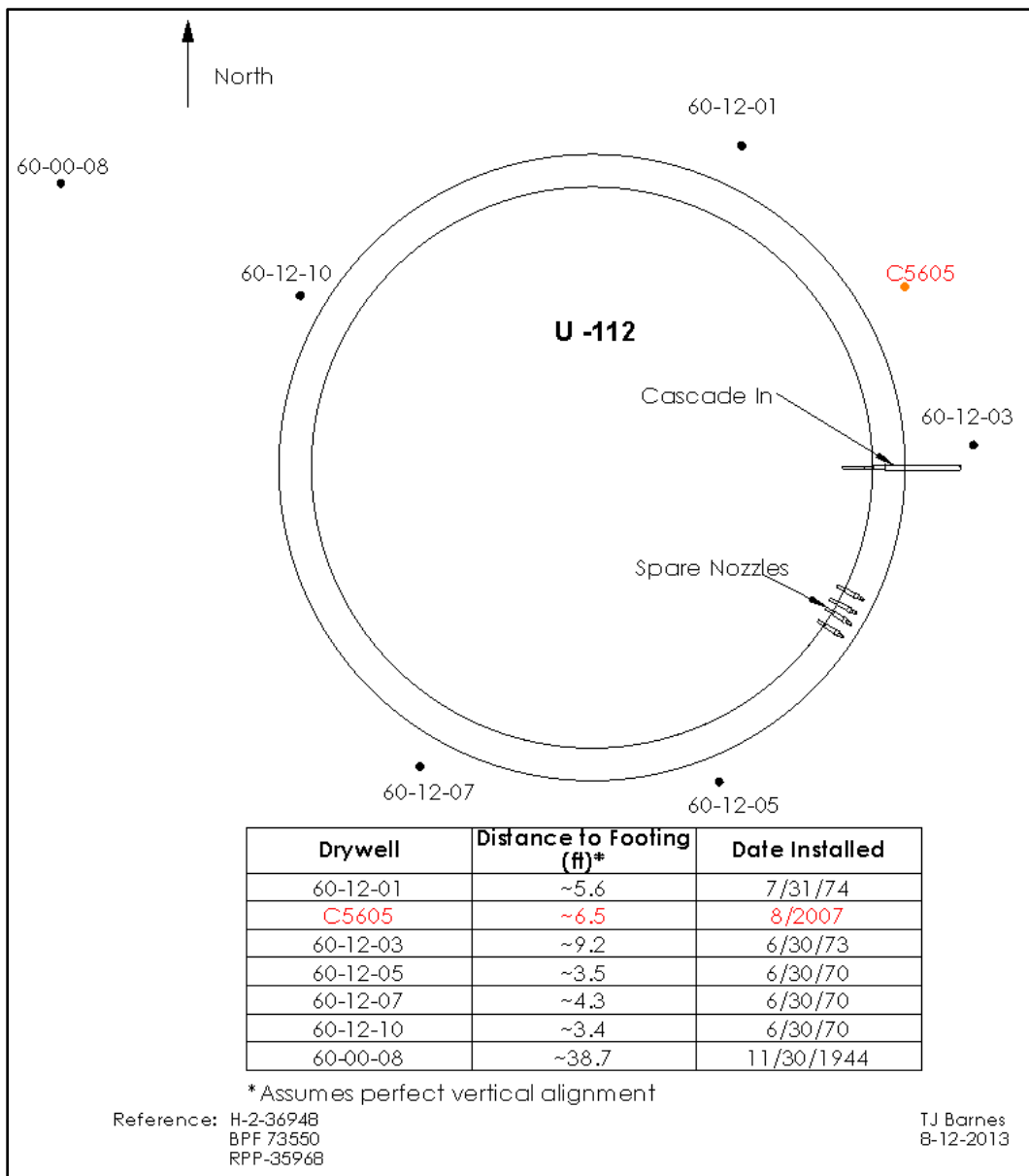
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6.1 TANK U-112 BACKGROUND HISTORY

This section provides information on the historical waste loss event associated with Single-Shell Tank (SST) 241-U-112 (U-112). There are six drywells located around tank U-112 with specified distances from the drywell to the tank footing shown in Figure 6-1: 60-00-08, installed in 1944, 60-12-05, 60-12-07, and 60-12-10 installed in 1970, 60-12-03, installed in 1973, and 60-12-01 installed in 1974. One nearby direct push, C5605, was installed in 2007.

The bottom of the tank footing is ~38-ft Below Grade Surface (BGS) with ~6-ft soil cover over the dome (WHC-SD-WM-TI-665; BPF-73550).

Figure 6-1. Tank U-112 Associated Drywells
Tank inner ring is steel liner; outer ring is outer edge of tank footing



6.2 TANK U-112 OPERATIONS SUMMARY

Tank U-112 first began receiving 221-T Plant (T Plant) first cycle waste (1C) typically neutralized with coating waste (CW) cascaded from tank U-111 in October 1947 (RPP-RPT-50097, Rev. 0). Tank U-112 is the third tank in the three tank cascade series which includes tanks U-110 and U-111. Tank U-112 was declared full in May 1948 (HW-10166-DEL, *Hanford Works Monthly Report May 1948*). No other transfers occurred through July 1951 and no records of tank transfers were available from August 1951 through March 1952.

By the end of April 1952, the supernatant was pumped out of tank U-112 as the waste volume was reported as 32 kgal; however, the tank that received this waste was not recorded (HW-27838). No additional transfers occurred through December 1953.

Beginning on January 13, 1954, concentrated salt waste from the REDOX plant continued to be transferred to tank U-110, which cascaded to tanks U-111 and U-112 through April 22, 1954. During this period, tank U-112 was filled to its nominal operating capacity of 514 kgal (HW-31811, *Separations Section Waste – Status Summary April 30, 1954*, page 5). No additional waste was added to tank U-112 from April 22, 1954 through August 1955, and the waste volume in the tank remained unchanged from 514 kgal.

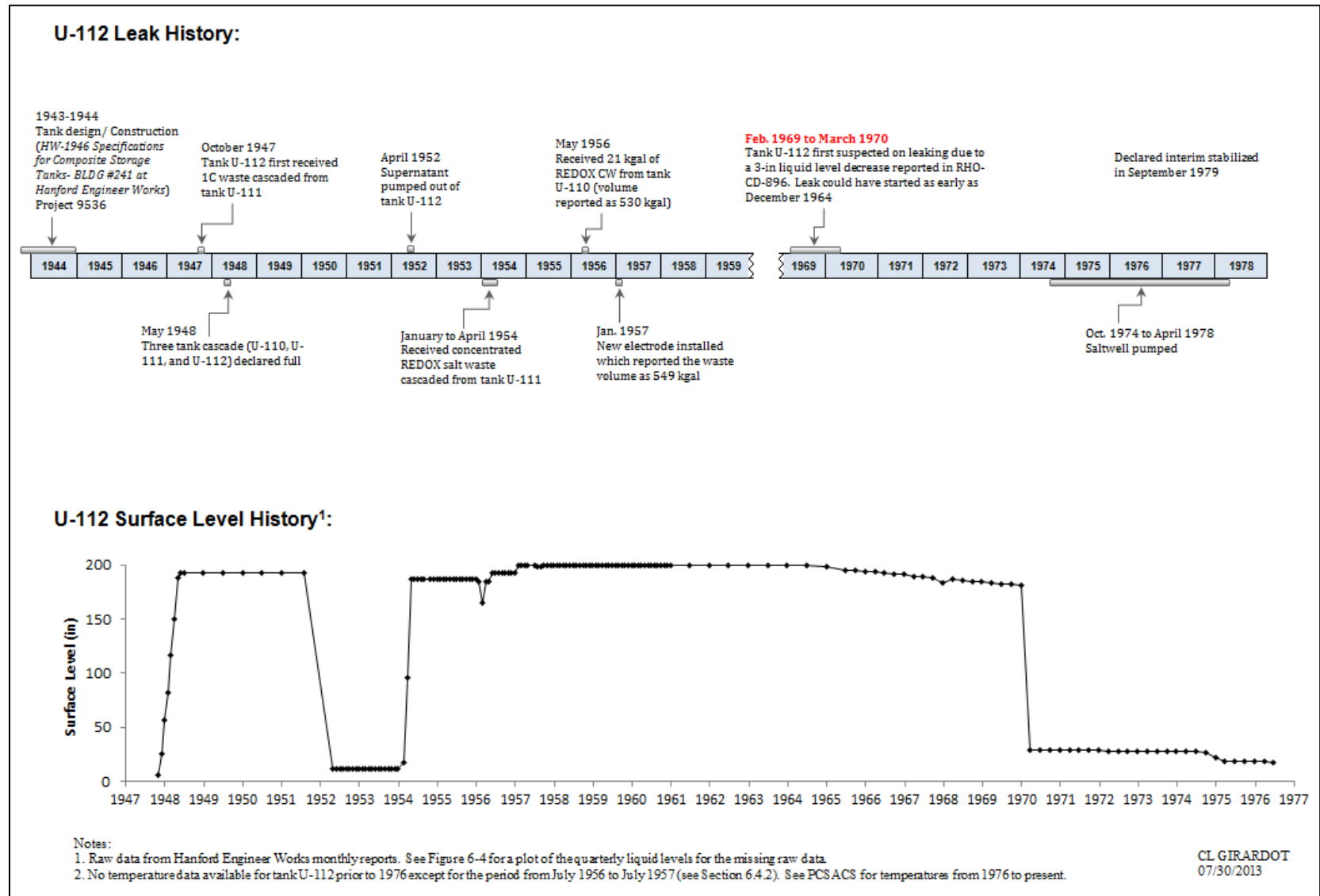
In May 1956, approximately 21 kgal of REDOX cladding (coating) waste (CW) was transferred from tank U-110 to tank U-112 (HW-43490, page 6). The volume of waste stored in tank U-112 was reported as 530 kgal following this transfer. Based on the reported volume of waste in tank U-112 in April 1954 (514 kgal) and May 1956 (530 kgal) following the transfer of CW (21 kgal) into tank U-112, there is an apparent 5 kgal discrepancy in the material balance for this transfer.

No additional waste was added to tank U-112 after May 1956. However, a new electrode measurement of the volume of waste stored in tank U-112 was conducted in January 1957 and reported as 549 kgal (HW-48144, *Chemical Processing Department Waste – Status Summary January 1, 1957 – January 31, 1957*, page 6). The volume of solids in tank U-112 was reported as 32 kgal. The reported volume of waste in tank U-112 remained unchanged from January 1957 through June 30, 1964. No additional transfers occurred through December 1969.

Tank U-112 was first suspected of leaking based on a 3-in liquid level decrease between February 1969 and March 1970 and classified as a “questionable integrity” tank (RHO-CD-896). Tank U-112 was pumped to a minimum heel of 24.5-in and removed from service in March 1970.

From October 1974 through April 12, 1978, the remaining pumpable liquid in tank U-112 was removed using a saltwell pump (DS-103174, *Data Sheet Salt Well Transfer: Tk 112U to Tk-109U*). Tank U-112 was declared administratively interim stabilized in September 1979. As of April 2013, tank U-112 contains 45 kgal of sludge with 4 kgal of drainable interstitial liquid (HNF-EP-0182).

The operational history of tank U-112 leak related details including liquid level is charted in Figure 6-2.

Figure 6-2. Operational Leak History of Tank U-112

6.3 TANK DESIGN/CONSTRUCTION

6.3.1 Tank Design

The steel bottoms of the U Farm tanks intersect the sidewall on a 4-ft radius knuckle transition (BPF-73550, Drawings D-2 and D-3). The rounded knuckle transition, the three-ply asphaltic membrane waterproofing between the liner and the concrete, a notched footing construction joint, and the concrete shell are features common to all U Farm tanks (see Section 3.1.1).

6.3.2 Tank Construction Conditions

The U Farm tanks were constructed between February 1944 and October 1944. Temperatures are not available for 1944 between May 18 and December 1. From the start of U Farm tank construction through May 18, 1944 there were two minimum temperatures of 12°F with daytime temperatures of 44°F and 57°F, one at 18°F, and four at 20°F with day time temperatures between 41°F and 56°F.

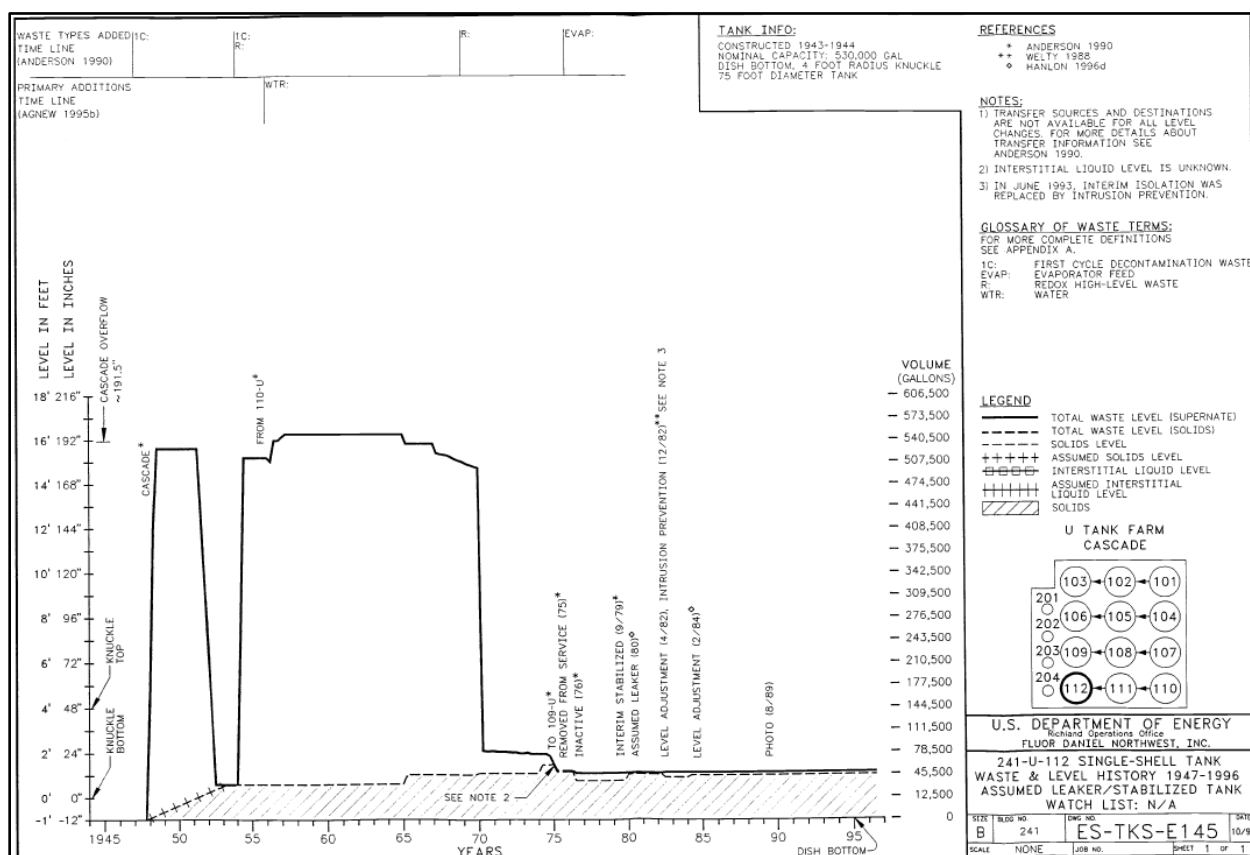
As described in Section 3.1.2, cold weather affects the ductile-to-brittle steel transition temperature, with 18°F being the assumed design temperature for the carbon steel liner, which could result in a fracture upon impact. However, in general, the temperatures during the U Farm construction time frame were much milder than those experienced during 241-SX Farm construction where ductile-to-brittle steel transition temperatures were exceeded.

Design, fabrication, and erection of the tank steel lining were required to be in accordance with current “Standards Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs” as promulgated by the “American Water Works Association” (BPF-73550). Welding requirements were required to conform to the American Welding Society’s “Code for Arc and Gas Welding in Building Construction”, Section 4.

6.4 TANK U-112 IN-TANK DATA

6.4.1 Liquid Level

The liquid level plot in Figure 6-3 indicates the transfer activity into and out of tank U-112. The liquid levels are end of quarter levels so this figure may not reflect all transfers into and out of the tank that occurred during the operational history. See Figure 6-2 for historical monthly liquid level readings.

Figure 6-3. Tank U-112 End of Quarter Surface Level

WHC-SD-WM-ER-325, Rev. 0, 1994, *Supporting Document for the SW Quadrant Historical Tank Content Estimate for U-Tank Farm.*

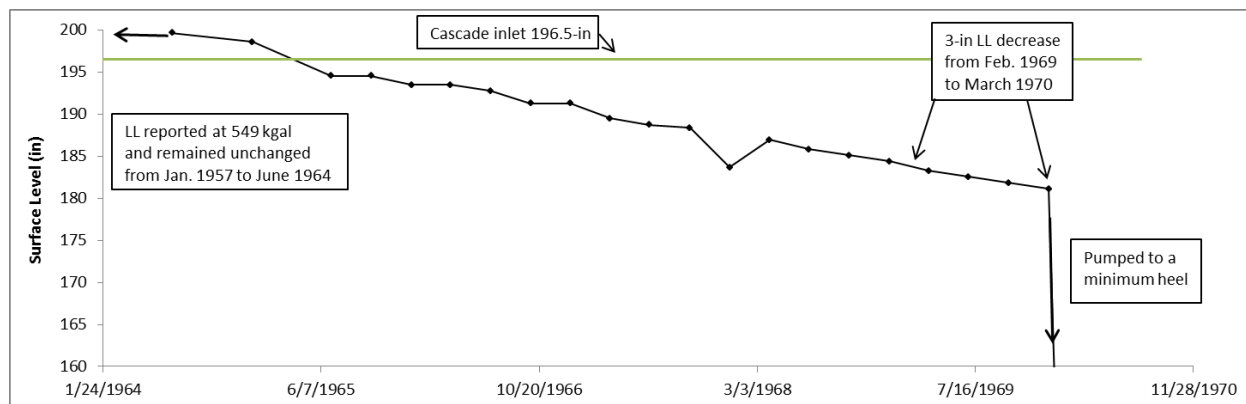
Tank U-112 was first suspected of leaking based on a 3-in liquid level decrease from 179-in in February 1969 to 176-in in March 1970 (RPP-CD-896). However, after reviewing historic liquid level data for tank U-112, it appears the leak could have started as early as December 1964 as the liquid level was declining in this earlier period (see Figure 6-4). It is not clear why RHO-CD-896 selected February 1969 through March 1970 for the leak determination when monthly data taken from December 1964 through March 1970 indicates the liquid level was decreasing much earlier.

The reported volume of 549 kgal in tank U-112 remained unchanged from January 1957 through June 30, 1964 and no transfers were reported during this time period. The next recoverable liquid level reading was reported December 31, 1964 and the waste volume was reported at 546 kgal (198.5-in). Liquid level readings continued to decline through December 1969 when the volume was reported as 498 kgal (181.1-in) giving a total waste volume decrease of 47 kgal.

Before June 30, 1965 the liquid level was reported to be above 196.5-in, the location of the cascade inlet line penetration. Since the liquid level was above this location and near the time when the liquid level started to decrease, it is possible there was a small leak from the cascade inlet line. However, since the liquid level continued to decrease below the location of the cascade inlet penetration then this likely indicated a tank liner leak. A sidewall leak seems

unlikely as peak radioactivity detected in drywell 60-12-01 was reported at approximately 50-ft BGS (see Section 6.5.1.1). It appears the leak is greater than the 8.5 kgal reported in RHO-CD-896 and could be as large as 47 kgal.

Figure 6-4. Tank U-112 Liquid Level June 1964 through March 1970



6.4.2 Temperature

No temperature data were recovered for tank U-112 from October 1947 when the tank was first put into service until July 1956. Sludge temperature plots for the one year period between July 1956 and July 1957 (RHO-CD-1172) indicated temperatures ranged from ~70°F to ~60°F with one spike in September 1956 at approximately 170°F. The one year of temperature data started two months after a reported 21kgal of CW waste had been added to 514kgal of REDOX concentrated salt waste. There had been a gradual decrease in liquid level during storage of REDOX concentrated salt waste in tank U-110 but there was no liquid level decrease experienced in tank U-112 for the cascaded REDOX waste from tank U-110 through tank U-111. Tank U-112, the last tank in the tank U-110 cascade would have experienced lower temperatures than those experienced in tank U-110. Similar temperature experience in tank U-110 ranged from ~140°F to ~115°F which were ~70°F to ~50°F higher than tank U-112. Average temperature for storage of REDOX and REDOX/CW waste was probably near 100°F based on the limited temperature data and the tank U-110 temperature information.

No temperature data were recovered for tank U-112 from July 1957 until 1976. Tank U-112 waste temperatures from 1976 to present which ranged from ~60°F to 70°F can be found in PCSACS. The tank was pumped to minimum heel in March 1970 after the tank was suspected of leaking due to the liquid level decreasing.

6.4.3 Liner Observations

Tank U-112 bottom liner observations could possibly be related to a tank U-112 liner failure, see section 6.4.5.

6.4.4 Chemistry-Corrosion

Tank U-112 began receiving 1C waste typically neutralized with CW cascaded from tank U-111 in October 1947 and stored three waste types during operation as shown in Table 6-1. The

typical concentration for nitrite, nitrate, and hydroxide for the waste types stored in tank U-112 is shown in Table 6-2. Nitrite and hydroxide are known as nitrate induced SCC inhibitors. One key characteristic for inhibiting SCC is to maintain a high nitrite concentration to nitrate concentration ratio (see Section 3.2.4).

Table 6-1. Tank U-112 Waste Storage Chronology

Date	Waste Type	Length of Storage
October 1947 to April 1952	1C/CW	~ 5 years
January 1954 to May 1956	R	~ 2 years
May 1956 to March 1970	R/CW	~ 14 years

1. R/CW ratio 514kgal/21kgal

Table 6-2. Waste Chemistries for Waste Types Stored in Tank U-112

Waste Type	[NO ₃ ⁻]	[NO ₂ ⁻]	[OH ⁻]	Meets Current DST Specification ²
1C ¹	1.54	0.26	0.28	No ³
CW ¹	0.6	0.9	1.0	Yes
R ⁴	4.83	0.74		No ⁵

- Reference WHC-EP-0449, 1991, *The Sort on Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Characteristic Groups*.
- Reference OSD-T-151-00007, Rev. 12, (2013), *Operating Specifications for the Double-Shell Storage Tanks*.
- Waste type 1C does not meet the current DST specification for waste chemistry; however, 1C was mixed with CW prior to adding to the tank. Depending on this ratio, the resulting waste may have met the DST specification.
- Reference WHC-EP-0772, 1994, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks*.
- Does not meet the current DST specification since the hydroxide and nitrite concentrations are not greater than or equal to 1.2M.

Tank U-112 stored REDOX concentrated salt waste for ~2 years when 21 kgal of CW was added to the existing 531 kgal of REDOX waste. The resulting combination of REDOX waste and CW would not meet the current DST specification for waste chemistry (OSD-T-151-00007, Rev. 12). Therefore, the REDOX waste and the REDOX/CW waste would have been present in the tank for 10 years when the liquid level started decreasing in 1964 and would continue to be stored for another six years when the tank was pumped in 1970. The REDOX and REDOX/CW wastes could be a concern for either pitting or SCC under the tank U-112 conditions even though waste temperatures probably averaged less than 100°F.

The other waste types stored in tank U-112 should not have resulted in pitting or SCC. The waste type 1C/CW was a combination of the acidic 1C waste in T Plant neutralized with the basic CW in T Plant. Depending on the ratio of 1C to CW, the resulting waste type likely met the OSD-T-151-0007 specification for waste chemistry since CW by itself meets the current DST specification.

6.4.5 Photographs

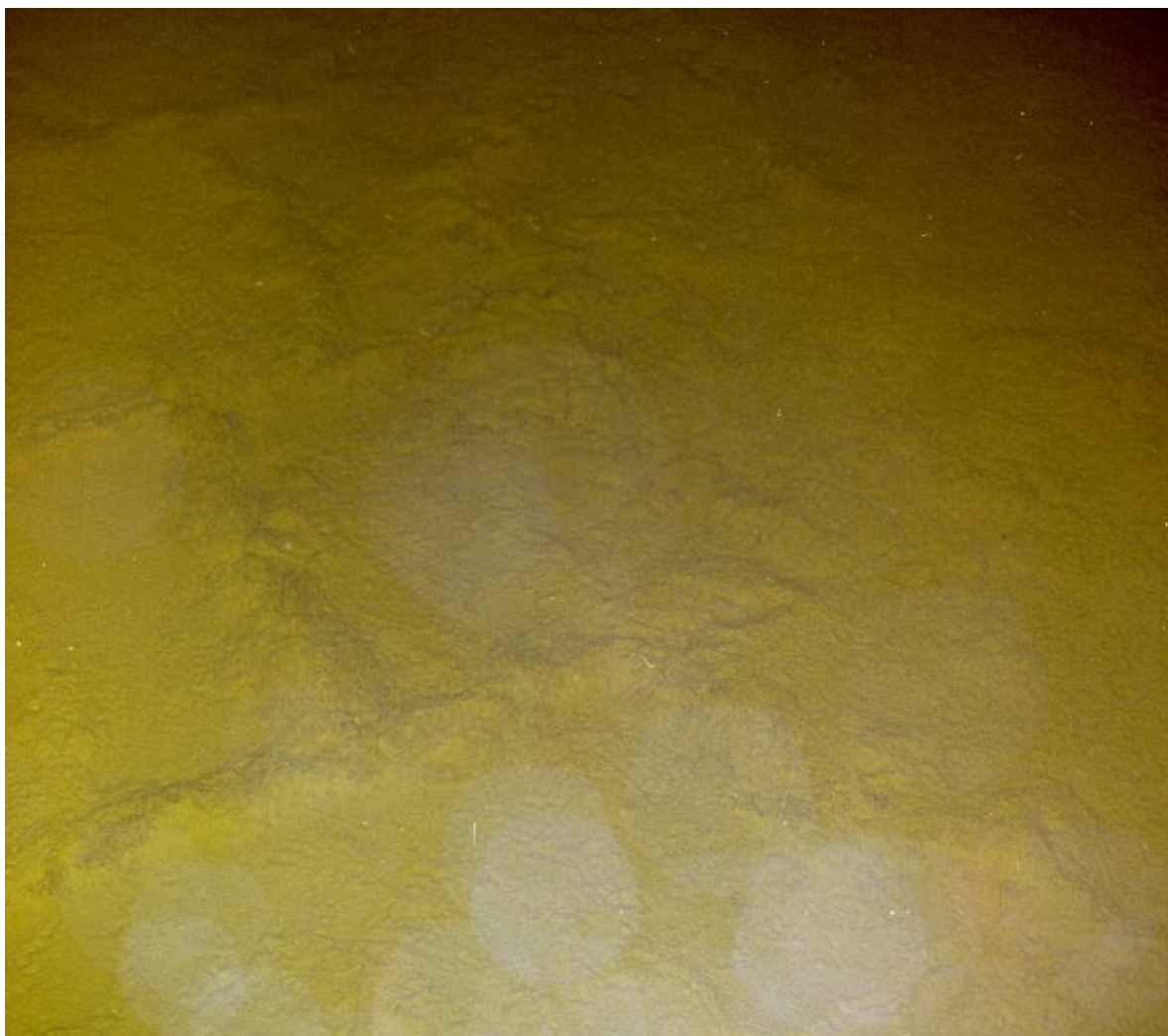
The earliest photographs recovered for tank U-112 were dated June 5, 1975. The photograph in Figure 6-5 shows the cascade inlet line and what may be an indistinct beach line above the cascade inlet line that may be a sign the tank was overfilled.

**Figure 6-5. Tank U-112 Photograph, June 5, 1975
(753800-1CN)**

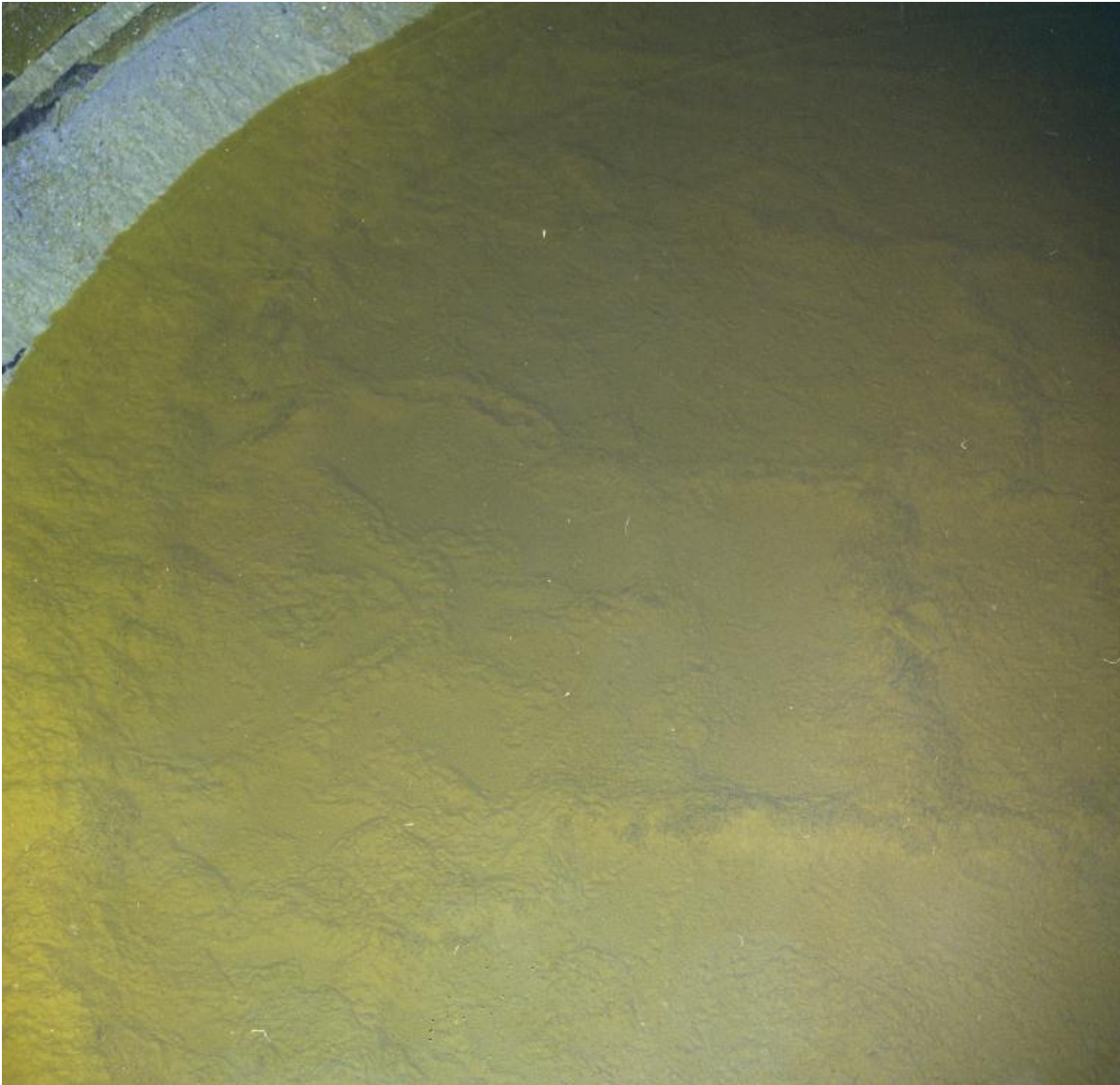


Photographs of the tank U-112 were taken on March 12, 1970 after pumping the tank to ~80 kgal with ~46 kgal of sludge. The photographs in Figure 6-6 and Figure 6-7 show a pattern of solids below the liquid surface that appears to follow plate weld lines on the bottom tank liner. This could possibly be related to deformation of the bottom plates creating stresses in the plates and welds as the weight of waste increased during filling and emptying. The 241-T Farm tanks experienced buckling of the bottom liner during construction of the tanks (see Figure 6-8) and all of the 241-T Farm tank bottom liners required replacement (HW-7-103, *Hanford Engineering Works Monthly Report April 1944*). A similar buckling of some or all of the U Farm tanks may have occurred and was either not as severe or not recognized which may have resulted in the pattern seen in Figure 6-6 and Figure 6-7 for tank U-112.

**Figure 6-6. Tank U-112 Photograph March 12, 1970
Apparent Weld Ridge Pattern
(701199-4CN)**



**Figure 6-7. Tank U-112 Photograph March 12, 1970
Apparent Weld Ridge Pattern
(701199-5CN)**



**Figure 6-8. 241-T Farm Bottom Liner Deformation during Construction
April 15, 1944
(D2314)**



6.5 TANK U-112 EX-TANK DATA

6.5.1 Drywells

There are six drywells located around tank U-112: 60-00-08, installed in 1944, 60-12-05, 60-12-07, and 60-12-10 installed in 1970, 60-12-03, installed in 1973, 60-12-01 installed in 1974, and a direct push installed in 2007. All of the radiation readings in drywells are assumed to be maximum or peak readings unless otherwise noted (see Section 3.3.2). The following subsections report the available drywell and direct push information including a summary and analysis section for tank U-112.

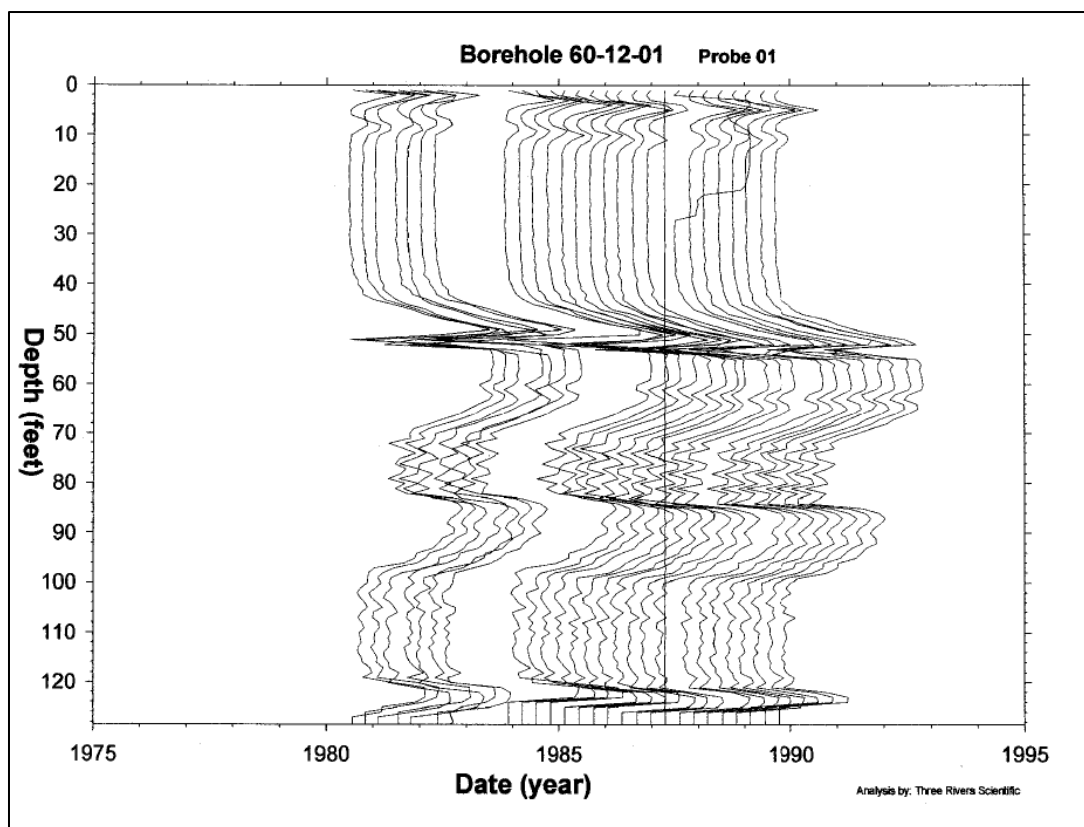
6.5.1.1 Drywell 60-12-01

Drywell 60-12-01 is located approximately 5.6-ft from the north northeast side of tank U-112. Drywell 60-12-01 was drilled in 1974 with the first recoverable reading on August 22, 1974 reported at 3,000K cpm at 50-ft BGS (see Appendix A3). The next recoverable reading reported a peak at 831.5K cpm at 53-ft BGS. Readings remained relatively stable to March 7, 1977. Following the use of new monitoring equipment, the peak was reported at approximately 340K

cpm at 50-ft BGS. Readings continued to be reported at roughly the same radioactivity and BGS level through October 1986 (see Appendix A3).

In September 1996, significant Cs-137 contamination was detected in this drywell and contamination occurs continuously from the ground surface to the bottom (GJ-HAN-41, *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank U-112*). From the ground surface to 3.5-ft BGS, between 50 and 68-ft and between 84 and 98-ft BGS, Cs-137 concentrations exceeded 2,000 pCi/g. Between 17 and 50-ft BGS, Cs-137 concentrations ranged from 1 to 9 pCi/g. Document GJ-HAN-41 reports, "The Cs-137 contamination encountered in the three depth intervals below the 50-ft depth probably resulted from a leak from tank U-112. The three separate contaminant plumes may have migrated from a single subsurface leak site to intersect the borehole." Figure 6-9 shows the depths of radioactivity from 1980 to 1989 with the Green probe (01) (RPP-7729).

Figure 6-9. Tank U-112 Drywell 60-12-01 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft BGS

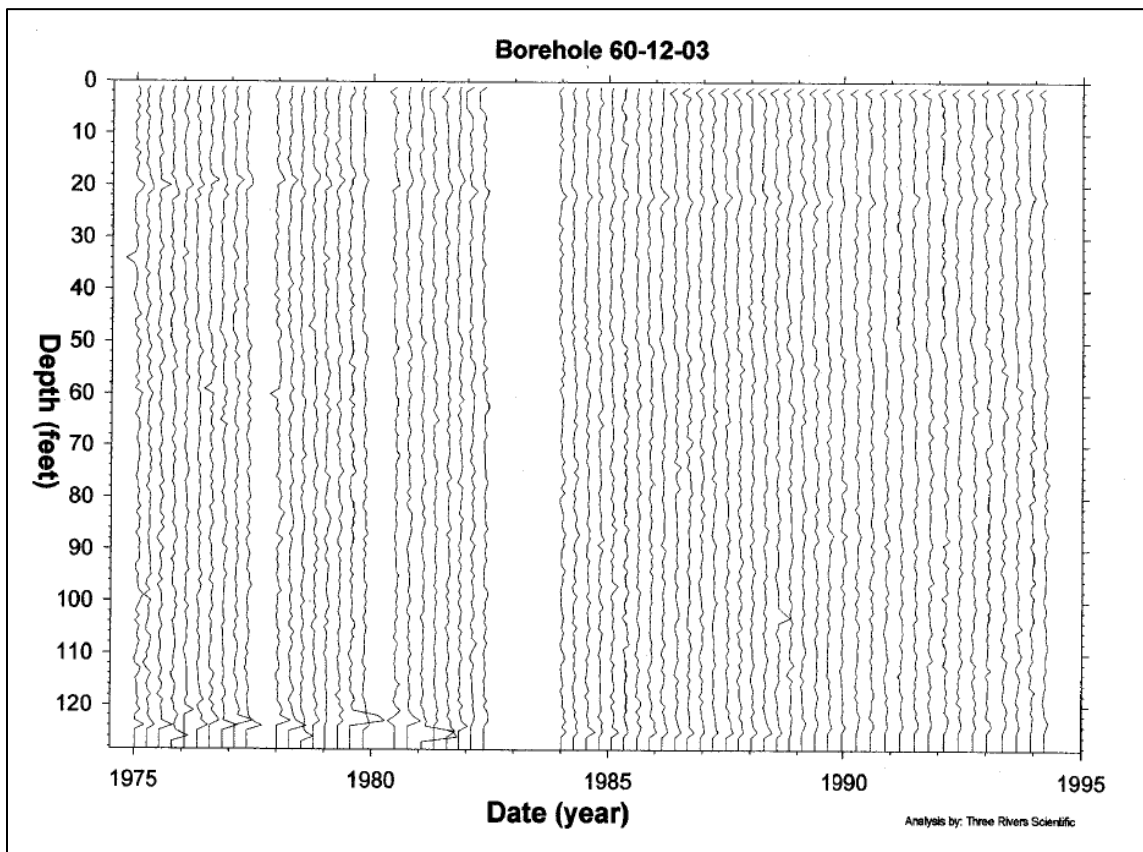
6.5.1.2 Drywell 60-12-03

Drywell 60-12-03 is located approximately 9.2-ft from the east side of tank U-112. Drywell 60-12-03 was drilled in June 1973 with the first recoverable reading on September 21, 1973 reported as less than values (see Appendix A3). Radioactivity continued to be reported as less than values through October 1986.

In September 1996, Cs-137 was the only man-made radionuclides detected in drywell 60-12-03 (GJ-HAN-41). From the ground surface to 22-ft BGS, at 48-ft BGS, and at the bottom of the drywell, Cs-137 contamination was detected intermittently. Most of the measured Cs-137 ranged between 0.14 and 0.2 pCi/g, the maximum concentration of 2 pCi/g was measured at the bottom of the drywell (GJ-HAN-41).

Since historical radioactivity in this drywell is very low, and the GJ-HAN-41 report indicated low levels of radioactivity, drywell 60-12-03 is not being included as part of the leak location for tank U-112. Figure 6-10 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 6-10. Tank U-112 Drywell 60-12-03 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft BGS

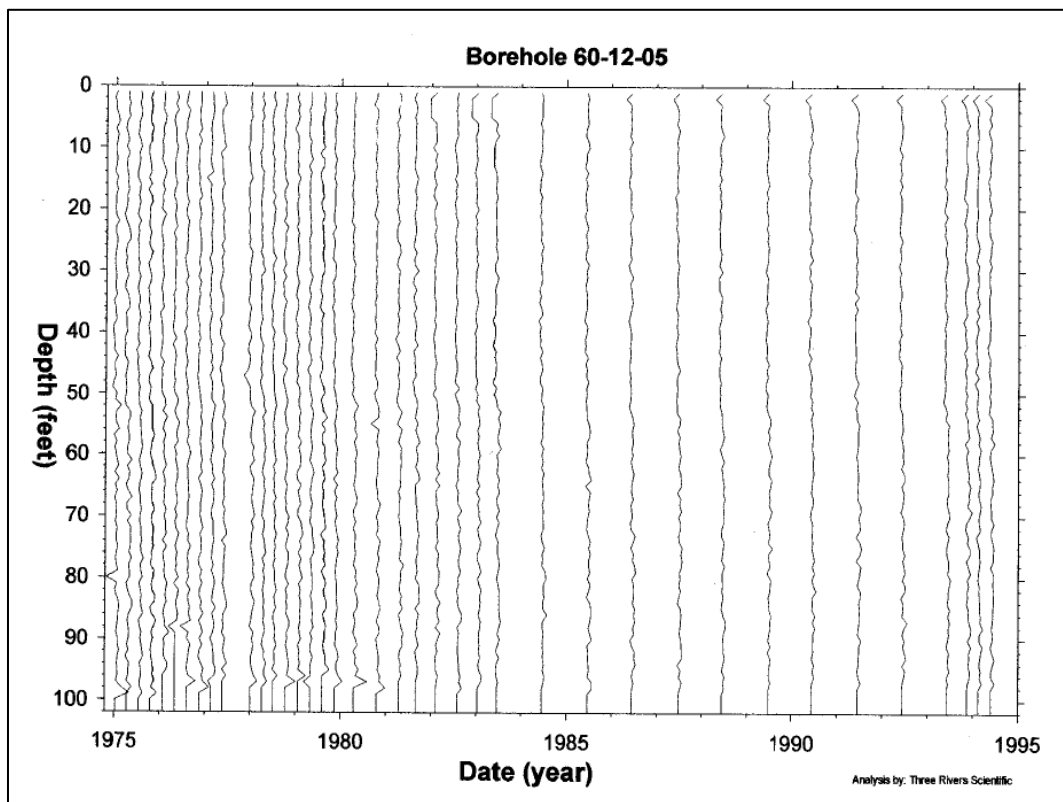
6.5.1.3 Drywell 60-12-05

Drywell 60-12-05 is located approximately 3.5-ft from the southeast side of tank U-112. Drywell 60-12-05 was drilled in June 1970 with the first recoverable readings reported on September 21, 1973 as less than values (see Appendix A3). Radioactivity continued to be reported as less than values through June 1986.

In September 1996, Cs-137 was the only man-made radionuclides detected in drywell 60-12-05 (GJ-HAN-41). From the ground surface to 11.5-ft BGS, 12.5, 15, 38, 42.5, between 52 and 53-ft, and from 49-ft to the bottom of the drywell, Cs-137 contamination was detected intermittently. The maximum concentration of just above 2 pCi/g was measured at the ground surface and subsurface concentrations typically ranged between 0.14 and 1 pCi/g (GJ-HAN-41).

Since historical radioactivity in this drywell is very low, and the GJ-HAN-41 report indicated low levels of radioactivity, drywell 60-12-05 is not being included as part of the leak location for tank U-112. Figure 6-11 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 6-11. Tank U-112 Drywell 60-12-05 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft BGS

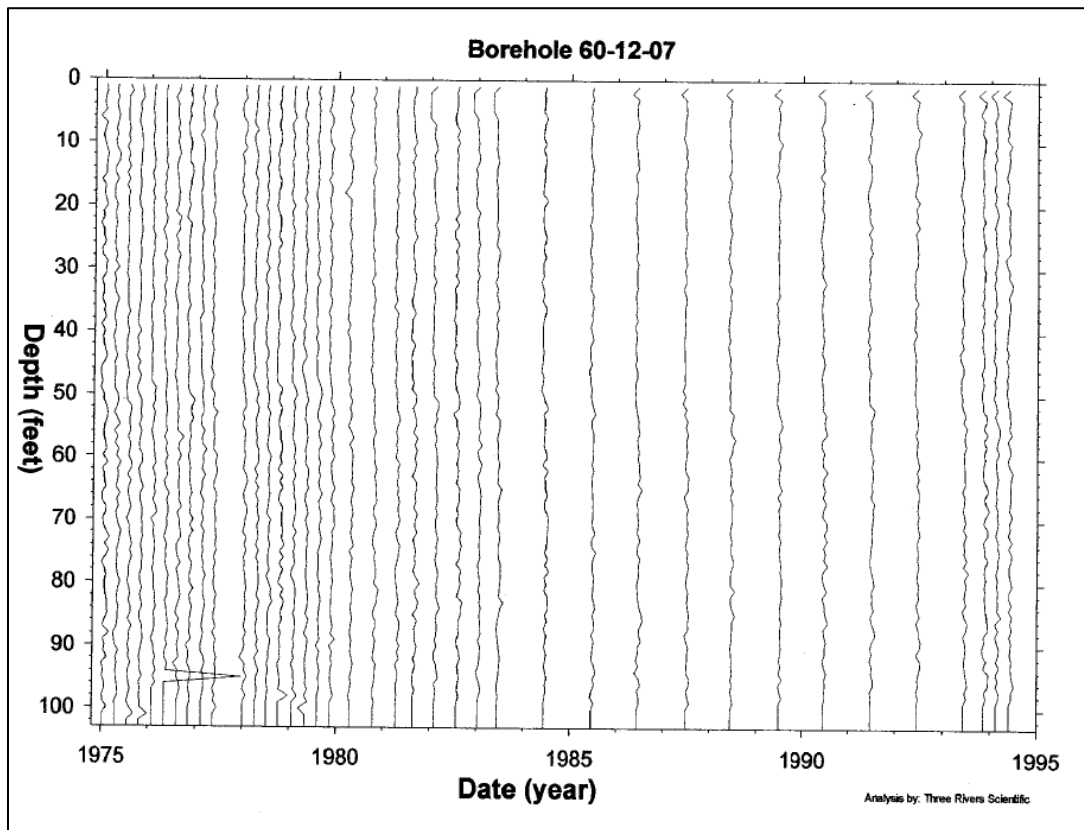
6.5.1.4 Drywell 60-12-07

Drywell 60-12-07 is located approximately 4.3-ft from the southwest side of tank U-112. Drywell 60-12-07 was drilled in June 1970 with the first recoverable reading reported on August 23, 1973 as less than values (see Appendix A3). Radioactivity continued to be reported as less than values through June 1986.

In September 1996, Cs-137 was the only man-made radionuclides detected in drywell 60-12-07 (GJ-HAN-41). The maximum Cs-137 concentration was about 11 pCi/g at the top of the drywell and subsurface concentrations ranged from 0.2 to 1 pCi/g (GJ-HAN-41).

Since historical radioactivity in this drywell is very low, and the GJ-HAN-41 report indicated low levels of radioactivity, drywell 60-12-07 is not being included as part of the leak location for tank U-112. Figure 6-12 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 6-12. Tank U-112 Drywell 60-12-07 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft BGS

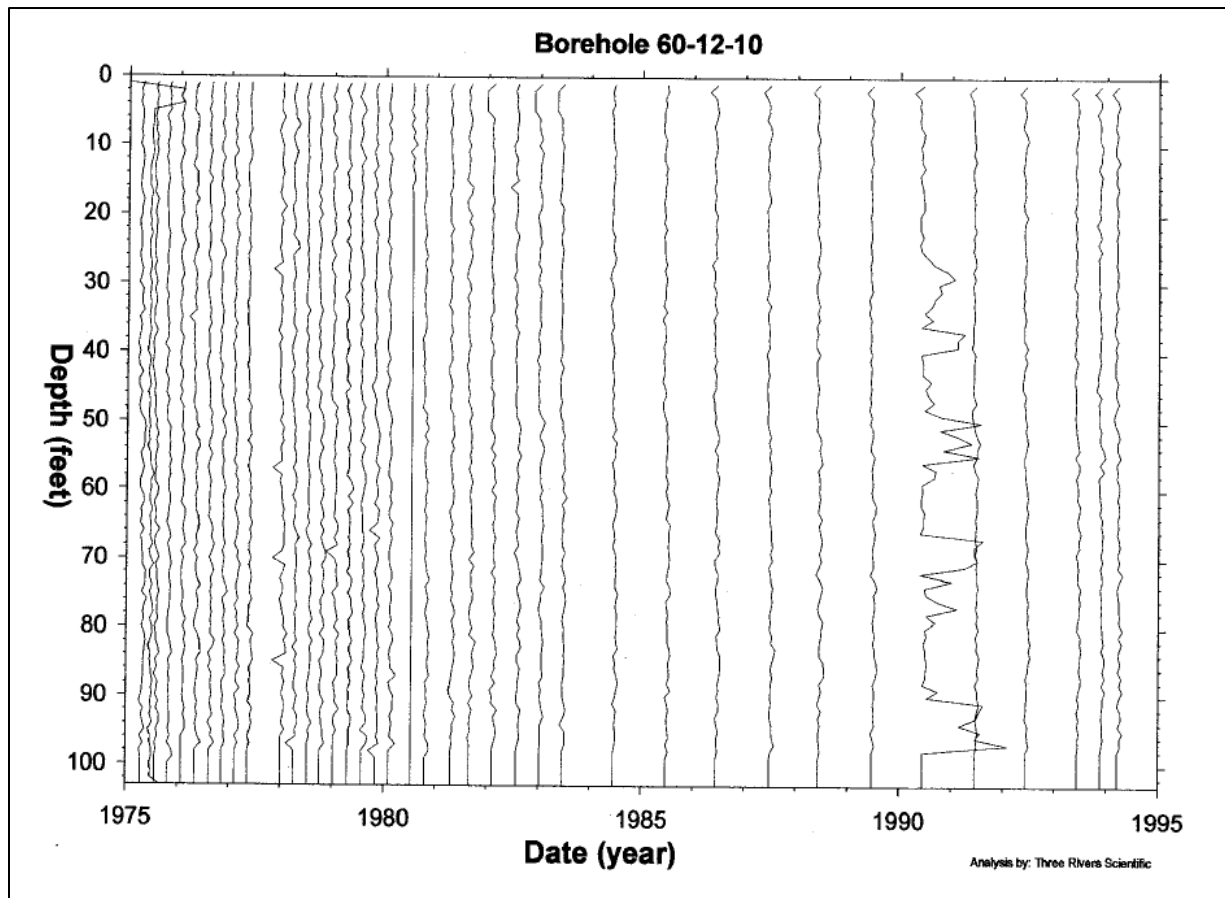
6.5.1.5 Drywell 60-12-10

Drywell 60-12-10 is located approximately 3.4-ft from the northwest side of tank U-112. Drywell 60-12-10 was drilled in June 1970 with the first recoverable reading reported on August 23, 1973 as less than values (see Appendix A3). Radioactivity continued to be reported as less than values through June 1986.

In September 1996, Cs-137 was the only man-made radionuclides detected in drywell 60-12-10 (GJ-HAN-41). The maximum Cs-137 concentration was about 1 pCi/g at the top of the drywell and subsurface concentrations ranged from 0.1 to 0.3 pCi/g (GJ-HAN-41).

Since historical radioactivity in this drywell is very low, and the GJ-HAN-41 report indicated low levels of radioactivity, drywell 60-12-10 is not being included as part of the leak location for tank U-112. Figure 6-13 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 6-13. Tank U-112 Drywell 60-12-10 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft BGS

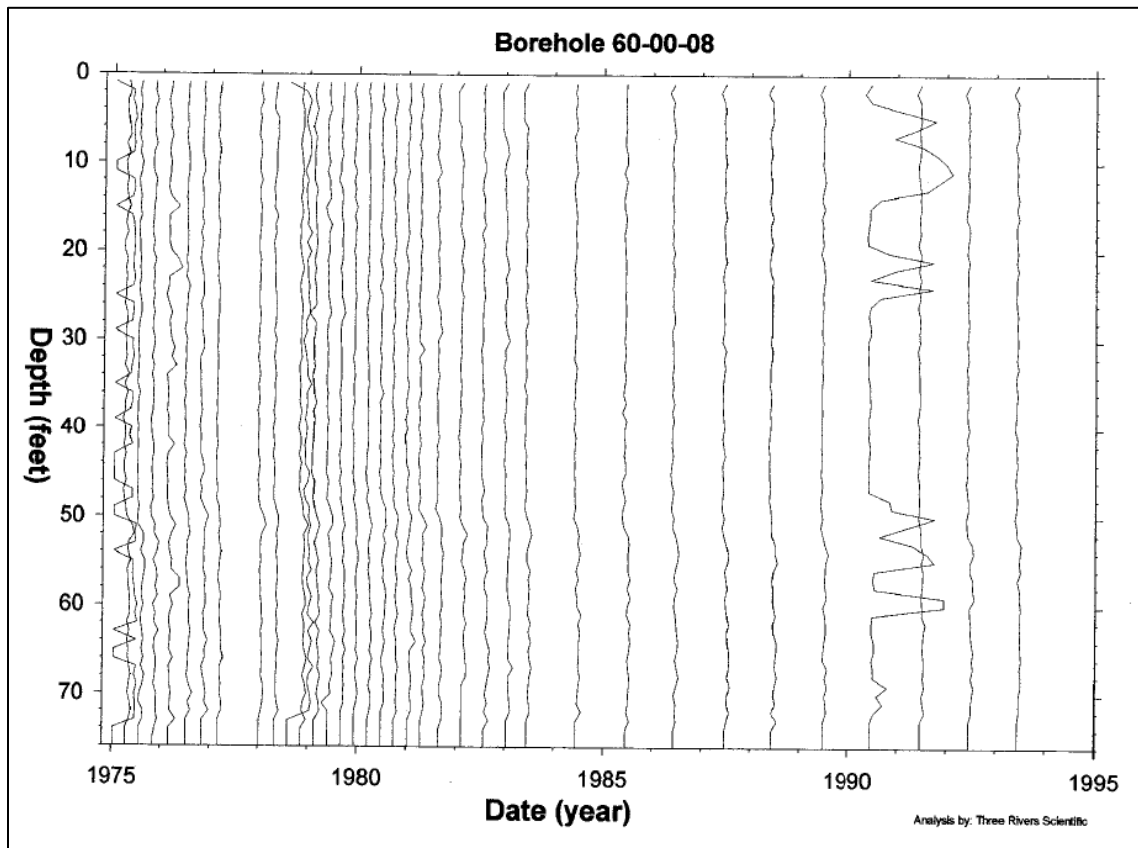
6.5.1.6 Drywell 60-00-08

Drywell 60-00-08 is located approximately 38.7-ft from the northwest side of tank U-112. Drywell 60-00-08 was drilled in 1944 with the first recoverable reading on August 22, 1973 reported as less than values (see Appendix A3). Readings continued to be reported as less than values through June 1986.

In September 1996, Cs-137 was the only man-made radionuclides detected in drywell 60-00-08 (GJ-HAN-41). The Cs-137 contamination was detected continuously from the ground surface to the maximum logging depth of 73.5-ft BGS with the maximum concentration of approximately 2 pCi/g detected at 53.5-ft BGS (GJ-HAN-41). Document GJ-HAN-41 states, "Though relatively low in magnitude, the Cs-137 contamination in this borehole is of particular interest because this borehole is positioned to detect contaminant plumes originating from the four smaller auxiliary tanks located in the southwest portion of the U Tank Farm. The trace amounts of Cs-137 contamination in this borehole are not indicative of leakage either from these tanks or from tank U-112."

Since historical radioactivity in this drywell is very low, and the GJ-HAN-41 report indicated low levels of radioactivity, drywell 60-00-08 is not being included as part of the leak location for tank U-112. Figure 6-14 shows the depths of radioactivity from 1975 to 1995 (RPP-7729).

Figure 6-14. Tank U-112 Drywell 60-00-08 (RPP-7729)



Note: Bottom of the tank footing is ~38-ft BGS

6.5.1.7 2007 Direct Push

In 2007, one direct push (C5605) was installed near tank U-112 (near drywell 60-12-01) for moisture and spectral gamma logging (see Figure 6-1).

Results identified elevated moisture contents (25%) in the 50 to 95-ft BGS range, while only background levels of Cs-137 were recorded throughout the logging (RPP-36007). Therefore, direct push C5605 is not included in the leak location for tank U-112.

6.5.1.8 Drywell Summary

Tank U-112 was first suspected of leaking based on a 3-in liquid level decrease between February 1969 and March 1970; however, the leak could have started as early as December 1964 (see Section 6.4.1). Drywells were installed near tank U-112 in 1970-1974.

Tank U-112 drywells 60-12-03, 60-12-05, 60-12-07, 60-12-10, and 60-00-08 do not indicate any radioactivity associated with a tank U-112 leak. Therefore, these drywells are not included in the leak location for tank U-112.

The first recoverable reading in August 1974 for drywell 60-12-01 indicate radioactivity. A peak of 3,000K cpm was reported in drywell 60-12-01 at 50-ft BGS. Radioactivity declined to approximately 830K cpm the next month in September 1974. Readings remained relatively stable through October 1986. It appears the source of the radioactivity detected in this drywell is tank U-112.

Direct push C5605, installed in 2007, reported elevated moisture content in the 50 to 95-ft BGS range and background levels of Cs-137 throughout the logging. Thus, direct push C5605 is not included in the leak location for tank U-112. No laterals were installed under tank U-112.

6.6 POSSIBLE TANK U-112 LINER LEAK LOCATION(S)

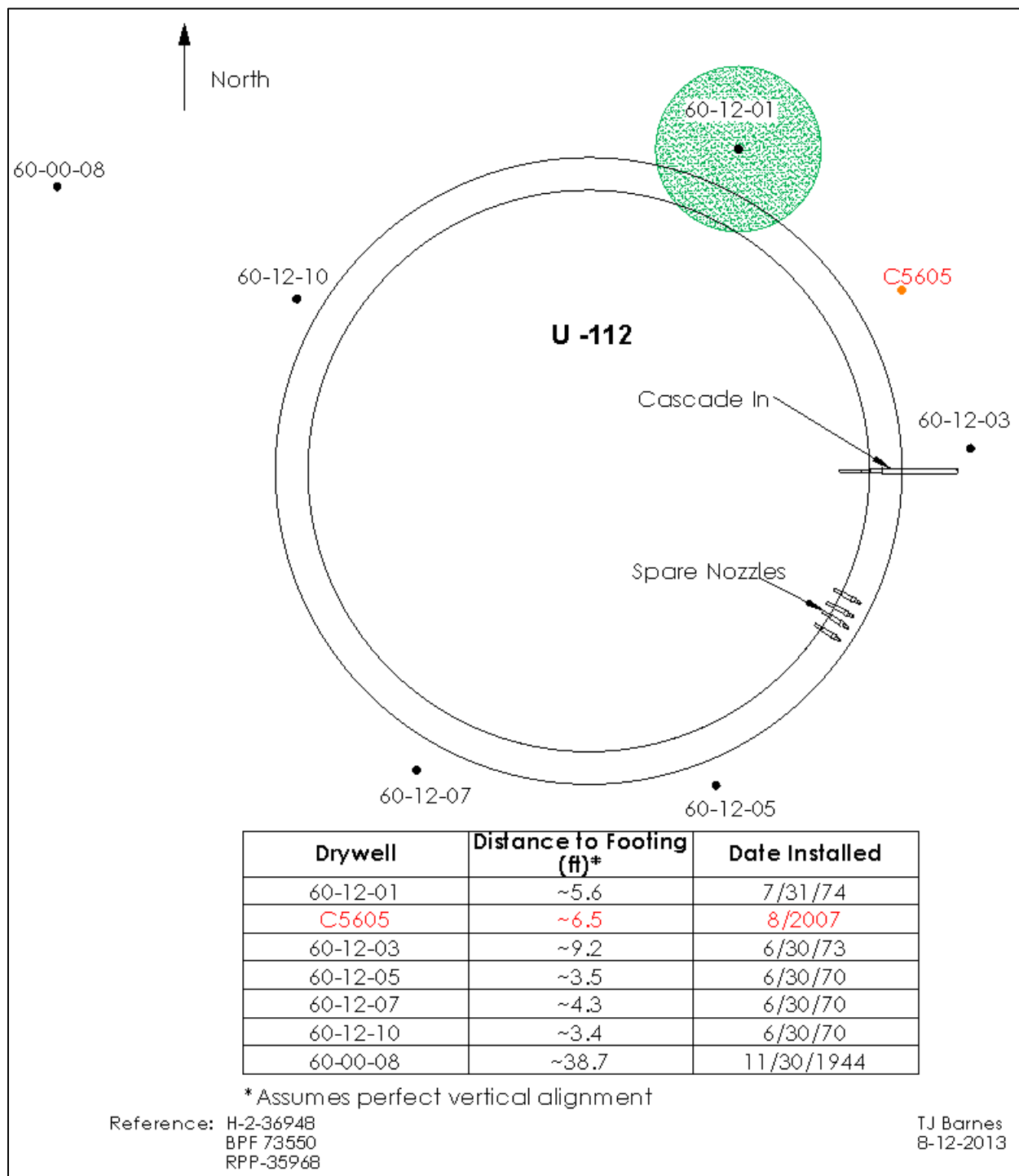
A liner leak may have penetrated the waterproof membrane at any location or pooled on the waterproof membrane and followed concrete cracks or construction joints to a different location for egress to the soil, including the top of the tank footing.

Tank U-112 had at least one liner leak site based on radioactivity detected in drywell 60-12-01, likely at or near the bottom of the tank. There is also a possibility of a small leak from the cascade inlet line which probably would not have been detected in any nearby drywells during this time.

6.6.1 Leak Detected in 1964

Tank U-112 was first reported as leaking due to a 3-in liquid level drop between February 1969 and March 1970 (RHO-CD-896). However, it appears the tank U-112 leak could have started as early as December 1964 due to the liquid level decreasing from December 1964 until March 1970, when the tank was pumped down to minimum heel. The leak was detected in drywell 60-12-01 in the northeast portion of the tank when the drywell was drilled in 1974 (see Figure 6-15). No other drywells indicated a tank U-112 leak.

Figure 6-15. Tank U-112 Possible Leak Location (1964)
 Tank inner ring is steel liner; outer ring is outer edge of tank footing



6.7 POSSIBLE TANK U-112 LINER LEAK CAUSE(S)

Tank U-112 was evaluated for five conditions known to contribute to a failed liner.

6.7.1 Tank Design

The U Farm tank design does not appear to be a factor contributing to a failed liner (see Section 3.1.1).

6.7.2 Thermal Conditions

Limited temperature data are available for tank U-112 from October 1947 when the tank was first put into service until 1976. Sludge temperature plots for the one year period between July 1956 and July 1957 (RHO-CD-1172) after receiving some CW with the existing REDOX waste indicated temperatures ranged from ~60°F to ~70°F with one spike in September 1956 at approximately 170°F. Tank U-112 did not experience evaporation liquid level decreases like Tank U-110. Tank U-112, the last tank in the tank U-110 cascade would have experienced lower temperatures than those experienced in tank U-110 (see Section 6.4.2).

Thermal shock creates stress both from rapid temperature rise as well as waste-induced high temperatures. Since no records are available during a period of evaporation, it is uncertain what the maximum temperature was in tank U-112 during operation as well as the rate of temperature rise when waste was added. The thermal attributes of the waste and other information (see Section 6.4.2) would indicate that thermal stresses were likely minimal and should not have challenged the tank storage limits.

Temperature requirements in ARH-951 (*Limitations for Use of Underground Waste Tanks*) issued December 18, 1969 indicated that tank temperatures should be held below 230°F.

6.7.3 Chemistry-Corrosion

Tank U-112 stored REDOX and REDOX/CW waste for ~10 years prior to the 1964 start of decreasing liquid levels at temperatures probably averaging ~100°F. The REDOX and REDOX/CW waste could have resulted in pitting or SCC under tank U-112 conditions. Other waste types stored in tank U-112 should not have resulted in pitting or SCC.

6.7.4 Liner Observations

A review of the available photographs for tank U-112 indicates some possible bottom liner deformation that may have resulted in stressing and weakening of the plates and welds. There is no documentation available indicating a liner bulge was present in tank U-112.

6.7.5 Tank Construction Temperature

The U Farm tank liners were constructed between February 1944 and October 1944. Only isolated minimum temperature were experienced during tank construction at or below 18°F with day time temperatures between 44°F and 57°F (see Section 6.3.2). Impact occurrences could have occurred during cold temperatures that may have triggered fissures in the steel liner;

however, the possibility seems much less than that which might have occurred during construction in other tank farms.

6.8 TANK U-112 CONCLUSIONS

Liquid level evidence and drywell radioactivity indicate that the tank U-112 liner leaked in at least one location in the north north-east portion of the tank at or near the tank base.

There are several liner leak cause conditions that were examined and the one that probably caused the tank U-112 liner leak was chemistry-corrosion from pitting and SCC from the storage of REDOX and REDOX/CW waste. Tank U-112 may also have experienced deformation of the bottom liner during construction which may have resulted in stressing and weakening of the plates and welds.

There appears to be very little contribution from other wastes as well as from tank design and construction temperatures. However, some or all of the factors can act serially or together to contribute to tank liner failure.

APPENDIX A3

TANK U-112 GROSS GAMMA DRYWELL DATA

**Table A3-1. Tank U-112 Drywell Radioactivity (K counts per minute) (August 1974 through October 1986)
(SD-WM-TI-356)**

60-12-01			60-12-03		60-12-05		60-12-07		60-12-10		60-00-08	
Date	Peak (K cpm)	Depth (ft)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)	Date	Peak (K cpm)
8/22/1974	3000	50	9/21/1973	< 12	9/21/1973	< 12	8/23/1973	< 12	8/23/1973	< 12	8/22/1973	< 12
9/12/1974	831.5	53	4/12/1974	< 12	4/12/1974	< 12	4/12/1974	< 12	7/18/1974	< 3	6/6/1974	< 12
N/A ¹			6/8/1974	< 3	6/8/1974	< 3	6/8/1974	< 3	N/A ¹		7/1/1974	< 3
N/A ¹			2/20/1974	< 3	N/A ¹		N/A ¹		N/A ¹		N/A ¹	
2/13/1975	782.1	52	N/A ¹		1/24/1975	< 3	2/5/1975	< 3	2/5/1975	< 3	1/24/1975	< 3
8/6/1975	794.9	51	8/11/1975	< 3	8/6/1975	< 3	8/6/1975	< 3	N/A ¹		8/5/1975	< 3
12/30/1975	799.7	52	12/30/1975	< 3	12/30/1975	< 3	12/30/1975	< 3	11/12/1975	< 3	N/A ¹	
N/A ¹			N/A ¹		N/A ¹		N/A ¹		N/A ¹		1/7/1976	< 3
5/11/1976	785	50	5/11/1976	< 3	5/11/1976	< 3	5/11/1976	< 3	N/A ¹		5/5/1976	< 3
10/19/1976	978.1	50	N/A ¹		N/A ¹		N/A ¹		11/10/1976	< 3	N/A ¹	
3/1/1977	932.9	50	1/5/1977	< 3	1/5/1977	< 3	1/5/1977	< 3	N/A ¹		1/5/1977	< 3
8/2/1977	902.6	50	N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹	
11/22/1977	843.1	51	11/23/1977	< 3	11/22/1977	< 3	11/22/1977	< 3	11/15/1977	< 3	11/1/1977	< 3
3/7/1978	822.3	51	N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹	
3/14/1978	338.8	50	N/A ¹		N/A ¹		N/A ¹		N/A ¹		N/A ¹	
11/6/1978	262.3	50	11/16/1978	< 3	11/16/1978	< 3	11/16/1978	< 3	11/2/1978	< 3	11/15/1978	< 3
11/5/1979	327	49	11/1/1979	< 3	11/1/1979	< 3	11/1/1979	< 3	11/1/1979	< 3	10/31/1979	< 3
11/3/1980	304	51	11/13/1980	< 3	10/16/1980	< 3	N/A ¹		10/16/1980	< 3	11/13/1980	< 3
12/21/1981	278.9	51	11/19/1981	< 3	11/19/1981	< 3	11/19/1981	< 3	11/19/1981	< 3	11/19/1981	< 3
12/6/1982	264.5	52	11/3/1982	< 3	10/21/1982	< 3	10/21/1982	< 3	10/21/1982	< 3	10/21/1982	< 3
11/28/1983	341.5	51	11/22/1983	< 3	6/15/1983	< 3	6/15/1983	< 3	6/15/1983	< 3	6/15/1983	< 3
10/29/1984	196.7	52	10/24/1984	< 3	6/13/1984	< 3	6/13/1984	< 3	6/13/1984	< 3	6/13/1984	< 3
11/26/1985	290	53	11/20/1985	< 3	6/19/1985	< 3	6/19/1985	< 3	6/19/1985	< 3	6/19/1985	< 3
10/29/1986	334.3	53	10/24/1986	< 3	6/10/1986	< 3	6/10/1986	< 3	6/10/1986	< 3	6/10/1986	< 3

Note: ¹N/A: Data not available

7.0 CONCLUSIONS

Liner leaks probably occurred at or near the base of all three leaking U Farm tanks. The bulging bottom liner of tank U-104 and the depth of radioactivity detected in tank U-104, U-110, and tank U-112 drywells all point to a liner leak near the bottom of the tank.

There are several liner leak cause conditions that were examined for tanks U-104, U-110, and U-112 which include tank design, construction conditions, thermal conditions, and chemistry-corrosion. Thermal conditions appear to be the most likely cause of the tank U-104 liner leak. Chemistry-corrosion, relating to the storage of REDOX waste appears to be the most likely cause of the leak(s) for tanks U-110 and U-112 and possible laboratory wastes for tank U-110. REDOX waste at elevated temperatures could have created an environment conducive to pitting and SCC. Tank U-112 may also have experienced deformation of the bottom liner during construction possibly creating stresses and weakening of the plates and welds.

Tank U-104 experienced a 5-ft bulge in the bottom liner which was detected while completing sluicing of the second batch of MW. The liner bulge was probably the result of temperature rate of rise especially during the second filling of the tank with MW. This could have set up a situation where vapor pressure under the bottom liner was greater than the hydrostatic pressure. The bulge probably weakened the bottom liner to the point of failure which was confirmed by subsequent leak testing and detection of drywell radioactivity.

Both tank U-110 and U-112 experienced liner failures that were detected by a liquid level decrease and subsequently confirmed by the detection of drywell radioactivity in one of the drywells surrounding each of the tanks. Corrosion may have been a factor in each case as both tank U-110 and U-112 stored REDOX waste which is conducive to pitting and SCC. Tank U-110 also stored several hundred thousand gallons of unknown laboratory waste which may have influenced corrosion. Tank U-112 may also have experienced deformation of the bottom liner during construction which may have resulted in stressing and weakening of the plates and welds.

There appears to be very little contribution from tank design and construction temperatures. However, some or all of the factors can act serially or together to contribute to tank failure.

Basic information on the leaking U Farm tanks and the U Farm sound tanks are listed separately in Table 7-1 and Table 7-2. The information was reviewed to identify any differences between leaking and sound tanks related to liner failure. A number of the sound tanks contained REDOX waste under similar conditions that may have caused corrosion that resulted in the tank U-110 and tank U-112 liner leaks.

The sound tank U-111 is one of the tanks that stored REDOX waste. It is in the curious position of being the second tank of the three tank cascade from tank U-110 to tank U-112 both of which are leaking tanks. This would seem to put into question the postulated REDOX waste corrosion effect unless there was some other unknown factor influencing corrosion rate or other conditions such as tank U-112 with the possibility of bottom liner stresses caused by poor construction of the bottom liner. There doesn't seem to be any of the basic information that stands out as the reason sound tanks did not experience liner leaks.

Table 7-1. U Farm Leaking Tanks

Leaking Tank	Waste Details		Leak Status		R Waste Storage		Thermal Conditions
	First Filled	Waste Type	Leak Detected	Indication of leak	Stored R Waste	R Only Storage Length	Estimated Max Temp
U-104	July 1947	MW, water	July 1956	Drywells	No	-	< 180°F
U-110	July 1946	1C/CW, R, CW, LW	July 1975	LL decrease, Drywells	Yes	~ 1.5 years	> 180°F
U-112	October 1947	1C/CW, R, CW	December 1964	LL decrease, Drywells	Yes	~ 10 years ¹	< 120°F

Notes: Waste Types: MW: Metal Waste; TBP: Tri-butyl phosphate waste; CW: coating waste; R: REDOX HLW; 1C: First-cycle decontamination waste; LW: laboratory waste

1. Stored R waste for 10 years until the leak was first detected (total storage length was ~ 16 years)

Table 7-2. U Farm Sound Tanks

Sound Tank	Waste Details		Leak Status		R Waste Storage ⁶		Thermal Conditions
	First Filled ¹	Waste Type	Leak Integrity Classification ²	Basis for Formal Leak Assessment	Stored R Waste	R Only Storage Length	Estimated Max Temp ³
U-101	February 1946	MW, R	“Confirmed leaker” but TFC-ENG-CHEM-D-42	Direct push logging and samples recommended	Yes	~ 3 years	92°F
U-102	June 1946	MW, R, NCPLX, EB, Resid.	Sound	-	Yes	~ 18 years	134°F
U-103	February 1947	MW, R, PNF, EB, Evap.	Sound	-	Yes	~ 18 years	132°F
U-105	December 1947	R, CW, MW, CPLX, EB, Resid.	Sound	-	Yes	~ 19 years	146°F
U-106	May 1948	MW, R, CCPLX, Resid., Evap.	Sound	-	Yes	~ 18 years	122°F
U-107	September 1948	CW, MW, EB, BNW, N, DW, CPLX, Evap., NCPLX	Sound	-	No	-	122°F
U-108	January 1949	CW, MW, EB, N, BNW, DW, PNF, Resid., EB	Sound	-	No	-	130°F
U-109	March 1949	CW, MW, EB, PNF, Resid.	Sound	-	Yes ⁴	~ 1 year	120°F
U-111	April 1947	1C, R, CPLX, PNF, EB	Sound	-	Yes	~20 years ⁵	130°F

Notes: Waste Types: TBP: Tri-butyl phosphate waste; 1C: First-cycle decontamination waste; CW: coating waste; MW: metal waste; EB: Evaporator bottoms; R: REDOX HLW; Evap: Evaporator feed (post 1976); NCPLX: Non-Complexed waste; Resid: Residual evaporator liquor; PNF: Partial neutralization feed; CPLX: complexed waste; DW: decontamination waste

- Reference: Tank Waste Information Network System
- Reference: RPP-RPT-50097, Rev. 0, *Hanford 241-U Farm Leak Inventory Assessment Report*.
- Reference: WHC-SD-WM-TI-591, Rev. 0, *Maximum Surface Level and Temperature Histories for Hanford Waste Tank*
- Received R waste from U-112 which was mixed with CW and EB
- 14 years were a mixed waste of R/CW, 6 years storage of only R
- Reference: WHC-MR-0132, *A History of the 200 Area Tank Farms*

8.0 REFERENCES

- ARH-951, 1969, *Limitations for Use of Underground Waste Tanks*, Richland, Washington.
- ARH-1601, 1974, *Specifications and Standards for the Operation of Radioactive Waste Tank Farms and Associated Facilities*, Atlantic Richfield Hanford Company, Richland, Washington.
- ARH-CD-222, 1974, *Characterization of the Effects of Diatomaceous Earth Additions to Hanford Wastes*, Atlantic Richfield Hanford Company, Richland, Washington.
- ARH-CD-336B, 1975, *Production and Waste Management Division Waste Status Summary April 1, 1975 through June 30, 1975*, Atlantic Richfield Hanford Company, Richland, Washington.
- ARH-CD-336C, 1975, *Production and Waste Management Division Waste Status Summary July 1, 1975 through September 30, 1975*, Atlantic Richfield Hanford Company, Richland, Washington.
- ARH-R-43, 1970, *Management of Radioactive Wastes Stored in Underground Tanks at Hanford*, Rev. 2, Atlantic Richfield Hanford Company, Richland, Washington.
- ASTM A7-39, 1939, *American Society for Testing and Materials, Standard Specifications for Steel for Bridges and Buildings*
- ASTM A283, 1946, *American Society for Testing and Materials, Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates*
- BPF-73550, 1944, *Specification for Construction of Composite Storage Tanks (B, C, T, and U Tank Farms)*, Hanford Engineer Works, Richland, Washington.
- DS-103174, 1978, *Data Sheet Salt Well Transfer: Tk-112U to Tk-109U*, Rockwell Hanford Operations, Richland, Washington.
- DSI, 1961, "104-U Tank" (internal memorandum from G. L. Hanson to M. K. Harmon, March 31), Atlantic Richfield Hanford Company, Richland, Washington.
- EM-TF-040.9a, 1956, "Inspection of Waste Storage Tank 241-U-104" (internal memorandum from E. F. Smith and F. H. Shadel to H. F. Peterson, August 7; attachment to internal letter 65431-79-002, "Tank 271-U-111, Imperfections on the Inside Surface of the Reinforced Concrete Dome" from F. R. Vollert to C. R. Carter, May 17, 1979), Rockwell International, Richland, Washington.
- GJ-HAN-33, 1996, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank U-104*, U.S. Department of Energy Grand Junction Projects Office, Grand Junction, Colorado.

GJ-HAN-39, 1996, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank U-110*, U.S. Department of Energy Grand Junction Projects Office, Grand Junction, Colorado.

GJ-HAN-41, 1996, *Vadose Zone Monitoring Project at the Hanford Tank Farms Tank Summary Data Report for Tank U-112*, U.S. Department of Energy Grand Junction Projects Office, Grand Junction, Colorado.

GJPO-HAN-8, *Vadose Zone Characterization Project at the Hanford Tank Farms U Tank Farm Report*, U.S. Department of Energy Grand Junction Projects Office, Grand Junction, Colorado.

H-2-2257, 1962, *Conductor Reel for Liquid Level Measurement*, General Electric Company, Richland, Washington.

H-2-36948, 2007, *Wells in 241-U Farm As-Built*, WRPS, Richland, Washington.

HNF-3018, 1998, *Single-Shell Tank Sluicing History and Failure Frequency*, COGEMA Engineering Corporation, Richland, Washington.

HNF-3136, 1998, *Analysis Techniques and Monitoring Results, 241-SX Drywell Surveillance Logs*, Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-EP-0182, 2013, *Waste Tank Summary Report for Month Ending April 30, 2013*, Rev. 301, CH2M Hill Hanford Group, Inc., Richland, Washington.

HW-1946, 1943, *Specifications for Composite Storage Tanks – Buildings #241 at Hanford Engineering Works*, General Electric Company, Richland, Washington.

HW-7-4542-DEL, 1946, *Hanford Engineer Works Monthly Report July 1946*, General Electric Company, Richland, Washington.

HW-7-6184-DEL, 1947, *Hanford Works Monthly Report April 1947*, General Electric Company, Richland, Washington.

HW-7283-DEL, 1947, *Hanford Engineer Works Monthly Report July 1947*, General Electric Company, Richland, Washington.

HW-8438-DEL, 1947, *Hanford Works Monthly Report December 1947*, General Electric Company, Richland, Washington.

HW-10166-DEL, 1948, *Hanford Works Monthly Report May 1948*, General Electric Company, Richland, Washington.

HW-10475-C-DEL, 1944, *Hanford Technical Manual Section C*, General Electric Company, Richland Washington

- HW-11226-DEL, 1948, *Hanford Works Monthly Report September 1948*, General Electric Company, Richland, Washington.
- HW-14946, 1949, *A Survey of Corrosion Data and Construction Details, 200 Area Waste Storage Tanks*, General Electric Company, Richland, Washington.
- HW-20742, 1951, *Loss of Depleted Metal Waste Supernate to Soil*, General Electric Company, Richland, Washington.
- HW-27838, 1952, *Waste Status Summary Period: April, May, and June 1952*, General Electric Company, Richland, Washington.
- HW-30851, 1954, *Waste Status Summary January 1954*, General Electric Company, Richland, Washington.
- HW-31811, 1954, *Separations Section Waste – Status Summary April 30, 1954*, General Electric Company, Richland, Washington.
- HW-33544, 1954, *Separations Section, Waste-Status Summary for October 1954*, General Electric Company, Richland, Washington.
- HW-33904, 1954, *Separations Section, Waste-Status Summary for November 1954*, General Electric Company, Richland, Washington.
- HW-43490, 1956, *Separations Section Waste – Status Summary for May, 1956*, General Electric Company, Richland, Washington.
- HW-44024-RD, 1956, *TBP Plant and Tank Farm Weekly Summary – Process Unit – 6-29-56 thru 8-31-56*, General Electric Company, Richland, Washington.
- HW-44860, 1956, *Separations Section, Waste – Status Summary July 1956*, General Electric Company, Richland, Washington.
- HW-45115 H, 1956, *Separations Technology Section Monthly Report – August, 1956*, General Electric Company, Richland, Washington.
- HW-48144, 1957, *Chemical Processing Department Waste – Status Summary January 1, 1957 – January 31, 1957*, General Electric Company, Richland, Washington.
- HW-51026, 1957, *Leak Detection – Underground Storage Tanks*, General Electric Company, Richland, Washington.
- LET-082172, 1972, “Maximum Operating Levels and Cascade Levels in 200-West Area Tank Farms” (internal letter from H.N. Raymond to C.J. Francis, August 21).
- LET-72730-80-097, 1980, “Review of Classification of Six Hanford Single-Shell “Questionable Integrity (QI)” Tanks” (internal letter from W.M. Lindsay to W.W. Schulz September 16).

- Oblath, S. B. and J. W. Congdon, 1987, "Inhibiting Localized Corrosion during Storage of Dilute SRP Waste", *Waste Management '87*, Volume 1, Tucson, AZ: Arizona Board of Regents: 599-602.
- OSD-T-151-00007, 2012, *Operating Specifications for the Double-Shell Storage Tanks*, Rev. 10, Washington River Protection Solutions, LLC., Richland, Washington.
- OSD-T-151-00017, 1983, *Operating Specifications for the Aging Waste Operations in Tank Farms 241-AZ and 241-AZ*, Rev. B-0, Rockwell Hanford Operations, Richland, Washington.
- OR 75-67, 1975, *Liquid Level Decrease in Tank 110-U*, Atlantic Richfield Hanford Company, Richland, Washington.
- PNL-5488, 1985, *Prediction Equations for Corrosion Rates of A-537 and A-516 Steels in Double Shell Flurry*, Pacific Northwest Laboratory, Richland, Washington.
- PNNL-13571, 2001, *Expert Panel Recommendations for Hanford Double-Shell Tank Life Extension*, Pacific Northwest National Laboratory, Richland, Washington.
- RHO-CD-896, 1980, *Review of Classification of Nine Hanford Single-Shell "Questionable Integrity" Tanks*, Rockwell Hanford Operations, Richland, Washington.
- RHO-CD-1172, 1981, *Survey of the Single-Shell Tank Thermal Histories*, Rockwell Hanford Operations, Richland, Washington.
- RHO-ST-34, 1981, *A Scientific Basis for Establishing Drywell-Monitoring Frequencies*, Rockwell Hanford Operations, Richland, Washington.
- RHO-RE-EV-4P, 1982, *Supporting Information for the Scientific Basis for Establishing Drywell Monitoring Frequencies*, Rockwell Hanford Operations, Richland, Washington.
- RPP-7729, 2001, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-U Tank Farm – 200 West*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.
- RPP-8321, 2001, *Analysis and Summary Report of Historical Drywell Gamma Logs for the 241-C Tank Farm 200 East Area*, CH2M HILL Hanford Group Inc., Richland, Washington.
- RPP-20820, 2004, *Waste Retrieval Leak Evaluation Report: Single-Shell Tanks*, Rev. 0, CH2M HILL Hanford Group Inc., Richland, Washington.
- RPP-32681, 2011, *Process to Assess Tank Farm Leaks in Support of Retrieval and Closure Planning*, Rev. 1, Washington River Protection Solutions, LLC., Richland, Washington.
- RPP-36007, 2007, *Small Diameter Geophysical Logging in the 241-U Tank Farm*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-ASMT-53793, 2012, *Tank 241-AY-102 Leak Assessment Report*, Rev. 0, Washington River Protection Solutions, LLC., Richland, Washington.

RPP-RPT-33306, 2008, *IQRPE Integrity Assessment Report for the 242-A Evaporator Tank System*, Rev. 0A, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-ENV-39658, 2009, *Hanford SX-Farm Leak Assessments Report*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

RPP-RPT-43704, 2011, *Hanford BY-Farm Leak Assessments Report*, Rev. 0, Washington River Protection Solutions, LLC., Richland, Washington.

RPP-RPT-47337, 2011, *Specifications for the Mineralization of the Stress Corrosion Cracking Threat in Double-Shell Tank Wastes*, Rev. 0, Washington River Protection Solutions, LLC., Richland, Washington.

RPP-RPT-50097, 2011, *Hanford 241-U Farm Leak Inventory Assessment Report*, Rev. 0, Washington River Protection Solutions, LLC., Richland, Washington.

RPP-RPT-54909, TBD, *Hanford Single-Shell Tank Leak Causes and Locations – Summary*, Washington River Protection Solutions, LLC., Richland, Washington.

SD-WM-TI-302, 1987, *Hanford Waste Tank Sluicing History*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

SD-WM-TI-356, 1988, *Waste Storage Tank Status and Leak Detection Criteria*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

TFC-ENG-CHEM-D-42, 2009, *Tank Leak Assessment Process*, Rev. B-2, CH2M HILL Hanford Group, Inc., Richland, Washington.

WHC-EP-0449, 1991, *The Sort on Radioactive Waste Type Model: A Method to Sort Single-Shell Tanks into Characteristic Groups*, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0772, 1994, *Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single Shell Tanks*, Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0132, 1990, *A History of the 200 Area Tank Farms*, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-ER-325, 1994, *Historical Tank Content Estimate for the South West Quadrant of the Hanford 200 East Area*, Rev. 0, ICF Kaiser Hanford Company, Richland, Washington.

WHC-SD-WM-TI-591, 1994, *Maximum Surface Level and Temperature Histories for Hanford Waste Tanks*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-TI-665, 2003, *Soil Load above Hanford Waste Storage Tanks*, Rev. 0C, CH2M Hill Hanford Group, Inc., Richland, Washington.

WSRC-TR-90-512, 1990, *Effect of Temperature on the Nitrite Requirement to Inhibit Washed Sludge*, Westinghouse Savannah River Company, Aiken, South Carolina.

Appendix A
Meeting Minutes

June 25, 2013

August 6, 2013

September 10, 2013



MEETING SUMMARY

From: D. G. Harlow
Phone: 373-5514
Location: Ecology Office
Date: June 25, 2013
Subject: Tank Farm Leak Integrity Assessments

A handwritten signature in cursive script, appearing to read "D. G. Harlow".

To: Distribution/Attendees

Attendees:

Jim Alzheimer, ECOLOGY
Jim Field, WRPS
Les Fort, WRPS
Crystal Girardot, WRPS

Don Harlow, WRPS
Jeremy Johnson, ORP
Ted Venetz, WRPS

PURPOSE:

The purpose of this meeting was to review and discuss aspects of the Tank U-104 Leak Causes and Locations draft report; as well as undertake a final review of the May 29, 2013 Meeting Summary on tank C-105.

Tank U-104 Leak Causes and Locations Status

The results from the tank U-104 analysis were discussed. It was concluded that the tank U-104 liner failed as a result of a liner bulge at the bottom of the tank detected in July 1956. The measured 5-ft bulge in the liner was discovered at the end of a sluicing campaign following the tank being refilled with metal waste (MW). Designated leak test water was added to tank U-104 in 1957 and pumped out in 1961 with a determined release of approximately 48 kgal. Discussed was the plausible mechanism for the tank liner to bulge to the extent measured may be the result of vaporization of moisture under the liner. How the moisture at the suspected time of bulging got under the liner, became trapped, vaporized, and overcame the hydrostatic pressure when the tank was emptied is unknown. No liner bulge was reported after the first MW sluicing of the tank.

The drywells around tank U-104 were installed in the 1974-1976 timeframe, approximately 18 years after the bulge was discovered. The first loggings of drywells 60-04-08, 60-04-10, 60-07-01, and 60-07-11 measured radioactivity. Two additional direct pushes (C5597 and C5601) were made in 2007.

Drywells 60-04-08, 60-04-10, 60-07-01, 60-07-11, and direct push C5601 all indicate radioactivity that could be the result of a tank leak. Radioactivity was detected 50 to 55-ft below grade surface (BGS) which is 12 to 17-ft below the base of the tank. Direct push C5597, located 35.6-ft to the northeast of tank U-104 next to the cascade line, detected a peak at ~24-ft BGS indicating a near surface release such as a pipeline leak. However, the source remains unknown and a tank liner leak cannot be ruled out.

It was concluded that the bottom liner bulge was likely the result of waste thermal conditions. There appears to be little contribution from tank design, construction temperatures, and/or waste chemistry. Drywell readings indicate waste was released southeast of tank U-104 at or near the tank footing.

Tank C-105 Meeting Summary – May 29, 2013

The tank C-105 meeting summary with attached comments from the Tank C-105 Leak Causes and Locations segment including comment resolutions was handed out for review and approval.

ACTIONS:

1. All: Review the May 29, 2013 meeting summary from tank C-105 and provide comments by July 18, 2013.
Status: Complete.
2. All: Provide comments for the Tank U-104 Leak Causes and Locations report by July 18, 2013.
Status: Complete. No comments were received.

NEXT MEETING:

Review Tank U-110 Leak Location and Cause report.

Date: Tuesday August 6, 2013

Time: 2:30 pm

Location: Ecology Room 3B



MEETING SUMMARY

From: D. G. Harlow
Phone: 373-5514
Location: Ecology Office
Date: August 6, 2013
Subject: Tank Farm Leak Integrity Assessments

A handwritten signature in cursive script, appearing to read "D. G. Harlow".

To: Distribution/Attendees

Attendees:

Jim Alzheimer, ECOLOGY
Joe Caggiano, ECOLOGY
Crystal Girardot, WRPS

Don Harlow, WRPS
Jeremy Johnson, ORP

PURPOSE:

The purpose of this meeting was to review and discuss aspects of the Tank U-110 Leak Causes and Locations draft report; as well as undertake a final review of the June 25, 2013 Meeting Summary on tank U-104.

Tank U-110 Leak Causes and Locations Status

The results from the tank U-110 analysis were discussed. It was concluded that the tank U-110 liner failed probably as a result of chemistry corrosion from storage of REDOX concentrated salt waste and/or laboratory waste (chemical composition unknown). Tank U-110 was first suspected of leaking based on a 0.5-in liquid level decrease that was reported between May 24, 1975 and June 26, 1975. No temperature data was recovered for tank U-110 from May 1946 when the tank was first put into service until 1974, except for a one year period from August 1956 to August 1957. Temperatures during REDOX waste storage were high enough to cause evaporation from June 1954 to August 1955; however, there were no indications of self-boiling in the reports recovered. Temperatures of CW transferred to the tank after pumping REDOX waste were reported to be ~140°F in August 1956 and declined to ~115°F by August 1957.

The drywells around tank U-110 were installed in the 1973-1976 timeframe, shortly after the tank was suspected of leaking. The only drywell that measured radioactivity was drywell 60-10-07 (drilled in 1974) which reported an initial peak at 33-ft BGS and subsequent peak at ~54-ft BGS. One additional direct push (C5607) was made in 2007 (adjacent to drywell 60-10-07) which confirmed a radioactivity peak at ~52-ft BGS.

It was suggested in the meeting to add in the decay curves from document RPP-7729 for drywell 60-10-07 to the report or indicate the radionuclides in the text.

It was concluded that the tank U-110 liner leaked in the south southwest portion of the tank at or near the tank base possibly as a result of chemistry corrosion. There appears to be little contribution from tank design and/or construction temperatures.

Tank U-104 Meeting Summary – June 25, 2013

The tank U-104 meeting summary was handed out for review and approval.

ACTIONS:

3. All: Review the June 25, 2013 meeting summary from tank U-104 and provide comments by August 20, 2013.
Status: In Progress.
4. All: Provide comments for the Tank U-110 Leak Causes and Locations report by August 20, 2013.
Status: In Progress.

NEXT MEETING:

Review Tank U-112 Leak Location and Cause report.

Date: Tuesday September 10, 2013

Time: 2:30 pm

Location: Ecology Room 3B



MEETING SUMMARY

From: D. G. Harlow
Phone: 373-5514
Location: Ecology Office
Date: September 10, 2013
Subject: Tank Farm Leak Integrity Assessments

A handwritten signature in cursive script, likely belonging to D. G. Harlow.

To: Distribution

Jim Alzheimer, ECOLOGY
Mike Barnes, ECOLOGY*
Joe Caggiano, ECOLOGY*
Crystal Girardot, WRPS*
Don Harlow, WRPS*
Jeremy Johnson, ORP
Ted Venetz, WRPS
Dennis Washenfelter, WRPS
*Attendees

PURPOSE:

The purpose of this meeting was to review and discuss aspects of the Tank U-112 Leak Causes and Locations draft report, approve the August 6, 2013 Meeting Summary on tank U-110, and distribute the complete U Farm Leak Causes and Locations draft report.

Tank U-112 Leak Causes and Locations Status

The results from the tank U-112 analysis were discussed. It was concluded that the tank U-112 liner failed probably as a result of chemistry corrosion from storage of REDOX concentrated salt waste (for a total of about 16 years) possibly coupled with bottom liner deformation (indicated in photographs of the waste surface taken March 1970). Tank U-112 was first suspected of leaking based on a 3-in liquid level decrease that was reported between February 1969 and March 1970 (RHO-CD-896). However, the leak may have started as early as December 1964 due to a declining liquid level and no transfers occurring during this time. No temperature data was recovered for tank U-112 from October 1947 when the tank was first put into service until 1976, except for a one year period from July 1956 to July 1957. Temperatures during this one year period were between 60 and 70°F which was two months after a reported 21 kgal of CW was added to 514 kgal of REDOX concentrated salt waste. Temperatures were likely less in tank U-112 as indicated compared to tank U-110 or U-111 as tank U-112 was the last tank in the cascade series.

The drywells around tank U-112 were installed in 1944 (drywell 60-00-08) and from 1970-1974, shortly after the tank was suspected of leaking. The only drywell that measured radioactivity was drywell 60-12-01 (drilled in 1974) which reported an initial peak at 50-ft BGS. One

additional direct push (C5605) was made in 2007 (located between drywells 60-12-01 and 60-12-03) which indicated moisture but only background levels of radioactivity.

It was suggested in the meeting that additional direct pushes are being performed in U Farm this fiscal year and possibly next fiscal year for U Farm and TX Farm and to add in any relevant results to the leak causes and locations reports as appropriate.

It was concluded that the tank U-112 liner leaked in at least one location in the north northeast portion of the tank at or near the tank base possibly as a result of chemistry corrosion. There appears to be little contribution from tank design and/or construction temperatures.

It was also suggested in the meeting to add in any available information on the contractor used during the construction of B, C, T, and U Farms and whether the same contractor was used for these tank farms or if multiple contractors were used. No records have been recovered indicating the quality control during construction of these earlier tank farms.

A revision to Figure 2-1 in the report was suggested to include tank U-101 as an assumed leaker which is identified in the Waste Status Summary monthly reports (HNF-EP-0182). Tank U-101 was subsequently designated to be assessed by the procedure TFC-ENG-CHEM-D-42 in RPP-RPT-50097 and therefore will not be analyzed for the leak causes and locations report. It was also recommended to add all of the 2007 direct pushes to this figure.

A comment was made during the meeting about whether sampling was done in the direct push (C5605) when it was installed in 2007. The report addresses this in Section 6.5.1.7 which identified moisture and spectral gamma logging performed in this direct push. Results identified elevated moisture contents but only background levels of Cs-137 were recorded. Relevant direct push results are included in the other two leaking U Farm tanks.

Tank U-110 Meeting Summary – August 6, 2013

The previously reviewed tank U-110 meeting summary was approved.

ACTIONS:

5. All: Review the September 10, 2013 meeting summary from tank U-112 and provide comments by September 24, 2013.
Status: Completed. Received editorial comments from Joe Caggiano and the meeting summary was updated.
6. All: Provide comments for the entire U Farm Leak Causes and Locations draft report by September 24, 2013.
Status: Completed. See Attachment I.

NEXT MEETING:

Review Tank T-106 Leak Location and Cause report.

Date: TBD
Time: TBD
Location: TBD

ATTACHMENT 1:

REVIEW COMMENTS with RESPONSES

J. A. Caggiano September 12, 2013

U FARM DRAFT REPORT COMMENTS

GENERAL:

1. There is a great deal of redundancy in this and other reports. The same information seems to be cut and pasted into several different sections. I would suggest you try to streamline the reports to reduce repetition. It gets tedious reading the same lines over and over. Some readers might get offended at this.

Response: Sections 1 and 2 of the document were designed to present background information on the tank farm in the document. Section 3 deals with common design features and construction details relevant to waste storage. Basic in-tank and ex-tank background is also presented in this section to be applied to individual leaking tanks that could affect causes for liner leaks and identification of possible liner leak locations. The last two subsections indicate how the previous information is used to address leak locations and causes. The next section(s) develop in-tank and ex-tank specific information for individual leaking tank(s). The individual leaking tank sections contain some consolidated information from sections 1 through 3 to be as close to stand alone as possible. This includes presenting relevant information as scenarios are developed through summaries of a leak cause and a leak location to a final conclusion. This results in repeating some information as the discussion progresses. This should help the reader who may want information on only one specific tank or a specific subsection to understand some of the background without referring to background section unless further information is needed.

2. Push holes are NOT drywells. They are generally constructed in pairs; the first hole is used for logging moisture and gross gamma to select intervals for sampling in the second hole that is generally pushed very nearby. These are one time logs and samples with no potential for later logging or sampling, as these holes are decommissioned shortly after their one-time use is completed. Drywells remain open (but capped and locked) so as to remain accessible for logging as conditions require. Most drywells were logged multiple times.

Response: Deleted the word “drywell” as it relates to direct pushes.

SPECIFIC COMMENTS:

1. Pg. i, para 4. First sentence should be amended to indicate radial “transport in the soil.”

Response: Inserted “transport in the soil” after the word “radial”.

2. Pg. i, para 4. Last sentence should be amended to include “or to point of egress near the tank bottom.” Slow leaks from a cascade or spare inlet line might “dribble” down the

tank wall and then flow laterally once they hit the footing. But high levels of Cs-137 at tank bottom likely indicate a leak at that location.

Response: Agree, indications point to egress of the waste near the bottom of the tank. The depth of detected radioactivity between 50-ft and 54-ft BGS, more than 10-ft below the bottom of the tank base, seemed to point that way. Details pertaining to the individual tanks are in the individual tank sections and indicate liner leaks could follow different paths to the point of egress to the soil. Also where there are indications of overfilling above the cascade or inlet lines such as tank U-112 the possibility of leakage from those sites are addressed.

3. Pg. 2-2. This figure needs to be either re-titled, or amended to include the C-200 series tanks. You may want to designate U-101 as an “assumed leaker” from the Hanlon reports which the leak assessment team did not believe.

Response: Retitled the figure, included tank U-101 as an assumed leaker, and modified the footnote pertaining to tank U-101 to indicate it was not included in the document and why. The 200 series tanks have not been included as they are not in the scope of the milestone.

4. Pg. 3-6, last para in 3.1.2. As suggested in the meeting, you may want to check to see if different contractors were involved in tank farm construction and whether they might have had different quality control standards regarding welding steel plates.

Response: The same contractor (Morrison-Bechtel-McCone) built all 64 B, C, T, U Tanks (HAN-10970, Volume 1, page 271). This and other tank contractors will be addressed in either the summary document or in the Common Factors document.

5. Pg. 3-8, Sect. 3.2.3. Bulging is listed as a cause for tank failure, but bulging is an effect because of some unidentified cause on which one can speculate. I would also add that any buckling that remains in the elastic realm would not produce a permanent bulge, but could weaken the steel and facilitate SCC or some other form of corrosion.

Response: Added the statement that a bulge is typically caused by rapid vaporization of moisture under the liner and that stressing the liner may not produce a permanent bulge. Susceptibility to corrosion was already mentioned in the paragraph.

6. Pg. 3-9, para 1 discusses operating specification to prevent SCC which were developed in 1983, well after all the SSTs were out of service. Provides guidance in hindsight, but is “too little, too late” for SSTs.

Response: Agree. The paragraph indicates many investigations led to the 1983 specification. The individual tank sections compare available historical corrosion chemistry data to later specification as a means to identify possible liner failure causes.

7. Pg. 3-10, last para Sect. 3.2.4. Sentence reads, “Therefore, waste chemistry conditions are speculative when sample and temperature data...” Consider speculating and what might be done further to investigate these speculations.

Response: Revised the last paragraph of section 3.2.4 to address the speculation comment.

8. Pg. 3-11, Drywells. First you say that the earliest drywells were constructed in 1970-1976, and in the following paragraph talk about the “00” series of drywells constructed shortly after tank farm construction. Correct these inconsistencies.

Response: Section 3.3.2, second sentence; added the words “tank specific” after the word “earliest”, now reads, “The earliest tank specific drywells were installed” Tank Farm drywells “00” series are addressed later in the paragraphs.

9. Pg. 4-5, last para. What was the LL decline for the “leak test water” added to this tank in 1957 and that remained for almost 4 years?

Response: April 1957 to March 23, 1961, see Section 4.4.1 for the details on the leak test water liquid level decrease of 50k gal over ~4 years.

10. Pg. 4-7. The figure should be called “U-104 Operating History”. Titled “Leak History”, it suggests that every entry should describe a release. Check other similar figures as well.

Response: The title of Figure 4-2 is “Operational Leak History of Tank U-104” and was intended to gather both Operational and Leak information in one timeline with emphasis placed in red on the more important entries. Figures 5.2 and 6.2 have the same wording for tanks U-110 and U-112.

11. Pg. 4-9, last para. Could the periodic “leveling out” of LL be due to lower evaporation rates during the colder winter months? Just a question for consideration.

Response: There may be a seasonal effect but reviewing the actual data used for the Figure 4-4 plot indicates inconsistent seasonal effects. This could be some kind of a data problem but the observation was included to indicate apparent uncertainty with the liquid level decrease for such a long period of observation with no pumping action.

12. Pg. 5-5, para 2. If 39 kgal of water were added to this tank at a time when tank storage space was scarce, there had to be a reason and I would guess that it was to lower temperature from those considered too high for tank stability or at least beyond operating specifications. If so, temperature conditions are even further supported. Do you know why cooling water was added?

Response: A flex jumper was found leaking in the 204-S diversion box and the water was transferred (HW-56972 Page D-2) and HW-57122 page 4 indicates the 39k gal of water was from 204-S. There probably was a temperature reduction in tank U-110 but it appears that the primary reason for the transfer was to remove the water from 204-S. The temperature towards the middle of 1957 was ~115°F which was about a year before the water transfer.

13. Pg. 6-5, para 5. 549 kgal would be about 19 kgal above the listed capacity for this tank and definitely an overfill which is supported by the “beach line” in Fig. 6-5. That raises the question of how reliable earlier LL were, given that this “new level” was found after replacing an electrode.

Response: Agree. The liquid level measurement reliability especially in the earlier years is a large subject to tackle and may not change the basic conclusions of the causes and locations of a tank liner leak. Reliability of liquid level as it relates to identifying tank leak causes and locations has been handled on a tank by tank basis by dropping suspect data, trending, identifying second sources, identifying collaborating information, and others. We plan on addressing this subject in the summary document.

14. Pg. 6-11, para 2 speaks of adding 21 kgal of CW which would be an overflow and probably to cool waste that was considered too hot and out of spec. Should any of this be mentioned?

Response: Figure 6-4 shows the liquid level above the cascade inlet with the liquid level decreasing. However, the liquid level continued to decrease after reaching the cascade inlet which indicated a leak. Section 6.4.2 indicated that the U-110 liquid level slowly decreased (probably as a result of the waste temperature and evaporation). However, the third tank in the cascade, tank U-112 did not experience a decreasing liquid level e.g. lower temperature and less or no evaporation. How much of a temperature effect the 21 kgal of CW had on the 514 kgal of cascaded REDOX waste in tank U-112 is speculative without detailed temperature data, however, two months after receiving the 21 kgal of CW, sludge temperatures range between 70°F and 60°F. Therefore, the temperature of the REDOX waste in tank U-112 must have been relatively low at least compared to tank U-110. Therefore, a projected average temperature was indicated as near 100°F (see Sections 6.4.1 and 6.4.2).

15. Pg. 6-13. In discussing the “replacement of tank bottom liners”, an April 1944 report is cited. As construction began in February, how far along could construction have been? Something seems amiss here.

Response: Construction of U Farm began in February 1944; however, the replacement of the bottom liners discussed in the April 1944 report is referring to the construction of T Farm. A photo was taken on January 19, 1944 of T Farm construction (P1147, N1545817) that indicates construction of the tank pads started earlier as some steel was laid out for a part of one tank. Photo P1955 N 1557899 taken March 23, 1944 shows the T Farm construction of the tanks with the knuckles in place. Photo P6507 N 1603404 taken September 2, 1944 shows the farm in the process of backfill. Photo P4709 N 1591787 taken September 19, 1944 shows the final backfilling of the farm. The time line is OK.