RPP-ASMT-46452
Revision 0

Tank 241-C-105
Leak Assessment Completion Report

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EXECUTIVE SUMMARY

Tank C-105 is a 530,000 gallon capacity, 75-foot diameter, mild steel-lined, reinforced concrete tank located in the southeast part of the 16-tank 241-C Tank Farm. The tank was placed in service in February, 1946, and deactivated in 1979. It was interim stabilized in 1995. The tank is currently classified as a "sound" tank.

In August, 1974, a radiation increase at 40-ft below grade was detected in a drywell located between tanks 241-C-104 (C-104) and C-105. Ten additional drywells were drilled in the vicinity to investigate the contamination source. When drywell 30-05-07 was drilled near tank C-105 in 1974 a significant radiation peak was discovered extending from 40 to 60-ft. below grade. The subsequent leak evaluation concluded that tank C-105 was a sound tank. Similar leak evaluations completed in 1976, 1988, and 1993 also concluded that tank C-105 was sound.

In February, 2008, a comprehensive review of previous tank waste loss events was completed for the 241-C Tank Farm, and documented in RPP-ENV-33418 Rev. 1, *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Releases*. The assessment concluded that the contamination around tank C-105 resulted from multiple events, and that the soil contamination detected in drywell 30-05-07 probably resulted from a tank leak. Subsequent to the report, a commitment for a tank C-105 formal leak assessment was made in letter 08-TPD-015, S. J. Olinger, Office of River Protection, to J. A. Hedges, State of Washington Department of Ecology, "Hanford C Farm Leak Assessments," April 9, 2008.

A leak assessment panel of experienced Washington River Protection Solutions, LLC engineers and managers was assembled to review the tank C-105 historical data and evaluate the tank's leak integrity. The team met between October 9, 2008, and November 17, 2008, to gather and review information, develop the Leak and Non-Leak Hypotheses, and reach a consensus recommendation for tank C-105. The recommendation was reported in RPP-ASMT-39801 Rev. 0, *Tank 241-C-105 Leak Assessment*:

> "...the existing 'Sound' leak integrity classification for tank C-105 [should] be maintained pending the collection of additional field data from a 'direct push' sample taken immediately adjacent to the cascade line penetration, and as close to the tank footing as practical. Following analysis of the direct push sample, the leak integrity status of tank C-105 would be revised, if necessary, and the leak assessment report revised and republished."

Direct push C7469 was completed in October, 2009. The leak assessment panel reconvened to review the direct push C7469 radiation log results and information from the 2008 leak assessment. During the review, the panel revised the 2008 Leak and Non-leak hypotheses:

Leak Hypothesis:

> "The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank was a tank leak."

Non-Leak Hypothesis:

> "The soil contamination peak in drywell 30-05-07 at the base of the tank was due to an overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base."

Log data from direct push C7469 indicate tank waste had overflowed through the tank sidewall inlet cascade line penetration, and moved downward through the soil column close to the tank. Soil contamination peaked at about 28-ft below grade before starting to decrease. The soil contamination continued to decrease with depth before rising again in a second, much more intense contamination peak at the base of the tank.

There is historical evidence that the tank sidewall spare inlet penetrations also experienced overflow leakage. However the soil contamination pattern beneath the spare inlet penetrations is different from that found near the inlet cascade line penetration.

The leak assessment panel's consensus probability of a leak from the tank was 0.42. A probability of < 0.5 favors the non-leak hypothesis – a waste overflow through the inlet cascade line penetration.

There was also consensus among the members of the leak assessment panel that a leak from tank C-105 could not be ruled out by the evidence from the Direct Push C7469 and other available data. The leak through the inlet cascade line penetration may have contributed to the peak at the base of the tank, but the extent is uncertain, and a tank leak is also plausible.

The panel recommended that the leak integrity status of tank C-105 be changed from "Sound" to "Assumed Leaker"; and that the estimated leak volume of < 2,000 gallons be adopted from RPP-ENV-33418 Rev. 1, *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Releases.*

The leak assessment results were presented to the Executive Safety Review Board on April 9, 2010. The Board concurred with both recommendations.

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Abbreviations and Acronyms

bgs	below ground surface
DOE-GJO	U.S. Department of Energy Grand Junction Office
DOE-ORP	U.S. Department of Energy Office of River Protection
FY	Fiscal Year
GM	Geiger-Mueller (radiation counter)
RCRA	Resource Conservation and Recovery Act of 1976
SGLS	spectral gamma logging system
SST	single-shell tank

Units

cfm	cubic feet per minute
Ci	curies
ft	foot
gal	gallon
in	inch
in^2	square inch
kgal	kilogallon (10^3 gallons)
μCi/ml	microcuries (10^{-6}curies) per milliliter soil
pCi/g	picocuries (10^{-12} curies) per gram soil

1.0 INTRODUCTION

This document describes the completion phase and provides the conclusion of the tank 241-C-105 (C-105) formal leak assessment first reported in RPP-ASMT-39801 Rev. 0, *Tank 241-C-105 Leak Assessment Report*. The earlier report recommended that the leak assessment be suspended pending the collection of additional field data from a 'direct push' sample taken immediately adjacent to the cascade line penetration, and as close to the tank footing as practical. Direct push C74691 was completed and logged in October 2009, and the leak assessment reopened.

Tank C-105 is a 530,000 gallon capacity, 75-ft diameter, mild steel-lined reinforced concrete single-shell tank located in the southeast part of the 16 tank 241-C Tank Farm. The tank was placed in service during the first quarter of 1955, and continued to receive and store waste until 1979 when the supernatant was removed. The tank was determined to comply with the interim stabilization criteria in October, 1995. The current inventory is 132-kgal sludge and 10-kgal drainable liquid (HNF-EP-0182, Rev. 261, *Waste Tank Summary Report for Month Ending December 31, 2009*).

The leak integrity status of tank C-105 first became suspect in 1974. After a radiation increase at 40-ft below ground surface (bgs) was discovered in drywell 30-04-02 between tanks C-104 and C-105, ten additional drywells were drilled in the vicinity. During installation of six of the drywells, highly contaminated soil had to be removed from near both ends of the cascade line connecting tank C-104 and tank C-105.

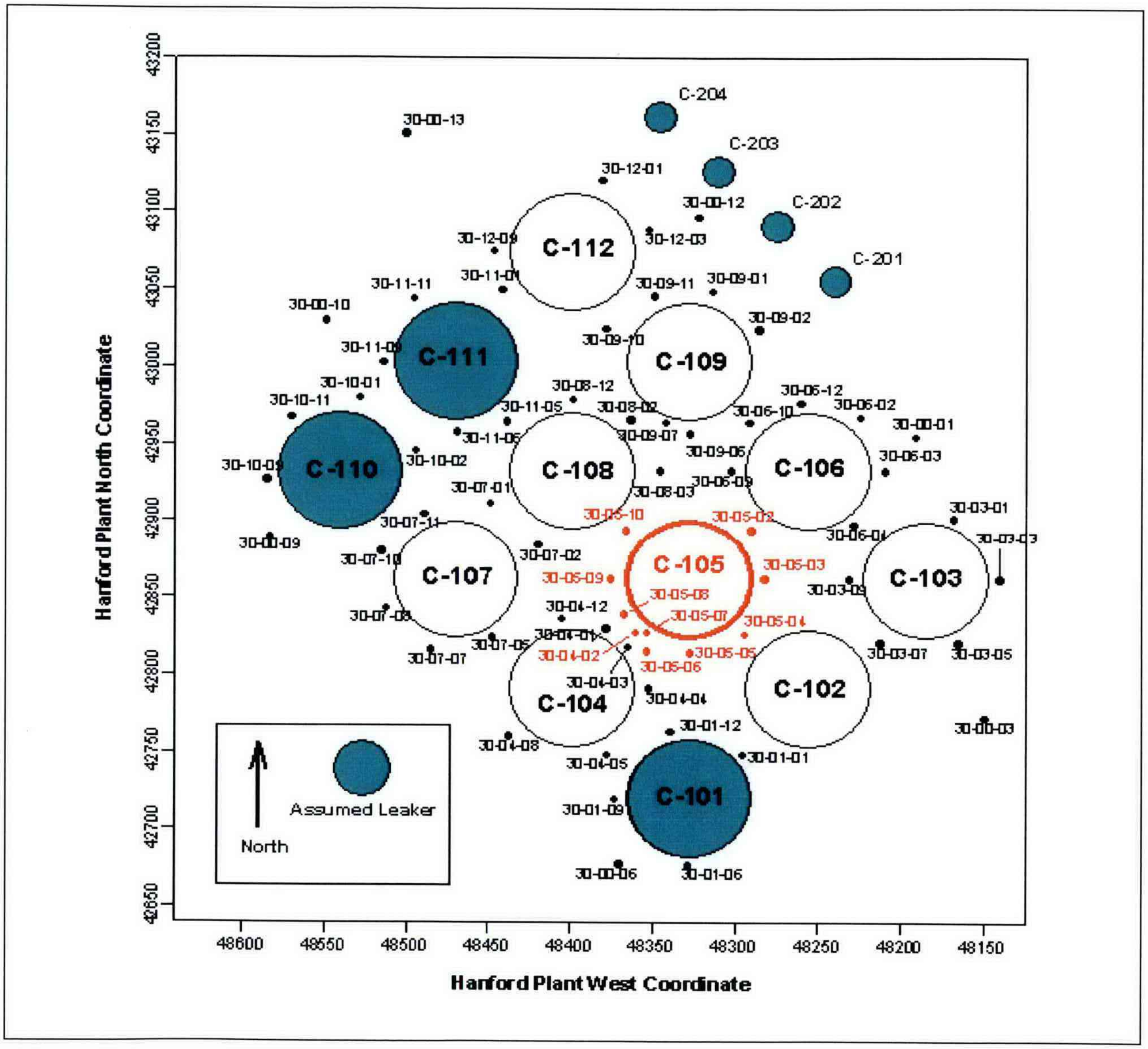
When drywell 30-05-07 was drilled close to tank C-105, a significant radiation peak was detected extending from 40-ft to 60-ft bgs. The peak radiation in the drywell was a factor of about $10^4 - 10^6$ times greater than radiation in any of the surrounding drywells, and there was no significant soil contamination from the ground surface down to the peak. Additional drywell scans between 1980 and 1997 interpreted the peak as a stable Cs^{137} peak, i.e., decaying according to the Cs^{137} half-life. An increase in the size of the peak was never detected.

After the drywell 30-05-07 discovery, the tank continued to be used in active service until 1978. Three leak assessments performed between 1974 and 1993 concluded that the tank was sound.

This report primarily focuses on the log data from direct push C7469 and their interpretation in context with other tank events. When necessary information from the earlier leak assessment document has been repeated to ensure a complete, stand-alone report of the formal leak assessment is presented.

Figure 1-1 Plan View of Tanks and Drywells in the 241-C Tank Farm

Tank C-105 is the second tank in the tank C-104, C-105, C-106 cascade. Drywells illustrated in the plan are identified by their associated tank number and clock position from North. (from GJ-HAN-83, Vadose Zone Characterization Project at the Hanford Tank Farms – Tank Summary Data Report for Tank C-105)



2.0 METHOD OF ANALYSIS

The method of analysis used for the formal leak assessment was Engineering Procedure TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*. The formal leak assessment process is based on probabilistic analysis to assess the mathematical likelihood (probability) that a specific tank is leaking or has leaked. The technical basis for the process and examples of the methodology can be found in HNF-3747 *Tank Leak Assessment Technical Background*. This is the same process the was used for the 2008 tank C-105 leak Assessment.

The leak assessment continuation used the same panel of experienced engineers and managers that was used for the 2008 assessment. The panel consisted of: D. J. Washenfelder, (Assessment Coordinator, Technical Integration Program Manager); D. G. Baide, (Single-Shell Tank Retrieval and Closure Project Engineering Manager); D. A. Barnes, (Lead Surveillance System Engineer, In-Tank and Ex-Tank Surveillance); D. W. Brown, (Work Planning Project / Single-Shell Tank and Administration Manager); J. G. Field (Closure and Corrective Measures, Single-Shell Tank Retrieval and Closure Engineer); and L. S. Krogsrud (241-C Tank Farm System Engineer). The team was augmented with one additional member, D. G. Harlow (Consultant, Technical Integration) who has current and prior tank farm experience. The team met between March 8, 2010 and March 12, 2010 to gather and review information, review and revise the Leak and Non-Leak Hypotheses, generate expert elicitation input, and reach a consensus recommendation for tank C-105.

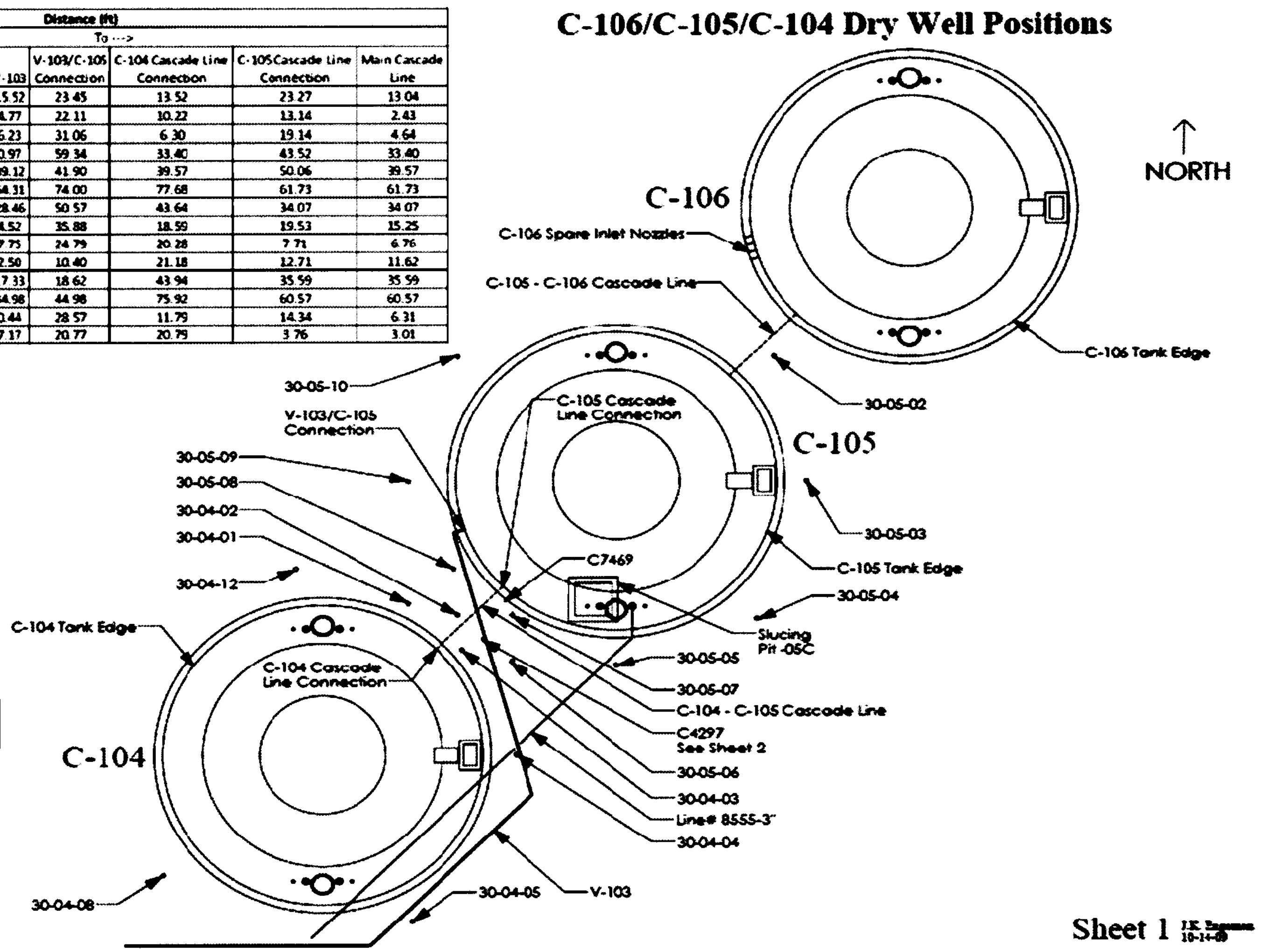
3.0 TANK C-104 – C-105 – C-106 DRYWELLS

Ten additional drywells were drilled to investigate the source of the 1974 radiation increase detected at 40-ft bgs in drywell 30-04-02 located between tanks C-104 and C-105 (Occurrence Report 74-120, *Increasing Dry Well Radiation Between Waste Tanks 104-C and 105-C*). Data from the drywells were reviewed in the RPP-ASMT-39801 report. The review highlighted the significance of drywell 30-05-07. The drywell showed low levels of Cs^{137} soil contamination from the surface down to about 30-ft bgs. Below 30-ft bgs Cs^{137} soil contamination increased over the interval from 33-ft to 67-ft, the practical limit of the 70-ft deep drywell. The Cs^{137} concentration was as high as 10^8 ρCi/g, a factor of $10^4 - 10^6$x greater than measured in any of the surrounding drywells.

Figure 3-1 Tanks C-104, C-105, C-106 Drywell Locations

Distance (ft)							
From --->	To --->						
Dry Wells	C-104 Tank Edge	C-105 Tank Edge	V-103	V-103/C-105 Connection	C-104 Cascade Line Connection	C-105 Cascade Line Connection	Main Cascade Line
30-04-01	5.53	20.72	15.52	23.45	13.52	23.27	13.04
30-04-02	9.99	12.97	4.77	22.11	10.22	13.14	2.43
30-04-03	4.52	18.75	6.23	31.06	6.30	19.14	4.64
30-04-04	8.00	36.11	0.97	59.34	33.40	43.52	33.40
30-04-12	9.86	41.81	39.12	41.90	39.57	50.06	39.57
30-05-04	71.71	10.62	64.31	74.00	77.68	61.73	61.73
30-05-05	35.78	9.11	28.46	50.57	43.64	34.07	34.07
30-05-06	12.94	14.44	4.52	35.88	18.59	19.53	15.25
30-05-07	19.51	4.25	7.75	24.79	20.28	7.71	6.76
30-05-08	18.89	6.65	2.50	10.40	21.18	12.71	11.62
30-05-09	35.06	11.55	17.33	18.62	43.94	35.59	35.59
30-05-10	69.47	11.39	44.98	44.98	75.92	60.57	60.57
C4297	10.37	13.26	0.44	28.57	11.79	14.34	6.31
C7468	20.64	2.38	7.17	20.77	20.79	3.76	3.01

Coordinates		
Structure	North	West
C-106	42931.4	48257.16
C-105	42860.69	48327.87
C-104	42789.98	48398.58
30-05-10	42893.00	48366.00
30-05-09	42861.00	48375.00
30-05-08	42838.00	48367.00
30-05-07	42826.00	48353.00
30-05-06	42814.00	48353.00
30-05-05	42813.00	48327.00
30-05-04	42825.00	48294.00
30-05-03	42861.00	48282.00
30-05-02	42893.00	48290.00
30-04-12	42835.00	48405.00
30-04-08	42759.00	48437.00
30-04-05	42747.00	48377.00
30-04-04	42790.00	48352.00
30-04-03	42817.00	48365.00
30-04-02	42826.00	48366.00
30-04-01	42829.00	48378.00
C4297	42819.84	48359.79
C7469	42829.68	48354.63

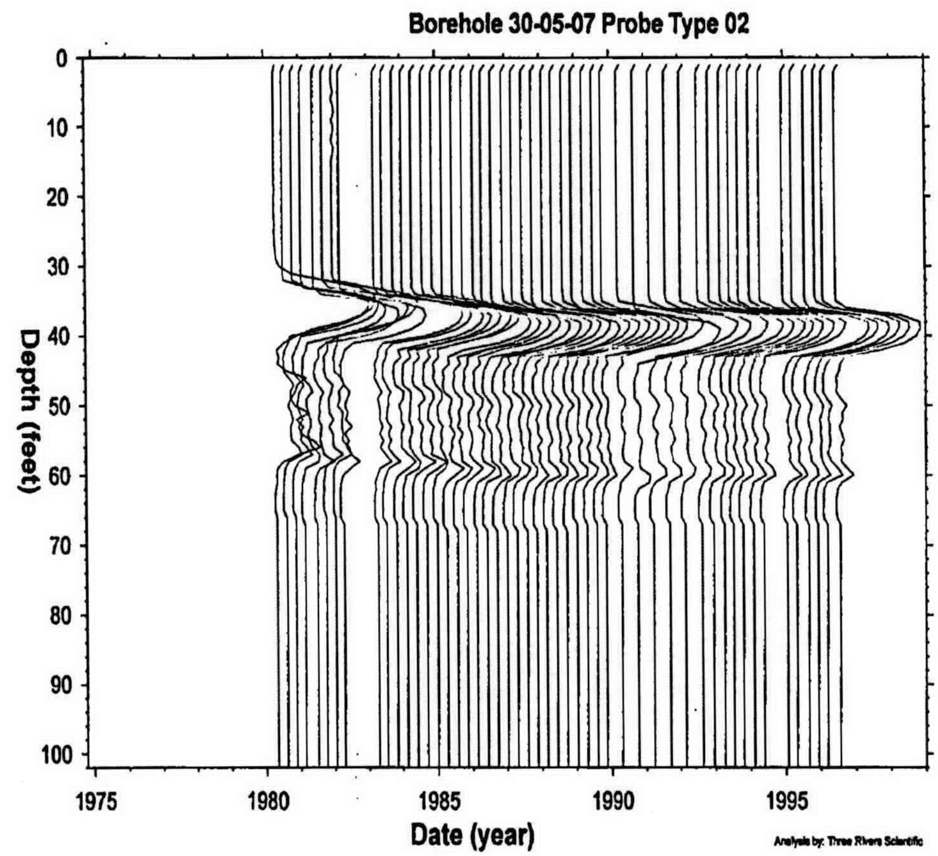


3.1 DRYWELL 30-05-07

Drywell 30-05-07 was drilled in July, 1974. A high activity peak was identified at a depth of 37-ft bgs with a GM probe (Figure 3-2).

Figure 3-2 Drywell 30-05-07 Gross Gamma

(from RPP-8321, Analysis and Summary Report of Historical Dry Well Gamma Log for the 241-C Tank Farm – 200 East Area)

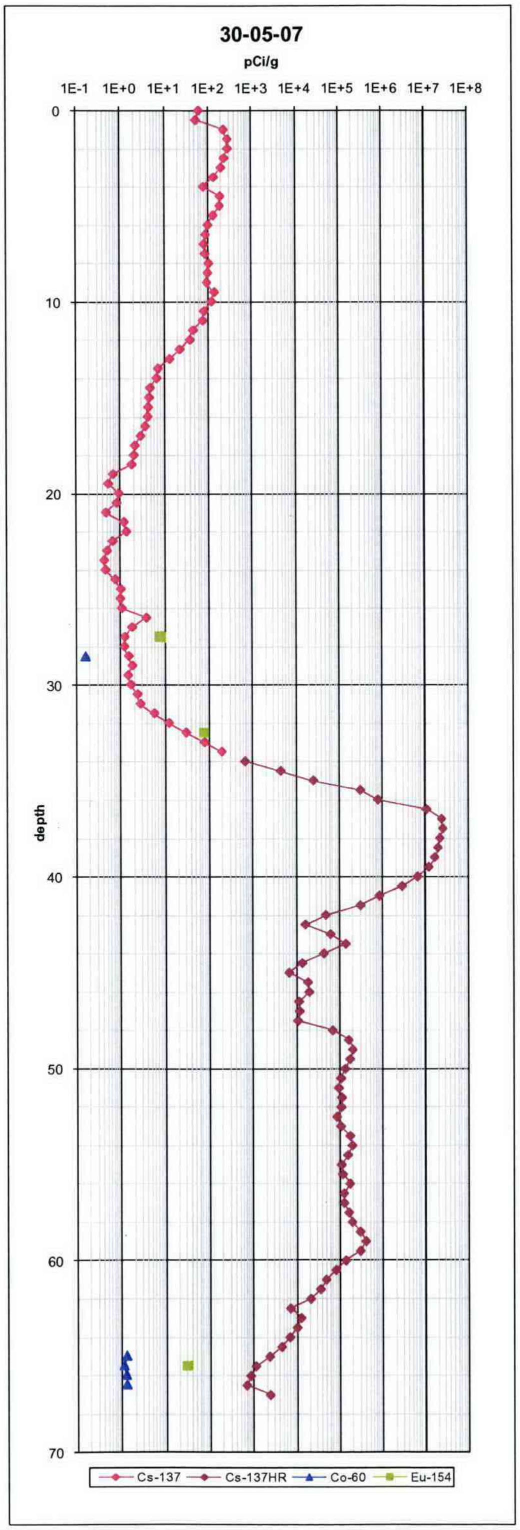


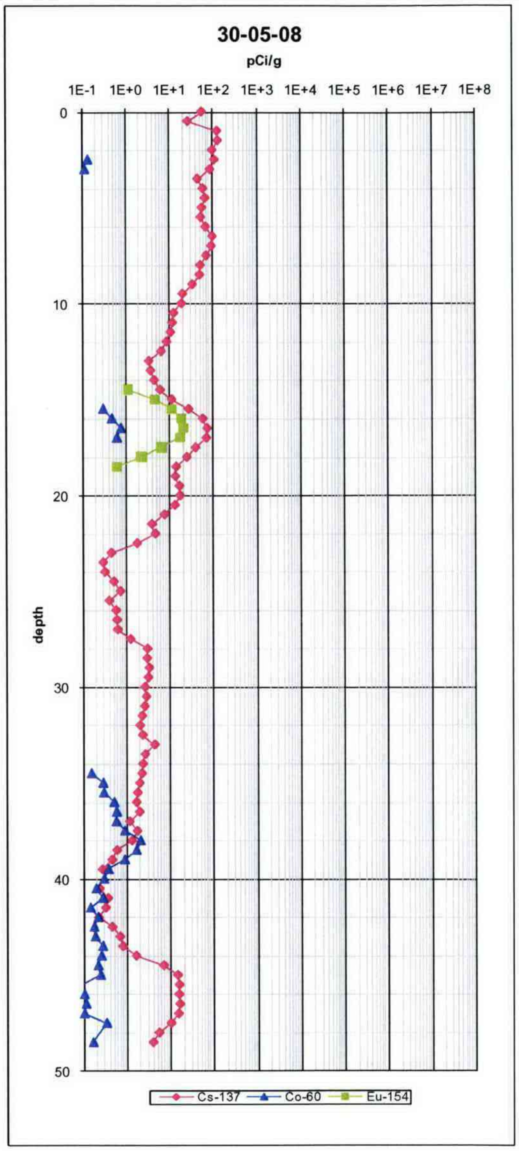
The gross gamma scans between 1974 and 1997, when the scans were discontinued, show that the peak was stable and decaying with a Cs^{137} half-life. The peak stability indicated that the peak was not being supplied by an active plume. If the peak was evidence of a tank leak, then the leak occurred prior to 1974 and apparently self-sealed by the time the drywell was drilled..

The Spectral Gamma Logging System (SGLS) was used to log the drywell in 1997. Figure 3-3 shows the SGLS log for drywell 30-05-07. The SGLS log for drywell 30-05-08, located about 20.5-ft from drywell 30-05-07, is shown for comparison.

Figure 3-3 Drywells 30-05-07 and 30-05-08 Spectral Gamma Logs

(from GJO-HAN-18, Vadose Zone Characterization Project at the Hanford Tank Farms – Tank Summary Data Report for Tank C-105 Addendum)





3.1.1 SELF SEALING TANK LEAKS

There is historical evidence that suggests leaking single-shell tanks can self-seal. These tanks generally have contained saturated salt waste. Tank C-105 stored unsaturated supernatant and sludge. Compared to saltcake solids, sludge solids are very fine, and contain a smaller amount of interstitial liquid. Capillary forces are high, making sludge slow draining, if it drains at all. Most sludge is highly viscous with a peanut butter-like consistency. It is possible that a small leak site could be closed off by a sludge plug comprised of fine solids.

Tank A-105 is an extreme example of the self-sealing properties of sludge. In January, 1965, the tank experienced a major steam eruption. The eruption bulged the bottom liner and tore it away from the sidewall around ¾ of the liner's circumference (Figure 3-4). Between January, 1965 and August, 1968, the liquid level in the tank was held static by adding cooling water to offset evaporation. In August, 1968 sluicing was started to remove the waste. The extent of damage was not revealed until the tank had been sluiced and the liner exposed.

During the 3-1/2 year period before the tank was sluiced, the estimated leakage was between 5-kgal and 15-kgal. After sluicing, an estimated 37-kgal of sludge still remained in the tank. Considering the extent of liner damage, the only plausible explanation for the relatively small leak volume is that the sludge sealed most of the leak path out of the tank.

If sludge in tank A-105 could self-seal the liner damage caused by the steam eruption, it is plausible that sludge could also self-seal smaller leaks in other tanks such as tank C-105.

. Figure 3-4 Torn and Buckled Liner in Tank A-105

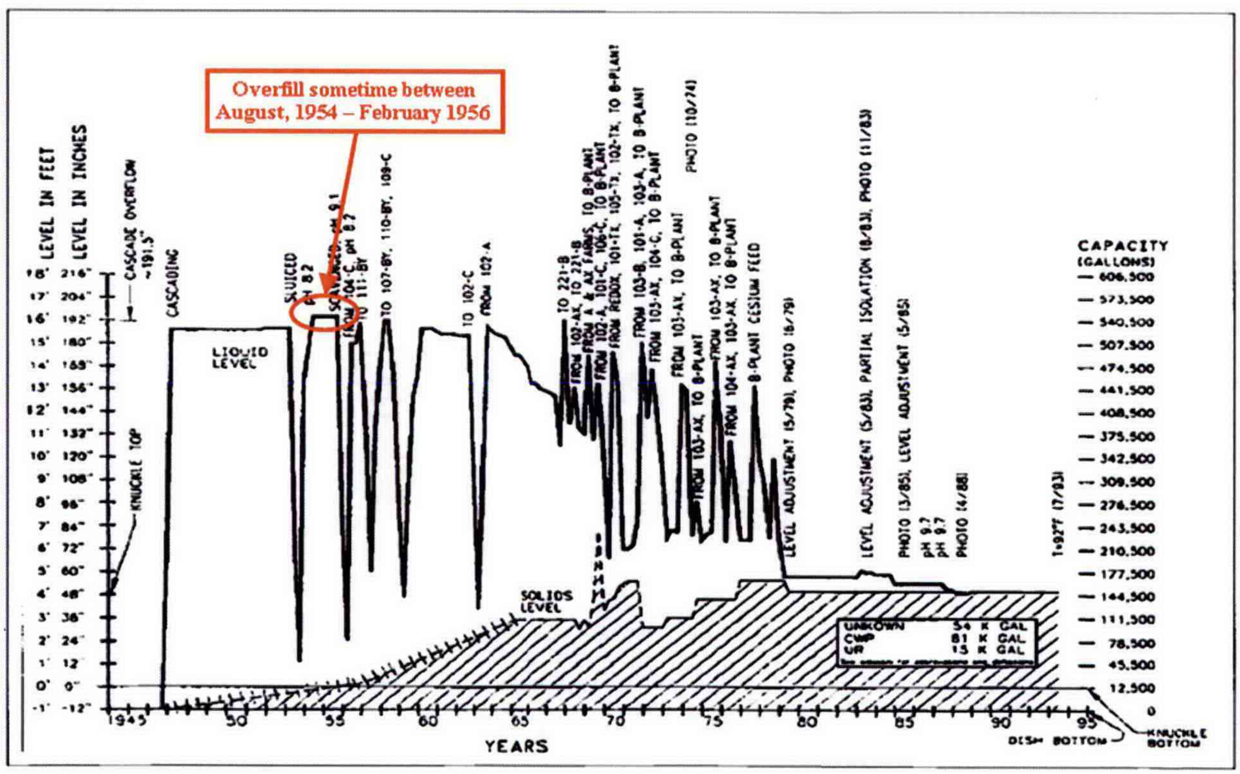
4.0 WASTE LEVEL

Quarterly production records show the waste volume in tank C-105 as 546-kgal during the August, 1954 – February, 1956 period (Figure 4-1). At this volume the inlet cascade line sidewall penetration would have been partially submerged in waste.

It is very likely that the stored volume was even greater than reported. In-tank photographs taken in October, 1974, and March, 1985, show evidence of a waste "beachline" above the cascade line inlet and the spare inlet sleeves in the tank sidewall (Figure 4-3). For the waste beachline to be this high, the stored volume would have had to exceed 558-kgal, submerging the inlet cascade line penetration and the four spare inlet line penetrations.

Figure 4-1 Tank C-105 Fill History

(from WHC-SD-WM-ER-349, Historical Tank Content Estimate for the Northeast Quadrant of the Hanford 200 East Areas)



Tank C-105 sidewall penetrations, their invert elevations at the sidewall referenced to the centerline of the tank bottom, and the liquid level and waste volume held in the tank at the invert elevations are displayed in Figure 4-2.

Figure 4-2 Tank C-105 Sidewall Penetration Elevations

(from H-2-1744, Tank Farm Riser & Nozzle Elev.; H-W-72743, Hanford Engineer Works – Bld. 241 75'-0" Dia. Storage Tanks T-U-B&C Arrangement; RPP-13109, Determination of Hanford Waste Tank Volumes; and W-71387, Hanford Engineer Works 75 Ft. Diam. Tanks Building No. 241 Concrete Details of Tank)

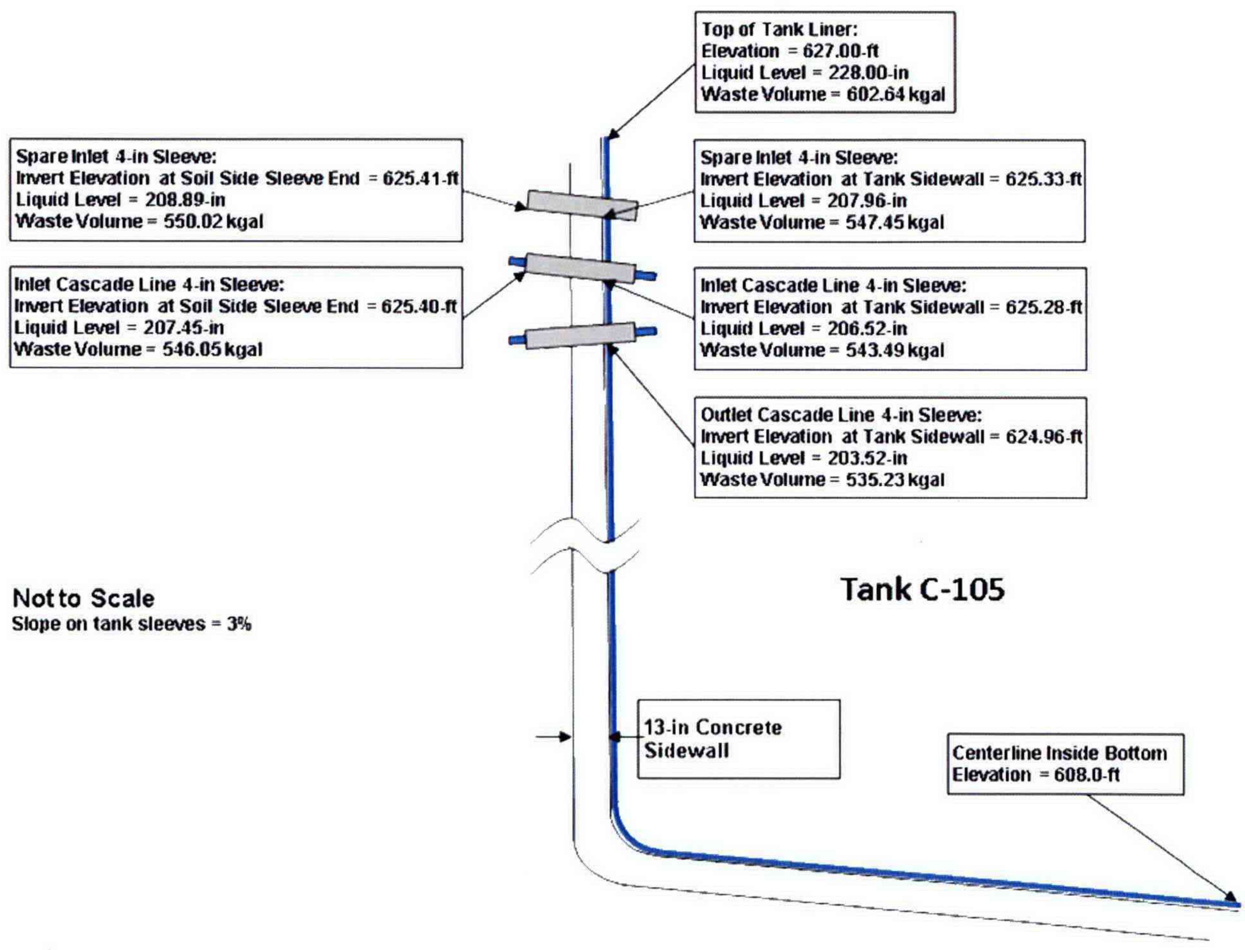
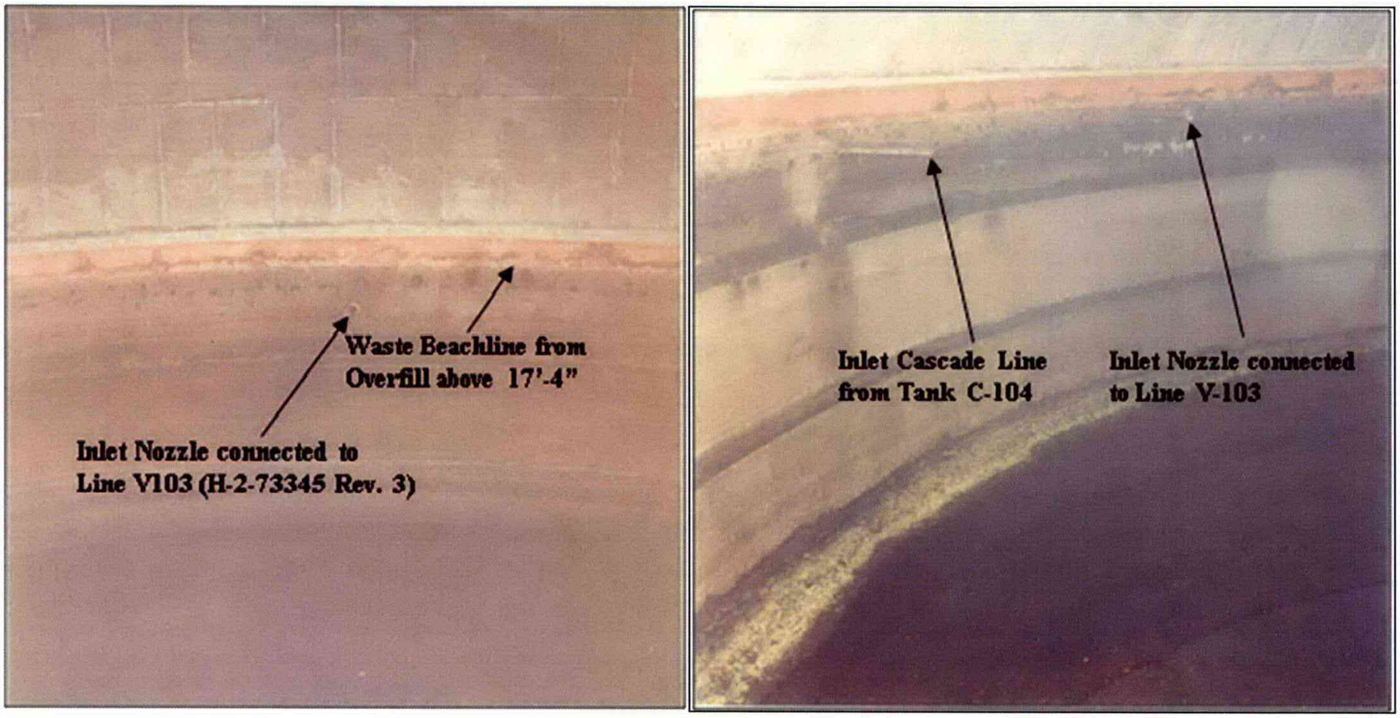


Figure 4-3 Tank C-105 Overflow Beachline with Cascade and Inlet Lines

Missing paint and the presence of a waste beachline above the spare inlet nozzles indicate that tank was filled above the spare inlets at one time. (Negative 746325-29CN, October 11, 1974) (from October 11, 1974 Negative 746325-29CN [Waste Level – 78.5-in] and March 28, 1985 Negative 8502079-6CN [Waste Level = 55-in])



There have been no unexplained waste level drops during the tank's operating history. Observed waste level decreases were attributed to evaporation.

4.1 CASCADE LINE LEAK

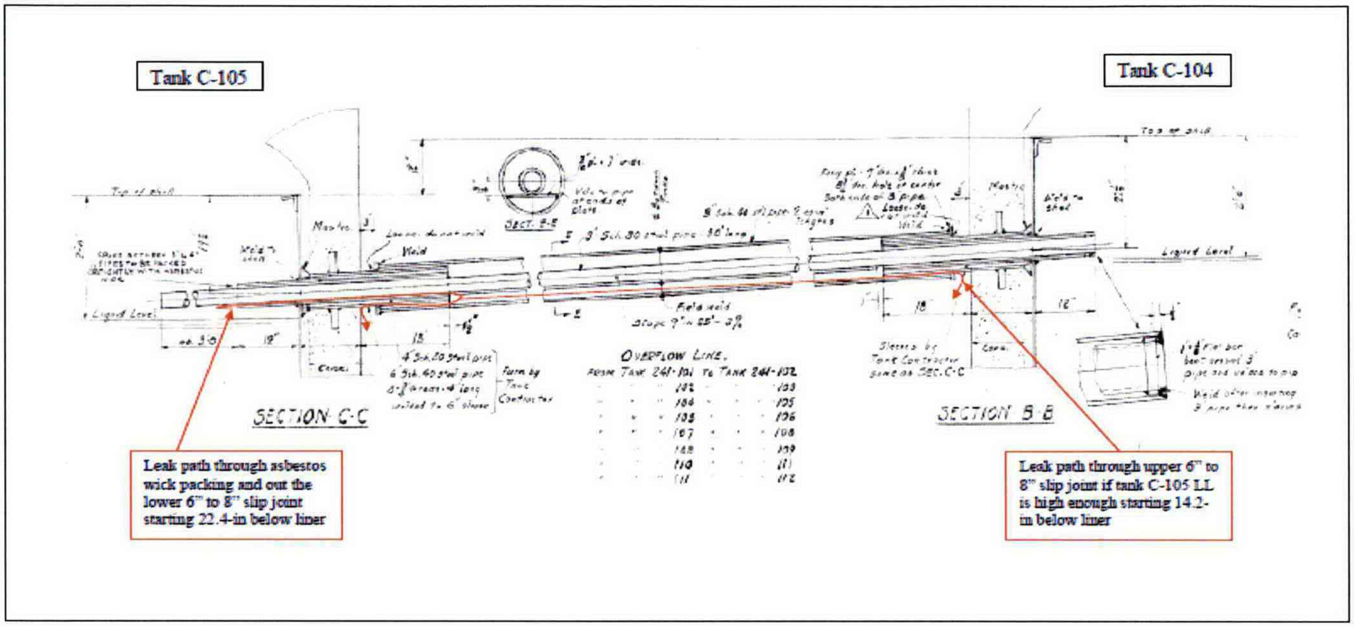
When the inlet cascade line and the spare inlet penetrations were submerged in the waste during the August, 1954 – February, 1956 period, it is likely that waste escaped through the sidewall penetrations.

The cascade line tank sidewall penetration consists of a 43-in long, 4-in diameter Schedule 80 pipe sleeve holding the cascade line. The 3/16-in annular space between the 4-in sleeve and the 3-in diameter Schedule 80 cascade line has a total cross-section of 1.88-in^2. During construction the space was tightly packed with asbestos wick to prevent waste from leaking through the gap if the tank was ever overfilled. It seems unlikely that the entire 43-in long annulus could have been packed with the asbestos wick considering its length and narrow width; probably the wick was inserted as far a practical from both ends and tamped in place.

The 4-in sleeve, in turn, is contained within a 6-in sleeve, which in turn is contained within an 8-in sleeve. Neither the 6-in sleeve, nor the 8-in sleeve, is sealed to the 4-in sleeve, so any waste making its way through the 4-in sleeve would eventually seep into the soil (Figure 4-4).

Figure 4-4 Tank C-104 to Tank C-105 Cascade Line Leak Paths

(*from Drawing H-W-72743, 75-ft Diameter Storage Tanks 241-T, U, B, & C, Arrangement*)



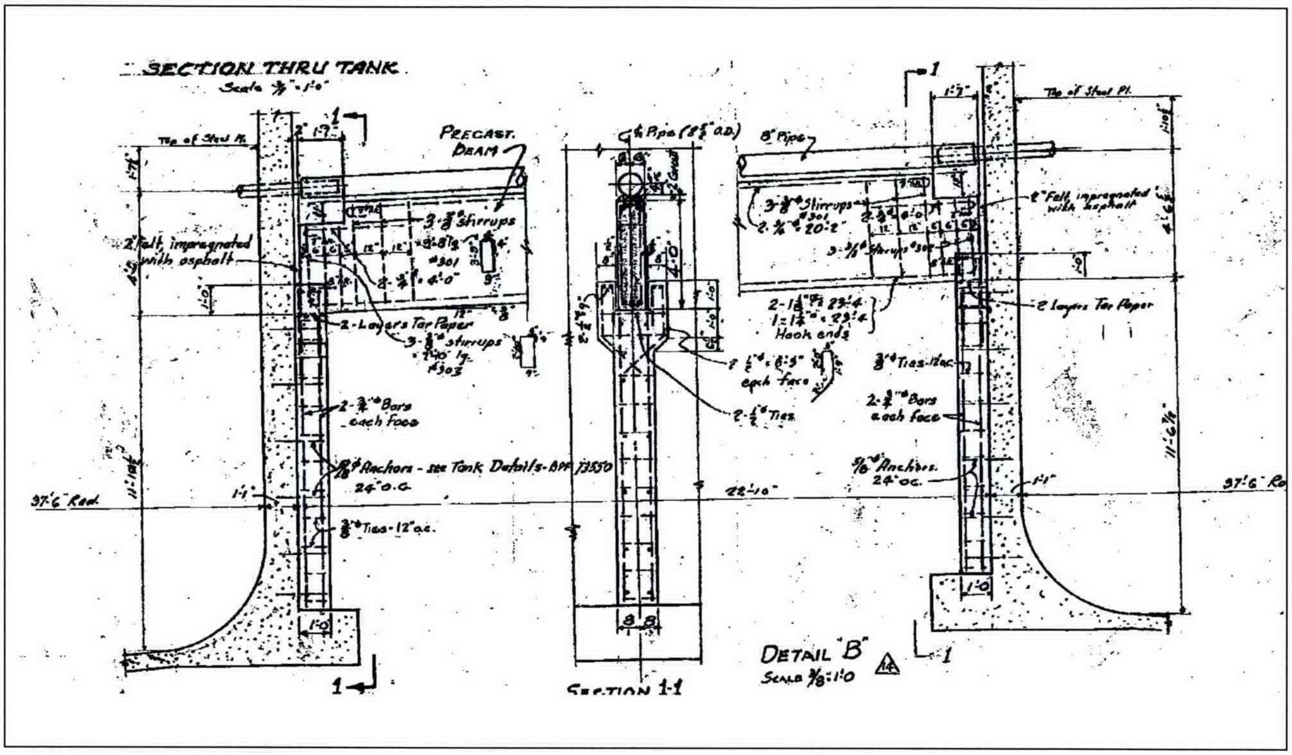
There is anecdotal evidence that the cascade line penetration would leak if it were submerged. The tanks in the 241-C tank farm are arranged in 3-tank cascades, with each downstream tank in the cascade set 12-in lower than the previous tank to facilitate gravity flow from one tank to the next, to the next. Tank C-104, located upstream of tank C-105, was equipped with both inlet and outlet cascade lines. The outlet penetration was set 3-in below the inlet penetration. During normal, gravity flow operation, the annular gap between the cascade line and the 4-in sleeve would be partially submerged. During installation of the drywells in 1974 evidence of past leakage was found near the tank C-104 outlet cascade line penetration.

If the outlet cascade line became plugged, then gravity drainage from the tank would stop, and the waste level would begin to rise, eventually backing into the inlet cascade line. The outlet line elevation is equivalent to 535-kgal of waste (Drawing H-2-1744 *Tank Farm Riser & Nozzle Elevations*). During the 1954 – 1956 period when the tank waste volume was reported as 546-kgal, the outlet cascade line must have been plugged. During that time, the waste level would have been about 1-inch above the outlet cascade line, completely submerging the asbestos wick-packed gap. The waste level would have been within 0.25-in of the bottom of the inlet cascade line's 4-in sleeve. Photographic evidence presented earlier shows that the inlet cascade line had been submerged by waste, indicating that the reported 546-kgal was understated.

The cascade line between tanks C-104 and C-105 is mounted on a concrete beam. The beam is supported by a series of vertical concrete columns. The arrangement is shown in Figure 4-5. At the tank C-105 sidewall the beam is supported by a concrete buttress attached to the tank sidewall. The concrete buttress extends from the base of the beam to the tank's footing. The interface between the buttress and the tank sidewall creates an inside corner on either side that extends the full length of the buttress.

Figure 4-5 Cascade Line Support Beam and Columns

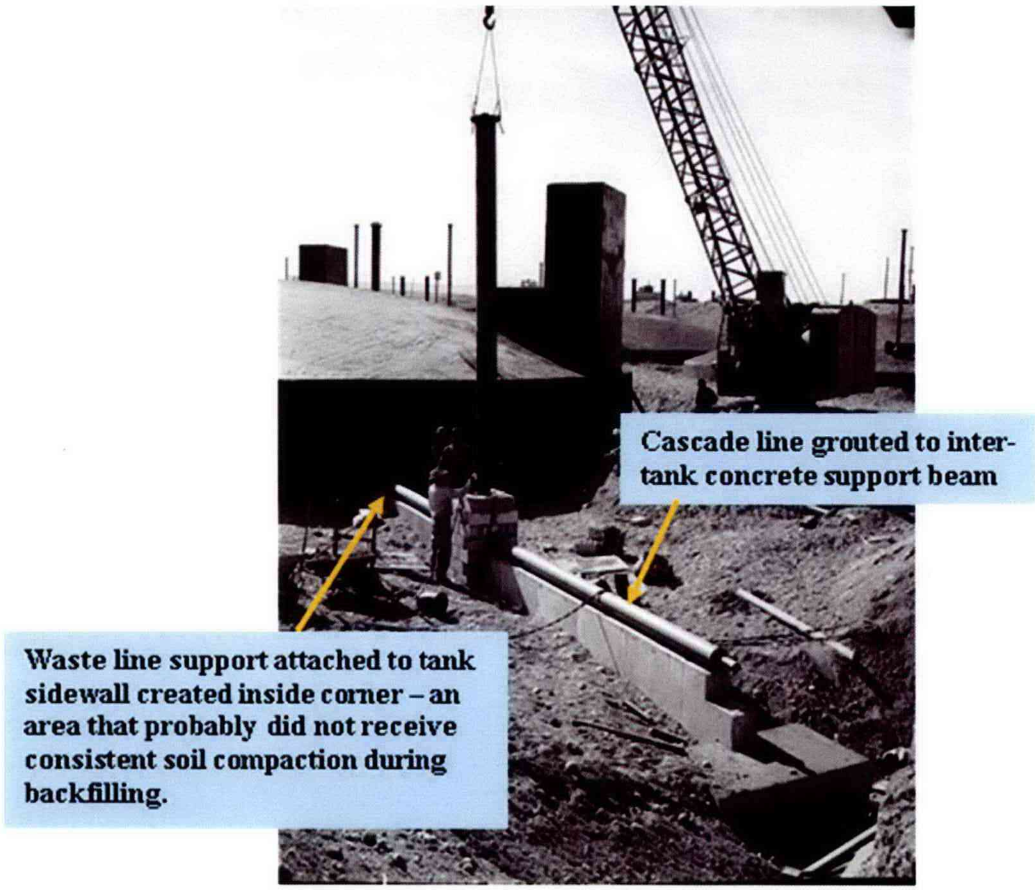
(*from Drawing W-71387, 75-ft Diameter Tanks 241-T, U, B, C, Concrete Details of Tank*)



The buttress and columns were installed before the tank excavation was backfilled. Once backfilling neared the tops of the columns, the beam was placed and the cascade line mounted on the beam (Figure 4-6). During backfilling, soil compaction of the inside corner formed by the buttress and the tank sidewall would have been problematic. It is likely that this area would not have been accessible for machine tamping, and therefore was probably not compacted to the same extent as the surrounding area. In the event of a leak through the cascade line penetration, the waste plume would move down through the loosely compacted soil column in the inside corner toward the tank footing. Lateral movement of the plume away from the inside corner would be restrained because of the higher compaction forces that had been applied to the backfill outside of the immediate area.

Figure 4-6 Cascade Line Installation in 241-BX Tank Farm

The 241-BX tank cascade line features illustrated in the photograph are identical to the 241-C tank features. Photographs of the 241-C tanks are not available.



4.2 SPARE INLET LINE PENETRATIONS

Tank C-105 was equipped with four spare inlet penetrations when it was constructed. The penetrations are located on 2-ft centers in the tank sidewall, about 1.5-in higher than the inlet cascade line.

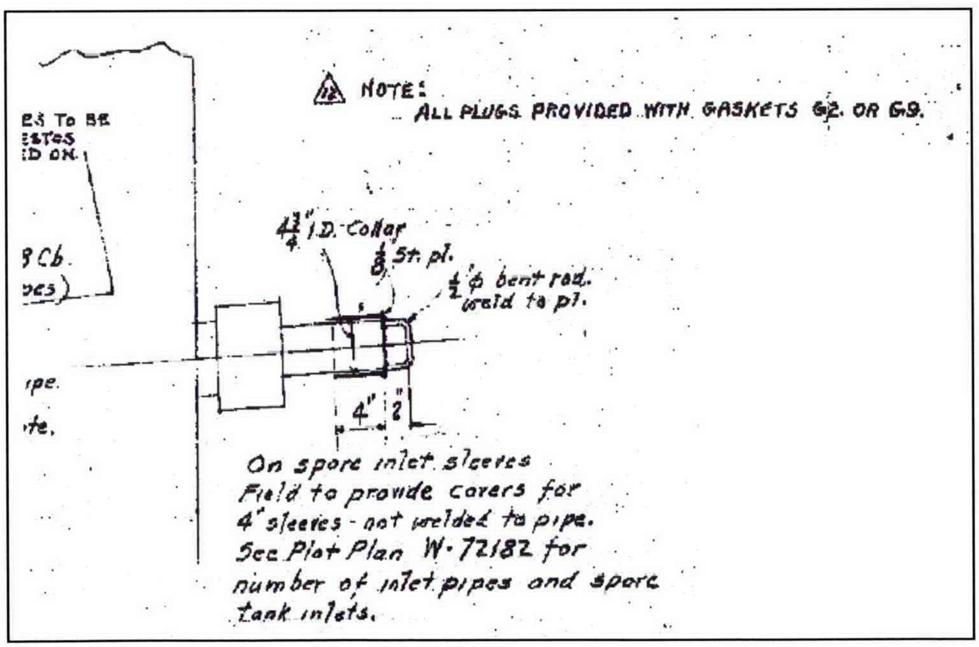
The penetrations consist of a 4-in schedule 80 open pipe stub covered on the soil side of the tank with a loose-fitting metal cap. The spare inlet penetration detail is shown in Figure 4-7. The 4-3/4-in id x 4-in long cap was fit over the 4-in pipe sleeve. The cover was not welded in place but provided with a gasket, according to the construction drawing. The outer diameter of 4-in Schedule 80 pipe is 4-1/2-in, so the clearance between the loose-fitting cap and the pipe sleeve was about 1/8-in. This created an open annular cross-section of about 1.82-in between the cap and the pipe sleeve. For the four spare inlet penetrations, the total open cross-sectional area was 7.26-in^2.

The as-built configuration of the spare inlet penetrations was investigated in 1951 after waste overflowed through a spare inlet on tank BX-102. Excavation revealed that, "... some [spare inlets] have blanks which are welded tight, some have tapered wooden plugs driven in the spare nozzle covered by a cap and sealed with waterproofing, and some have caps covered with a waterproofing membrane and then sealed in cement." (HW-20742, *Loss of Depleted Metal Waste Supernate to Soil*).

The tank C-105 spare inlet penetrations were excavated in October,1967, to connect one of them to the new V-103 process line. During the excavation, soil contamination of 3.71 µCi/ml (~1.8 x 10^6 pCi/g) was found beneath the penetrations indicating waste had leaked out through the caps. The Cs^{134}:Cs^{137} ratio of the contaminated soil indicated that the contamination was not from the waste stored in tank C-105 at the time of the excavation. There is no documentation of the as-found condition of the spare inlet penetrations or their loose-fit caps.

Figure 4-7 Spare Inlet Penetration and Cap

(*from Drawing H-W-72743, 75-ft Diameter Storage Tanks 241-T, U, B, & C, Arrangement*)

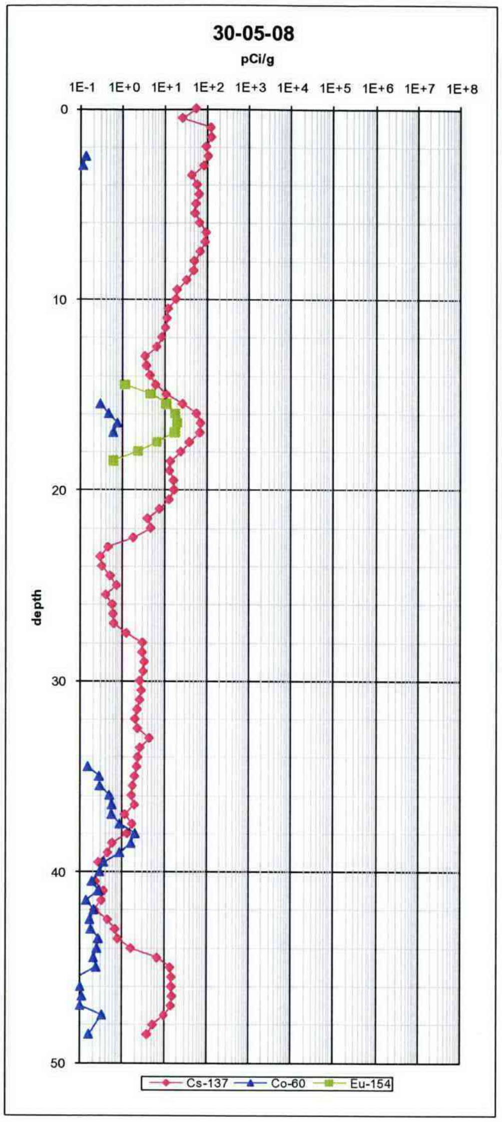


It is likely that the soil contamination occurred when the tank was overfilled during the 1954 – 1956 time period. Interestingly, drywell 30-05-08, located 8.9-ft. from the termination of the spare inlet penetrations 18-in outside of the tank, and 4.65-ft from the edge of the 2-ft wide tank footing, has never showed evidence of a contamination plume. Low concentrations of Cs^{137} soil contamination extend from the surface down to about 50-ft bgs (Figure 4-8).

During tank excavation backfilling, access to the area around and beneath the spare inlet penetrations would not have been restricted as it was near the inlet cascade line penetration. Soil compaction should have been uniform. With uniformly compacted soil, waste leaking through the spare inlet penetrations should have moved downward and outward simultaneously. If the leak had been large, the plume should have been intercepted by drywell 30-05-08 when it was drilled in 1974.

During the line V-103 tie-in, the contaminated soil beneath the spare inlet penetrations was removed. It is likely that only enough contaminated soil was removed to shield the work area for the construction crew to complete the tie-in. After construction the area was backfilled with clean soil. No matter the size of the excavation, part of the leak plume should still have been evident over the 15-ft distance from the spare inlet penetrations down to the top of the tank footing if the leak was very large. The leak plume remnant should have been detected by drywell 30-05-08. It is likely that the volume of waste that leaked through the spare inlet penetrations during the 1954 – 1956 overfill was not very large.

Figure 4-8 Drywell 30-05-08 Spectral Gamma Log

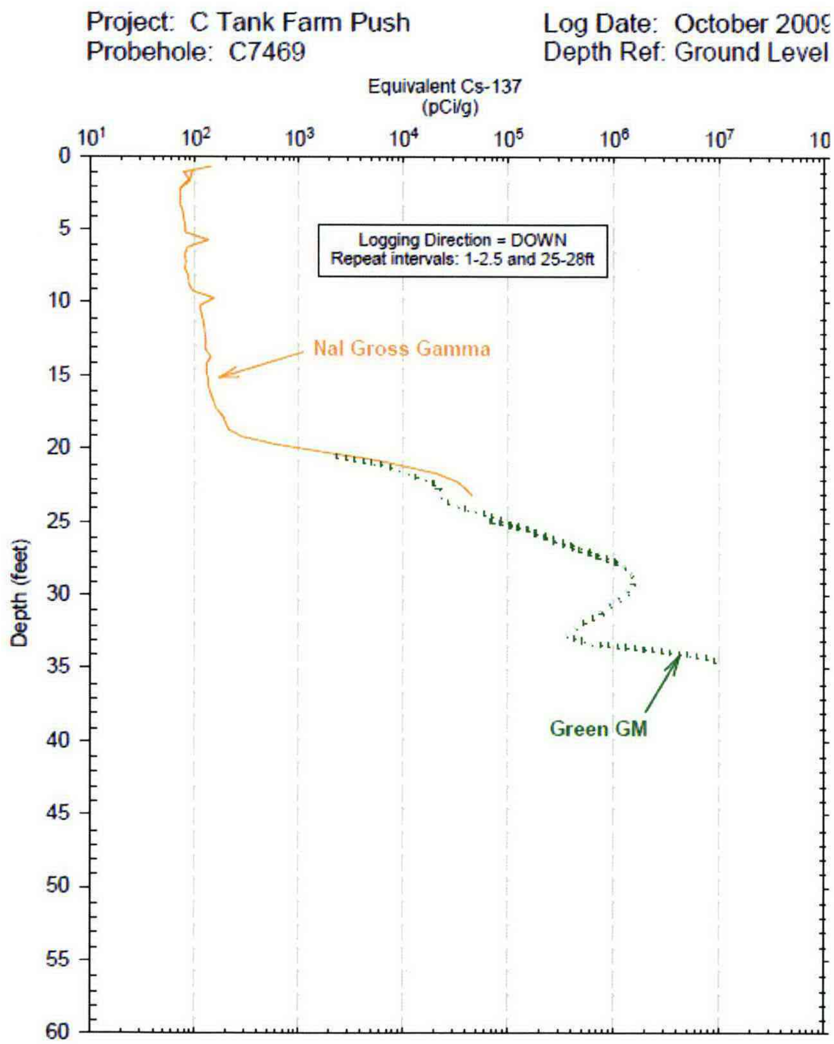


5.0 DIRECT PUSH C7469 RESULTS

Direct push C7469 was completed and logged (Figure 5-1) in October, 2009. It was located 3.8-ft from the inlet cascade line sidewall penetration, and 2.3-ft from the tank sidewall, and pushed down to the tank footing.

Figure 5-1 Direct Push C7469 Small Diameter Gamma Survey

(from RPP-RPT-43725, Small Diameter Geophysical Logging for C Tank Farm Leak Assessment of Tank 241-C-105)



Logging was started with a sodium iodide detector until high count rates from soil contamination saturated it at about 23.5-ft bgs. A lower sensitivity "Green – GM detector was used to complete the log of the lower portion of the direct push.

Log data show the presence of increased soil contamination at the depth of the inlet cascade line indicating tank waste had leaked through the sidewall penetration. Soil contamination continued to increase below the penetration, reaching a peak concentration of ~ 1 x 10^6 pCi/g at about 28-ft bgs before starting to decrease. The concentration at 28-ft bgs is similar to the concentration reported beneath the spare inlet penetrations during the 1967 excavation for line V-103.

The increase in soil contamination with depth is contrary to expectations – typically the highest soil contamination would be found adjacent to a leak site, and would decrease with distance. It is possible that the contrary behavior of the inlet cascade penetration leak plume resulted from limited soil compaction at the inside corners formed between the cascade line buttress and the tank sidewall described in Section 4.1. The waste plume would move down through the loosely compacted soil column in the inside corner toward the tank footing. Lateral movement of the plume away from the inside corner would be restrained because of the higher compaction forces that had been applied to the backfill outside of the immediate area.

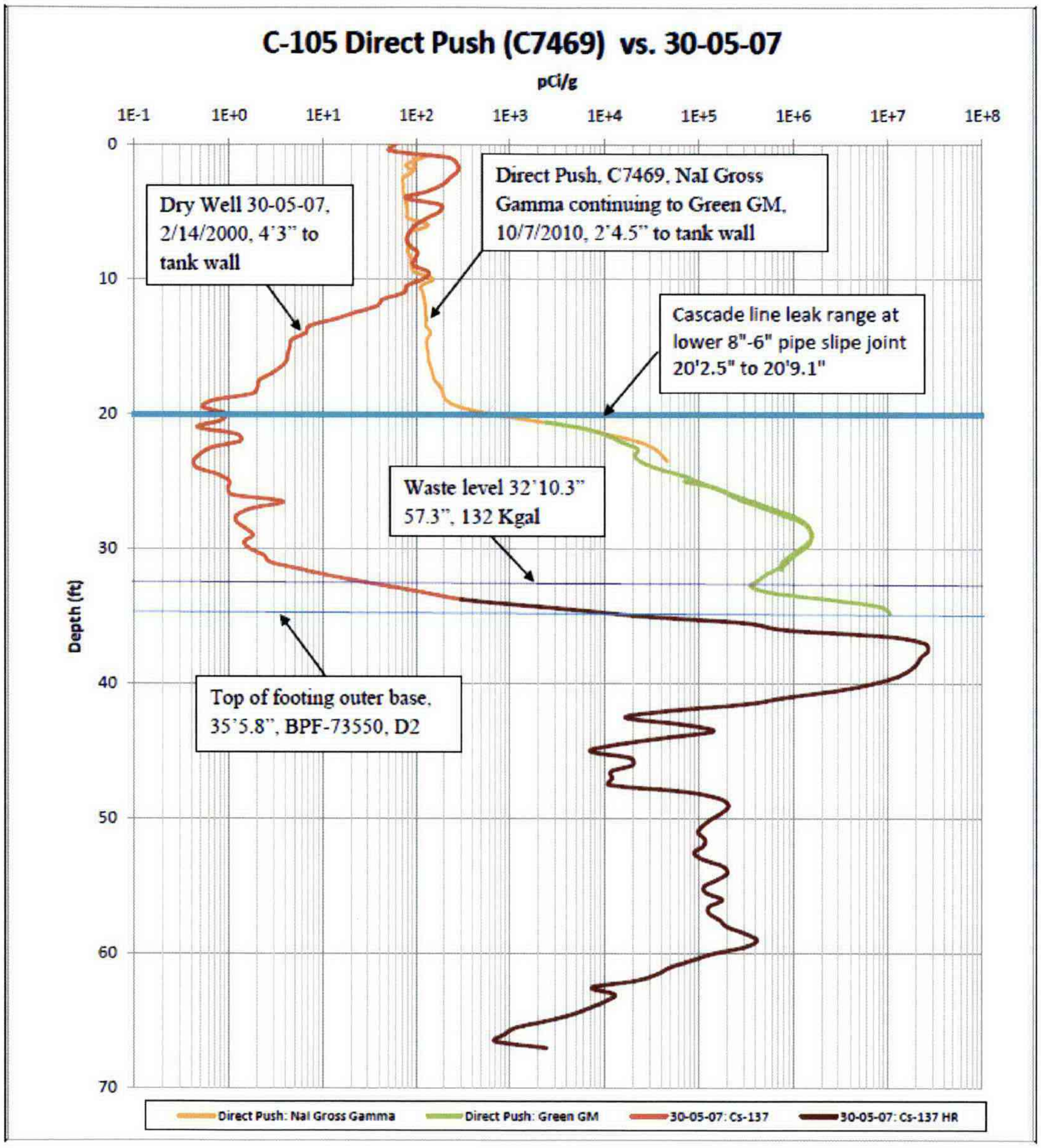
Below the 28-ft bgs peak, the soil contamination continued to decrease with depth before rising again in a second, much more intense contamination peak at the base of the tank. The peak indicates that either the inlet cascade line penetration leak accumulated at the tank base, or else a second waste source is present at this depth.

Figure 5-2 combines the logs from drywell 30-05-07 and Direct Push C7469. Drywell 30-05-07 is located 7.71-ft from the sidewall exit of the inlet cascade line penetration, and 4.25-ft from the tank sidewall – roughly twice the distance from the features as C7469. The drywell 30-05-07 log shows no evidence of the inlet cascade line penetration leak detected by C7469. At the top of the tank footing, drywell 30-05-07 logged soil contamination of ~ 1 x 10^4 pCi/g; at this same depth C7469 recorded ~ 1 x 10^7 pCi/g, an attenuation factor of 1000x over a horizontal distance of 3.9-ft.

The direct push was terminated at the tank footing when resistance was met so a side-by-side comparison deeper in the soil is not possible. Immediately below the tank footing, the soil contamination detected in drywell 30-05-07 continues to increase, peaking at a maximum Cs^{137} concentration of ~ 4 x 10^7 pCi/g. The concentration in this lower peak is 20 - 40x higher than the upper peak detected at 28-ft bgs by C7469.

Figure 5-2 compares the radiation logs of Direct Push C7469 and drywell 20-05-07.

Figure 5-2 Direct Push C7469 and Drywell 30-05-07 Soil Contamination Profiles Comparison



6.0 LEAK – NON-LEAK HYPOTHESES

After considering the log data from Direct Push C7469 and the soil contamination profiles of drywells 30-05-07 and 30-05-08, the panel revised the December, 2008, Leak – Non-Leak hypotheses:

Leak Hypothesis:

"The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak."

Non-Leak Hypothesis:

"The soil contamination peak in drywell 30-05-07 at the base of the tank was due to an overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base."

7.0 RECONCILIATION OF WASTE LEAK SOURCES

7.1 WASTE OVERFLOW THROUGH SPARE INLET PENETRATIONS

Sometime before 1967 tank waste overflowed out of the open, loosely capped spare inlet penetrations. The overflow most likely occurred sometime during the August, 1954 – February, 1956 period when the tank waste volume was reported to be 546-kgal. Photographic evidence from 1974 and 1985 shows an historic waste beachline above both the inlet cascade line penetration and the spare inlet penetrations. For the spare inlet penetrations to be submerged, the waste volume would have been greater than 558-kgal, and higher than the reported volume.

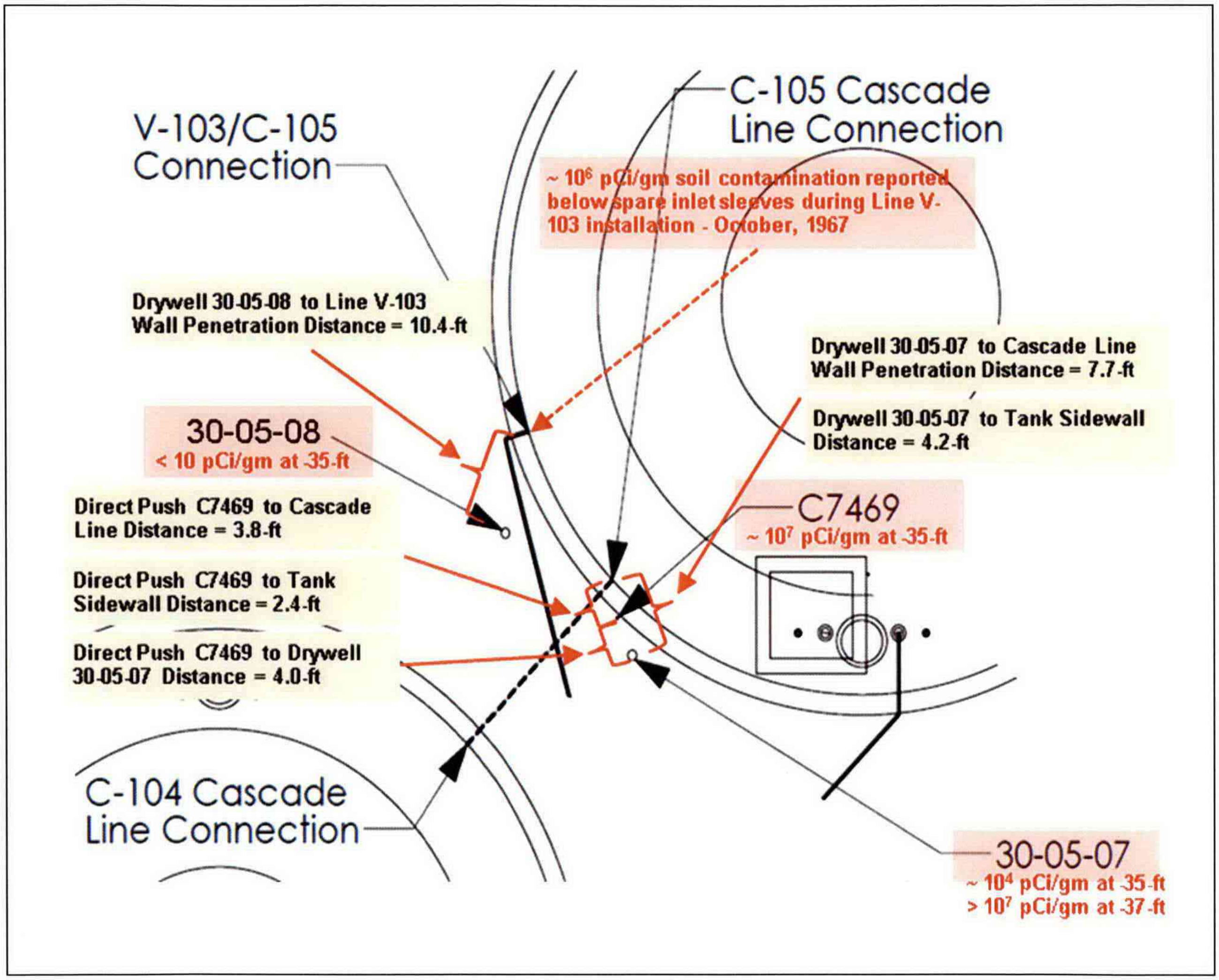
The spare inlet penetrations consist of an open 4-in, Schedule 80 pipe. A 4.75 id x 4-in deep loose fitting cap covers the open end of the pipe where it terminates beyond the tank sidewall. The construction drawing for the covers indicates that a gasket was to be installed in the cap; however a field investigation conducted in 1951 found that a variety of closure methods had been used in conflict with the approved design. The investigation was initiated by a significant waste overflow through the spare inlet penetrations of tank BX-102.

The gap between the 4-in spare inlet penetration and the loose fitting cap created a 1/8-in wide annulus, with a total cross-section of 1.82-in^2. The cross-section of the four penetrations together was equal to 7.26-in^2.

As the waste level in the tank rose, waste began filling the open spare inlet penetrations, eventually encountering the loose-fitting caps. As the tank continued to fill, waste began seeping along the gap between the pipe and cap, traveling the 4-in distance that the cap covered the pipe, and eventually reaching the soil. This would have begun once the waste volume reached 550-kgal. Photographic evidence shows that at one time the spare inlet penetrations were completely submerged, so the entire 7.26-in^2 gap area would have been leaking waste.

In 1967 when the spare inlet penetrations were excavated to connect Line V-103, soil contamination in the range of 1 – 2 x 10^6 pCi/g was found beneath the penetrations. The contaminated soil was removed – probably only to the extent necessary to complete the tie-in – and the area backfilled with clean soil.

Figure 7-1 Tank Features and Separation Distances



In 1974 when drywell 30-05-08 was drilled 10.4-ft from the closest spare inlet penetration, no significant soil contamination was detected from grade to well below the tank base. Regardless of how deep the Line V-103 excavation was, a leak plume remnant should still have been evident over at least part of the 15-ft vertical distance from the spare inlet penetrations down to the top of the tank footing if the overflow was very large.

The area around the spare inlet penetrations should have been readily accessible for soil compaction during backfilling of the original tank farm excavation. The compacted soil should have facilitated migration of the plume outward from the tank toward drywell 30-05-08.

The separation distance between the inlet cascade line penetration and direct push C7469 is 3.8-ft, and the distance between the inlet cascade line penetration and drywell 30-05-07 is 7.7-ft. Over the 3.9-ft distance separating direct push C-7469 and drywell 30-05-07, there is a 1000x reduction in measured soil contamination at the depth of the tank footing. This is in an area of suspect soil compaction (Figure 7-1).

Drywell 30-05-08 is located 8.9-ft from the termination of the spare inlet penetrations 18-in outside of the tank. Even allowing an additional 1000x reduction in measured soil contamination for the additional distance, it seems like the drywell would have detected some soil contamination if the overflow was very large.

7.2 WASTE OVERFLOW THROUGH INLET CASCADE LINE PENETRATION

The cascade line tank sidewall penetration consists of a 43-in long, 4-in diameter Schedule 80 pipe sleeve holding the cascade line. The 3/16-in annular space between the 4-in sleeve and the 3-in diameter Schedule 80 cascade line has a total cross-section of 1.88-in^2. During construction the space was tightly packed with asbestos wick to prevent waste from leaking through the gap if the tank was ever overfilled. It seems unlikely that the entire 43-in long annulus could have been packed with the asbestos wick considering its length and narrow width; probably the wick was inserted as far a practical from both ends and tamped in place.

The inlet cascade line penetration would have been submerged when the tank was overfilled. Waste would have entered the annular space, with some managing to seep through the asbestos wick, and leak into the soil. The leak path was tortuous compared to the unimpeded leak path through the gap between the spare inlet penetrations and their loose fitting caps.

However, there is anecdotal evidence that the cascade line penetration would leak if it were submerged for an extended time period. Tank C-104, located upstream of tank C-105, was equipped with both inlet and outlet cascade lines. The outlet penetration was set 3-in below the inlet penetration. During normal, gravity flow operation, the annular gap between the cascade line and the 4-in sleeve would be partially submerged. During installation of the drywells in 1974 evidence of past leakage was found at the tank C-104 end of the cascade line.

Direct Push C7469 detected leakage from the inlet cascade line penetration beginning at about 20-ft bgs, the depth of the inlet cascade line penetration. Soil contamination reached a peak concentration of the ~ 1 x 10^6 pCi/g at 28-ft bgs before starting to decrease. The concentration at 28-ft bgs is similar to the concentration reported beneath the spare inlet penetrations during the 1967 excavation for line V-103.

The increase in soil contamination with depth is contrary to expectations – typically one would expect that the highest soil contamination would be found adjacent to a leak site, and would decrease with distance. It is possible that the contrary behavior of the cascade inlet penetration leak plume resulted from limited soil compaction at the inside corners formed between the cascade line buttress and the tank sidewall, and pooling on the concrete at the base of the tank.

Below the 28-ft bgs peak, the soil contamination continued to decrease with depth before rising again in a second, much more intense contamination peak at the base of the tank. The peak indicates that either the inlet cascade line penetration leak accumulated at the tank base, or else a second waste source is present at this depth.

7.3 WASTE LEAK FROM TANK

While there is evidence that both the spare inlet penetrations (i.e., the Line V-103 excavation) and the inlet cascade line penetration (i.e., the upper peak on the C7469 log) have leaked waste in the past, the difference in soil contamination found beneath the two sets of penetrations is difficult to reconcile. The leak path for the two penetrations is significantly different. The four spare inlet penetrations have a leak path total cross-section of 7.26-in^2 and a leak path length of about 4-in to the soil. The path is virtually unimpeded. The inlet cascade line penetration has a leak path cross-section of 1.88-in^2 and a leak path length of 43-in to the soil. The path is filled with tightly packed asbestos wick.

The leak path cross-section through the spare inlet penetrations is nearly 4x larger than through the inlet cascade line penetration, and more than 10x shorter. The spare inlet path is unimpeded, while the inlet cascade line penetration is filled with asbestos wicking.

When tank C-105 was overfilled, and the waste overflowed through both sets of penetrations, the volume lost through the spare inlet penetrations should have been much greater than through the inlet cascade line penetration, based on the difference in penetration design. Soil contamination at about 4×10^7 pCi/g is found at the base of the tank below the inlet cascade line penetration. Radiation logs from drywell 30-05-08 show no detectable soil contamination at the base of the tank below the spare inlet penetrations. It is probable that the origin of at least part of the soil contamination peak at the base of the tank is from the inlet cascade line penetration, accounted for by vertical channeling through the poorly compacted soil as noted earlier. The separation distance between drywell 30-05-08 and the spare inlet penetrations and the consequent greater soil attenuation may have prevented detection of the overflow through the spare inlet penetrations.

However, the parallel existence of a small leak through the tank's liner cannot be ruled out by the data. If a liner leak contributed to the peak, then the leak occurred sometime earlier than 1974 and had self-sealed by the time drywell 30-05-07 was drilled. There has been no change in the drywell's gross gamma or spectral gamma logs since 1974 other than normal Cs^{137} radioactive decay, and a gentle downward migration.

The tank continued to be used for liquid waste storage for nearly five years after the contamination peak was discovered. It was finally emptied to a sludge heel in June, 1979. After it was emptied, cooling water was regularly added to the tank to control the sludge temperature through evaporative cooling. Partial records indicate that between June, 1979, and February, 1986, more than 96-kgal of water were added, with no detectable change in the peak at the base of the tank (RHO-RE-EV-97 *Tanks 105-C and 106-C Stabilization Study, Appendix C Calculation of Heat Generation Rate Estimates*).

The potential for self-sealed leaks from sludge tanks has been discussed earlier, and tank A-105 cited as an extreme example. Tank C-105 supported a variety of missions during its operating life. By 1965, 40-in of PUREX Plant coating removal waste sludge had accumulated in the tank. Coating removal waste had a notorious reputation for plugging waste transfer lines. Historical records show at least ten instances of plugged waste transfer lines between 1957 and 1973 blamed on coating removal waste.

Beginning in 1968 tank C-105 became the staging tank for transferring cesium ion exchange feed from the 244-AR Vault to the 221-B Plant for fission product separation. The 244-AR Vault sludge separation process included a settle and decant step to limit the carryover of Sr^{90} solids into the cesium feed. The settling step was ineffective, and Sr^{90} solids began accumulating in tank C-105. By the time the 244-AR Vault process was suspended in 1978, 17-in of high temperature sludge had accumulated on top of the coating removal waste in tank C-105. In 1974 when drywell 30-05-07 was drilled and the contamination peak detected, tank C-105 had already been accumulating high-temperature sludge entrained with the cesium feed for about seven years.

With plug-prone coating removal waste filling the bottom of the tank, and a blanket of high temperature waste restricting the infiltration of supernatant, and later cooling water, it is easy to imagine how the plug could have formed, and how it could have remained protected and stable.

8.0 ESTIMATED LEAK VOLUME

A leak volume from tank C-105 was previously estimated and published in RPP-ENV-33418 Rev. 1 *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Waste Release* (pages 91 – 92). A range of < 40 gallons to 1,900 gallons was reported using different assumptions about the diameter of the plume. The leak volume was subsequently reported as < 2,000 gallons in RPP-PLAN-39114 Rev. 1 *Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area* C (page 3-2).

Appendix D provides a refinement to the original calculation; however refinement does not change the estimated leak volume of < 2,000 gallons.

9.0 CONCLUSION

The method of analysis used for the formal leak assessment was Engineering Procedure TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*. The formal leak assessment process is based on probabilistic analysis to assess the mathematical likelihood (probability) that a specific tank is leaking or has leaked. The technical basis for the process and examples of the methodology can be found in HNF-3747 *Tank Leak Assessment Technical Background*. This is the same process that was used for the 2008 tank C-105 leak Assessment.

Probability is defined as a measure of the state of knowledge or belief about the likelihood that a specific state of nature (e.g., a tank has leaked or is leaking) is true. Probability must be between 0 (absolute certainty that the state of nature is not true) and 1 (absolute certainty that the state of nature is true). The process starts with a prior probability independent of the available data. This establishes any pre-evaluation bias and is typically established at 0.5 that the tank is leaking or has leaked without consideration of the specific data initiating this process (i.e., no pre-evaluation bias, either for or against a leak). Then reviews of in-tank data and ex-tank data are used to establish conditional probabilities for whether the leak hypothesis or the non-leak hypothesis is supported by the data. The conditional probabilities are used to adjust the leak probability toward a leak hypothesis (probability > 0.5) or a non-leak hypothesis (probability < 0.5).

The leak assessment panel's consensus probability of a leak was 0.42. A probability of < 0.5 favors the non-leak hypothesis – a waste overflow through inlet cascade line penetration.

Although the elicitation scores varied, there was consensus among the members of the assessment panel that a leak from tank C-105 could not be ruled out by the evidence from the Direct Push C7469 and other available data. The leak through the inlet cascade line penetration may have contributed to the peak at the base of the tank, but the extent is uncertain, and a tank leak is also plausible.

The panel recommended that the leak integrity status of tank C-105 be changed from "Sound" to "Assumed Leaker", with an estimated leak volume of < 2,000 gallons. The results of the formal leak assessment were presented to the Executive Safety Review Board on April 9, 2010. The Board concurred with the recommendations.

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APPENDIX A - Tank C-105 Leak Assessment Team Meetings #1 - #2 Meeting Minutes

A.1 MEETING #1

MEETING MINUTES

SUBJECT: Tank C-105 Leak Assessment Update Meeting #1				
TO: Distribution	BUILDING: 2750E/A229			
FROM: D. J. Washenfelder	CHAIRMAN: D. J. Washenfelder			
DEPARTMENT-OPERATION-COMPONENT	**AREA**	**SHIFT**	**DATE OF MEETING**	**NUMBER ATTENDING**
Engineering - Technical Integration	200-E		03/08/2010	8

Distribution:
D. A. Barnes*+
D. G. Baide*+
M. V. Berriochoa
D.W. Brown+
J.G. Field*+
D. G. Harlow*+
L.S. Krogsrud*+
G. E. Reeploeg*
E.C. Shallman*+

*Attendees
Team Members+

Background
A tank C-105 leak assessment was performed in 2008 and documented in RPP-ASMT-39801 Rev. 0, December, 31 2008. The tank C-105 leak assessment was the result of a comprehensive review of previous tank waste loss events completed for the 241-C Tank Farm, and documented in RPP-ENV-33418 Rev. 1, *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Releases,* February, 26 2008 The assessment concluded that the contamination around tank C-105 resulted from multiple events, and that the soil contamination detected in drywell 30-05-07 was probably the result of a tank leak. A subsequent commitment for a formal tank C-105 leak assessment was made by reference in letter 08-TPD-015, S. J. Olinger, Office of River Protection to J. A. Hedges, State of Washington Department of Ecology, "Hanford C Farm Leak Assessments," April 9, 2008.

The 2008 leak assessment used a panel of experienced Washington River Protection Solutions, LLC engineers and managers to review the tank C-105 historical data and evaluate the tank's leak integrity.

Based on review of the in-tank and ex-tank data, the panel developed plausible hypotheses for the observed tank behavior as follows:

Leak Hypothesis:

"Prior to 1980, tank 241-C-105 leaked near the base, leading to the high Cesium-137 concentration at drywell 30-05-07."

Non-Leak Hypothesis:

"Cesium-137 at drywell 30-05-07 was due to a waste spill or pipeline leak."

The consensus of the assessment team was that both the leak hypothesis and the non-leak hypothesis are plausible explanations for the observed radiation readings in drywell 30-05-07. In 1980 the first high dose-rate radiation scans were available for the drywell. These scans showed that the radiation peak activity was decreasing at the ^{137}Cs half-life decay rate. The radiation reading in the drywell near the base of the tank could be the result of a small leak that self-sealed prior to 1980.

A leak through the cascade line penetration in the tank's sidewall may have occurred when the tank was overfilled between 1954 and 1956. A leak that migrated down the tank sidewall and accumulated on the tank's footing would also explain the observed drywell data. A similar phenomenon is believed to have occurred in at least one other single-shell tank.

Although the observed drywell data slightly favored the leak hypothesis, additional field data collected near the cascade line sidewall penetration would be required to reach a definitive conclusion about the tank's leak integrity status.

The recommendation of the assessment team was that the existing "Sound" leak integrity classification for tank C-105 be maintained pending the collection of additional field data from a "direct push" sample taken immediately adjacent to the cascade line penetration, and as close to the tank footing as practical. Following analysis of the direct push sample, the leak integrity status of tank C-105 would be revised, if necessary, and the leak assessment report revised and republished.

The tank C-105 direct push was conducted adjacent to the cascade line and logging was completed on October 7, 2009. A report issued documenting the results, RPP-RPT-43725 Rev. 0, *Small Diameter Geophysical Logging for C Tank Farm Leak Assessment of Tank 241-C-105.*

The direct push (C7469) logging results were reviewed and compared with other information. A presentation (attached) was prepared and the 2008 leak assessment panel was reconvened along with two additional members. The results of the initial meeting of the panel following the direct push are presented in the following discussion and action sections

Next Meeting

The next assessment team meeting is scheduled for 3-12-2010, 0700, in 2750/B225. The agenda will include:

- Review new data and information.
- Review the hypothesis for possible changes.
- Expert elicitation forms

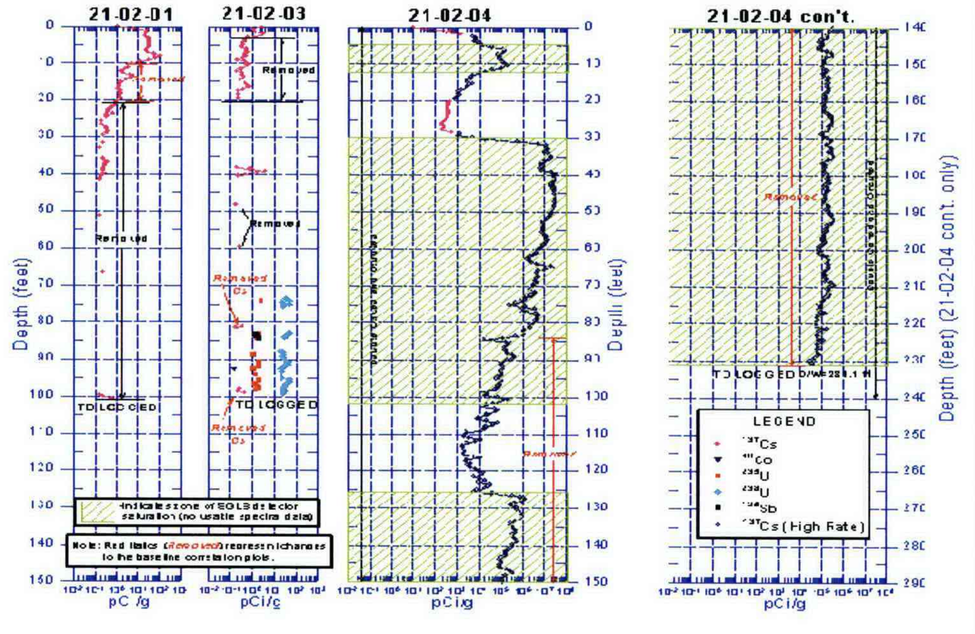
Discussion:

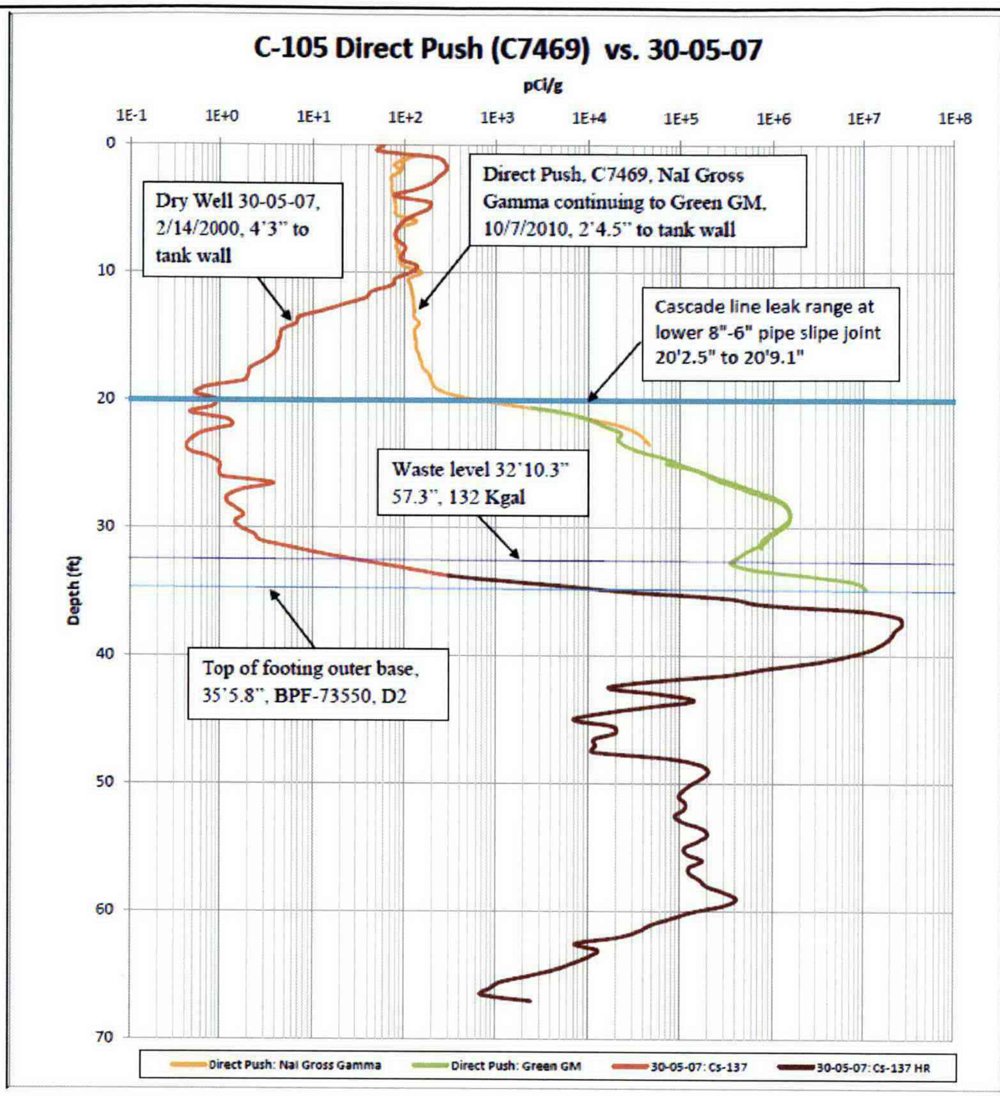
The results of the C7469 direct push seemed to confirm that a leak had occurred at the cascade line probably through the asbestos wick packing and then through the 8' to 6" pipe slip joint located 3-inches from the tank wall. Leakage through the spare nozzles had already been established when contamination was found while digging in the area for installation of the V-103 line to one of the spares. The spare inlet nozzle leaks may also have contributed to the C7469 log results.

The existence of a peak at ~32-feet and then a reduction of almost an order of magnitude then up to a higher peak at the foundation, ~35½-feet, in the C7469 log readings raised questions as to what may have caused the two peak phenomenon. This along with the apparent lack of lateral migration from a cascade line leak provoked discussions centered on soil conditions and compaction, probe types, probe saturation at the higher readings, Cs^{137} saturation of soil ion exchange sites, Na affects on Cs^{137} migration, pooling of a leak at the foundation potentially causing lateral migration. Tanks with similar drywell behavior were also discussed for possible comparisons (tank BX-102, overflow through a potentially loose fitting cap on a spare line).

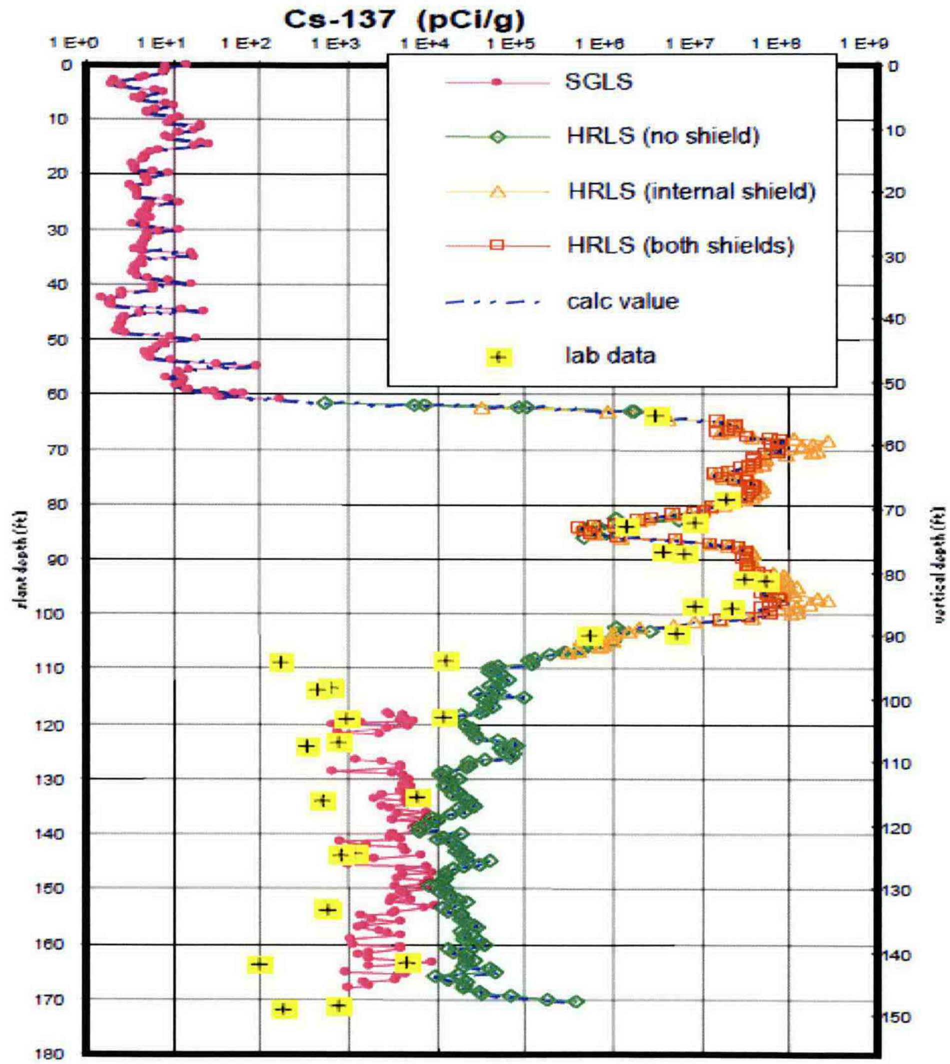
Further interpretations will attempt to be pursued with other experienced personnel.

	Member	Action
1.	D. J. Washenfelder	Contact Rick McCain, Stoller Corp, for detailed interpretation of the C7469 direct push results. *Status:* Contact made and McCain is reviewing the C7469 direct push results.

2.	J. G. Field	Compare tank C-105 and BX-102 drywell logs for similarities/differences in the cascade line and spare inlet line overfill effects. *Status:* Complete. The tank BX-102 drywell 21-02-04 is located approximately 4 ft from the southeast side of tank BX-102. This was likely from a spare inlet overflow the log results show a vertical movement of about 4-feet over the ~4' distance to the drywell from the tank. Then a gradual decrease with increasing depth. The leak volume was 90,000-gallons or more as opposed to between 100 and 1,000-gallons for the tank C-105 leak.  **Figure C-2. Summary of Interpreted Data Set for the BX Tank Farm** The tank C-105 combined drywell 30-05-07 with C7469 indicated on the following graph shows the 30-05-07 drywell as increasing contamination with increasing depth, the opposite of the tank BX-102 21-02-04 drywell. One of the 30-05-07 drywell interpretations has been a pooling of the waste at the foundation of the tank and lateral migration to the drywell. Another interpretation could be that the smaller tank C-105 leak required more depth (10 - 12-feet) to reach the 30-05-07 drywell 4-feet 3-inches from the tank wall.

<table>
<tr><td></td><td></td><td>
</td></tr>
<tr><td>3.</td><td>J. G. Field</td><td>Contact Three Rivers Scientific personnel for a detailed interpretation of the C7469 direct push results.

Status:</td></tr>
</table>

4.	J. G. Field	Review tank SX-108 double peak drywell for possible comparison with tank C-105, C7469 direct push. *Status:* Complete. The tank SX-108 drywell log/sample data is shown on the following graph:  This shows an example where there is both logging and sample data and that the two are similar. SX-108 was a bottom leaker. Past estimates were 35,000 gal. With cooling water it could have been 50-100,000 gal. This spread out across several dry wells and laterals (considerable lateral movement, see figures after this table). This is a different situation than is present for tank C-105.

5.	E. C. Shallman	Review drywell logs/samples and backfill stratigraphy

Status: Nearby borehole stratigraphy and thoughts from D. A. Myers:

The soil samples collected during drilling of C4297 show some geologic changes over the depth range of 30 to 40 ft that could support movement of contamination away from the tank wall. C4297 is 11.3-feet SW of C7469.

29.25-31.25 Pebbly sand, weakly to moderately consolidated, poorly sorted, mostly coarse sand. (Figures A.5 through A.8, PNNL-15503 Rev. 1, *Characterization of Vadose Zone Sediments Below the C Tank Farm: Borehole C4297 and RCRA Borehole 299-E27-22*)

36.4-37.4 Gravelly sand, 25% Gr., **10% Silt**, 35% sand. Weakly consolidated, poorly sorted. (Figures A.9 and A.10) The silt causes the sand to clump on the gravel particles.

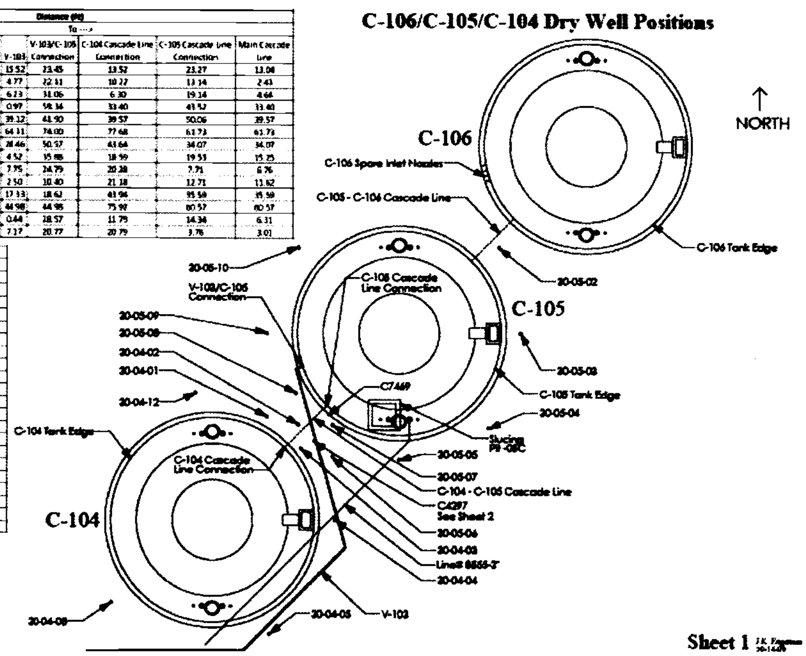
39.05-40.05 Gravelly sand, 30% Gr., 70% sand, gravels to 6 cm (cobbles). (Figures A.11 and A.12)

The interesting difference in these is the silt in the 36.4 to 37.4 ft core. This fine grained unit could serve both to transport water and retain cesium. So it is the important piece of the puzzle. With the increase in cesium high in the column, next to the tank, the concentration gradient would seem to point toward the pipeline as the source of contamination. Because the materials overlying the silty unit is a relatively coarse sand, horizontal migration along the contact of these units is a likely phenomenon.

Distance (ft)							
From --->	To --->						
Dry Wells	C-104 Tank Edge	C-105 Tank Edge	V-103	V-103/C-105 Connection	C-104 Cascade Line Connection	C-105 Cascade Line Connection	Main Cascade Line
30-04-01	5.53	20.72	15.52	23.45	13.52	23.27	13.00
30-04-02	9.99	12.07	4.77	22.11	10.27	13.14	2.43
30-04-03	4.52	18.75	6.23	31.06	6.30	19.14	4.64
30-04-04	0.00	36.11	0.97	58.34	33.40	43.52	33.40
30-04-12	9.86	41.81	39.12	41.90	39.57	50.06	39.57
30-05-04	71.71	30.62	64.11	74.00	77.68	61.73	61.73
30-05-05	35.78	9.13	28.46	50.57	43.64	34.07	34.07
30-05-06	17.94	14.48	4.52	35.98	18.59	19.53	15.25
30-05-07	19.51	4.25	7.75	24.79	20.28	7.71	6.76
30-05-08	18.89	6.65	2.50	10.40	21.18	12.71	11.62
30-05-09	35.06	11.55	17.33	18.62	43.96	35.59	35.59
30-05-10	69.47	11.39	44.98	44.98	75.97	60.57	60.57
C4297	10.37	13.26	0.44	18.57	11.79	14.34	6.31
C7469	20.64	2.18	7.17	20.77	20.79	3.76	3.01

Coordinates		
Structure	North	West
C-106	42931.4	48257.56
C-105	42860.69	48327.87
C-104	42788.98	48398.58
30-05-10	42898.00	48366.00
30-05-09	42861.00	48375.00
30-05-08	42838.00	48367.00
30-05-07	42826.00	48353.00
30-05-06	42814.00	48351.00
30-05-05	42813.00	48327.00
30-05-04	42825.00	48294.00
30-05-03	42861.00	48282.00
30-05-02	42898.00	48290.00
30-04-12	42836.00	48405.00
30-04-08	42758.00	48437.00
30-04-05	42747.00	48377.00
30-04-04	42790.00	48352.00
30-04-03	42817.00	48365.00
30-04-02	42826.00	48366.00
30-04-01	42825.00	48378.00
C4297	42819.84	48358.79
C7469	42829.68	48354.63

C-106/C-105/C-104 Dry Well Positions



Sheet 1

References:

Briefings:

Correspondence - Emails:

Date	Title

Correspondence - Letters:

Number	Title

Documents:

Number	Title
RPP-ASMT-39801, Rev. 0	Tank 241-C-105 Leak Assessment Report
RPP-RPT-43725, Rev. 0	Small Diameter Geophysical Logging for C Tank Farm Leak Assessment of Tank 241-C-105

Drawings:

Number	Title

A.2 MEETING #2

MEETING MINUTES

SUBJECT: Tank C-105 Leak Assessment Update Meeting #2				
TO: Distribution	BUILDING: 2750E/A229			
FROM: D. J. Washenfelder	CHAIRMAN: D. J. Washenfelder			
DEPARTMENT-OPERATION-COMPONENT	**AREA**	**SHIFT**	**DATE OF MEETING**	**NUMBER ATTENDING**
Engineering - Technical Integration	200-E		03/12/2010	8

Distribution:

D. A. Barnes*+
D. G. Baide*+
M. V. Berriochoa
D.W. Brown+
J.G. Field*+
D. G. Harlow*+
L.S. Krogsrud*+
G. E. Reeploeg*
E.C. Shallman*

*Attendees
Team Members+

Background

A tank C-105 leak assessment was performed in 2008 and documented in RPP-ASMT-39801 Rev. 0, December 31, 2008. The tank C-105 leak assessment was the result of a comprehensive review of previous tank waste loss events completed for the 241-C Tank Farm, and documented in RPP-ENV-33418 Rev. 1, *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Releases,* February, 26 2008 The assessment concluded that the contamination around tank C-105 resulted from multiple events, and that the soil contamination detected in drywell 30-05-07 was probably the result of a tank leak. A subsequent commitment for a formal tank C-105 leak assessment was made by reference in letter 08-TPD-015, S. J. Olinger, Office of River Protection to J. A. Hedges, State of Washington Department of Ecology, "Hanford C Farm Leak Assessments," April 9, 2008.

The 2008 leak assessment used a panel of experienced Washington River Protection Solutions, LLC engineers and managers to review the tank C-105 historical data and evaluate the tank's leak integrity.

Based on review of the in-tank and ex-tank data, the panel developed plausible hypotheses for the observed tank behavior as follows:

Leak Hypothesis:

"Prior to 1980, tank 241-C-105 leaked near the base, leading to the high Cesium-137 concentration at drywell 30-05-07."

Non-Leak Hypothesis:

"Cesium-137 at drywell 30-05-07 was due to a waste spill or pipeline leak."

The consensus of the assessment team was that both the leak hypothesis and the non-leak hypothesis were plausible explanations for the observed radiation readings in drywell 30-05-07. In 1980 the first high dose-rate radiation scans were available for the drywell. These scans showed that the radiation peak activity was decreasing at the ^{137}Cs half-life decay rate. The radiation reading in the drywell near the base of the tank could be the result of a small leak that self-sealed prior to 1980.

A leak through the cascade line penetration in the tank's sidewall may have occurred when the tank was overfilled between 1954 and 1956. A leak that migrated down the tank sidewall and accumulated on the tank's footing would also explain the observed drywell data. A similar phenomenon is believed to have occurred in at least one other single-shell tank.

Although the observed drywell data slightly favored the leak hypothesis, additional field data collected near the cascade line sidewall penetration would be required to reach a definitive conclusion about the tank's leak integrity status.

The recommendation of the assessment team was that the existing "Sound" leak integrity classification for tank C-105 be maintained pending the collection of additional field data from a "direct push" sample taken immediately adjacent to the cascade line penetration, and as close to the tank footing as practical. Following analysis of the direct push sample, the leak integrity status of tank C-105 would be revised, if necessary, and the leak assessment report revised and republished.

The tank C-105 direct push was conducted adjacent to the cascade line and logging was completed on October 7, 2009. A report issued documenting the results, RPP-RPT-43725 Rev. 0, *Small Diameter Geophysical Logging for C Tank Farm Leak Assessment of Tank 241-C-105* has been published.

These are the minutes of the second and final meeting for the tank C-105 Leak Evaluation Update.

Discussion:

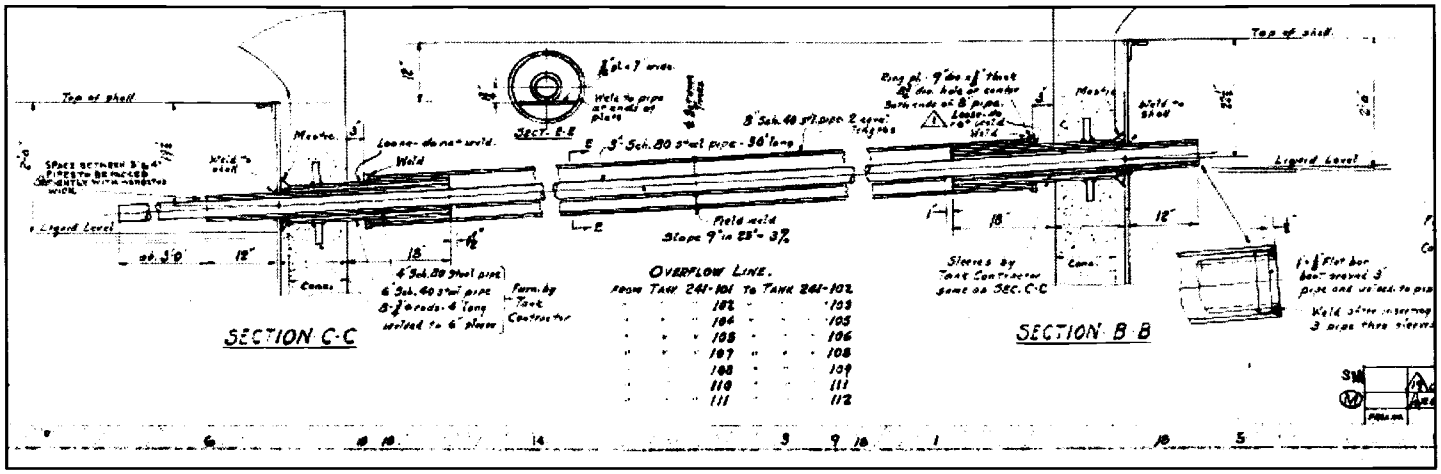
Tank C-105 Leak Assessment Update, Meeting #2 covered the following:

- Review of the new data and information.
- Review the hypothesis for possible changes.
- Expert elicitation forms

<u>Review of new data and information</u>

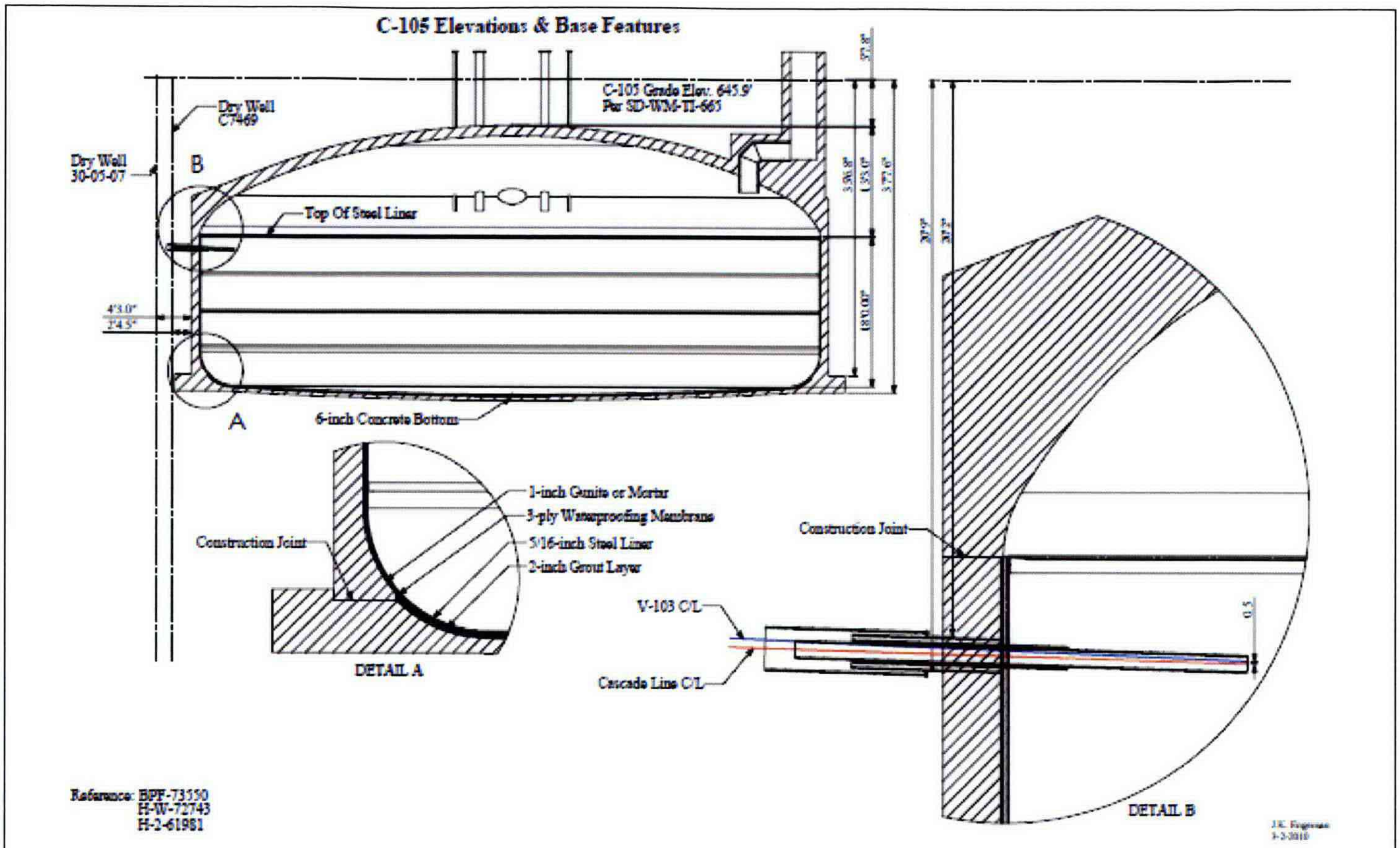
The direct push C7469 log results indicated that contamination was found at the level of the cascade line interface with tank C-105 and followed the tank sidewall with two peaks, one at the tank foundation base where the direct push ended. C7469 is 2.38-feet from the tank and 3.76-feet from the cascade line connection.

A possible cascade line/tank interface leak would follow a path through the asbestos wick packing between the 3-inch inner pipe and a 4-inch pipe sleeve and then out the 8-inch to 6-inch pipe slip joint located 3-inches from the tank wall.

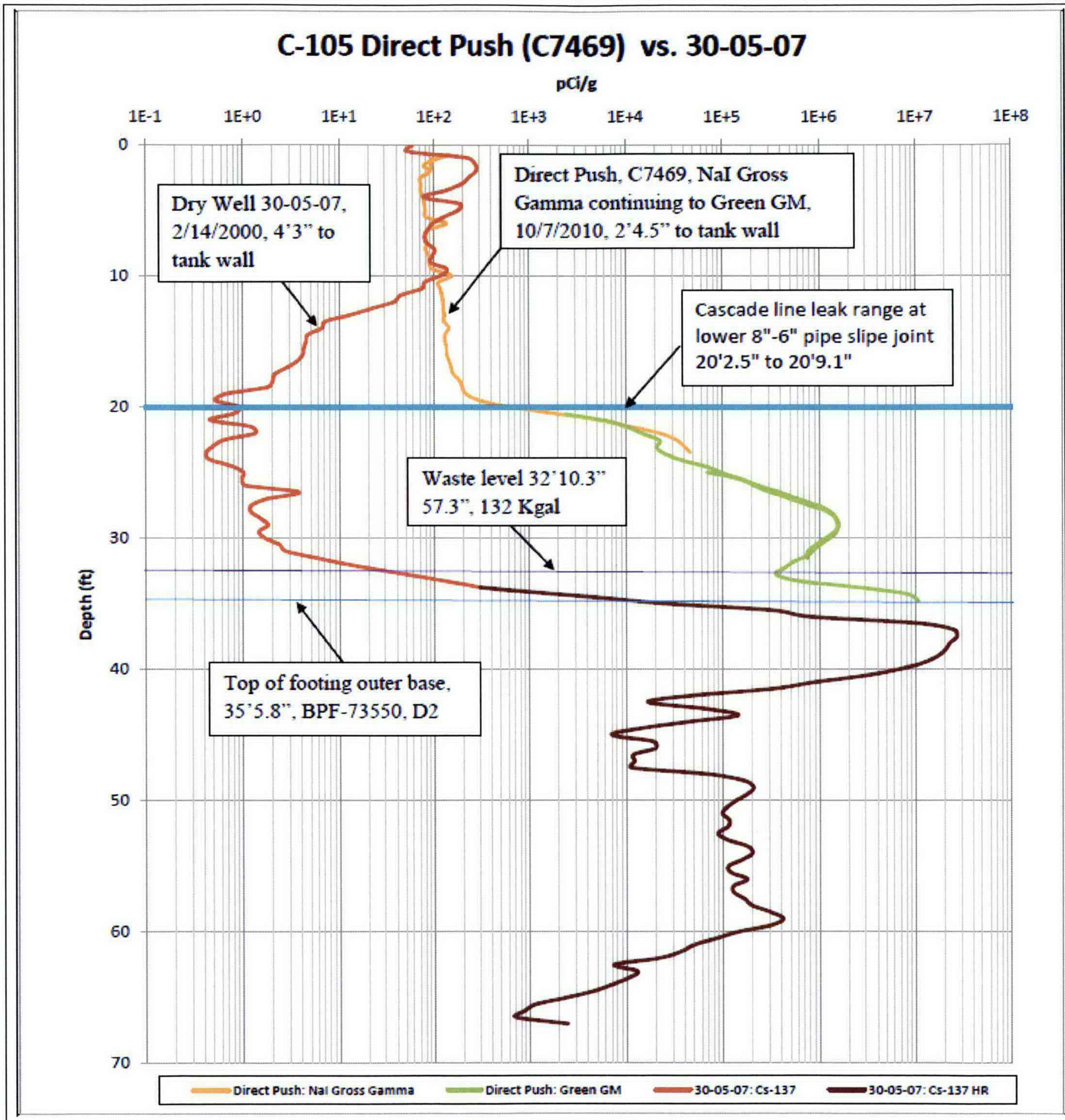


(Tank 241-C-105 Spare Inlet Nozzle Cap (Drawing H-W-72743 *Hanford Engineer Works - BLD.#241 75'0" Dia. Storage Tanks T-U-B & C Arrangement*)

The leak is thought to have traveled down the tank sidewall following the cascade line support column and pooled at the tank foundation. Potentially less compacted course gravely-sandy soil near the tank wall and support column could have caused the leak to preferentially follow the path down the sidewall. No other drywells seemed to indicate a lateral spreading of any leak beyond drywell 30-05-07 which was about 7.7-feet laterally from the cascade line leak point. After reaching the tank foundation the leak most likely pooled as mentioned above and was forced laterally to some extent by the existence of a silt layer at the bottom of the tank, PNNL-15503 Rev. 1, *Characterization of Vadose Zone Sediments Below the C Tank Farm: Borehole C4297 and RCRA Borehole 299-E27-22*. This was thought to have contributed to the increase in the 30-05-07 drywell. Drywell 30-05-07 has been stable, decaying with a Cs^{137} half life, since being installed in July 1974 to the last readings in 2004.



The double peak in the C7469 log results was discussed at length. Probe paralysis was thought to have been seen in other drywells when the radiation readings reached into the 10^5 ρCi/g range with a dip in readings following and then a return to a higher peak. However, results of Action Item #4 in Meeting Minutes #1 for tank SX-108 drywell C3082 where a similar double peak occurred indicated that a comparison was not applicable. Another possibility was that the probe was closer to the tank wall than thought and that it was actually reading radiation from waste through the wall. However, the C7469 log results did not appear to correlate with the waste level. The double peak situation could also have indicated the possibility of soil property changes or that another leak source was being detected.


C-105 Direct Push (C7469) vs. 30-05-07
pCi/g
1E-1
1E+0
1E+1
1E+2
1E+3
1E+4
1E+5
1E+6
1E+7
1E+8
Depth (ft)
0
10
20
30
40
50
60
70
Dry Well 30-05-07, 2/14/2000, 4'3" to tank wall
Direct Push, C7469, NaI Gross Gamma continuing to Green GM, 10/7/2010, 2'4.5" to tank wall
Cascade line leak range at lower 8"-6" pipe slipe joint 20'2.5" to 20'9.1"
Waste level 32'10.3" 57.3", 132 Kgal
Top of footing outer base, 35'5.8", BPF-73550, D2
Direct Push: NaI Gross Gamma
Direct Push: Green GM
30-05-07: Cs-137
30-05-07: Cs-137 HR

The following schematic indicates the relative positions and dimensions of the tank C-104 and tank C-105 drywells and other features.

Distance (ft)							
From --->	To --->						
Dry Wells	C-104 Tank Edge	C-105 Tank Edge	V-103	V-103/C-105 Connection	C-104 Cascade Line Connection	C-105 Cascade Line Connection	Main Cascade Line
30-04-01	5.53	20.72	15.52	23.45	13.52	23.27	13.04
30-04-02	9.99	12.97	4.77	22.11	10.22	13.14	2.43
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30-05-04	71.71	10.62	64.31	74.00	77.68	61.73	61.73
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30-05-06	12.94	14.44	4.52	35.88	18.59	19.53	15.25
30-05-07	19.51	4.25	7.75	24.79	20.28	7.71	6.76
30-05-08	18.89	6.65	2.50	10.40	21.18	12.71	11.62
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30-05-05	42813.00	48327.00
30-05-04	42825.00	48294.00
30-05-03	42861.00	48282.00
30-05-02	42893.00	48290.00
30-04-12	42835.00	48405.00
30-04-08	42759.00	48457.00
30-04-05	42747.00	48377.00
30-04-04	42790.00	48352.00
30-04-03	42817.00	48365.00
30-04-02	42826.00	48366.00
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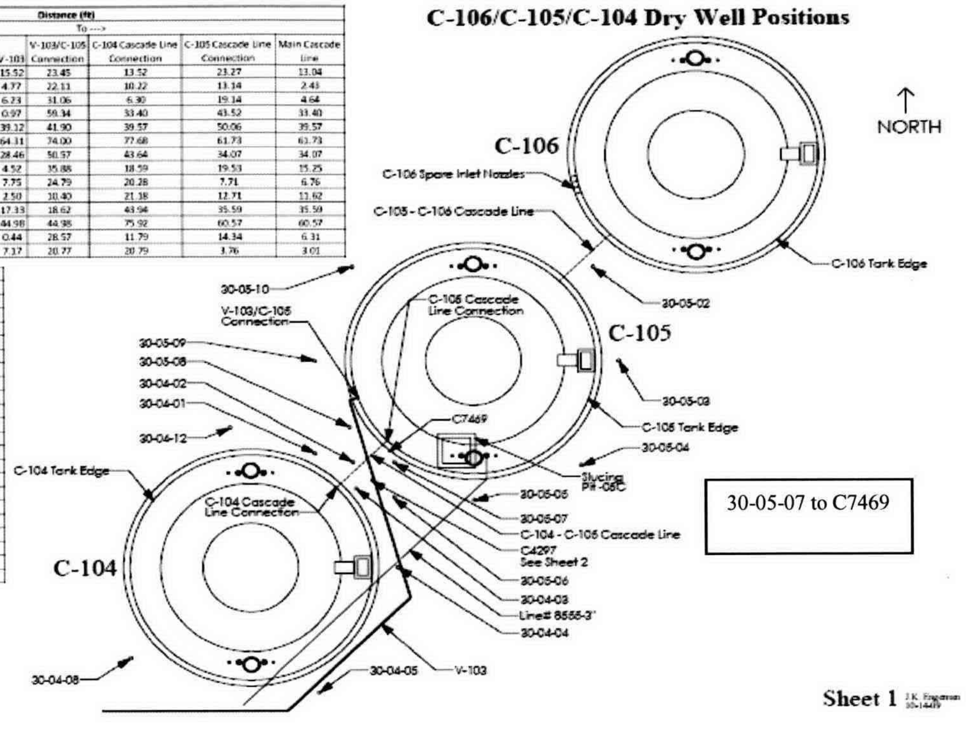
C7469	42829.68	48354.63



Spare inlet nozzle leakage during the overfill event had been established when contamination was found while digging in the area for installation of the V-103 line to one of the spares. The spare inlet nozzle leaks probably did not contribute to the C7469 log results as drywells 30-05-08 and 30-05-09 did not indicate a leak. These two drywells were approximately 10-feet on both sides of the spare inlet nozzles and 7-12-feet from the tank wall. This may also be a case were a leak close to the tank followed the sidewall to the base and was not detected by existing drywells that were beyond the soil contamination.

The profile of tank C-105 drywell 30-05-07 seemed to be at odds with what was considered to be a normal leak response at a nearby drywell. The normal response was thought to be a fairly immediate lateral movement of the leak with a peak at the onset and a tapering off of the contamination levels with depth. The tank BX-102 drywell 21-02-04 which had this response to spare inlet line leaks was reviewed and compared with tank C-105 and drywell 30-05-07. Tank BX-102 spare inlet lines and distance to the drywell has roughly the same relationship as the tank C-105 cascade line/tank interface and the 30-05-07 drywell. However, the log profiles differ considerably with 21-02-04 rising sharply to a peak in a fairly short vertical distance then tapering off with depth and 30-05-07 rising slowly at a much deeper vertical distance from a cascade line/tank interface leak to a peak at the foundation of the tank. The leak volume from tank BX-102 is estimated as > 90,000 gallons, while the volume based on drywell calculations of contamination below tank C-105 base was estimated to be less than 2,000 gallons. The leak volume differences could explain the differences in log profiles. The information from tank C-105 drywell C7469 also indicated that the cascade line/tank interface leak appeared to have followed the tank wall as opposed to spreading laterally. A similar drywell close to tank

BX-102 is not available.

The overall review of the C7469 direct push and the 30-05-07 drywell log results by the leak assessment panel and consultations with outside experts indicated that the most likely cause was a leak from the cascade line interface with tank C-105 when the tank was overfilled between 1954 and 1956. However, a tank leak could not be ruled out.

Review the hypothesis for possible changes

The panel developed an amended Leak – Non-Leak Hypothesis to provide a more definitive basis for the two alternatives as follows:

Leak Hypothesis:

"The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak."

Non-Leak Hypothesis:

"The soil contamination peak in drywell 30-05-07 at the base of the tank was due to overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base."

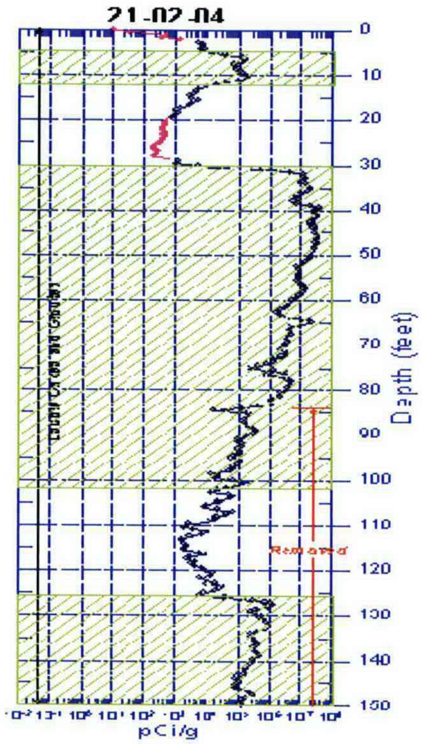
Expert elicitation forms

Following the development of the amended hypotheses the leak assessment panel proceeded to score the appropriate Expert Elicitation leak assessment probabilities. The combined panel Expert Elicitation score was 0.42 resulting in a 58% probability that the tank did not leak.

	Member	Action
1.	D. J. Washenfelder	Contact Rick McCain, Stoller Corp, for detailed interpretation of the C7469 direct push results. *Status:* Conclusions from the McCain review of the C7469 direct push results: The log profile in C7469 is generally consistent with a contamination plume beginning at the approximate elevation of the cascade line invert. C7469 is much closer to that point than 50-05-07. It is also likely that compaction of backfill was relatively less immediately adjacent to the tank wall, and that contamination from a cascade line leak may have followed a loose zone along the tank wall to the top of the footing, where it moved laterally to 30-05-07. C7469 is both closer to the cascade line and closer to the tank wall, so this scenario is consistent with the current data. Therefore, the most likely explanation for the profile observed in C7469 is a plume originating from a point at or near where the cascade line enters the tank. However, the possibility of an incursion cannot be entirely eliminated without a recent log

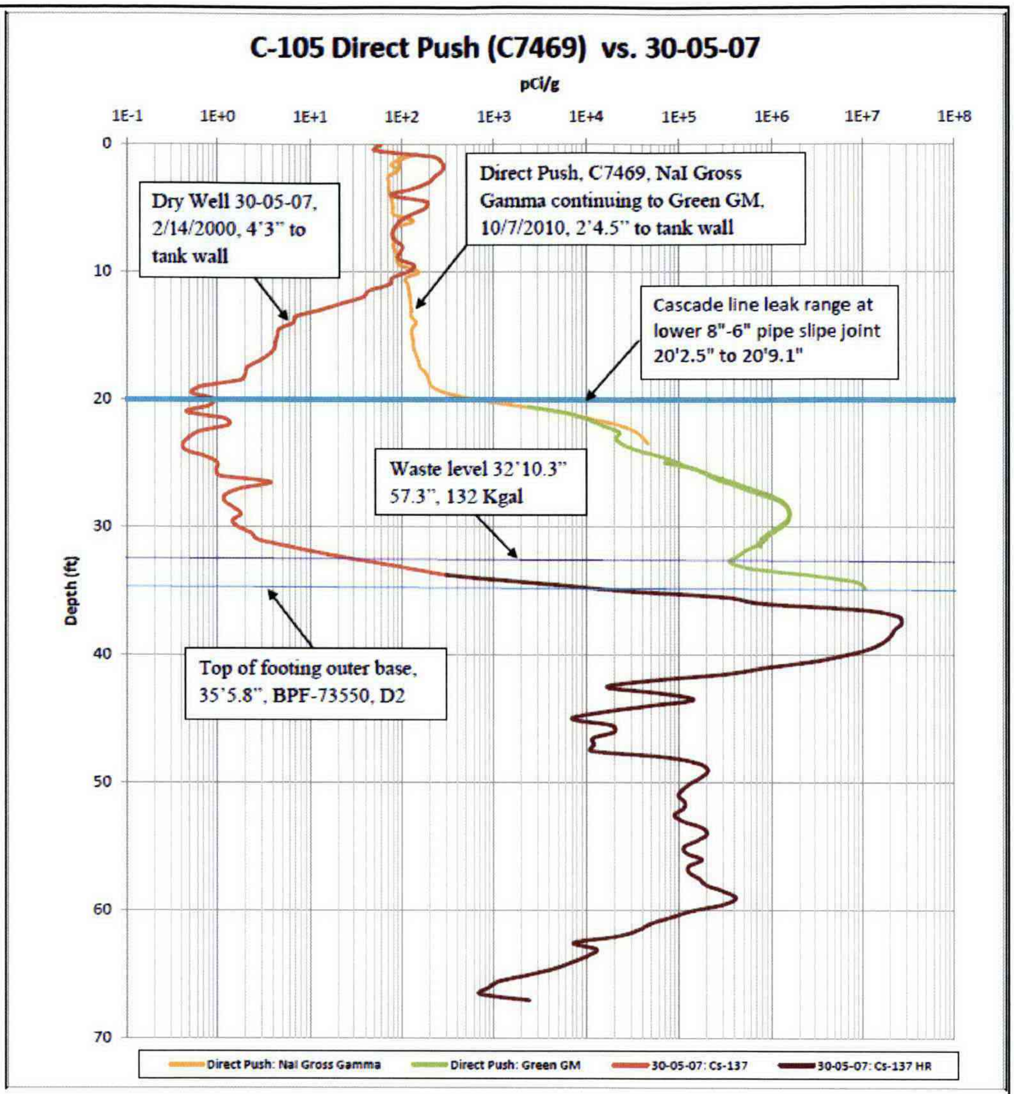
			from 30-05-07. All available data indicate that contamination has been relatively stable in 30-05-07, at least until 2004 (the last time the hole was logged). Comparison of total gamma profiles between 30-05-07 and C7469 suggest that estimated Cs derived from total gamma activity is affected by the high activity, but the overall character in C7469 is very different. It appears that C7469 has encountered substantially more contamination in the interval from 20 to 35 feet. Since the last log in 30-05-07 was run over 5 years ago, the possibility of a recent increase in contamination over the broader area cannot be entirely refuted. However, C7469 is known to be closer to the wall of tank C-105 and closer to the point where the cascade line enters the tank. There is a possibility that the C7469 log is detecting scattered gammas from waste inside the tank. The most likely explanation is that C7469 is intercepting contamination that originated from the cascade line connection and flowed along or near the contact between the tank wall and backfill.

	2.	J. G. Field	Compare tank C-105 and BX-102 drywell logs for similarities/differences in the cascade line and spare inlet line overfill effects. *Status:* Complete. Updated dimensions. The tank BX-102 drywell 21-02-04 is located 5.2-ft from the tank wall on the southeast side of tank BX-102 and about 8.7-ft from the middle of the four spare inlet lines. The spare inlets are spaced 2-ft apart. **Tank BX-102 Drywell**



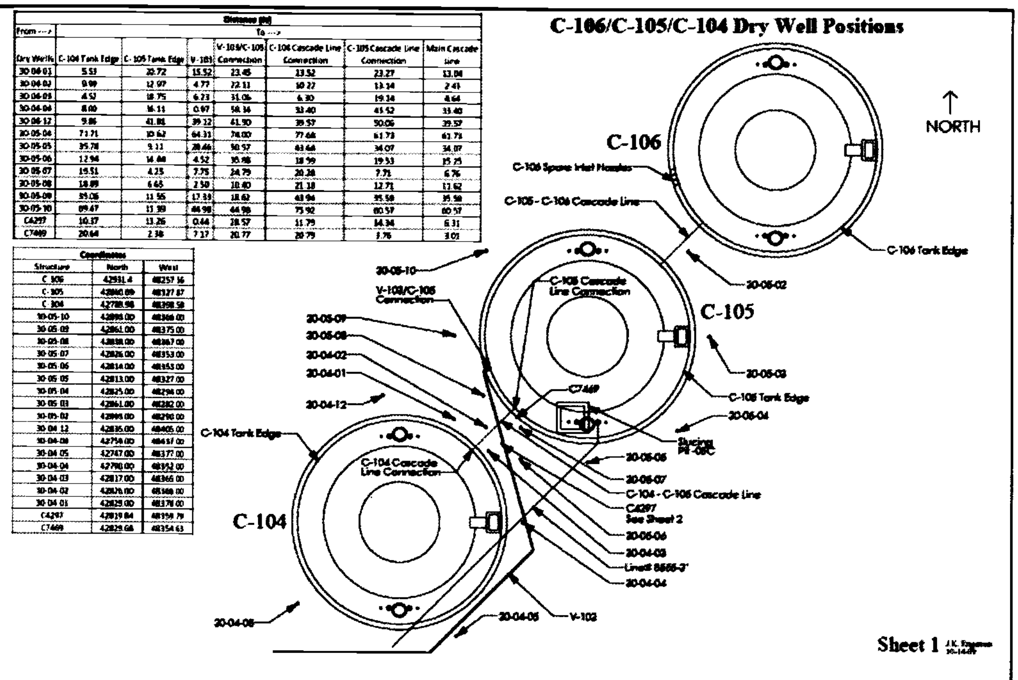
The spare inlet lines are at an elevation of 632.33 which is a depth of 23.22-ft bgs. The above plot appears to have started increasing ~4.5-ft below the depth of the spare inlet lines to a peak at ~31.5-ft and gradually decreased with increasing depth. The leak volume was 90,000-gallons or more as opposed to between 40 and 2,000-gallons for the tank C-105 leak.

The tank C-105 combined drywell 30-05-07 with C7469 logs indicated on the following graph shows the 30-05-07 drywell as increasing contamination with increasing depth, the opposite of the tank BX-102, 21-02-04 drywell. One of the 30-05-07 drywell interpretations has been a pooling of the waste at the foundation of the tank and lateral migration to the drywell. Another interpretation could be that the smaller tank C-105 leak required more depth (10 - 12-feet) to reach the 30-05-07 drywell 4-feet 3-inches from the tank wall.



3.	J. G. Field	Contact Three Rivers Scientific personnel for a detailed interpretation of the C7469 direct push results. *Status:* Complete. Randy Price and Russ Randall (Three Rivers Scientific) reviewed the tank C-105 meeting slides and informally provided the following conclusion which was similar to Rick Mc Cain's (Stoller): The direct push data indicates activity was coming from the cascade line and suggests that the activity in dry well 30-05-07 could be from the cascade line/tank interface. However, none of the data definitively precludes the possibility of a tank leak in addition to a cascade line leak.
4	J. G. Field	Review tank SX-108 double peak drywell for possible comparison with tank C-105, C7469 direct push. *Status:* Complete. See Tank C-105 Leak Assessment Update Meeting

		Minutes #1.
5.	E. C. Shallman	Review drywell logs/samples and backfill stratigraphy *Status:* Complete: Nearby borehole stratigraphy and thoughts from D. A. Myers: The soil samples collected during drilling of C4297 show some geologic changes over the depth range of 30 to 40 ft that could support movement of contamination away from the tank wall. C4297 is 11.3-feet SW of C7469. 29.25-31.25 Pebbly sand, weakly to moderately consolidated, poorly sorted, mostly coarse sand. (Figures A.5 through A.8, PNNL-15503 Rev. 1, *Characterization of Vadose Zone Sediments Below the C Tank Farm: Borehole C4297 and RCRA Borehole 299-E27-22*) 36.4-37.4 Gravelly sand, 25% Gr., **10% Silt**, 35% sand. Weakly consolidated, poorly sorted. (Figures A.9 and A.10) The silt causes the sand to clump on the gravel particles. 39.05-40.05 Gravelly sand, 30% Gr., 70% sand, gravels to 6 cm (cobbles). (Figures A.11 and A.12) The interesting difference in these is the silt in the 36.4 to 37.4 ft core. This fine grained unit could serve both to transport water and retain cesium. So it is the important piece of the puzzle. With the increase in cesium high in the column, next to the tank, the concentration gradient would seem to point toward the pipeline as the source of contamination. Because the materials overlying the silty unit is a relatively coarse sand, horizontal migration along the contact of these units is a likely phenomenon.



References:

Briefings:

Correspondence - Emails:

Date	Title

Correspondence - Letters:

Number	Title

Documents:

Number	Title
RPP-ASMT-39801, Rev. 0	Tank 241-C-105 Leak Assessment Report
RPP-RPT-43725, Rev. 0	Small Diameter Geophysical Logging for C Tank Farm Leak Assessment of Tank 241-C-105

Drawings:

Number	Title

APPENDIX B - Tank C-105 Leak Assessment Team Expert Elicitation Forms

Expert Opinion: D. A. Barnes

Tank C-105 Leak Assessment Update Expert Elicitation Form 2010-03-08
(From HNF-3747, Rev. 0)

Elicitation Date: 3/12/2010

Elicitation from: D. A. Barnes

Eliciation by: Leak Assessment Team

Hypotheses:

Leaker: The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak.

Non-Leaker: The soil contamination peak in drywell 30-05-07 at the base of the tank is due to overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base.

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.50	0.50	1.00

No pre-assessment bias was introduced.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.40	0.60	0.67

Level data from the early 1950's confirmed that the tank was filled above the cascade line and spare nozzles, supporting the alternate hypopthesis, (along with photo evidence). Also, level did not drop beyond expected evaporation in later years, also supporting alternate hypothesis.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (If no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL). If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL). If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.30	0.70	0.43

The gross gamma at the drywell 05-07 supports a leak, (clean until bottom, major peak at base of tank), but the GGL from the push supports the alternate hypothesis. In fact, it confirms that the overflow at the cascade line did occur, but does not rule out the possibility that a tank leak may have also occurred. The spectral data was only taken at the drywell, so it can only support a tank leak. (If spectral data was available closer to the cascade line I would most likely confirm the overfill, but the data is not available.) Since the data at the drywell is so different from the push, both conclusions can be supported, thus the neutrol score.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.70	0.30	2.33

The spectral data is only available at the drywell, so it can only support the leak hypothesis. If spectral data were available nearer to the cascade overfill it would most likely support the alternate hypothesis, but the data is not available. Because box 8 or 9 must be marked NA, this number is not used in the analysis. The gross gamma value was bumped higher to account for this.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.60	0.40	1.50

All of the gross and spectral data taken together slightly support the cascade line overfill, based primarily on the push data.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM) 0.67	L(LOW) 1.00	L(SLM|LOW) 1.00	L(LOW|SLM) 1.00
L(GGL) 0.43	L(SGL) 2.33	L(GGL|SGL) 1.00	L(SGL|GGL) 1.50

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio		L(SLM,LOW)
		0.67

If SLM and no LOW: L(SLM,LOW) = L(SLM)
If LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio		L(SGL,GGL)
		0.64

If GGL and no SGL: L(SGL,GGL) = L(GGL)
If SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis		L(in,ex)
		0.43

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.30	0.70	0.43

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. Ω_1= L(in,ex) x Ω_0
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Expert Opinion: D. W. Brown

Tank C-105 Leak Assessment Update Expert Elicitation Form 2010-03-08
(From HNF-3747, Rev. 0)

Elicitation Date: 3/12/2010

Elicitation from: D. W. Brown

Eliciation by: Leak Assessment Team

Hypotheses:

Leaker: The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak.

Non-Leaker: The soil contamination peak in drywell 30-05-07 at the base of the tank was due to overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base.

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio: L:NL
p(L)	p(NL)	Ω_0
0.50	0.50	1.00

Although this was a high waste temperature tank there was no prior information that would support evidence of a tank leak.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.40	0.60	0.67

Surface level data show that historical tank levels were reached that would allow for a leak path throught the packing material associated with the tank cascade line interface. This was supported by both level measurements and tank photographs that indicate a waste ring above this interface area.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.60	0.40	1.50

Gross gamma data available could not distinguish between a tank leak as the primary source from a tank, and the cascade line interface area leak as the primary source. Data associated with push (C7469) did not provide the expected data to further support the tank to cascade line interface area leak as the most likley source which was expected. The spike near the bottom of the tank would require an explanation that waste traversed down the side of the tank wall and pooled on the tank base instead of a tank leak causing the spike. Data could not conclusively identify that as a high potential but it is thought that a leak did occur at the tank to cascade line interface.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.60	0.40	1.50

Spectral Gamma data available could destinguish from a tank leak as the primary source or a tank to cascade line interface area leak as the primary source. The spike near the bottom of the tank would require an explanation that waste traversed down the side of the tank wall and pooled on the tank base instead of a tank leak causing the spike. Data could not conclusively identify that as a high potential but it is thought that a leak did occur at the tank to cascade line interface.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	0.50	0.50	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.67	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
1.50	1.50	1.00	1.00

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio	L(SLM,LOW)
	0.67

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	
GGL & SGL; SGL most important? (Mark Part 9 NA)	X

Ex-Tank Liklihood Ratio	L(SGL,GGL)
	1.50

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis	L(in,ex)
	1.00

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.50	0.50	1.00

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. $\Omega_1 = L(in,ex) \times \Omega_0$
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Expert Opinion: J. G. Field

Tank C-105 Leak Assessment Update Expert Elicitation Form 2010-03-08
(From HNF-3747, Rev. 0)

Elicitation Date: 3/12/2010

Elicitation from: J. G. Field

Eliciation by: Leak Assessment Team

Hypotheses:

Leaker: The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak.

Non-Leaker: The soil contamination peak in drywell 30-05-07 at the base of the tank was due to overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base.

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.50	0.50	1.00

The tank contained high heat waste (~5 Ci/gal Cs-137), but more and more we are finding that many of what some thought were tank leaks were line leaks, spills and overflows. Therefore, no preference was given for a tank leak or cascade line leak.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.40	0.60	0.67

The surface level measuremnts show that the liquid level was above the cascade line and the tank overflowed in the past. This supports the cascade leak hypothesis. The stable liquid level after transfers stopped indicates that the tank is not currently leaking. However, transfers during tank operation resulted in constantly changing liquid levels such that a potential liquid level decrease due to a tank leak could not be determined.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

<table>
<tr><td>Surface Level Measurement - Liquid Observation Well Interdependence</td><td>p(SLM|LOW,L)
(if no LOW, enter NA)</td><td>p(SLM|LOW,NL)</td><td>L(SLM|LOW)</td></tr>
<tr><td></td><td>NA</td><td>NA</td><td>1.00</td></tr>
</table>

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL). If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

<table>
<tr><td>Liquid Observation Well - Surface Level Measurement Interdependence</td><td>p(LOW|SLM,L)
(if no SLM, enter NA)</td><td>p(LOW|SLM,NL)</td><td>L(LOW|SLM)</td></tr>
<tr><td></td><td>NA</td><td>NA</td><td>1.00</td></tr>
</table>

Considering that in-tank data sources may be interdependent:

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL). If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

<table>
<tr><td>Gross Gamma Drywell Logs</td><td>p(GGL|L)
(if no GGL, enter NA here and in Parts 8 and 9)</td><td>p(GGL|NL)</td><td>L(GGL)</td></tr>
<tr><td></td><td>0.40</td><td>0.60</td><td>0.67</td></tr>
</table>

This includes historical gross gamma logging and current direct push logging. Both show high gamma activity at the base of the tank, the historical gamma did not show the magnitude of the activity observed later by SGLS/HRLS logging. The direct push log shows a potential Cs-137 path between the cascade line and 30-05-07. However the double peak leaves open the possibility of leaks from different sources and the upper peak shows lower activity levels, more consistent with line leaks observed in other nearby drywells ad boreholes.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

<table>
<tr><td>Spectral Gamma Drywell Logs</td><td>p(SGL|L)
(if no SGL, enter NA here and in Parts 8 and 9)</td><td>p(SGL|NL)</td><td>L(SGL)</td></tr>
<tr><td></td><td>0.70</td><td>0.30</td><td>2.33</td></tr>
</table>

High Cs-137 activity (1E8 pCi/g) at the base of a tank is generally a clear sign of a tank leak. Other drywells near cascade line leaks show much lower activity. Past analyses based on spectral gamma measurements attributed the 30-05-07 activity to a cascade line leak. However, logging and sampling results for additional drywells and borehole C4297 showed a tank leak was more likely than previously believed.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

<table>
<tr><td>Gross Gamma Log - Spectral Gamma Log Interdependence</td><td>p(GGL|SGL,L)</td><td>p(GGL|SGL,NL)</td><td>L(GGL|SGL)</td></tr>
<tr><td></td><td>NA</td><td>NA</td><td>1.00</td></tr>
</table>

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.40	0.60	0.67

The direct push logging results combined with the spectral gamma results show a pathway for a small cascade leak flowing down the side of the tank and pooling at the base near drywell 30-05-07. However, the second peak suggests the possibility of a second leak from the tank. If the cascade line leak migrated to 30-05-07 one would expect to see activity in other drywells or activity higher in 30-05-07.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.67	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.67	2.33	1.00	0.67

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio	L(SLM,LOW)
	0.67

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio	L(SGL,GGL)
	0.44

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis	L(in,ex)
	0.30

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.23	0.77	0.30

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. Ω_1= L(in,ex) x Ω_0
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Expert Opinion: D. G. Harlow

Tank C-106 Leak Assessment Update Expert Elicitation Form 2010-03-08
(From HNF-3747, Rev. 0)

Elicitation Date: 3/12/2010

Elicitation from: D. G. Harlow

Eliciation by: Leak Assessment Team

Hypotheses:

Leaker: The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak

Non-Leaker: The soil contamination peak in drywell 30-05-07 at the base of the tank is due to overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio: L:NL	
p(L)	p(NL)	Ω_0	This is a single shell tank and a high heat tank.
0.60	0.40	1.50	

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)	Surface level was above the cascade line from the photographs and liquid level measurements. The cascade line could have leaked back through the asbestos wick between the 3" line and the 4" sleeve.
	0.40	0.60	0.67	

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.40	0.60	0.67

Historical gross gamma and the direct push show high gamma at the base of the tank. The direct push indicates Cs-137 starting at the cascade line level and going to a peak at 28 ft at the same level of contamination as the soil samples taken at the spare inlet lines then tapering off until a second increase starts at the base of the tank. The second peak at the base of the tank was an order of magnitude greater than the soil sample. Historical gammas did not increase from the original found in 1974 through the end of logging in 1997.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.70	0.30	2.33

The spectreal gamma data at 30-05-07 did not indicate a leak of the cascade line even though it was only 4-ft from the direct push. The only correlation was the same and higher Cs-137 level below the tank level with the direct push logging the latter stopped at the tank foundation.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.40	0.60	0.67

It does not appear that the cascade line leak can attributed to the peak at the base of the tank. There is a probability that the first direct push peak can be attributed to the cascade line and the second peak may be from a tank leak.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.67	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.67	2.33	1.00	0.67

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio		L(SLM,LOW)
		0.67

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio		L(SGL,GGL)
		0.44

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(SGL)

Combined Likelihood Ratio for Leak Hypothesis		L(in,ex)
		0.30

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.31	0.69	0.44

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. $\Omega_1 = L(in,ex) \times \Omega_0$
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Expert Opinion: L. S. Krogsrud

Tank C-105 Leak Assessment Update Expert Elicitation Form 2010-03-08
(From HNF-3747, Rev. 0)

Elicitation Date: 3/12/2010

Elicitation from: L. S. Krogsrud

Eliciation by: Leak Assessment Team

Hypotheses:

Leaker:

Non-Leaker:

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio: L:NL
p(L)	p(NL)	Ω_0
0.60	0.40	1.50

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.40	0.60	0.67

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersitial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.60	0.40	1.50

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.75	0.25	3.00

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.60	0.40	1.50

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.67	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
1.50	3.00	1.00	1.50

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio		L(SLM,LOW)
		0.67

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio		L(SGL,GGL)
		2.25

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis		L(in,ex)
		1.50

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.69	0.31	2.25

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. Ω_1= L(in,ex) x Ω_0
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Expert Opinion: D. J. Washenfelder

Tank C-105 Leak Assessment Update Expert Elicitation Form 2010-03-08
(From HNF-3747, Rev. 0)

Elicitation Date: 3/12/2010

Elicitation from: D. J. Washenfelder

Eliciation by: Leak Assessment Team

Hypotheses:

Leaker: The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak.

Non-Leaker: The soil contamination peak in drywell 30-05-07 at the base of the tank is due to overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base.

Prior Probability - Part 1

True State L	True State NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.40	0.60	0.67

Prior probability of a tank C-105 leak is judged to be higher than for other, similar, SSTs because of the high temperature PSN waste stored in the tank from 1963 - 1967, and the 90Sr-bearing sludge later accumulated in the tank from entrainment during PAS processing at 244-AR vault. The estimated heat output of the tank was ~85,000 BTU/hr at times. The probability is judged to be less than 0.5 because tank C-106 saw more aggressive temperature conditions and is classified as a "sound" tank; and because multiple, historic leak assessments of tank C-105 did not identify a tank leak.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. $\Omega_0 = p(L)/p(NL)$

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.20	0.80	0.25

Surface level data indicate that the tank was overfilled for a period of 19 months between during 1953 - 1955, and that the spare sidewall inlets and cascade line inlet were both submerged in waste. In-tank photographs showing the waste beachline above the elevation of the sidewall and cascade lines confirms the overfill.

When the tank was quiescent, decreases in surface level were small, and ascribed to evaporation. The tank continued to be used after 30-015-07 was drilled in 1974, and the contamination spike at the -35-ft level was first discovered, further confirming no unexplained decreases in surface level were observed.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

No LOW in this tank.

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.60	0.40	1.50

The gamma logs from direct push C7496 were considered as part of the gross gamma log inventory even though the counts were converted to equivalent Cs-137, and reported like an SGLS result. For the period between 1980 and 1994 where gross data are available, the peak at the -35-ft level remains stable. There is no peak broadening or increase in peak height indicating an active leaksite nearby. In fact the peak seems to be migrating deeper into the soil over the 15 year period. It is likely that the peak was created by a source that became inactive before the 30-05-07 well was drilled in 1974.

It is possible leakage at the cascade line penetration of the tank sidewall could be responsible for the 30-05-07 peak. However, the soil contamination level increases as depth (and distance) from the sidewall penetration increases. This establishes a reverse gradient that doesn't make sense, except possibly for a small leak.

A sidewall penetration leak from tank BX-102 shows high soil concentration from just below the penetration to near the base of the tank. This was for a large volume overflow. Possibly for a small leak, the gradient could be reversed. The cascade line is supported by a vertical pillar at the location where it penetrates the tank sidewall. The intersection of the pillar and sidewall creates a vertical, full depth concave surface where the pillar is attached to the tank sidewall. It extends down to the footing. It is likely that soil compaction in this area is lower than else where around the tank where heavy compaction

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.50	0.50	1.00

No discriminating information is provided by the spectral gamma logs from 1994 or 2000. The latest spectral gamma log was completed in 2004, and overlays the 2000 data.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.80	0.20	4.00

The gross gamma data are more important since they span the greatest number of years. Data are readily available from 1980 - 1994. The spectral gamma logs were repeated too infrequently to be used in preference to the gross gamma logs.

Additionally the spectral gamma logs that were made are consistent with the gross gamma logs. Both support a waste leak from the tank at the -35-ft level, and from the cascade line sidewall penetration.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.25	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
1.50	1.00	1.00	4.00

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio	L(SLM,LOW)
	0.25

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio	L(SGL,GGL)
	6.00

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(SGL)

Combined Likelihood Ratio for Leak Hypothesis	L(in,ex)
	1.50

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.50	0.50	1.00

It is unlikely that the cascade line penetration leak is responsible for the peak at the -35-ft level in drywell 30-05-07. The contamination gradient does not behave like a known large volume sidewall penetration leak in tank BX-102. Evidence, including the reverse gradient, suggests it was a small volume leak. Even with loosely compacted soil creating a channel down the tank sidewall, it is unlikely that it made a significant contribution to the 30-05-07 peak.

The only other likely explanation for the 30-05-07 peak is that the tank leaked sometime before 1974 and self-sealed by the time drywell 30-05-07 was drilled in 1974.

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. $\Omega_1 = L(in,ex) \times \Omega_0$
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

APPENDIX C - Tank C-105 Leak Assessment Executive Safety Review Board Briefing April 10, 2010

washington river protection solutions

Completion of Tank C-105 Leak Assessment

D. J. Washenfelder

April 9, 2010

Tank C-105 Leak Assessment History

- Formal Leak Assessment recommended by RPP-ENV-33418, *"Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Waste Releases"*
- 5th attempt to identify source of radiation peak at base of tank
- Assessment results first presented to ESRB December 16, 2008

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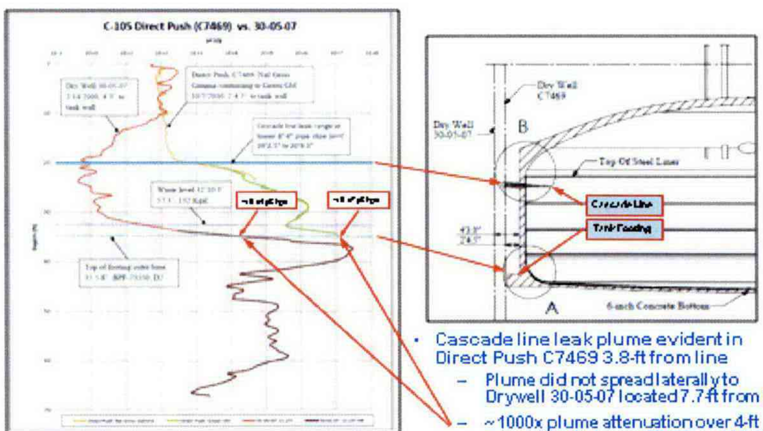
Tank C-105 Leak Assessment History

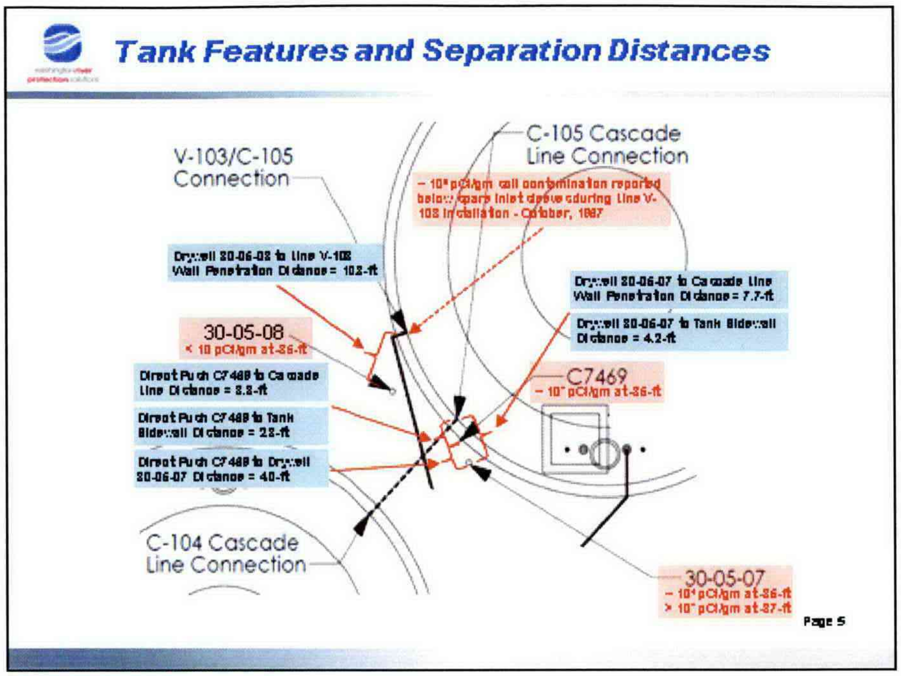
- Conclusion and Recommendations from 2008 Leak Assessment
  - Cascade line could be the source of the radiation peak at base of tank
  - Complete a "direct push" sample immediately adjacent to the cascade line wall penetration, and as close to the tank footing as practical, to resolve the leak site ambiguity.
  - Reconvene leak assessment panel following analysis of the direct push sample
- C7469 Direct Push logged October 7, 2009

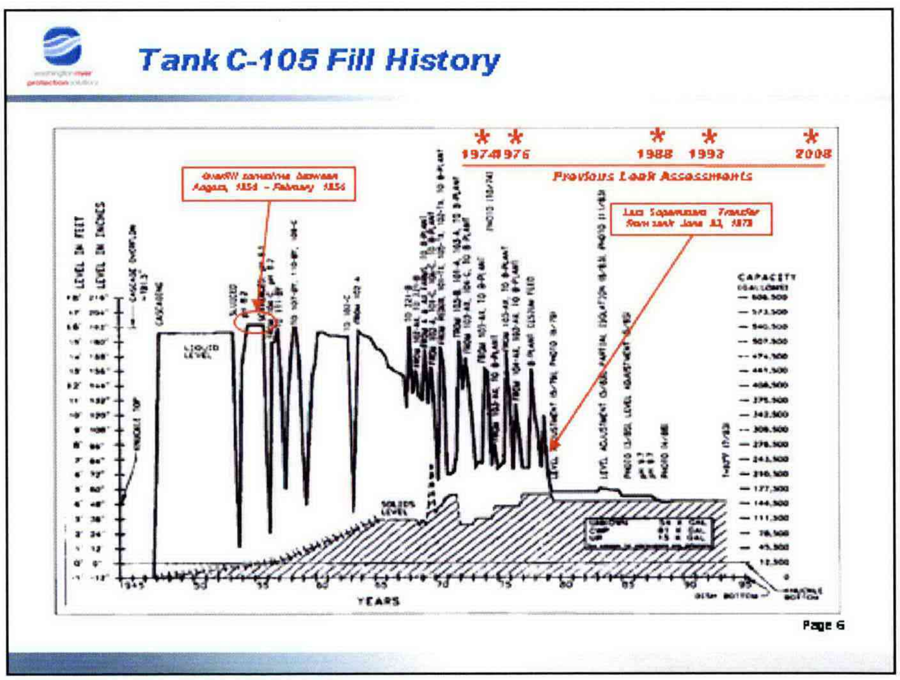
Page 3

Comparison of C7469 Direct Push and Drywell 30-05-07 Logs with Tank Features

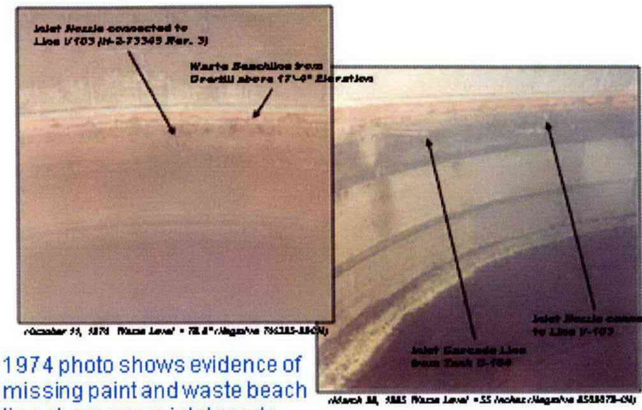


- Cascade line leak plume evident in Direct Push C7469 3.8-ft from line
  - Plume did not spread laterally to Drywell 30-05-07 located 7.7-ft from line
  - ~1000x plume attenuation over 4-ft separation between C7469 and 30-05-07 at depth of tank footing
- By 1974 plume had moved laterally and vertically below tank footing


Tank Features and Separation Distances
V-103/C-105 Connection
C-105 Cascade Line Connection
Drywell 30-06-02 to Line V-103 Wall Penetration Distance = 10.2-ft
Drywell 30-06-07 to Cascade Line Wall Penetration Distance = 7.7-ft
Drywell 30-06-07 to Tank Sidewall Distance = 4.2-ft
30-05-08
< 10 pCi/gm at 36-ft
Direct Push C7469 to Cascade Line Distance = 3.3-ft
Direct Push C7469 to Tank Sidewall Distance = 2.3-ft
Direct Push C7469 to Drywell 30-06-07 Distance = 4.0-ft
C7469
C-104 Cascade Line Connection
30-05-07
Page 5


Tank C-105 Fill History
1974 1976 1988 1993 2008
Previous Leak Assessments
CAPACITY
YEARS
Page 6

In-Tank Evidence of Overfill



1974 photo shows evidence of missing paint and waste beach line above spare inlet nozzle elevation which is higher than cascade line

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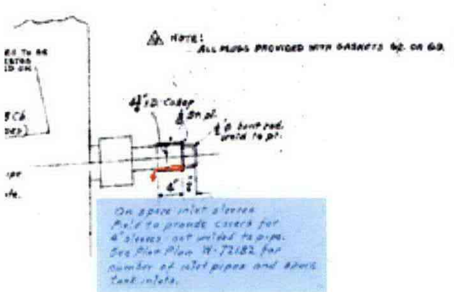
Sidewall Sleeve Leak Path from Overfill

- The 4-3/4" ID x 4" nozzle cover is fit over the 4" Sch. 80 pipe sleeve and not welded in place
- The OD of 4" Sch. 80 pipe is 4-1/2", so the annular gap between the nozzle cover and the pipe sleeve would be about 1/8"
- Pipe sleeve terminates 18" from tank wall



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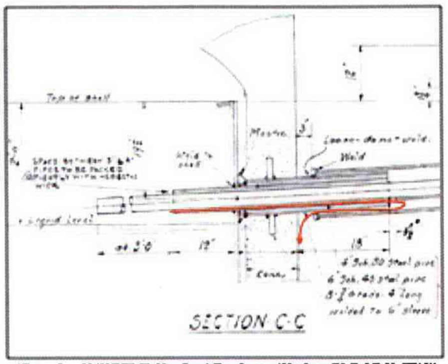
Cascade Line Sleeve Leak Path from Overfill

Leak path through 43-in long asbestos wick- packed 3/16-in annular gap between 3-in cascade line and 4-in pipe sleeve and then out the 8-in to 6-in pipe slip joint located 3-in from the tank wall.



(Drawing H-W-72743 Hanford Engineer Works - BLD.241 75'0" Dia. Storage Tanks T-U-B & C Arrangement)

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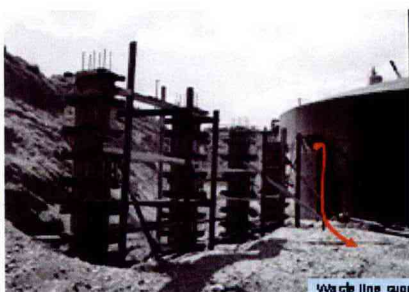
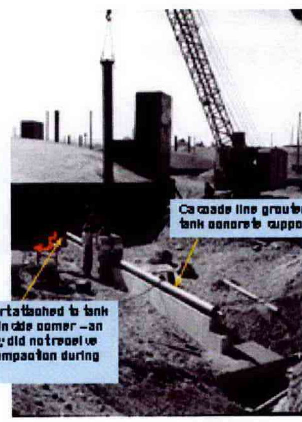
Cascade Line Leak Path via Uncompacted Soil Column to Tank Base





Viaducts were extended to sidewall sleeves in the first tank of the 3-tank cascades. Tank C-104 has a viaduct; tank C-105 does not.

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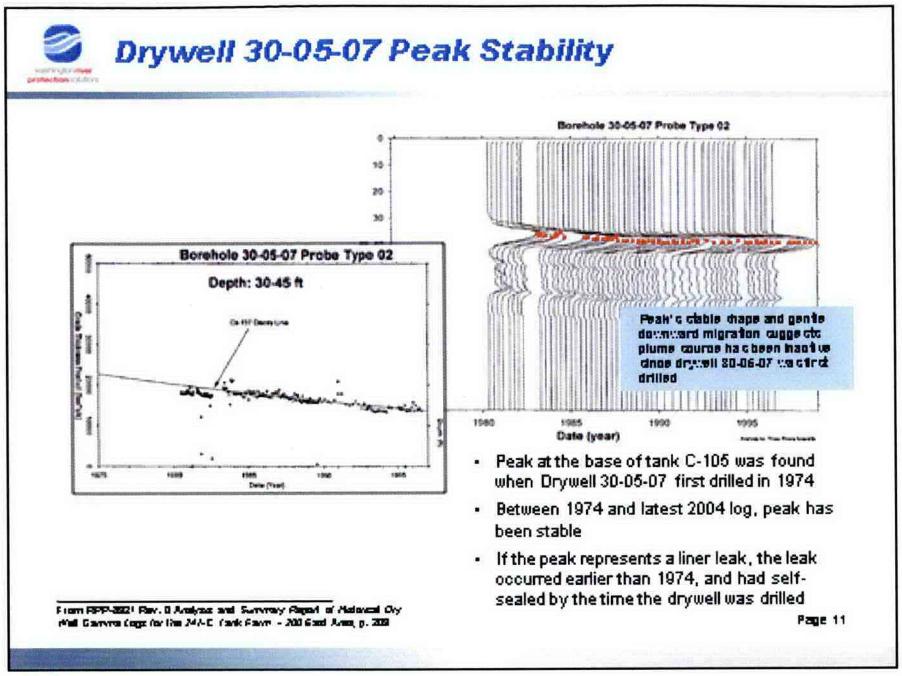
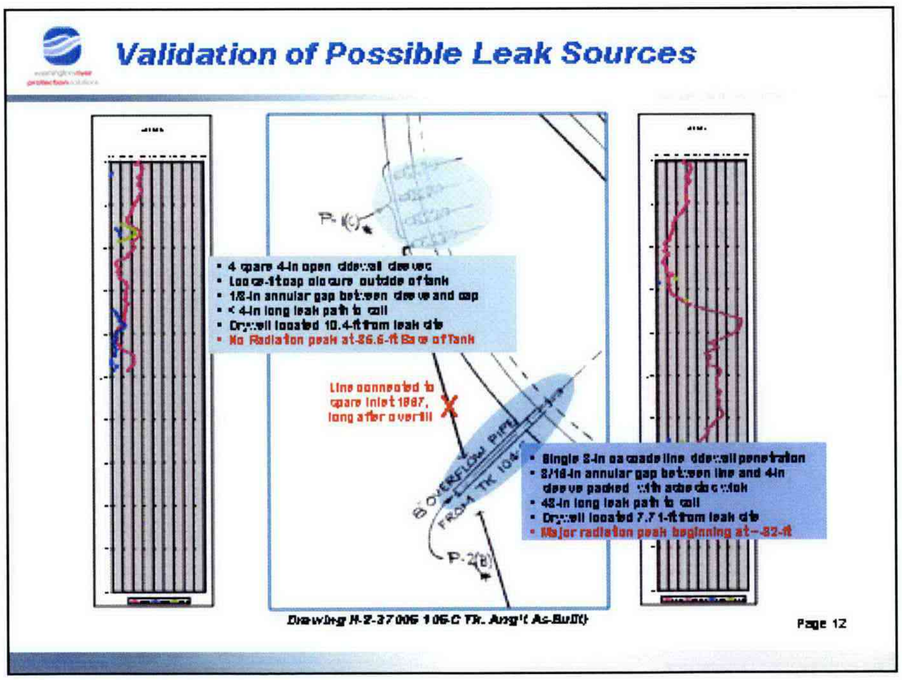

Drywell 30-05-07 Peak Stability
Borehole 30-05-07 Probe Type 02
Borehole 30-05-07 Probe Type 02
Depth: 30-45 ft
Date (year)
Peak's stable shape and gentle downward migration suggests plume source has been inactive since drywell 30-05-07 was first drilled
Peak at the base of tank C-105 was found when Drywell 30-05-07 first drilled in 1974
Between 1974 and latest 2004 log, peak has been stable
If the peak represents a liner leak, the leak occurred earlier than 1974, and had self-sealed by the time the drywell was drilled
Page 11


Validation of Possible Leak Sources
4 spare 4-in open sidewall sleeves
Loose-fit cap closure outside of tank
1/8-in annular gap between sleeve and cap
< 4-in long leak path to soil
Drywell located 10.4-ft from leak site
No Radiation peak at 36.6-ft Base of Tank
Line connected to spare inlet 1967, long after overfill
Single 3-in cascade line sidewall penetration
3/16-in annular gap between line and 4-in sleeve packed with asbestos wick
48-in long leak path to soil
Drywell located 7.71-ft from leak site
Major radiation peak beginning at ~32-ft
Drawing H-2-37006 105-C Tk. Arng't As-Built
Page 12

Validation of Possible Leak Sources

- Regardless of the duration of the overfill, the leak volume through gaps between the 4 sidewall sleeves and their loose-fitting caps (7.26-in^2 total cross-section) should have been greater than the leak volume through the long asbestos-packed gap (1.88-in^2 cross-section) in the cascade line sleeve.
- It follows that a peak at the base of the tank below the spare sidewall sleeves should also be much greater than a peak at the base of the tank beneath the cascade line penetration if the source was an overfill.

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Validation of Possible Leak Sources

- Observed data conflict with this leak axiom
  - No detectable peak beneath the sidewall sleeves where a larger overfill leak should have collected (even assuming another 1000X attenuation for additional separation distance)
    - No pipe viaduct to interfere with backfill compaction, so plume should have spread laterally
  - Significant peak at the tank base near the cascade line. A small leak through the asbestos-packed cascade line gap should not have been detected.
- It does not seem credible that a leak through the cascade line penetration can be the sole source of the radiation peak at the base of the tank...

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Could a Leak Have Self-Sealed?

Extreme Self-Sealing Example – Tank A-105 Tank:

- Tank filled to capacity December, 1964
- January, 1965 Steam Eruption
  - Bulged liner 8.5-ft, creating ~80,000 gallon void space
  - Liquid level held static by cooling water additions to offset evaporation January, 1965 - August, 1968
  - Estimated waste leak volume 5,000 – 15,000 gallons over 43 months after accounting for evaporation
  - Liner ripped from sidewall over ¾ of circumference
  - Remaining Sludge Volume after sluicing in 1978*
    - 12,700 gallons above liner
    - ✓26,200 gallons beneath liner
    - 7,500 – 9,000 gallons between liner and sidewalls

*An Estimate of Bottom Topography, Volume and Other Conditions in Tank 105A, Hanford, Washington, 1978

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Potential for Self-Sealing Leak – Tank C-105

Ripped and buckled floor liner in Tank A-105

- 40-in of PUREX coating waste solids accumulated in bottom of tank by 1965
  - Notorious pipeline plugging susceptibility: 10 pipeline failures blamed on coating waste plugging 1957 – 1973
- High-heat sludge carried over into tank during 244-AR Vault processing 1968 – 1978
  - Sludge layer was ~ 17-inches thick when processing terminated
- By 1974 when drywell 30-05-07 was drilled, tank had been receiving high-heat sludge carryover for ~ 7 years
- Active ventilation and cooling water additions started in 1971 to keep tank from overheating
  - Continuing water additions did not affect peak stability

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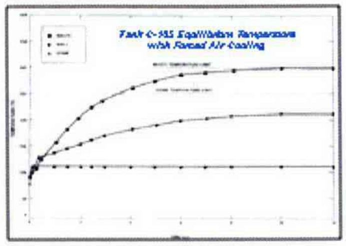
Potential for Self-Sealing Leak – Tank C-105



RHO-RE-EV-87 Tanks 105-C and 106-C Stabilization Study, Appendix C Calculation of Heat Generation Rate Estimates, and Appendix D Heat Transfer Modeling, May, 1987

10 years after 244-AR vault processing ended, thermal modeling of tank C-105 predicted an equilibrium waste temperature of 300°F with ambient air temperature forced ventilation cooling if water additions were terminated

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Updated Leak – No-Leak Hypotheses – Tank C-105

- No-Leak Hypothesis:

  "The soil contamination peak in drywell 30-05-07 at the base of the tank is due to overfill of the tank above the cascade line. Waste leaked at the cascade line/tank interface and migrated down the outside of the tank with minimal lateral migration and pooled at the base."

- Leak Hypothesis:

  "The major contributor to the soil contamination peak in drywell 30-05-07 at the base of the tank is a tank leak."

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Leak Assessment Expert Panel Elicitations

Name	Tank C-105 Expert Elicitation Tank Leak Probability
D.A. Barnes	0.31
D.W. Brown	0.50
J.G. Field	0.23
D.G. Harlow	0.31
L.S. Krogsrud	0.69
D.J. Washenfelder	0.50
Averaged Probability of Tank C-106 Leak	0.42

Tank	Expert Elicitation Tank Leak Average Probability
C-110	0.10
C-111	0.06
A-103	0.03
AX-102	0.07
SX-104	0.10
C-106	0.42

- It is unusual for a TFC-ENG-CHEM-D-42 formal leak assessment to result in such a wide range of leak probabilities.
- This is also the first formal leak assessment where the elicitations resulted in an average leak probability above 0.10.
  - The elicitation range and the average value reflect uncertainty regarding tank C-105's leak source.

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Leak Assessment Conclusion

- Based on review of the log data from the C7469 direct push, the team concluded that a leak from tank C-105 could not be ruled out by the available evidence
  - The leak through the cascade line wall sleeve likely contributed to the peak at the base of the tank, but extent is uncertain
  - Additional direct pushes are unlikely to help further discriminate among possible leak sources
- Recommendation:

  "Change tank C-105 leak integrity status from "Sound" to "Assumed Leaker" with estimated leak volume < 2,000 gallons."

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Basis for Estimated Leak Volume

- RPP-ENV-33418 Rev. 1 *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Waste Releases,* p.91
  - Minimum volume = ~ 40 gal
    - Uses 3-ft separation distance between tank and drywell 30-05-07, and 30-ft measured depth of 10^7 –10^5 pCi/gm soil contamination
      - i.e., 3-ft x 30-ft cylinder
  - Maximum volume = < 2,000 gal
    - Uses 12-ft separation distance between tank and direct push C4297, lateral migration extending 12 feet under tank, and ¼ of tank circumference
      - i.e., 24-ft x 30-ft cylinder of soil
  - Both estimates use 4.34 Ci/gal Cs-137 221-B Plant Cs-IX Feed present in tank in 1969, and
    - 2.0 gm/cm3 soil density
- RPP-PLAN-39114 Rev. 1 *Phase 2 RCRA Facility Investigation/Corrective Measures Study Work Plan for Waste Management Area* C, p. 3-2 reports leak volume as < 2,000 gal

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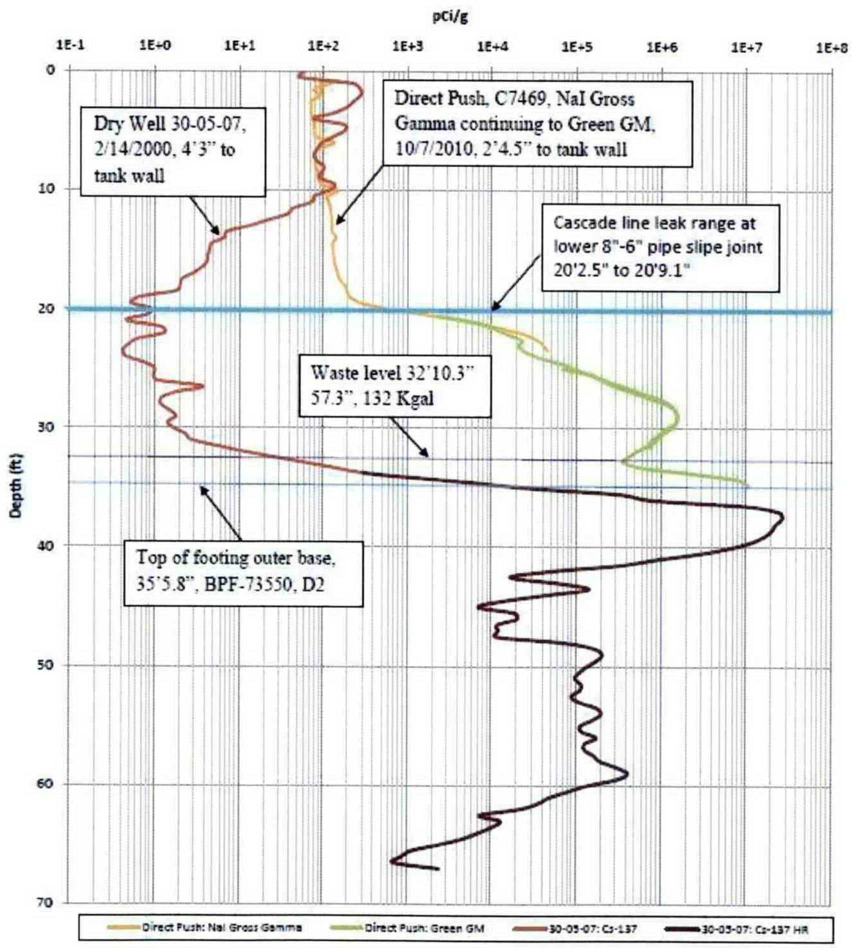
APPENDIX D - Tank C-105 Revised Tank Leak Estimate Based on direct push log data

The original tank leak estimate proposed in RPP-ENV-33418, Rev. 1, only included measurements from drywell 30-05-07, as this was the only drywell with significant gamma activity. With the addition of data from the new direct push, C7469, additional gamma activity was noted at depths between 21 and 35 feet bsg. This revised estimate will incorporate the new activity and determine if the original estimate is substantially affected by the results of the direct push data.

As in the original estimate, any potential leak is assumed to have a Cs^{137} concentration of 4.34 Ci/gal, which was reported as the concentration for PSN-IX supernatant in tank C-105 in ARH-1945, *B Plant Ion Exchange Feed Line Leak*. The soil density was assumed to be 2.0 g/cm^3.

The gamma activity data is given in Figure D-1. At depths between 21 and 35 feet bsg, the Cs^{137} is logged at about 10^6 ρCi/g.

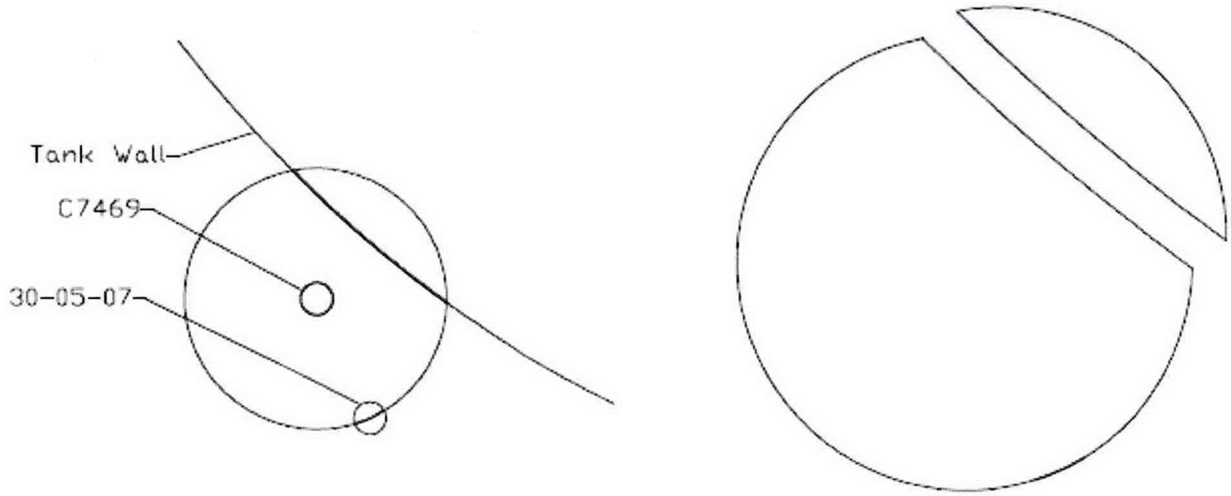
Figure D-1 C-105 Direct Push (C7469) vs. Drywell 30-05-07



The minimum and maximum tank leak estimates were calculated in much the same way as the original estimates, and are as follows:

1. For a minimum leak volume, a 14-ft long cylinder, with a point source leak and a 4-ft radius is assumed. The length of the cylinder is provided by the length of the plume, from 21 to 35-ft bsg, and the radius is estimated as the distance from the direct push to the nearest drywell which did not see any activity, drywell 30-05-07. This radius actually intersects the tank, so the cylinder has a lens-shaped section removed, as shown in Figure D-2.

Figure D-2 Minimum Leak Volume Estimate Plume Shape



The lens is the sum of two circular sections. The area of a circular section is given by:

$$A_{CS} = R^2 \cos^{-1}\left(\frac{R-h}{R}\right) - (R-h)\sqrt{2Rh - h^2}$$

Where: R = radius of the circle, and h = the height of the circular section.

The heights of the two circular sections can be calculated by determining the point of intersection between the two radii, which in this case is 37.37-ft. The height associated with radius 37.5-ft is then 0.13-ft, and the height association with the 4-ft radius is 1.49-ft. The area of the lens, then, is:

$$A_{lense} = 37.5^2 \cos^{-1}\left(\frac{37.5-0.13}{37.5}\right) - (37.5-0.13)\sqrt{2*37.5*0.13-0.13^2} + 4^2\cos^{-1}\left(\frac{4-1.49}{4}\right) - (4-1.49)\sqrt{2*4*1.49-1.49^2} \approx 7\ ft^2$$

The area of the plume, then, is:

$$A_{plume} = \pi * 4^2 - 7 = 43.27\ ft^2$$

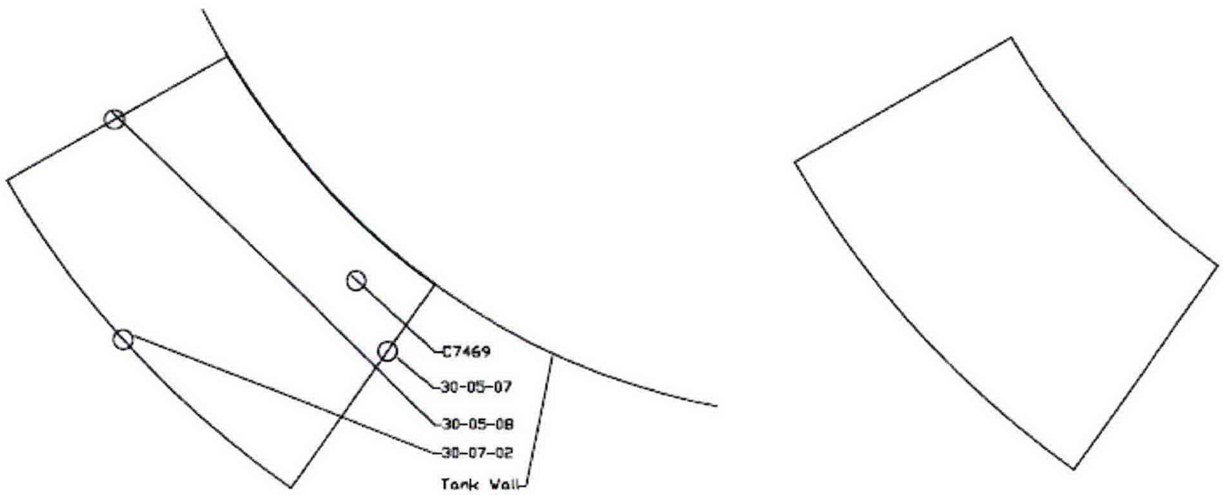
The estimate, then, is:

$$43.27\ ft^2 * 14\ ft * \left(\frac{12\ in}{ft}\right)^3 * \left(\frac{2.54\ cm}{in}\right)^3 * \frac{2\ g}{cm^3} * \frac{10^6\ pCi}{g} * \frac{Ci}{10^{12}\ pCi} * \frac{gal}{4.34\ Ci} = \boxed{7.9\ gal}$$

When this is added to the original leak volume estimate of 38 gal, the total adjusted minimum volume is 46 gal.

2. For a maximum leak volume, a more complicated plume shape was assumed. Theoretically, a plume could have travelled "above" the push, "below" the push, and away from the tank. This section is bounded below by drywell 30-05-07, above by drywell 30-05-08, and out by drywell 30-04-02. This shape is depicted in Figure D-3. The plume then extends down 14-ft, as with the minimum estimate.

Figure D-3 Maximum Leak Volume Estimate Plume Shape



This shape has outer radius, R_2, of 50.47-ft, and inner radius, R_1, of 37.5-ft. To determine the fraction of the total circle, the central angle of the triangle formed by the center of the tank, drywell 30-05-08, and drywell 30-05-07 was used. This triangle had lengths 44.15-ft, 41.75-ft, and base 18.43-ft. Using the law of cosines, the central angle was found and divided by 360 to determine the fraction of the total circle:

$$Fraction = \frac{1}{360} * \cos^{-1}\left(\frac{18.43^2 - 41.75^2 - 44.15^2}{2 * 41.75 * 44.15}\right) = 0.068$$

The area of the shape was then calculated:

$$A = 0.068 * \pi(50.47^2 - 37.5^2) = 243.74\ ft^2$$

And the maximum leak volume estimate, then, is:

$$243.74ft^2 * 14ft * \left(\frac{12\ in}{ft}\right)^3 * \left(\frac{2.54cm}{in}\right)^3 * \frac{2\ g}{cm^3} * \frac{10^6\ pCi}{g} * \frac{Ci}{10^{12}\ pCi} * \frac{gal}{4.34\ Ci} = \boxed{44.53\ gal}$$

When added to the original leak volume estimate of 1900 gal, the total adjusted maximum volume is 1944.53 gal.

CONCLUSION

The original estimate reported a maximum waste loss of less than 2000 gal. Even with the addition of the data found from direct push C7469, the estimate remains below this 2000 gal, and it can be safely stated that the new data does not appreciably alter the original tank leak volume estimate.

APPENDIX E - RPP-RPT-43725 Small Diameter Geophysical Logging for C Tank Farm Leak Assessment of Tank 241-C-105

RPP-RPT-43725
Revision 0

SMALL DIAMETER GEOPHYSICAL LOGGING FOR C TANK FARM LEAK ASSESMENT OF TANK 241-C-105

Russel Randall and Randall Price
Energy*Solutions* Federal Services, Inc.

Date
November, 2009

washington river protection solutions

Post Office Box 1500
Richland, Washington

Prepared for the U.S. Department of Energy
Office of River Protection

RPP-RPT-43725, Rev. 0

SMALL DIAMETER GEOPHYSICAL LOGGING FOR C TANK FARM LEAK ASSESMENT OF TANK 241-C-105

by

Russel Randall, PhD and Randall Price

to

Energy*Solutions* Federal Services, Inc.
2345 Stevens Drive
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October 2009

Pacific Northwest Geophysics
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Kennewick, Washington 99338

Three Rivers Scientific
3740 Grant Court
West Richland, Washington 99353

RPP-RPT-43725, Rev. 0

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LIST OF FIGURES

TERMS

Bgs	Below ground surface
Energy*Solutions*	Energy*Solutions* Federal Services, Inc.
GM	Geiger Mueller
OD	outside diameter
NaI	Sodium-Iodide
PNG	Pacific Northwest Geophysics

RPP-RPT-43725, Rev. 0

SMALL DIAMETER GEOPHYSICAL LOGGING FOR C TANK FARM LEAK ASSESMENT OF TANK 241-C-105

1 PROBEHOLE SURVEYS

Pacific Northwest Geophysics (PNG) and Three Rivers Scientific provided small diameter logging in a probehole installed near the cascade overflow pipe line of single shell tank 241-C-105, in C Tank Farm.

Logging surveys were conducted with the sodium-iodide (NaI) scintillation gross gamma detector and the moderate sensitivity Geiger-Mueller (GM) gross gamma detector. The logs were collected according to approved procedures (PNG 2009). Detector calibration certificates for the NaI and Green-GM detectors are presented in section 2 (Gamma Detector Calibrations).

Non-standard logging conditions were provided because radioactive contamination was encountered inside the probehole. The survey was acquired (as requested) from the top of the probehole (ground surface) down to the bottom. Logging was halted before the probe touched the bottom of the casing, which was at 11 meters (36 ft). The probehole was surveyed twice. The first survey was conducted with the Green GM detector positioned above the NaI detector. The second survey was conducted with the Green GM detector positioned at the bottom of the tool string, so that the gamma activity at the bottom of the probehole could be measured.

Due to concerns about contamination control, the log repeat measurement could only be acquired at the beginning of the survey. The computed results of the main and repeat intervals were reviewed and the results agree within the uncertainty of the measurement counting statistics. The repeat log data are presented with the main log plot.

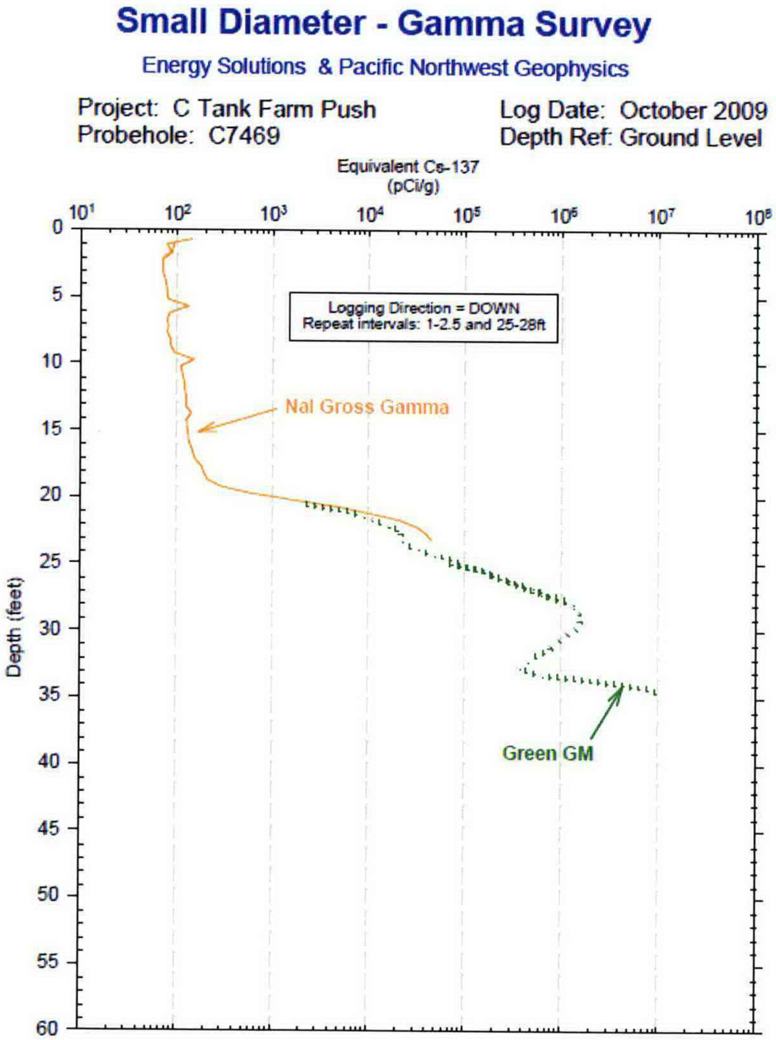
The gross gamma survey data were dead-time corrected and the results were converted to the eCs-137 calibration units. Zero depth reference is at the ground surface. The survey results for the probehole are presented as a depth versus concentration plot.

The survey results for the NaI detector are shown as an orange solid line and the results for the Green GM detector are shown as a green dotted line. The plot scale for eCs-137 is logarithmic from 10 to 100,000,000 pCi/g (i.e. 10^1 to 10^8 or seven orders of magnitude).

The radiation levels within subsurface exceeded the NaI detection range of 68,000 pCi/g (eCs-137) at 7.16 meters bgs (23.5 ft). The radiation levels in the probehole continued to increase toward the bottom of the probehole and activity exceeded the Green GM detection range of 43,000,000 pCi/g of eCs-137 at 10.7 meters bgs (35 ft). The dead-time limit for measuring gamma radiation activity is 80% for both the NaI and Green GM detectors.

The log survey results for probehole C7469 are shown in the following plot.

RPP-RPT-43725, Rev. 0



2

2 GAMMA DETECTOR CALIBRATIONS

The gross gamma detectors were calibrated for both Eq ^{226}Ra and Eq ^{137}Cs. Eq ^{226}Ra is a measurement standard in the geophysical logging industry and is appropriate for gross gamma detectors to establish the activity levels of the naturally occurring radionuclides (KUT). The calibration for Eq ^{137}Cs assumes that all of the gammas are due to the presence of ^{137}Cs. The gamma activity encountered in this probehole exceeded the levels of the naturally occurring radionuclides, consequently the plot shows only Eq ^{137}Cs

The calibration for the NaI detector is discussed first, followed by the Green GM calibration.

The gross gamma scintillation detector uses a NaI crystal. The NaI crystal (1 in. long) is hydroscopic and is enclosed in a hermetically sealed can (1 in. diameter) to maintain its integrity.

The NaI gamma surveys were logged at 2 ft/minute. A spectrum of 256 channels was collected each 0.5 ft from the top of the probehole to the bottom. Detector count rates were dead-time corrected and the gamma survey data was processed as gross gamma response to determine the concentration of eRa-226 in pCi/g.

The dead time correction is a nonparalysable relationship (Knoll, 1979) and is described by the following equation:

$$C_t = \frac{C_{obs}}{1-\varepsilon \cdot C_{obs}}$$

where C_t is the true or dead time corrected count rate in c/s, C_{obs} is the observed count rate in c/s, and ε is the dead time factor of 8.92μs. The dead-time factor was determined when the detector was calibrated for eCs-137 in the Hanford vadose well 299-W10-72.

The NaI gross gamma detector was also calibrated for eCs-137 (pCi/g). Calibration for eCs-137 was performed in Hanford vadose well 299-W10-72 (Cs-137 calibration standard). The Cs-137 in the well is stable, except for the 30 year half-life decay of the radioisotope. Also, distribution of Cs-137 ranges from less than 1 pCi/g to 40,000 pCi/g along the well path (depth). The concentrations of Cs-137 were established by two HPGe detectors (70% and High Rate tools, operated by Stoller Corp). Casing in the well is 0.288 in. thick. In order to duplicate the 0.38 in. casing of the small diameter probeholes a section of steel tubing 0.095 in. thick was installed over the detector for calibration. The conversion factor from detector count rate (cps) to eCs-137 is 0.384 (pCi/g per cps) for casing thickness of 0.38 in. See Figure 2 for the NaI calibration certificate.

The Green GM detector has lower sensitivity than the NaI detector and is designed to measure high gamma ray flux. The Green GM detector count rates were dead-time corrected (as described above for the NaI detector).and the gamma survey data was processed to determine the concentration of eCs-137 in pCi/g. The dead-time factor for the Green GM detector is 160μs. The Green GM calibration certificate is shown in Figure 3.

Figure 1. NaI Calibration Certificate.

Certificate of Calibration

SD.NaI.1

March 17, 2009

Data were taken at the Hanford KUT models on March 17, 2009. SD.NaI.1 is the designated Scintillator tool. Two models were used for the gross gamma calibration (SBU and SBL). Ten spectra were recorded for each model in order to perform statistical analysis. The observed deviations were seen to be near the theoretically predicted variation, refer to the files compressed: StatisticsNaI.xls for this analysis.

The instrument was covered with 0.38 inch wall-thickness probe-tubing.

The coefficient analysis is determined by the algorithm described in the document WHC-SD-EN-TI-293, Rev. 0. The gross gamma calibration for equivalent ^{226}Ra in pCi/g is a regression function and is generally defined by:

$$Ra = a*GR + b$$

Where Ra is the Eq. ^{226}Ra in pCi/g, and GR is the observed gross gamma count rate (c/s), dead time corrected. The coefficients of a & b are the fit coefficients. A more physical relationship constrains the intercept (b) to a zero value. This computation yields improved response extrapolated to low concentrations of K, U, and Th (clean zones). The coefficients were determined to be:

$$a = .1078 \quad Eq.^{226}Ra\ pCi/g\ /\ (c/s)$$

$$b = 0$$

The calibration for eCs-137 in pCi/g for the SD.NaI.1 instrument is described in RPP-RPT-27605, *Gamma Surveys of Single Shell Tank Laterals for A and SX Tank Farm* (Randall and Price 2006). The gross gamma calibration for equivalent ^{137}Cs in pCi/g is a regression function and is generally defined by:

$$Cs = \alpha*GR$$

Where Cs is the eCs-137 in pCi/g, and GR is the observed gross gamma count rate (c/s), dead time corrected. The coefficient α is the fit coefficient.

There is a ratio of eRa-226 calibration coefficient to the eCs-137 calibration coefficient for each instrument. The ratio between the two coefficients in Randall and Price (2006) is 2.27. Thus a factor of 2.27 times the eRa-226 calibration will yield the eCs-137 calibration coefficient. Thus: α=0.245 eCs-137 (pCi/g)/(c/s)

Digital files condensed as Cal_SDGR-NaI_2009-v0.zip. This compressed file contains:

- Calibration raw data
- Spreadsheet data formatting

The undersigned certifies that the data archived in the file "Cal_SDGR-NaI_2009-v0.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-293, "Procedures for Calibrating Scintillation Gamma-Ray Well Logging Tools Using Hanford Formation Models" and that the above stated calibration coefficients are correct and applicable for the tool SD.NaI.1 effective March 21, 2009.

Signature:
/s/ Russel Randall, PhD — Date: March 25, 2009
Three Rivers Scientific

Figure 2. Green GM Calibration Certificate.

Certificate of Calibration

SD.Green.GM

March 17, 2009

Data were taken at the Hanford KUT models on March 17, 2009. SD.Green.GM is the designated Green GM tool. One model was used for the gross gamma calibration (SBH). Ten spectra were recorded in order to perform statistical analysis. The observed deviations were seen to be near the theoretically predicted variation, refer to the files compressed: "StatisticsGGM.xls" for this analysis.

The instrument was covered with 0.38 inch wall-thickness probe-tubing.

The coefficient analysis is determined by the algorithm described in the document WHC-SD-EN-TI-293, Rev. 0. The gross gamma calibration for equivalent ^{226}Ra in pCi/g is a regression function and is generally defined by:

$$Ra = a*GR + b$$

Where Ra is the Eq. ^{226}Ra in pCi/g, and GR is the observed gross gamma count rate (c/s), dead time corrected. The coefficients of a & b are the fit coefficients. A more physical relationship constrains the intercept (b) to a zero value. This computation yields improved response extrapolated to low concentrations of K, U, and Th (clean zones). The coefficients were determined to be:

$$a = 363.9 \quad Eq.^{226}Ra \ pCi/g \ / \ (c/s)$$
$$b \equiv 0$$

The calibration for eCs-137 in pCi/g for the SD.Green.GM instrument is described in RPP-RPT-27605, *Gamma Surveys of Single Shell Tank Laterals for A and SX Tank Farm* (Randall and Price 2006). The gross gamma calibration for equivalent ^{137}Cs in pCi/g is a regression function and is generally defined by:

$$Cs = \alpha*GR$$

Where Cs is the eCs-137 in pCi/g, and GR is the observed gross gamma count rate (c/s), dead time corrected. The coefficient α is the fit coefficient.

There is a ratio of eRa-226 calibration coefficient to the eCs-137 calibration coefficient for each instrument. The ratio between the two coefficients is 4.81 (*Small Diameter Geophysical Logging In the 241-U Tank Farm*, Randall and Price 2008). Thus a factor of 4.81 times the eRa-226 calibration will yield the eCs-137 calibration coefficient and α=1746 eCs-137 (pCi/g)/(c/s)

Digital files condensed as Cal_SDGR-GrGM_2009-v0.zip. This compressed file contains:

- Calibration raw data
- Spreadsheet data formatting

The undersigned certifies that the data archived in the file "Cal_SDGR-GrGM_2009-v0.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-293, "Procedures for Calibrating Scintillation Gamma-Ray Well Logging Tools Using Hanford Formation Models" and that the above stated calibration coefficients are correct and applicable for the tool SD.Green.GM effective March 17, 2009.

Signature:
/s/ Russel Randall, PhD   Date: March 25, 2009
Three Rivers Scientific

3 REFERENCES

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