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ENVIRONMENTAL RESTORATION PROGRAM

Evaluation and Monitoring Plan for Consolidation Tanks: Gunite and Associated Tanks Operable Unit, Waste Area Grouping 1, Oak Ridge National Laboratory, Oak Ridge, Tennessee

ENERGY SYSTEMS

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FOR THE UNITED STATES
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PREFACE

This report, "Evaluation and Monitoring Plan for Consolidation Tanks: Gunite and Associated Tanks Operable Unit, Waste Area Grouping 1, Oak Ridge National Laboratory, Oak Ridge, Tennessee" (ORNL/ER-396), was developed under Work Breakdown Structure 6.1.01.41.05.05.05 (Activity Data Sheet 3301 "WAG 1"). This document provides the Environmental Restoration Program with an evaluation and monitoring plan for using Tanks W-8 and W-9, of the Gunite and Associated Tanks (GAAT), as consolidation tanks. Information provided in this report forms part of the technical basis for criticality safety, systems safety, engineering design, and waste management as they apply to the GAAT CERCLA treatability study and waste removal activities.

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ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
EPA	U.S. Environmental Protection Agency
FFA	Federal Facility Agreement
FS/PP	Feasibility Study/Proposed Plan
GAAT	Gunite and associated tanks
LLLW	Liquid low-level waste
NTF	North Tank Farm
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
P_D	Probability of detection
P_{FA}	Probability of false alarm
STF	South Tank Farm
WOCC	Waste Operations Control Center
PS1	Pump Station 1

EXECUTIVE SUMMARY

This report describes the results of an integrity evaluation of Tanks W-8 and W-9, part of the Gunite and Associated Tanks (GAAT), in the South Tank Farm at Oak Ridge National Laboratory (ORNL), together with a plan for monitoring those tanks for potential releases during the GAAT CERCLA treatability study and waste removal activities. This work was done in support of an ORNL plan to use W-8 and W-9 as consolidation tanks during remediation of the other tanks in the North and South Tank Farms. The analysis portion of the report draws upon both tank-internal measurements of liquid volume change and tank-external measurements of the change in electrical conductivity of the groundwater in the dry wells adjacent to each tank. The results of the analysis show that both W-8 and W-9 are liquid-tight and are suitable for use as consolidation tanks. The recommended monitoring plan will utilize the dry well conductivity monitoring method as the primary release detection tool during the CERCLA activities. This method is expected to be able to detect releases of less than 0.5 gal/h with a 95% probability of detection, most of the time.

The results described here validate three prior independent efforts: a liquid integrity assessment made in 1995, a structural integrity assessment made in 1995 by experts in the field of gunite tanks, and a structural integrity assessment made in 1994 using a three-dimensional, finite-element computer model. This work, along with the three prior efforts, shows that Tanks W-8 and W-9 are structurally sound and liquid-tight. Based upon this work it is concluded that these tanks are suitable for use as consolidation tanks during the GAAT CERCLA treatability study and waste removal actions and it is recommended that the tanks be monitored for potential releases during this period using the methods described in this report.

1. INTRODUCTION

A CERCLA treatability study and waste removal program is being implemented for the Gunite and Associated Tanks (GAAT) Operable Unit (OU) at the Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. A draft feasibility study (FS)/proposed plan (PP) was prepared for this OU [U.S. DOE 1966a]. The revised draft FS/PP is expected to be issued in March 1997. The FS/PP primarily addresses the actions that will be taken to remove waste from the two gunite tanks (W-3 and W-4) in the North Tank Farm (NTF) and the six gunite tanks (W-5, W-6, W-7, W-8, W-9 and W-10) in the South Tank Farm (STF). The CERCLA treatability study will use Tanks W-3 and W-4 in the NTF to evaluate in-tank sluicing for removing waste from the gunite tanks. This method will then be used to remove the waste from the six tanks in the STF. In order to facilitate the transfer of processed waste, it is planned that Tanks W-9 and W-8 will be used as temporary consolidation tanks. This report provides an evaluation of theliquid integrity of these two tanks and the liquid release detection monitoring that is recommended during their use as consolidation tanks.

Recent studies have been conducted to evaluate the *structural and liquid integrity*[1] of the gunite tanks, including Tanks W-8 and W-9. The structural integrity was examined in two independent efforts. The first, in 1994, involved a detailed engineering design study of the tanks using a finite-element computer model [SAIC 1994]. The second, in 1995, entailed an evaluation of the integrity of the GAAT, based upon dome and wall calculations performed by a recognized expert in gunite tank design and construction [Hanskat 1995]. Both of these reports concluded that the tanks were sound and not in danger of collapse, failure or rupture.

In 1995, a detailed study was performed on the liquid integrity of the gunite tanks in the NTF and STF [Energy Systems 1996]. This study evaluated long-term liquid level records for the tanks. The results of this study conclusively showed that six of the eight gunite tanks (W-3, W-4, W-5, W-6, W-8 and W-9) were liquid-tight; that is, they unambiguously demonstrated that the contents of the tanks were not leaking out. Data quality for the other two tanks (W-7 and W-10) was too poor for a conclusive analysis; however, there was nothing in the data to indicate or suggest that these tanks were leaking. Based on these liquid and structural integrity studies and other logistical considerations, it was determined that Tanks W-9 and W-8 could be used as temporary consolidation tanks during remediation activities.

As part of the 1995 liquid integrity study, the external monitoring of conductivity in the dry wells as a release detection method was also evaluated. The purpose was to develop a method for real-time detection of potential releases during waste removal activities that did not rely on internal liquid level measurements. In 1996, the conductivity monitoring method was evaluated in more detail, and simulated liquid release demonstrations were conducted [Vista Research 1996]. The results of these studies indicated that externally monitoring conductivity in the dry wells adjacent to the gunite tanks is a very effective method for real-time release detection and should be used as the primary release detection method during the CERCLA treatability study and waste removal activities. As a result, dry well conductivity monitoring will be used as the primary release detection

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As used here, liquid integrity refers to the ability of a tank to contain the materials placed into it; structural integrity refers to the ability of a tank to resist rupture, failure, or collapse.

method while W-9 and W-8 are being used as consolidation tanks and to monitor all of the tanks during sluicing and waste removal.

This report documents the structural and liquid integrity studies which support the use of W-9 and W-8 as consolidation tanks, reviews the principles behind the dry well conductivity monitoring method, and provides a recommended consolidation tank monitoring plan. A summary of the structural and liquid integrity studies is provided in Sect. 2. The external dry well monitoring method and the 1996 evaluation are presented in Sect. 3. Additional analysis of the liquid integrity of Tanks W-9 and W-8 using 1996 data is provided in Sect. 4. The monitoring plan for Tanks W-9 and W-8 is presented in Sect. 5, reporting/documentation in Sect. 6, and conclusions in Sect. 7. A copy of the 1996 Vista Research report on the conductivity monitoring method and simulated liquid release demonstrations is provided in the appendix.

2. REVIEW OF PREVIOUS WORK

This section provides a summary of four recent studies of the structural and liquid integrity of the GAAT. These include: (1) a 1994 structural analysis of the 50-ft-diameter gunite tanks in the STF using a finite-element model [SAIC 1994]; (2) an evaluation of the dome and wall strength of the gunite tanks based on industry experience, construction specifications and field observations [Hanskat 1995]; (3) an evaluation of the liquid integrity of the GAAT involving both internal tank liquid-level leak test analysis and external dry well conductivity monitoring [Vista Research 1995]; and (4) a detailed evaluation of dry well conductivity monitoring and simulated liquid release demonstrations [Vista Research 1996]. These studies indicated that Tanks W-8 and W-9 have sufficient structural and liquid integrity to be used as consolidation tanks and that they could be safely monitored for potential releases using the external dry well conductivity monitoring method. Additional detail on these studies is provided below.

2.1 STRUCTURAL INTEGRITY FINDINGS

SAIC conducted a finite-element analysis of the STF gunite tanks for Martin Marietta Energy Systems in 1994. This study evaluated the structural integrity of a tank using a 3-D, finite-element model. The inside liners of the gunite tanks were not considered in the structural model because apparent liner deterioration has been noted in some of the tanks. Both static and dynamic loadings were considered in the analysis, including seismic hazards. The results of the analysis were presented in a 1994 report by SAIC, "Structural Analysis of Underground Gunite Storage Tank" [SAIC 1994]. The report conclusions were that the tanks are in reasonably good condition and that dome and wall buckling is not a problem. Seismically induced stresses ranged from 5 to 22% of the maximum static stresses. The maximum compressive stress is 385 psi, which is well below the allowable compressive stress in concrete.

In April 1995 a meeting was held in Oak Ridge, Tennessee, with representatives from the LMES GAAT project team and two nationally recognized experts in gunite tank construction (Mr. Charles S. Hanskat, P.E., from Hanskat & Associates and Mr.Steven Gebler of the American Concrete Institute). The meeting's purpose was to discuss the current structural condition of the GAAT. As a result of this meeting, a report was prepared by Hanskat & Associates on the evaluation of the dome and wall strength of the GAAT under current loading conditions [Hanskat 1995]. The evaluation was based on accepted engineering methodologies used in the pre-stressed concrete tank industry and on industry-standard codes and specifications. The conclusions of the evaluation are that the tanks are generally sound and can comfortably carry the currently imposed loads. Hanskat concluded that the tanks' designs appear more conservative in wall and dome thicknesses than current tank design standards. The pre-stressing used during construction (in the 1940s) may not be adequate for long-term pre-stressing losses; he noted however, that the tanks are buried, and pressure from the surrounding soil should maintain compression and substantially prevent or reduce the potential for cracking. The only tanks of concern were W-5 and W-6 because of the liner deterioration observed in videos of these tanks. Some additional testing of W-5 and W-6 was recommended. No structural problems were noted for Tanks W-8 and W-9.

2.2 LIQUID INTEGRITY FINDINGS

In 1995, Vista Research conducted a preliminary evaluation of liquid integrity monitoring methods for LMES in support of the GAAT CERCLA treatability study. This evaluation involved Tanks W-3 and W-4 in the NTF and Tanks W-5 through W-10 in the STF. Internal liquid level data from the tanks for 1995 were analyzed to determine the threshold liquid volume changes that could be detected and to assess the tightness of the tanks. The data were analyzed by means of the same methodology that is used in the leak testing program for the active tank system at ORNL [Energy Systems 1995; 1996]. In addition, conductivity and water level data were collected and analyzed from the dry wells adjacent to Tanks W-3, W-4 and W-8. This was done to evaluate the feasibility of using conductivity monitoring of the groundwater in the dry wells as an external release detection method for the tanks.

The results of this evaluation are documented in the February 1996 Vista Research report "Preliminary Evaluation of Liquid Integrity Monitoring Methods for Gunite and Associated Tanks at the Oak Ridge National Laboratory, Oak Ridge, Tennessee (ORNL/ER-349)" [Energy Systems 1996]. This study conclusively showed that six of the eight gunite tanks (W-3, W-4, W-5, W-6, W-8 and W-9) were liquid-tight; that is, the contents of the tanks were not leaking out. Data quality for W-7 and W-10 was not sufficient for a conclusive analysis, but there was nothing in the data to suggest that these tanks were leaking. The analysis of the dry well data showed that conductivity monitoring could be used as an external release detection method. Additional evaluation of the conductivity monitoring method was conducted in 1996, including simulated liquid release demonstrations on Tanks W-3 and W-4. A description of the conductivity monitoring method and the 1996 evaluation is provided in Sect. 3.

3. DRY WELL CONDUCTIVITY MONITORING METHOD

Dry well conductivity monitoring is recommended to detect potential releases from the consolidation tanks (W-8 and W-9). The method can also be used to monitor the other tanks in the NTF and STF during rwaste removal operations. A preliminary evaluation of the conductivity monitoring method was conducted in 1995 as part of a liquid integrity analysis of the gunite tanks [Energy Systems 1996]. Additional data collection and evaluation of the external conductivity monitoring method was conducted in 1996 on the dry wells adjacent to Tanks W-3 and W-4 in the North Tank Farm [Vista Research 1996].

The conductivity monitoring method makes use of the existing dry well system that is adjacent to each of the gunite tanks. This method takes advantage of the fact that the electrical conductivity of the liquid in the gunite tanks is very high (10,000 to 20,000 μmho/cm) relative to the electrical conductivity of the groundwater in the dry wells (200 to 500 μmho/cm). The two main assumptions on which the conductivity monitoring method for the gunite tanks is based are: (1) the conductivity of the water in the dry wells is significantly lower than the conductivity of the liquids in the gunite tanks, and releases from the tanks, if they flow into the dry wells, will result in measurable and significant changes in the conductivity of the water in the dry wells; and (2) the tank and dry well system is designed to keep the ground water below the bottom of the tank pads so that if liquid is released from a tank it will flow onto the pad at the base of the tank and drain into the dry well. These assumptions were confirmed during the studies conducted in 1995 and 1996 [Energy Systems 1996; Vista Research 1996]. A plan view of the NTF and STF showing the tanks, dry wells and drain system is provided in Fig. 3.1. A diagram showing the construction of a typical gunite tank, tank pad and dry well is provided in Fig. 3.2.

As part of the 1996 work, simulated liquid release demonstrations on W-3 and W-4 were conducted. As implied by their descriptive name, the demonstrations were designed to simulate the release of LLLW by generating a metered flow of a salt-water solution at the upper side wall of one of the tanks, with this flow *simulating* a hole in the side of the tank. Fig. 3.2 shows the well point and monitoring instrumentation used for the simulated liquid release demonstration. The tests verified that potential releases from the tanks could be detected by monitoring conductivity in the dry wells. The demonstration also quantified the changes in conductivity that could be expected from different potential release rates from the tanks. The simulated liquid release demonstration was conducted by draining a high-conductivity salt-water solution into well points adjacent to Tanks W-3 and W-4 and monitoring the dry wells for changes (increases) in conductivity above the normal range of baseline values. The conductivity of the salt water was comparable to the conductivity of the liquids in the tanks. The resulting changes in conductivity in the dry wells during the simulated releases were analyzed to evaluate the integrity and continuity of the tank pad and dry well systems and to quantify the effectiveness and detection capabilities of the external conductivity monitoring method.

The 1996 evaluation of the dry well conductivity monitoring and the simulated liquid release demonstration was documented in a report [Vista Research 1996]. Simulated release rates from 0.5 to 4.5 gallons per hour (gal/h) were used in the demonstrations on Tanks W-3 and W-4. Even at the lowest rate (0.5 gal/h), the change in conductivity in the dry wells was easily detected within a few hours. A comparison of baseline conductivity data to the response to simulated releases also demonstrated that the tanks were liquid-tight. The conductivity monitoring data from April through

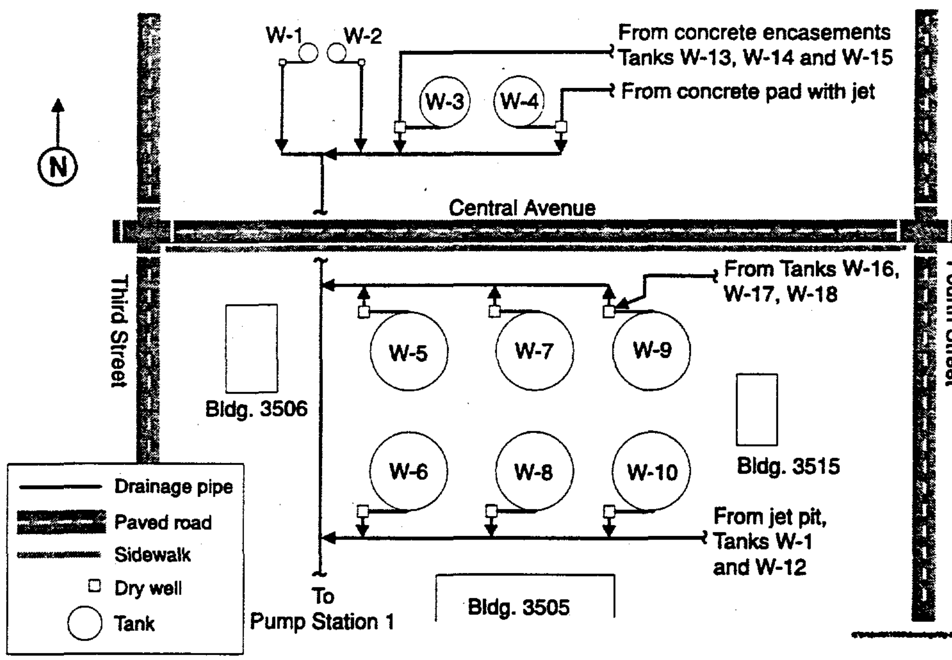

Fig. 3.1. Dry well and drain system in the North and South Tank Farms, leading to Pump Station 1.

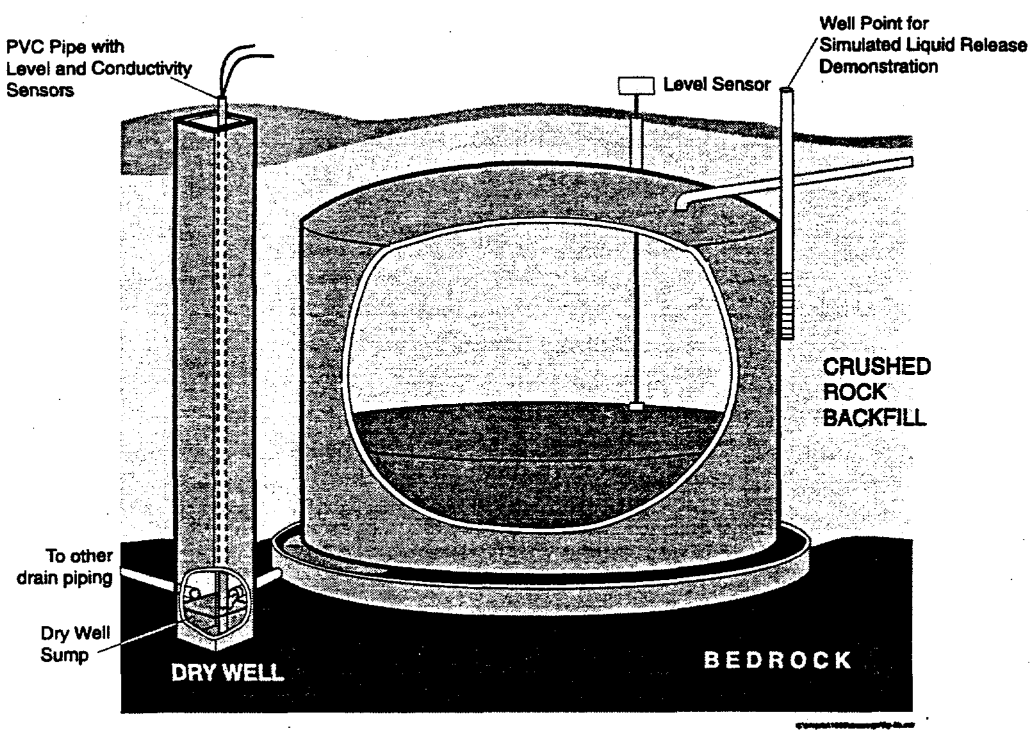

Fig. 3.2. Typical gunite tank, dry well and tank pad construction.

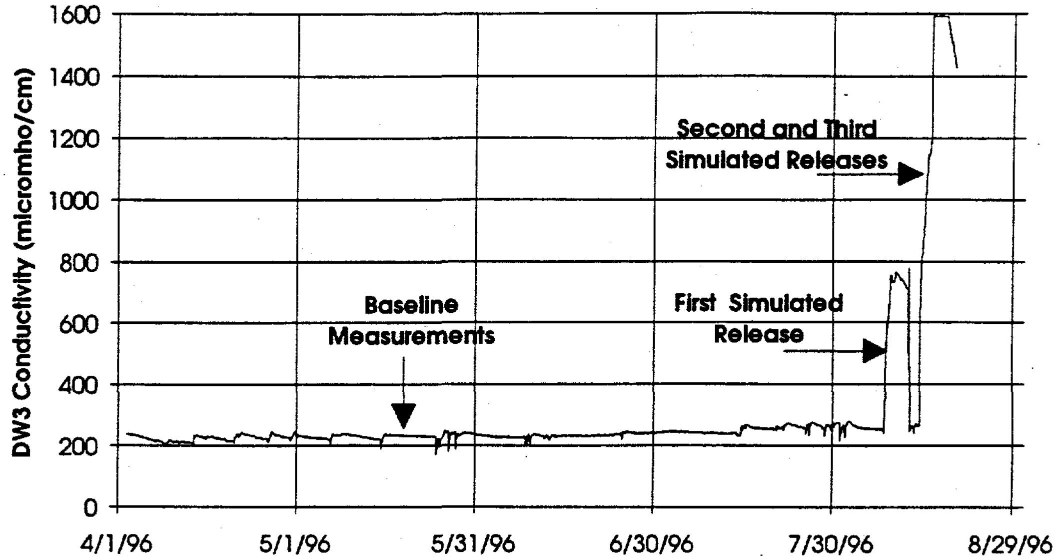

Fig. 3.3. Plot of DW-3 conductivity data from 1April through 21 August 1996, showing baseline measurements and the response to the simulated liquid releases (0.5, 1.5 and 4.5 gal/h) at Tank W-3.

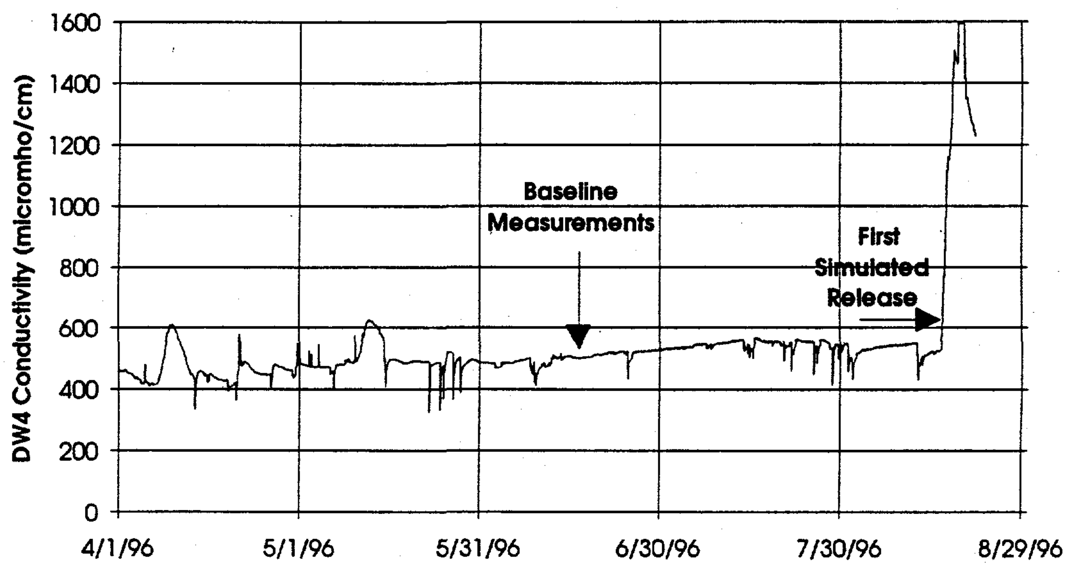

Fig. 3.4. Plot of DW-4 conductivity data from 1 April through 21 August 1996, showing baseline measurements and the response to the first simulated release (0.5 gal/h) at Tank W-4.

August 1996 is provided in Figs. 3.3 and 3.4 (W-3 and W-4 dry wells, respectively). These figures clearly show that the conductivity stays relatively constant up to the beginning of August, when the simulated liquid release demonstrations were conducted. The response to the simulated liquid releases, easily detected in the conductivity data, is dramatic. The results of these demonstrations show that the external conductivity monitoring method can be used to detect potential releases from the gunite tanks in the North and South Tank Farms during the CERCLA treatability studies and waste removal activities.

In addition to the Tank W-3 and W-4 dry well systems, the integrity of the drain system connecting the dry wells to Pump Station 1 (PS1) was also evaluated as part of the demonstration. The data from a conductivity sensor located at PS1 was used for this analysis. The conductivity data from PS1 was analyzed to see if, at the higher simulated release rates used during the demonstration, a response could be detected downstream at PS1 to provide some indication as to the integrity of the drain system. Two high-rate simulated releases of 18.0 and 420.0 gal/h were used to evaluate the PS1 response. A significant and measurable increase in conductivity was recorded at PS1, indicating that the simulated releases were contained by the dry well and drain system and conveyed to PS1.

As a result of the documented field studies [Energy Systems 1996; Vista Research 1996], external conductivity monitoring in the dry wells can be used during the waste removal from the six gunite tanks in the STF. This method can also be used on the two tanks selected for consolidation of wastes (W-9 and W-8). Based on STF data collected during 1995 [Energy Systems 1996], it is expected that the conductivity and water level data from the dry wells for Tanks W-8 and W-9 will have larger fluctuations than observed in the NTF. Therefore, prior to using W-8 and W-9 for consolidation of wastes, baseline data should be collected from the tanks and dry wells. This information can be used to establish the appropriate interpretation and threshold levels for the conductivity monitoring.

It is recommended that dry well conductivity monitoring be used as the primary release detection method for the W-8 and W-9 consolidation tanks. The external conductivity monitoring will provide real-time release detection for the consolidation tanks which periodic analysis of internal liquid level data cannot. As a back up to the conductivity monitoring, however, analyses of liquid level data from the tanks should continue to be conducted.

Sect. 4 provides a current analysis of the liquid integrity of Tanks W-8 and W-9, using liquid level data collected routinely from these tanks at the Waste Operations Control Center (WOCC) at ORNL. This analysis builds on the work done in 1995 [Energy Systems 1996]. During baseline and operational monitoring for the consolidation tanks, internal liquid level data should continue to be collected and analyzed as a backup to the external conductivity monitoring method. The recommended plan for baseline data collection and the monitoring of the tanks during waste removal activities in the STF is provided in Sect. 5.0 of this report.

4. 1996 LIQUID LEVEL ANALYSIS FOR TANKS W-8 AND W-9

The dry well conductivity monitoring method described in Sect. 3 has been used successfully to detect small ***simulated*** releases from the tanks [Vista Research 1996]. The conductivity method also demonstrated that Tanks W-3 and W-4 in the NTF are liquid-tight [Vista Research 1996]—results which validated the liquid integrity findings determined from an analysis of liquid volume changes based on internal tank liquid level data. While the conductivity method is proposed as the primary leak detection tool during the waste removal activities in the NTF and STF, conductivity monitoring equipment similar to that in the NTF has not yet been installed in the STF. This is because there is material in the bottom of the STF dry wells, and a portion of this material must be removed or pushed aside before the conductivity sensors can be installed. The installation of instruments into the dry wells of Tanks W-8 and W-9 is planned to be conducted in the spring of 1997 so that baseline data collection can be initiated and the operational release detection parameters determined.

Since the conductivity monitoring method has not yet been implemented in the STF and since it is recommended that Tanks W-8 and W-9 be used for consolidation purposes, it is necessary to show that these tanks are currently liquid tight and suitable for use as consolidation tanks during the GAAT waste removal activities. The analysis of the liquid integrity of Tanks W-8 and W-9 using the internal liquid level data for 1996 is provided below.

4.1 PRECIPITATION AND OTHER NON-PROGRAMMATIC SOURCES OF IN-LEAKAGE

As described in the liquid integrity report [Energy Systems 1995], the liquid volume in the GAAT tanks typically increases slowly with time. That report analyzed segments of the WOCC-recorded time-serial liquid volume data from the GAAT tanks, sampled from a data set that spanned a 15-month period, from April 1994 through July 1995, and concluded that the tanks were not leaking and that most of the in-leakage appeared to be related to rainwater and other surface runoff seeping into the tanks from the top. Recent analyses continue to show the same trends. This is illustrated in Figs. 4.1 and 4.2, which show the volumes in Tanks W-8 and W-9, respectively, over a subsequent 15-month period, from about 1 August 1995 through the end of October 1996. The periods when the maintenance logs show that the level measurement system was worked on or otherwise serviced are also shown in the figures. These service records show that many of the abrupt level shifts exhibited by the data are explained as sensor errors and/or "zero-reference" re-adjustments during the servicing and calibration periods.

Both of the volume plots from the 1995-96 data shown in the figures generally exhibit a level that remains more or less constant during the summer and fall, with slow volume increases during the winter and spring. After compensating for the maintenance-related level shifts, the average daily volume increases for W-9 amount to about 0.5 gal/h during the periods of increase, and for W-8 about 1.5 gal/h. These small increases are consistent with observations of non-programatic in-leakage of water seeping into the tops of the tanks, in and around pipe openings, as seen on tank videos. While numerous LLLW tanks at ORNL show a liquid volume response that is directly, positively, and promptly correlated with rainfall and surface-water runoff, Tanks W-8 and W-9 show only a very weak correlation, with about a two-day lag period between the onset of a heavy rain and a small increase in the rate of in-leakage. Taken together, these two results suggest that the net in-leakage into the tanks is caused by a combination of surface water reaching the tank's topside penetrations after heavy rains, along with a slower seepage of water from gradual infiltration through the ground.

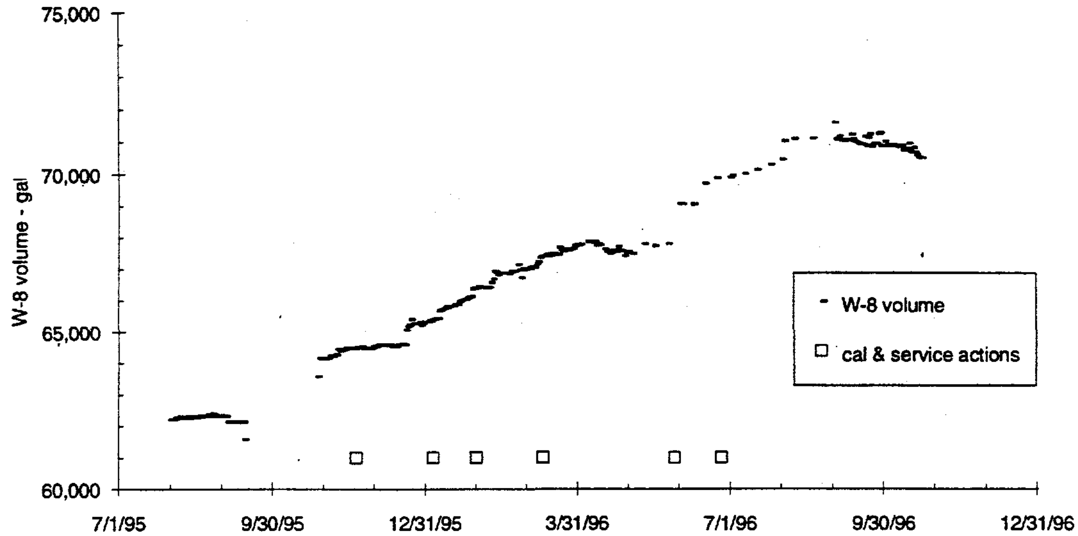

Fig. 4.1. Plot of volume versus time for Tank W-8.

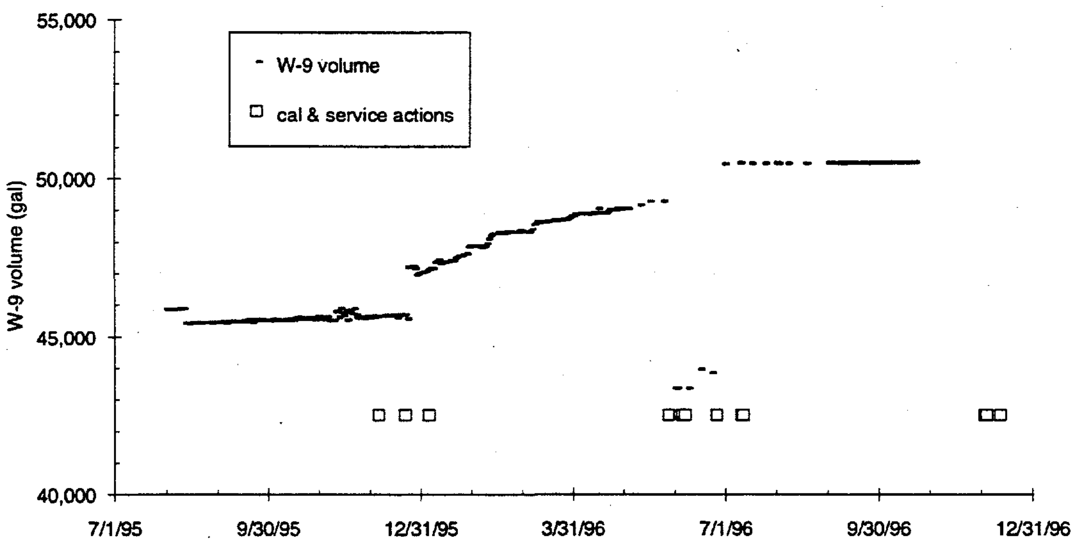

Fig. 4.2. Plot of volume versus time for Tank W-9.

Further support for this suggestion is found in the 1995-96 dry well demonstrations [Energy Systems 1995] and in Sect. 3 of this report. In these two separate examinations of water levels in the dry wells, the indication is that except for periods of very heavy and sustained rainfall, the drain system that connects the NTF and STF excavations to the process waste collection system is effective in maintaining the local groundwater level at or about at the level of the drain inlets in the tank's dry wells; these inlets are located at an elevation that is just slightly lower than the bottom of each of the tanks. Since the groundwater level is maintained at or below the bottom of each tank most of the time, and below the surface of the LLLW liquid in the tanks all of the time (including Tanks W-8 and W-9), there can be no positive external hydrostatic head on the tank trying to force water in. Therefore, any observed in-leakage *must* be coming from non-programmatic sources at the top of the tank, rather than being forced into the tank through a hole in its side or bottom. This is an important observation because it conclusively demonstrates that the in-leakage *is not* coming from a hole in the side or bottom of the tank. (Further, if the rate of inflow is not correlated with the liquid level inside the tank, this also conclusively shows that the tank itself is tight. This is because a change of head pressure on a leak would change the leak rate. An experiment could be run to demonstrate this, but it is beyond the scope of the present effort.)

Since the video-observed in-leakage from the tank-top penetrations is qualitatively comparable to the measured rate of in-leakage, and since there are no sources of in-leakage at the sides or bottom of the tanks, this suggests that Tanks W-8 and W-9 are liquid-tight. In the section below, we will use the leak testing methods developed as part of the Federal Facility Agreement for the ORR for ORNL's large, active-use LLLW tanks to "test" W-8 and W-9 for releases, and to quantify the suggestions above.

4.2 LIQUID INTEGRITY ASSESSMENTS—INTERNAL METHOD

The 1995 liquid integrity assessments of the GAAT tanks [Energy System 1995] followed an analysis approach that paralleled the analysis underlying the 1995 and 1996 structural integrity assessments for the large, Category C LLLW tank systems [U.S. DOE 1995; U.S. DOE 1996a]. This approach consisted of utilizing 48-h segments of tank level data selected from non-rainy periods (under the assumption that rain effects, while small, could influence the test result), calculating the volume rate and the volume variance during the analysis interval, and performing a null hypothesis analysis on the ensemble of test data to determine if the body of data showed any statistically significant volume losses. This same analysis is used here to examine GAAT Tanks W-8 and W-9 for the significance of the volume changes. A noteworthy difference is that, in this analysis, we more closely follow the Category C leak test and annual assessment approach in that here we temperature-compensate the volume data, just as is done for the Category C tank data. The reason this is done here is because, in conducting this analysis, it was observed that there was a strong temperature correlation in the data that, if removed, could improve the statistical estimates. This is illustrated in Figs. 4.3 and 4.4. Fig. 4.3 shows a scatter plot of the WOCC-measured volume in Tank W-9 over a two-week period in September 1996, plotted as a function of air temperature during that period, as measured by ORNL's meteorological tower, which is located about 1,500 ft northwest of the tank. This figure shows that as the air temperature increases, the measured volume decreases. This effect is the result of the sensor wire on the level sensor expanding (growing longer) with increasing temperature; as the wire descends into the tank from the top, it senses the liquid sooner than it would at a colder temperature, and thus signals an apparent and wholly artificial increase in volume. By calculating the strength of the effect (the "influence coefficient" in the parlance of the Category C leak testing protocols) and removing the temperature effect, we get a "temperature compensated volume." This is illustrated in Fig. 4.4, which shows the raw, WOCC-recorded volume in W-9 over a two-week period. The raw data are shown as the discrete points, while the temperature-compensated data are shown as the continuous-line plot. Inspection of these plots clearly shows that an (analysis based upon the temperature-compensated data will result in more definitive results, with

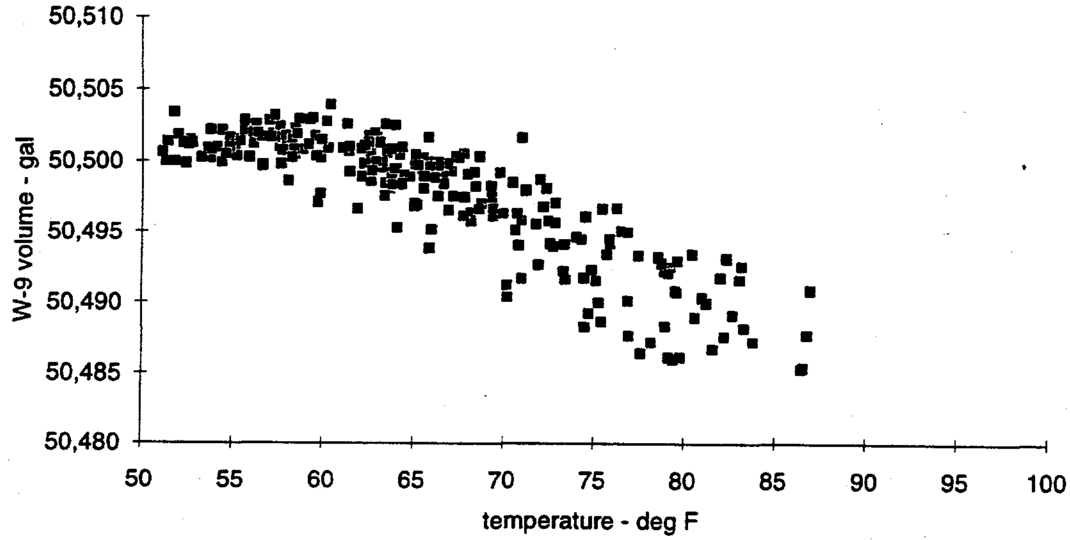

Fig. 4.3. Scatter plot of volume versus air temperature for Tank W-9 (15 to 26 September 1996).

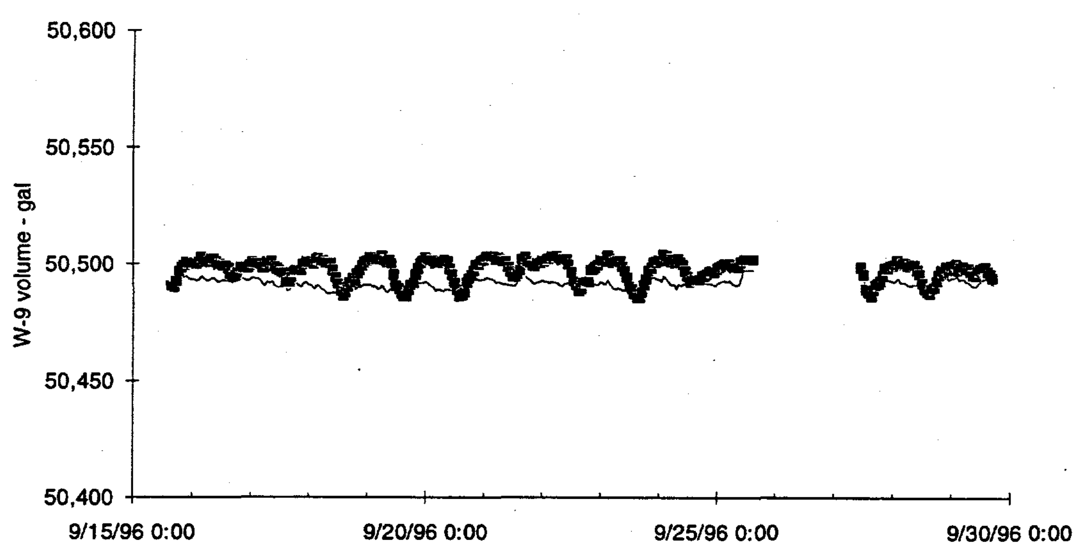

Fig. 4.4. Raw and temperature-compensated volume (points and curve, respectivley) for W-9.

less ambiguity as a result of the noise or fluctuations in the data. Since temperature compensation of the volume measurement is part of the Category C testing protocols, we have included it here as part of this analysis.

4.2.1 Liquid Integrity of W-9

The liquid integrity assessment for Tank W-9 reported here is based upon a test of the null hypothesis—that there is no significant difference between the measured liquid volume rates in the tank and a volume leak rate of zero gallons per hour. To make this test, the analysis sets were chosen so that they spanned the seasons (spring, summer, and fall) to reduce any seasonal biases. Within these seasons, we selected data that were free of known (or suspected) sensor operation or data recording problems, free of periods where administrative transfers were made (September–October 1995) and free of noise or other spurious effects, and that were of sufficient duration that several sequential 48-h data samples could be obtained to reduce the statistical uncertainty. The resulting data set was comprised of 20 48-h data intervals from the WOCC-recorded volume data from W-9, selected from the then-available data that spanned the period 1 August 1995 through 22 October 1996.

As described in the preliminary evaluation [Energy Systems 1995], a regression analysis and least squares fit to the temperature-compensated level (volume) data were made and the regression parameters were tabulated, including the slope of the regression line in gallons per hour, m (the volume rate in that interval), and the standard deviation of the y-estimate, σ_y, in gallons. The results of this analysis are tabulated in Table 4.1, which shows the segment start date, m, and σ_y. The data in this table represent 40 days' worth of data selected from the 15-month data interval, or about a 10% sample of the total data set, which is considered to be representative.

A plot of the (m,σ_y) pairs in Table 4.1 are shown in Fig. 4.5; for the data shown in this figure, the standard deviation of the m-values is 0.63 gal/h and the standard deviation of the σ_y-values is 4.1 gal. Following the convention of the preliminary evaluation [Energy Systems 1995], "bad" data in this set—point pairs that lie outside of an ellipse represented by twice the standard deviations—are deleted from the analysis. In this case, one pair at (2.31, 18.06) is removed. The remaining data have a mean volume rate, <VR>, of -0.035 gal/h, with a standard deviation of 0.37 gal/h.

The statistical significance of $\langle VR \rangle = -0.035$ and $\sigma_{vr} = 0.37$ with N-1 = 18 degrees of freedom is tested by calculating the test statistic,

$$t_s = N^{1/2} \langle VR \rangle / \sigma_{vr} = 18^{1/2} \times (-0.035) / (0.37) = -0.401.$$

From a Student's t-distribution, the critical value, t_c, corresponding to a t with 18 degrees of freedom and a one-sided 5% significance level is 1.734. Since $|ts| < tc$, we accept the null hypothesis (formally we "fail to reject...") and conclude that the measured volume rate, $\langle VR \rangle = -0.035$ gal/h, for W-9, is the same as 0 gal/h. In other words, we can say with a confidence level of 95% that W-9 is not leaking. (It is noted here that the same conclusion was drawn for W-9 in the previous analysis [Energy Systems 1995]. Further, in that analysis of 28 48-hour data segments, <VR> was -0.038 gal/h and σ_{vr} was 0.307. This suggests not only that W-9 is not leaking (which can be stated with a 95% confidence level) but that the in-leakage, evaporation, and other factors that can affect the level in the tank have not changed since the last 15-month analysis period. Following the procedures developed by the Environmental Protection Agency [U.S. EPA 1990], the data shown in Table 4.1 can be used to estimate the minimum detectable leak that could be detected in W-9 using the existing

Table 4.1.

Volume Rate and Standard Deviation of Y-estimates Determined from W-9 Volume Time Histories

Segment Date	m (gal/h)	σ_y (gal)
02/14/96	-0.19	6.63
02/16/96	0.03	4.31
02/17/96	-0.02	2.92
02/24/96	-0.35	6.41
02/26/96	0.34	4.79
02/28/96	-0.32	2.17
03/01/96	-0.005	8.71
03/01/96	-1.01	10.8
07/01/96	0.92	6.18
07/03/96	-0.15	7.36
07/05/96	0.29	6.85
07/07/96	0.08	4.38
07/09/96	-0.25	2.8
07/11/96	2.31	18.06
09/15/96	-0.05	1.27
09/17/96	-0.05	1.69
09/19/96	0.07	2.02
09/21/96	-0.09	1.22
09/23/96	0.05	2.02
09/27/96	0.04	1.77

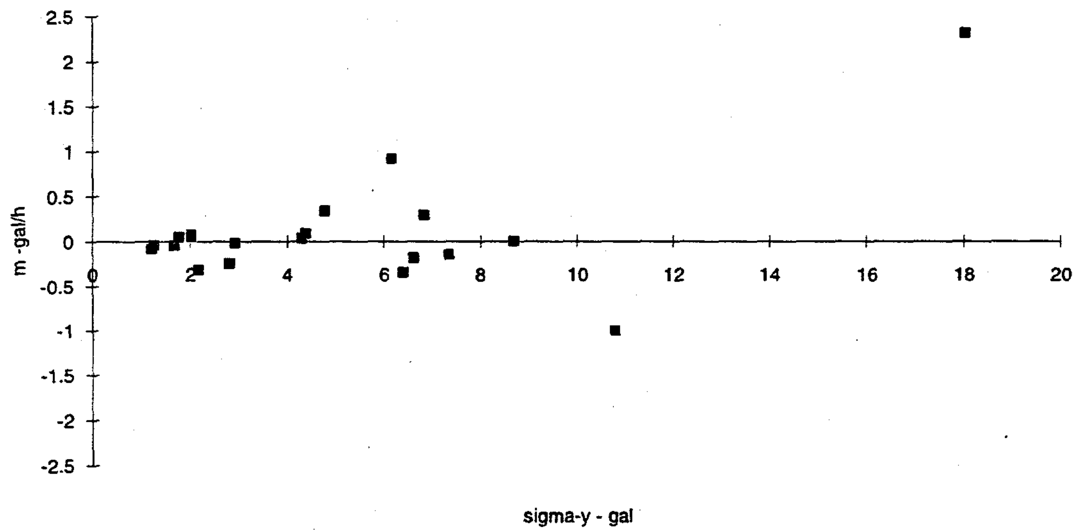

Fig. 4.5. Scatter plot of volume rate versus standard deviation (Tank W-9).

in-tank instrumentation, based upon a 48-hour data segment and for specified performance criteria. Using the EPA-accepted values of 95% for the probability of detection and 5% for the probability of false alarm [U.S. EPA 1990] shows that the threshold, T, required to obtain a P_{FA} of 5% can be determined from a data set by the equation:

$$P\{t \geq (T\text{-}B/\sigma)\} = 0.05,$$

where B is the bias of the data used for the estimate, σ is the standard deviation of the data, and t is the one-sided t-statistic for N-1 degrees of freedom. For the regression statistics obtained from the W-9 data (Table 4.1), the bias is essentially zero; therefore, $T_{05} = t\sigma$, or $T_{05} = 1.734 \times 0.37 = 0.64$ gal/h to achieve a P_{FA} of 5% on a single test. In [U.S. EPA 1990], the EPA shows that the minimum detectable leak rate with a P_D of 95% is twice the calculated threshold, T_{05}, or 1.28 gal/h for Tank W-9.

4.2.2 Liquid Integrity of W-8

The analysis of the W-8 data follows the same procedures as were outlined for Tank W-9. In the case of W-8, however, there was significantly greater noise in the selected data sets than there was in the corresponding W-9 data. Table 4.2 shows the volume rate and standard deviation of the y-estimates determined from about 48 days of the W-8 volume time histories, for the same analysis periods selected for the W-9 analysis. A plot of the (m,σ_y) pairs in Table 4.2 are shown in Fig. 4.6; for the data shown in this figure, the standard deviation of the m-values is -0.92 gal/h and the standard deviation of the σ_y-values is 58.5 gal. Removing the "bad" data in this set—the pair at (-21.3, 241)—reduces the analysis set to 23 volume rate estimates that have a mean value of -0.03 gal/h and standard deviation of 2.5 gal/h.

Following the analysis in Sect. 4.2.1 above, a t-statistic is calculated for these data using N = 23, <VR> = -0.03 gal/h, and sm = 2.5 gal/h. When we compare the calculated value of the t-statistic, -0.06, to the t-critical value of 1.717 for 22 degrees of freedom, we are required to accept the null hypothesis that Tank W-8 is non-leaking.

In this analysis the procedures used in Sect. 4.2.1 are followed in estimating the performance of the method on Tank W-8. The threshold, T, required to obtain a P_{FA} of 5% is $T_{05} = t\sigma$, or $T_{05} = 1.717 \times 2.5 = 4.34$ gal/h. The corresponding minimum detectable leak rate with a P_D of 95% is twice the calculated threshold, T_{05}, or about 8.7 gal/h for Tank W-8. It is concluded from this analysis that W-8 is non-leaking,
and that any leak greater than 8.7 gal/h would be detected.

4.2.3 Analysis Summary

The analysis of the internal method of liquid integrity monitoring shows that GAAT Tanks W-8 and W-9 are liquid-tight to within the statistical uncertainties inherent in the analysis. Because the local groundwater level is usually at or below the level of the bottoms of the tanks, leaks cannot be masked by a positive hydrostatic head on the outside of the tank. Thus, the analysis would be expected to detect leaks in the tanks, if they were present. Since both of the tanks are known to receive in-leakage from the top, and since the rate of this in-leakage is qualitatively consistent with that observed in the videos, it is concluded that both Tanks W-8 and W-9 demonstrate liquid integrity and are suitable for use as consolidation tanks during the CERCLA treatability study and waste removal actions.

Table 4.2

Volume Rate and Standard Deviation of Y-estimates Determined from W-8 Volume Time Histories

Segment Date	m (gal/hr)	σ_y (gal)
2/15/96	0.05	4.32
2/17/96	0.06	7.77
2/25/96	0.23	11
2/27/96	-0.19	9.11
2/29/96	0.45	20.1
7/1/96	4.65	62
7/3/96	0.25	62.6
7/5/96	1.17	82.5
7/7/96	-21.3	241
7/9/96	0.93	44.6
7/11/96	-0.85	86.9
9/1/96	1	22.3
9/3/96	-0.25	52.1
9/5/96	0.31	35.7
9/7/96	-0.54	52.1
9/9/96	-2.5	46.1
9/11/96	-0.59	8.6
9/13/96	-1.3	65.6
9/15/96	-1.82	40.3
9/17/96	-4.08	119
9/19/96	5.24	49.5
9/21/96	-7	122
9/23/96	1.23	34.2
9/27/95	2.82	196

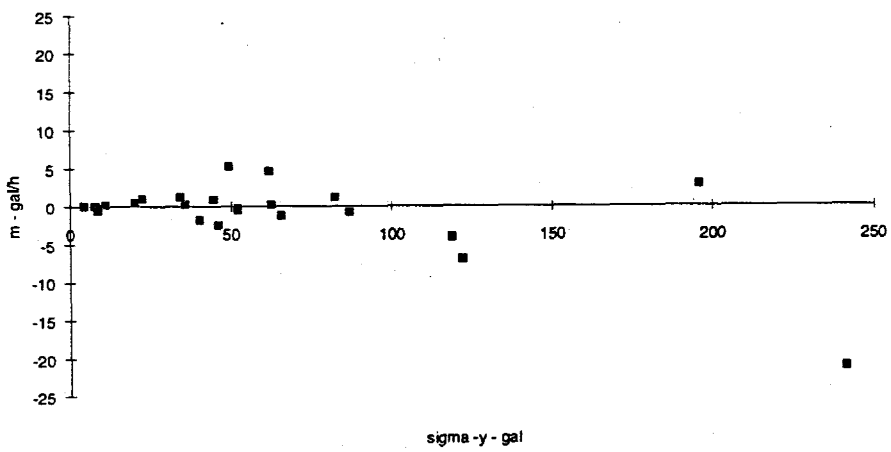

Fig. 4.6. Scatter plot of volume rate versus standard deviation (W-8).

5. MONITORING PLAN FOR CONSOLIDATION TANKS W-8 AND W-9

The monitoring plan for consolidation Tanks W-8 and W-9 should include both baseline and operational data collection. Baseline data collection should be conducted during the spring and summer of 1997 prior to operational use of the tanks, and the operational data collection for release detection monitoring should be conducted once W-8 and W-9 are in use as consolidation tanks. Tank W-9 is expected to be the primary consolidation tank, with W-8 as a backup; however, the same type of instrumentation, measurements and testing can be applied to each tank. Conductivity measurements in the dry wells is the recommended primary method employed for detection of potential releases from Tanks W-8 and W-9. As part of the baseline data collection effort, simulated liquid release tests will be conducted at each tank to develop tank-specific responses that can be used during operational monitoring. Analysis of liquid level data from the tanks should continue to be used as a backup to the conductivity monitoring. Additional details on the baseline and operational monitoring recommendations for Tanks W-8 and W-9 are provided below.

5.1 BASELINE MONITORING

It is recommended that baseline data be collected from the dry wells associated with Tanks W-8 and W-9. These dry wells are located at the southwest and northwest corners of Tanks W-8 and W-9 respectively, as shown in Fig. 3.2. Both conductivity and water level sensors will be installed in each of the dry wells. These instruments will provide data on the variations in the level and conductivity of the groundwater in the dry wells during routine non-rainy periods and during significant rainfall events. Previous work in the STF has shown that water levels may fluctuate as much as 4 ft during significant rainfall events and that conductivity values increase significantly. The baseline data collection will be used to develop thresholds and response patterns that will allow us to discriminate between normal/rain-induced fluctuations and the large, steady increases in conductivity that would be measured if a release occurred. This will mitigate false alarms and provide for a more robust release detection system.

A cross section of a typical STF gunite tank and dry well is shown in Fig. 5.1. The dry wells in the STF have approximately 1.0 to 1.5 ft of material in the bottom. As shown in the diagram, the material extends above the tops of the inlet and outlet drains to the dry wells. Field measurements indicate that the groundwater level is also at about the same level as the material. In order to instrument the dry wells, the material will be moved/augured out of the way with long-handled tools, and the conductivity and level sensors will be installed inside PVC well pipe as illustrated in Fig. 5.1. The PVC pipe and sensors will be installed directly in front of the inlet drain leading from the tank pad to the dry well. The bottom 10 ft of the well pipe will consist of pre-slotted well screen and the upper 12+ ft will be of solid PVC pipe. The screened interval will help keep out sediment and material and still allow the free flow of water from the drain pipe to the sensors.

The recommended baseline measurements of conductivity and water level in the dry wells will be recorded on a data logger located in the STF. Measurements will be recorded every hour and the data will be downloaded and processed approximately every two weeks. Hourly measurements of rainfall and temperature will be obtained from the ORNL meteorological station and will be used in the analysis of the dry well data. In addition, conductivity, radiation, and level measurements from PS1 will be analyzed. The STF dry wells are connected to PS1 by a tile drain system. The normal

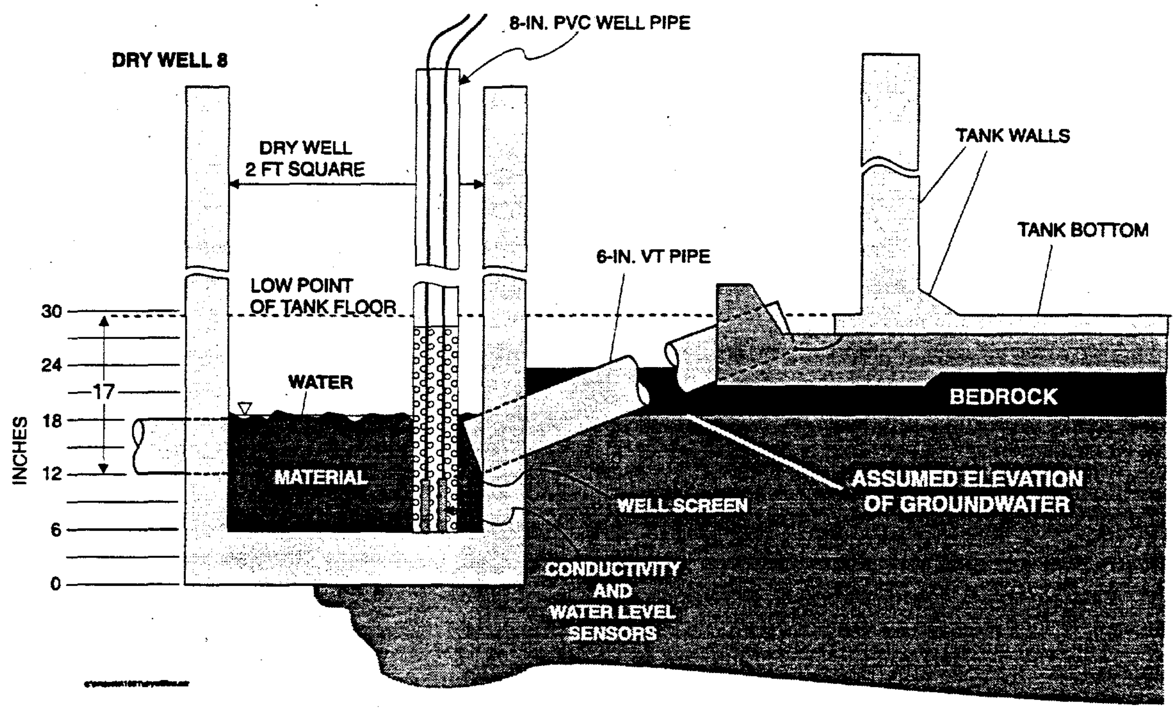

Fig. 5.1. Cross-sectional diagram of typical dry well in the STF. The water in the dry well is at approximately the same level as the groundwater; the layer of material is approximately 1.0 ft thick. Conductivity and water level instrumentation will be located as shown.

water level in the dry wells is only slightly higher than the inlet elevation to PS1 and, therefore, PS1 is believed to be the control for all of the groundwater drained by the STF dry well system. The data from PS1 will be used to confirm the continuity and hydraulics of the STF drain system and refine the procedures for the operational dry well monitoring for Tanks W-8 and W-9.

The baseline data collection should take place from April through the beginning of August 1997. A technical memorandum will then be prepared documenting the results and providing specific procedures for the W-8 and W-9 operational monitoring. As part of the baseline evaluation, simulated liquid release tests will be conducted on Tanks W-8 and W-9. The results of these demonstrations will also be included in the technical memorandum. The operational monitoring and simulated liquid release test plans are described below.

5.2 OPERATIONAL MONITORING

The primary objective of the dry well conductivity monitoring, during use of W-9 and W-8 as consolidation tanks, is release detection. Therefore, it is planned that during this period the monitoring sensors will be connected to WOCC or the remediation system control equipment. The system will be set up to provide the operators with real-time data and conductivity threshold alarms. Hourly data will be logged, for the purposes of documenting the monitoring activities as well as providing additional data with which to refine the release detection procedures. A detailed operational monitoring plan will be provided in the baseline-monitoring technical report discussed above. Monthly data summaries and quarterly reports will be prepared during the operational monitoring of the W-8 and W-9 consolidation tanks. Additional information on reporting and documentation is provided in Sect. 6.

5.3 SIMULATED LIQUID RELEASE DEMONSTRATIONS (W-8 AND W-9)

Simulated liquid release tests are planned for Tanks W-8 and W-9 as part of the baseline monitoring activities. The purpose of the tests is to quantify the change in conductivity that can be expected in the dry wells as a result of liquid releases from the tanks. These tests will be very similar to the ones conducted on Tanks W-3 and W-4 in the NTF. (The results of those demonstrations are presented in the report which is included as an appendix to this document.) For the tests on W-8 and W-9, a steel drain pipe will be installed adjacent to each tank, as close to the outer edge of the tank as possible, and on the opposite side of the tank from the dry well. This pipe, 1.5 to 2.0 in. in diameter and having a slotted well screen point on the end, will be used to simulate a liquid release. Water with a conductivity similar to the that of the tank contents (16,000 μmhos/cm) will be poured into the top end of the pipe at a controlled rate. The water will exit through the slotted end of the pipe and seep down the side of the tank, onto the tank pad. From there it will be directed toward the dry well drain. The resulting changes in conductivity in the dry wells will be analyzed to determine threshold release rates at which conductivity changes can be detected, the rate of conductivity change and the maximum change in conductivity that can be expected. Changes in conductivity will also be recorded at PS1. The response at PS1 to high rate/high conductivity simulated releases will be used to further evaluate the continuity of the STF dry well and drain system. The results of this test will be presented in a baseline technical memorandum.

5.4 INTERNAL TANK LIQUID LEVEL MONITORING (W-8 AND W-9)

The liquid levels in the consolidation tanks W-8 and W-9 should continue to be monitored during the baseline and operational periods. As a backup to the external dry well conductivity monitoring, selected data sets on liquid level will be analyzed to confirm the liquid integrity of the tanks . The data from the current water level instrumentation are noisy and have some quality problems; therefore, it is planned that a water-level pressure transducer will be placed in each tank to provide a second set of data for analysis and comparison. The pressure sensors will be connected to the same data logging system that will be collecting the data from the dry wells. During baseline monitoring, liquid level integrity analyses will be conducted for each tank and the results presented in the technical memorandum on baseline monitoring.

6. REPORTING/DOCUMENTATION

It is recommended that the reporting and documentation for baseline data collection and operation of W-8 and W-9 as consolidation tanks include the following:

	Report Title	Date/Frequency
1.	Simulated Liquid Release Test Plan	May 1997
2.	Baseline Monitoring Report for Tanks W-8 and W-9	August 1997
3.	Monthly Operational Data Summary	Starting October 1997/Monthly
4.	Annual Report	Annually

The Simulated Liquid Release Test Plan will be very similar to the one that was approved for the demonstrations on Tanks W-3 and W-4 in the NTF. The plan will provided details on the high-conductivity potassium chloride mixture that will be used to simulate the tank contents and on the different release rates and monitoring procedures that will be used during the tests. The plan will be submitted for information to the DOE and the TDEC. It is expected that the plan will be issued by early May and the tests conducted in June 1997.

The Baseline Monitoring Report For Tanks W-8 and W-9 would be prepared and issued in August 1997. The report would document: (1) the results of the baseline conductivity monitoring in the dry wells; (2) the results of the simulated liquid release tests; (3) the results of the level monitoring and integrity analysis; and (4) the procedures for dry well monitoring during use of the consolidation tanks.

The Monthly Operational Data Summary would be prepared as a letter report with plots of the dry well conductivity data for W-8 and W-9 and any comments as needed. The proposed Annual Report would present twelve months of monitoring data for the consolidation tanks that documents the seasonal variation in the dry well conductivity measurements and any significant events or observations.

7. CONCLUSIONS

The results of the consolidation tank evaluation described here validate three prior independent efforts: a liquid integrity assessment made in 1995, a structural integrity assessment made in 1995 by experts in the field of gunite tanks, and a structural integrity assessment made in 1994 using a three-dimensional, finite-element computer model. The work reported here, along with the three prior efforts, shows that Tanks W-8 and W-9 are structurally sound and liquid-tight. Based upon this work it is concluded that these tanks are suitable for use as consolidation tanks during the GAAT CERCLA treatability study and waste removal activities. It is recommended that the tanks be monitored for potential releases during this period using the methods described in this report. The specific conclusions of this and the prior reports are:

- The 1994 and 1995 structural integrity reports [SAIC 1994; Hanskat 1995] concluded that the tanks were in reasonably good condition, that the walls and dome were in no danger of buckling or cracking, and that the construction of the tanks is such that they can reasonably be expected to carry the currently imposed loads for many more years.

    - The 1995 liquid integrity report [Energy Systems 1996] conclusively showed that Tanks W-3, W-4, W-5, W-6, W-8, and W-9 in the STF are liquid-tight. Because of data quality problems W-7 and W-10 could not be conclusively evaluated; however, there is nothing in the data to suggest that these tanks are leaking. This report also indicated that external monitoring using dry well conductivity was a viable release detection method for these tanks.

- The analysis of 1996 liquid level data from Tanks W-8 and W-9 presented in this report showed that these tanks are liquid-tight to within the statistical uncertainties inherent in the analysis and are suitable for use as consolidation tanks.

- The 1996 report on the simulated liquid release demonstrations concluded that dry well conductivity monitoring can be used for real-time release detection during the CERCLA treatability study and waste removal actions for the gunite tanks in the NTF and STF. The results of this report indicate that this method can also be used to monitor W-8 and W-9 while they are being used as consolidation tanks.

- It is recommended that the dry wells for Tanks W-8 and W-9 be instrumented as soon as possible so that the baseline conductivity data can be collected and the specific release detection response characteristics for W-8 and W-9 can be developed. As a backup to the conductivity monitoring, additional liquid level data would be collected from Tanks W-8 and W-9 using both the existing level gauge and a pressure transducer.

8. REFERENCES

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Appendix

SIMULATED LIQUID RELEASE DEMONSTRATIONS ON GUNITE TANKS W-3 AND W-4 IN THE NORTH TANK FARM

Vista Research Report No. 1060-TR-96-001
September 1996

Report No. 1060-TR-96-001

Simulated Liquid Release Demonstration on Gunite Tanks W-3 and W-4 in the North Tank Farm

LMES Subcontract No. 91X-SP750C
Vista Research Project No. 1060

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Executive Summary

A CERCLA treatability study is underway to investigate means to remove waster from the gunite and associated tanks (GAAT) located in the North and South Tank Farms (NTF and STF) at Oak Ridge National Laboratory (ORNL). Most of these tanks contain a supernate (mostly water) over a layer of sludge. A part of the CERCLA treatability study will entail sluicing--- jetting water into a gunite tank to loosen and suspend the sludge--- so that the supernatant and the sludge can be removed. The current plans are to conduct the sluicing demonstration on tanks W-4 and W-3 which are in the NTF. The experience gained from this demonstration will be used to design and implement the removal of waste from the gunite tanks in the STF.

To provide a means to assure the integrity of the GAAT during the CERCLA treatability study and subsequent waste removal operations, an external method for detecting releases from the tanks has been demonstrated and is discussed here. The release detection method takes advantage of the fact that the electrical conductivity of the liquid in the gunite tanks is very high, compared to the conductivity of the groundwater in the dry well and drain system connected to the tanks. The method detects liquid releases from tanks by examining measured conductivity data from the dry wells for significant increases above background concentrations. A preliminary assessment of the method was conducted in 1995 as part of the liquid integrity assessment of the gunite tanks (Reference 1), however, a conclusive demonstration of the method was needed: 1) to unambiguously show that the method worked, and 2) to assess the sensitivity of the method to (simulated) releases at various rates.

The simulated liquid release demonstrations were conducted on tanks W-3 and W-4 in August, 1996. Technical support for the demonstration was provided by Vista Research, Inc. and the ORNL I&C Division. The demonstration entailed releasing a precisely metered 9,000 μmho/cm potassium chloride solution near the top and immediately next to the tank walls to simulate a release of liquid low level waste (LLLW) from the tanks. Release rates from 0.5 to 420 gallons per hour were employed to simulate small through large leaks from the tanks. The results indicate that, even at the lowest flow rate, releases can easily be detected by monitoring the conductivity of the liquids in the dry wells adjacent to each tank. The results also showed that the tank pad and dry well systems associated with tanks W-3 and W-4 are functioning as originally designed and that potential LLLW releases from the tanks will collect on the tank pads and flow to the dry wells. The results also showed that, at the higher flow rates, the releases could be detected at Pump Station 1 within minutes after the release occurred.

The simulated liquid release measurements described in this report conclusively demonstrate the viability of the conductivity method for externally monitoring tanks W-3 and W-4 during all of the treatability study activities. Further, it is recommended, that similar demonstrations be conducted on the dry well and drain system in the South Tank Farm in order to design a liquid release detection system that can be employed continuously during all phases of the gunite tank waste removal operations, including the in-tank sluicing operations.

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1.0 Introduction

A CERCLA treatability study is underway to investigate means to remove waste from the gunite and associated tanks (GAAT) located in the North and South Tank Farms (NTF and STF) at Oak Ridge National Laboratory (ORNL). Most of these tanks contain a supernate (mostly water) over a layer of sludge. A part of the CERCLA treatability study will entail sluicing---jetting water into a gunite tank to loosen and suspend the sludge--- so that the supernatant and the sludge can be removed. The current plans are to conduct the sluicing demonstration on tanks W-4 and W-3 which are in the NTF. The experience gained from this demonstration will be used to design and implement the waste removal from the gunite tanks in the STF.

To provide a means to assure the integrity of the GAAT during the CERCLA treatability study and subsequent waste removal operations, an external method for detecting releases from the tanks, using conductivity measurements has been demonstrated and is discussed here. A preliminary evaluation of the conductivity monitoring method was conducted in 1995 as part of a liquid integrity analysis of the gunite tanks and is documented in Reference (1). Baseline monitoring of conductivity in the dry wells adjacent to tanks W-3 and W-4 has been conducted since November, 1995. Preliminary results of the monitoring are provided in Reference (2). In order to confirm that potential releases from the tanks could be detected by monitoring conductivity in the dry wells, a simulated liquid release demonstration, on tanks W-3 and W-4, was conducted during August, 1996. The demonstration also quantified the changes in conductivity that could be expected from different potential release rates from the tanks. This report documents the results of this demonstration.

The external conductivity monitoring method makes use of the existing dry well system that is adjacent to each of the gunite tanks. This method takes advantage of the fact that the conductivity of the liquid in the gunite tanks is very high (10,000-20,000 μmho/cm) relative to the conductivity of the groundwater in the dry wells (200-500 μmho/cm). The two main assumptions on which the conductivity monitoring method for the gunite tanks is based are: 1) the conductivity of the water in the dry wells is significantly lower than the conductivity of the liquids in the gunite tanks and releases from the tanks, if they flow into the dry wells, will result in measurable and significant changes in the conductivity in the dry wells; and 2) the tank and dry well system is designed so that if liquid is released from a tank it will flow onto the pad at the base of the tank and drain into the dry well. The first assumption has been verified by tank sampling data and by the ongoing monitoring in the dry wells (References 1 & 2). The demonstration, discussed in this report, provided: 1) field verification that a simulated liquid release will flow on to the pad at the base of the tanks, into the dry wells and be detected; and 2) quantification of the response and resulting change in conductivity in the dry wells.

The simulated liquid release demonstration was conducted by draining a high conductivity liquid mixture into well points adjacent to tanks W-3 and W-4 and monitoring the dry wells for changes (increases) in conductivity above the normal range of baseline values. The demonstration was conducted on tank W-3 first and then on W-4. The data loggers and sensors located at each dry well, that were being used to collect baseline data, were also used to collect the data for the demonstration. This provided continuity between the baseline and simulated liquid release measurements. The resulting changes in conductivity in the dry wells during the simulated releases were analyzed to evaluate the integrity and continuity of the tank pad and dry well systems and to quantify the effectiveness and detection capabilities of the external conductivity monitoring method for tanks W-3 and W-4.

In addition to the tank W-3 and W-4 dry well systems, the integrity of the drain system connecting the dry wells to Pump Station 1 (PS1) was also evaluated as part of the demonstration. The data from a conductivity sensor, located at Pump Station 1 (PS1), was used for this analysis. The volume of water involved in the demonstration (approximately 300 gallons over several weeks) is relatively small compared to the base flow through Pump Station 1 (approximately 38 gallons per minute) and the lower rate simulated liquid releases were not expected to be detectable. However, the conductivity data from PS1 was analyzed to see if, at the higher simulated release rates used during the demonstration, a response could be detected down stream at PS1 to provide some indication as to the integrity of the drain system.

The demonstration conclusively showed that the dry well conductivity monitoring method can be used to externally monitor tanks W-3 and W-4 during all of the CERCLA treatability study activities in the NTF. This method can also be adapted for release detection during waste removal from the six gunite tanks in the STF. The demonstration also verified the integrity of the drain system from the NTF to PS1. This report presents the results of the simulated liquid release demonstration including analysis of the baseline monitoring, demonstration, and PS1 data. A description of the gunite tanks, dry well and drain systems in the NTF, STF and PS1 is provided in Section 2. The simulated liquid release demonstration is described in Section 3. The results are presented in Section 4 and conclusions and recommendations are provided in Section 5. Figures are included at the end of the sections in which they are first referenced.

2.0 Description of the Gunite Tanks, Well Points, Dry Wells and Sensors

The tanks of primary interest in this investigation are the two gunite tanks (W-3 and W-4) in the NTF. A diagram of the NTF, showing the locations of tanks W-3 and W-4, the dry wells (DW3 and DW4) and the well points (WP3 and WP4) used for the simulated release demonstration, is provided on Figure 1. As shown on the diagram W-3 and W-4 are located in the southeast corner of NTF. Each of these tanks is 25 ft in diameter and approximately 12 feet high (excluding the dome cover), with a capacity of 42,500 gallons. On Figure 2 an overview diagram is provided of the tanks in the NTF and STF along with the locations of the dry wells associated with each of the tanks (W-3 through W-10) and the drain system leading to PS1. A diagram of a typical gunite tank, dry well and well point is shown on Figure 3.

The well points (WP3 and WP4) were installed as close to the tank wall as possible. During the demonstration this allowed the high conductivity water to drip down the side of the tank and on to the pad, thus simulating the liquid release pathway that would be expected from a tank. The well points consist of two 9 ft long lengths of pipe that were installed at the edges of Tanks W-3 and W-4 in January, 1996 during the excavation activities around W-3 and W-4. During this time, the domes of the tanks were uncovered and it was an ideal time to locate the vertical edge of the tank walls and install the pipes so they were right on the edge of the tanks. Each of the pipes has a three foot length of 2 inch diameter steel well screen on the bottom as illustrated on Figure 3. The well screen allows the water to seep out and down the side of the tank to simulate a liquid release.

The dry wells were originally designed as part of an under drain system for the tanks. The dry wells are 2 ft by 2 ft concrete wells that extend from the surface to about 2 feet below the base of the tanks. The dry wells are all connected by an eight inch diameter clay tile pipe that drains the water from the dry wells and the back fill that surrounds the tanks and carries the water down to PS1. This drain system effectively keeps the groundwater below the bottom of the gunite tanks and tank pads, (Reference (1)). If liquids are released from a tank and onto the pad, the water would be expected to flow into the dry well and be detected by the conductivity monitoring system.

The dry wells are constructed with a six inch deep sump below the bottom of the inlet and outlet drains (Figure 3), which provides a convenient arrangement for the installation of the conductivity monitoring sensors. The dry wells associated with tanks W-3 and W-4, DW3 and DW4, are each instrumented with a water level transducer and a combined conductivity and temperature probe. The sensors are inside of a 2 inch diameter pvc pipe. The pvc pipe protects the sensors from the sediment at the bottom of the dry wells and facilitates installation and removal of the sensors. The pipe is perforated over the bottom two feet to allow the sensors to be in direct contact with the water in the dry well sumps. Diagrams of dry wells DW3 and DW4 showing the sensor installations are provided on Figures 4 and 5 respectively. These diagrams also show the approximate amount of sediment in the sump of each dry well.

The inlet drain from the tank pad and the outlet drain for each dry well are at the same elevations as shown on Figures 4 and 5. In addition, the water levels in DW3 and DW4 are at, or slightly above, the bottom lip of the inlet and outlet drains. Water which collects on the tank pad and flows into the dry well during a rainfall event, or during a simulated liquid release, will tend to flow in a direct path from the inlet to the outlet drain. The amount of mixing which occurs in the dry well will be dependent on the rate of flow into the dry well, the density of the liquid, and the concentration gradient between the in-flowing liquid and the water in the dry well. As a result, the rate at which the water in the dry well increases in conductivity in response to the inflow of high conductivity water or decreases after an inflow has stopped will depend on the mixing efficiency of a particular dry well and rainfall and groundwater conditions.

The conductivity sensors located in DW3 and DW4 are In-Situ Model CTS-200 combined conductivity and temperature probes. They have a nominal range of 0-1500 μmho/cm and a maximum reading of approximately 1592 μmho/cm. The range of the sensor is approximately three to five times higher than the normal baseline conductivity in the dry wells but still provides sufficient sensitivity to measure changes from rainfall, temperature and other seasonal effects. In-Situ pressure transducers with a range of 0 to 10 psi are also located in the dry wells. These provide data on water level changes in the dry wells, resulting from rainfall infiltration and other seasonal effects, which can be compared against conductivity changes. The baseline conductivity, temperature and water level data is recorded hourly on In-Situ data loggers located at the dry wells. An interim analysis of the baseline conductivity, temperature and water level data from the dry wells is provided in Reference 2.

The baseline conductivity, prior to the demonstration, was approximately 200 to 250 μmho/cm in DW3 and 500 to 550 μmho/cm in DW4. The differences in readings between the two dry wells results from calibration and offset differences between the two sensors and also slight differences in the ground water and drainage conditions around each dry well, (Reference 2). On June 6, 1996, a separate set of conductivity measurements was obtained using a YSI hand held conductivity probe. The conductivity readings were 518 μmho/cm for DW3 and 660 μmho/cm for DW4. These results were higher but in the same range as the data logger values and showed a smaller difference between DW3 and DW4. However, for the simulated liquid release demonstration the absolute value of the baseline conductivity in each of the dry wells is not as important as the change (increase) in conductivity which is detected above the baseline measurements as a result of the simulated releases. A description of the Simulated Liquid Release Demonstration is provided in the next section and the data and results from the baseline measurements and the demonstration are presented in Section 4.

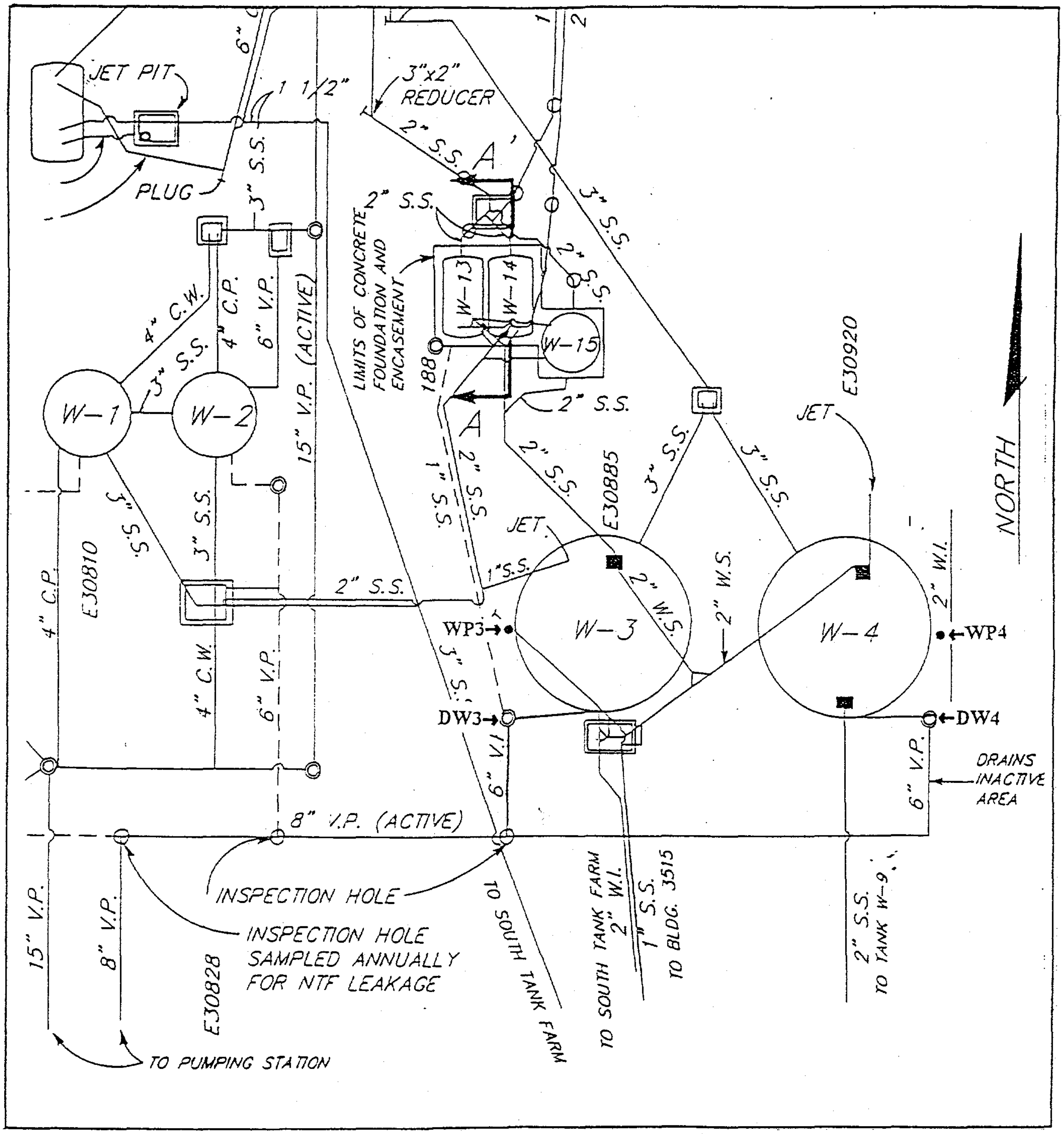


Figure 1. North Tank Farm showing location of tanks (W-3 and W-4), dry wells (DW3 and DW4) and well points (WP3 and WP4).

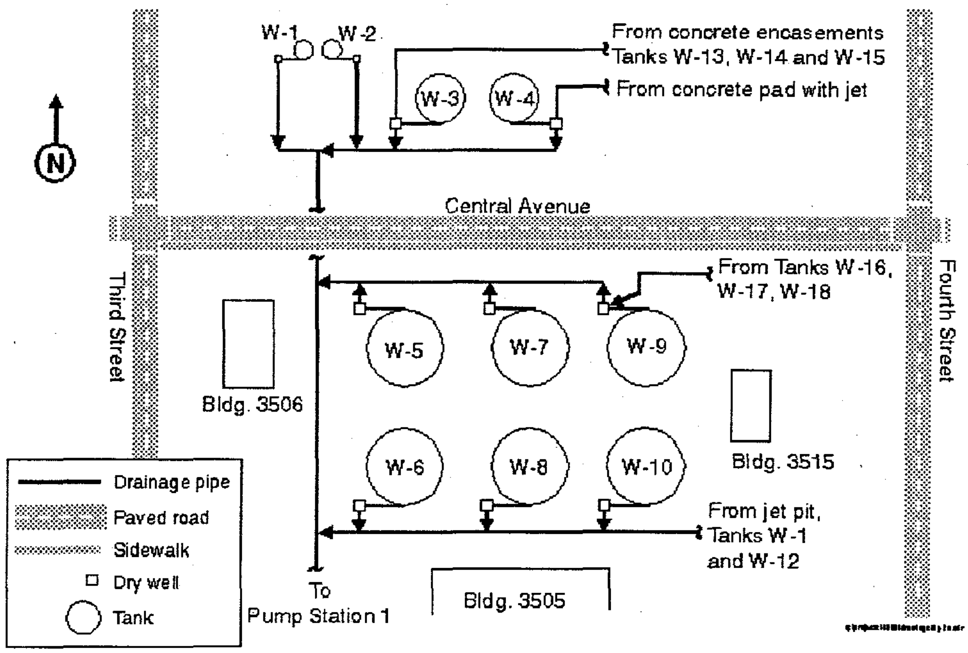


Figure 2. Dry well and drain system in the North and South Tank Farms, leading to Pump Station 1.

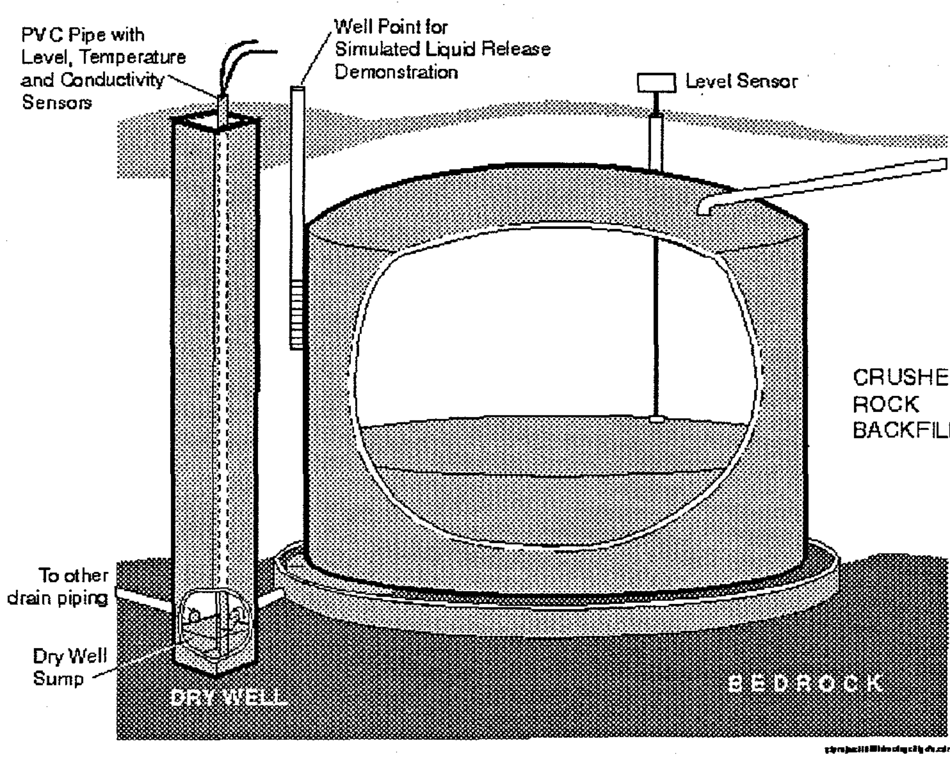


Figure 3. Typical gunite tank, dry well and well point.

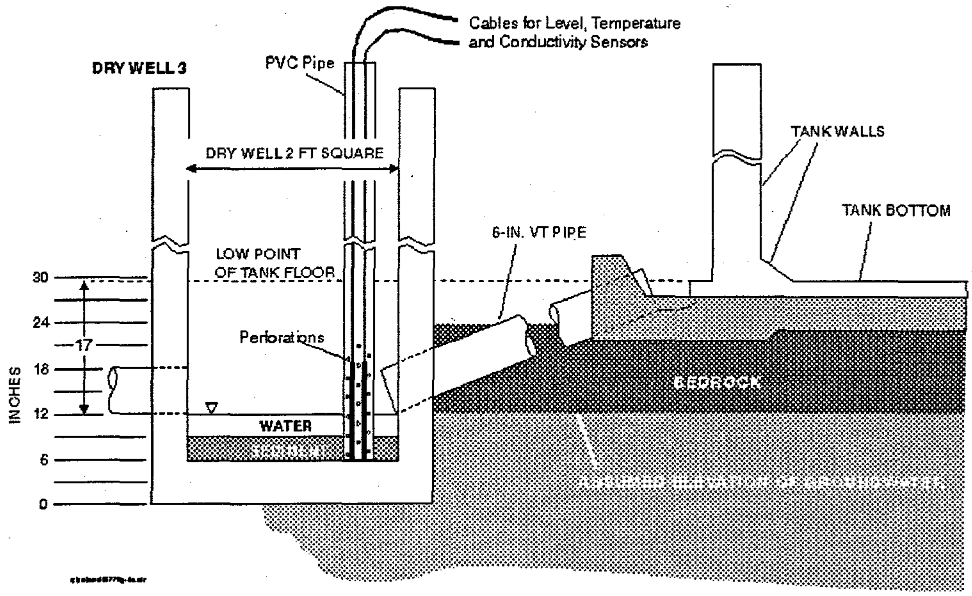


Figure 4. Cross-sectional diagram of DW3 showing sensor installation and sediment layer at bottom of dry well.

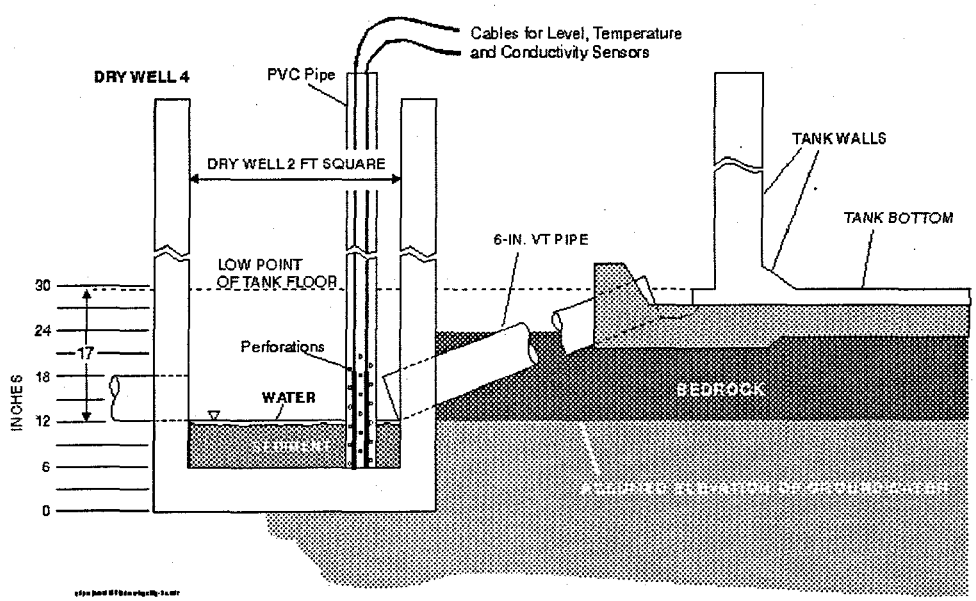


Figure 5. Cross-sectional diagram of DW4 showing sensor installation and sediment layer at bottom of dry well.

3.0 Description of the Simulated Liquid Release Demonstration

The simulated liquid release demonstration on gunite tanks W-3 and W-4 was conducted from August 7 through August 23, 1996. The demonstration was conducted by draining a high conductivity liquid mixture into well points WP3 and WP4 and monitoring the dry wells (DW3 and DW4) for changes (increases) in conductivity above the normal range of baseline values. The high conductivity liquid consisted of water with potassium chloride added to give a conductivity similar to the tank contents (9000μmho/cm). The liquid was gravity drained into the well points using a range of controlled flow rates to simulate different tank release rates.

The demonstration was conducted using the well point at W-3 first and then using the well point at W-4. Three different simulated release rates were used at tank W-3 (0.5, 1.5 and 4.5 gallons per hour (gph)) and three different simulated release rates were used at tank W-4 (0.5, 18.0 and 420 gph). At each tank the lowest release rate was used first and then succeeding rates were chosen based on the response in the dry well to the lower rate. The lowest rate (0.5 gph) was chosen based on the previous study, (Reference 1), which showed that 0.5 gph was approximately the minimum leak rate that could be detected in the tanks by using the more conventional in-tank level data analysis. The subsequent rates were chosen to evaluate the rate at which the conductivity would change in a dry well at higher release rates and the concentration level that would be reached in a dry well for a given release rate and duration. During the two highest release rate simulations at W-4 (18.0 and 420 gph), the conductivity data from PS1 was also analyzed to evaluate the continuity and integrity of the drain system from the dry wells in the NTF to PS1.

The equipment, for the simulated liquid releases, was setup on the steel platform which has been constructed over tanks W-3 and W-4. The platform will be used to support equipment during the sluicing operations on the tanks and provided a convenient location for staging the simulated liquid release demonstration. The equipment consisted of a 55 gallon drum, a variable speed peristaltic pump, plastic containers for mixing the potassium chloride and water, graduated containers for flow rate measurements and miscellaneous tubing and equipment. For the simulations at W-3 and W-4, the 55 gallon drum was located on the platform directly above the well point for each tank. A concentrated solution of potassium chloride was premixed in a plastic container and then poured into the 55 gallon drum. Water was then added to the drum until the liquid in the drum was at the desired concentration of 9000 μmho/cm . A length of steel tubing was placed in the drum to facilitate pumping liquid out of the drum. The steel tubing was connected to the pump with a short length of flexible tubing. The output from the pump was connected to top of the well point with length of flexible tubing and a funnel arrangement. Pictures of the equipment and the simulation setup are provided in the Appendix.

Prior to each release simulation, the concentration of the liquid in the drum was checked with a YSI conductivity probe and the flow rate from the pump was checked using a graduated container. Each simulation was started by turning on the pump and letting it run for several days at the low rates and for a few hours at the higher rates. The data loggers were set to record data at a one minute data rate for the first simulated release at W-3. The data rate was then set to every ten minutes for the all of the other simulated releases except for the highest simulated release rate at W-4 (420 gph) which was recorded at one minute intervals. The conductivity readings on the data loggers were checked periodically during each simulated release to determine if the concentrations were changing, had leveled off or had exceeded the maximum range of the conductivity sensor (1592 μmho/cm). Prior to the end of each simulation the pump flow rate and liquid conductivity were rechecked. At the end of each simulation data continued to be collected to measure the change in conductivity in the dry well after the simulated release was stopped.

A list of the simulated releases conducted at tanks W-3 and W-4, including dates, duration, conductivity and flow rate is provided on Table 1.

Table 1. Simulated liquid releases for W-3 and W-4, (8/7/96 through 8/23/96).

TANK	RATE	CONCENTRATION (μmho/cm)	DATE/TIME	DURATION
W-3	0.5 gph	9000	8/7 8:55 - 8/9 10:20	49 hr 25 min
W-3	1.5 gph	9000	8/13 8:45 - 8/15 8:12	47 hr 27 min
W-3	4.5 gph	9000	8/15 8:18 - 8/15 10:00	1 hr 40 min
W-4	0.5 gph	9000	8/15 11:00 - 8/19 8:30	93 hr 30 min
W-4	18.0 gph	9000	8/22 8:10 - 8/22 11:00	2 hr 50 min
W-4	420 gph	9850	8/23 9:17 - 8/23 9:25:45	7.75 min

4.0 Results

The results of the simulated liquid release demonstration at tanks W-3 and W-4 are presented in this section and include a discussion of: the baseline conductivity monitoring; the DW3 and DW4 conductivity data collected during the simulated releases; and the PS1 conductivity data collected during the two highest simulated liquid releases at tank W-4.

Baseline Monitoring

Baseline conductivity monitoring in DW3 and DW4 was initiated at the end of November, 1995. An interim report (Reference 2) provided the results of the monitoring for the period from November up through the end of March, 1996. The additional conductivity monitoring data for the period from April up to and including the demonstration in August is provided on Figures 6 and 7. The conductivity data for DW3 is plotted on Figure 6 and DW4 data is plotted on Figure 7. Figure 6 is annotated to show the conductivity increases that resulted from the simulated liquid releases at tank W-3 during the demonstration. Figure 7 is annotated to show the increase in conductivity from the first simulated release at tank W-4. The data for the two higher simulated releases at tank W-4 are not plotted on Figure 7 because the higher rates resulted in the sensor in DW4 to exceed it's upper limit immediately after initiating the releases.

The data on Figure 6 and 7 clearly show that the increase in conductivity from even the first and lowest simulated liquid release rates is easily detected above the baseline conductivity in the dry wells. These results indicate that potential releases of 0.5 gph or even less can be detected using the dry well conductivity method. The results also provide field verification of the connection between the tank pad and the dry well and that potential releases from tanks W-3 and W-4 can be expected to flow on the pad and into the dry well.

Tank W-3 Simulated Releases

The first simulated release for tank W-3 was conducted for approximately two days until the concentration in DW3 appeared to level off. Approximately four days were allowed between the first and second simulation to allow the conductivity in DW3 to decrease to ambient levels. A rainfall event occurred during this time which helped considerably to lower the conductivity in DW3. The second simulated release for tank W-3 was conducted at three times the first rate for approximately the same duration. The third simulated release rate on W-3 was started immediately after the end of the second release and lasted less than two hours, at which time the limit of the conductivity sensor in DW3 was exceeded.

A detailed plot of dry well DW3 conductivity data for the first simulated liquid release at tank W-3 is shown on Figure 8 and a plot for the second and third releases is shown on Figure 9. Figure 8 and 9 are annotated to show when the releases started and ended (see Table 1 in Section 3). The data on Figure 8 shows that within approximately two hours after the 0.5 gph release began the conductivity in the dry well began to increase. Over a period of a day it increased from 250 to over 700 μmho/cm, approximately 22 μmho/cm per hour, and leveled off.

As discussed above, the response in the dry well to this first and lowest release rate was easily detected and quantified.

After the end of the first liquid release, the conductivity in the dry well began to slowly decrease from groundwater flowing in and out and diluting the higher conductivity water left in the dry well. As shown on Figure 8, however, the rate of decrease was much slower that the rate of increase during the liquid release. The reasons for this are due to the construction of the dry wells, as discussed in Section 2, and the significant density and concentration difference between the potassium chloride solution and the groundwater in the dry well. As discussed in Section 2, the inlet and outlet drain and the groundwater are all at about the same level in the dry well. Liquids entering from the inlet drain will most likely flow in a direct path to the outlet drain with minimal mechanical mixing. During the liquid release period, the denser potassium chloride solution, mixes more readily with the water in the dry well sump than the normal influx of groundwater does after the release period. This could account for the conductivity increasing faster during the releases and decreasing slower after the releases.

The data on Figure 8 also shows the effect of a significant rainfall event (1 to 2 inches) that occurred on August 11. The net effect was to flush out the dry well and return the conductivity of the water to the normal baseline level. This indicates that rainfall events will, most likely, reduce the detectability of small liquid releases from the tanks. Within one or two days after a significant rainfall event, however, small releases would again be easily detected.

The second release at tank W-3 was conducted at a rate of 1.5 gph which is three times the initial rate. The plot on Figure 9 shows that the conductivity increased from approximately 250 to 800 μmho/cm in 8 hours, (68 μmho/cm per hour), which is about three times as fast as during the first release. After several days the conductivity increased to approximately 1150 μmho/cm and appeared to be leveling off. At this time the rate was increased three fold again to 4.5 gph. This rate caused a rapid increase in conductivity and after about an hour the conductivity in the dry well exceeded the limit of the sensor (1592μmho/cm).

The results of the simulated releases on tank W-3 clearly demonstrated the continuity between the tank pad, drain and dry well system and the detectability of potential tank releases on the order of 0.5 gph or even less. The rate of increase in conductivity in the dry well was proportional to the first two simulated release rates. At rates of 4.5 gph and above, however, the conductivity in the dry well can be expected to increase rapidly to above the limit of the sensor. At the completion of the simulated releases for tank W-3, the equipment was relocated on the platform over the well point (WP4) for tank W-4.

Tank W-4 Simulated Releases

The first simulated release (0.5 gph) for tank W-4 was conducted for approximately twice as long (4 days) as the first simulation on W-3. This was done to see if, at the lowest rate, the conductivity in DW4 would eventually exceed the limit of the sensor (1592 μmho/cm) if the simulation was run long enough. The last two rates used at W-4 were significantly higher and were used to see if the simulated releases could be detected at PS1. A higher conductivity solution (9850 μmho/cm) was used for the highest rate (420 gph) to improve the chances of detecting it at PS1.

A detailed plot of dry well DW4 conductivity data for the first simulated tank release (0.5 gph) at tank W-4 is shown on Figure 10. Figure 10 is annotated to show when the release begins and ends. The response in DW4 is similar to that in DW3. The conductivity data shown on Figure 10 begins to increase approximately two hours after initiating the first release. In the first 24 hours the conductivity increases from 550 to over 1100 μmho/cm, approximately 23 μmho/cm per hour. This is basically the same as the rate of increase recorded in DW3 for the initial simulated release of 0.5 gph. The main difference between the DW3 and the DW4 data is that the low rate liquid release at tank W-4 was conducted for twice as long. The plot on Figure 10 shows that the conductivity in DW4 flattens out twice during the release period but the overall trend continues to increase and the limit of the sensor is reached before the end of the release period.

This result indicates that even very small potential releases from the tanks will eventually cause the limit of the conductivity sensor in the dry well to be reached. This result is useful in selecting an alarm limit for the monitoring system. If the alarm is set at around 1500 μmho/cm it will be triggered by even relatively small releases from the tanks yet be high enough to minimize false alarms. Because the limit of the conductivity sensor was reached during the first simulated liquid release, the increased flow rates used at tank W-3 were not used at tank W-4. Instead it was decided to use two high flow rates for the final two simulated releases. The rate of 18.0 gph was chosen because it was the maximum flow rate for the peristaltic pump and the maximum flow rate of 420 gph was chosen because it was the maximum flow out of a 55 gallon drum that could be accomplished by siphoning. As discussed earlier these two flow rates were designed to evaluate the integrity of the drain system from the dry wells to PS1.

Pump Station 1 Data

A plot of the conductivity data a PS1 during the second (18.0 gph) and third (420 gph) simulated liquid releases at tank W-4 are shown on Figure 11. The start and stop times for the two simulated releases are shown on the figure. The total volume of liquid used in each of these releases was approximately 50 gallons. The time from the beginning of each release and the apparent arrival at PS1 is also noted on the plot. This data clearly shows a detectable response at PS1 from the high rate simulated tank releases at W-4 (18.0 and 420 gph). The shape of the response curves are also consistent with the magnitude and duration of each release. The first curve has a lower peak value than the second and is more spread out corresponding to the 18.0 gph release rate over three hours. The second curve has a very sharp maximum peak consistent with the 420 gph release rate for just seven minutes. The arrival time at PS1 for the 420 gph release was much faster than the 18.0 gph release because the rate was over 20 time faster. The results from the two high rate releases demonstrate the continuity of the drain system and indicate that potential liquid releases from tanks W-3 and W-4 will be contained by the drain system and flow through PS1.

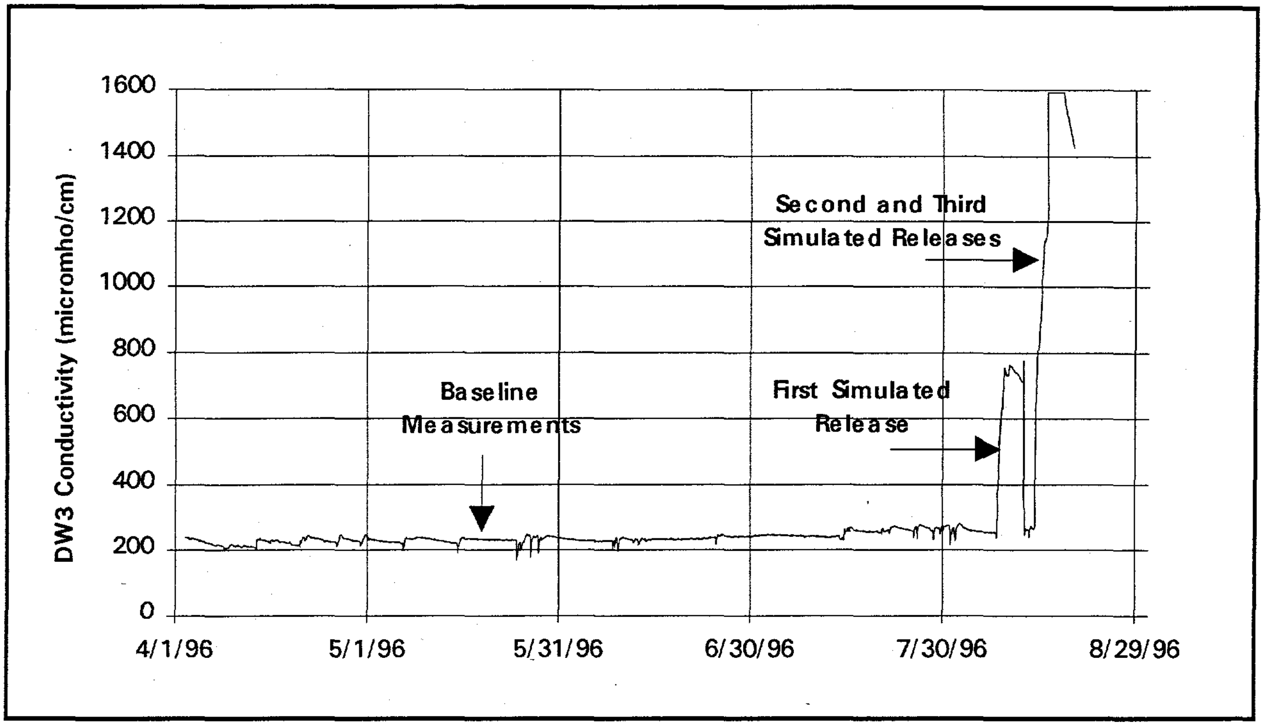
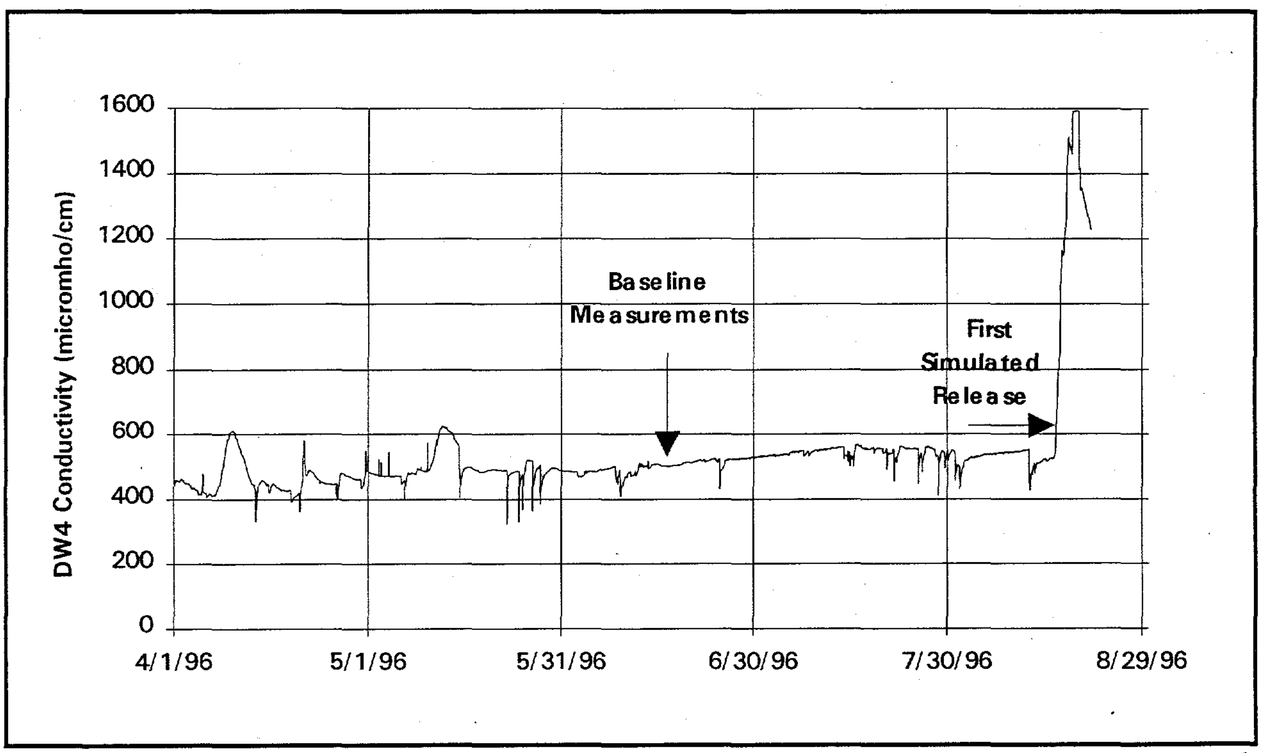


Figure 6. Plot of dry well DW3 conductivity data from 4/1/96 through 8/21/96 showing baseline measurements and the response to the simulated liquid releases (0.5, 1.5 and 4.5 gph) at Tank W-3.



Figures 7. Plot of dry well DW4 conductivity data from 4/1/96 through 8/21/96 showing baseline measurements and the response to the first simulated release (0.5 gph) at tank W-4.

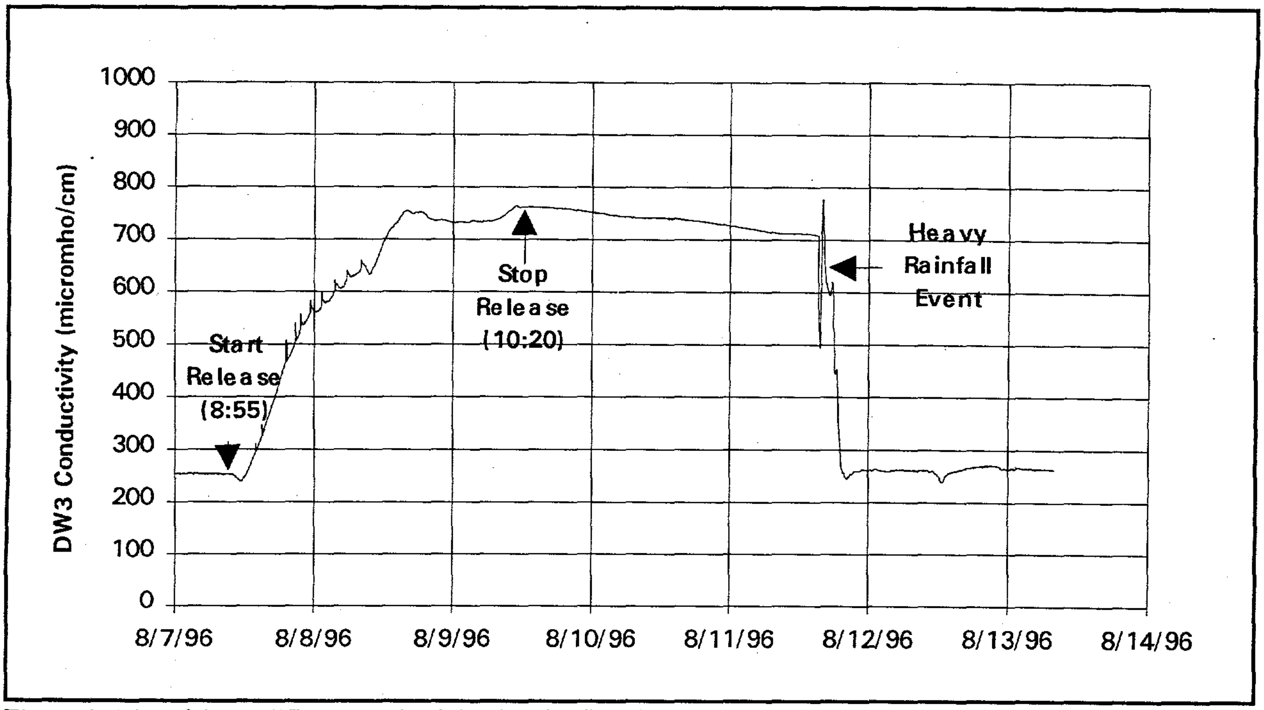


Figure 8. Plot of dry well DW3 conductivity data for first simulated liquid release at tank W-3.

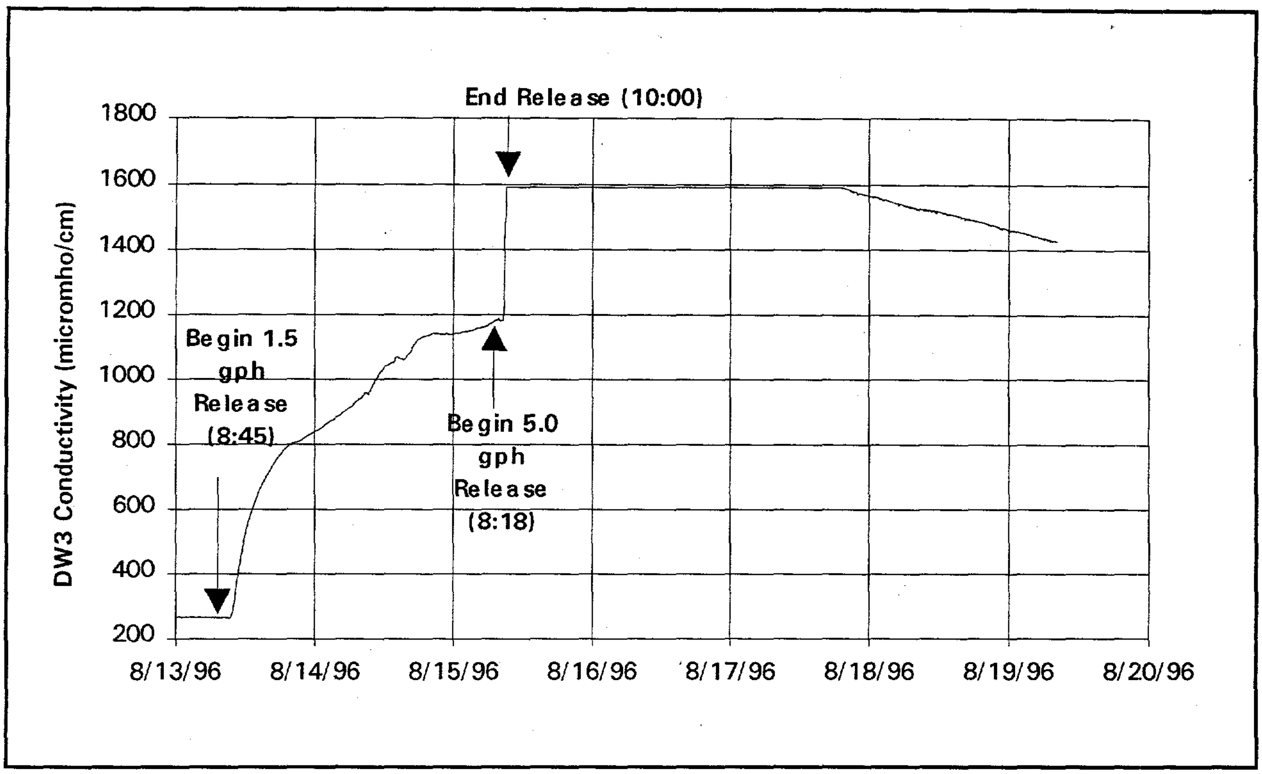


Figure 9. Plot of dry well DW3 conductivity data for second and third simulated liquid releases at tank W-3.

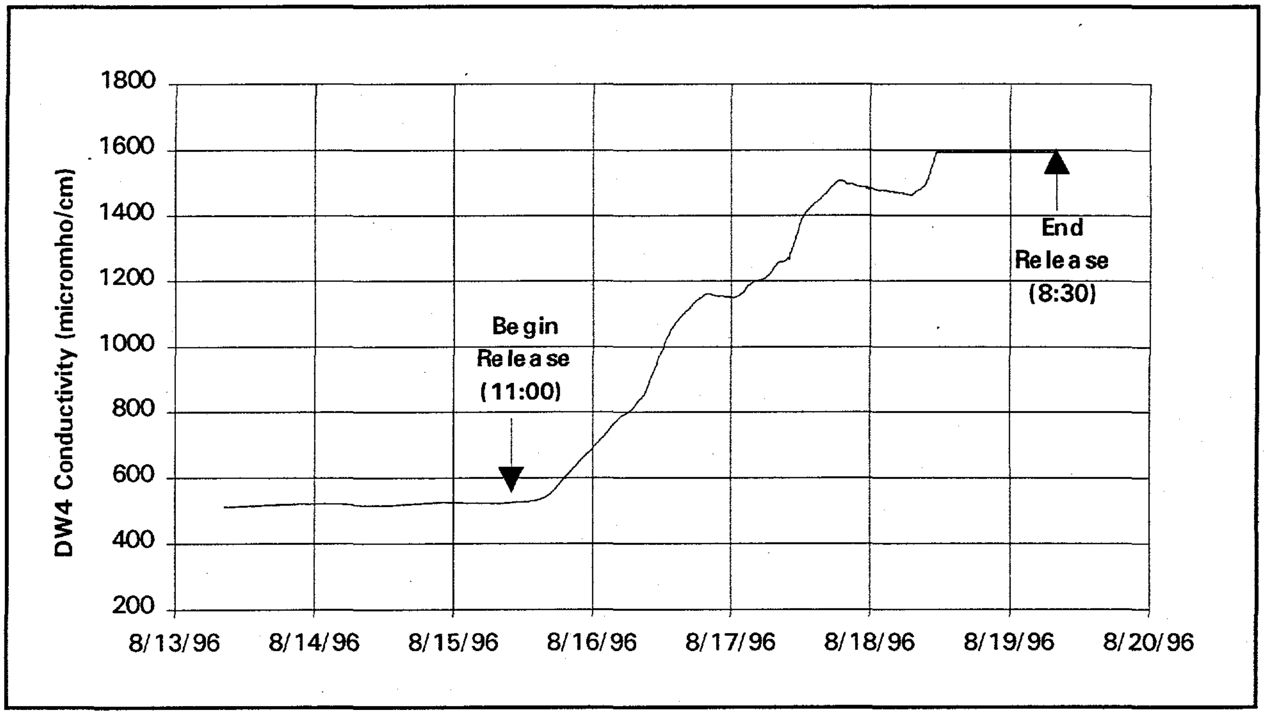


Figure 10. Plot of dry well DW4 conductivity for first simulated liquid release (0.5 gph) at tank W-4.

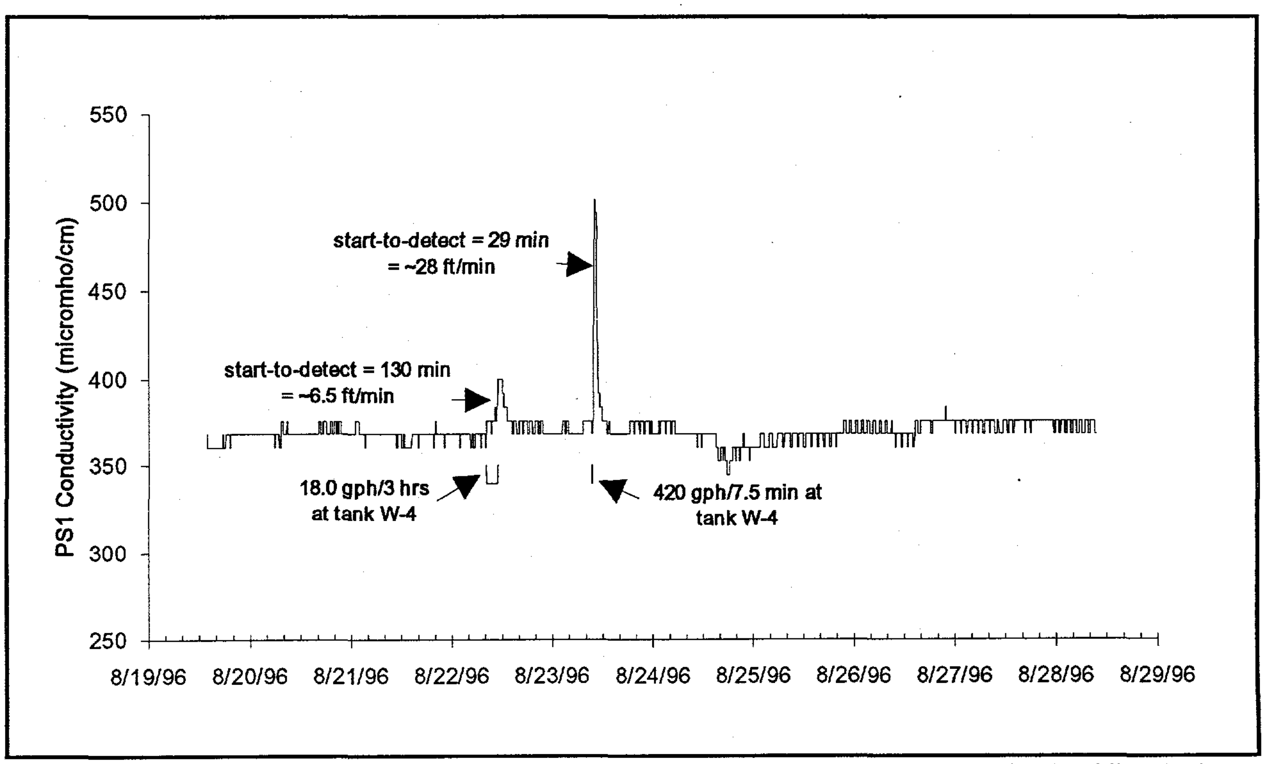


Figure 11. Plot of Pump Station 1 conductivity data for second and third (18.0 and 420 gph) simulated liquid releases at tank W-4.

5.0 Conclusions and Recommendations

Conclusions

The simulated liquid release demonstrate achieved its objectives and provided field verification that potential liquid releases from tanks W-3 and W-4 can be expected to flow into the dry wells and be detected by monitoring the conductivity of the water in the dry wells. The results also showed that even the lowest simulated release rate (0.5 gph) produced a significant increase in conductivity in the dry well that was easily identifiable above the baseline conductivity of the water in the dry well. The use of conductivity monitoring in the dry wells was conclusively demonstrated to be a viable and robust method for detecting, quantifying and providing an alarm system for potential liquid releases from tanks W-3 and W-4 during the sluicing operations and other waste removal activities. The demonstration also showed integrity of the drain system from DW3 and DW4 and that any potential releases from W-3 and W-4 should be contained with in the drain system and pass through PS1.

Recommendations

- Modify the conductivity monitoring equipment in DW3 and DW4 for use during all of the treatability study activities including the sluicing operations in tanks W-3 and W-4.
  - Connect the conductivity sensors from the dry wells to one of the control trailers in the North Tank Farm.
  - Set the control system to provide a real-time read out of the conductivity measurements in the dry wells and to alarm if conductivity values exceed (a preliminary value of)1500 μmho/cm.
- Begin operating the modified dry well monitoring system as soon as possible and continue the monitoring activities throughout the treatability study activities in the NTF.
- Conduct similar simulated liquid release demonstrations in the STF. These activities should be conducted during the spring of 1997.
  - Determine the baseline conductivity characteristics in the STF dry wells and develop the appropriate analysis and thresholds for using the method for release detection during waste removal activities at each of the tanks.
  - Evaluate the integrity and continuity of the drain system from the STF dry wells to PS1.
- Based on the results of the STF demonstrations, design and install the appropriate monitoring system for use during the removal of waste from the six gunite tanks in the STF.

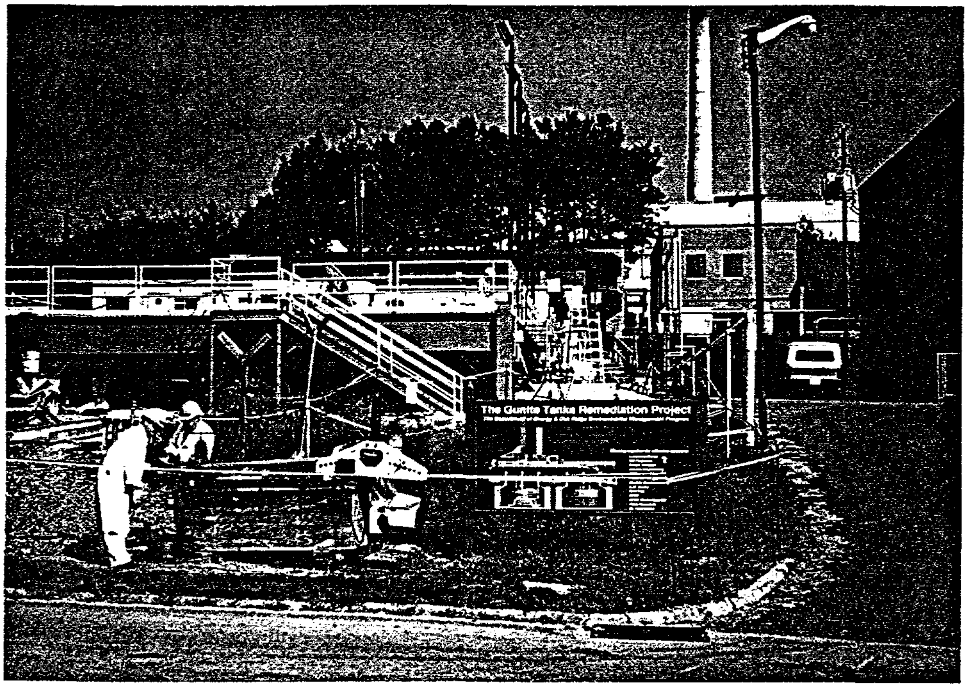
References

Reference 1 Vista Research, Inc., "Preliminary Evaluation of Liquid Integrity Monitoring Methods for Gunite and Associated Tanks at the Oak Ridge National Laboratory, Oak Ridge, Tennessee," Lockheed Martin Energy Systems, ORNL/ER-349 (1996).

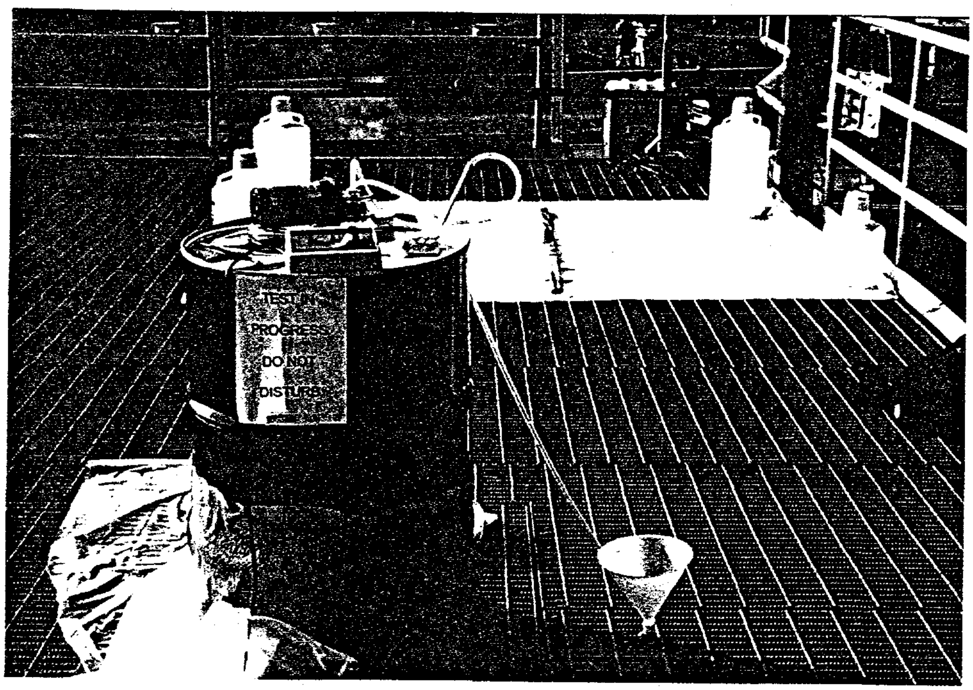
Reference 2 Vista Research, Inc., "External Method of Liquid Integrity Monitoring for Tanks: Baseline Conductivity Data from Dry Wells 3 and 4 (for the period 22 November 1995 through 31 March 1996)," Vista Research Technical Memorandum No. 1058-TM-96-001, 23 April 1996.

Appendix

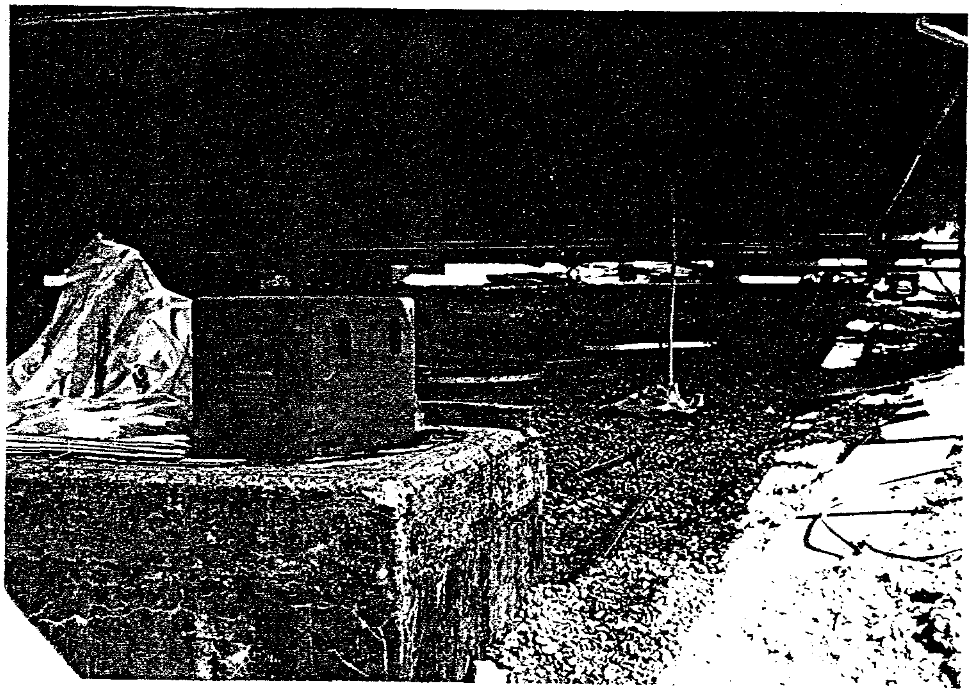
Pictures of Simulated Liquid Release Demonstration Equipment



View looking north, of the platform over tanks W-3 and W-4
in the North Tank Farm.

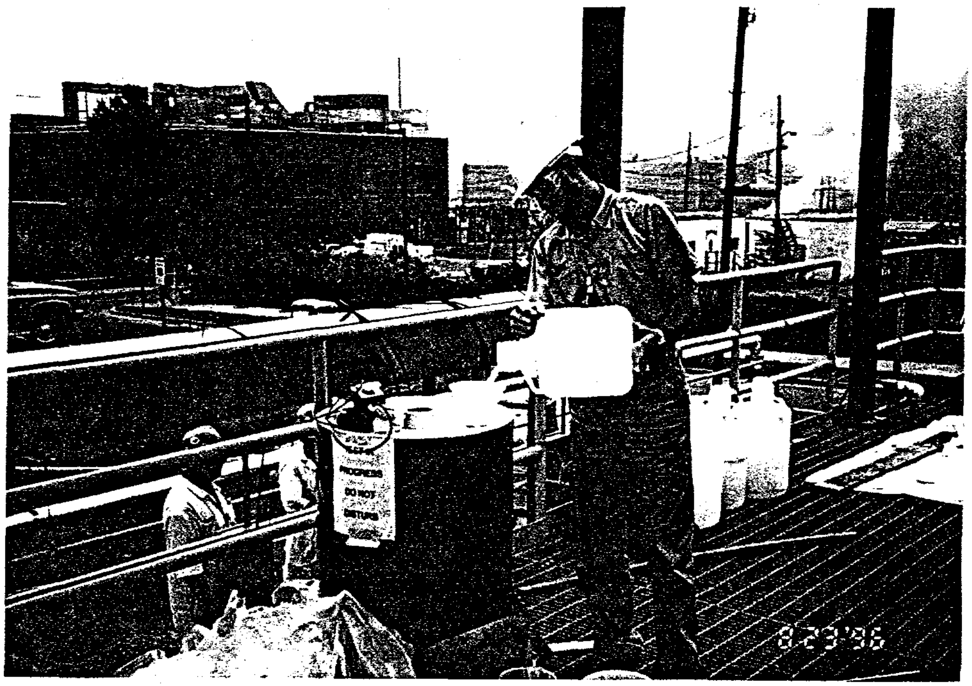


Simulated liquid release equipment located over WP3 on the platform showing:
the 55 gallon drum with the KCl solution, the peristaltic pump and controller
and the tubing leading to the funnel on the grate over WP3.

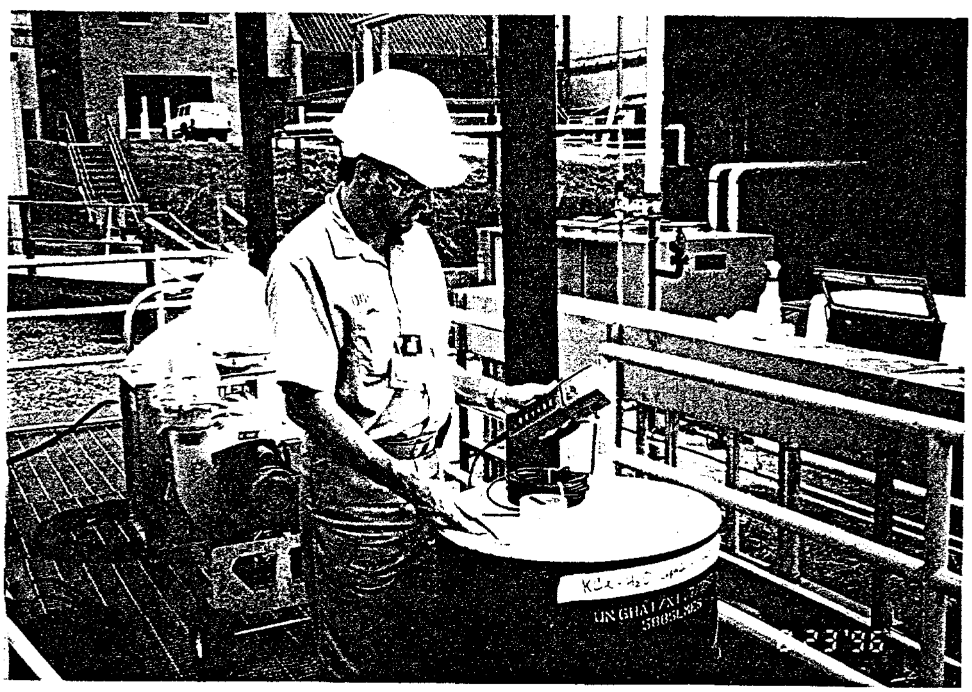


View looking under the platform, showing the tubing connection from the funnel to the well point (WP4) and the data logger at DW4

Close-up of data logger at DW3 being downloaded to a PC. The cables leading to the sensors in the dry well are under the plastic cover



Preparation of KCl solution in the 55 gallon drum



Checking the conductivity of the solution with a YSI conductivity probe.

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