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Summary of Tank Information Relating Salt Well Pumping to Flammable Gas Safety Issues

S. M. Caley
L. A. Mahoney
P. A. Gauglitz

September 1996

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest National Laboratory
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Executive Summary

The Hanford Site has 149 single-shell tanks (SSTs) containing radioactive wastes that are complex mixes of radioactive and chemical products. Active use of these SSTs was phased out completely by November 1980, and the first step toward final disposal of the waste in the SSTs is interim stabilization, which involves removing essentially all of the drainable liquid from the tank. Stabilization can be achieved administratively, by jet pumping to remove drainable interstitial liquid, or by supernatant pumping. To date, 116 tanks have been declared interim stabilized; 44 SSTs have had drainable liquid removed by salt well jet pumping. Of the 149 SSTs, 19 are on the Flammable Gas Watch List (FGWL) because the waste in these tanks is known or suspected, in all but one case, to generate and retain mixtures of flammable gases, including hydrogen, nitrous oxide, and ammonia. Salt well pumping to remove the drainable interstitial liquid from these SSTs is expected to cause the release of much of the retained gas, posing a number of safety concerns.

The scope of this work is to collect and summarize information, primarily tank data and observations, that relate salt well pumping to flammable gas safety issues. While the waste within FGWL SSTs is suspected of retaining flammable gases, the effect of salt well pumping on the waste behavior is not well understood. This study is being conducted for the Westinghouse Hanford Company as part of the Flammable Gas Project at the Pacific Northwest National Laboratory (PNNL).[a] Understanding the historical tank behavior during and following salt well pumping will help to resolve the associated safety issues.

Results have been collected for drainable porosity, changes in trapped gas from the correlation of waste level with barometric pressure, changes in surface level with volume of liquid removed by pumping, evidence of subsidence, number and size of gas releases estimated from drops in waste surface level following pumping, changes in neutron logs (to infer phenomena other than the lowering of the liquid level), and flammable gas levels in tanks that have recently been pumped.

One of the most interesting results was the analysis of rapid (within a one-month period) surface level drops occurring after pumping. Drops in surface level could be indicative of subsidence and/or a gas release event. The one-month period was chosen because many SSTs only have passive ventilation so gas releases over a one-month period are important. The analysis showed that small level drops (less than 2 inches) were the most frequent, with 41 events happening over 383 tank years (the sum of the number of years that have passed (to date) since pumping for each tank).

Another interesting result can be seen by comparing the dL/dP values before and after salt well pumping. We expected salt well pumping to decrease the amount of trapped gas, with this

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decrease being reflected by a positive change in dL/dP. In the two salt cake tanks for which reliable dL/dP data were available, this theory was confirmed. However, for the sludge tanks that had reliable dL/dP data, the change in dL/dP was more often negative.

Other data reviewed provided useful information about the relationship between salt well pumping, post-pumping subsidence, and flammable gas releases, however, these data were not consistent and therefore it was difficult to draw conclusions. Statistical analyses might help to provide more information about the relationship between gas releases and pumping rates and a probability distribution of how long after pumping subsidence events (i.e., possible gas releases) might occur. In the future, it would be beneficial for understanding the effects of salt well pumping if a consistent set of continuous data were recorded during and after pumping campaigns for flammable gas levels (including hydrogen and ammonia), pumping rates, surface levels (either FIC or Enraf), neutron log interstitial liquid levels, and subsidence.

Acknowledgments

The authors wish to thank Jeanne A. Lechelt of WHC for providing access to the daily updated files for Tanks 241-S-108, -S-110, and -T-108 on the server WHC198\SALTWELL, and Randy A. Heller of BCSR, Melissa J. Holm of WHC, and Stephen F. Bobrowski of PNNL for their assistance in gaining access to the Tank Waste Information Network System (TWINS2) Interface and the Surveillance Analysis Computer System (SACS) database. The authors also wish to thank Mike R. Koch, W. Jerry Lehman, and David A. Bragg of WHC, Doug K. DeFord and Terry L. Warnick of ICFKH, and Paul D. Whitney, C. Steve. Simmons, and Richard G. Brown of PNNL for providing access to their project files and data summaries that were not readily available in published documents. In addition, the authors wish to thank Elaine R. Schalla of BCSR for providing access to in-tank photographs via the VIDON photo library. Finally, the authors wish to thank Loni M. Peurrung of PNNL for writing the Excel macros used to convert the two-minute-data for Tanks 241-S-108, S-110, and T-108 to hourly averages.

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1.0 Introduction

The Hanford Site has 149 single-shell tanks (SSTs) containing radioactive wastes that are complex mixes of radioactive and chemical products. Active use of these SSTs was phased out completely by November 1980, and the first step toward final disposal of the waste in the SSTs is interim stabilization (Swaney 1996). Stabilization can be achieved administratively, by jet pumping to remove drainable interstitial liquid, or by supernatant pumping. Of the 149 SSTs, 116 have been declared interim stabilized; 44 have had drainable liquid removed by salt well jet pumping (Hodgson et al. 1996; Swaney 1996; ICF Kaiser 1994a, 1994b, 1995),[a][b] although liquid removal is not complete in some of these tanks. Interim stabilization is intended to reduce the liquid content of wastes to the greatest extent technically and economically feasible to minimize the risk associated with loss of tank integrity and the release of tank contents to the environment. To be stabilized, essentially all of the supernatant liquid and drainable liquid contained within the waste must be removed.

Nineteen of the SSTs on the Hanford site have been placed on the Flammable Gas Watch List (FGWL) because the waste in these tanks is known or suspected, in all but one case, to generate and retain mixtures of flammable gases, including hydrogen, nitrous oxide, and ammonia (Hopkins 1995; Hanlon 1996). To date, none of these tanks has had drainable liquid removed by salt well jet pumping. Salt well pumping to remove the drainable interstitial liquid from SSTs, however, is expected to release much of the retained gas, posing a number of safety concerns. Accordingly, this study seeks to understand the historical behavior of tanks during and after salt well pumping to provide insight into the potential behavior of the FGWL tanks when they are salt well pumped. This study is being conducted for Westinghouse Hanford Company as part of the Flammable Gas Project at the Pacific Northwest National Laboratory (PNNL).[c]

Salt well pumping, or interim stabilization, is a well-established operation that began in the mid-1970s for removing drainable interstitial liquid from SSTs (Grimes 1978). The first salt well jet pumping was conducted in BY-107 in 1975, and in 1978 the first SSTs were designated as interim stabilized (Swaney 1996). While salt well pumping has been conducted in many tanks for years, there has been little previous work on how it releases retained gas. In general, understanding gas release mechanisms in SSTs is in an early stage of development, but

(a) Personal communication and data transmittal, L.A. Mahoney from D.K. DeFord, August 6, 1996.

(b) Lechelt, J. A. 1995. *Temperatures of Interim Stabilized Salt Cake Tanks*. 71330-95-006. Westinghouse Hanford Company, Richland, Washington.

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preliminary studies are beginning to elucidate the most likely behavior.[a] Still, there is evidence that certain SSTs are retaining gas in amounts that, if released rapidly compared with the mixing and dilution within the dome space of the tanks, could lead to a flammable condition in the tank dome space (Hodgson et al. 1995, 1996; Whitney 1995).

Salt well pumping of SSTs on the FGWL is expected to begin soon, so it is important to understand how it will affect the waste and the release of flammable gases. A safety assessment (SA) for salt well pumping a FGWL tank, prepared by Los Alamos National Laboratory, was recently completed and is being reviewed.[b] This SA contains perhaps the most thorough collection to date of historical data on salt well pumping and waste behavior. In addition to discussing waste behavior, the SA also addressed the potential mechanisms of gas release during salt well pumping.[c] In a more recent study, Peurrung et al. (1996) studied gas release during salt well pumping in detail, and Gauglitz et al. (1996) quantified to what degree bubbles can be retained in drained salt cake simulants. While these studies provide valuable information on salt well pumping and flammable gas issues, a great deal of data remain to be collected and evaluated.

The objective of this study is to collect and summarize information, primarily tank data and observations, that relate salt well pumping to flammable gas safety issues. In general, the approach is to collect pertinent data from the periods both before and after the initiation of salt well pumping and compare them to glean insight into the effects of salt well pumping on waste behavior. We have investigated drainable porosity, changes in trapped gas from the correlation of waste level with barometric pressure, changes in surface level with volume of liquid removed by pumping, evidence of subsidence, number and size of gas releases estimated from drops in waste surface level following pumping, changes in neutron logs (to infer phenomena other than the lowering of the liquid level), and flammable gas levels in the dome spaces of tanks that have recently been pumped. In each of the following sections we focus on specific data, or collections of data, that address each of these specific topics. This study was an initial investigation into the historical data relating salt well pumping to flammable gas issues, so the data collection and evaluation are certainly not complete. In some cases, data are shown for all of the tanks where salt well pumping has been initiated. In other cases, the data collection focused on a few high priority tanks that are of particular interest.

(a) A variety of plausible gas release mechanisms were discussed by RT Allemann et al. in a letter report entitled, *A Discussion of Some Release Mechanisms for Sudden Gas Release from Single-Shell Tanks at Hanford* (PNL-WTS-101095) (October 1995).

(b) This safety assessment is currently the draft document WHC-SD-WM-SAD-034 Rev. 0, *A Safety Assessment for Salt Well Jet Pumping Operations in Tank 241-A-101: Hanford Site, Richland, Washington* (1996).

(c) The calculation of gas release summarized in the SA is also reported by J.W. Spore in a Los Alamos National Laboratory Calc-Note entitled *Conservative Gas Releases for Tank 241-A-101* (TSA10-CN-WT-SA-GR-046, 1996).

2.0 Waste Porosity and Void Fraction

2.1 Drainable Porosity

Drainable porosity is a term used by tank farm waste management engineers to indicate how much liquid can be removed from a tank when it is pumped. Drainable porosities are calculated for salt-well-pumped tanks once they are deemed interim stabilized and are reported in the *Single-Shell Tank Leak Stabilization Record* (Swaney 1996). In Swaney, drainable porosity is the ratio of the interstitial liquid removed by pumping to the theoretical equivalent interstitial liquid removed at 100% porosity and is calculated as follows:

$$\text{Porosity} = \frac{\text{NPV} - \text{PS}}{\left(\text{ILL}_i - \dfrac{\text{PS}}{2.75\ \text{kgal/in}} - \text{ILL}_f\right) 2.75\ \text{kgal/in}} \qquad (2.1)$$

where

NPV is the net pumped volume (kgal)
PS is the pumped supernate (kgal)
ILL_i and ILL_f are the initial and final interstitial liquid levels, respectively (in inches); however, in Swaney (1996) diptube level measurements were used rather than ILL measurements to calculate drainable porosity.
2.75 kgal/in is the volume per unit height for a standard SST of diameter 75 feet.

Figure 2.1 depicts how bubble retention may affect drainable porosity. If retained gas bubbles exist in the tank waste, less liquid will be removed by pumping because some of the space is occupied by bubbles. As a result, the calculated drainable porosity would be less because the net pumped volume is less.

Porosities for the 37 SSTs that have been interim stabilized by salt well pumping to date (Swaney 1996) were compared to see if there was any correlation between potential bubble retention and porosity. Table A.1 in Appendix A lists the calculated drainable porosities for each interim-stabilized-salt-well-pumped tank as reported by Swaney (1996). Figure 2.2 groups these tanks by their potential for retained gas to see if there is any correlation with porosity. None of the 19 tanks on the FGWL (Hopkins 1995; Hanlon 1996) have been salt well pumped; however, some of the 37 interim-stabilized-salt-well-pumped tanks (Swaney 1996) have been singled out in various studies as having the potential for retained gas. The first two groupings of tanks in Figure 2.2 are those on the short list and the cluster-expanded list as defined in a recent SST prioritization study.[a] These

(a) Brewster, M.E. and B.J. Palmer. 1995. *Prioritization of Single Shell Tanks for Study of Gas Retention and Episodic Release.* PNL-WTS122295. Pacific Northwest National Laboratory, Richland, Washington.

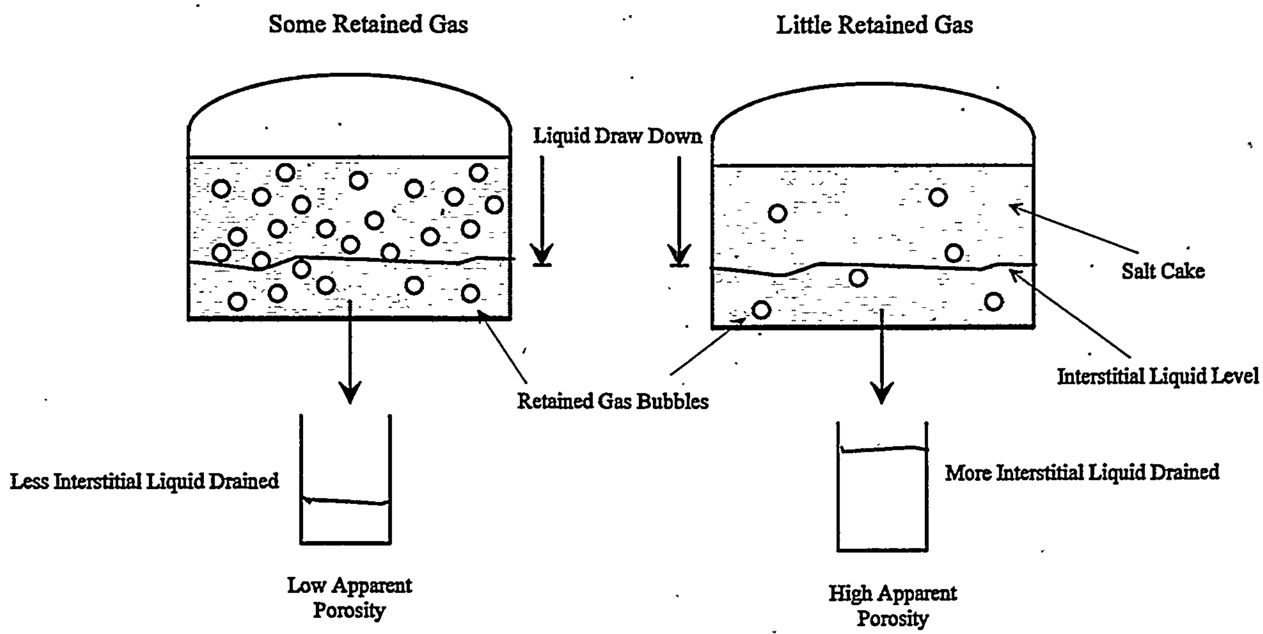

Figure 2.1. Bubble Retention May Affect Drainable Porosity

tanks are followed by those flagged by Whitney (1995). None of the other 37 tanks have been singled out as having the potential for trapped gas. Figure 2.2 also shows the percent salt cake (as opposed to sludge) of the waste in each tank (Hanlon 1996).

Figure 2.2 does not indicate any relationship between drainable porosity and the potential for trapped gas. One might have expected that tanks flagged as having the potential for trapped gas (short list, cluster expanded list, and Whitney list) would have had lower calculated porosities than non-flagged tanks. However, as Figure 2.2 shows, porosity values span nearly the entire range (0-66% porosity) for all tanks. In addition, although the 0% salt cake (100% sludge) tanks appear to have a lower average porosity, again there is no evident correlation between porosity and waste percent salt cake.

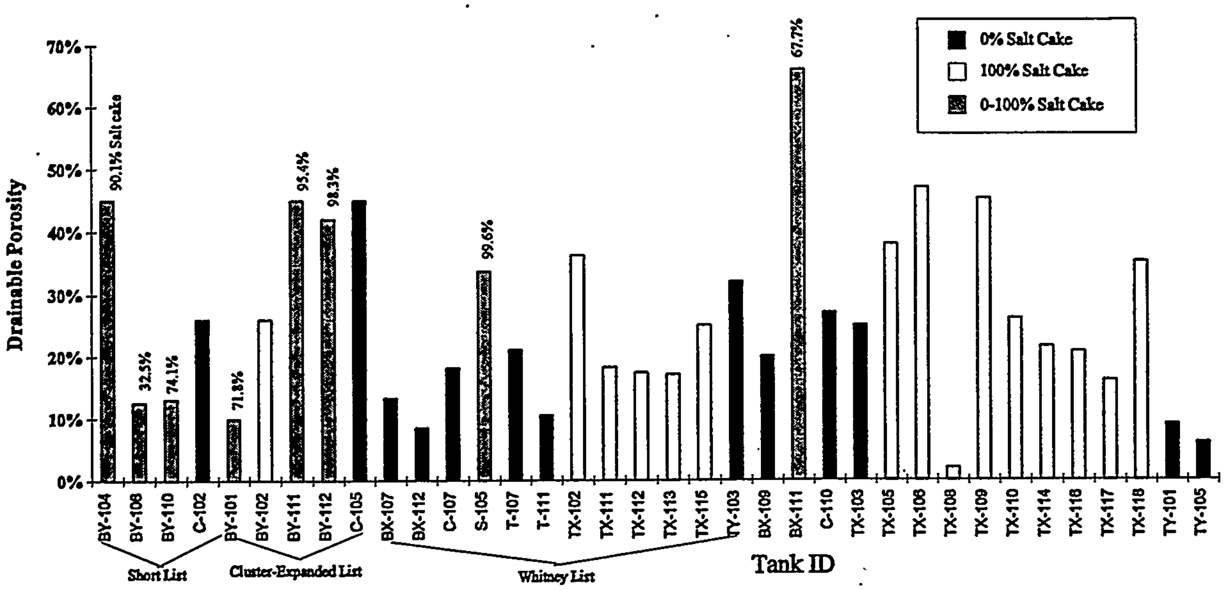

Figure 2.2. Porosity Versus Tank Grouping and Percent Salt Cake

2.2 Void Fraction

The in situ void fraction (volumetric fraction of undissolved gas) in tank waste can be directly measured by the void fraction instrument and/or the retained gas sampler. It can also be inferred from data for long-term surface level trends or for short-term level perturbations induced by atmospheric (that is, barometric) pressure changes. No SSTs are equipped with direct measurement instrumentation, so the latter approach is taken in this section.

The barometric response of the waste level is referred to as "dL/dP" and is calculated as the slope of the correlation of waste surface level, or interstitial liquid level, with atmospheric pressure. The level data are detrended – that is, long-term level change trends are removed – before the short-term correlations are made. This method is described more completely by Whitney (1995). The dL/dP data used in this report were obtained from a database maintained by Whitney and are approximately 50th-percentile (i.e., median) values.[(a)] Table A.1 in Appendix A lists the dL/dP data for each tank.

(a) Personal communication and data transmittal, L.A. Mahoney from P.D. Whitney, August 7, 1996.

Because dL/dP is a correlation slope, it has its own inherent statistical deviation. That error band is much greater for measurements made with manual tape (MT) and neutron log (N-ILL) instruments than for those made with the FIC (tank waste surface level gauge made by the Food Instrument Corporation) and Enraf (Enraf 854 ATG level detector manufactured by Enraf Incorporated) instruments. Accordingly, this report discusses only dL/dP values that were derived from either FIC or Enraf measurements.

Gas compresses (has less volume) with increasing pressure and expands (greater volume) with decreasing pressure, so higher void fractions in waste are expected to produce more negative values of dL/dP. Positive dL/dP values have no known physical significance. From Hopkins (1995), the relationship between dL/dP and the in situ void fraction α is

$$\alpha = (-dL/dP)\,(P/L) \tag{2.2}$$

where α = in-situ void fraction
P = average hydrostatic pressure in the layers where gas is present
L = the total depth of the wetted waste

Equation (2.2) shows that the quantity (dL/dP)/L can be used as a surrogate for the void fraction.

Salt well pumping may affect the void fraction in a tank in several different ways. First, as shown in Figure 2.3, when salt well pumping removes drainable liquid, many of the retained bubbles will be released, decreasing the total gas volume. This is particularly true for salt cake waste (Peurrung et al. 1996), and probably less true for sludge waste. When the gas volume decreases, the dL/dP value becomes less negative; the dL/dP should become zero if no gas remains. It is also possible that the void fraction in the undrained parts of the tank could increase after pumping. The total moles of gas in the undrained region decreases because of gas releases, but the remaining gas expands because the liquid above it has been removed and the hydrostatic pressure on it reduced. Another possibility for increased void fraction after pumping is that air infiltrates into the zone around the salt well pump where the liquid profile is farthest drawn down. This air could then become trapped when pumping ceases and the liquid profile "heals" (reaches a uniform equilibrium level). This gas, being primarily air, would not pose a flammable gas safety concern, but it would be indistinguishable from evolved flammable gas, as far as the value of dL/dP was concerned.

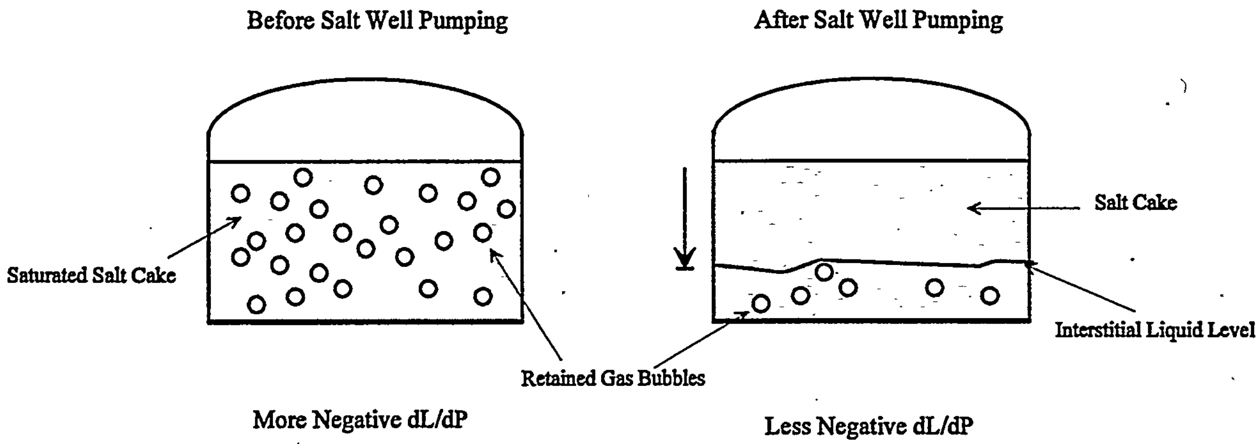

Figure 2.3. Salt Well Pumping May Affect dL/dP

In situ gas can be present in one of two forms (Gauglitz et al. 1994). Pore-filling bubbles displace only the interstitial liquid and are confined to the pores of the waste; their presence can be shown only by N-ILL measurements of fluctuation in interstitial liquid level. These pore-filling bubbles (in which capillary force is insufficient to overcome compressive forces) are likeliest to occur in wastes that have high yield strengths or high hydrostatic head and large pores. Gas may also take the form of bubbles that displace waste particles and liquid alike and therefore contribute to changes in the solid surface level. These particle-displacing bubbles are most common in weak or shallow wastes with small pores.

These issues should be kept in mind when considering the relationship between the porosity and the void fraction. For bubbles that are confined to the pore space, the porosity determines the upper limit on the void fraction. For bubbles that expand and displace the waste, the void fraction could conceivably exceed the gas-free porosity of the waste material. In this case, the drainable liquid fraction as estimated during salt well pumping would be based on the inherent interstitial porosity, while the gas fraction would be independent of porosity.

Figure 2.4 shows the relationship between the drainable porosity and the dL/dP value before salt well pumping for those tanks where sufficient FIC/Enraf measurements were available. Most of the representative data were for sludge tanks; only three salt cake tanks are plotted. The dotted line represents the expected trend; low porosity values are associated with more negative dL/dP

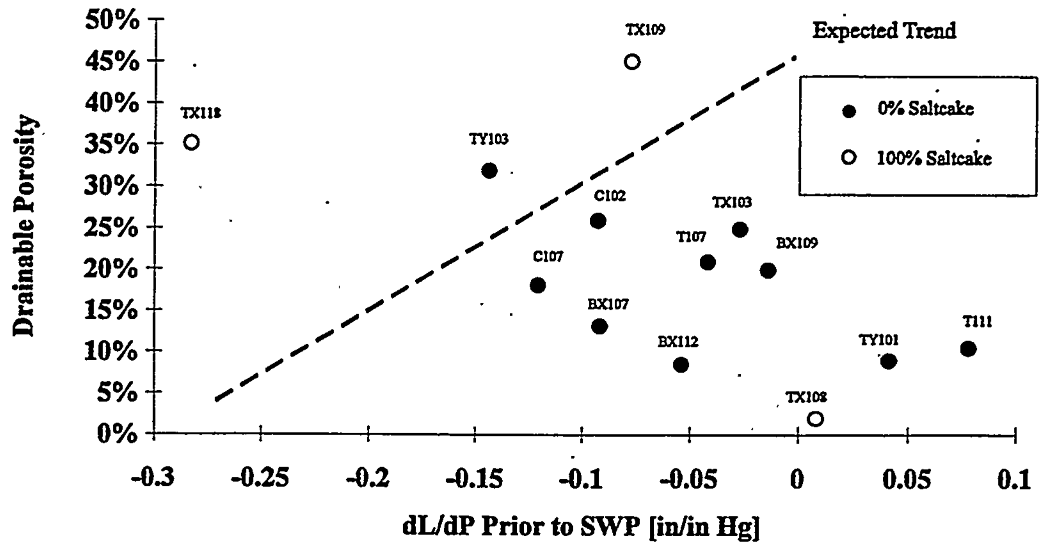

Figure 2.4. Relationship Between Drainable Porosity and dL/dP Before Pumping

values because both indicate high void fractions. As seen in the figure, the data do not follow the expected trend. In fact, the opposite trend can be inferred. However, because only about 30% of the tanks had sufficient FIC or Enraf measurements to get dL/dP data, it is difficult to draw any conclusions from this analysis.

The effects of salt well pumping on the in-situ void fraction can be illustrated by comparing the dL/dP values before and after pumping events. Figure 2.5 is a plot of the change in the (dL/dP)/L due to pumping versus the value of the same variable before pumping. The values plotted are limited to those tanks where sufficient FIC/Enraf measurements were available before and after pumping. In effect, this plot shows the change in the void fraction as it relates to the initial void fraction. If salt well pumping resulted in reducing the void fraction to zero (i.e., release of all the retained gas), the data would fall along the line shown in the plot. A more negative value of the change in (dL/dP)/L, the surrogate void fraction, indicates a higher void fraction after pumping.

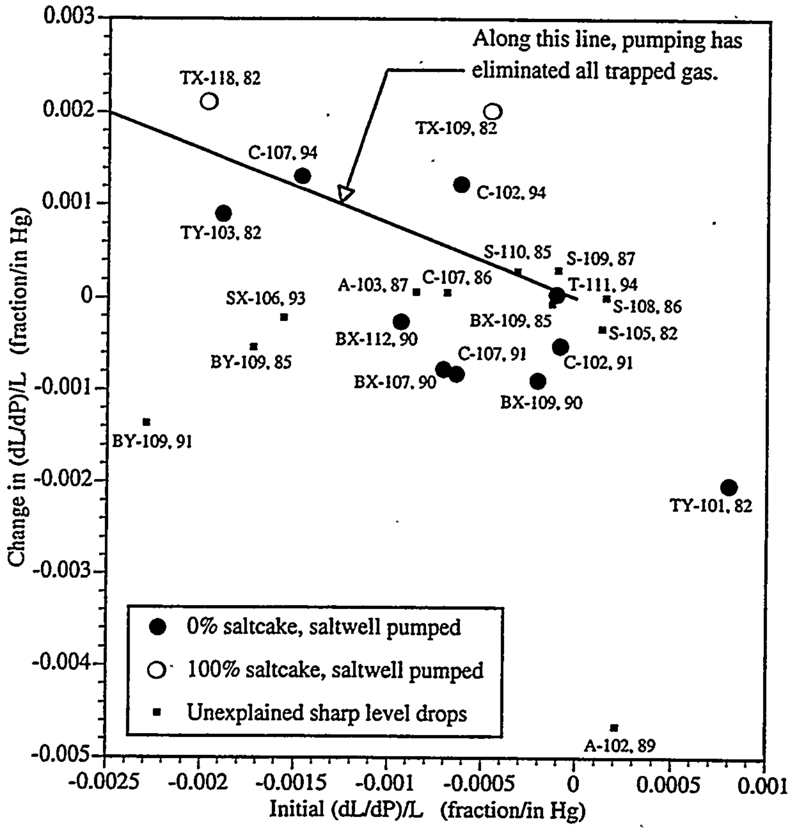

Figure 2.5. Changes in the Surrogate Void-Fraction During Salt Well Pumping

The events that are plotted in Figure 2.5 include the known salt well pumping events (dates from Hodgson et al. 1996; Swaney 1996; ICF Kaiser 1994a, 1994b, 1995)[(a)(b)] as well as other sharp drops in surface level[(c)] whose cause was not recorded. These may have included supernatant removal as well as salt well pumping.

Evidence exists that salt well pumping releases gas from salt cake waste (Peurrung et al. 1996), but this mechanism is not likely to occur in tanks with sludge waste. Accordingly, it is not surprising that for the sludge tanks shown in Figure 2.5, the change in (dL/dP)/L was more negative, indicating an increase in void fraction. It appears that these tanks increased their gas

(a) Personal communication and data transmittal, L.A. Mahoney from D.K. DeFord, August 6, 1996.

(b) Lechelt, J. A. 1995. *Temperatures of Interim Stabilized Salt Cake Tanks.* 71330-95-006. Westinghouse Hanford Company, Richland, Washington.

(c) Level data were downloaded by S.M. Caley via the TWINS2 Interface from the SACS database (Glasscock 1993), August 1996.

3.0 Salt Well Pumping and Flammable Gas Measurements

Flammable gas releases constitute one of the primary safety concerns connected with salt well pumping of the Hanford waste tanks. It is therefore worth considering the possible effects of pumping on the waste's gas content and reviewing the available measurements of flammable gas concentrations in the dome space before, during, and after pumping.

Salt well pumping is often an intermittent process. Liquid is pumped from a screened well placed approximately in the center of the tank until the liquid level is at the top of the non-drainable waste (that in which water is held by capillary forces). The radial liquid profile in the waste is roughly the shape of an inverted bell curve, with its lowest point at the well screen and its highest points at the tank walls. When the liquid level in the well falls too low to support pumping, the pump is shut off and the interstitial liquid is allowed to equilibrate, followed by starting the pump again. In general, the well can be pumped dry much more rapidly than it can be refilled by liquid level equilibration. It follows that a substantial amount of the waste volume is draining and releasing gas while the pump is off or running at low speed, not just while the pump rate is high. Thus gas releases and high flammable gas concentrations may not occur simultaneously with periods of high pumping rates. An examination of the relative timing of the two variables is needed to clarify this point.

Flammable gas monitoring data are available only for the most recent pumpings: Tanks 241-BY-103, BY-106, BY-109, S-108, S-110, and T-104. The three BY tanks were monitored only for the last six weeks or so of salt well pumping, meaning that any earlier gas releases were off the record. It is our recommendation that future salt well pumping campaigns include continuous gas monitoring of both insoluble (hydrogen) and soluble (ammonia) gases.

Figures 3.1 through 3.6 are plots of the measured flammable gas concentrations in the dome space versus time. The pumping rate and the cumulative gallons pumped are also plotted over the same interval. The flammable gas concentration is expressed in percent of the lower explosive limit (LEL), which is 4% for hydrogen. As for other flammable gases known to be present in some tanks, measurements indicate that methane is rarely a significant contributor to flammability (Brown 1996a), and ammonia data are not available. The pumping flow rate is expressed as a percentage of 20 gpm so that the flammable gas levels and pumping rate could be shown on the same scale.

3.1 Tank 241-BY-103

Salt well pumping of Tank BY-103 began in early August 1995. Figure 3.1 shows the flammable gas and pumping data during September and October 1995 and also includes a table of grab sample measurements (Brown 1996a). In September, the standard hydrogen monitoring system (SHMS) cabinet was not yet installed, so flammable gases were measured via hand

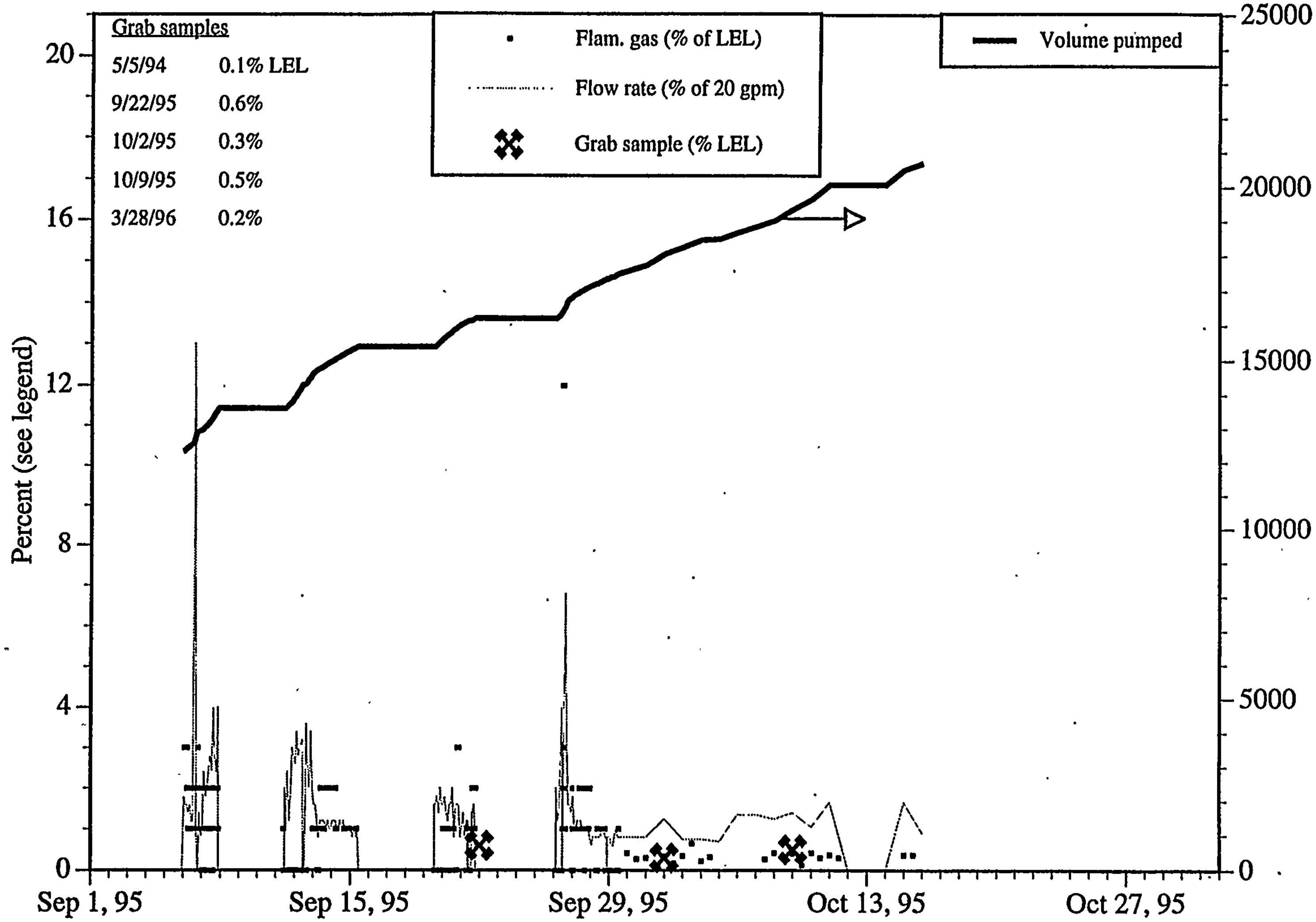

Figure 3.1. Flammable Gas and Salt Well Pumping Data for Tank 241-BY-103

sampling every 15 minutes through what was to become the SHMS probe.[a] The October data, which measured only hydrogen gas and were taken every 12 hours, were obtained through the complete SHMS system.[b] The pumping data, which were measured every 2 hours during September and subsequently were daily averages, were provided by cognizant engineers.[a][c]

The flammable gas concentrations were consistently below 4% of the LEL during the period of record, except for one 12% LEL outlier (of unknown cause) in late September. This datum may be in error, but it is interesting that it occurred together with a spike in pumping rate. On the other hand, the highest gas measurements did not always appear aligned with rapid pumping. The grab samples showed low flammable gas concentrations before pumping, a slight increase in concentration during pumping, and after pumping ended the concentrations declined to pre-pumping levels within six months.

3.2 Tank 241-BY-106

Pumping of Tank BY-106 began in early August 1995. Figure 3.2 depicts the flammable gas and pumping data during September and October 1995 and also includes a table of grab sample measurements (Brown 1996a). The sources and nature of the plotted data are the same as for Tank 241-BY-103, except for one thing. Before September 19, the flammable gas probe connections were reversed such that gas was being sampled from the riser near the top of the tank rather than, as was intended and usual, from a point just above the waste surface. The result is that from September 1 to September 19, the apparent flammable gas concentrations were much higher, owing to buoyant stratification of the hydrogen. (Tank 241-BY-106 has a very low ventilation factor [WHC 1996].)

Though we have no way to estimate the near-waste hydrogen concentrations from the dome-top hydrogen measurements, the latter (being amplified values) do provide a much more visible reflection of gas release, and in that way are useful. It is clear from the early-September portion of Figure 3.2 that the flammable gas concentrations followed the flow rate rather closely, with only slight lag. In the later parts of the pumping campaign, much less variation can be seen. Comparing Figure 3.2 with Figure 3.1, it appears that similar pumping rates produced lower concentrations in BY-106 than in BY-103. The difference may be within the accuracy of measurement at the low end

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(a) Personal communication and data transmittal, L.A. Mahoney from T.L. Warnick, August 1, 1996.

(b) Personal communication and data transmittal, L.A. Mahoney from R.G. Brown, August 22, 1996.

(c) Personal communication and data transmittal, L.A. Mahoney from D.K. DeFord, August 6, 1996.

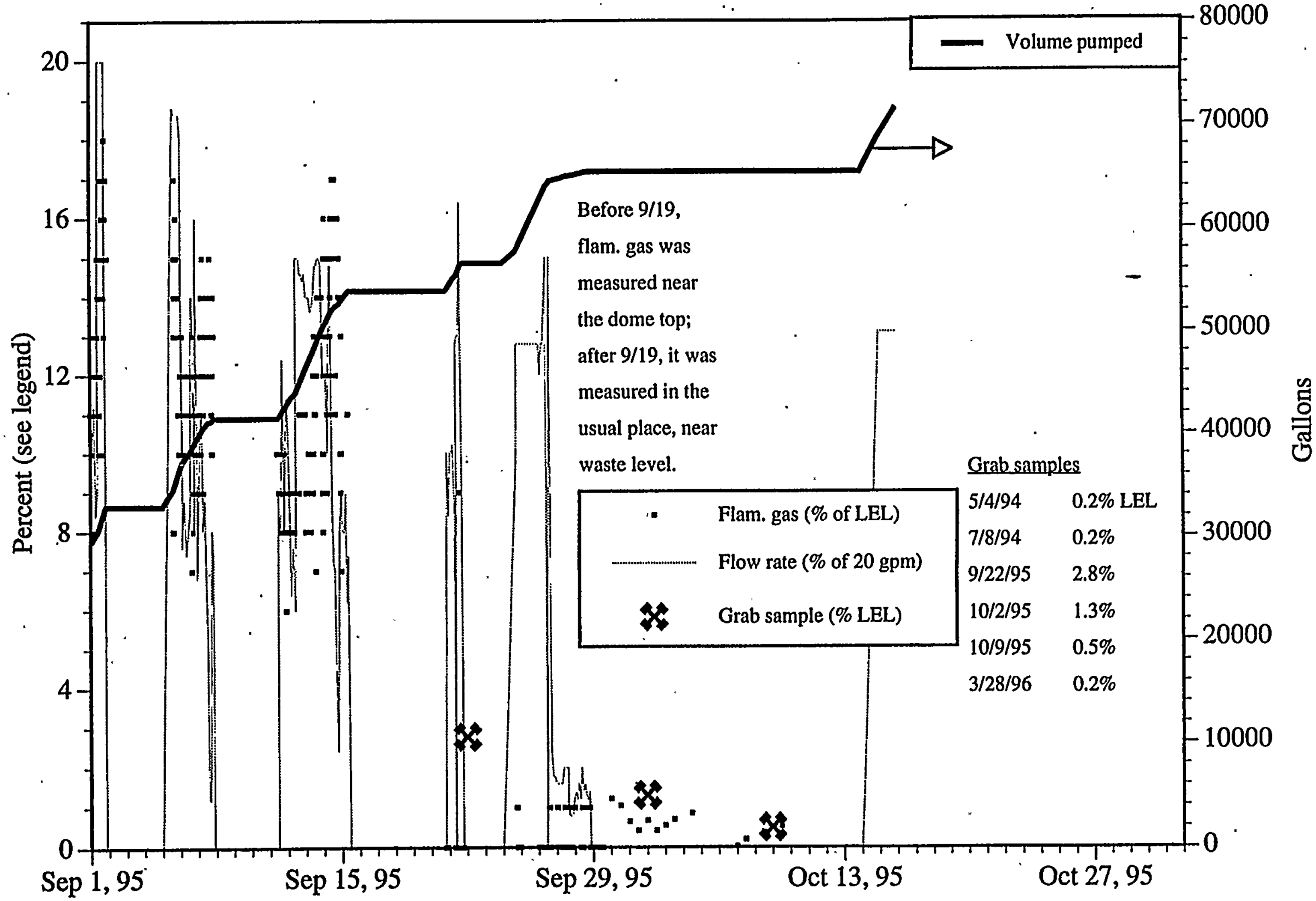

Figure 3.2. Flammable Gas and Salt Well Pumping Data for Tank 241-BY-106

of the range, though. The grab samples showed low flammable gas concentrations before pumping, a large increase in concentration during pumping, and after pumping was complete, the concentrations declined to pre-pumping levels within months.

3.3 Tank 241-BY-109

Figure 3.3 depicts the flammable gas and pumping data during September and October 1995 for Tank BY-109 and also includes a table of grab sample measurements (Brown 1996a). The sources and nature of the plotted data are the same as for Tank 241-BY-103. Note, incidentally, that (as shown by the total gallons pumped) this period of record contained much less of the pumped volume for BY-109 than for the other two BY tanks. (Salt well pumping had occurred between June and August 1994, October 1994 and February 1995, and June to October 1995.) Thus liquid levels in BY-109 were near the bottom of the tank, which could have affected its gas releases.

The flammable gas levels in BY-109 were comparable (4% LEL) to those seen in BY-103, even though the pumping rates were lower in BY-109. As in BY-103, some 12% LEL outliers appeared in late September, once again aligned with or slightly lagging a pumping spike. There were no grab sample data prior to pumping; the data taken during and after pumping showed a continuous decrease to very low concentrations about 6 months after pumping.

3.4 Tank 241-S-108

Figure 3.4 shows the flammable gas and pumping data for Tank S-108 from March through August 1996; salt well pumping is ongoing in S-108 at this time. All of the variables were measured every two minutes[(a)] and converted to hourly averages for easier plotting. Where flow rate data were incomplete, they were supplemented from other sources.[(b)] S-108, like the three BY tanks just discussed, contains more than 80% salt cake (see Table A.1 for more information).

The flammable gas measurements in S-108 were low, less than 2% of LEL. The bulk of the measured concentrations lie in the "noise level" below 0.5% LEL.[(c)] In addition, it is not at all clear that the gas concentration peaks were consistently tied to the pumping rate.

(a) Data downloaded by S.M. Caley, September 1996, from the comma separated variable (CSV) files on the WHC198\SALTWELL server, maintained by R.N. Kersey.

(b) Personal communication and data transmittal, L.A. Mahoney from D.K. DeFord, August 6, 1996.

(c) Personal communication, S.M. Caley with R.N. Kersey, September 4, 1996.

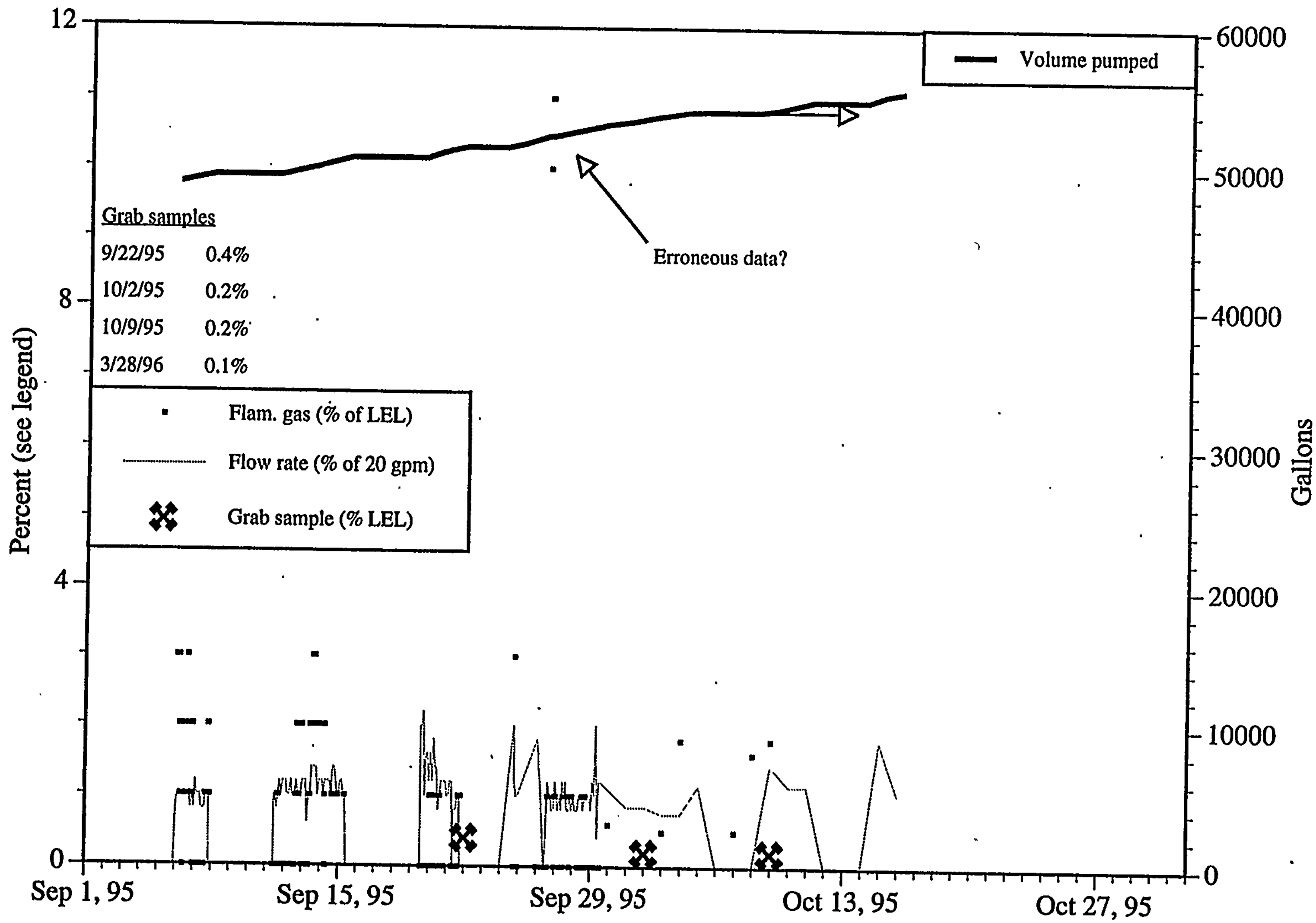

Figure 3.3. Flammable Gas and Salt Well Pumping Data for Tank 241-BY-109

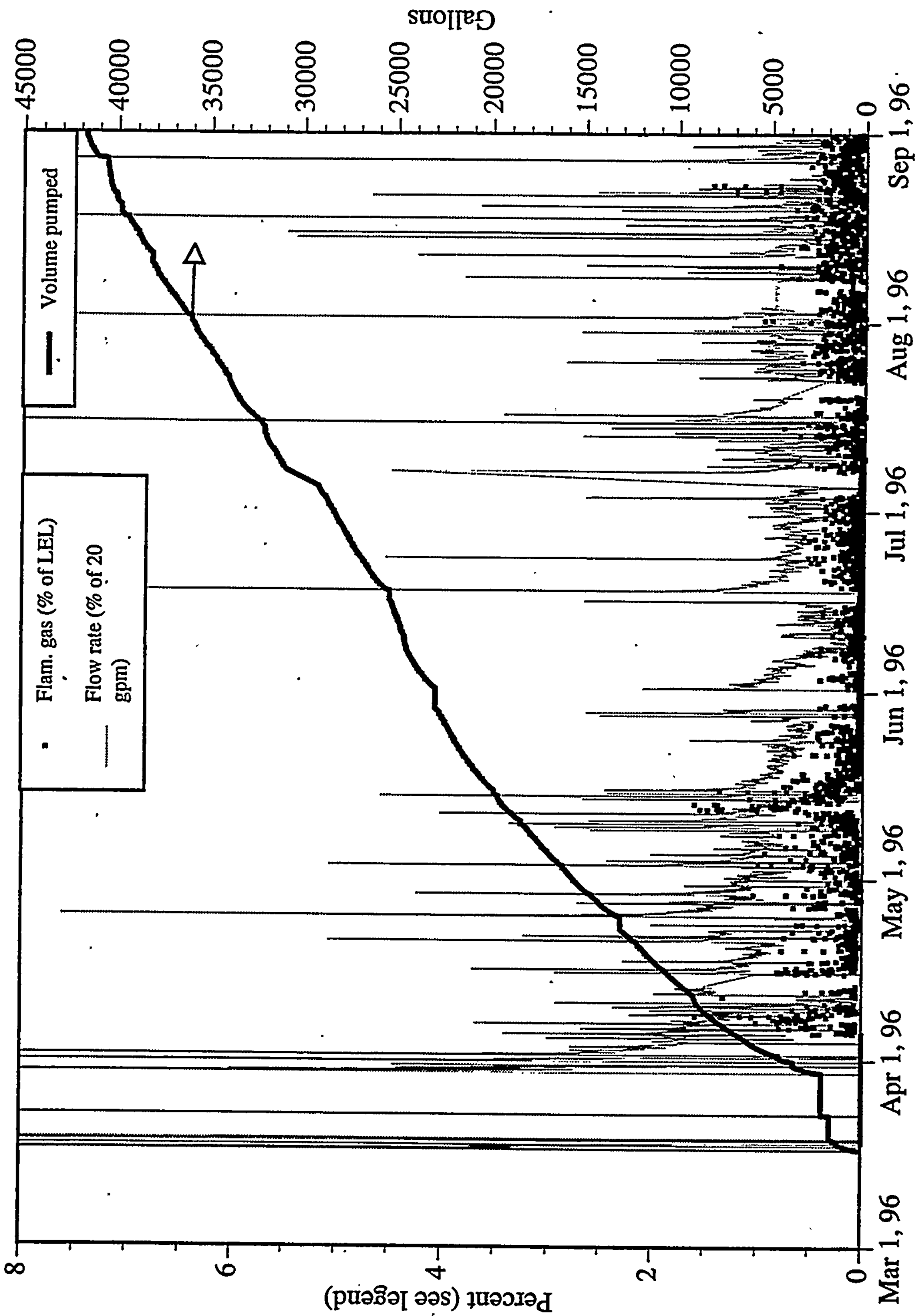

Figure 3.4. Flammable Gas and Salt Well Pumping Data for Tank 241-S-108

3.5 Tank 241-S-110

Figure 3.5 depicts the flammable gas and pumping data for Tank S-110 from March through August 1996; salt well pumping is ongoing in S-110. The sources and nature of the plotted data are the same as for Tank 241-S-108, though the pumping rate and total data may not be not complete. Tank S-110 is 66% salt cake.

The flammable gas measurements in S-110 were in the same range as those in S-108, but concentration peaks seemed to be better matched with pumping peaks. Note that some pumping occurred in late February 1996, then went on hold; gas concentrations measured during the hiatus were down in the noise level of 0.5% LEL.

3.6 Tank 241-T-104

Figure 3.6 depicts the flammable gas and pumping data for Tank T-104 from March through August 1996; salt well pumping is ongoing in T-104. The sources and nature of the plotted data are the same as for Tank 241-S-108. Tank T-104 is 0% salt cake (100% sludge).

Once again, flammable gas concentrations stayed at 2% LEL or less. During the first 20,000 gallons or so of pumping, concentrations remained predominantly in the noise level. After that time, more of the relatively high concentrations were seen; the peaks appeared to be decreasing steadily with time, a phenomenon not as visible in the other tanks. However, the average pumping rate (as seen in the slope of the cumulative volume) has been roughly constant throughout the period. These data agree with modeling results reported by Peurrung et al. (1996).

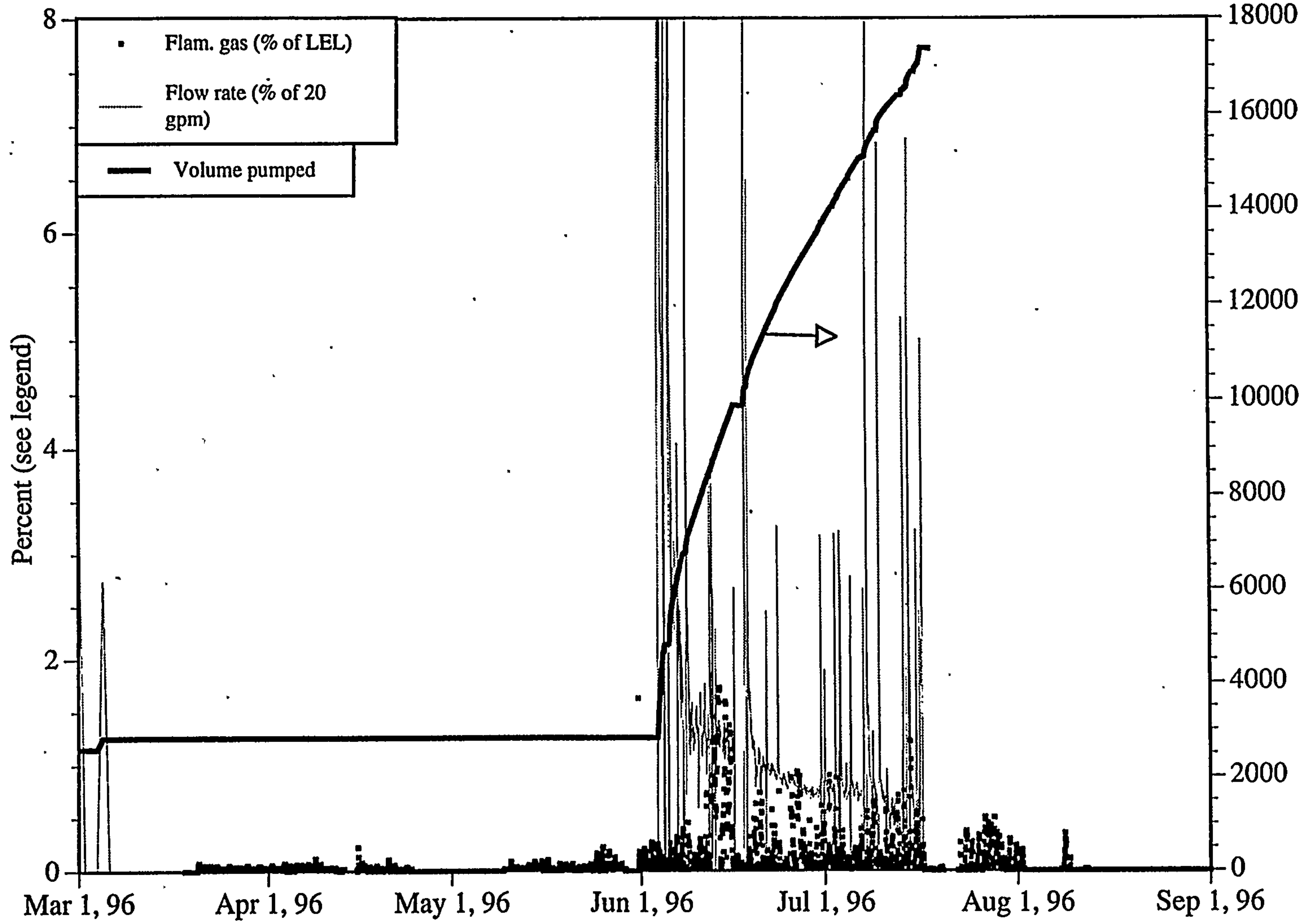

Figure 3.5. Flammable Gas and Salt Well Pumping Data for Tank 241-S-110

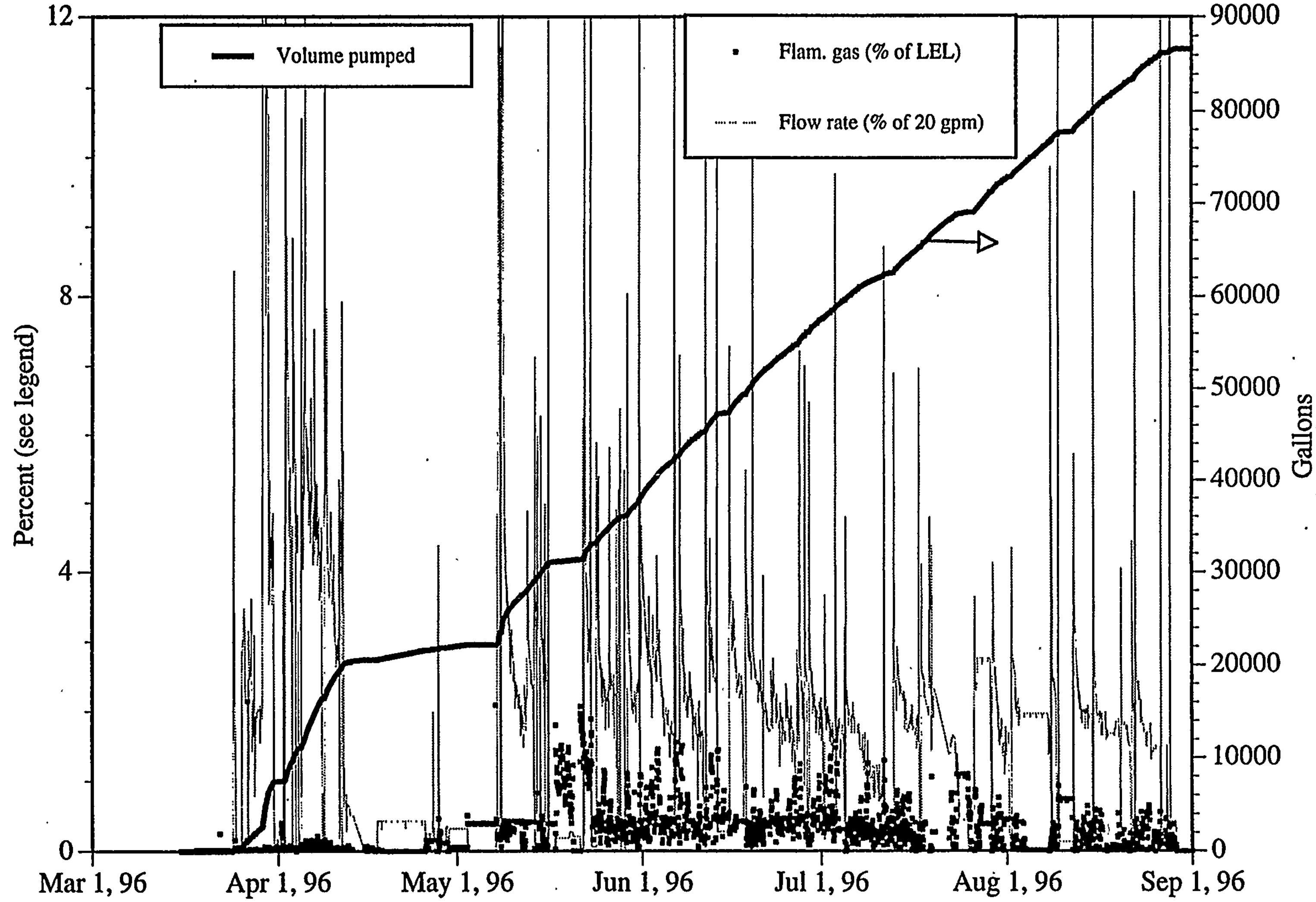

Figure 3.6. Flammable Gas and Salt Well Pumping Data for Tank 241-T-104

4.0 Waste and Liquid Levels During Pumping

Direct measurements of hydrogen, or flammable gas, during salt well pumping are available for only a few tanks (discussed in Section 3). However, other data can indirectly provide some insight into the processes going on in salt well pumping and the possible effects on flammable gas release. We have therefore reviewed the pumping and level data for the eight tanks for which a full set of data was available. Unfortunately, it was difficult to find salt well pumping-rate data. Although these data are recorded daily on salt well pumping procedure sheets (and supposedly maintained in data centers for five years), we only located limited data for one tank. In addition to searching the appropriate data centers, we also made inquiries of individuals who were cognizant engineers during the pumping campaigns, and others who might have kept some data, but we were only able to locate daily-average pumping data for tanks that have been pumped since 1994. Waste Tank Summary Reports date back to 1966 and contain monthly pumped volume measurements for all tanks. If located, these could provide rudimentary pumping information for tanks not discussed in this section. It is our recommendation that future salt well pumping campaigns record pumping rate and level data electronically for easy access.

Figure 4.1 and Figures 4.3 through 4.8 are plots of surface levels (measured with manual tape or FIC) and interstitial liquid levels (ILLs) versus time.[a] The large plots show the total history of the levels and include (where available) the diptube measurements at the beginnings and ends of the salt well pumping campaigns. The diptube levels were taken from the *Single Shell Tank Leak Stabilization Record* (Swaney 1996). The small inset plots cover only the period of time for which pumping data were found[b] and show surface level, measured ILL, and cumulative gallons pumped (taking the beginning of the data as zero gallons, though in some cases the data begin in mid-campaign). These insets also show a variable called the "theoretical ILL." This is given by

$$\text{Theo. ILL} = (\text{Meas. ILL at the start of pumping data}) - (\text{kgal Pumped}/2.75\text{kgal/in}) \tag{4.1}$$

Here the factor of 2.75 is the conversion from liquid volume to inches of depth in a standard single-shell tank. Thus the "theoretical ILL" shows where the interstitial liquid level would be for 100% porosity, that is, pure liquid. Because the porosity is expected to be less than 100%, owing to the presence of waste solids and gases, the measured ILL is expected to be well below the "theoretical ILL." The difference between the two values gives some indication of the size of the non-liquid volume fraction. One complicating factor is that if gas below the liquid level expands as the result of pumping, it may raise the measured ILL further above the theoretical ILL.

(a) Level data were downloaded by S.M. Caley via the TWINS2 Interface from the SACS database (Glasscock 1993), August 1996.

(b) Pumping data came from a personal communication and data transmittal, L.A. Mahoney from D.K. DeFord, August 6, 1996.

4.1 Tank 241-BX-111

Figure 4.1 displays the level histories for BX-111. The overall salt well pumping campaign lasted from October 22, 1993 to early 1995, but we have pumping data only for the final part, May 1994 to February 1995. By this time, (as is evident in Figure 4.1) the supernatant was gone and the remaining liquid was well down into the waste.

During pumping, the liquid level at the liquid observation well (LOW) dropped by about 50 inches (of which about 10 inches were supernatant, based on the figure), while the solid surface level fell less than 15 inches. The surface level recently has appeared to rebound to almost its previous level, though these data need confirmation. This apparent rebound had no effect on the ILL.

As the inset part of Figure 4.1 shows, the waste surface level was essentially constant between May 1994 and the end of pumping. In the first pumping interval, the theoretical and measured ILLs remained about equal, suggesting that supernatant or a concealed liquid layer was being drained. As expected, the measured ILL fell below the theoretical ILL during the second, larger interval of pumping. Since the difference between the measured and the theoretical ILLs is about equal to the drop in the theoretical ILL, the liquid fraction in the drained zone was roughly 50%. For comparison, Brown (1996b) estimates a total liquid fraction of 65% for this BX-111 pumping campaign. Table A.1 lists Brown's estimated liquid fractions for all tanks.

Figure 4.2 contains many of the neutron log profiles taken in Tank 241-BX-111 between 1986 and the present. This set of neutron logs covers only the early part of the pumping campaign and ends almost exactly when the pumping data in Figure 4.1 start. Unfortunately, these detailed log data[(a)] were not yet available (in a useable format) for any other pumped tank. However, Appendix C gives a detailed discussion of the analysis of a set of neutron logs for Tank 241-S-106, a non-pumped tank that has had very large level growth, presumably due to the retention of gas bubbles.

The black lines on the left-hand side of Figure 4.2 show the profiles during pumping; they are overlaid on a set of gray (speckled) profiles, representing the seven years prior to pumping. This direct overlay allows a comparison of the calibration variation during pumping with that before pumping started. In general the range of variation is the same, although the maximum readings for one profile, that for the day on which pumping started (October 22, 1996), are well below all the others. As has been suggested in previous studies (Simmons 1996), the calibration variation is substantial enough to make it meaningless to directly compare the magnitudes of neutron log profiles taken at different times.

(a) Neutron log data came from a personal communication and data transmittal, L.A. Mahoney from P.D. Whitney, August 27, 1996.

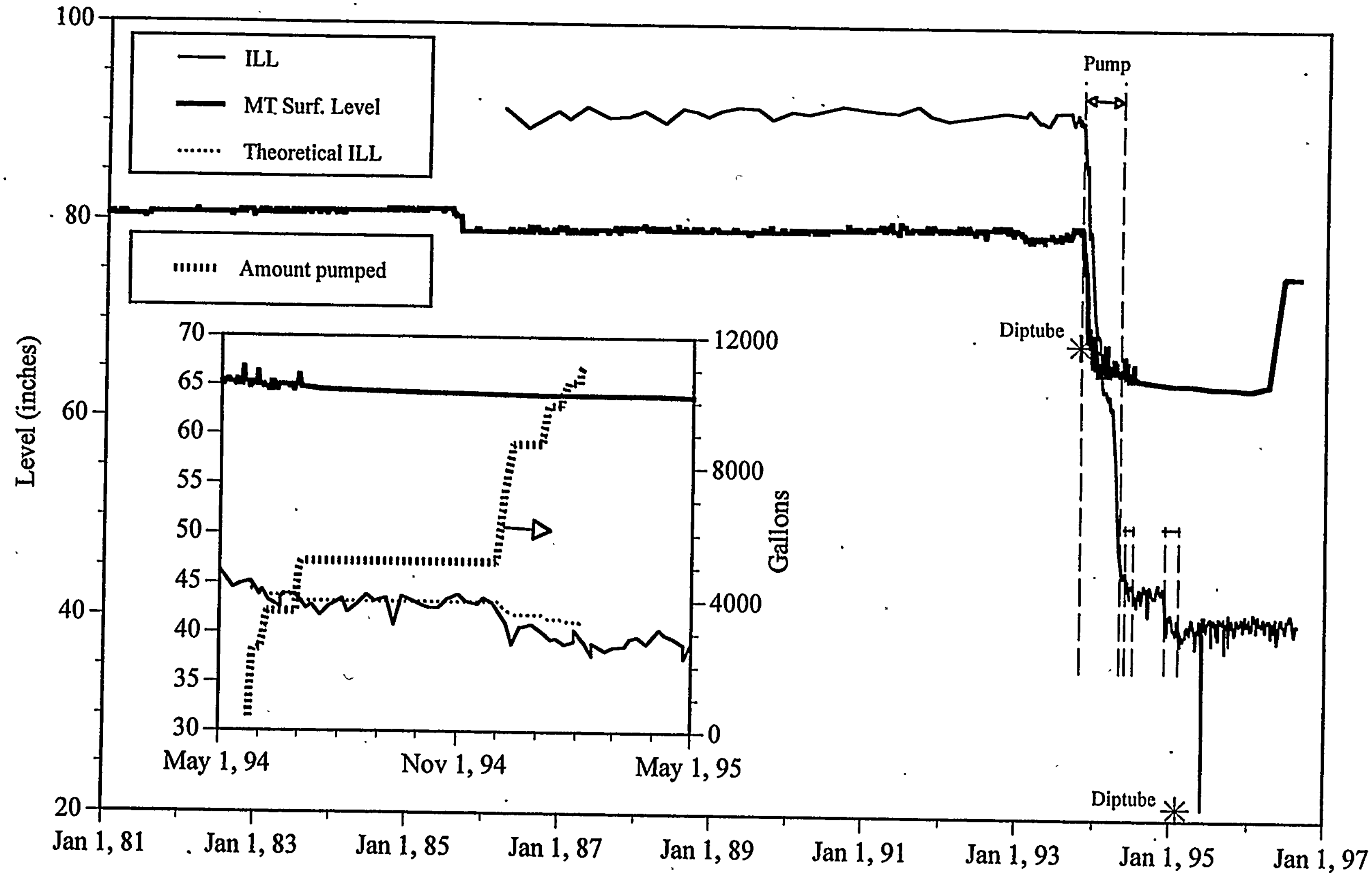

Figure 4.1. Recorded Level and Salt Well Pumping Data for Tank 241-BX-111

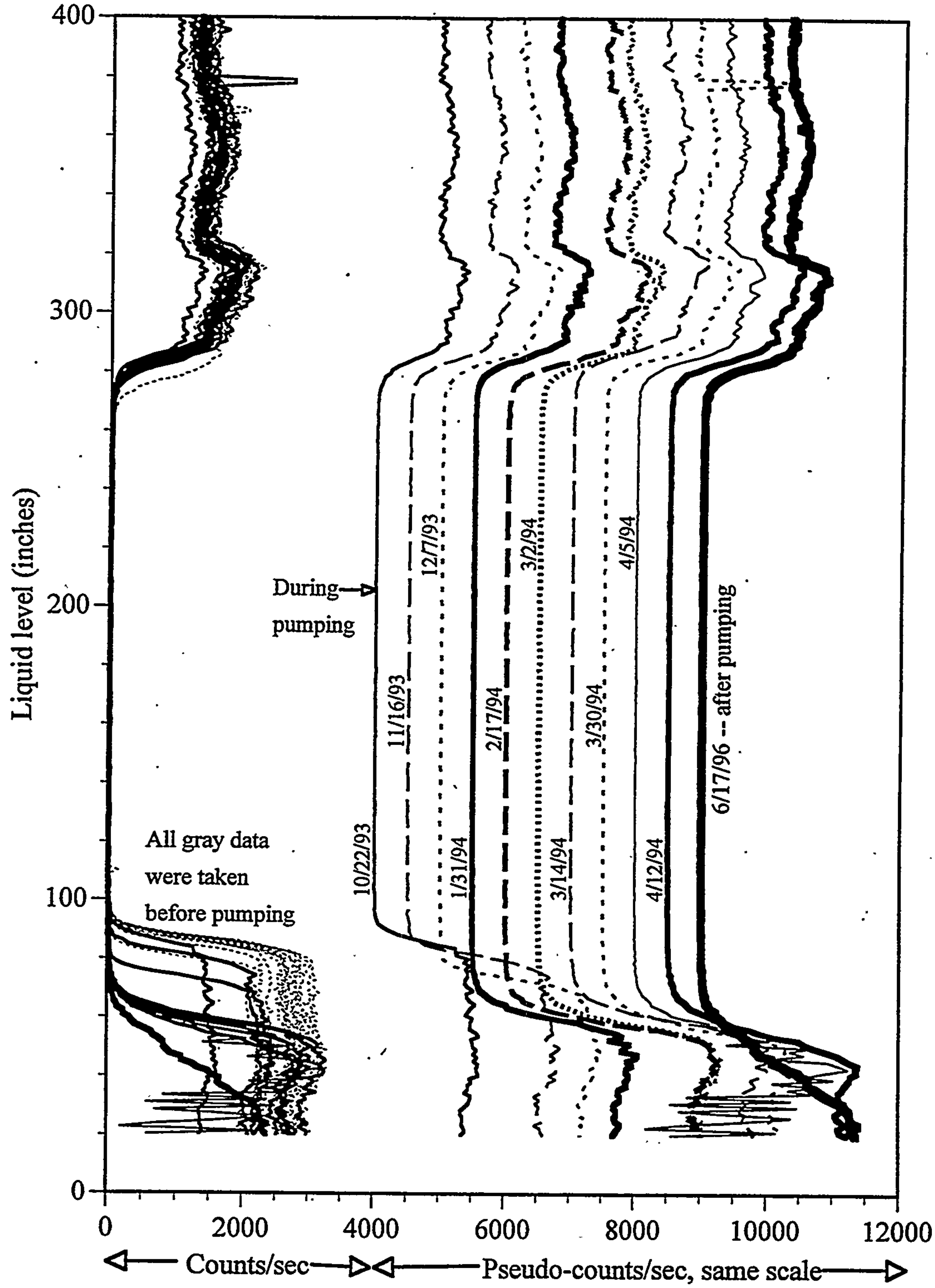

Figure 4.2. Neutron Log Profiles for Tank 241-BX-111 Before, During, and After Salt Well Pumping

The shapes of the profiles are, however, comparable, as the right side of Figure 4.2 shows. Here the profiles taken during pumping between October 22, 1993, and April 30, 1994, are laid out next to each other, evenly spaced to make them easier to compare. Initially the profile below about 90 inches is virtually vertical, allowing for noise. As time passes and pumping continues, the profile develops a more peaked shape. This can best be seen in the April 12, 1994, profile, which reaches a maximum number of counts at about 40 inches, decreases sharply as it moves down through the waste, then levels out at a constant, lower value for the bottom 20 or 30 inches.

The smaller number of counts in the lowest layer of waste indicates that less liquid is present in this layer. One possibility is that the waste has compacted, or subsided, and the solids volume fraction is accordingly higher near the bottom, and the liquid fraction lower. However, there is no sign of overall subsidence in the surface level at this time (Figure 4.1). Another possibility is that gas in the lowest layer has expanded because of the decrease in hydrostatic head above it. This could also decrease the local liquid fraction and the number of counts measured.

Finally, the last neutron log measurement was taken quite recently, June 17, 1996, well after pumping was completed. The waste and liquid levels are clearly lower than in early 1994, and there is no longer any sign of peaking in the profile. There is apparently more liquid in the lowest layer of the waste than in any higher layer, an observation which is not consistent with the compaction hypothesis. It is consistent with the idea that expanded gas had been present in the lowest layer in 1994 but since that time has been largely released.

4.2 Tank 241-BY-102

Figure 4.3 displays the level histories for BY-102. The overall salt well pumping campaign, the second one for this tank, lasted from May 30, 1994, to early 1995, and the pumping data shown cover that entire period. During the second pumping campaign, the liquid level at the LOW dropped by 2 or 3 inches (none of it supernatant, based on the figure), while the surface level fell about 8 inches. The liquid level at the LOW is supposedly higher than the solid surface level in spite of prior pumping. The surface level recently has appeared to slump further, though without having any effect on the ILL. These observations (if accurate) suggest that the solids in BY-102 might have collapsed into a lower-porosity form, expelling liquid from the pores, leading to a decrease in the solid surface level and a roughly constant liquid level. Another possibility is that the LOW has become sealed off from the remainder of the liquid in the tank by Ostwald ripening or some other crystal consolidation process that has sealed the pores of the waste around the well.

As the inset in Figure 4.3 shows, the theoretical ILL fell well below the measured ILL during the second, larger pumping interval. This is not an expected trend, as it suggests a liquid fraction of more than 100%. The apparent discrepancy resulted from the measured ILL's remaining roughly constant, which is hard to explain considering that the diptube liquid level decreased by 30 inches. These data suggest inaccurate LOW readings, possibly because the liquid around the LOW did not respond to the lower liquid levels in the salt well, and/or the liquid in the annulus around the LOW was trapped and did not drain.

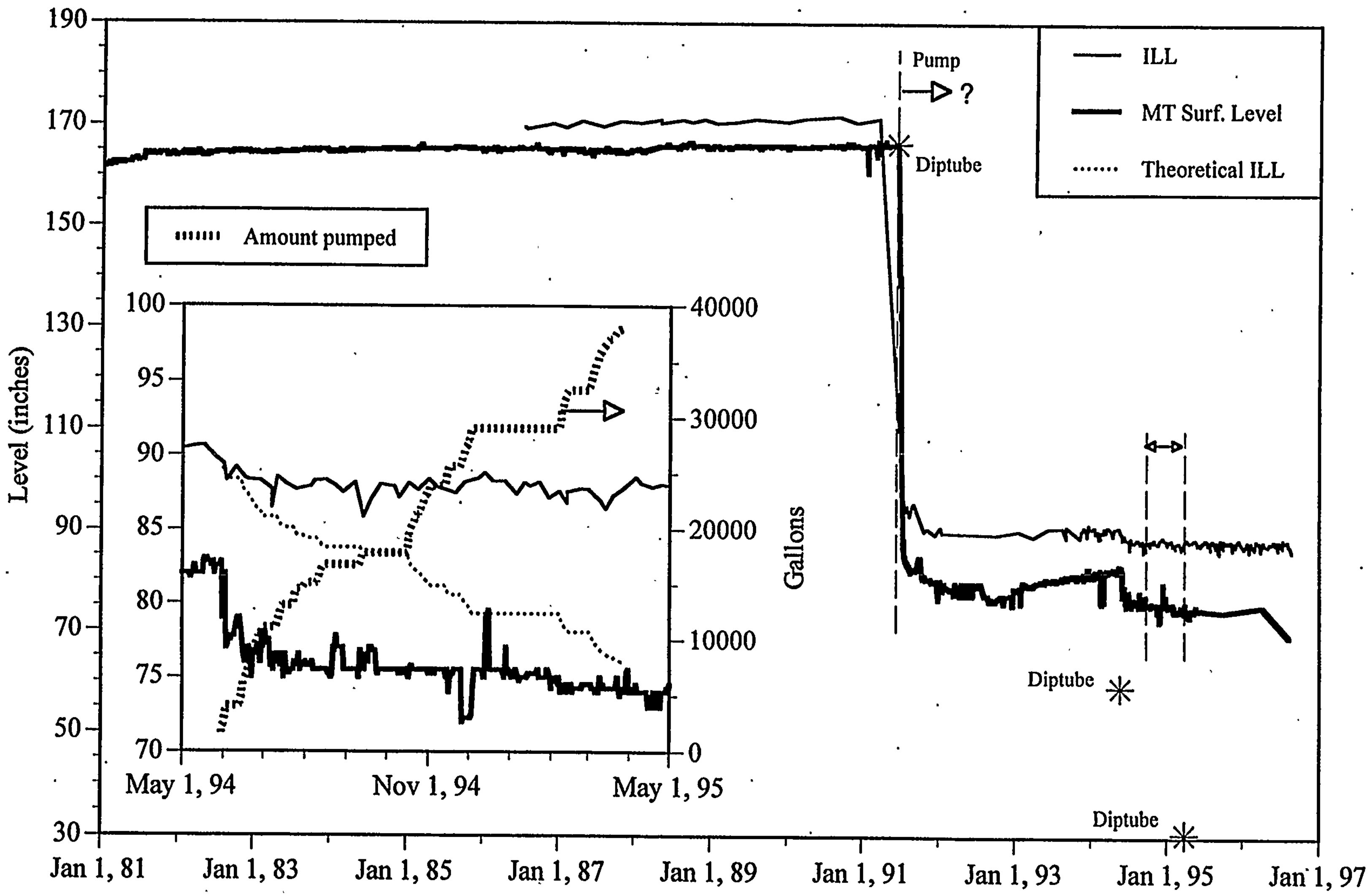

Figure 4.3. Recorded Level and Salt Well Pumping Data for Tank 241-BY-102

4.3 Tank 241-BY-103

Figure 4.4 displays the level histories for BY-103. The overall salt well pumping campaign lasted from August 5, 1995, to October 16, 1995, and the pumping data shown cover that entire period. During pumping, the liquid level at the LOW remained constant, while the surface level apparently rose about 8 inches, all in spite of the removal of about 5 inches of 100% liquid (based on Figure 4.4). This surface level rise is not just a single data point but has been confirmed by several measurements. Although we have not confirmed it, this might indicate some change in measurement location. Several tanks did have their surface level reference points changed from the side dish bottom to the center bottom of the tank, resulting in a difference of approximately 12 inches. As was the case for BY-102, the theoretical ILL is lower than that measured, and the measured ILL remained constant during pumping. The meaning of these observations is not clear and suggests inaccurate LOW readings, possibly because the liquid around the LOW did not respond to the lower liquid levels in the salt well, and/or the liquid in the annulus around the LOW was trapped and did not drain.

4.4 Tank 241-BY-106

Figure 4.5 displays the level histories for BY-106. The overall salt well pumping campaign lasted from August 10, 1995, to October 16, 1995. The pumping data cover that entire period. During pumping, the liquid level at the LOW dropped about 45 inches while the surface level fell about 30 inches. In the year since pumping ended, the surface level has risen very slightly while the ILL has climbed about 10 inches. The time scale is too long for the ILL rise to be the result of pumping-induced gas expansion. Gas generation and solids consolidation are other possible causes.

In the inset plot, the measured ILL dropped substantially below the theoretical ILL during pumping. The measured ILL decreased about 1.5 times as much as the theoretical, leading to a rough estimate of a 60% liquid fraction. Brown (1996b) did not estimate a liquid fraction for this tank, so no comparison can be made.

4.5 Tank 241-BY-109

Figure 4.6 displays the level histories for BY-109. The overall salt well pumping campaign lasted from May 31, 1994, to October 16, 1995. The pumping data cover that entire period. During pumping, both the surface level and the LOW liquid level dropped about 20 inches. Since pumping ended, both the surface level and the ILL have continued to decline at roughly equal rates. Waste collapse or subsidence might explain the decrease in surface level but is not consistent with the ILL behavior; the interstitial liquid level would be expected to rise during a collapse.

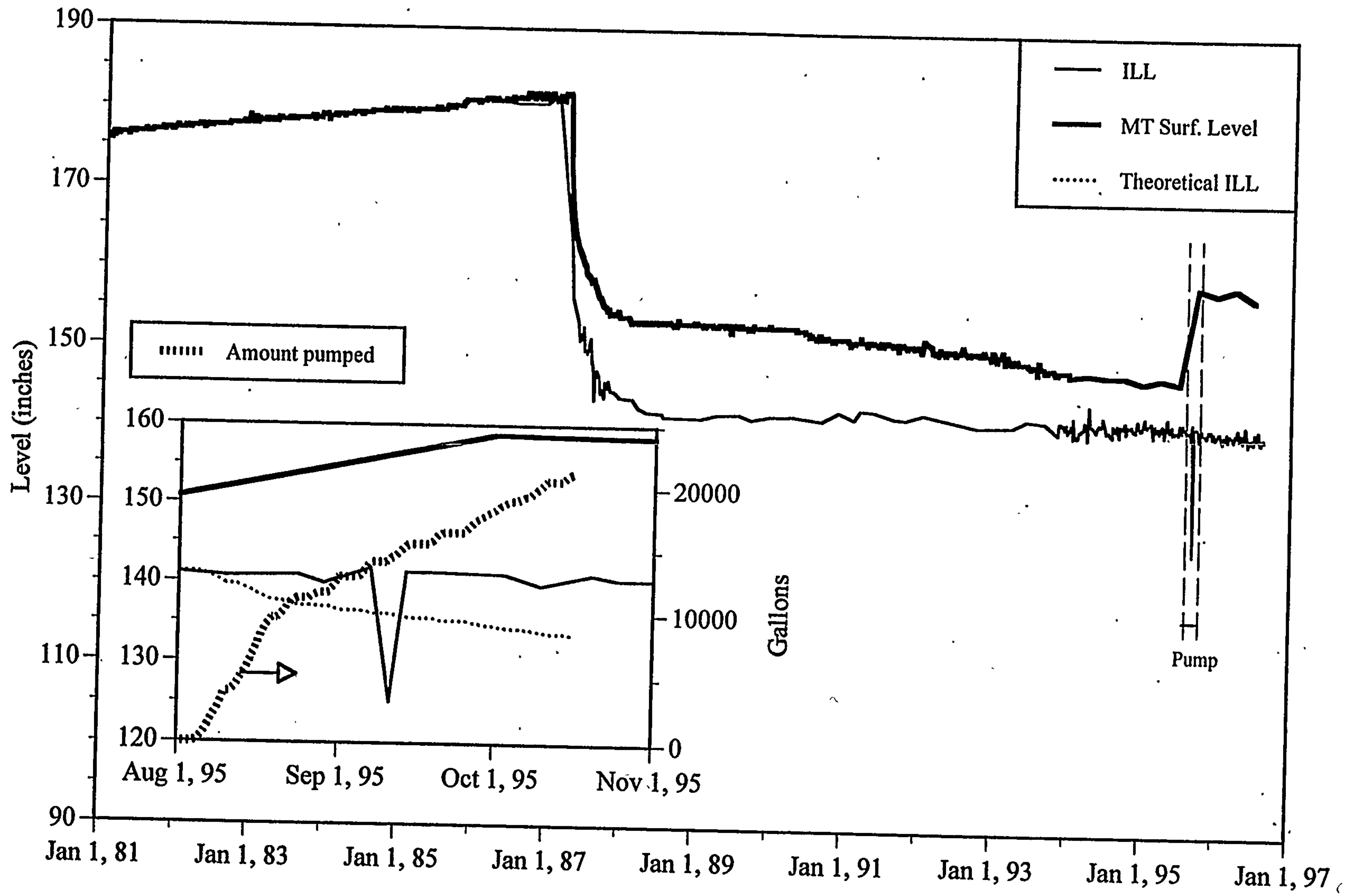

Figure 4.4. Recorded Level and Salt Well Pumping Data for Tank 241-BY-103

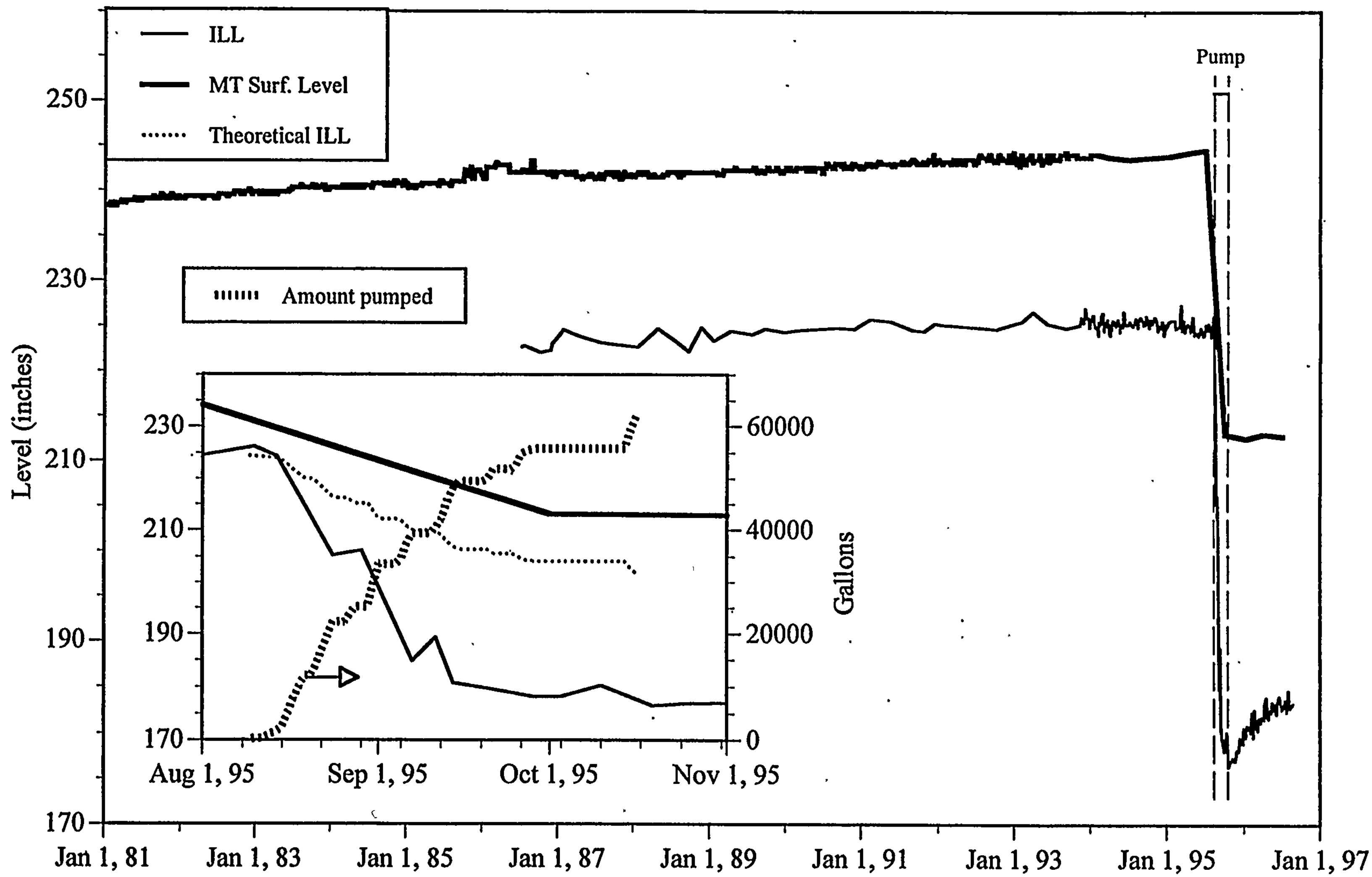

Figure 4.5. Recorded Level and Salt Well Pumping Data for Tank 241-BY-106

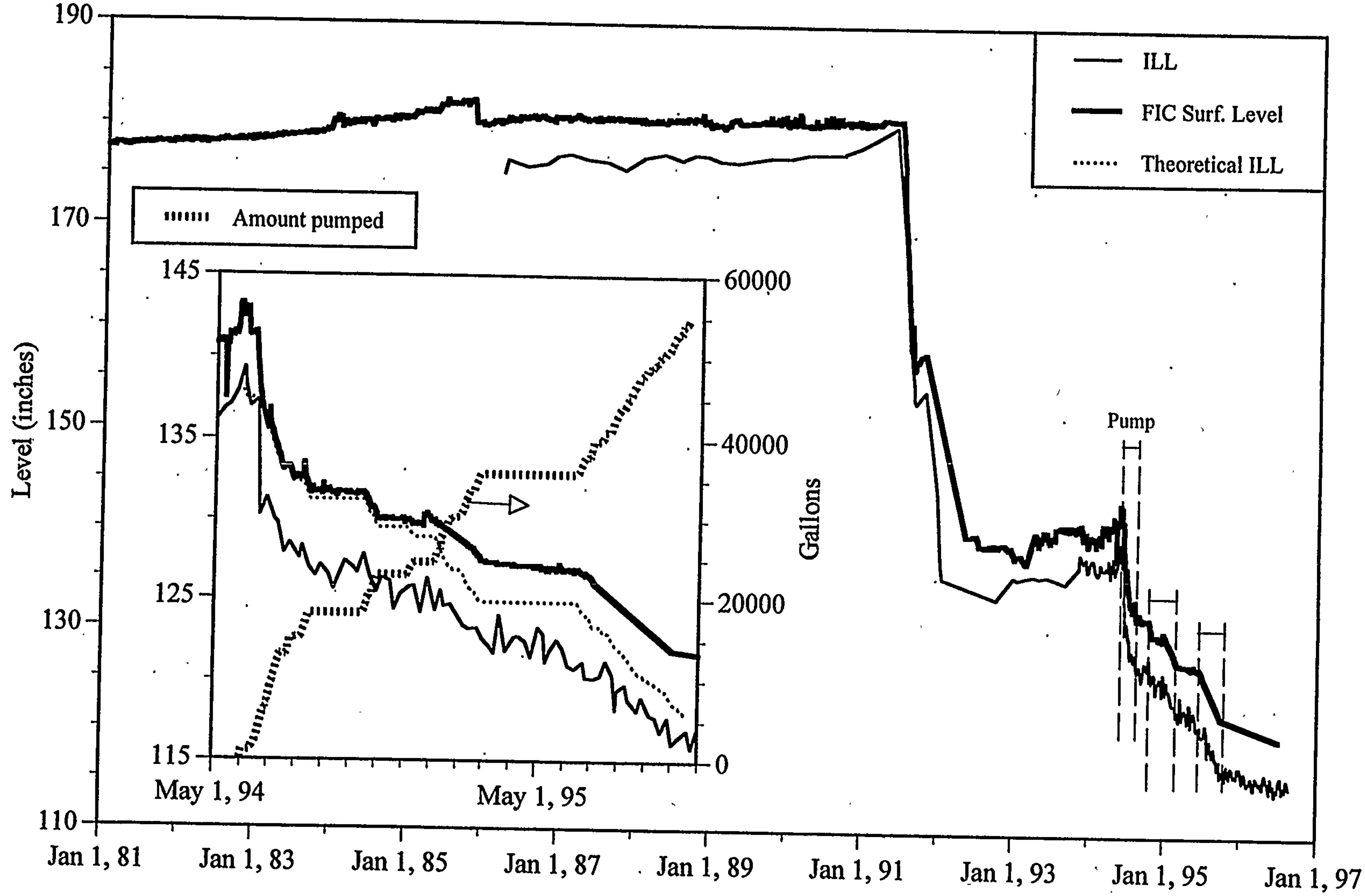

Figure 4.6. Recorded Level and Salt Well Pumping Data for Tank 241-BY-109

The measured ILL dropped further below the theoretical ILL in the first few months of pumping (June to September 1994) than in later months. In January 1995, the measured ILL rises with respect to the theoretical, as if the liquid fraction in that layer of the waste had increased (or been pushed up by expanding gas). After that point the absolute difference between the two levels is roughly constant, as though a 100% liquid layer were being pumped. This possibility is not particularly consistent with the 42% liquid fraction that Brown (1996b) estimated for this pumping campaign.

4.6 Tank 241-S-110

Figure 4.7 displays the level histories for S-110. The overall salt well pumping campaign began on February 24, 1996, and continues to the present. The pumping data cover the entire period. During pumping, the surface level has remained constant and the LOW liquid level has dropped about 20 inches. The measured ILL has dropped more than 3 times as much as the theoretical, meaning that the liquid fraction in this campaign has been roughly 30%. By contrast, Brown (1996b) estimated a liquid fraction of 50% for the S-110 pumping carried out in 1979.

4.7 Tank 241-T-104

Figure 4.8 displays the level histories for T-104. The overall salt well pumping campaign began on March 24, 1996, and continues to the present. The pumping data cover the entire period. Pumping has removed about 10 inches of supernatant. The surface level has fallen about 10 inches (ignoring an apparent spike that could have been an error) and the LOW liquid level has dropped about 30 inches. After the supernatant was pumped, the measured ILL dropped about twice as much as the theoretical, meaning that the liquid fraction in this campaign has been roughly 50%. Brown (1996b) did not estimate a liquid fraction for this tank, so no comparison can be made.

4.8 Tank 241-T-111

Figure 4.9 displays the level histories for T-111. The overall salt well pumping campaign lasted from May 15, 1994, to February 8, 1995. The pumping data cover the entire period. As Figure 4.9 shows, this tank contained more than 10 inches of supernatant from the beginning of pumping to the end, though some doubt is thrown on this observation by the recent (post-pumping) sudden rise of the surface level to a point higher than the LOW liquid level. This suggests that either the ILL or the surface level measurements had been in error during pumping. Although not confirmed, it is possible that the surface level measurement location was moved, which, as discussed in Section 4.3, has occurred in several tanks. The diptube level ended about 20 inches lower than the LOW level (the ILL), which is consistent with liquid gradient readings in other tanks; that consistency suggests that the ILL measurements were more likely to have been correct than the surface levels.

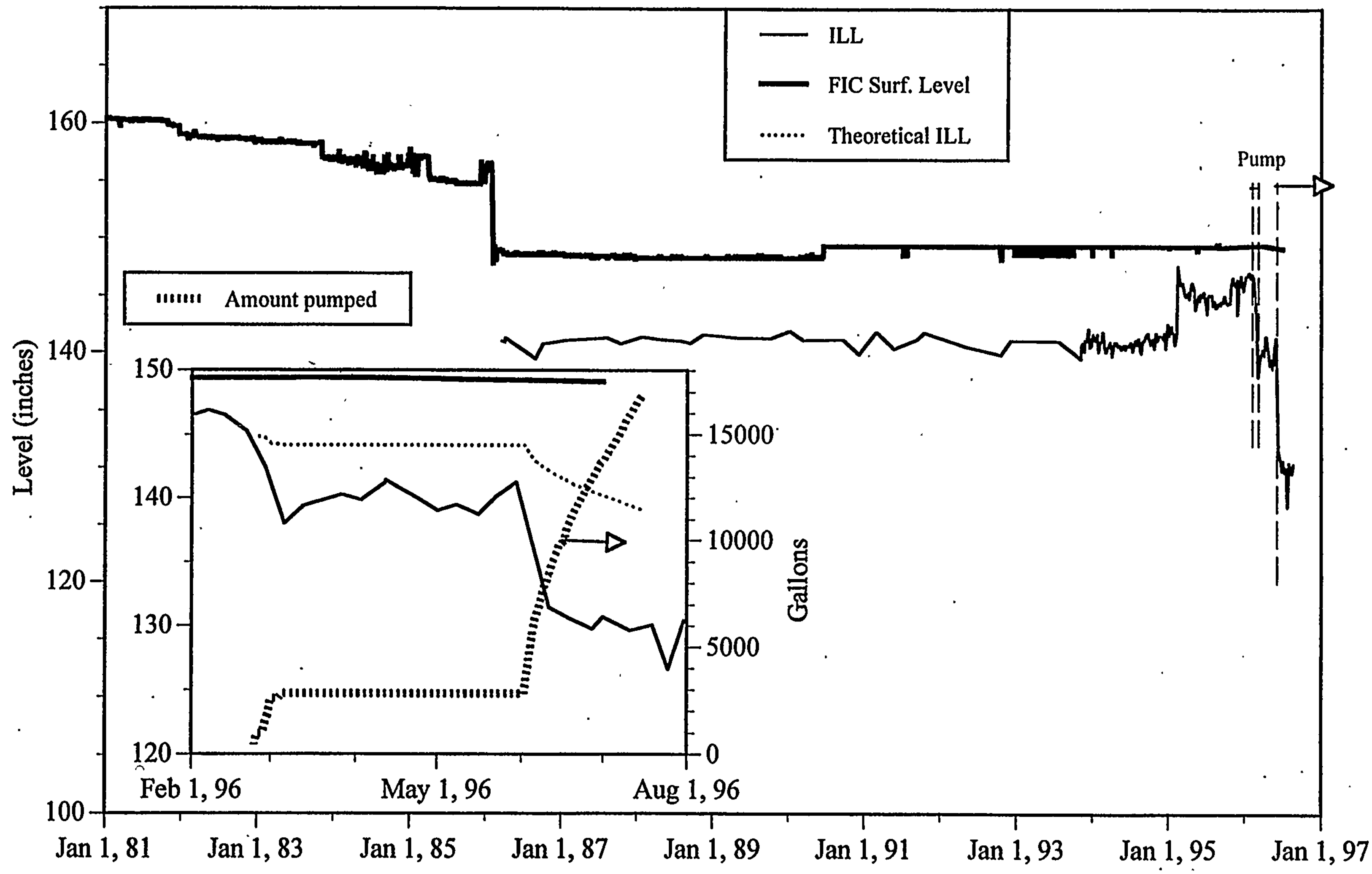

Figure 4.7. Recorded Level and Salt Well Pumping Data for Tank 241-S-110

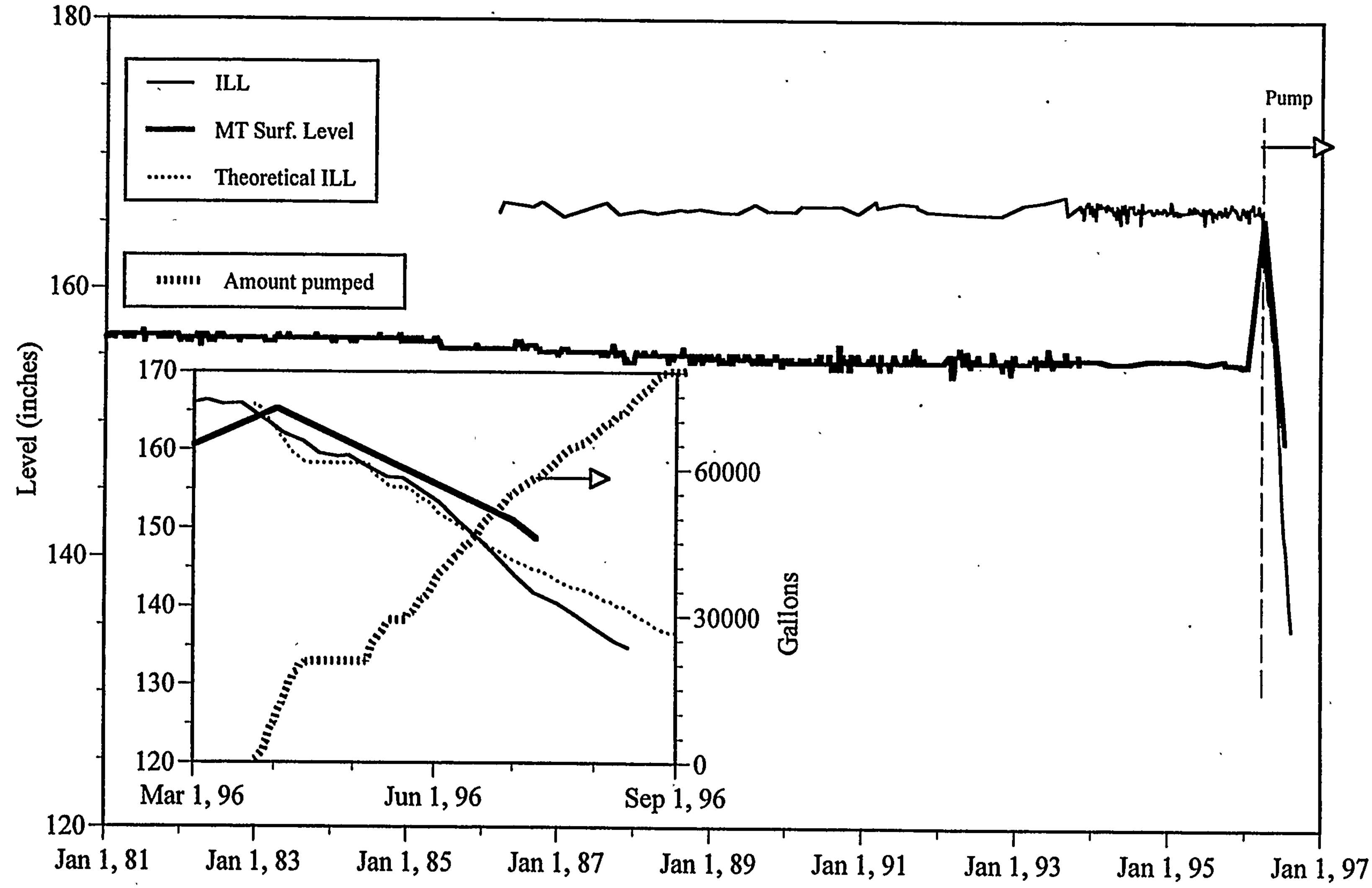

Figure 4.8. Recorded Level and Salt Well Pumping Data for Tank 241-T-104

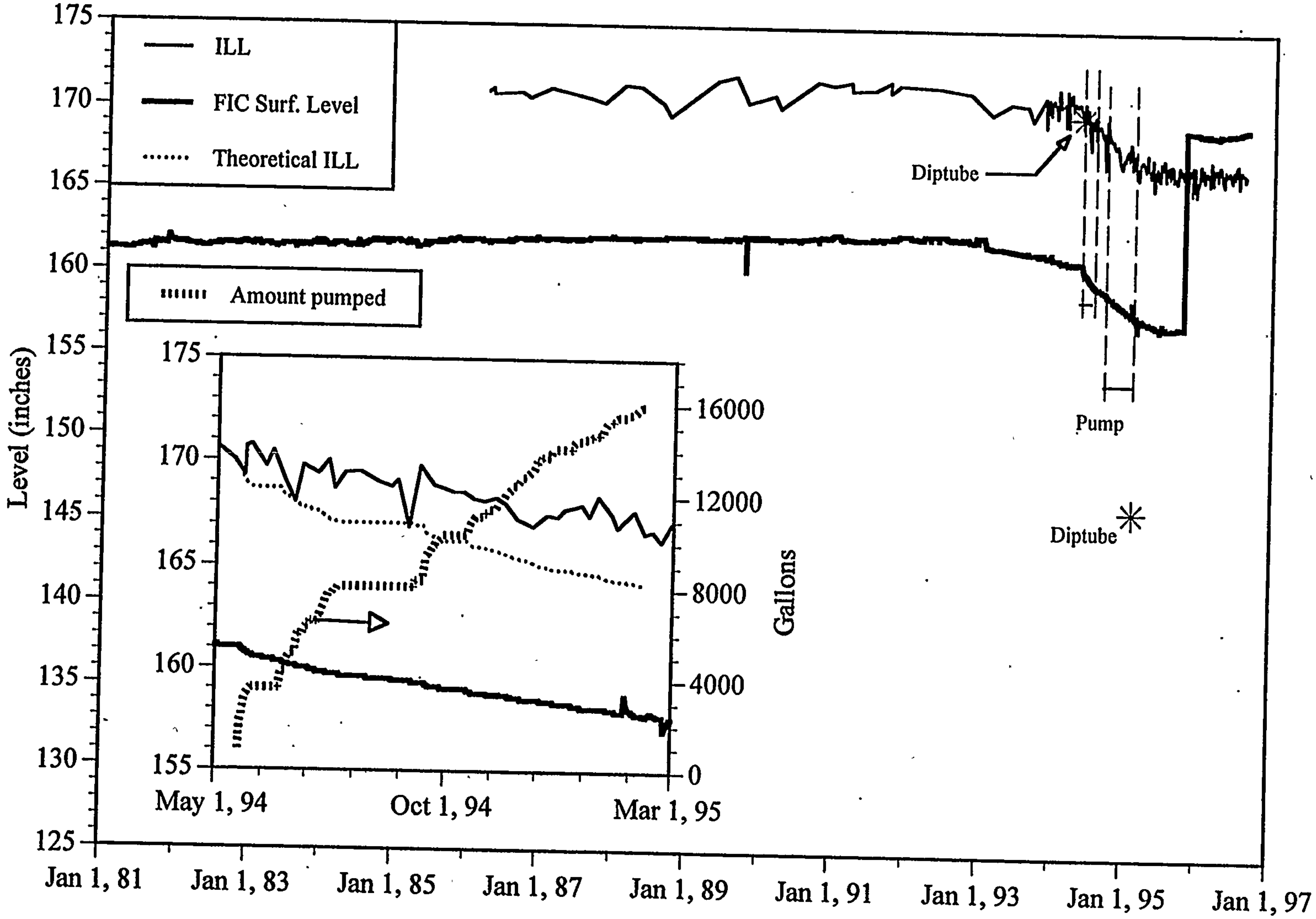

Figure 4.9. Recorded Level and Salt Well Pumping Data for Tank 241-T-111

The theoretical and measured ILLs decrease in parallel, as if supernatant had been pumped. Although the theoretical ILL gives the appearance of being below the measured ILL, this is largely an artifact caused by calculating the initial theoretical ILL from a low-point fluctuation in the measured ILL.

5.0 Subsidence

Waste level subsidence may be indicative of a gas release event. When gas is released, the resulting void space could be filled by solids, resulting in a significant drop in the waste surface level. Historical surface level plots[(a)] for all 44 tanks that have been salt well pumped to date (Hodgson et al. 1996; Swaney 1996; ICF Kaiser 1994a, 1994b, 1995)[(b)(c)] were studied to quantify the number and magnitude of somewhat rapid (within a one-month period) surface level drops occurring after pumping had stopped. The one-month period was chosen because many SSTs only have passive ventilation so gas releases over a one-month period are important. Surface level drops of less than 0.5 inches were ignored since they were within the noise of the measurement devices. A level drop was only considered if there were several data at the new level (i.e., single point drops were ignored).

Table B.1 in Appendix B is a record of the surface level drops occurring for each tank. Events (drops in waste surface level) were grouped in 1-inch intervals. The number of tank years is defined as the number of years that have passed (to date) since pumping ended. Figure 5.1 shows a histogram representing the quantity of each 1-inch interval drop for all tanks.

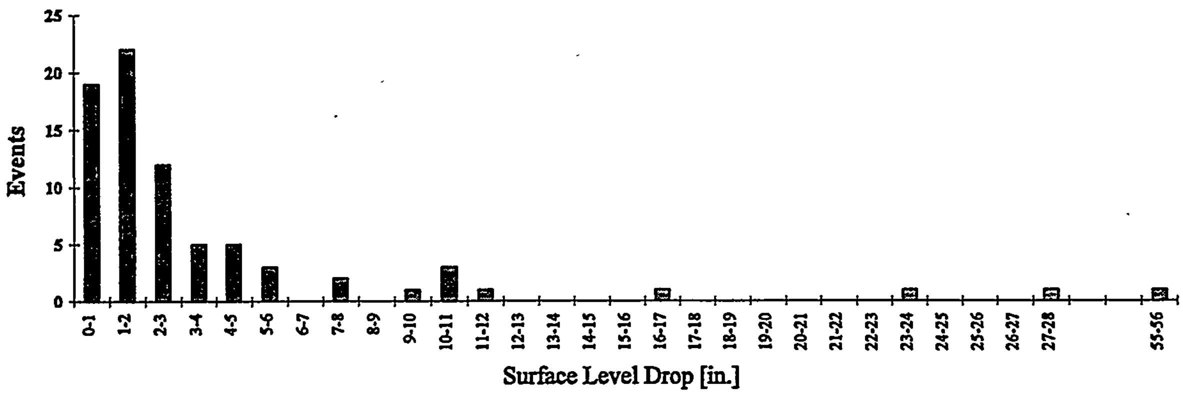

Figure 5.1. Inventory of Surface Level Drops Occurring within a One-Month Period Since Pumping Ended – the Sum of the Number of Tank Years was 383

(a) Level data were downloaded by S.M. Caley via the TWINS2 Interface from the SACS database (Glasscock 1993), August 1996.

(b) Personal communication and data transmittal, L.A. Mahoney from D.K. DeFord, August 6, 1996.

(c) Lechelt, J. A. 1995. *Temperatures of Interim Stabilized Salt Cake Tanks.* 71330-95-006. Westinghouse Hanford Company, Richland, Washington.

Figure 5.1 shows that the majority of surface level drops were less than 3 inches. However, there were several large drops, with the largest being a 55 inch drop (Tank 241-BY-101). It is difficult to say if the larger surface level drops were actual waste subsidence or just a variation in the measurement method. The fact that several data exist at the lower level rules out instrument reading error but not the possibility of an adjustment in the location of the measurement device.

Page 4 of Table B.1 shows the total number of events for each tank. These totals were used to prioritize the tanks for obtaining more data relative to subsidence. Other appropriate data (in addition to surface levels) include pumping rates, interstitial liquid levels, diptube readings, and in-tank photographs (both before and after pumping). Table A.1 (the data summary table) indicates that only one tank (241-BX-111) of the 44 that have had confirmed pumping has all of these data available. Seventeen other tanks have all of the relevant data except for pumping data, which was ranked lowest for giving evidence of subsidence. Data were reviewed for several of these eighteen tanks to see if evidence of subsidence was apparent. Unfortunately, most of the data were inconclusive. For some tanks that showed several events (drops in surface level), no evidence of subsidence was visible in the in-tank photographs and/or the interstitial liquid level data did not rise as would be expected during a collapse, while for other tanks that registered no events, photographs indicated subsidence had occurred. For example, post-pumping photographs for tanks 241-TX-110 and TX-115, which had the most drops in surface level (7 and 6, respectively), showed no evidence of subsidence, while photographs of tank 241-BX-111, which had no surface level drops, showed evidence of subsidence. It is our recommendation that future salt well pumping campaigns monitor subsidence with in-tank videos during and after pumping, because subsidence events can occur years after pumping has stopped.

Data for three tanks are presented in detail below. Tank 241-BX-111 is included because all relevant data were available, even though no drops in surface level occurred. The other two tanks (241-BY-111 and 241-TX-111) appear to have fairly consistent data that suggest subsidence has occurred.

5.1 Tank 241-BX-111

As Table A.1 indicates, Tank 241-BX-111 has the most extensive data available. Section 4.1 discusses the level data, salt well pumping data, and neutron log profiles available for this tank. Figure 4.1 shows the recorded level data and salt well pumping data. As discussed above, no surface level drops are evident after pumping; in fact, the surface level recently appears to have rebounded to almost its previous level (before pumping began), while the interstitial liquid level has remained fairly constant. Figure 4.2 shows the neutron log profiles before, during, and after pumping. As discussed in Section 4.1, the one profile available after pumping (June 7, 1996) shows that there is apparently more liquid in the lowest layer of the waste than in any higher layer, an observation which is not consistent with subsidence. However, Figures 5.2 and 5.3, before and after in-tank photographs, seem to indicate subsidence has occurred.

Figure 5.2. In-Tank-Photograph of 241-BX-111 (Proof #93070202-22CN), Taken Before Salt Well Pumping (7/16/93)

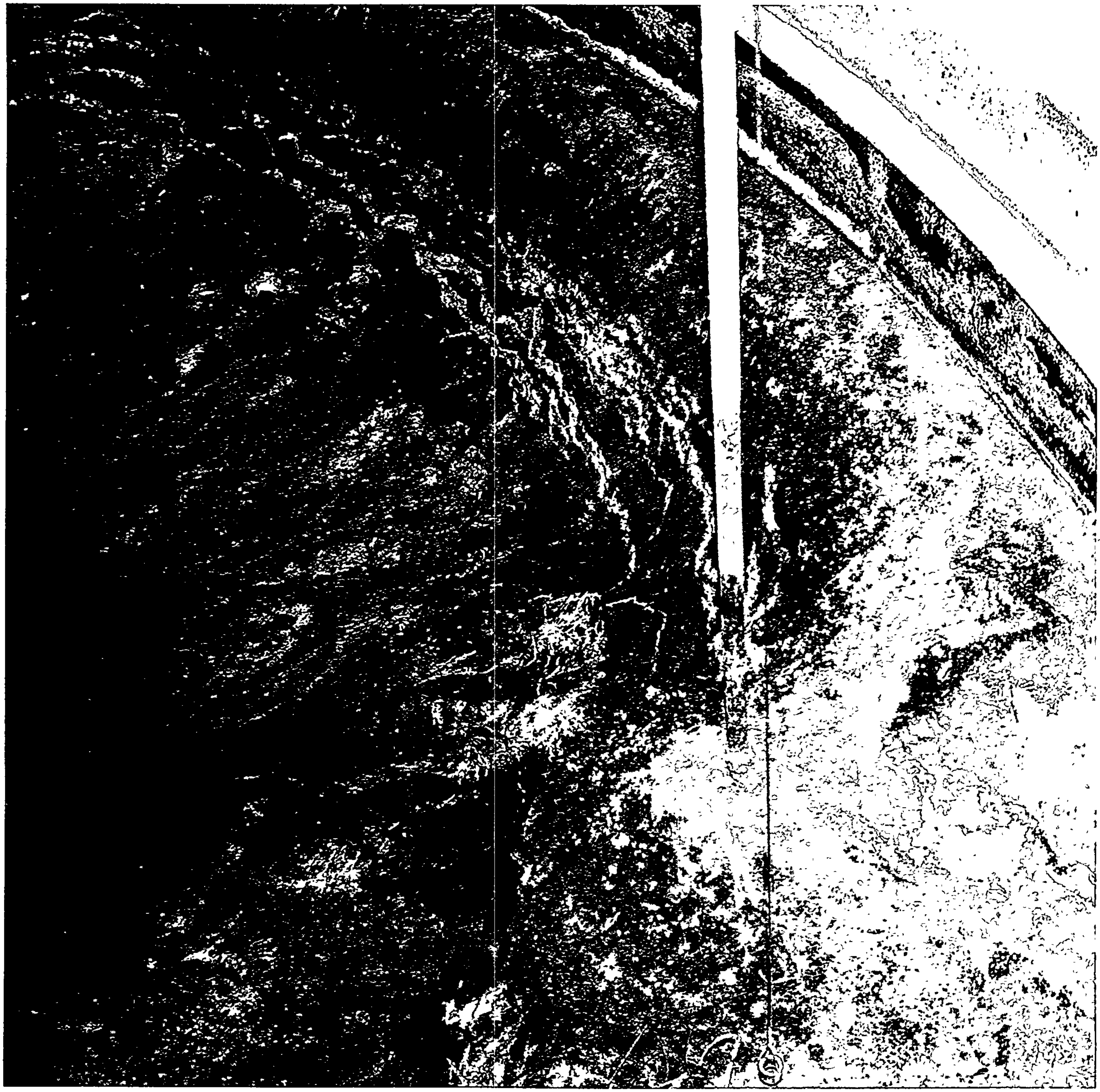

Figure 5.3. In-Tank Photograph of 241-BX-111 (Proof #94050992-1CN), Taken After Salt Well Pumping (5/19/94)

Figure 5.2 was taken on July 16, 1993, right before the initiation of the first pumping interval. The manual tape reading was 6 feet, 7 inches. The waste surface is wet and smooth. Solids and scum appear to be floating on the dark brown liquid surface. Exposed salt cake clings to the side of the tank near the temperature probe at the right-hand side of the photograph. Figure 5.3 was taken on May 19, 1994, between the conclusion of the first pumping interval and the start of the second. Again, the temperature probe is on the right-hand side of the photograph, indicating that both figures show similar views of the waste surface. As before, exposed salt cake clings to the side of the tank, however, the waste surface in this post-pumping photograph is much different than in the pre-pumping one. The surface is dry, cracked, and uneven—indicative of subsidence.

5.2 Tank 241-BY-111

Figure 5.4 shows the recorded level history for Tank 241-BY-111.[a] Salt well pumping occurred between August 3, 1983, and November 16, 1984 (Swaney 1996). Diptube levels before and after pumping were found in Swaney (1996). Interstitial liquid level was not available until after 1986 (after salt well pumping had stopped). No pumping rate data were available for this tank. Figure 5.5 shows the historical surface level for Tank BY-111 on an expanded scale. Two post-pumping surface levels drops are evident in Figure 5.5; the first is a 2-3 inch drop occurring in June 1989, and the second is a 4-5 inch drop occurring in October 1989. As seen in Figure 5.4, the ILL remained constant during these two events.

Figures 5.6 and 5.7 are in-tank photographs of Tank BY-111 taken before and after salt well pumping, respectively. Figure 5.6 was taken on February 5, 1981, when the recorded manual tape reading was 30 feet, 3.5 inches. A temperature probe and air lift circulator are visible on the left side of the photograph. The photograph shows an uneven, yellowish salt cake surface with floating liquid. Figure 5.7 was taken on October 31, 1986, and the recorded manual tape reading was 14 feet, 6 inches. The same temperature probe and air lift circulator visible in Figure 5.6 are again visible on the left of this photograph. Protruding from the surface in the bottom left corner are old, discarded measurement tapes. Exposed salt cake clings to the side of the tank. This photograph shows a very different surface than the pre-pumping photograph; it is an uneven, dry, cracked salt cake that varies from a white to medium grey color. Subsidence seems evident from this photograph even though it was taken before the two previously discussed level drops occurred.

(a) Level data were downloaded by S.M. Caley via the TWINS2 Interface from the SACS database (Glasscock 1993), August 1996.

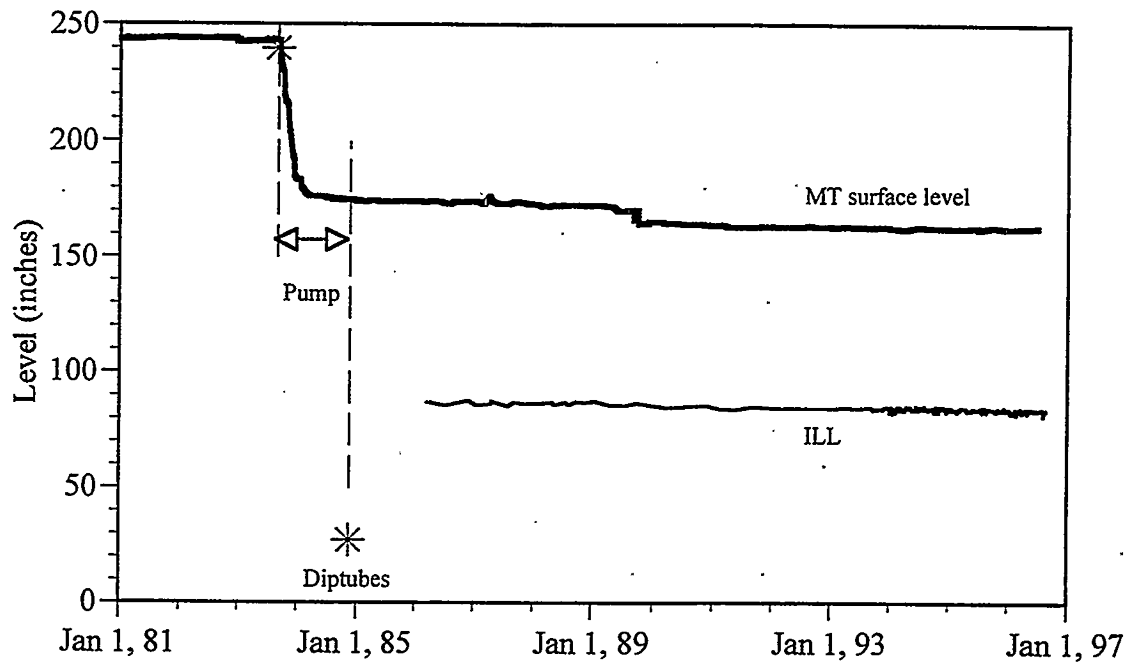

Figure 5.4. Recorded Level Data for Tank 241-BY-111

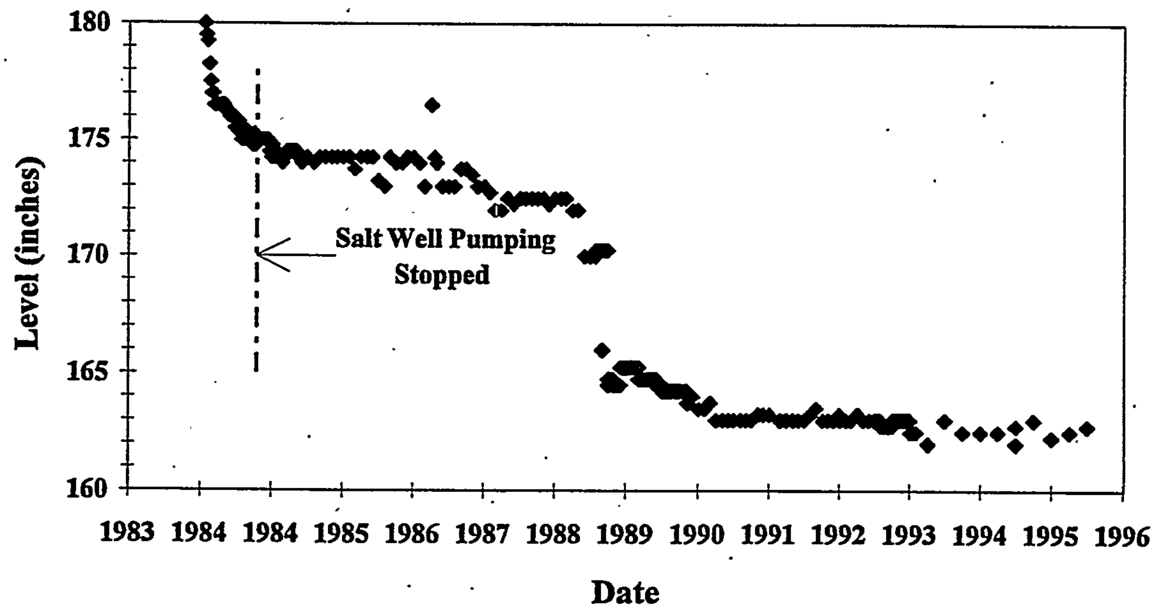

Figure 5.5. Recorded Surface Level Data for Tank 241-BY-111

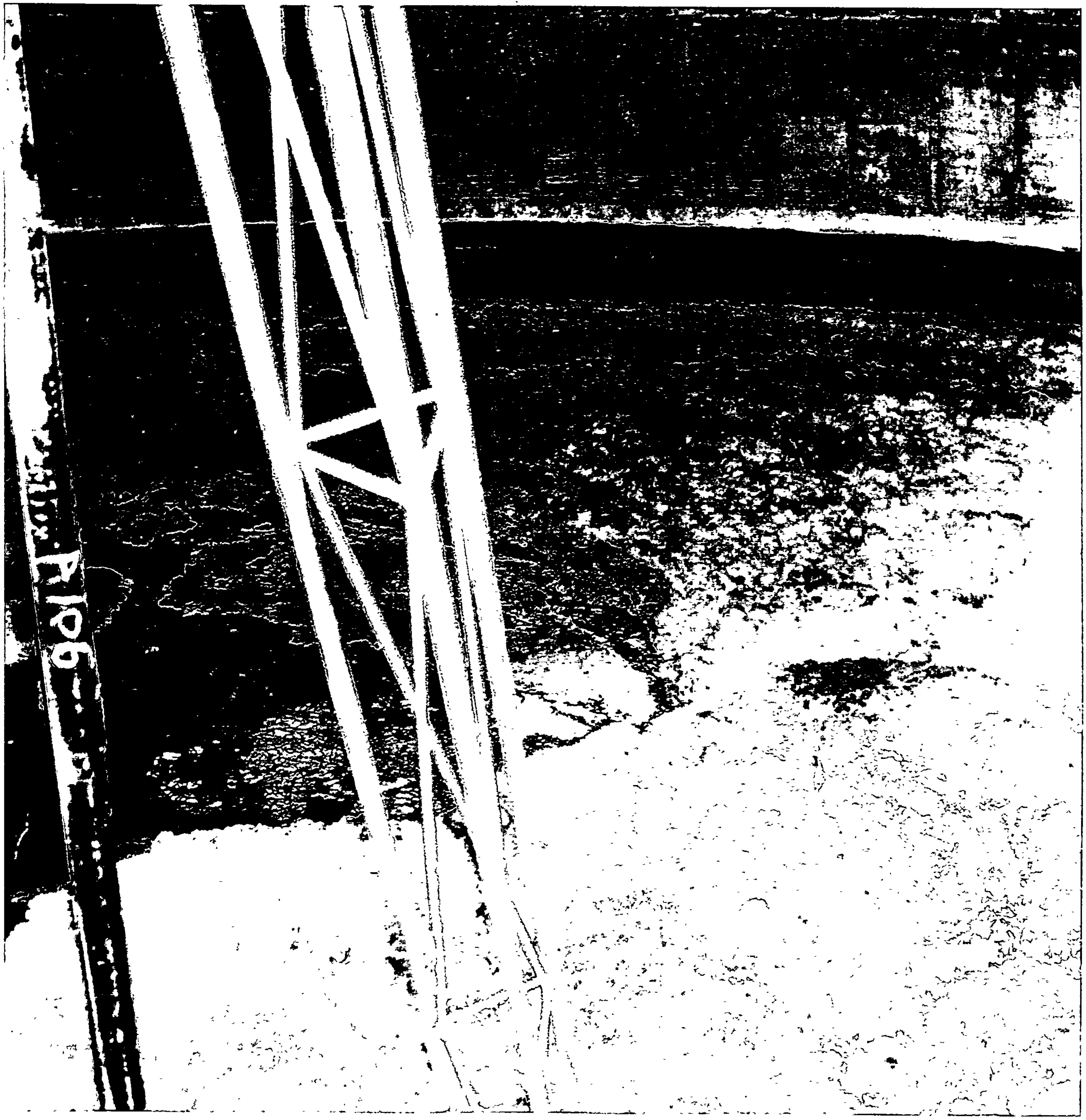

Figure 5.6. In-Tank Photograph of 241-BY-111 (Proof #094677-6CN), Taken Before Salt Well Pumping (2/5/81)

Figure 5.7. In-Tank Photograph of 241-BY-111 (Proof #8606972-13CN), Taken After Salt Well Pumping (10/31/86)

5.3 Tank 241-TX-111

Figure 5.8 shows the recorded level history for Tank 241-TX-111.[a] Salt well pumping occurred between January 29 and December 15, 1982 (Swaney 1996). Diptube levels before and after pumping were found in Swaney (1996). Interstitial liquid level was not available until after 1986 (after salt well pumping had stopped). No pumping rate data were available for this tank. Figure 5.9 shows the historical surface level for Tank TX-111 on an expanded scale. Three post-pumping surface levels drops are evident in Figure 5.9. The first is a 1-2 inch drop occurring in January of 1987, the second is a 3-4 inch drop occurring in October of 1989, and the third is a 0-1 inch drop occurring in January of 1991. Interestingly, since January 1996 the surface level has steadily risen to about the same level that existed before the 3–4 inch drop that happened in October 1989. Figure 5.8 shows that the interstitial liquid level has remained fairly constant during this surface level rise.

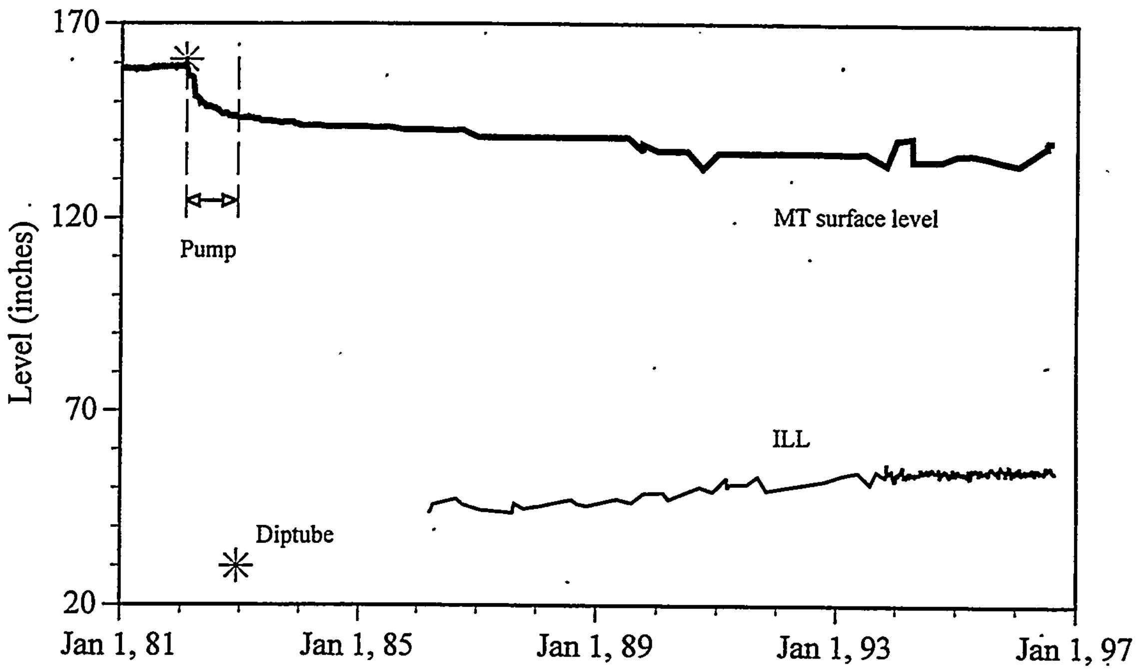

Figure 5.8. Recorded Level Data for Tank 241-TX-111

(a) Level data were downloaded by S.M. Caley via the TWINS2 Interface from the SACS database (Glasscock 1993), August 1996.

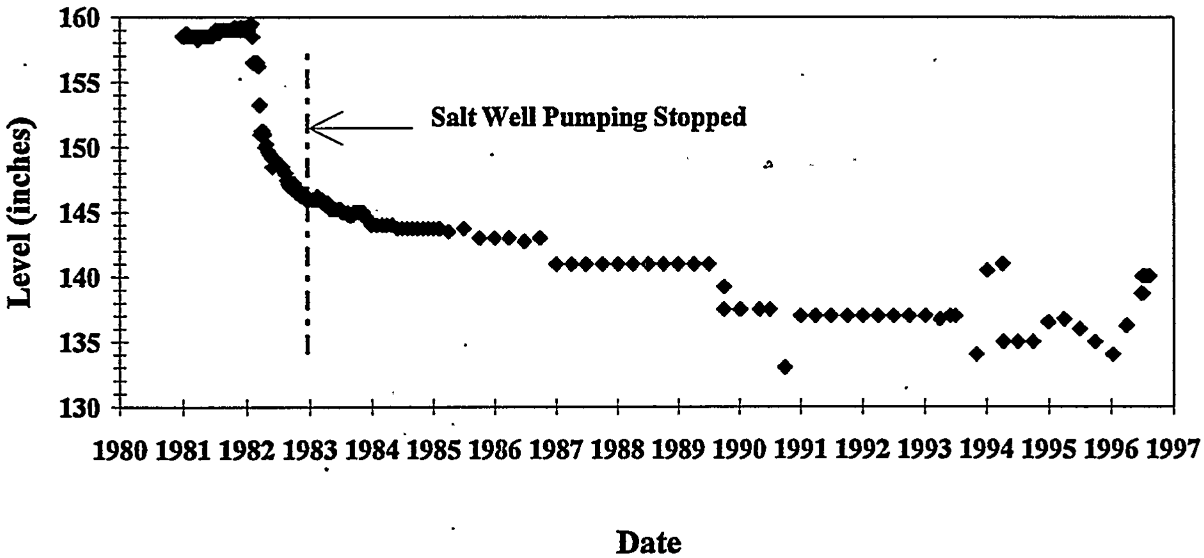

Figure 5.9. Recorded Surface Level Data for Tank 241-TX-111

Figures 5.10 and 5.11 are in-tank photographs of Tank TX-111 taken before and after salt well pumping, respectively. Figure 5.10 was taken on March 3, 1981, when the recorded manual tape reading was 13 feet, 12.5 inches. An air sweep is visible in the center of the photograph. The waste surface appears to be a mostly floating salt cake with a few pools of liquid. Figure 5.11 was taken on April 11, 1983, and the recorded manual tape reading was 12 feet, 1.25 inches. The same air sweep that was visible in Figure 5.10 is again visible in this photograph. This photograph shows a very different surface than in the pre-pumping photograph; it is dry, cracked, and uneven. Subsidence seems evident from this photograph even though it was taken before the three previously discussed level drops occurred.

Figure 5.10. In-Tank Photograph of 241-TX-111 (Proof #095069-11CN), Taken Before Salt Well Pumping (3/3/81)

Figure 5.11. In-Tank Photograph of 241-TX-111 (Proof #106951-11CN), Taken After Salt Well Pumping (4/6/83)

6.0 Conclusions

These are our observations based on our review of the available data pertinent to salt well pumping and its effects on retained gas:

- We had expected bubble retention to decrease drainable porosity because gas-occupied pore space is not available to contain liquid, as discussed in Section 2. However, as Figures 2.2 and 2.4 show, no such trend was apparent.

- We had expected salt well pumping to decrease the trapped gas void fraction because of gas release, with the decreased void fraction reflected by a positive change in dL/dP. In the tanks for which reliable dL/dP data were available, almost all of which were sludge tanks, the change in dL/dP was more often negative (as seen in Figure 2.5).

- We had expected hydrogen (or flammable gas) concentrations to closely follow high pumping rates, as rapid drainage released trapped bubbles. As Figures 3.1 through 3.6 show, the temporal correlation of gas concentration and pumping is not consistent. It is difficult to judge the relationship of pumping and gas concentration in the BY tanks, no gas measurements were taken except during pumping. Furthermore, the highest measured concentrations were only slightly above the "noise level"

- During pumping, a consistent, progressive change in the shape of the neutron log profile was seen in Tank 241-BX-111, the only tank for which profiles were available this fiscal year. The profile change (shown in Figure 4.2) seems to indicate the gradual expulsion of liquid from the lowest layer of waste.

- A theoretical ILL was defined (Section 4) by subtracting the inches of 100% liquid pumped from the measured ILL at the time pumping started. We had expected that during pumping the measured ILL would be less than the theoretical ILL because the liquid fraction of the waste was less than 100%. However, in at least two tanks (of the eight for which we have data), the measured ILL was nearly constant throughout pumping and was greater than the theoretical ILL.

- The inventory of subsidence events occurring after pumping (Figure 5.1) shows that small level drops occur more frequently than large ones. Table B.1 (Appendix B) shows that several tanks had multiple events.

- In many cases, in-tank photographs were inconsistent with recorded level data. Photographs may have showed cracking (indicative of subsidence) while no level drops occurred, or photographs showed no cracking when several level drops occurred.

Some of the inconsistencies between expected and observed behavior could be resolved given access to data that we have not been able to obtain. In addition, to gain a better understanding of the effects of salt well pumping, we recommend that future salt well pumping campaigns record a consistent, continuous set of data, including continuous gas monitoring of both insoluble (hydrogen) and soluble (ammonia) gases; continuous recording of the gallons of liquid removed and of the waste surface level (FIC or Enraf); periodic recording of the ILL from neutron logs; and continuous in-tank video monitoring for subsidence. Following is a list of how the existing data may be studied to attempt to resolve the inconsistencies:

- We do not expect to find any more data pertinent to porosity and dL/dP. However, further analysis might clarify how different types of bubbles may affect the relationship between porosity and void fraction.

- According to Brown (1996a), flammable gas monitoring data are only available for tanks on the FGWL and the three BY tanks included in Section 3. Since the issuance of Brown's report, gas monitoring data for three other tanks (the ones currently being pumped) have also been collected. No other flammable gas monitoring data are available for tanks that have been pumped. Flammable gas grab samples may be available for additional tanks, but these will not improve our understanding of how pumping rate affects gas release.

- We do not expect to find any more flammable gas monitoring data. However, a statistical analysis performed on the existing data might establish whether a correlation exists between pumping rate and gas release. The recent modeling study by Peurrung et al. (1996) suggested the form that such correlations may take, but this has not been validated with the limited tank data available.

- Additional neutron profiles exist in the Computer Automated Surveillance System (CASS) database (Spurling 1991) but were not available at this time in a useable format. If available, further analysis of profiles taken during and after pumping may provide insight into the location and behavior of gas during pumping.

- A complete set of level data are available on the SACS database (Glasscock 1993) via the TWINS2 Interface. However, a more detailed analysis of the locations of the measurement devices with respect to each other and the salt well pump might explain some of the anomalous level behavior. Waste Tank Summary Reports date back to 1966 and contain monthly pumped volume measurements for all tanks. These would provide rudimentary pumping information for tanks not presented in this report.

- We assembled a probability distribution of the sizes of surface level drops which gives an idea of the relative probabilities for gas releases of different sizes. Further analysis could be performed to determine how long after pumping these events occurred; this would give an idea of how long safety measures must be in place.

- Because in-tank photographs often disagreed with predicted subsidence events based on level data, we feel that in many cases the level data may be in error.

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Appendix A

Raw Data Summary

Appendix A

Raw Data Summary

Table A.1 contains a summary of data that are pertinent to porosity, subsidence, and gas release, for all the tanks which are known to have been salt well pumped. (Other tanks may also have been pumped but the events have not been confirmed.) Some tanks -- BY-102, C-102, C-107, and C-110 -- were listed as having been pumped more than once. The events are distinguished in the table with the label "a" or "b" added to the tank ID.

The sources and definitions of the data in Table A.1 are given below.

(1) The pumping start and stop dates were derived from Swaney (1996) or from information supplied by a cognizant engineer.[a]

(2) The drainable porosity values were taken from the Swaney (1996). The drainable porosity is the ratio of the total interstitial liquid removed to the theoretical equivalent interstitial liquid that would be removed at 100% porosity. It is based on flow and volume measurements taken during salt well pumping.

(3) The total liquid fractions were taken from Brown (1996b). They include concealed pockets and layers of liquid as well as interstitial liquid.

(4) The values for (dL/dP)/L are the surrogate void fractions derived from the waste level barometric response, as described in Section 2.2 of this report. They were calculated from data supplied by P. Whitney.[b]

(5) The percentage of salt cake in the tanks was derived from Hanlon (1996) and was based on a historical review of tank contents. The dates of the last in-tank photos and videos were found in the same reference.

(a) Personal communication and data transmittal, L.A. Mahoney from D.K. DeFord, August 6, 1996.

(b) Personal communication and data transmittal, L.A. Mahoney from P.D. Whitney, August 7, 1996.

(6) Some of the tanks in Table A.1 have been designated as higher priority for modeling of flammable gas retention and release. The category "SL" means that the tank is on the prioritization Short List.[a] "CSL" means that the tank is in the same composition cluster (Remund et al. 1995) as one of the tanks on the Short List and is therefore also of interest.

(7) The level data is taken from the SACS database (Glasscock 1993) via the TWINS2 Interface, which specifies which instrument(s) is/are used for each tank.

(8) The VIDON Center photo files were searched to determine the last photo shoot before the pumping event and the first shoot after pumping. The dates are given in the "prior" and "later" photo columns.

(9) In some cases it was possible to find extra data that had been taken during salt well pumping. The sources of these data are given in Sections 3 and 4 of this report. Such data can include daily pumping volumes and flow rates ("Pd"), pumping rates and volumes collected at intervals of one hour or less ("Ph"), and hydrogen or flammable gas concentrations measured at intervals of one hour or less ("H2").

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Table A.1. Summary of data for all confirmed salt well pumpings.

Tank ID	Pump Start Date (1)	Pump Shutoff Date (1)	Drainable Porosity (2)	Total Liq. Fraction (3)	(dL/dP)/L (4)	% Saltcake (5)	Category (6)	DataType (7)	Prior Photo (8)	Later Photo (8)	Other Data (9)	Last In-Tank Photo (5)	Last In-Tank Video (5)
BX-107	6/20/90	9/14/90	13.2%		-0.0015	0.0%		FIC	10/28/86	9/11/90		9/11/90	
BX-109	6/28/90	Sep-90	20%	19%	-0.0015	0.0%		FIC	5/8/86	9/11/90		9/11/90	
BX-110	12/4/93	12/20/93				4.4%		MT	7/31/85	7/14/94		7/15/94	10/13/94
BX-111	10/22/93	2/4/95	66%	65%		67.7%	CSL	MT/N-ILL	7/16/93	5/19/94	Pd	5/19/94	2/28/95
BX-112	7/5/90	Sep-90	8.5%	14%	-0.0006	0.0%		FIC	7/28/89	9/11/90		9/11/90	
BY-101	4/28/83	1/28/84	9.9%	28%		71.8%	CSL	MT/N-ILL	2/24/83	9/19/89		9/19/89	
BY-102a	6/12/91	?	26%	56%		100.0%	CSL	MT/N-ILL	9/11/87			9/11/87	4/11/95
BY-102b	5/30/94	3/27/95		56%		100.0%	CSL	MT/N-ILL	9/11/87		Pd	9/11/87	4/11/95
BY-103	8/5/95	10/16/95		71%		98.8%	CSL	MT/N-ILL	9/7/89		H2/Pd/Ph	9/7/89	
BY-104	4/20/83	11/1/84	45% *	66%		90.1%	SL	MT/N-ILL	4/27/83			4/27/83	
BY-106	8/10/95	10/16/95				85.2%	CSL	MT/N-ILL	11/4/82		H2/Pd/Ph	11/4/82	
BY-107	1975	Jul-79		89%		77.0%	SL	MT/N-ILL	6/12/74	10/15/86		10/15/86	
BY-108	12/31/83	12/9/84	12.5%			32.5%	SL	MT	4/28/83	10/15/86		10/15/86	
BY-109	5/31/94	10/16/95		42%	-0.0040	80.4%	SL	FIC/N-ILL	10/15/86		H2/Pd/Ph	10/15/86	
BY-110	5/20/84	12/23/84	13%	61%		74.1%	SL	MT/N-ILL				7/26/84	
BY-111	8/31/83	11/16/84	45% *	62%		95.4%	CSL	MT/N-ILL	2/5/81	10/31/86		10/31/86	
BY-112	4/28/82	5/7/84	42%	67%		98.3%	CSL	MT/N-ILL	1/17/80	7/18/84		4/14/88	
C-102a	11/18/91	Jan-92	26%	20%	-0.0006	0.0%	SL	FIC	5/18/76			5/18/76	8/24/95
C-102b	9/28/94	7/15/95		20%	0.0006		SL	FIC	5/18/76		Pd	5/18/76	8/24/95
C-105	5/7/93	10/23/95	45% *			0.0%	CSL	FIC	4/1/88			8/5/94	8/30/95
C-107a	11/19/91	1/28/92	18.1%	29%	-0.0021	0.0%		FIC					
C-107b	9/28/94	7/28/95		29%	-0.0002			FIC			Pd		
C-110a	11/27/91	1/28/92	27%	30%		0.0%		MT	8/12/86			8/12/86	5/23/95
C-110b	9/28/94	5/28/95		30%				MT			Pd	8/12/86	5/23/95
S-105	Aug-78	Oct-78	33.7%	34%	-0.0003	99.6%	CSL	FIC/N-ILL	5/2/74	4/12/89		4/12/89	
S-108	3/8/96	ongoing		43%		99.3%	CSL	FIC	3/12/87		H2/Pd/Ph	3/12/87	
S-110	2/24/96	ongoing		50%		66.4%	CSL	FIC/N-ILL	3/12/87		H2/Pd/Ph	3/12/87	
T-104	3/24/96	ongoing				0.0%		MT/N-ILL	6/29/89		H2/Pd/Ph	6/29/89	
T-107	9/14/95	4/14/96				0.0%		FIC	7/12/84		Pd	7/12/84	
T-111	5/15/94	2/8/95	10.5%	13%	-0.0001	0.0%		FIC/N-ILL	4/13/94		Pd	4/13/94	2/13/95
TX-102	12/4/81	11/14/82	36.3%	50%		100.0%		MT/N-ILL	6/18/80	11/10/82		10/31/85	
TX-103	12/2/81	6/1/83	25%			0.0%		FIC	6/18/80	10/3/85		10/31/85	
TX-105	3/30/82	8/8/83	38%	48%		100.0%		MT	12/3/80	10/24/89		10/24/89	
TX-106	12/18/81	4/16/83	47%	40%		100.0%		MT/N-ILL	5/29/81	10/31/85		10/31/85	
TX-108	12/3/81	1/12/83	2%			100.0%		FIC/N-ILL	5/29/81	4/12/83		9/12/89	
TX-109	3/16/82	3/4/83	45.2%		0.0018	100.0%		FIC/N-ILL	6/18/80	4/15/83		10/24/89	
TX-110	12/18/81	12/15/82	26.1%	37%		100.0%		MT/N-ILL	6/30/80	4/15/83		10/24/89	
TX-111	1/29/82	12/15/82	18.2%	70%		100.0%		MT/N-ILL	3/3/81	9/12/89		9/12/89	
TX-112	12/7/81	11/17/82	17.3%	26%		100.0%		MT/N-ILL	6/3/81	4/12/83		11/19/87	
TX-113	3/11/82	5/11/82	17%	45%		100.0%		MT/N-ILL	1/23/81	4/11/83		4/11/83	9/23/94
TX-114	1/29/82	11/24/82	21.5%	46%		100.0%		MT/N-ILL	10/9/81	10/14/82		4/11/83	2/17/95
TX-115	3/30/82	8/8/83	25%			100.0%		MT/N-ILL	1/28/81	6/15/88		6/15/88	
TX-116	3/10/82	12/12/82	20.7%			100.0%		MT	1/28/81	4/11/83		10/17/89	
TX-117	12/18/81	6/6/82	16%			100.0%		MT/N-ILL	11/11/81	4/11/81		4/11/83	
TX-118	2/12/82	2/11/83	35.2%	34%	0.0002	100.0%		FIC/N-ILL	12/19/79			12/19/79	
TY-101	11/12/82	2/14/83	9%		0.0005	0.0%		FIC	7/31/80	4/6/83		8/22/89	
TY-103	8/23/82	12/18/82	32%		-0.0010	0.0%		FIC/N-ILL	6/4/82	4/6/83		8/22/89	
TY-105	11/4/82	12/10/82	6%			0.0%		MT	10/14/82	4/15/83		9/7/89	

Appendix B

Inventory of Surface Level Drops

Table B.1. Level Drops Occurring Within One Month

Tank ID	Pump Shutdown Date	# Tank Years	# Events 0-1"	# Events 1-2"	# Events 2-3"	# Events 3-4"	# Events 4-5"
BX-107	9/14/90	5.92	0	1	0	0	0
BX-109	Sep-90	5.92	0	0	0	0	0
BX-110	12/20/93	2.67	0	0	0	0	0
BX-111	2/4/95	1.5	0	0	0	0	0
BX-112	Sep-90	5.92	0	0	0	0	0
BY-101	1/28/84	12.58	1	0	0	0	0
BY-102	3/27/95	1.42	0	0	0	0	0
BY-103	10/16/95	0.83	0	0	0	0	0
BY-104	11/1/84	11.75	0	0	1	0	1
BY-106	10/16/95	0.83	0	0	0	0	0
BY-107	7/31/79	17.083	1	2	0	0	1
BY-108	12/9/84	11.67	1	0	0	0	0
BY-109	10/16/95	0.83	0	0	0	0	0
BY-110	12/23/84	11.67	0	0	0	0	0
BY-111	11/16/84	11.75	0	0	1	0	1
BY-112	5/7/84	12.25	0	0	0	0	0
C-102	7/15/95	1.083	0	0	0	0	0
C-105	10/23/95	0.83	0	1	0	0	0
C-107	7/28/95	1.083	0	0	0	0	0
C-110	5/28/95	1.25	0	0	0	0	0
S-105	Oct-78	17.83	2	0	0	2	0
S-108	ongoing	0	NA	NA	NA	NA	NA
S-110	ongoing	0	NA	NA	NA	NA	NA
T-104	ongoing	0	NA	NA	NA	NA	NA
T-107	4/14/96	0.33	0	0	0	0	0
T-111	2/8/95	1.5	0	0	0	0	0
TX-102	11/14/82	13.75	0	0	0	0	1
TX-103	6/1/83	13.17	0	0	0	0	0
TX-105	8/8/83	13	2	0	1	1	0
TX-106	4/16/83	13.33	1	1	0	0	0
TX-108	1/12/83	13.58	0	0	0	1	0
TX-109	3/4/83	13.42	0	1	0	0	0
TX-110	12/15/82	13.67	0	2	3	0	1
TX-111	12/15/82	13.67	1	1	0	1	0
TX-112	11/17/82	13.75	0	2	0	0	0
TX-113	5/11/82	14.25	0	0	2	0	0
TX-114	11/24/82	13.75	2	1	1	0	0
TX-115	8/8/83	13	2	3	1	0	0
TX-116	12/12/82	13.67	2	1	0	0	0
TX-117	6/6/82	14.17	1	2	0	0	0
TX-118	2/11/83	13.5	0	0	0	0	0
TY-101	2/14/83	13.5	0	2	0	0	0
TY-103	12/18/82	13.67	1	0	1	0	0
TY-105	12/10/82	13.67	2	2	1	0	0
	Total Events/Total Years	383.02	19 0.049606	22 0.057438	12 0.03133	5 0.013054	5 0.013054

Table B.1. Inventory of Surface Level Drops Occurring Within One Month, Continued

Tank ID	# Events 5-6"	# Events 6-7"	# Events 7-8"	# Events 8-9"	# Events 9-10"	# Events 10-11"	# Events 11-12"	# Events 12-13"
BX-107	0	0	0	0	0	0	0	0
BX-109	0	0	0	0	0	0	0	0
BX-110	0	0	0	0	0	0	0	0
BX-111	0	0	0	0	0	0	0	0
BX-112	0	0	0	0	0	0	0	0
BY-101	0	0	0	0	0	0	0	0
BY-102	1	0	0	0	0	0	0	0
BY-103	0	0	0	0	0	0	0	0
BY-104	0	0	0	0	0	1	0	0
BY-106	0	0	0	0	0	0	0	0
BY-107	0	0	0	0	0	0	0	0
BY-108	0	0	0	0	0	0	0	0
BY-109	0	0	0	0	0	0	0	0
BY-110	0	0	0	0	1	1	0	0
BY-111	0	0	0	0	0	0	0	0
BY-112	0	0	0	0	0	0	0	0
C-102	0	0	0	0	0	0	0	0
C-105	0	0	0	0	0	0	0	0
C-107	0	0	0	0	0	0	0	0
C-110	0	0	0	0	0	0	0	0
S-105	0	0	0	0	0	1	0	0
S-108	NA	NA	NA	NA	NA	NA	NA	NA
S-110	NA	NA	NA	NA	NA	NA	NA	NA
T-104	NA	NA	NA	NA	NA	NA	NA	NA
T-107	0	0	0	0	0	0	0	0
T-111	0	0	0	0	0	0	0	0
TX-102	0	0	0	0	0	0	0	0
TX-103	0	0	0	0	0	0	0	0
TX-105	0	0	0	0	0	0	0	0
TX-106	0	0	0	0	0	0	1	0
TX-108	0	0	0	0	0	0	0	0
TX-109	0	0	1	0	0	0	0	0
TX-110	0	0	1	0	0	0	0	0
TX-111	0	0	0	0	0	0	0	0
TX-112	0	0	0	0	0	0	0	0
TX-113	1	0	0	0	0	0	0	0
TX-114	0	0	0	0	0	0	0	0
TX-115	0	0	0	0	0	0	0	0
TX-116	0	0	0	0	0	0	0	0
TX-117	0	0	0	0	0	0	0	0
TX-118	1	0	0	0	0	0	0	0
TY-101	0	0	0	0	0	0	0	0
TY-103	0	0	0	0	0	0	0	0
TY-105	0	0	0	0	0	0	0	0
Total	3	0	2	0	1	3	1	0
Events/Total Years	0.007833	0	0.005222	0	0.00261	0.007833	0.002611	0

Table B.1. Inventory of Surface Level Drops Occurring Within One Month, Continued

Tank ID	# Events 13-14"	# Events 14-15"	# Events 15-16"	# Events 16-17"	# Events 17-18"	# Events 18-19"	# Events 19-20"	# Events 20-21"
BX-107	0	0	0	0	0	0	0	0
BX-109	0	0	0	0	0	0	0	0
BX-110	0	0	0	0	0	0	0	0
BX-111	0	0	0	0	0	0	0	0
BX-112	0	0	0	0	0	0	0	0
BY-101	0	0	0	0	0	0	0	0
BY-102	0	0	0	0	0	0	0	0
BY-103	0	0	0	0	0	0	0	0
BY-104	0	0	0	0	0	0	0	0
BY-106	0	0	0	0	0	0	0	0
BY-107	0	0	0	0	0	0	0	0
BY-108	0	0	0	0	0	0	0	0
BY-109	0	0	0	0	0	0	0	0
BY-110	0	0	0	0	0	0	0	0
BY-111	0	0	0	0	0	0	0	0
BY-112	0	0	0	0	0	0	0	0
C-102	0	0	0	0	0	0	0	0
C-105	0	0	0	0	0	0	0	0
C-107	0	0	0	0	0	0	0	0
C-110	0	0	0	0	0	0	0	0
S-105	0	0	0	0	0	0	0	0
S-108	NA	NA	NA	NA	NA	NA	NA	NA
S-110	NA	NA	NA	NA	NA	NA	NA	NA
T-104	NA	NA	NA	NA	NA	NA	NA	NA
T-107	0	0	0	0	0	0	0	0
T-111	0	0	0	0	0	0	0	0
TX-102	0	0	0	0	0	0	0	0
TX-103	0	0	0	0	0	0	0	0
TX-105	0	0	0	0	0	0	0	0
TX-106	0	0	0	0	0	0	0	0
TX-108	0	0	0	0	0	0	0	0
TX-109	0	0	0	0	0	0	0	0
TX-110	0	0	0	0	0	0	0	0
TX-111	0	0	0	0	0	0	0	0
TX-112	0	0	0	0	0	0	0	0
TX-113	0	0	0	1	0	0	0	0
TX-114	0	0	0	0	0	0	0	0
TX-115	0	0	0	0	0	0	0	0
TX-116	0	0	0	0	0	0	0	0
TX-117	0	0	0	0	0	0	0	0
TX-118	0	0	0	0	0	0	0	0
TY-101	0	0	0	0	0	0	0	0
TY-103	0	0	0	0	0	0	0	0
TY-105	0	0	0	0	0	0	0	0
Total	0	0	0	1	0	0	0	0
Events/Total Years	0	0	0	0.002611	0	0	0	0

Table B.1. Inventory of Surface Level Drops Occurring Within One Month, Continued

Tank ID	# Events 21-22"	# Events 22-23"	# Events 23-24"	# Events 24-25"	# Events 25-26"	# Events 26-27"	# Events 27-28"	# Events 55-56"	Total # Events
BX-107	0	0	0	0	0	0	0	0	1
BX-109	0	0	0	0	0	0	0	0	0
BX-110	0	0	0	0	0	0	0	0	0
BX-111	0	0	0	0	0	0	0	0	0
BX-112	0	0	0	0	0	0	0	0	0
BY-101	0	0	0	0	0	0	0	1	2
BY-102	0	0	0	0	0	0	0	0	1
BY-103	0	0	0	0	0	0	0	0	0
BY-104	0	0	0	0	0	0	0	0	3
BY-106	0	0	0	0	0	0	0	0	0
BY-107	0	0	0	0	0	0	0	0	4
BY-108	0	0	0	0	0	0	0	0	1
BY-109	0	0	0	0	0	0	0	0	0
BY-110	0	0	1	0	0	0	0	0	3
BY-111	0	0	0	0	0	0	0	0	2
BY-112	0	0	0	0	0	0	0	0	0
C-102	0	0	0	0	0	0	0	0	0
C-105	0	0	0	0	0	0	0	0	1
C-107	0	0	0	0	0	0	0	0	0
C-110	0	0	0	0	0	0	0	0	0
S-105	0	0	0	0	0	0	0	0	5
S-108	NA	NA	NA	NA	NA	NA	NA	NA	NA
S-110	NA	NA	NA	NA	NA	NA	NA	NA	NA
T-104	NA	NA	NA	NA	NA	NA	NA	NA	NA
T-107	0	0	0	0	0	0	0	0	0
T-111	0	0	0	0	0	0	0	0	0
TX-102	0	0	0	0	0	0	1	0	2
TX-103	0	0	0	0	0	0	0	0	0
TX-105	0	0	0	0	0	0	0	0	4
TX-106	0	0	0	0	0	0	0	0	3
TX-108	0	0	0	0	0	0	0	0	1
TX-109	0	0	0	0	0	0	0	0	2
TX-110	0	0	0	0	0	0	0	0	7
TX-111	0	0	0	0	0	0	0	0	3
TX-112	0	0	0	0	0	0	0	0	2
TX-113	0	0	0	0	0	0	0	0	4
TX-114	0	0	0	0	0	0	0	0	4
TX-115	0	0	0	0	0	0	0	0	6
TX-116	0	0	0	0	0	0	0	0	3
TX-117	0	0	0	0	0	0	0	0	3
TX-118	0	0	0	0	0	0	0	0	1
TY-101	0	0	0	0	0	0	0	0	2
TY-103	0	0	0	0	0	0	0	0	2
TY-105	0	0	0	0	0	0	0	0	5
Total	0	0	1	0	0	0	1	1	
Events/Total Years	0	0	0.00261	0	0	0	0.00261	0.00261	

Appendix C

Analysis of Neutron Log Data

Appendix C

Analysis of Neutron Log Data

Neutron log data are routinely collected in SSTs to determine the liquid level within the waste. The log response, which is typically collected as a function of depth to give a profile, depends on the amount of water present and is therefore capable of detecting the transition between dry and wet waste. While the log response is sensitive to the presence of liquid and should therefore be sensitive to the presence of gas bubbles that have displaced liquid, these neutron log data have not previously been used to detect the presence of gas bubbles. Changes in liquid level, determined from neutron logs, have been used to estimate the amount of trapped gas, but the log response below the liquid level has not been used for this purpose.

In Section 4 (Figure 4.2), we showed how the neutron log response varied during salt well pumping but gave no basis for why these data may indicate gas bubble behavior. In this appendix, we analyze the neutron log response for SST S-106. Log data from this tank were analyzed to learn whether the log response below the liquid level contained useful information related to trapped gas. This tank was chosen because it is an extreme example of very large level growth, presumably due to the retention of gas bubbles, and should be a relatively easy test case.

Our analysis of the neutron log data has two steps. First, each neutron log was normalized to give an equivalent response in a region where the water content varies little. In this work, we chose the soil layer above the tank as our region for normalizing. Figures C.1 and C.2 show the original and normalized log response as a function of elevation from the tank bottom.[a] It is not possible to distinguish the different curves on these plots, but a comparison of Figures C.1 and C.2 show that the variation in the normalized log response is smaller. The second step was to calculate an average of the normalized response in the region below the liquid level in the tank. Figure C.2 shows the region of the data used for determining this average. This average of the normalized counts/sec should decrease if gas bubbles displace liquid.

Figure C.3 shows average response between 1986 and 1996. The decreasing trend in response is very apparent, and the line shown on the figure was aligned by eye. The counts/sec reduced from 1390 to 1290, or about 8%, over this period. In comparison, the surface level increased about 16.5 cm, or about 4%, during this same period (Whitney 1995). Based on these data and the knolwedge that the neutron log responds to the amount of water present, it seems plausible that these neutron log data are showing the expected increase in retained gas for S-106. This analysis, while preliminary and only for a single tank, suggests that the neutron log data may be useful for detecting the behavior of gas bubbles during salt well pumping.

(a) Neutron log data came from a personal communication and data transmittal, P.A. Gauglitz from P.D. Whitney, September 11, 1996.

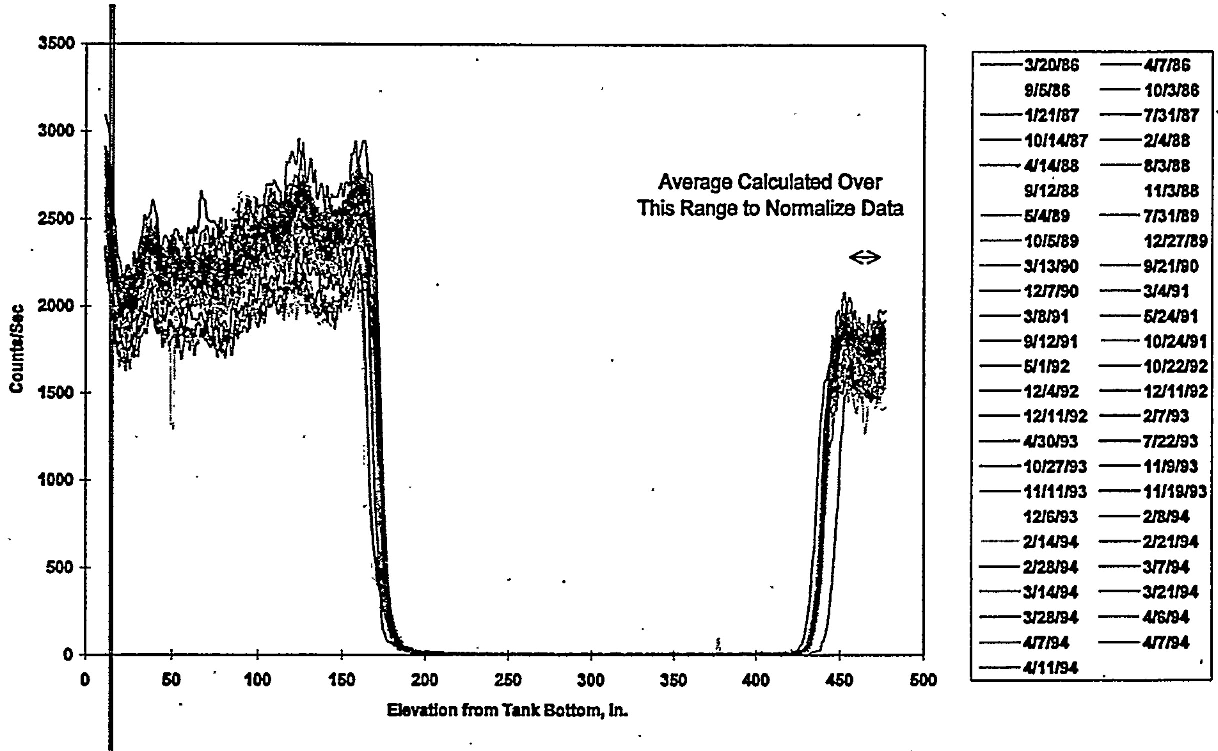

Figure C.1. Neutron Log Response for S-106

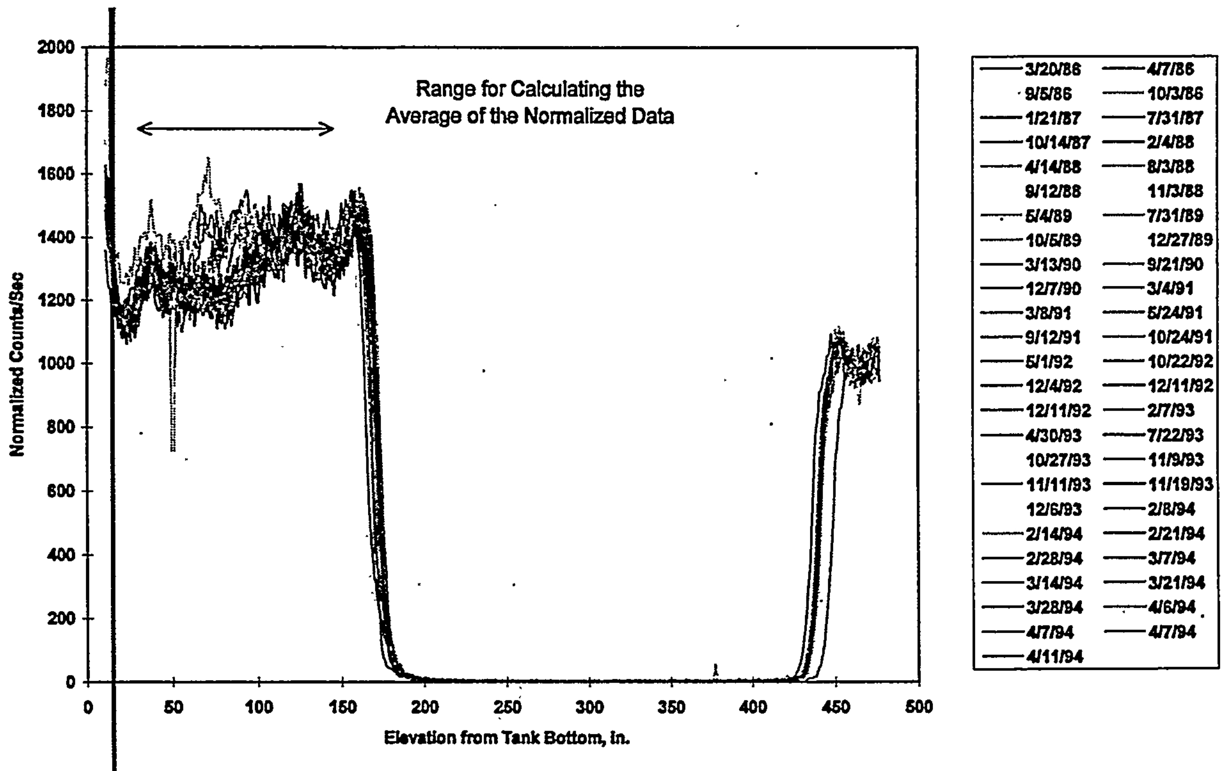

Figure C.2. Normalized Neutron Log Response for S-106

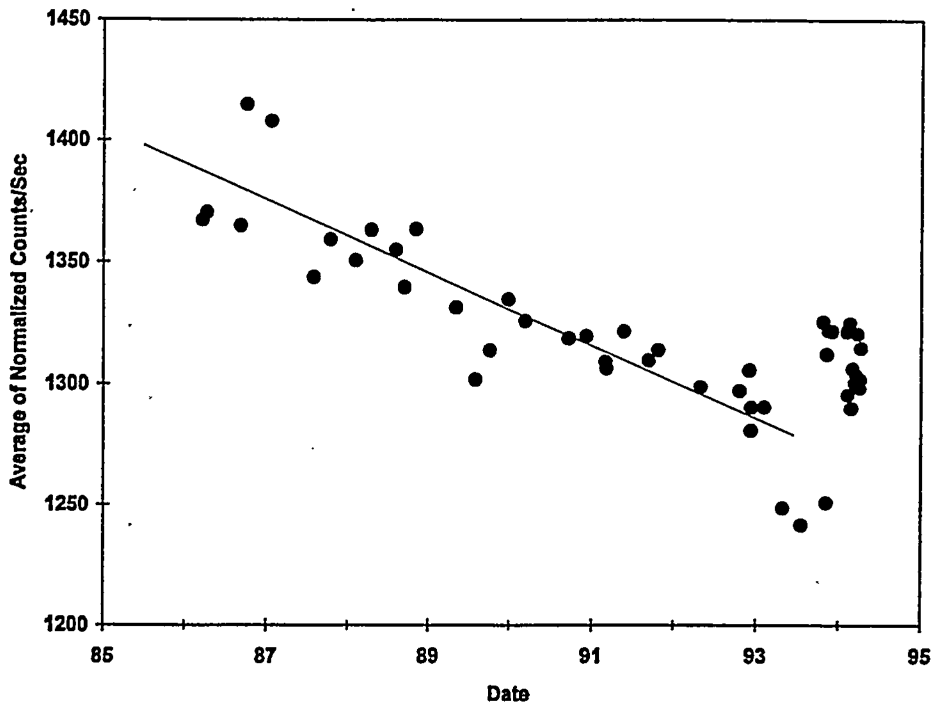

Figure C.3. Variation over Time of Average of Normalized Log Response for S-106

References

Whitney, P.D. 1995. *Screening the Hanford Tanks for Trapped Gas.* PNL-10821, Pacific Northwest National Laboratory, Richland, Washington.

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