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High Resolution Resistivity Leak Detection Data Processing and Evaluation Methods and Requirements

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Abstract: This document describes how HRR leak detection data are processed and evaluated for SST leak detection during tank waste retrieval operations. Operational requirements for HRR implementation are also provided.

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HIGH RESOLUTION RESISTIVITY LEAK DETECTION DATA PROCESSING AND EVALUATION METHODS AND REQUIREMENTS

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List of Acronyms and Abbreviations

CEES	Columbia Energy and Environmental Systems
CH2M HILL	Hanford tank farm contractor
HRR	high resolution resistivity
LD	leak detection
HGI	hydroGEOPHYSICS, Inc.
HLAN	Hanford Local Area Network
IP	internet protocol
TFC	Tank Farm Contractor
WTS	Drywell-to-Surface (electrode)
WTT	Drywell-to-Tank (electrode)
WTW	Drywell-to-Drywell (electrode)

IMPLEMENTATION NOTE: This document forms the basis for a number of subsequent documents and procedures required for full implementation of High Resolution Resistivity (HRR) as a leak detection methodology during Single-Shell Tank (SST) waste retrieval operations. HRR will not be fully implemented for leak detection until all supporting documents and procedures are prepared, approved, released, and fully implemented. Until HRR is fully implemented, it is in demonstration mode. While HRR is still in demonstration mode the methods and procedures in this document are guidelines which should be followed to the extent practical.

1 PURPOSE

This document has two purposes:

- Describe how data generated by High Resolution Resistivity (HRR) leak detection (LD) systems deployed during single-shell tank (SST) waste retrieval operations are processed and evaluated.
- Provide the basic review requirements for HRR data when HRR is deployed as a leak detection method during SST waste retrievals

2 SCOPE

This document is applicable to processing and evaluation of HRR resistivity data obtained from tanks on which HRR is installed as described in RPP-32478, *High Resolution Resistivity Leak Detection Equipment Description.*

The information in this document supersedes all previous descriptions of HRR data processing and evaluation for leak detection purposes, when that data is obtained from tanks on which HRR is installed as described in RPP-32478.

3 INTRODUCTION

RPP-32478 describes the basic theory behind HRR as a LD method for SSTs during waste retrieval, the equipment used, where it is located, the form of data generated, and how the HRR raw data are transmitted for subsequent processing. See RPP-32478 for the definition of resistivity as applied to SST leak detection in the Hanford tank farms, and an explanation of the units.

This document, RPP-32477, describes:

1. How a pre-retrieval HRR resistivity baseline is established
2. How raw retrieval data are converted to processed data
3. How processed data are evaluated by software for leak detection
4. How the HRR data website is used
5. How processed data are reviewed for tank leak detection

6. How raw data are reviewed for tank leak detection
7. How data anomalies are evaluated
8. Data review requirements

The HRR raw data consist of a calculated resistivity value for each drywell-to-drywell (WTW), drywell-to-tank (WTT) or drywell-to-surface (WTS) electrode pair. The raw data obtained during waste retrieval are processed by a subcontractor through software that analyzes for changes which indicate the data may be statistically trending away from an established pre-retrieval baseline. Trends away from the baseline can be indicative of physical changes in the soil around a tank resulting from a tank leak. The data can also be evaluated manually for trends.

High resolution resistivity as employed on an SST during waste retrieval does not provide a 'Yes/No' means of leak detection. High resolution resistivity provides information on changes in the resistivity of the soil surrounding a tank. No noticeable change in the average resistivity between any drywell-to-electrode pairs is interpreted as there being no evidence of a leak from the tank to the soil. A noticeable change in the average resistivity is evaluated to determine if there is an explanation for the change. If there is no valid explanation for the change other than a potential tank leak, the tank leak assessment process is entered.

Specific terms used in this document are defined as follows:

Anomaly: An anomaly is a change in the HRR data for one or more electrode data pairs that:

- results in an action level indication from the automated data processing system, or,
- is deemed to be an anomaly by an HRR Data Evaluator based upon manual review of processed or raw data

Baseline Slope Threshold: The maximum and minimum slopes calculated for a data pair in the baseline data period, with a 3σ standard deviation applied, are the baseline slope thresholds for that data pair.

Data Pair: Two specific electrodes between which a resistivity data point is obtained. The transmitting electrode is always listed first.

Data Point: The resistivity value obtained between a data pair at a specific time.

Exceedance: A slope which is outside the baseline threshold range for that data pair.

HRR Data Evaluator: The HRR data evaluator is a person designated by Tank Farm Contractor (TFC) management as qualified to evaluate HRR data.

Slope: The change in resistivity for a data pair over a given time period is the slope. For the automated data processing used for HRR leak detection the duration for measuring a data pair slope is 48 hours.

Unexplained Anomaly: An anomaly which has been evaluated as described herein and documented as requiring entry into the tank leak assessment process in procedure TFC-ENG-CHEM-D-42.

The automated data processing software brings consistency to the evaluation process and minimizes the manual review which would otherwise be necessary. Automated evaluation of processed HRR data also brings a level of objectivity to the routine data analysis compared to subjective manual review. Software processing of the raw data and performing an automated data analysis can minimize to an extent the number of false alarms (i.e., data anomalies evaluated as not resulting from a tank leak). However, occasional anomalies are still expected with the automated software. Therefore, a final decision as to whether an unexplained anomaly exists or not is based on the experience and knowledge of an HRR Data Evaluator.

All anomalies are evaluated systematically, but in the end the decision as to whether an unexplained anomaly exists or not is subjective.

4 BACKGROUND

The first HRR LD system was installed on tank S-102 and began operation in May of 2004. From October 2005 through October 2006 HRR was used during the retrieval of waste from tank C-103. In December 2006 a third HRR system began operation during the retrieval of tank C-108 waste. The fourth HRR system began operation during C-109 waste retrieval in June 2007. Daily reports were provided through mid-May 2007 by the subcontractor for each tank during the retrieval process. These reports summarized the status of the equipment, pertinent environmental data, and provided a judgment as to whether the tank was leaking or not. Since mid-May of 2007 the data evaluation has been performed by the tank farm contractor. Subcontractors provide and own the HRR equipment and the data processing software.

A leak simulant injection test was also performed adjacent to S-102 from January through May of 2006.

A description of the data processing methodology and leak evaluation process for the initial S and C farm HRR installations was provided in RPP-22820, *HRR LDM Data Processing, Assessment, and Reporting Procedure for S-102,* and RPP-24576, *HRR LDM Data Processing, Assessment, and Reporting Procedure for C-Farm.* Revision 0 of RPP-17191, *SST Deployment Demonstration and Injection Leak Testing of The HRR Long Electrode LDM System,* provided a similar description of the data processing and leak evaluation process, along with specifics of the leak injection test planned and subsequently performed at S-102.

Starting before May of 2004, and continuing through start of the leak injection test the HRR data processing methods were improved as experience was obtained. The data processing information in RPP-17191 was updated in March 2006 to reflect the improved data processing methodology at that time. The data processing descriptions in RPP-22820 and RPP-24576 were then obsolete.

The processing methodology described in RPP-17191 required significant and costly manual data evaluation by the subcontractor. Work was initiated in 2007 to automate much of the data processing and transfer the data interpretation to the TFC. This work resulted in evolution of some of the data algorithms used, and preparation of revised

software. This updated HRR leak detection and data evaluation process was implemented in May 2007 and is described in the rest of this document.

5 DATA PROCESSING

The HRR system takes voltage and amperage readings as described in RPP-32478. The resistivity value for a data pair is calculated from the voltage and amperage data by equipment in the onsite S or C –Farm control trailer. The raw resistivity data plus the voltage and amperage readings on which they are based are sent to the weather collection computer located in the same control trailer. In the weather collection computer the raw resistivity data are combined with the weather data, 'time stamped', and sent electronically to hydroGEOPHYSICS, Inc. (HGI) located in Tucson, Az for processing.

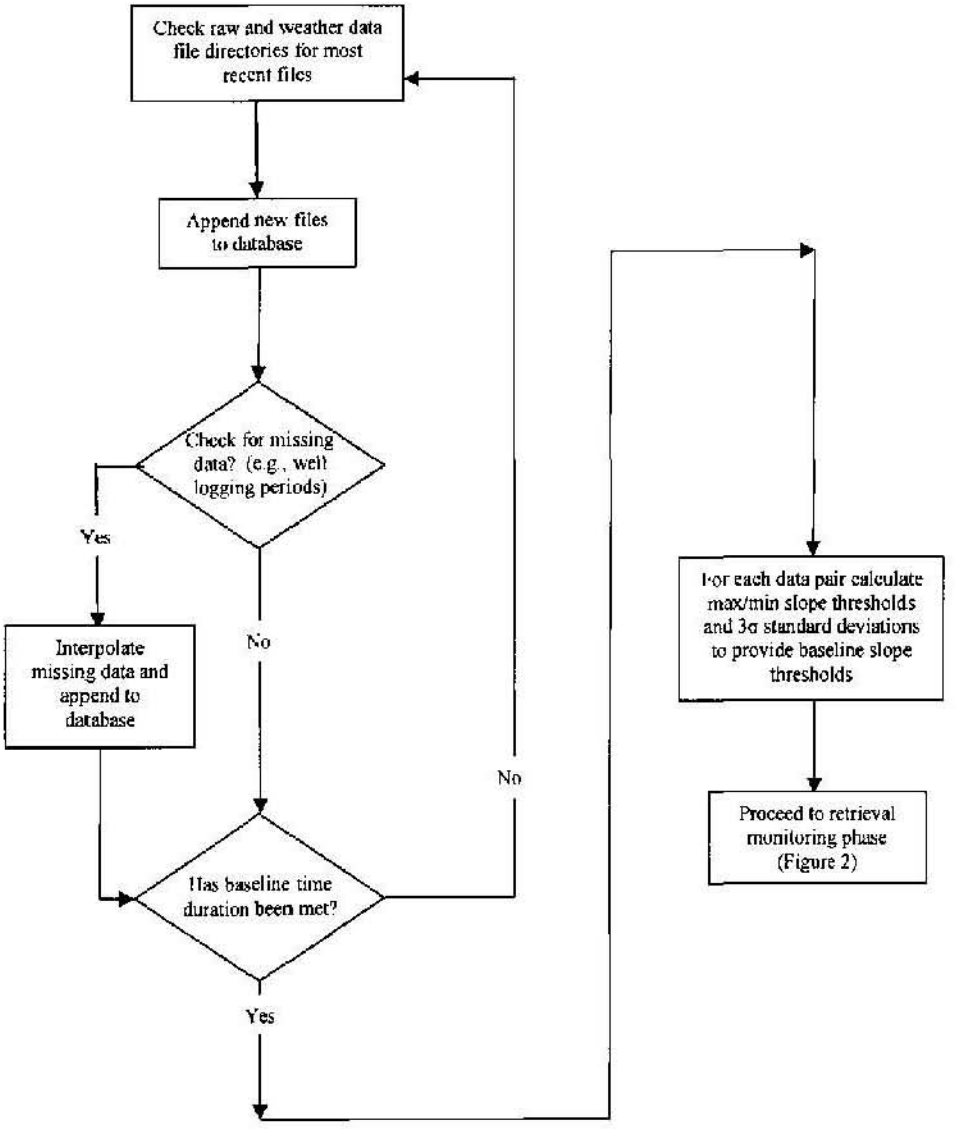
At the subcontractor facility the raw resistivity data are converted into processed data by spike rejection and filtering (smoothing) and then analyzed by the automated data processing software, LDM AutoPro™ Software (AutoPro™). The output is available for viewing through a website (LDM AutoView™) portal maintained by Columbia Energy and Environmental Services (CEES) in Richland, Wa. This website provides a visual interface with leak detection information for each tank monitored.

The AutoView™ website information is reviewed and interpreted by the tank farm contractor. The AutoPro™ data processing software is under configuration management by the subcontractor. The AutoPro™ software and AutoView™ website is expected to be updated and improved with time. Layout and use of the website is described in detail in CEES-0368, *AutoView Software User's Guide*. This manual is maintained current following website improvements. The data processing description in this document (RPP-32477) is not planned to be revised following a change unless significant or key changes are made that would alter the methodology or decision making process.

5.1 Baseline Phase Data Processing

Figure 1 shows the data processing performed during the baseline period. Baseline slopes are calculated for all electrode combinations. The baseline period is necessary to provide a standard that retrieval phase data are compared against to observe changes. The baseline duration must be long enough to cover routine variations of temperature, precipitation and electrical background noise. The shorter the baseline duration the smaller the baseline slope threshold range will be for comparison use during retrieval monitoring. As the baseline slope threshold range gets smaller, the narrower the range for an 'acceptable' variation in data pair slopes becomes, and the frequency of anomalies will increase accordingly. Subcontractor experience has shown that a 14 day period is usually sufficient for baseline duration. If significant weather changes or electrical noise occur it may be necessary to increase the baseline duration to avoid having a skewed baseline slope threshold range. Shorter baseline durations are possible, but choosing a duration shorter than 14 days could result in more frequent anomalies and subsequent data evaluation, and potentially cause unnecessary retrieval shutdowns.

Figure 1. Baseline Data Processing



For the S-102 HRR system approximately 360 data pairs are read in a nominal 17 minute period. For the C-103 system 78 data pairs were read over a nominal 18 minute period. The C-Farm system with C-108 and C-109 reads 160 data pairs over a nominal 15 minute period. Assuming data are obtained on a nominal 15-20 minute cycle, a 14 day baseline period will include about 1000 to 1350 data points for each data pair.

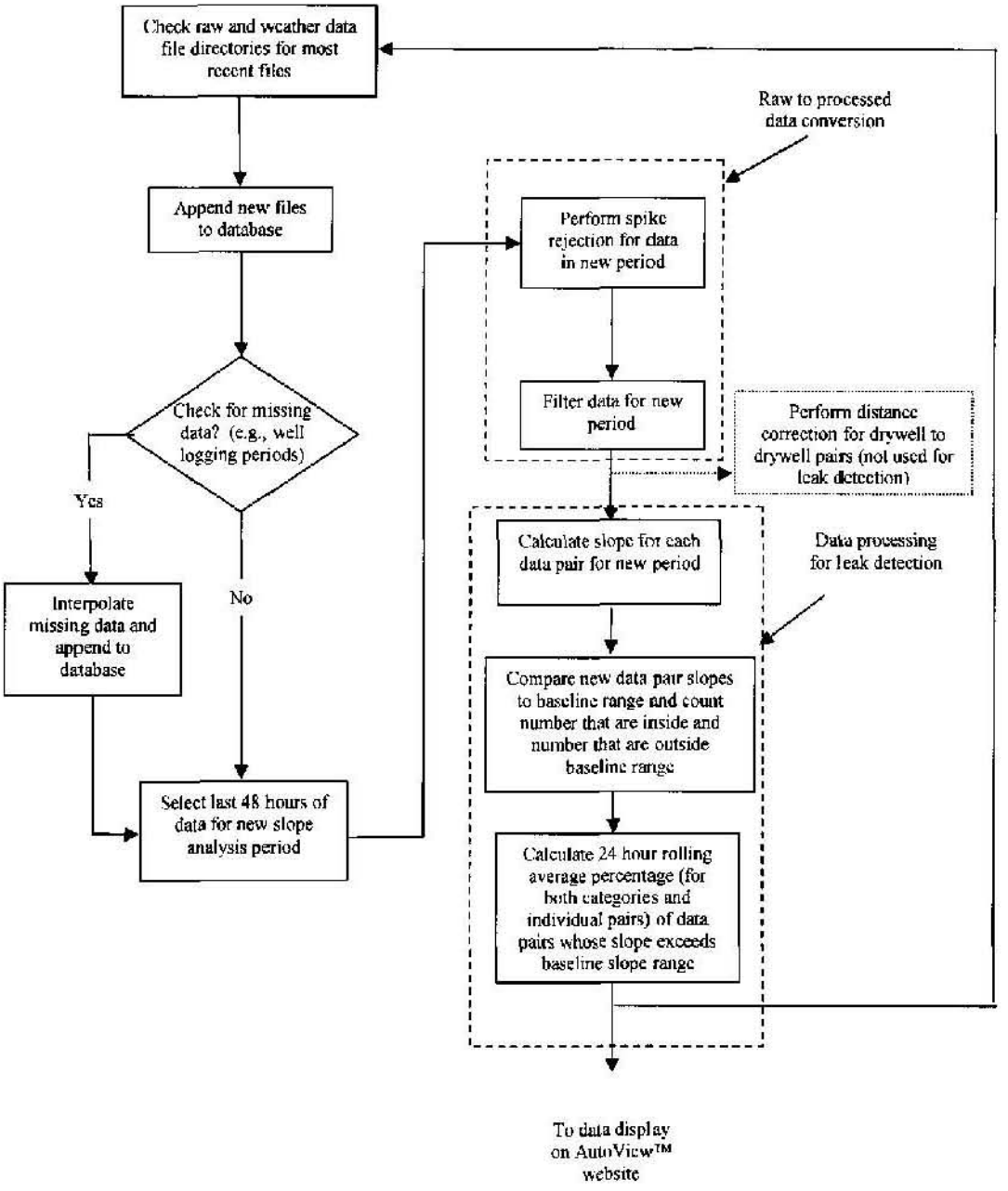
Raw data are accumulated until the baseline collection period is complete. The baseline slopes are then calculated for each data pair. During the slope calculation step the software measures the slope over a 48-hour period, drops off the oldest set of data, adds the newest set of data, and repeats the slope measurement over the incremented 48 hour period. This process is repeated until all the baseline data are analyzed. Two days of data are required before the first slope measurement can be obtained. i.e., Assuming exactly 4 data points are taken per hour would result in 192 data points in a 48 hour period and 1344 data points in a 14 day period. The first slope measurement for a data pair is performed using the data pair resistivity difference between data sets 1 and 193. The second slope measurement would be performed using the data pair resistivity difference between data sets 2 and 194, the third uses data sets 3 through 195, etc. The last slope calculation would use the data pair resistivity difference between data sets 1153 and 1344. There would thus be 1153 slope measurements for each data pair for the baseline period, at 4 data points per hour for 14 days.

When the baseline data collection is complete the data are passed through the raw to processed data conversion described in Section 5.2.1 and then are statistically evaluated to arrive at maximum (largest positive resistivity change in any 48 hour increment) and minimum (largest negative resistivity change in any 48 hour increment) slopes for each data pair in the 14 day baseline period, and a slope standard deviation. The maximum and minimum slopes with a 3σ standard deviation applied bound the baseline slope threshold range for that data pair. The baseline data are also statistically evaluated and a distance correction method resulting from this evaluation is applied to the WTW and WTS data to account for the large range of raw data magnitudes recorded as a result of the varying distances between the electrodes. This distance correction method can help enhance visual analysis of subtleties in WTW and WTS data and could potentially be used to support leak volume estimation should there be a leak from the tank. The slope thresholds are calculated after distance corrections have been applied to the WTW and WTS data. No distance correction is applied to the WTT data.

5.2 Retrieval Phase Data Processing

Retrieval phase data processing is show in Figure 2. There are two general steps performed by the automated data software, conversion of raw data to processed data and analysis of processed data for statistically significant trends away from the baseline.

Figure 2. Retrieval Data Processing



5.2.1 Conversion of Raw Resistivity Data to Processed Data

During retrieval monitoring the raw resistivity data are sent automatically from the equipment at S farm and C farm to a raw database file at HGI. The AutoPro™ software obtains an update from the raw database file every hour. Conversion of raw data takes the last 48 hours of data, rejects data spikes, and filters the data. Rejection of spikes requires that about five data points beyond a spike pass before the spike is rejected. Filtering requires ten data points to pass before filtering is applied. Thus, a processed data point may be 16 to 19 data points behind the latest raw data point when the processed data point is first used in the leak detection process (1 to 4 data points behind when added to the database + 5 data points behind for spike rejection + 10 data points behind for filtering). This results in the most recent processed data point being about 4 to 6 hours old, assuming a 15 to 20 minute data cycle.

Figure 3 is an example of raw resistivity data obtained over a 25 day period selected at random for three WTT pairs for tank S-102 during retrieval monitoring. Figure 4 is the same data after spike rejection and filtering/smoothing. The benefit of spike rejection and data filtering can be seen, although the same general data trend can be observed in both figures.

5.2.2 Automated Data Processing for Leak Detection

Once the raw resistivity data have been converted to processed data, the slope for the past 48 hours for a data pair is measured. The slope is compared by the software to the baseline slope threshold range for that data pair. If the slope exceeds the threshold range (i.e., exceeds the maximum or minimum baseline slope threshold) a value of "1" is assigned to the data point in the software, if the slope is within the threshold range a value of "0" is assigned to it. This calculation is done for each data pair.

The cycle is then repeated. The data points older than 48 hours are dropped off and the latest set of data appended. The spike rejection-filtering-slope calculation process is repeated for each cycle, and a "1" or "0" value assigned to the new slope depending upon whether the new slope exceeds the baseline threshold range or not.

The "1"s and "0"s are used to calculate a rolling average percentage for how often each WTT and WTW data pair exceeded their baseline slope threshold range in the past 24 hours. A rolling average is calculated for each WTT and WTW data pair, and also for the WTT and WTW data pair categories. No rolling average is calculated for the WTS electrode category.

The duration selected for calculation of the rolling average needs to be long enough so that false alarms are minimized, but short enough so that actual slope changes are noted in a timely manner. Subcontractor experience has shown a 24-hour duration provides a reasonable and useful rolling average.

The 24-hour rolling average for all WTT data is called the Leak Potential. This value is compared to an action level setpoint stored in the software and is only applied to WTT data. The action level setpoint for WTT data is 50%. This number is based upon subcontractor experience with:

- The Mock Tank Site testing (PNNL-14192, *Results of Performance Evaluation Testing of Electrical Leak-Detection Methods at the Hanford Mock Tank Site – FY 2002-2003,* and RPP-14606, *Performance Test Assessment of HRR-SCRT, ERT-PET, and ERT-LET Ex-Tank Resistivity Leak Detection Methods Fiscal Year 2002-2003),*
- The S-102 Leak Injection Test (RPP-30121, *Tank 241-S-102 High-Resolution Resistivity Leak Detection and Monitoring Testing Report*), and,
- Several years of experience with HRR operations in tank farms.

When the Leak Potential value exceeds the action level setpoint there is likely a positive correlation to a physical change. The data must be evaluated when this action level is exceeded and tank conditions reviewed as needed to determine if the tank may be leaking or if there is another explanation for the data trend.

For a sound tank, the average of all slopes measured during the retrieval process over an extended time should be close to zero, assuming there are no competing impacts such as, but not limited to, temperature changes, precipitation or electrical background changes.

Figure 3. Example of Raw Data

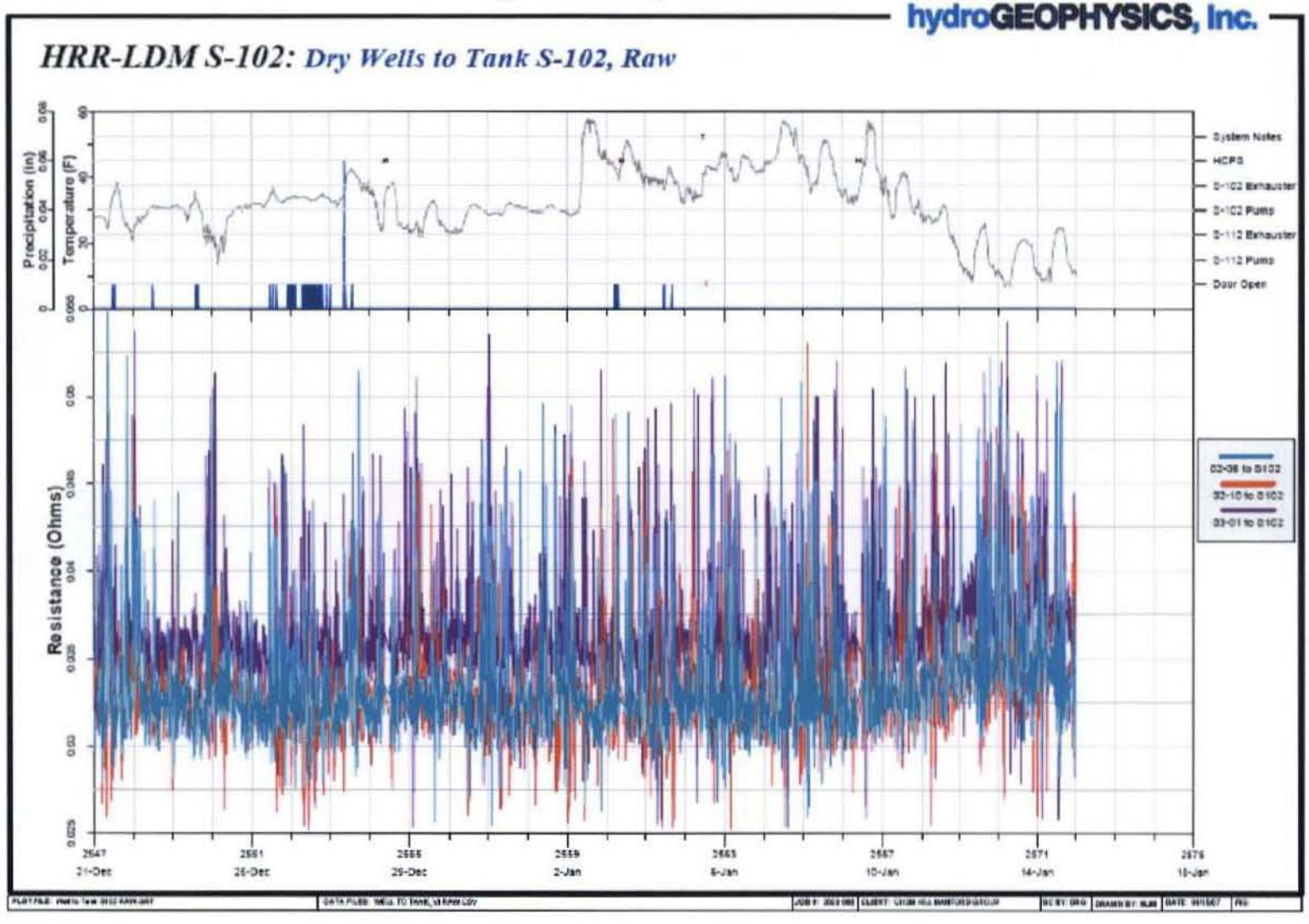
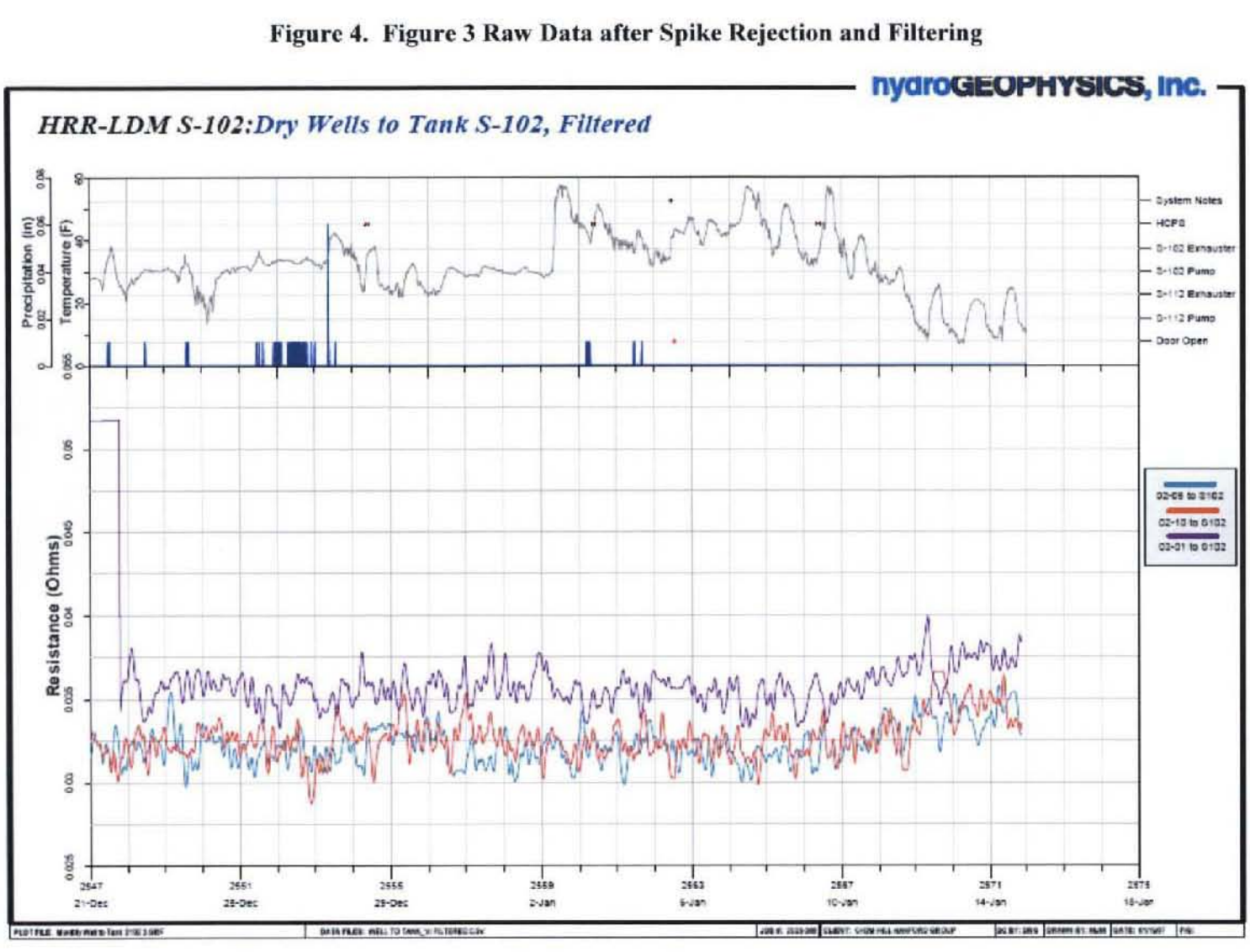


Figure 4. Figure 3 Raw Data after Spike Rejection and Filtering



6 DATA DISPLAY AND EVALUATION

6.1 Data Display Website

This section provides an overview of the steps associated with using the HRR leak detection website.

Figure 5 shows an example of the first AutoView™ screen. Each tank farm with an operating HRR system installed is depicted. The tank farm for which HRR information is needed is selected and the second screen appears. Figure 6 is an example of the second AutoView™ screen for S-Farm. The specific tank for which data are needed is selected and the third screen appears. Figure 7 is an example of the third AutoView™ screen for S-102.

The third screen shows the specific tank along with the tank electrode (thermocouple for S-102), all drywells and any surface electrodes connected to the HRR system for that tank. The tank electrode is shown as a circle, drywells are shown as triangles, and surface electrodes are shown as squares.

To the left of the tank is a table called Threshold Exceedance Summary listing WTT and WTW with headings of Min, Max and Mean. Above this table is a selection box for 'Well to Tank' or 'Well to Well' information. Figure 7 shows 'Well to Tank' in the selection box. With 'Well to Tank' selected the tank electrode color indication is based on the latest Leak Potential value, the 24-hour rolling average percentage for WTT exceedances calculated by the software. If the Leak Potential is less than the action limit the tank electrode is green. If the Leak Potential meets or exceeds the action limit, the tank electrode color turns red. When this occurs the drywell electrode color may also change color, depending upon the average WTT exceedance percentage for that drywell. If the 24-hour rolling average percentage for WTT exceedances for a drywell is <30%, the color remains green. If it is ≥30% but <50% the color is amber. If the 24-hour rolling average percentage for WTT exceedances for a drywell is ≥50% the drywell icon will be red.

Moving the cursor over each drywell shows the current 24-hour rolling average for exceedances for that WTT data pair.

Figure 5. AutoView™ Website Screen 1

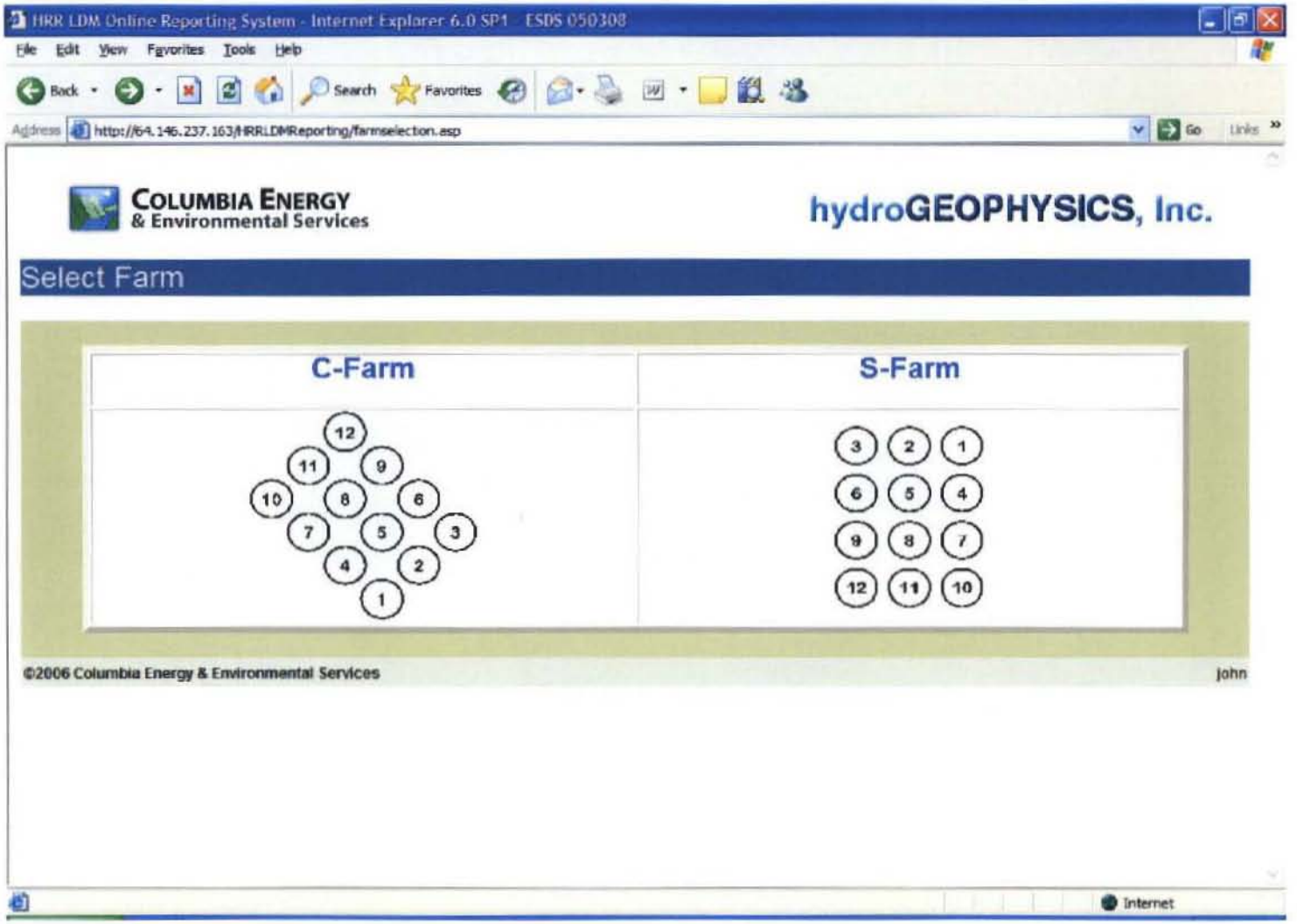


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Figure 6. AutoView™ Website Screen 2

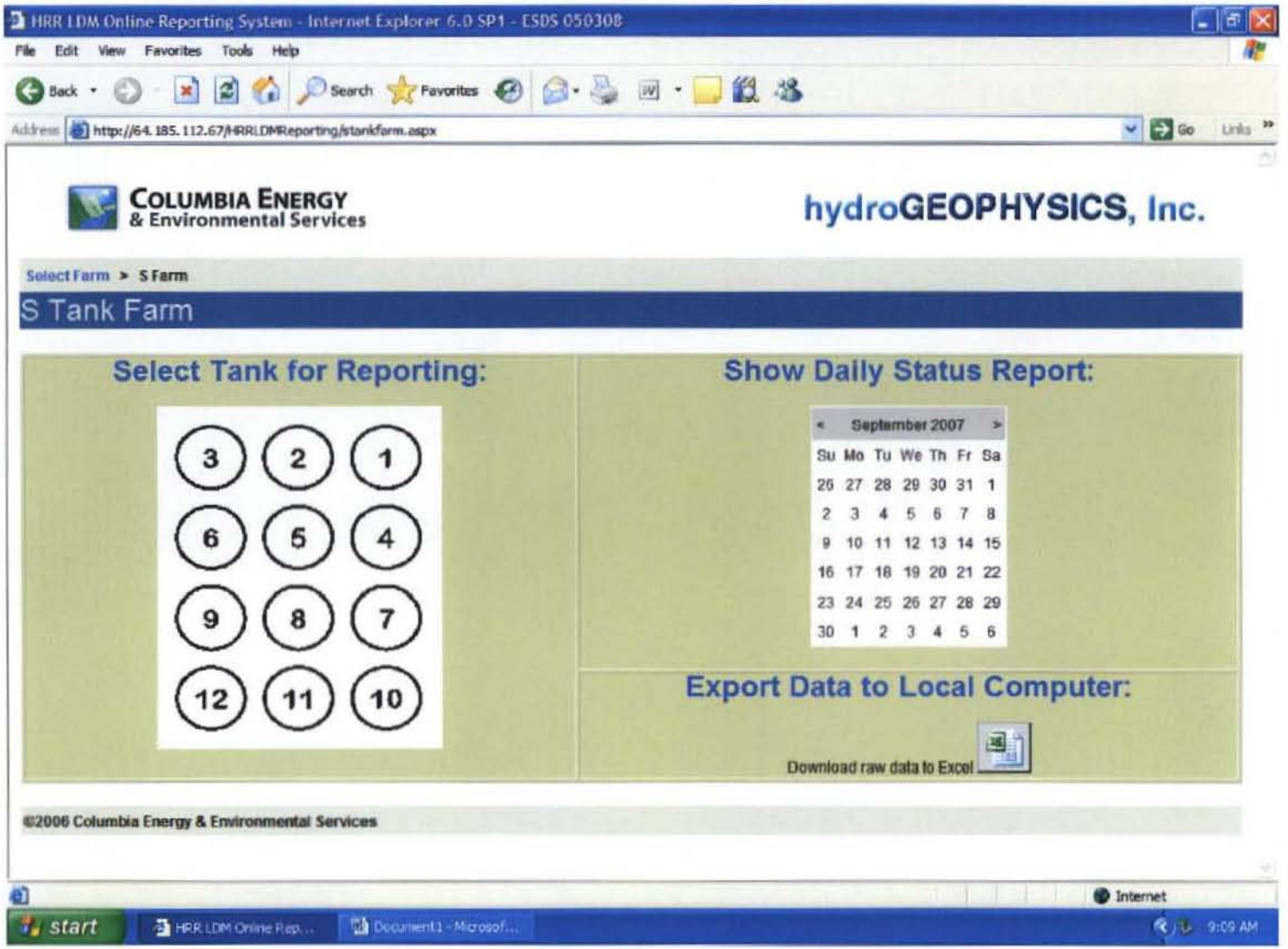

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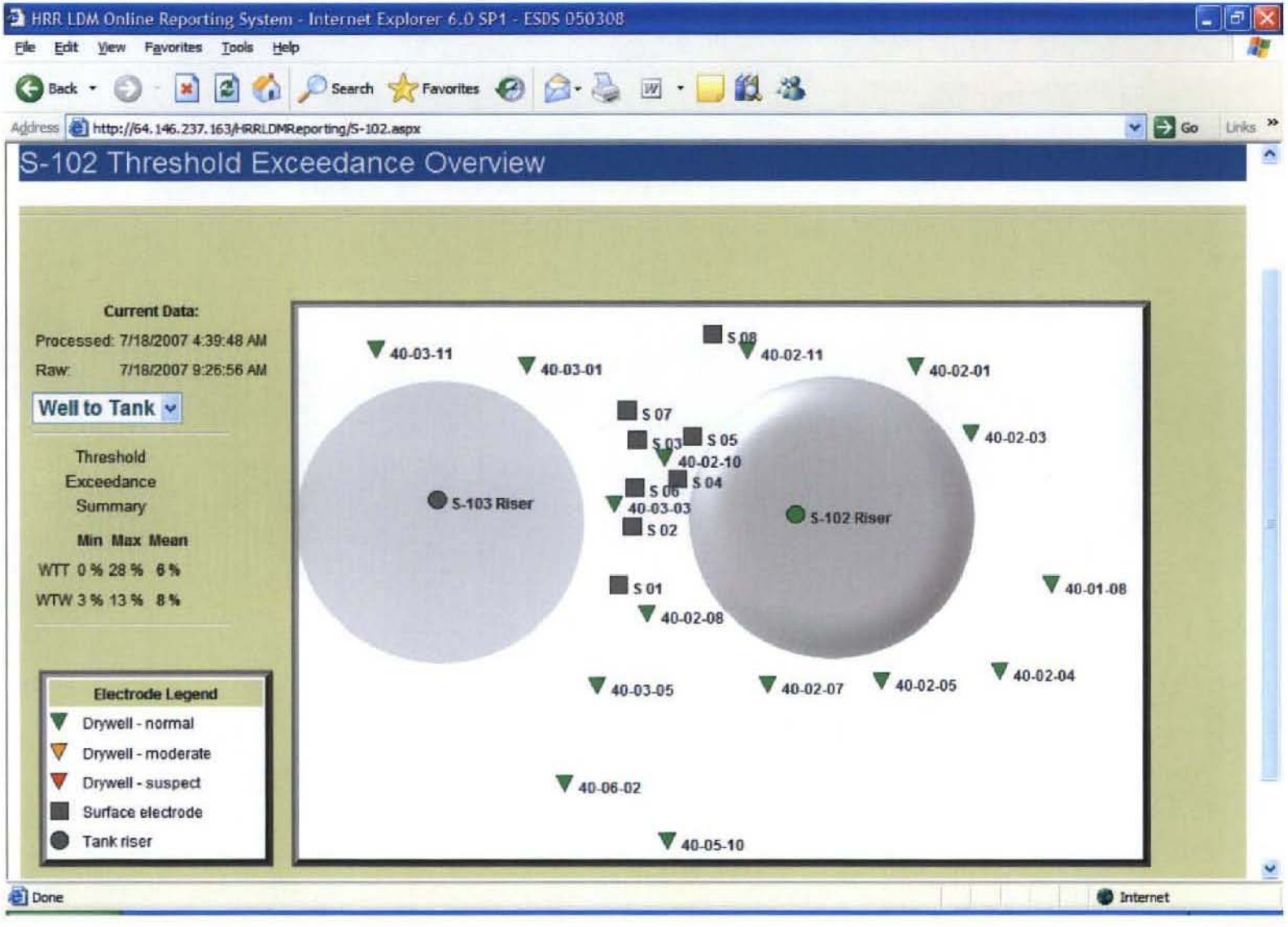
Figure 7. AutoView™ Website Screen 3



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The Min value in the WTT table is the minimum current 24-hour rolling average WTT exceedance percentage among all of the drywells shown on the screen. The Max value is the maximum current 24-hour rolling average for WTT exceedance percentage among all drywells shown on the screen. The Mean value is the average of all 24-hour WTT rolling average exceedance percentages for all the drywells shown. The Min, Max and Mean values are rounded to the nearest percentage point.

When 'Well to Well' is selected in Screen 3, the screen view remains essentially the same. Moving the cursor over a drywell when in WTW mode shows the current 24-hour rolling average percentage for all WTW data pairs with that drywell as transmitter. In the 'Well to Well' mode the tank electrode color indication has no meaning.

The Min value in the WTW table is the minimum current 24-hour rolling average WTW exceedance percentage among all of the drywells shown on the screen. The Max value is the maximum current 24-hour rolling average for WTW exceedance percentage among all drywells shown on the screen. The Mean value is the average of all 24-hour WTW rolling average exceedance percentages for all the drywells shown.

The color for each surface electrode is always grey.

Clicking on any drywell in the third screen whether in WTT or WTW mode pulls up the fourth screen, which lists all the other electrodes in that tank's HRR system which act as receiver electrodes for the selected drywell. Figure 8 is an example of the fourth AutoView™ screen, assuming drywell 40-02-07 was selected in the third screen. This screen permits selection of processed data pair information with the selected drywell as the transmitting electrode. The box next to each electrode can be checked to see a plot of the processed data for the selected drywell and that receiver drywell, tank electrode, or surface electrode. In the Figure 8 example drywells 40-01-08, 40-02-01, 40-02-04, 40-02-05, 40-02-11, 40-03-01, 40-05-10, and 40-06-02 are selected.

Clicking on "Use these receiving electrodes" brings up the fifth screen, (Figure 9). This screen permits selection of preset time periods or specific starting and ending times for data review. Figure 9 shows the dates 7/16/2007 to 7/17/2007 selected. Clicking on "Continue" provides a plot of the selected processed resistivity data points over the chosen time period. Weather data (air temperature and precipitation) are also included on the plot. Figure 10 is a plot of the data selected in Figures 8 and 9.

Raw resistivity data may be downloaded directly from the website and evaluated at the discretion of the HRR Data Evaluator. This is performed from Screen 2 (Figure 6). Clicking on the 'Download raw data to Excel' icon in the 'Export Data to Local Computer' block will bring up a screen (not shown) that permits downloading data, including weather data (future). The time period for raw data is entered on this screen, the raw data downloaded in Excel™ format, and plotted for review.

The website is monitored routinely by the subcontractor. Should a problem be noted they can evaluate the HRR system hardware to determine if there is an equipment problem. The subcontractor may also be notified by the TFC to investigate a potential equipment error. If there is an equipment problem the data files could have erroneous data. In this case the subcontractor may need to modify the data files as practical using interpolation to minimize impact of erroneous data on the 24-hour rolling average number.

Figure 8. AutoView™ Website Screen 4

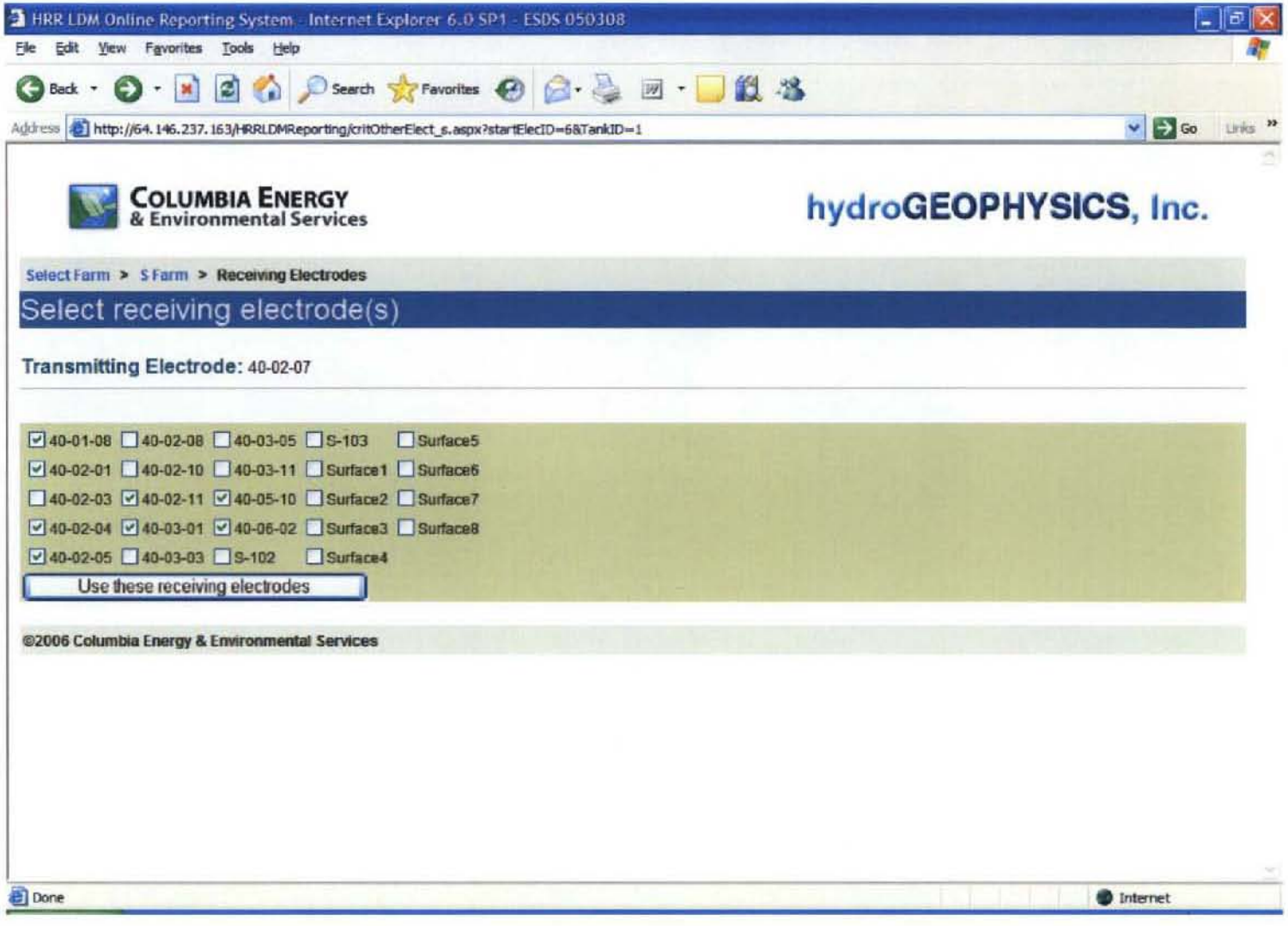

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Figure 9. AutoView™ Website Screen 5

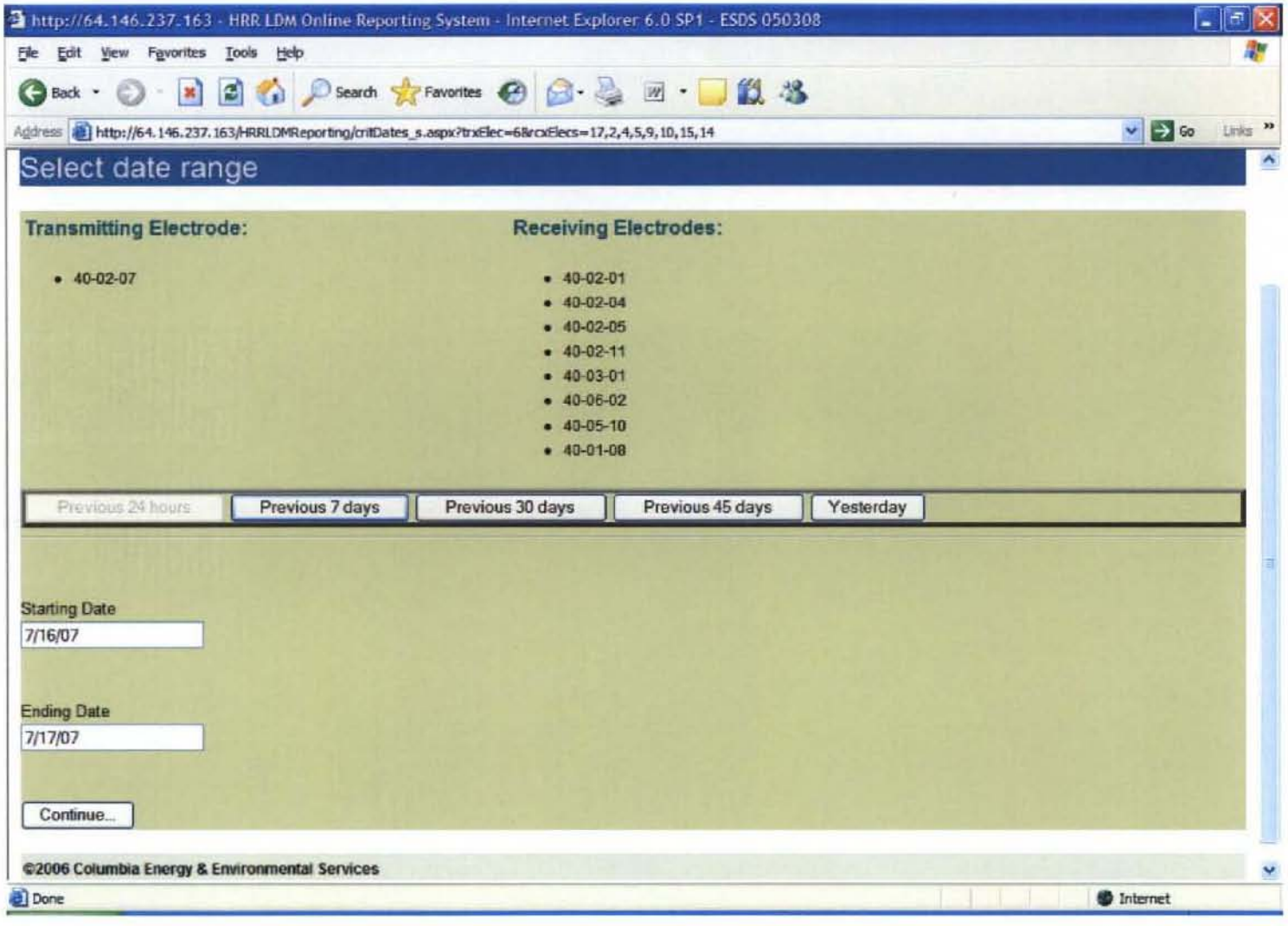

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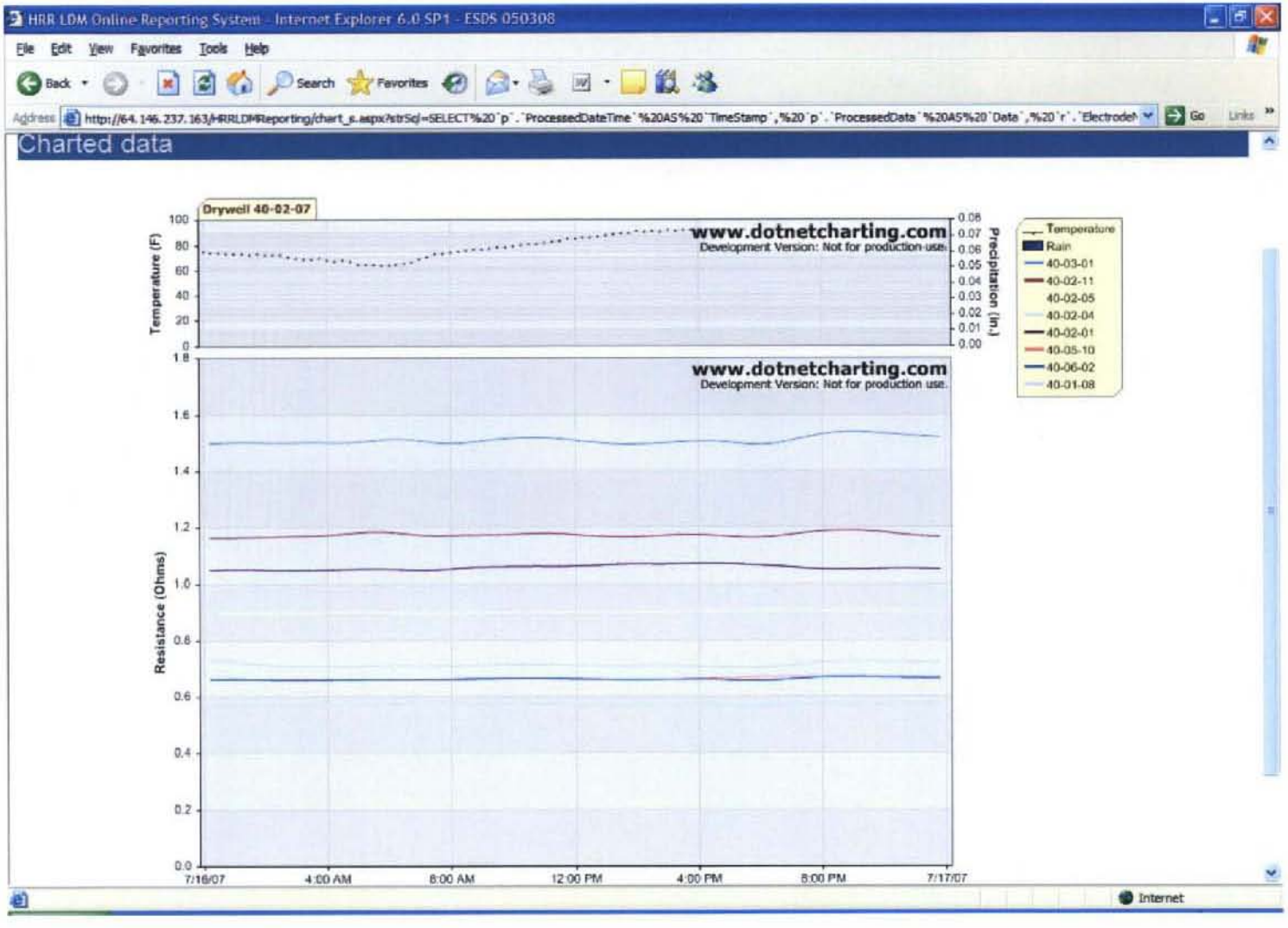
Figure 10. Example of Processed Data Plot



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Recent status reports providing subcontractor information related to equipment operation are available from the website via Screen 2 (Figure 6).

6.2 Leak Detection Data Review

The data review process consists of reviewing the HRR data for data trends away from the baseline. The latest data may be reviewed any time from the website. See Section 7.2 for minimum required data review frequency. There is no one data trend that automatically indicates a tank is or is not leaking. Each change has to be evaluated and a decision made as to whether the change has a reasonable potential for being caused by a tank leak.

Leak detection data review may entail use of WTT, WTW, or in limited circumstances WTS data. The automated data processing software uses the WTT electrode pair data as the primary means of leak detection. This coupling provides the "mise-a-la-masse" (electrical connection with the tank waste) data pair expected to be the most sensitive to changes in the soil adjacent to a tank resulting from a tank leak.

WTW data are used for leak detection when the waste level in a tank has been lowered to the point where the bottom of the tank electrode is exposed, or if the connection wire to the tank electrode is out of service. If the bottom of the tank electrode is exposed, WTT data can no longer be used for data review unless electrical continuity data are documented that show the tank electrode is in electrical contact with the waste via a different path.

Any WTS electrode data are used for information at the discretion of the HRR data evaluator. Experience has shown that WTS data are much more susceptible to precipitation and diurnal temperature changes. There are no surface electrodes planned for tanks on which HRR is projected to be used for the next few years, excluding those in service at S-102. If surface electrodes are used, the data can only be reviewed manually, no exceedances are calculated for WTS data.

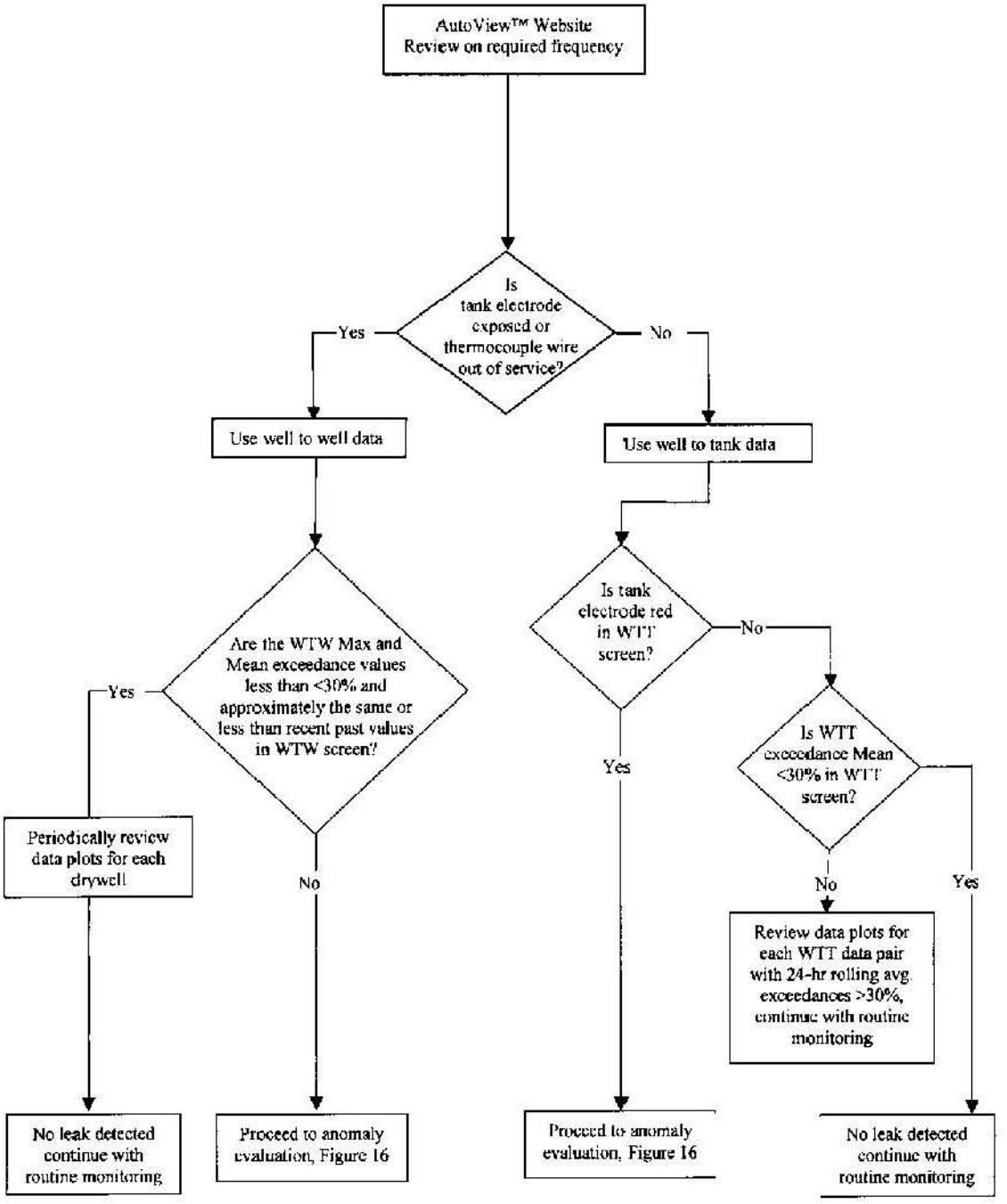
Figure 11 provides an overview of the data review process.

6.2.1 Data Review – Well-to-Tank Data

There are three leak detection review methods available for WTT data. They are:

- Observation of the AutoView™ website for tank electrode color and threshold exceedance information
- Observation of processed data plots
- Downloading raw data followed by preparation and review of raw data plots

Figure 11. Recommended Data Review Process



6.2.1.1 WTT Data Review - Tank Electrode Color Indication and Threshold Exceedance Values

This requires observation of the tank electrode color and threshold exceedance values displayed on the AutoView™ website in the WTT screen for the tank being reviewed. This is the quickest and easiest method of leak detection review. The actual data trends are not observed, but the color of the tank electrode and the threshold exceedance mean value indicates whether the data are trending away from the baseline.

The color indications for the tank electrode (in the WTT screen) and the threshold exceedance data interpretations are:

- If the tank electrode is green and the Mean WTT threshold exceedance value is <30% there is no leak detected.
- If the tank electrode is green but the Mean WTT threshold exceedance value is ≥30% the WTT data may be trending away from the baseline and data review is advised.
- A red indication or a Mean WTT threshold exceedance value ≥50% means WTT resistivity data show a statistically significant trend away from the baseline that must be evaluated.

It is expected that occasional red indications for the tank electrode and drywell icons will occur due to the nature of the HRR data variation, even with the filtering and smoothing done by the raw data to processed data conversion.

Leak detection data review using the website tank electrode color and threshold exceedance Mean value in WTT mode requires:

1. A qualified person review the AutoView™ website WTT screen,
2. Observe the color indicated for the appropriate tank electrode and the appropriate threshold exceedance Mean value,
3. Record this observation, and,
4. Perform any additional steps required by implementing procedures.

6.2.1.2 WTT Data Review - Processed Data Plots

Leak detection review by viewing of WTT processed data plots is a manual review of resistivity data plots instead of relying on the automated data processing generated tank electrode color and Mean exceedance values. Leak detection evaluation using processed data plots may be selected at the discretion of the HRR Data Evaluator.

Leak detection data review using processed data plots requires:

1. A qualified person review the AutoView™ website WTT screen,
2. Prepare and observe processed data plots as necessary,
3. Make an evaluation based upon the processed data plots,
4. Record this evaluation, and,
5. Perform any additional steps required by implementing procedures.

The guidelines used for data plot evaluation are:

1. If the data trend (slope of data line) is approximately zero, the data do not show evidence of a tank leak.
2. If the data trend wanders up and down over a relatively short period, (for the purpose of this document this is assumed a nominal daily or less period) but the average slope over the time is approximately zero, the data are assumed to not show evidence of a tank leak.
3. If there is an average zero slope followed by a step increase or decrease in the data followed by an average zero slope at the changed resistivity value, the data are assumed to show no reasonable evidence of a tank leak, but review is recommended to try and determine the cause of the step change. (Step changes in the resistivity were noted a number of times during the S-102 leak injection test, but not very often since. These were probably due to starting or stopping of locally grounded electrical equipment.)
4. If the data trend increases or decreases steadily without returning to the previous nominal value, this could be a potential leak and further evaluation is required.

Figure 10 is an example of data trends which per the first guideline are interpreted to mean there is no evidence of a tank leak. Figure 12 is an example of data trends which per the second guideline are interpreted to mean there is no reasonable evidence of a tank leak.

Figure 13 is an example of what a data trend from a leaking tank may look like. Figure 13 is the raw data from the first S-102 leak injection test. Under leaking tank conditions the resistivity response could be either an increase, as shown in Figure 13, or a similar plot where the resistivity decreases. There has not yet been a tank monitored by an HRR system that has been known to leak during waste retrieval, so it cannot be stated exactly what the data trend may look like for a leaking tank. The data response in Figure 13 is similar to that seen during leak injection test periods of the Mock Tank tests. The system geometries used during the Mock Tank testing and during the leak injection test attempted to simulate to the degree practical an underground storage tank leaking a salt solution, but neither geometry closely approximated a buried 75 ft. diameter tank encased in concrete with drywells around it used as HRR electrodes. The predominant change looked for as indicative of a potential leak is a continual data trend up or down which does not return to its nominal original level. Such a trend may be indicative of an actual change in soil resistivity in the region monitored by the electrodes.

See Section 6.2.2.2 on WTW processed data review for additional examples of WTT response during the entire S-102 leak injection testing period.

Figure 12. Example of Variable Resistivity With Nominal Zero Slope Trend.

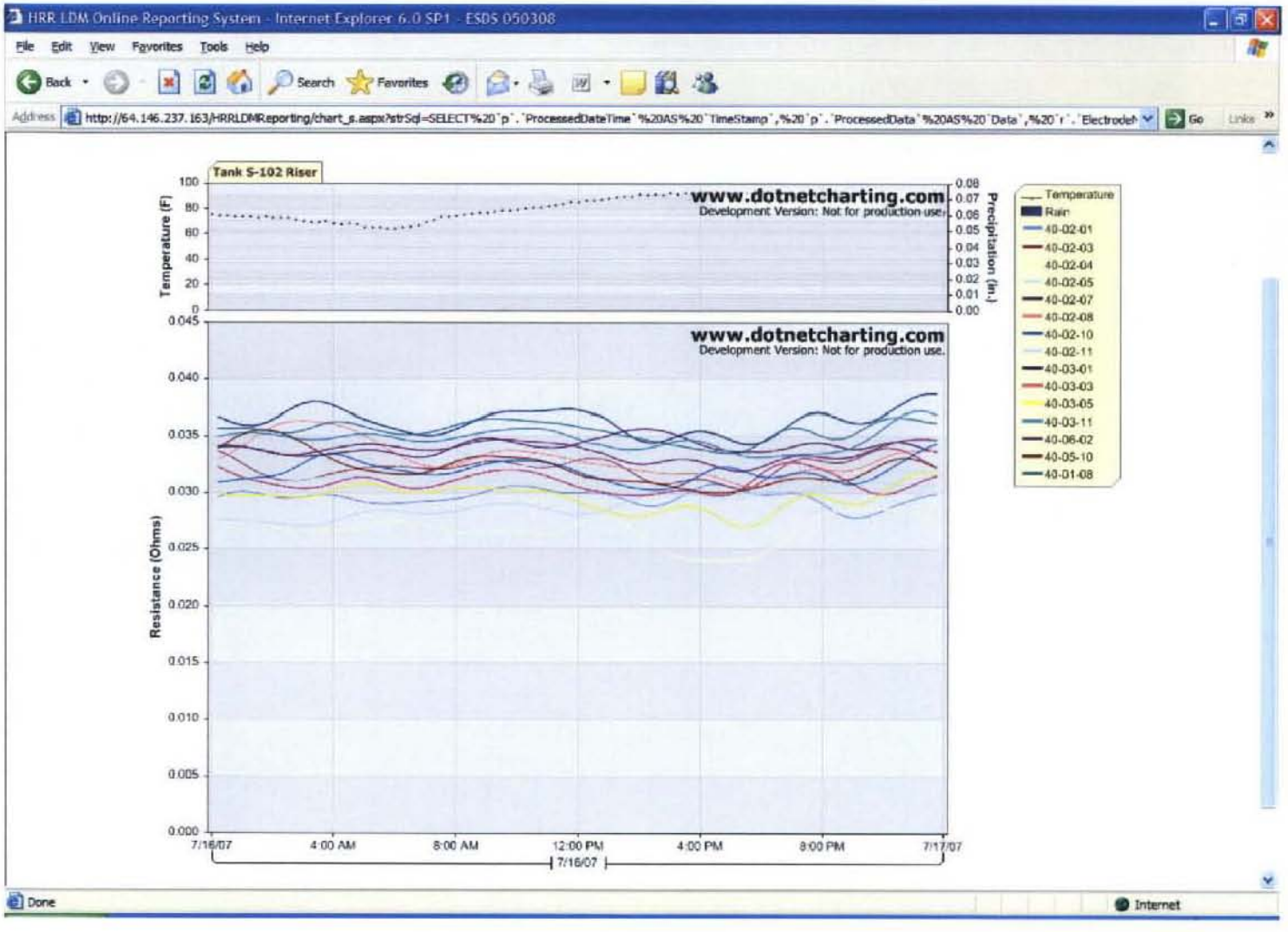
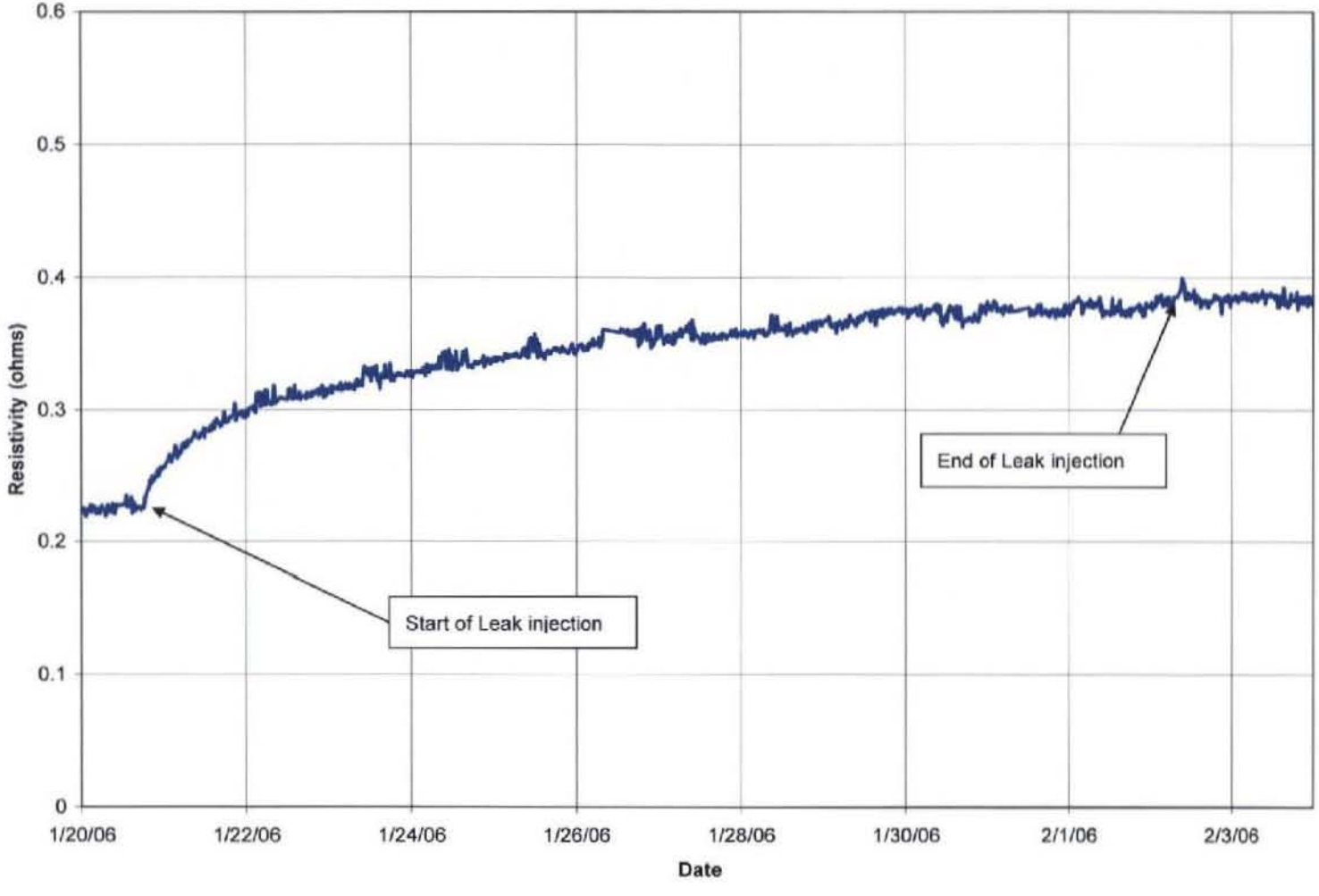


Figure 13. Plot of WTT Resistivity Trend during First S-102 Leak Injection Test



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6.2.1.3 WTT Data Review - Raw Data Plots

Leak detection review by evaluation of WTT raw data plots is a subjective manual review of resistivity data plots similar to WTT processed data review. Leak detection review using raw data plots may be selected at the discretion of the HRR Data Evaluator. Raw data review is usually selected when processed data are unavailable for a certain period, or it is desired to observe unprocessed data.

Leak detection data review using raw data evaluation requires:

1. A qualified person review the AutoView™ website WTT screen,
2. Download the raw data,
3. Prepare plots of the raw data,
4. Make an evaluation based upon the raw data plots,
5. Record this observation, and,
6. Perform any additional steps as required by implementing procedures.

The same guidelines and discussion in Section 6.2.1.2 on WTT processed data review apply to WTT raw data review.

6.2.2 Data Review – Well-to-Well Data

The WTW data are used for leak detection when the WTT data can't be used, or when selected by the HRR Data Evaluator. The WTW electrode data must be used for leak detection when the tank electrode is no longer in contact with tank waste and electrical resistance data are not available to show electrical continuity between the tank electrode and the waste via some other route.

There are three leak detection review methods available for WTW data. They are:

- Observation of the AutoView™ website for WTW threshold exceedance information
- Observation of processed data plots
- Downloading raw data followed by preparation and review of raw data plots

6.2.2.1 WTW Data Review - Threshold Exceedance Values

This requires observation of the threshold exceedance values displayed on the AutoView™ website in the WTW screen for the tank being reviewed. The tank electrode color is not used in the WTW screen. An increase trend in the threshold exceedance Max and Mean compared to past Max and Mean values is investigated by reviewing processed or raw data plots.

Leak detection data review using the threshold exceedance Max and Mean values in WTW mode requires:

1. A qualified person review the AutoView™ website WTW screen
2. Observe the WTW Max and Mean exceedance values,

3. Record this observation,
4. Investigate any above average reading trends when compared to past data for selected electrode pairs
5. Periodically review processed or raw data plots in addition to the Max and Mean exceedance values,
6. Perform any additional steps required by implementing procedures.

Both the Max and Mean values are reviewed for WTW data because if the WTW data are less sensitive to a leak compared to WTT data it is possible for only a few drywells to show a response to a leak, especially if the leak location was on the side of a tank. The average WTW exceedance value for all WTW data pairs could still be reasonably low while the average for one or two pairs was high due to the leak. If only the Mean values were looked at routinely the detection of a leak could be delayed.

In addition to checking both the Max and Mean values, if the WTW data are not as sensitive to a tank leak as the WTT data there might be a small trend change in the WTW data plots that could be missed when only viewing the WTW Max and Mean exceedance values. When WTW only data are used for leak detection the WTW Max and Mean exceedance values should not be used exclusively, i.e., WTW processed or raw data plots should be reviewed periodically as described in Sections 6.2.2.2 or 6.2.2.3 to provide additional confidence in the data review, even if there are no change in the WTW Max and Mean exceedance values. The frequency for this periodic plot review is determined by the HRR Data Evaluator.

6.2.2.2 WTW Data Review - Processed Data Plots

Leak detection review by viewing of WTW processed data plots is a manual review of resistivity data plots instead of relying on the WTW Max and Mean exceedance values. Leak detection evaluation using processed data plots may be selected at the discretion of the HRR Data Evaluator.

Leak detection data review using processed data plots requires:

1. A qualified person review the AutoView™ website WTW screen,
2. Prepare and observe processed data plots as necessary,
3. Make an evaluation based upon the processed data plots,
4. Record this evaluation, and,
5. Perform any additional steps required by implementing procedures.

The guidelines used for data evaluation and plot interpretation are the same as given in 6.2.1.2 for WTT processed data plots. However, WTW data plots are expected to show less sensitivity to a tank leak than WTT data plots, at least initially following a leak, so data should normally be evaluated over a duration long enough to notice a trend. This period should be at least a week until there is more experience obtained with WTW data review.

Figures 14 and 15a through 15d are provided to enable the reader to subjectively compare WTT and WTW data resistivity changes for data from selected data pairs during the S-102 leak injection testing period.

Figure 14 shows the layout of the 15 drywells used for the S-102 leak injection test. Six selected drywells are highlighted (40-03-03, 40-02-11, 40-02-08, 40-03-01, 40-02-03, and 40-02-04), along with the simulated 'tank' (drywell 40-02-10). These six drywells are located approximately 18, 37, 38, 42, 82 and 102 ft. respectively from the simulated 'tank'. Figure 14 shows 4 dashed lines indicating 4 of the data pairs between the selected drywells. These data pairs are 40-03-01 to 40-02-04, 40-03-03 to 40-02-03, 40-02-08 to 40-02-11, and 40-03-03 to 40-02-11.

Figures 15a to 15d compare the percent change in resistivity for each drywell pair (WTW data) with the percent change in resistivity for each of the two drywells in the pair to the 'tank' (WTT data), as a function of the volume of leak simulant solution injected into the ground.

These figures show that the initial response to a leak was more obvious in all cases when observing the WTT data. For some of the pairs the WTW change eventually overtook the WTT change. Regardless of whether or not the WTW response eventually overtook the WTT response, the WTW change was eventually observable for most of the selected data pairs.

Figures 15a to 15d are raw data plots. Processed data plots would show the same trend, but be smoother.

6.2.2.3 WTW Data Review - Raw Data Plots

Leak detection review by evaluation of WTW raw data plots is a subjective manual review of resistivity data plots similar to WTW processed data review. Leak detection review using raw data may be selected at the discretion of the HRR Data Evaluator. Raw data review is usually selected when processed data are unavailable for a certain period, or it is desired to observe unprocessed data.

Leak detection data review using raw data evaluation requires:

1. A qualified person review the AutoView™ website WTW screen,
2. Download the raw data,
3. Prepare plots of the raw data,
4. Make an evaluation based upon the raw data plots,
5. Record this observation, and,
6. Perform any additional steps as required by implementing procedures.

The same guidelines and discussion in Section 6.2.2.2 on WTW processed data review apply to raw data review.

Figure 14. Location of Drywells Used During S-102 Leak Injection Test

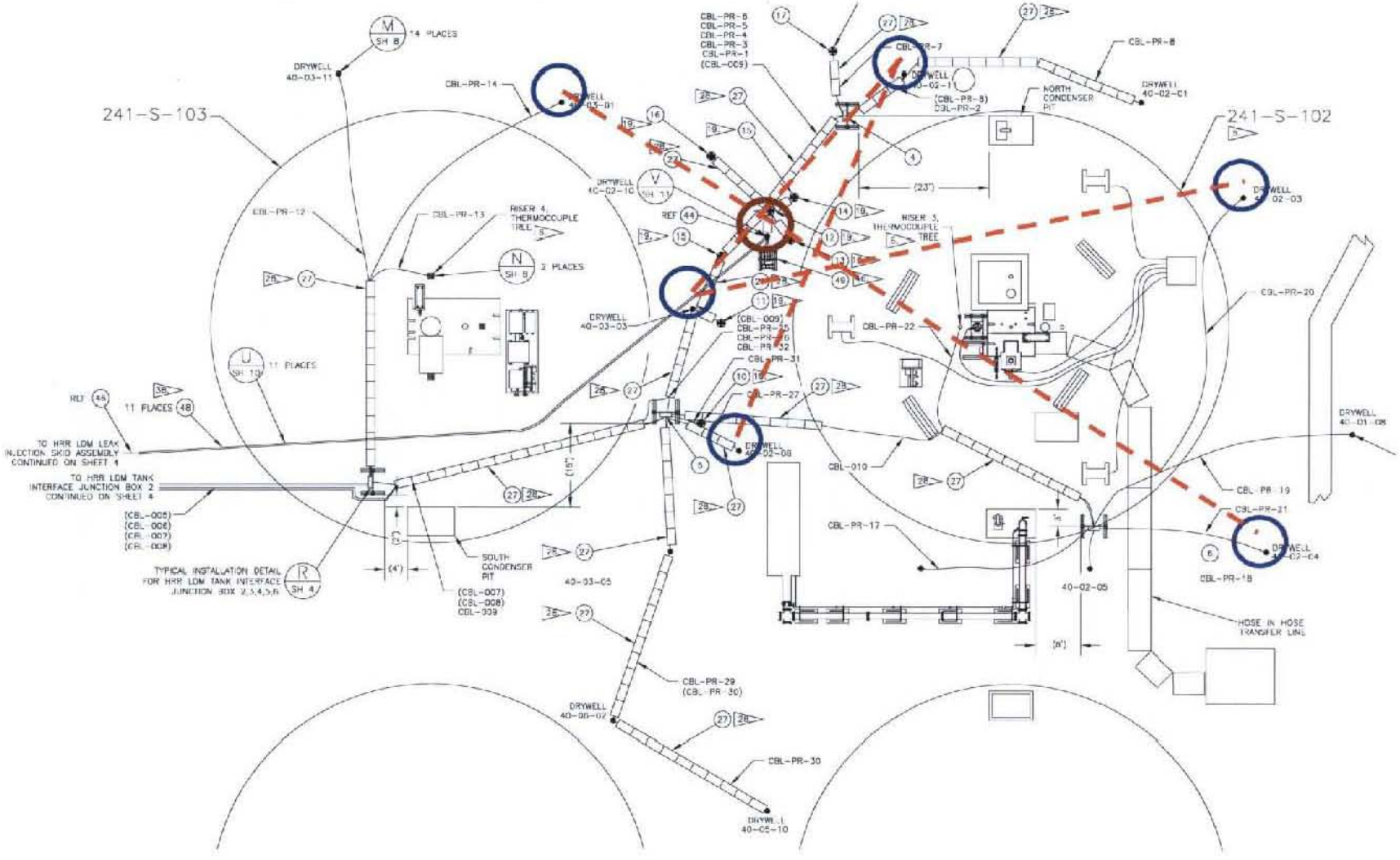

Figure 15a. Comparison of Change in Resistivity for Drywell Pair 40-02-08 to 40-02-11 with Change in Resistivity for Each Drywell to Injection Well 'Tank' during S-102 Leak Injection Testing

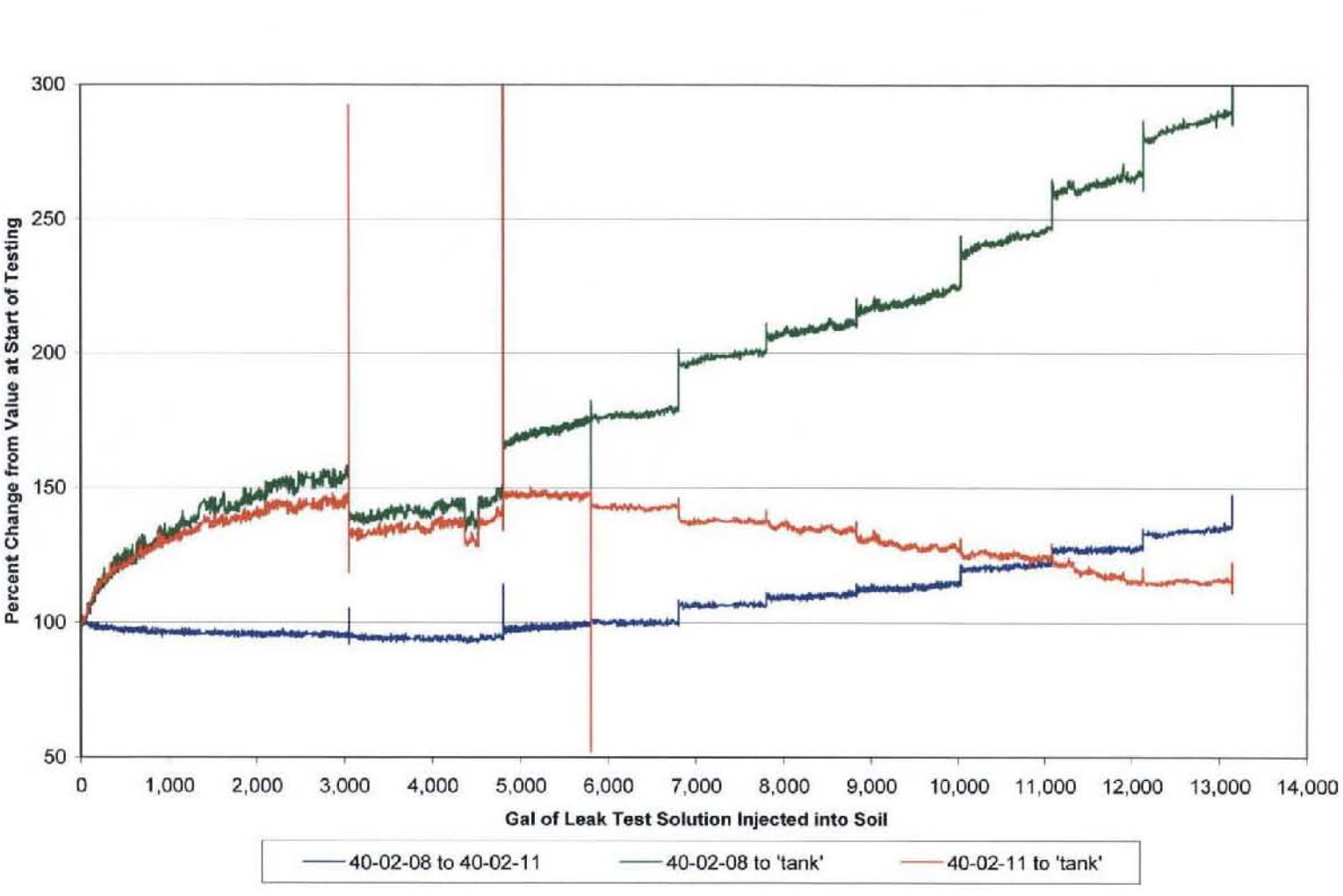

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Figure 15b. Comparison of Change in Resistivity for Drywell Pair 40-02-03 to 40-03-03 with Change in Resistivity for Each Drywell to Injection Well 'Tank' during S-102 Leak Injection Testing

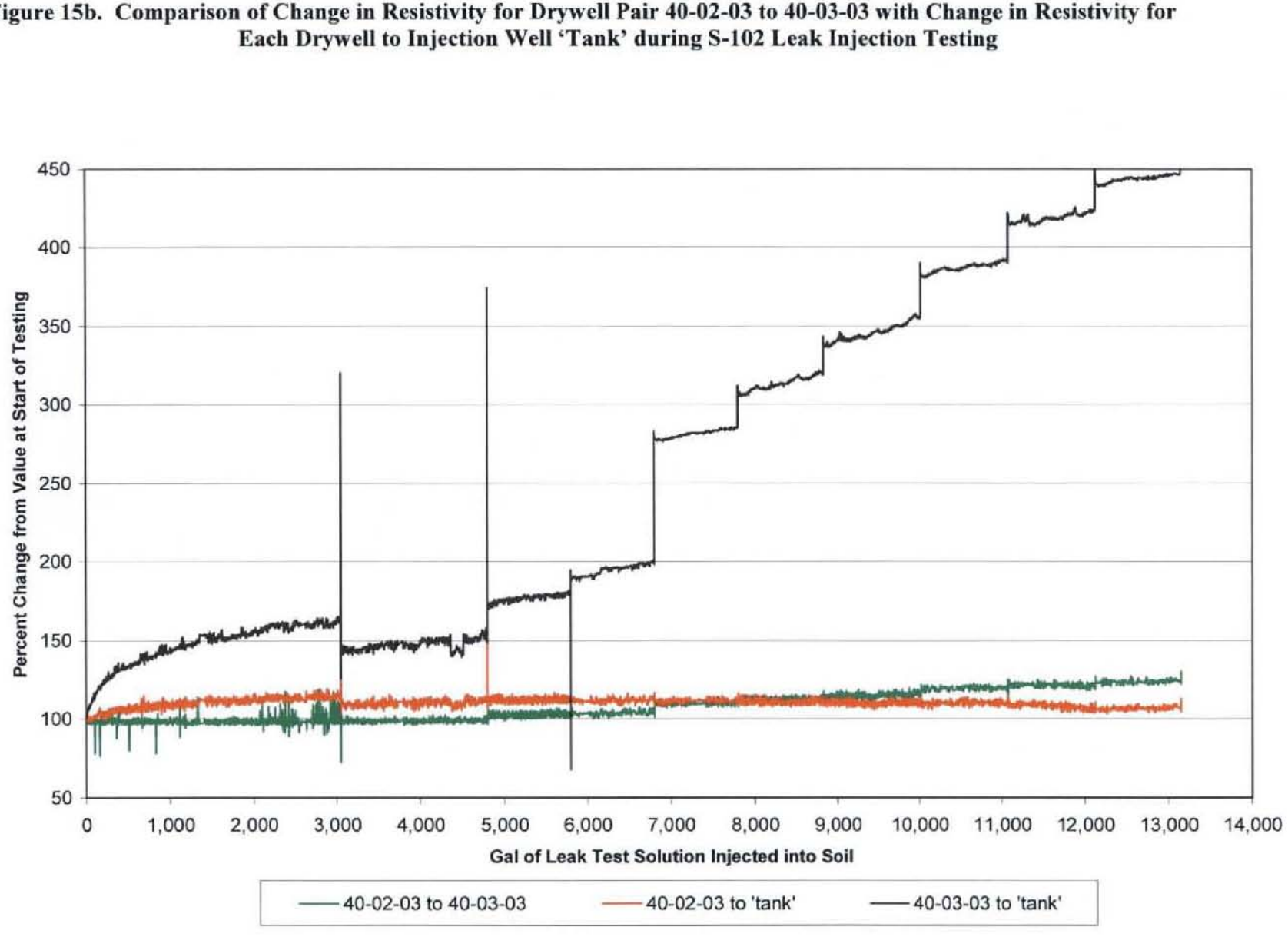

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Figure 15c. Comparison of Change in Resistivity for Drywell Pair 40-02-04 to 40-03-01 with Change in Resistivity for Each Drywell to Injection Well 'Tank' during S-102 Leak Injection Testing

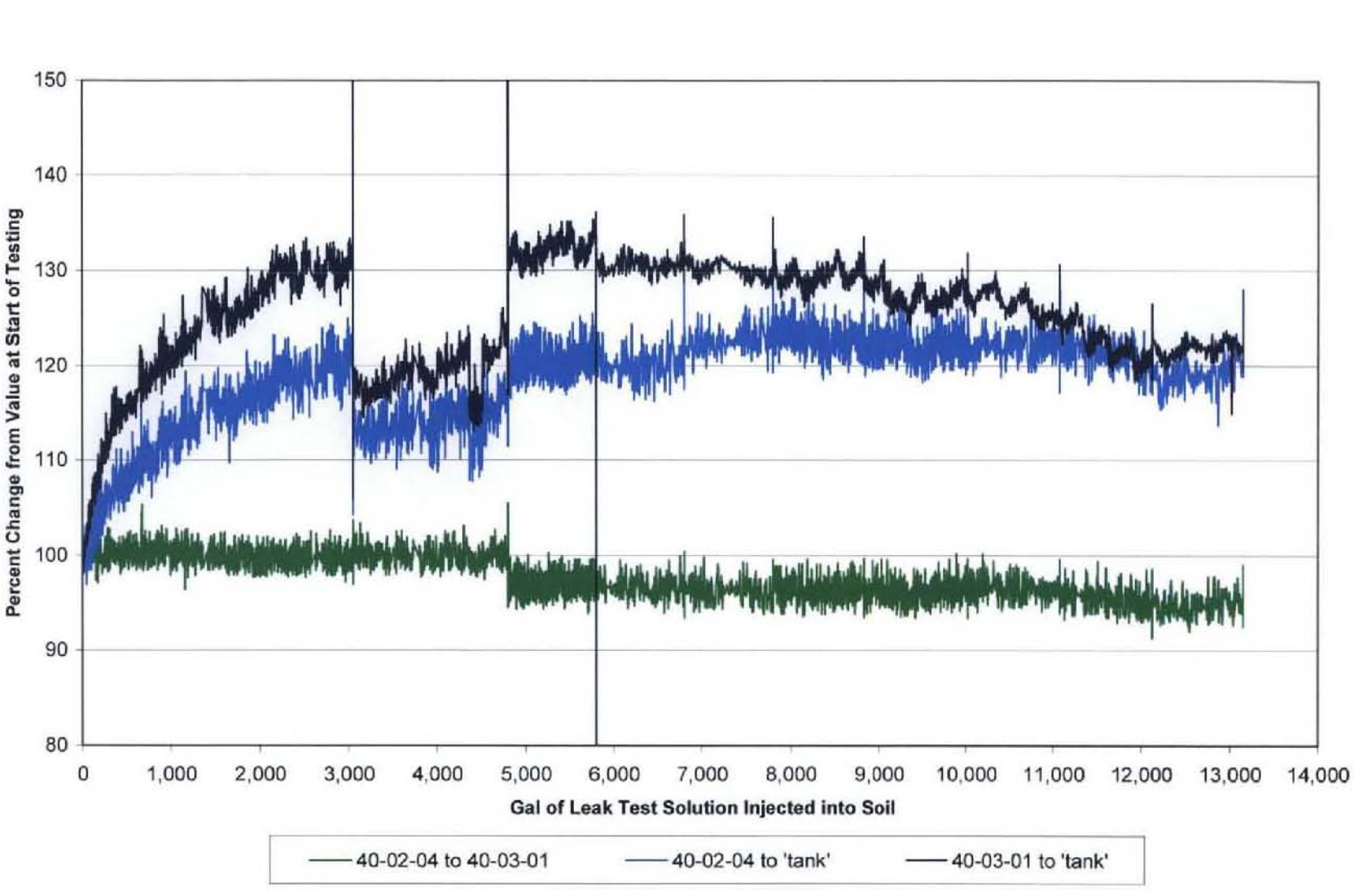

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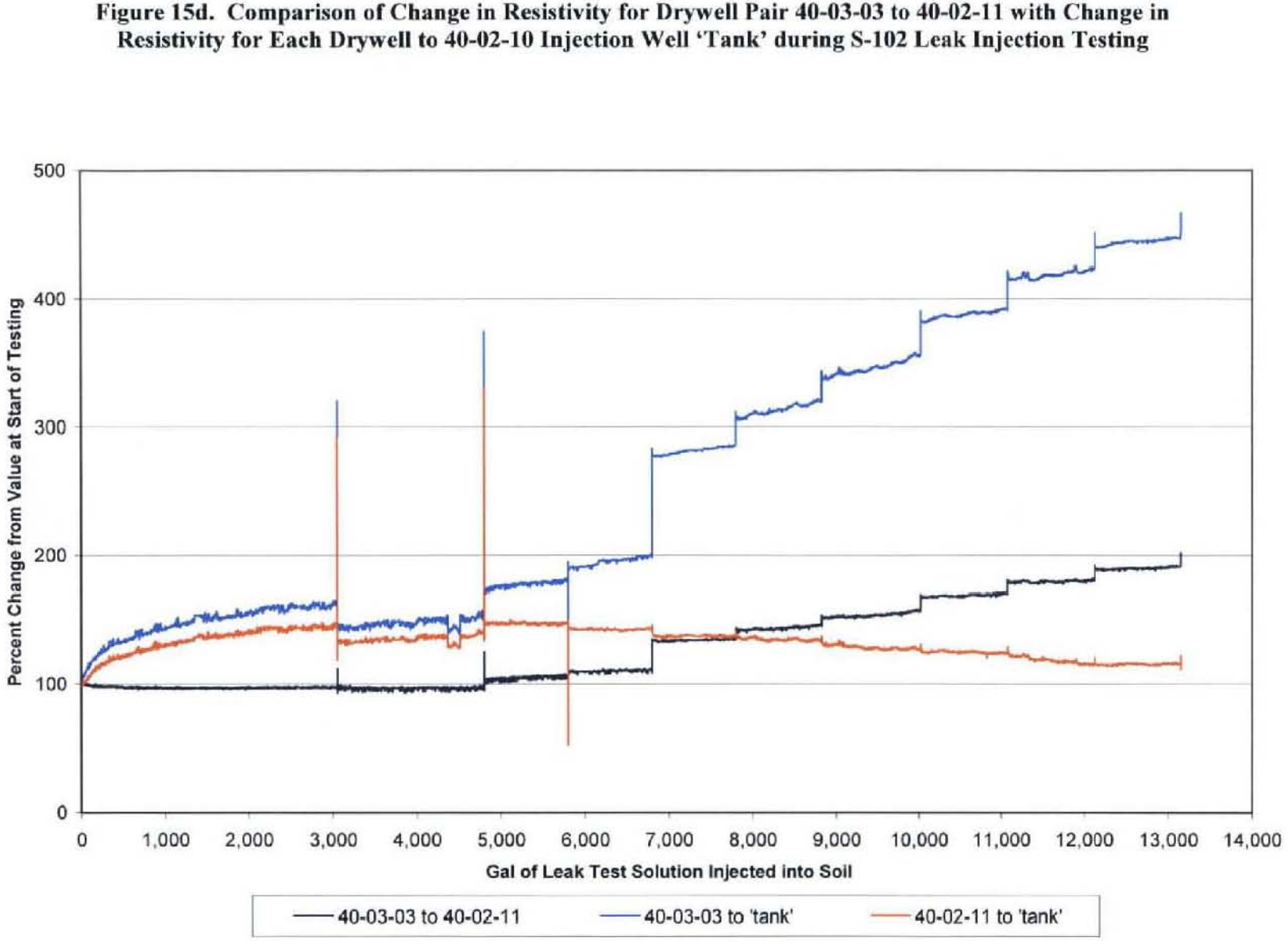
Figure 15d. Comparison of Change in Resistivity for Drywell Pair 40-03-03 to 40-02-11 with Change in Resistivity for Each Drywell to 40-02-10 Injection Well 'Tank' during S-102 Leak Injection Testing



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6.2.3 Data Review – Well-to-Surface Electrode Data

There is no WTS-only data review. Surface electrodes may be used where desired to provide WTS resistivity information in areas where additional resistivity information is desired. If WTS data are available they can be used at the discretion of the HRR Data Evaluator to prepare plots for manual review.

6.3 Anomaly Evaluation

An anomaly exists either when the automated data software indicates the action level has been exceeded based upon tank electrode color in the WTT screen, or an anomaly is judged to exist by the HRR Data Evaluator upon review of any HRR data.

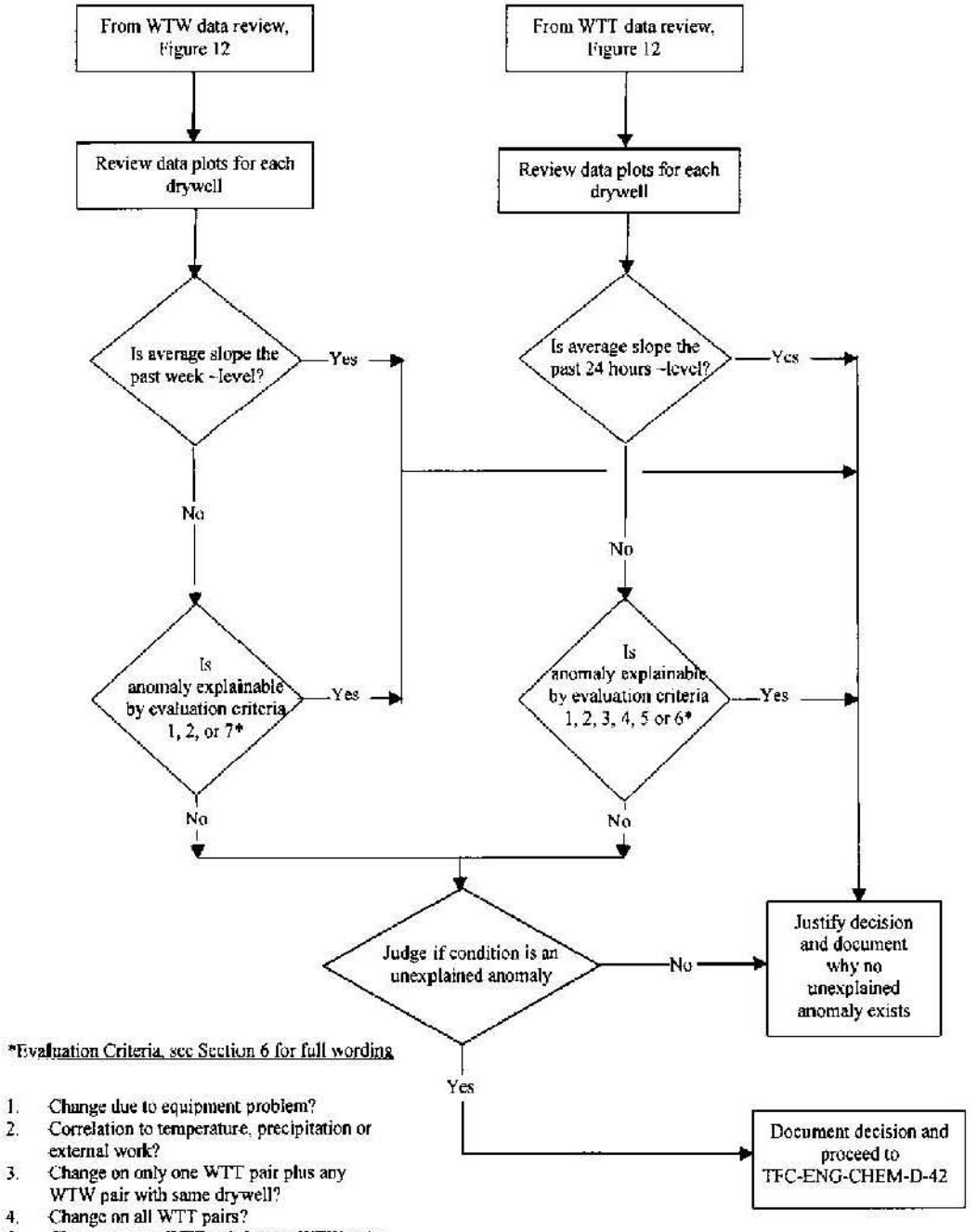
Figure 16 provides the recommended process for anomaly evaluation. Anomaly evaluation is only performed by an HRR Data Evaluator.

The first step in the anomaly review process is to review the data. If the data vary but show no evident overall slope change, such as in Figure 12, the anomaly is explained by the number of fluctuations being interpreted by the data processing software as outside the baseline change threshold.

If there is a change to the average slope during the period there are up to 7 criteria to consider. Criteria 3 through 6 are for WTT data only. These may be evaluated in any order. These are:

1. Are there any obvious equipment problems, either with the HRR equipment or startup/shutdown of electrical/mechanical equipment in the area?
2. Is there a correlation to recent temperature changes (including diurnal variations) or precipitation events, or was there some other change that could have altered the electrical noise background?
3. If only one WTT pair shows a change, plus there is a change on one or more WTW pairs associated with the same drywell, the problem is likely an electrical issue associated with that drywell.
4. If the change is evident on all WTT pairs the problem is likely an electrical issue associated with the tank electrode.
5. Is the change seen on only one WTT pair but no WTW combinations with that drywell?
6. Is the change seen on more than one WTT pair, but not all, either with or without showing on associated WTW pairs?
7. If forward and reciprocal WTW information are similar for a drywell pair, the equipment for that drywell pair can be assumed to be working properly. If the forward and reciprocal WTW information are not similar, a review of the status of the equipment in the field is recommended to try and determine the source of the change.

Figure 16. Recommended Anomaly Evaluation Process



*Evaluation Criteria, see Section 6 for full wording

1. Change due to equipment problem?
2. Correlation to temperature, precipitation or external work?
3. Change on only one WTT pair plus any WTW pair with same drywell?
4. Change on all WTT pairs?
5. Change on one WTT pair but no WTW pairs with same drywell?
6. Change on > one but < all WTT pairs?
7. Are forward and reciprocal data for affected WTW pairs dissimilar?

If criteria 1 or 2 explain the change, the anomaly is explained and the tank is assumed to not be leaking. If there appears to be some correlation to temperature or precipitation events for criterion 2, but the change is more than would be expected, the system should continue to be evaluated for a length of time as deemed necessary by the HRR Data Evaluator.

If criteria 3 or 4 explain the change, the anomaly is probably explainable and the tank assumed to not be leaking, but a review of the status of the equipment in the field is recommended to try and determine the source of the change. See paragraph below on limitations to use of criteria 3 through 6.

If criteria 5 or 6 can be answered 'Yes' the change could be an unexplained anomaly and the evaluation process must continue.

Criterion 7 uses reciprocal WTW data to help validate whether soil conditions are changing. Reciprocal data means similar information is shown for drywell pair A-B when A is the transmitting electrode and B the receiver, as is evident when B is the transmitting electrode and A the receiver. Criterion 7 is not applicable to WTT data since there are no reciprocal tank electrode to drywell data pairs, i.e., the tank electrode is not used as a transmitting electrode. The reason for this is discussed in RPP-32478. If criterion 7 shows no similar reciprocal values for all WTW data pairs in question, the anomaly is explained and the tank is assumed to not be leaking. If any of the WTW data pairs in question show similar reciprocal values the change could be an unexplained anomaly and the evaluation process must continue.

Criteria 1 and 2 are based upon subcontractor experience and upon experience gathered to date with the HRR operations at tank farms.

Criteria 3 through 6 were developed by the subcontractor to aid in the interpretation of WTT data during the S-102 leak injection test since, unlike with WTW pairs, there are no reciprocal data for WTT pairs. While these criteria proved consistent for use during the leak injection test there is no certainty they will always be applicable for leak detection during use on a tank during retrieval. Application of criteria 3 through 6 requires the HRR Data Evaluator to make an informed judgment about the cause of an anomaly. Criteria 3 through 6 should not be applied to assume a tank isn't leaking without a thorough review of the available data which enables a justifiable decision that the anomaly is due to some other cause than a tank leak.

Criterion 7 is based upon considerable subcontractor experience with HRR type systems.

If none of the criteria rule out an unexplained anomaly a decision has to be made by the HRR Data Evaluator as to whether an unexplained anomaly exists. This is a judgment decision as to whether the tank leak assessment procedure, TFC-ENG-CHEM-D-42, should be entered.

The decision on whether an unexplained anomaly exists is subjective. There may be inconclusive evidence associated with any of the criteria, or there may be factors not listed in this document which could explain the changing trend. There may be other data such as a stable tank Enraf gauge liquid level reading, beginning before the anomaly appeared, that shows the tank isn't leaking.

The existence of an anomaly requires entering the anomaly evaluation process as shown in Figure 16. A documented decision signed by the HRR Data Evaluator is required for all anomaly evaluations. The documentation method shall be delineated in implementing procedures.

7 DATA REVIEW AND EVALUATION REQUIREMENTS

This section provides the upper level requirements for implementation of HRR for tank leak detection during SST waste retrieval operations. Details for HRR data review and evaluation are to be provided in appropriate implementing procedures.

7.1 Authorized Data Review Personnel

Requirements:

1. Leak detection data review by observation of the AutoView™ website tank electrode color indication and threshold exceedance mean values may be performed by any person authorized, and trained, to use the AutoView™ website.
2. Leak detection data review by interpreting processed or raw data plots may only be performed by an authorized HRR Data Evaluator.
3. Anomaly evaluations may only be performed by an authorized HRR Data Evaluator.
4. HRR Data Evaluators shall be trained, and shall be designated in writing.

Basis:

Due to the subjective nature of much of the data review and anomaly evaluation process, only qualified personnel shall be permitted to make an official review of HRR resistivity data or to evaluate that data for indication of a potential tank leak. A plan for training and designating authorized HRR Data Evaluators will be developed and implemented as part of the administrative implementation of HRR.

7.2 Leak Detection Data Review Frequency

Requirement:

1. The leak detection data review for an SST undergoing retrieval with an operable HRR leak detection system shall be performed at least once per calendar day during active waste retrieval operations. Active waste retrieval operations means operation of waste intruding mechanical equipment to remove waste from the tank or addition of liquid to the tank for the purpose of aiding waste removal. Operation of equipment for maintenance purposes where retrieval is not attempted, or the addition of liquid such as equipment flushes or line drainbacks are not active waste retrieval operations.
2. The HRR leak detection data review shall be documented.

Basis:

WAC 173-303.640 (6)(b)(ii) requires:

> *(b) The owner or operator must inspect at least once each operating day:*
>
> *(ii) Data gathered from monitoring any leak detection equipment (e.g., pressure or temperature gauges, monitoring wells)...*

Stipulation of a once per calendar day frequency for HRR leak detection data review during active retrieval operations meets the requirement to inspect the data at least once per operating day, and supports early leak detection for a tank undergoing waste retrieval.

The data review must be documented to provide auditable evidence the leak detection data review was performed. The documentation method will be specified in procedures as part of the administrative implementation of HRR.

7.3 Anomaly Evaluation Documentation

Requirement:

All anomaly evaluations shall be documented.

Basis:
Documentation is necessary for historical purposes to maintain the rationale for decisions made. The documentation method will be specified in procedures as part of the administrative implementation of HRR.

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