Evaluation of Background Metals Concentrations in Soils and Bedrock at CSSA

Section 1 - Introduction

1.1 - Purpose of Report

This report describes the field methods, results, and conclusions of the investigation conducted to determine background metals levels in soils and Glen Rose Limestone bedrock at Camp Stanley Storage Activity (CSSA) in Boerne, Texas. This work was performed by Parsons, Inc. (Parsons), under contract to the United States Air Force (USAF) Air Mobility Command (AMC).

This document represents an amendment to the Revised Evaluation of Background Metals Concentrations in Soils and Bedrock (Parsons ES, June 1997). The previous evaluation was initially revised due to the questionable practices of the laboratory that analyzed the majority of the background soil samples used in the evaluation. Further revisions were made based on decisions to combine data from eight soil types (as defined by the U.S. Department of Agriculture) into one large group of soil data, update the statistical methodology to meet current standards and accepted practices, and augment the background data set for Glen Rose Limestone.

1.2 - Project Authorization

Parsons was contracted by AL/OEB to perform investigations at waste management units at CSSA under contract number F33615-89-D-4003, delivery order 126. Subsequent revisions to this report have been made under contract F11623-94-D-0024 with AMC, delivery order RL17 due to questionable practices by the laboratory.

1.3 - Regulatory Basis

Current closure activities at solid waste management units (SWMUs) at CSSA are being conducted in accordance with federal and state regulations (40 Code of Federal Regulations (CFR) 265 Subpart G and Title 30 Texas Administrative Code (TAC) Chapter 335 Subchapter S, respectively). The Texas Risk Reduction Rules, promulgated in 30 TAC 335 Subchapter S, establish comprehensive, risk-based standards for remediation of soil, groundwater, surface water, and air contamination. These rules apply to all remedial actions undertaken in response to a release or spill of a solid waste or hazardous substance. There are three alternate levels of environmental remediation:

1. Risk Reduction Standard 1 (RRS1): Closure/remediation to background;
2. Risk Reduction Standard 2 (RRS2): Closure/remediation to health-based standards and criteria; and
3. Risk Reduction Standard 3 (RRS3): Closure/remediation with controls.

Although the closure standard to be selected at each SWMU has not yet been determined, RRS1 (clean closure) will generally be the first choice. Closure under RRS1 requires comparison of site contaminant levels to facility background levels or practical quantitation limits (PQLs), whichever is higher, for all environmental media. This document provides the background metals concentrations for soils and Glen Rose Limestone at CSSA.

1.4 - Objectives and Scope

The objective of the background sampling and analysis is to provide a validated data set and statistically derived Upper Tolerance Limits (UTLs) for soils and the Glen Rose Limestone for use in SWMU closures or other work deemed necessary by CSSA. To accomplish this objective, the following tasks were performed:

- Established the background sample sets and collected samples from each set;
- Performed validation of the background sample analytical data;
- Statistically evaluated the analytical data for each sample set; and
- Presented the results of the background sampling and analysis in this document.

This report is intended to be used as a reference document for future closure or other environmental activities at the post. The ultimate purpose of this report is to establish background metal concentrations for soils and the Glen Rose Limestone at CSSA.

Section 2 - Methodology

This section describes the procedures used in determining data needs and collecting, verifying, validating, reviewing, and evaluating data.

Overview

The evaluation of background metals levels in soils and bedrock at CSSA was initiated in early 1994 when ten samples each of background bedrock and soil were collected in association with closure of CSSA's SWMU F-14. These ten samples (SS1-SS10) were analyzed by NET Laboratory for nine metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and zinc) and results were used to determine a representative background concentration for bedrock and one for soil. At the time that these samples were collected, CSSA was not required to determine background concentrations per soil type. Therefore, samples SS1 through SS10 were collected without regard to soil type.

Later in 1994, regulatory agencies required that CSSA individually evaluate each of eight soil types occurring at the facility, as well as the one rock type (Glen Rose Limestone) which outcrops at the facility. At that time, the only ongoing investigation was at the B-20 OB/OD area, where six metals (arsenic, barium, cadmium, chromium, lead, and mercury) levels were being evaluated. Three soil types (Krum Complex, Crawford and Bexar stony soils, and Brackett-Tarrant association) occur at the B-20 site; therefore, additional background soil samples were collected for these three soil types for the six metals of concern. A total of 25 additional samples (SS11-SS35) were necessary to create a set of ten samples for each of the three soil types. These additional samples were analyzed by Terra Laboratory and the results were used to determine representative background levels of arsenic, barium, cadmium, chromium, lead, and mercury in Krum Complex, Crawford and Bexar stony, and Brackett-Tarrant association soils.

When investigations of several other SWMUs were initiated in 1996, additional background sampling was conducted to provide sufficient data for determining background levels of the previously identified five metals (arsenic, barium, cadmium, chromium, lead, and mercury), as well as copper, nickel, and zinc for the Glen Rose Limestone and all eight soil types at CSSA. A minimum of ten samples of each soil type are required for a statistically valid evaluation. The additional sampling included 45 samples (SS36-SS80) analyzed for eight metals, and 25 samples (SS11-SS35) for copper, nickel, and zinc. These samples were analyzed by ITS Laboratory and results were used to determine background concentrations for each of the eight metals in eight soil types and bedrock.

In November 1999, Parsons recollected samples analyzed by ITS Laboratory. Background samples were collected in the same locations as those collected previously and samples were identified with the same ID number; however, all rework samples were preceded by "RW" to distinguish them as rework samples (i.e., "RW-BKGR-SS11). The revised background sample analytical program is summarized in **Table 2.1**.

In addition to the resampling to replace ITS Laboratory analytical results, ten additional Glen Rose limestone background samples were also collected to augment the data set for that unit. One background limestone sample was collected at each of ten locations labeled SB11 through SB20.

Preparation of the revised statistical evaluation (using the 1999 rework data) was initiated in 2001. At this time, the possibility of combining the data from eight soil types into one large group of soil data was considered. In addition, changes to the statistical methodology were considered to ensure that the report meets current standards and accepted practices. A letter notifying TNRCC of the planned changes was submitted on November 26, 2001, and CSSA met with TNRCC to discuss the planned changes on January 10, 2002. Arguments supporting combination of the data from eight soil types were presented in the letter, and included:

- All of the soil at CSSA is derived from one bedrock unit, the Glen Rose Limestone. Composition is not anticipated to vary significantly across the site. Soils consist of calcareous clay across the facility. Differences in soil types identified by the USDA are based primarily on slope and vegetative cover, not metals content.
- Statistically, combining the data from the eight soil types results in a more accurate representation of the true background upper tolerance limit (UTL) due to the larger data set (in most cases, 80 samples total vs. 10 samples per soil type). Pooling observations across soil types lowers estimates of the population variance which in turn lowers the UTL since the UTL is a function of the standard deviation and the tolerance coefficient. The coefficients are also smaller as a consequence of pooling the data.
- Remediation goals for SWMUs could not be practically applied using multiple soil types with different background levels. At sites where there are multiple soil types, each with dissimilar background UTLs, remediation goals across the site would vary.

Pooling of the data is justified if the data have the same population mean and variance. These assumptions were investigated by performing Analysis of Variance (ANOVA) evaluations, which test the hypothesis that there is no effect of soil type on mean metal concentrations. Hartley's Fmax test was used to assess the tenability of the ANOVA assumption that the variances of the metals concentrations were equivalent among soil types. Tests of these assumptions are presented in **Appendix C**.

2.2 - Background Sample Sets

The objective of this investigation is to establish background metals concentrations for the Glen Rose Formation and for CSSA soils. The data will be used as comparison criteria during future SWMU closures at CSSA. Analytical data for

samples collected during this investigation will provide background comparison levels for ongoing and future SWMU closure activities.

Existing background data for surface soils and subsurface soils have been used to the fullest extent possible. Ten background surface soil and ten subsurface rock (limestone) samples were collected in February 1994 as part of the F-14 site closure (ES, 1994), and twenty-five background samples were collected during the B-20 Remedial Investigation (Parsons ES, 1995). Since a minimum of ten samples of each soil and rock type are required for the statistics (as specified by the TNRCC), a total of 90 background samples were collected. The remaining forty-five samples were collected specifically for this evaluation. **Table 2.1** summarizes the analytical methods, laboratories, sample dates, and associated projects for the background sample collection.

The F-14 and B-20 data sets are described below:

- **F-14 Closure Investigation, February 1994 (ES, 1994)**. Soil samples BKGR-SS1 through BKGR-SS10 were collected from background locations shown in **Figure 3.1** (in pocket). One to two background samples were collected of seven different soil types: Brackett soils, Brackett-Tarrant association, Crawford and Bexar stony soils, Krum complex, Lewisville silty clay, Tarrant association, and Trinity and Frio soils. Soil samples were collected between 0.5 and 1.0 foot below ground surface, and background Glen Rose Formation samples were collected at various depths based on depth to limestone at each location. The depths ranged from 4.5 to 20 feet below ground level (bgl). Soil and rock samples were analyzed for metals by method SW6010, with the exception of nickel (by SW7520).

- B-20 Remedial Investigation, December 1994 (Parsons ES, 1995). Soil samples BKGR-SS11 through BKGR-SS35 were collected from background locations shown on **Figure 2.1**. These background samples consisted of three soil types: Krum complex, Crawford and Bexar stony soils, and Brackett-Tarrant association. These three soil types are found at the B-20 site. Samples were collected between 0.5 and 1.0 foot bgl and were analyzed for arsenic (SW7062); barium, cadmium, and chromium (SW6010); lead (SW7420 or SW6010); and mercury (SW7471). The report was submitted to TNRCC and EPA in September 1995 for review, and the results were used as a basis for additional work at the B-20 site in a plan of action submitted to the agencies dated 26 October 1995. TNRCC provided one comment regarding public notification, and EPA verbally approved the plan of action in a phone call to Parsons ES on December 12, 1995.

The nine metals for which background data are needed for SWMU closure comparisons at CSSA are arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and zinc. The nine metals were chosen based on known waste disposal records and process knowledge.

2.3 - Sampling Procedures

As stated previously, background samples were collected during two previous investigations, as well as during this evaluation. Sample collection and handling procedures during these three investigations were identical. However, laboratory analysis varied slightly because three laboratories were used. Furthermore, analytical methods and detection limits varied between labs.

Background sampling locations are shown in **Figure 2.1**. Soil types shown on this figure are based on the Bexar County Soil Survey (USDA, 1991). The field team leader and a representative of CSSA familiar with present and past property uses made the final determination of all sampling locations in the field. [Two samples, SS39 and SS60, have been omitted from the statistical calculations due to their proximity to recently discovered waste sites.] All background surface soil samples were collected at a depth of approximately 0.5 foot, as in previous investigations. The surface soil was cleared away with a decontaminated shovel or trowel. The sample was then collected with a decontaminated trowel into a stainless steel bowl. The soil was mixed to collect a homogeneous sample, and any rocks or vegetation were removed from the sample. The sample was then transferred into the appropriate sample jars and prepared for shipment.

2.3.1 Sample Handling Procedures

Samples collected from new sample locations were numbered consecutively, starting with BKGR-SS36 (the last previous background sample collected was BKGR-SS35). Samples collected from existing locations for additional metals analyses were identified by the existing location identification. All samples were collected into their appropriate glass bottles with Teflon-lined lids. Sample bottles were new and were supplied by the analytical laboratory. Sample labels were affixed to each container to identify the collector's name, date and time of collection, sample number, and analysis to be performed.

Sample containers were placed on ice for storage and shipment. Individual sample bottles were wrapped in bubble pack and placed in sealed plastic bags to prevent breakage during shipment. The bags were placed into insulated shipping coolers with ice to maintain a proper temperature (4 degrees Celsius). A chain-of-custody (COC) record describing the contents of the cooler was placed in a sealed plastic bag and taped to the upper lid of the cooler.

Standard sample COC procedures were maintained. Samples were kept in a secured area when not in the immediate possession of the sampler. Custody seals were placed on the coolers to prevent tampering during shipment. The sealed sample coolers were shipped via overnight delivery.

2.3.2 Decontamination

All sampling equipment was decontaminated prior to use with an Alconox® soap scrub wash, potable water rinse, and American Society of Testing and Materials (ASTM) Type II reagent grade water rinse. Decontaminated equipment that was not used immediately after air drying was wrapped with aluminum foil for storage or transport.

2.3.3 Laboratory Analysis

Analytical techniques followed procedures described in *Test Methods for Evaluating Solid Waste*, U.S. Environmental Protection Agency, SW-846 and the HQ Air Force Center for Environmental Excellence (AFCEE) *Quality Assurance Project Plan (QAPP)* (AFCEE, 1996). All new data were analyzed by APPL Laboratory in Fresno, California, and reported in accordance with AFCEE QAPP requirements. Samples collected during the F-14 investigation were analyzed by National Environmental Testing (NET) in Bartlett, Illinois, and samples collected during the B-20 investigation were analyzed by Terra Laboratories in League City, Texas.

2.3.3.1 Analytical Methods

Laboratory analytical methods are summarized in **Table 2.1**. Since different laboratories were used, methods varied. The metals barium, chromium, copper, and zinc were all analyzed using method SW-6010 during each investigation. Arsenic and mercury were analyzed using methods SW-7060 and SW-7471, respectively. Cadmium was analyzed using SW-6010 during the F-14 and B-20 investigations, but SW-7130 was used for the recent background samples. Lead was analyzed using SW-7421 during the F-14 investigation and during the recent background sampling. During the B-20 investigation, either SW-6010 or SW-7421 was used, depending on the dilution necessary. Finally, nickel was analyzed using method SW-6010 during the B-20 investigation and during the recent background sampling. During the F-14 investigation, method SW-7520 was used for nickel.

2.3.3.2 Detection Limits

Due to the use of different laboratories and methods, detection limits for each analyte varied between samples. Since the metals barium, copper, chromium, lead, nickel, and zinc were detected in every sample, the difference in detection limits is of little consequence to this evaluation. The detection limits of these analytes were sufficiently low to meet project needs (i.e., levels are lower than

RRS2 criteria). Detection and quantitation limits, to the extent that they are available, are listed in **Table 2.2**.

Because different laboratories, and, in some cases, different analytical methods were used, various detection and quantitation limits did occur for arsenic, cadmium, and mercury. Laboratory SQLs were used in place of nondetected values, where appropriate.

2.3.4 Quality Assurance / Quality Control

To check field and laboratory QA/QC procedures, field duplicate samples and rinsate samples were sent to the laboratory. The laboratory also analyzed matrix spike/matrix spike duplicates (MS/MSDs).

Equipment rinsate blanks were collected at a frequency of one per day of sampling per sampling team. Equipment blanks were collected by pouring ASTM Type II reagent grade water into the sampling equipment before transferring the water into the sample bottle. These samples were collected to determine if decontamination procedures were sufficient.

Field duplicate samples were collected to determine the accuracy and precision of the laboratory analysis. These samples were collected at a rate of one per ten samples per analysis. When it was time to collect a duplicate sample, sufficient volume for two samples was collected. The sample was then split between two bottle sets.

MS/MSD samples were analyzed for every batch of samples (batches will not exceed twenty samples) to determine the effect of matrix interference on the analytical results. The MS/MSD samples were collected from the same location as one of the background samples and were collected at a frequency of one per twenty samples per analysis.

2.3.5 Data Verification and Validation

In each laboratory analytical section, the analyst performing the test reviewed 100 percent of the definitive data. After the analyst's review was completed, 100 percent of the data was reviewed independently by a senior analyst or by the supervisor of the respective analytical section using the same criteria. Calibration, QC requirements, corrective action requirements, and flagging criteria specified in the AFCEE QAPP are followed. The laboratory QA section performed a 100 percent review of 10 percent of the completed data packages, and the laboratory project manager performed a check review on all the completed data packages.

A Parsons senior chemist reviewed the entire definitive data report package, and with the field records, applied the final data qualifiers for the definitive data. The laboratory applied data qualifying flags to each environmental field QC sample. The

Parsons senior chemist reviewed the field QC samples and field logs, and then flagged any of the associated samples identified with the field QC sample, in accordance with the AFCEE QAPP. Data validation also included evaluation of holding times, instrument performance checks, calibrations, blanks, matrix spike sample recoveries, duplicate sample recoveries, atomic adsorption (AA) post-digestion spike recoveries, and field duplicate samples. The Parsons chemist also determined if the data quality objectives were met and calculated the percent completeness for each project.

2.3.6 CSSA Data Approval Process

CSSA chemists or a designated consultant chemist verified at least 10 percent of the CSSA data packages submitted by Parsons. The purpose of the review was to confirm that the quality of data was established by Parsons' verification process and to obtain an understanding of the data usability.

2.4 - Statistical Evaluation

2.4.1 Statistical Approach

Background concentrations were calculated using methods presented in two U.S. Environmental Protection Agency documents:

- *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*, Interim Final Guidance, February 1989 (EPA, 1989).
- *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*, Draft Addendum to Interim Final Guidance, July 1992 (EPA, 1992b).

The background concentrations were calculated by determining the 95 percent UTL of the results. The 95% UTL is the upper bound value on a large fraction of the concentration distribution. Use of the UTL for this purpose was recently approved by the TNRCC in a similar study at a nearby U.S. Air Force facility (Kelly AFB, 1999), and this test was also used in the background metal concentration evaluation for the B-20 site at CSSA (Parsons ES, 1995). Furthermore, the UTL on background data is used as a screening level concentration for comparison with soil boring concentrations at potentially contaminated areas (EPA, 1989). For background soil data, the UTL predicts the upper range of background concentrations from a relatively small data set.

The UTL is designed for use on data that consist mainly of positive detections. Since background data sets typically contain many non-detects, several tests and procedures must be conducted on those sets of data. Non-detect data must be evaluated and manipulated in a manner depending on the percentage of non-detects within the sample population.

This document presents UTL results for each of the nine metals evaluated (arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and zinc), calculated with observations pooled across eight soil types. Distributional assumptions were tested prior to calculating the UTL. The Shapiro-Wilk test was used to determine if the data fit a normal or lognormal distribution. If the distributional assumption could not be verified, then a non-parametric UTL was used. In addition, box plots were generated to identify possible outliers (defined as 1.5 * Interquartile range). Any possible outlier values identified by the box plots were tested using the extreme studentized deviate test to verify if they were, in fact, outliers.

2.4.2 Procedures for Non-Detects

If an analyte was present at a concentration that is less than the SQL, the analytical result was reported as not detected. The laboratory SQL was used in the statistical calculations for all non-detected values.

All data with "U" or "UJ" qualifiers were considered to be non-detect. The laboratory SQL for the analyte was used for all non-detect values. The statistical procedures applied to each data set depended on the percentage of non-detects. There were three possibilities:

1. If the data showed a normal or lognormal distribution, and contained less than 15% non-detect results, a parametric tolerance limit was established. Non-detect values were replaced with a value of one-half the SQL. If the data were not normally distributed, a non-parametric UTL was used.

2. For between 15% and 50% non-detect results, Cohen's or Aitchinson's adjustment was made to the sample mean and the standard deviation to continue with a parametric UTL. However, if the data were not normally distributed, no adjustments were made and a non-parametric UTL was established.

3. For between 50% and 90% non-detect results, a non-parametric UTL was established. A non-parametric UTL is not based on a normal or lognormal distribution. The largest value detected in the data set was used as the non-parametric tolerance limit.

4. For greater than 90 percent non-detect results, the Poisson UTL was established.

2.4.3 Adjustment of Sample Mean and Standard Deviation

Both Cohen's Adjustment and Aitchinson's Adjustment can be used to adjust the sample mean and sample standard deviation to account for data below the detection limit. To determine if Cohen's or Aitchinson's Adjustment was more

appropriate for a particular set of data during this statistical evaluation, two separate probability plots were constructed. Both Cohen's and Aitchinson's Adjustments require that the data be normally or lognormally distributed. In this evaluation, the most lognormal distribution was determined by evaluating the correlation coefficients and probability plots for the censored data and the detects-only data. These two plots make it possible to infer how the distribution of the non-detects is linked to the distribution of the detected values. This information dictates the use of Cohen's or Aitchison's adjustments.

2.4.3.1 Censored Probability Plots

A censored probability plot was constructed to test Cohen's underlying assumption that nondetects have been "censored" at their detection limit. To construct the censored probability plots, the combined set of detects and nondetects was ordered, and normal quantiles were computed for the data set as in a regular probability plot. However, only the detected values and their associated normal quantiles were actually plotted. If the shape of the censored probability plot was more linear than the detects-only probability plot, then Cohen's assumption was considered to be acceptable, and Cohen's adjustment was made to estimate the sample mean and standard deviation.

2.4.3.2 Detects Only Probability Plot

To test the assumptions of the Aitchinson method, a detects-only probability plot was constructed. The assumptions underlying Aitchinson's adjustment are that non-detects represent zero concentrations and that detects and nondetects follow separate probability distributions. Only detected measurements were used to construct the detects-only probability plots. Nondetects were completely ignored. Normal quantiles were computed only for the ordered detected values. The same number of points and concentration values were plotted on both the detects-only and censored probability plots; however, different normal quantiles were associated with each detected concentration. If the detects-only probability plot was more linear than the censored data probability plot, then the underlying assumptions of Aitchinson's method were considered to be reasonable.

Section 3 - Results and Conclusions

This section presents the results of the laboratory analyses and the statistical calculations. Possible future uses of the calculated background values are also described.

Analytical results for background Glen Rose Formation limestone samples are presented in **Table 3.1**. Background limestone samples were collected from ten borings drilled in 1994 during the F-14 investigation (ES, 1994a) and ten borings drilled in 1999 as part of the background investigation. All 20 lab samples were used in the statistical evaluations, except for the lead and nickel evaluations. As shown in **Table 3.1**, concentrations of lead and nickel detected in 1999 were significantly lower than the concentrations detected in 1994. Although the data packages for each data set were carefully reviewed and no problems were identified with the analysis, QA/QC of the recent samples is presumed to be superior to that of the 1994 samples. Therefore, the ten higher 1994 lead and nickel results have been omitted from the statistical evaluation, leaving a sample size of ten for these two metals.

Analytical results for background soil samples are presented in **Table 3.2**. As described in Section 2, samples SS1 through SS10 were collected during the F-14 investigation (ES, 1994a), and samples SS11 through SS35 (all metals except copper, nickel, and zinc) were collected during the B-20 investigation (Parsons ES, 1995). The remaining samples were collected as part of this investigation.

The concentrations in **Tables 3.1** and **3.2** were used for the statistical calculations presented in **Appendices A and B**. Calculated background concentrations are summarized in **Table 3.3**. Sample locations are presented on **Figure 2.1**. The values in **Table 3.3** represent background metals concentrations in the Glen Rose Formation limestone and soils at the entire CSSA facility.

The concentrations listed in **Table 3.3**, or PQLs, whichever are higher, will be used as comparison criteria for closure of CSSA SWMUs under RRS1. CSSA will pursue closure of SWMUs at the facility under RRS1 wherever it is technically and economically feasible. CSSA intends to use this report as a reference document for these future closures, as well as other appropriate environmental activities at the facility.

In addition to the metals analyses, one sample of each soil type was analyzed to determine pH. These results are listed in **Table 3.4** and the data package for the pH analysis is included in **Appendix E**.

Section 4 - References

AFCEE, 1996. *Quality Assurance Project Plan*, Version 1.0, HQ Air Force Center for Environmental Excellence. January 1996.

Army, 1971. Report of Engineering Survey, Industrial Waste and Wastewater Treatment Plant, CSSA. Environmental Health Engineering Department, Fifth U.S. Army Medical Laboratory, October 1971.

Army, 1990. Camp Bullis: Admirably Suited to All Purposes of Military Training. A History of the Leon Springs Military Reservation, 1890-1990. Fort Sam Houston Museum, U.S. Army, 1990.

EPA, 1988. *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses*. U.S. Environmental Protection Agency, 1988.

EPA, 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*, Interim Final Guidance, EPA/530/SW-89/026. U.S. Environmental Protection Agency, Office of Solid Waste. February 1989.

EPA, 1992a. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*, Draft Addendum to Draft Interim Guidance. U.S. Environmental Protection Agency, Office of Solid Waste. July 1992.

EPA, 1992b. *Test Methods for Evaluating Solid Waste*, SW-846, U.S. Environmental Protection Agency, November 1992.

ES, 1994a. *Closure Report for the F-14 Accumulation Site, Camp Stanley Storage Activity, Texas*, EPA Identification No. TX2210020739, TNRCC Identification No. 69026. Parsons Engineering Science, Inc., September 1994.

ES, 1994b. *Partial Facility Closure Plan, B-20 Detonation Area, Camp Stanley Storage Activity*, volumes I and II. Parsons Engineering Science, Inc., March 1994.

Hammond, 1984. Hydrogeology of the Lower Glen Rose Aquifer, South-Central Texas, W.W. Hammond, The University of Texas at Austin, Ph.D. dissertation, 1984.

Kelly AFB, 1994. *Background Levels of Inorganics in Soils at Kelly Air Force Base*. United States Air Force Installation Restoration Program. San Antonio Air Logistics Center. Prepared by Haliburton NUS. March 1994.

Kelly AFB, 1999. Addendum to Final Background Levels of Inorganics in Soils at Kelly AFB. Prepared by Mobile District Corps of Engineers. October 1999.

Parsons ES, 1995. *Remedial Investigation Report for B-20 Former Open Burn/Open Detonation Area, Camp Stanley Storage Activity, Texas*. Parsons Engineering Science, June 1995.

Shapiro and Wilk, 1965. *An Analysis of Variance Test for Normality (complete samples).* Biometrika, volume 52, pg. 591-611. S.S Shapiro and M.B. Wilk. 1965.

TWDB, 1983. Groundwater Availability of the Lower Cretaceous Formations in the Hill Country of South-Central Texas. John B. Ashworth, Texas Water Development Board, Report 273, 1983.

USDA, 1991. *Soil Survey, Bexar County, Texas*. U.S. Department of Agriculture, Soil Conservation Service, series 1962, number 12, June 1966, reissued June 1991.

USGS, 1984. Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States. U.S. Geological Survey Professional Paper 1270, 1984.

USGS, 1985. Identification and Tabulation of Geological Contacts in the Edwards Aquifer, San Antonio Area, Texas. U.S. Geological Survey. By Ted A. Small, May 1985.

Whitney, 1952. Some Zone Marker Fossils of the Glen Rose Formation of Central Texas. Journal of Paleontology, vol. 26, no. 1, pp 65-73, by Marion Isabelle Whitney. January 1952.