1,152,000 gallons at a maximum depth of 8 feet (Cimarron Corporation, October, 1994).

The decommissioning of Uranium Waste Pond #1 was initiated in March of 1976 with the construction and installation of a dike across the south half of Waste Pond #1. This constructed dike consisted of a four-foot plywood barrier that was covered with an EPDM liner. This dike was weighted and staked to the bottom and sidewalls of Uranium Waste Pond #1. The installation of this dike enabled the sediments in Uranium Waste Pond #1 to be consolidated into a much smaller area.

Excess water from Uranium Waste Pond #1 was decanted and pumped to Uranium Waste Pond #2 beginning on April 13, 1976 and continuing through April 22, 1976. In April of 1976, water from the Plutonium Emergency Pond and the Uranium Emergency Pond was also pumped to Uranium Waste Pond #1 to facilitate their closure. No visible sludge remained in either the Plutonium Emergency Pond and the Uranium Emergency Pond after all water was pumped to Uranium Waste Pond #1.

The solidification of the sludge remaining in Uranium Waste Pond #1 commenced on July 30, 1976. The solidification process was accomplished by using a pump to fill 55-gallon drums with the contaminated sludges, which were then placed on conveyors adjacent to the mixing operation. After filling the 55-gallon drums with contaminated sludges (approximately 80-85%), a mixer was inserted and Portland cement was gradually added to produce a solidified waste form. Waste solidification operations were completed on October 27, 1976 for Uranium Waste Pond #1.

A total of 865 55-gallon drums (approximately 6,500 cubic feet) of solidified waste sludges from Uranium Waste Pond #1 were generated

which contained approximately 3,000 grams of U-235. This solidified waste from Uranium Waste Pond #1 was shipped off-site to a commercial low-level radioactive waste disposal facility.

Uranium Waste Pond #1 was sampled by Cimarron Corporation, the Oklahoma Department of Health (predecessor agency of the Oklahoma Department of Environmental Quality) and the NRC after completion of the water treatment project and the subsequent sludge solidification. The Oklahoma Department of Health sampled Uranium Waste Pond #1 in October of 1977 and the NRC sampled Uranium Waste Pond #1 in November of 1977. The analysis results from these sampling events were then compared for consistency.

Cimarron Corporation received written permission from the Oklahoma Department of Health to backfill and cover Uranium Waste Pond #1 on March 2, 1978. Cimarron Corporation received written permission from the NRC to backfill and cover Uranium Waste Pond #1 on July 10, 1978. Uranium Waste Pond #1 was subsequently backfilled and covered between August 3, 1978 and November 1, 1978. Uranium Waste Pond #1 was closed by crushing the asphalt liner into the pond. The clay dike material and clean soil was utilized to fill in the depression of approximately four feet.

A December 14, 1978 NRC Inspection Report stated that the burial of the "five liquid effluent retention ponds was completed during the inspection." Initial seeding and fencing were performed between November 2, 1978 and March 20, 1979. Sprigging and fertilization of Uranium Waste Pond #1 was performed from July 18, 1979 to October 30, 1979.

On January 8, 1993, the NRC sent a letter to Cimarron Corporation stating the following: "... the five former wastewater ponds that were

closed in 1978 must be addressed in detail. A thorough characterization of these ponds must be included, and the Decommissioning Plan must describe how you plan to address any contamination in excess of levels acceptable for release for unrestricted use." As a result of this letter from the NRC, Cimarron Corporation initiated an extensive characterization program for Uranium Waste Pond #1.

In March of 1993, a 10-meter by 10-meter grid was established for Uranium Waste Pond #1 and 1-foot composited soil samples were obtained via coring down to a depth of 6 feet. Several samples revealed concentrations exceeding the Option #1 level (i.e. 30 pCi/g) in several locations. Additional samples were collected in these locations down to a depth of 9 feet. In addition, random sampling was also performed on Uranium Waste Pond #1 down to a depth of 12 feet, which demonstrated that total uranium concentrations were below 30 pCi/g below 10 feet in depth. This information is discussed in detail Section 12.0 of the Cimarron Characterization Report.

Additional characterization work was initiated in 1996 to supplement the characterization work performed in 1993. The characterization work initiated in 1996 on Uranium Waste Pond #1 was performed to supplement the original 10-meter by 10-meter grid sampling size, such that the sampling frequency was reduced to a maximum of a 5-meter by 5-meter grid size. The additional composite samples obtained in 1996 were collected in one-foot intervals to a depth of 6 feet. Approximately 1,600 soil samples were collected during these characterization efforts. Offset sampling was also performed in numerous locations to determine the aerial extent of residual concentrations of total uranium.

Based upon reviews of the 5-meter by 5-meter grid sample results, Cimarron Corporation performed additional characterization work.

Twenty-one (21) locations with elevated concentrations of total uranium at the 5-6 foot depth interval were selected for additional offset sampling. These samples were obtained in one-foot intervals to a depth of 10 feet unless rock was encountered and resulted in 780 additional samples being obtained. In 1997, additional 5-meter by 5-meter grid locations were also selected for sampling below 6 feet in depth.

In response to the NRC staff's comments on the Cimarron Decommissioning Plan (Cimarron Corporation, April, 1995) dated July 1, 1997, Cimarron Corporation committed to re-enter and decommission Uranium Waste Pond #1 under the BTP Option #1 criteria as applied through the NRC's guidance on "Methods for Surveying and Averaging Concentrations of Thorium in Contaminated Sub-surface Soil". The derivation of the enriched uranium guideline values based upon this NRC guidance is discussed in detail in the Cimarron FSSR for Phase III, Sub-Area "O" - Subsurface (Cimarron Corporation, March, 1998) which is currently being reviewed by NRC staff.

A comprehensive review of all the characterization data identified 14 locations with composite sample results exceeding the guideline value developed under the NRC guidance documents (i.e. 220-pCi/g total uranium). Remediation of Waste Pond #1 was performed with a trackhoe excavator. Surface soils were removed to gain access to the contaminated soils with concentrations above the guideline value. Excavation of contaminated soils exceeding the guideline value continued as necessary down to a depth of approximately 12 feet unless rock was encountered. Excavated contaminated soils were stockpiled and sampled in accordance with the NRC approved in-situ sampling protocol prior to being placed in the on-site BTP Option #2 Disposal Cell. Approximately 23,000 cubic feet of BTP Option #2 soils were removed from these 14

locations. Soils from unaffected areas were utilized to backfill the excavations and were also sampled and analyzed.

Utilization of the NRC guidance, coupled with Cimarron's desire to assure full compliance, resulted in an additional excavation of soil volumes from Uranium Waste Pond #1 (Uranium Waste Pond #1 was previously excavated in 1976). Additional soil sampling and confirmatory surveys were also performed after these areas were excavated. The complete set of all characterization data for Uranium Waste Pond #1 was evaluated under the NRC's guidance ("Methods for Surveying and Averaging Concentrations of Thorium in Contaminated Sub-surface Soil") to demonstrate that the soils within Uranium Waste Pond #1 were in compliance with the BTP Option #1 criteria.

4.4 Uranium Waste Pond #2

Uranium Waste Pond #2 was built in January of 1971. Uranium Waste Pond #2 had a compacted clay bottom liner with EPDM poly-rubber sidewalls anchored at the bottom and the top of the dike. Axis measurements along the centerline to the top of the dike were approximately 405 feet by 270 feet. The bottom area was approximately 90,000 ft^3 in size and the capacity was approximately 3,025,000 gallons at a maximum depth of 4 feet (Cimarron Corporation, October, 1994).

The decommissioning of Uranium Waste Pond #2 was initiated in March of 1976. Excess water from Uranium Waste Pond #1 was decanted and pumped to Uranium Waste Pond #2 beginning on April 13, 1976 and continued through April 22, 1976. Uranium Waste Pond #2 was closed and decommissioned without the removal or solidification of sludge due to the fact that sludge was never generated in Uranium Waste Pond #2.

Uranium Waste Pond #2 was sampled by Cimarron Corporation, the Oklahoma Department of Health (predecessor agency of the Oklahoma Department of Environmental Quality) and the NRC after completion of the water treatment project. The Oklahoma Department of Health sampled Uranium Waste Pond #2 in October of 1977 and the NRC sampled Uranium Waste Pond #2 in November of 1977. The analysis results from these sampling events were then compared for consistency. Cimarron Corporation received written permission from the Oklahoma Department of Health to backfill and cover Uranium Waste Pond #2 on March 2, 1978. Cimarron Corporation received written permission from the NRC to backfill and cover Uranium Waste Pond #2 on July 10, 1978. Uranium Waste Pond #2 was subsequently backfilled and covered between August 3, 1978 and November 1, 1978. Uranium Waste Pond #2 was closed by removing the EPDM poly rubber sidewalls, and the underlying clay dike material and clean soil was utilized to partially fill in the depression of approximately four feet.

A December 14, 1978 NRC Inspection Report stated that the burial of the "five liquid effluent retention ponds was completed during the inspection." Initial seeding and fencing were performed between November 2, 1978 and March 20, 1979. Sprigging and fertilization of Uranium Waste Pond #2 was performed from July 18, 1979 to October 30, 1979.

On January 8, 1993, the NRC sent a letter to Cimarron Corporation stating the following: "... the five former wastewater ponds that were closed in 1978 must be addressed in detail. A thorough characterization of these ponds must be included, and the Decommissioning Plan must describe how you plan to address any contamination in excess of levels acceptable for release for unrestricted use." As a result of this letter from the NRC, Cimarron Corporation initiated an extensive characterization program for Uranium Waste Pond #2.

In early 1993, a 10-meter by 10-meter grid was established for Uranium Waste Pond #2 and 1-foot composited soil samples were obtained via coring down to a depth of 6 feet. Several samples revealed concentrations exceeding the Option #1 level (i.e. 30 pCi/g) in several locations. Additional sampling, including random sampling, was also performed on Uranium Waste Pond #2 down to a depth of 12 feet, which demonstrated that total uranium concentrations were below 30 pCi/g below 9 feet in depth. This information is discussed in detail in Section 12.0 of the Cimarron Characterization Report.

Additional characterization work was initiated in 1996 to supplement the characterization work performed in 1993. The characterization work initiated in 1996 on Uranium Waste Pond #2 was performed to supplement the original 10-meter by 10-meter grid sampling size, such that the sampling frequency was reduced to a maximum of a 5-meter by 5-meter grid size. The additional composite samples obtained in 1996 were collected in one-foot intervals to a depth of 5 feet. Approximately 3,300 soil samples were collected during these characterization efforts. Offset sampling was also performed in numerous locations to determine the aerial extent of residual concentrations of total uranium.

Based upon reviews of the 5-meter by 5-meter grid sample results, Cimarron Corporation performed additional characterization work. Twenty-nine (29) locations with elevated concentrations of total uranium were selected for additional offset sampling. These samples were obtained in one-foot intervals to a depth of 5 feet and resulted in approximately 400 additional samples being obtained.

In response to the NRC staff's comments on the Cimarron Decommissioning Plan (Cimarron Corporation, April, 1995) dated July 1,

1997, Cimarron Corporation agreed to re-enter and decommission Uranium Waste Pond #2 under the BTP Option #1 criteria as applied through the NRC's guidance on "Methods for Surveying and Averaging Concentrations of Thorium in Contaminated Sub-surface Soil". The derivation of the enriched uranium guideline values based upon this NRC guidance is discussed in detail in the Cimarron FSSR for Phase III, Sub-Area "O" - Subsurface (Cimarron Corporation, March, 1998) which is currently being reviewed by NRC staff.

A comprehensive review of all the characterization data identified 29 locations with composite sample results exceeding the guideline value developed under the NRC guidance documents (i.e. 220-pCi/g total uranium). Remediation of Waste Pond #2 was performed with a trackhoe excavator. Surface soils were removed to gain access to the contaminated soils with concentrations above the guideline value. Excavation of contaminated soils exceeding the guideline value continued as necessary down to a depth of approximately 9 feet. Excavated contaminated soils were stockpiled and sampled in accordance with the NRC approved in-situ sampling protocol prior to being placed in the on-site BTP Option #2 Disposal Cell. Approximately 7,000 cubic feet of BTP Option #2 soils were removed from these 29 locations. Soils from unaffected areas were utilized to backfill the excavations and were also sampled and analyzed.

Utilization of the NRC guidance, coupled with Cimarron's desire to assure full compliance, resulted in an additional excavation of soil volumes from Uranium Waste Pond #2 (Uranium Waste Pond #2 was previously excavated in 1976). Additional soil sampling and confirmatory surveys were also performed after these areas were excavated. The complete set of all characterization data for Uranium Waste Pond #2 was evaluated under the NRC's guidance ("Methods for Surveying and Averaging

Concentrations of Thorium in Contaminated Sub-surface Soil") to demonstrate that the soils within Uranium Waste Pond #2 were in compliance with the BTP Option #1 criteria.

4.5 Summary

As discussed above in sections 4.1 through 4.4, Burial Areas #1 and #2 and Uranium Waste Ponds #1 and #2 have been remediated such that all materials exceeding the BTP Option #1 criteria have been removed. These materials have either been shipped off-site for disposal to a commercial Low-level Radioactive Waste Disposal Facility or placed in the NRC approved BTP Option #2 Disposal Cell.

The remediation of Burial Area #1 was completed and this area was backfilled in 1993, the remediation of Burial Area #2 was completed and this area was backfilled in 1997, and the remediation of Waste Ponds #1 and #2 were also completed and the areas were backfilled in 1997.

Significant volumes of BTP Option #2 and #4 materials were removed from Burial Areas #1 and #2 and Waste Ponds #1 and #2. The majority of this remediation work was completed recently, between 1993 and 1997. As a result, the source terms from these four areas that were available for potential contamination of the groundwater have recently been removed.

A review of historical groundwater data reveals that groundwater in the four areas described above (Burial Areas #1 and #2 and Waste Ponds #1 and #2) has been impacted by previous site operations. The trending analysis which is included in Section 5.0 demonstrates that the groundwater monitoring results are continuing a downward trend (i.e. confirming that maximum site concentrations in groundwater have already occurred). This also coincides with the recent removal of the sources of

potential groundwater contamination from Burial Areas #1 and #2 and Waste Ponds #1 and #2.

4.6 References

ORISE, January 31, 1989, "Interim Report of the Confirmatory Survey of portions of the Sequoyah Fuels, Cimarron Corporation Plant (Pu-Plant and Burial Ground #1)."

ORISE, January 7, 1991, "Confirmatory Survey of Cimarron Corporation Mixed Oxide Fuel Fabrication Plant."

ORISE, November 18, 1991, "Confirmatory Radiological Survey of the Sanitary Lagoons at the Cimarron Corporation Facility, Crescent, Oklahoma."

ORISE, July 22, 1992, "Confirmatory Radiological Survey of the Former Burial Ground. Cimarron Corporation Facility at Crescent, Oklahoma."

Cimarron Corporation, October, 1994, "Radiological Characterization Report for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility."

ORISE, November 1, 1994, "Confirmatory Survey of 2 Soil Piles proposed for on-site storage. Kerr-McGee Corporation, Crescent, Oklahoma."

Cimarron Corporation, April, 1995, "Decommissioning Plan for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility."

ORISE, November 13, 1995, "Confirmatory Survey of South U-Yard Remediation, Kerr-McGee Corporation, Crescent, Oklahoma."

Cimarron Corporation, May, 1996, "Final Status Survey Report for Phase III, Sub-Area "L" (Sub-surface)."

Cimarron Corporation, March, 1998, "Final Status Survey Report Phase III – Sub-Area "O" (Sub-surface)."

5.0 GROUNDWATER QUALITY IN IMPACTED AREAS

Several groundwater/surface water characterization and assessment studies have been performed for the Cimarron Facility to determine whether or not groundwater has been impacted by previous site operations and, if so, the extent of that impact. Results of those studies have been discussed in previous sections of this Report and are further summarized in this Section. Also, the anticipated behavior of operations derived species in the shallow subsurface is discussed briefly in this Section. The Cimarron facility implemented an extensive and continuous environmental monitoring program for determining the impacts of facility operations and subsequent remediation on the environment. This Section reviews historic and current groundwater data to determine impacts from past operations; and discusses changes to groundwater quality since issuance of the Grant Report (1989). These historic data are provided in Appendix attached to this Report.

The facility's annual environmental reports submitted to the NRC over the last twenty (20) years have revealed that groundwater has been impacted in localized areas by previous site operations. Additionally, the Grant (1989) report, submitted in support of the BTP Option #2 On-Site Disposal Cell application, concluded that groundwater near or downgradient of former waste management areas has been impacted by previously managed waste materials. Grant also explained the mechanisms by which uranium entered the groundwater at these affected areas and discussed those mechanisms that would further mitigate the impacts as closure progressed. A decreasing concentration trend is to be expected and should continue with the removal of the source of contamination (e.g., source term) during the decommissioning process. Grant predicted "that separation of the uranium and the production salts would lead to decreasing mobility." This means that without a continuing recharge of complexing ions such as fluoride or nitrate, the uranium remaining would become less and less mobile.

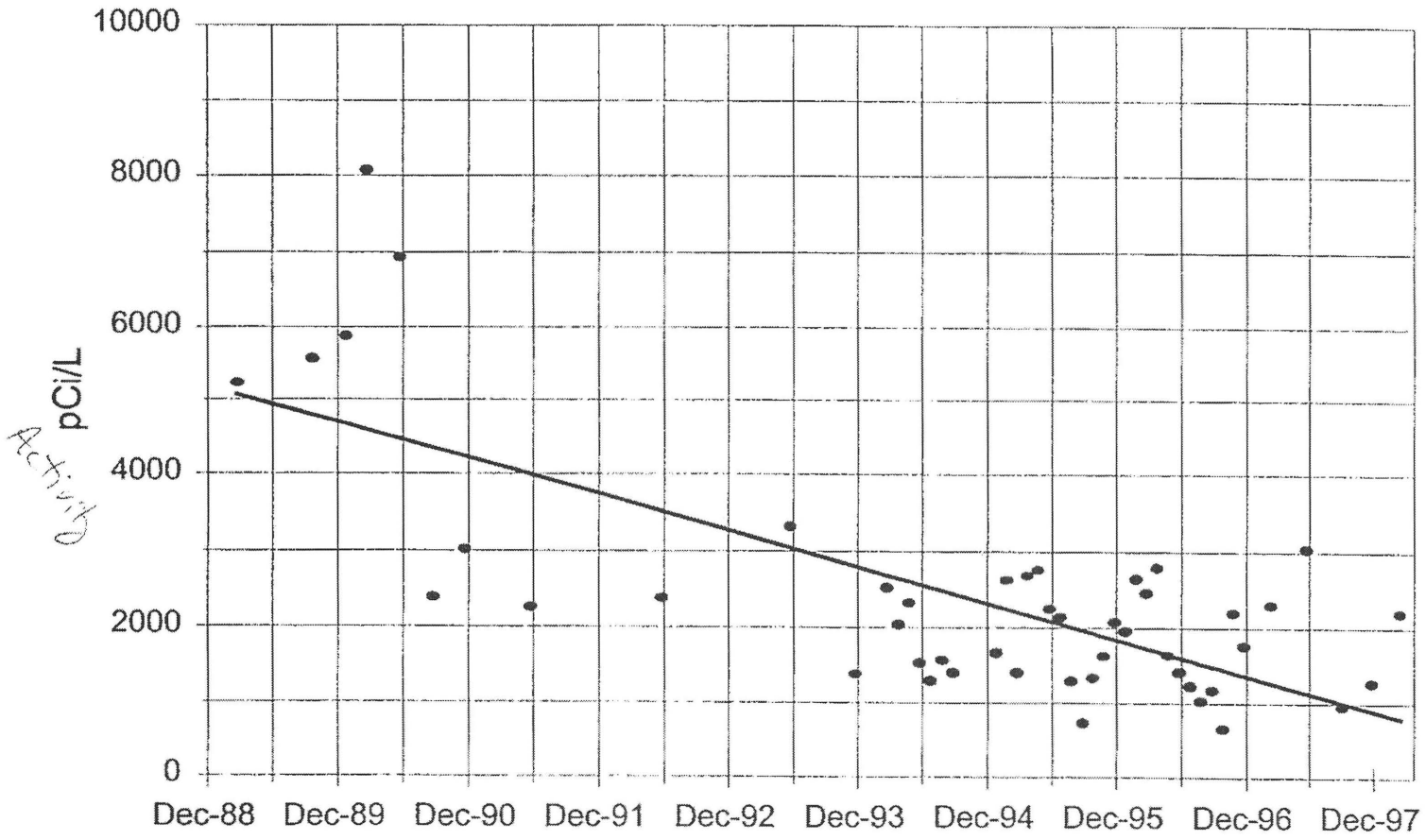
As discussed in Section 4.0, the Uranium Waste Ponds (U-Ponds), process building areas, and former waste (302 burials) burial areas have been remediated per BTP Option #1 criteria. With source removal complete, the detection of constituents above background at the monitoring wells reflect residual amounts of constituents remaining either in the soil, in the unsaturated zone, or in the water-bearing stratum.

To briefly discuss the impact to the groundwater and trending associated with affected areas onsite, environmental data is presented in this Section. The 1996 "Groundwater and Surface Water Assessment" (Chase 1996) included a comprehensive evaluation of the entire sitewide environmental monitoring data base. The evaluation concluded that the analytical data for the shallow groundwater near or downgraident from the four former waste management areas discussed below should be included in trend analyses for illustrating the downward concentration trend for residual contamination in groundwater at the site.

5.1 Burial Area #1

Well #1315 was installed between trenches into the shallow groundwater monitoring area formerly occupied by Burial Area #1. A cross section showing the location of this well in relation to the groundwater is provided by Drawing No. 98-XSEC-2 (Ref. To Section 2.0, page 2-8). When Burial Area #1 was excavated the trenches remained open for several years resulting in some residual activity (Option #1 concentrations) leaching from the vadose zone into the shallow groundwater. Cimarron believes that with the sources removed, and the area backfilled with clean unaffected soil, and vegetated, the general decreasing groundwater concentration trends noted since 1988 will continue. This decreasing trend is shown by Figure 5.1. Well #1315 peaked in March 1990 at 8,080 pCi/L with the most recent analysis (March 1998) showing a total uranium

Figure 5.1-- Well 1315 Total Uranium
Linear Curve Fit



of 2,200 pCi/L. The last four quarters have averaged 1,866 pCi/L total uranium.

As noted by Figure 5.1, the concentration of total uranium in Well #1315 decreased rapidly from its peak in March 1990 to September 1990 (i.e., from 8,070 pCi/L to 2,386 pCi/L, respectively). In order to determine if continued decreases in groundwater concentrations were occurring from September 1990 forward, a plot of these concentrations for total uranium was completed. Figure 5.2 shows total uranium data for the monitoring period for Well #1315 from September 1990 forward. The computer generated linear curve fit function (i.e., Corel Quattro Pro Version 6) shows an average decrease in total uranium concentration of 5.3% per year for this data set.

Downgradient from Well #1315, two additional wells were installed (Wells #1316, and #1317). The total uranium concentration trending for Well #1316 is shown by Figures 5.3. Well #1316 shows continued decreasing trending; with Well #1316 peaking at 1,880 pCi/L in 1991 and decreasing to 109 pCi/L for the latest analysis. Trending for Well #1317 is shown by Figure 5.4; this figure shows a slightly increasing total uranium concentration. However, Well #1317's latest analytical result (March 1998) shows total uranium at 62.7 pCi/L; this well peaked at 499 pCi/L in 1990. The June 1997 result of 408 pCi/L total uranium may be an anomalous result because it does not fit the data set. With this data point treated as an outlier, the concentrations show a continually decreasing trend.

Site water quality data for these wells monitoring former Burial Area # 1 reflect removal of the source and the immobility of uranium in the subsurface. Wastes were buried in this management area and later exhumed and disposed off-site. Upgradient Well #1314 shows

Figure 5.2--Well 1315 Total Uranium

Linear Curve Fit

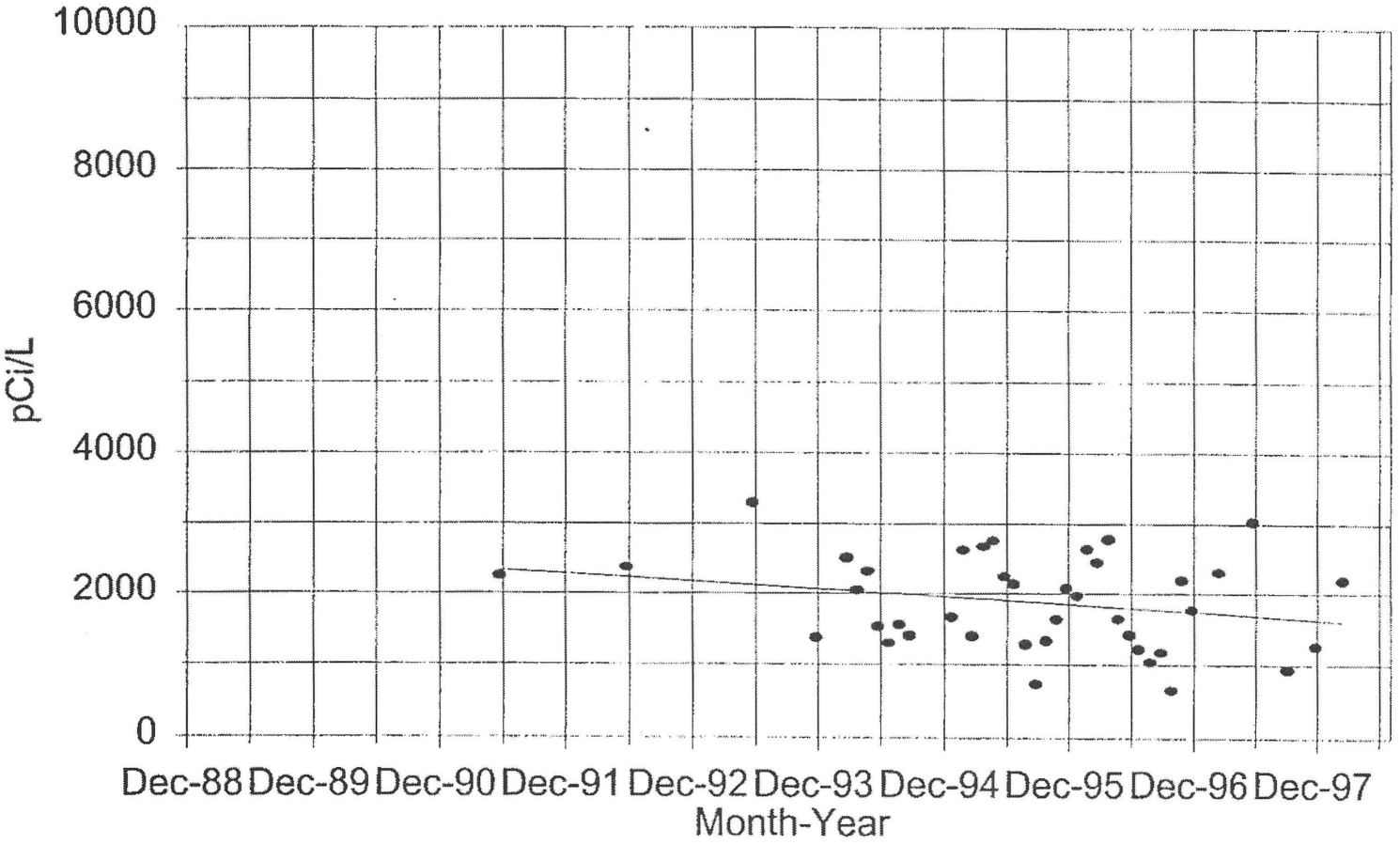


Figure 5.3--Well 1316 Total Uranium
Linear Curve Fit

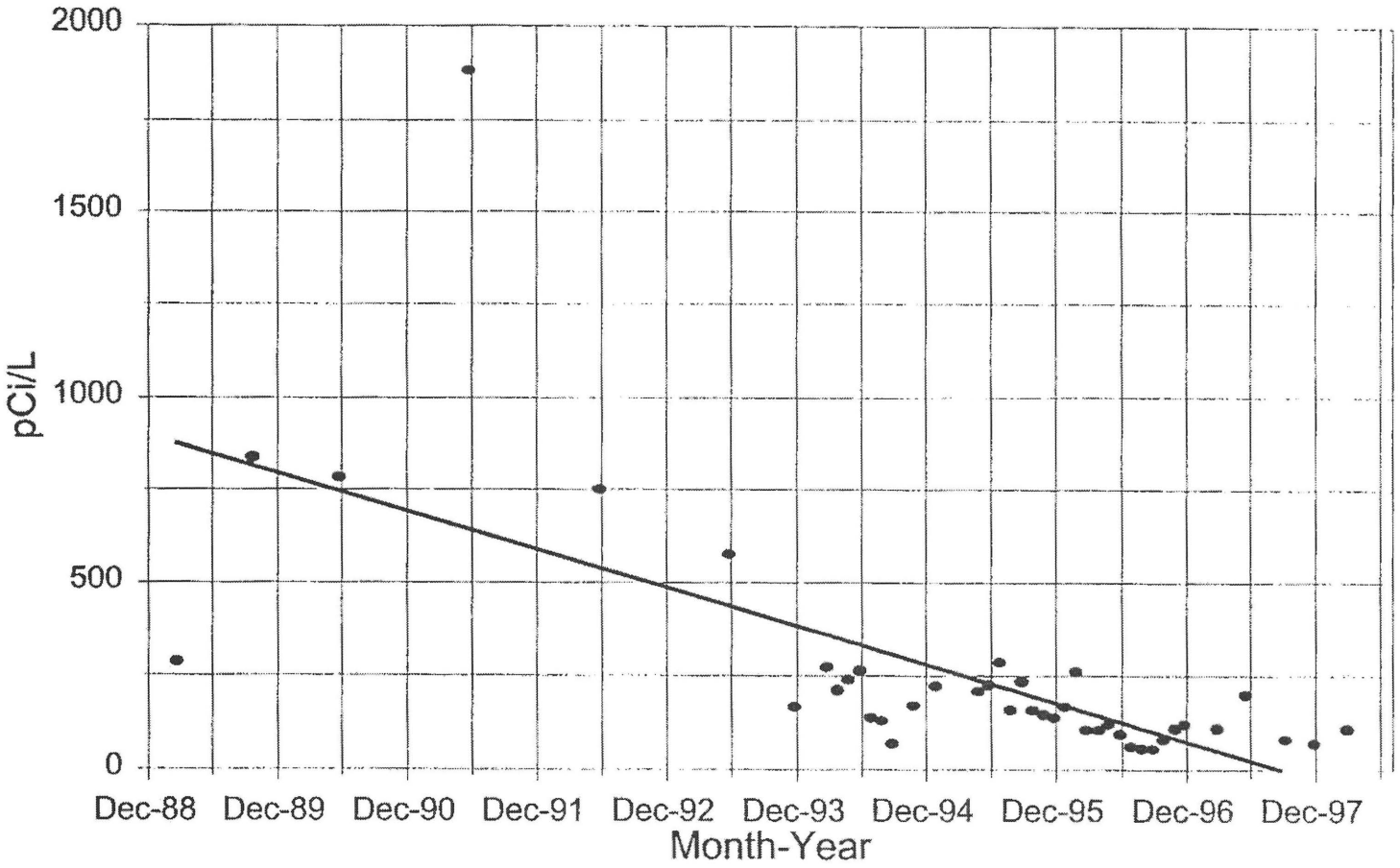
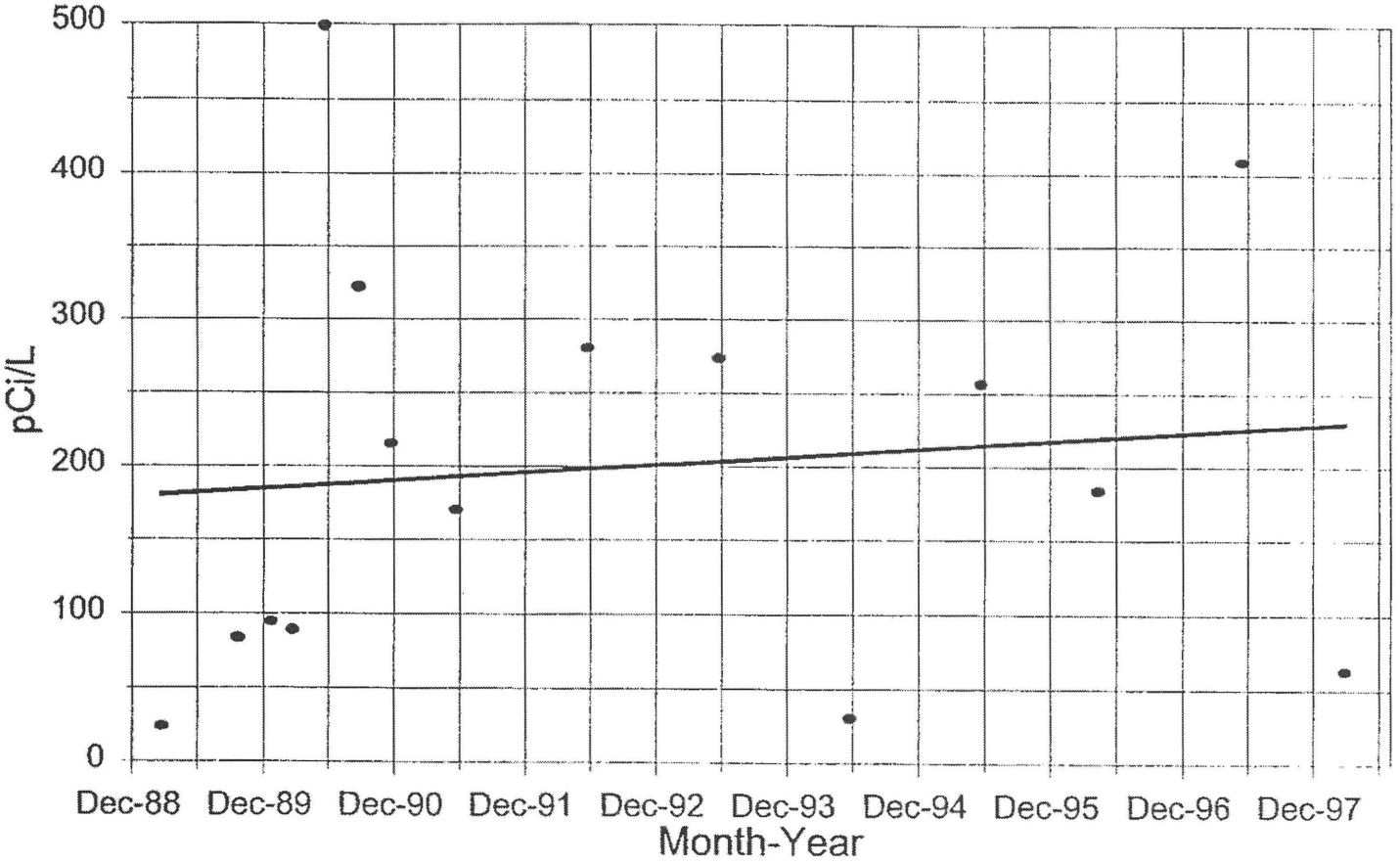


Figure 5.4--Well 1317 Total Uranium

Linear Curve Fit



background U-238 concentrations of about 2 pCi/L. Concentrations have increased across the former burial area, and decreased rapidly with distance downgradient of the area. Migration around this area reflects the influence of the leachate chemistry upon uranium Kd's . Within the former burial area, Kd's probably are much smaller than in the natural system. The Kd's increase with distance from the facility as the groundwater chemistry approaches that of the native groundwater.

As discussed, the concentrations of total uranium in Well #1315, located within the former burial ground, and Well #1316, located near Well #1315, peaked in years 1990 and 1991 respectively and are subsequently decreasing in concentration. The temporary increase is believed to be related to rainfall retention and percolation during the time the trench was open and being excavated. The area remained open waiting NRC approval to backfill. This former burial area was excavated between 1986 and 1988 and the excavation remained open until early 1993. The area was backfilled and contoured to promote drainage.

A recently installed well (Well #1344) adjacent to the Cimarron River, downgradient former Burial Area #1, shows a total uranium concentration of 4.5 pCi/L. This concentration is considered equivalent to the 7 to 8 pCi/L average total uranium concentrations recorded for the Cimarron River.

The change in total uranium concentrations with distance from the former burial ground reflects the influence of the changing groundwater chemistry upon uranium with distance from the source and the influence from surface water infiltration and subsurface dispersion. The mobility of uranium in the groundwater is further discussed in Section 6.2.

5.2 Uranium Waste Pond #2

Well #1336 and surface water seep location #1208 monitor the groundwater impacted from former U-Pond #2. A cross section showing the location of the wells and seeps relative to the groundwater is provided by Drawing 98-XSEC-1 (Ref. To Section 2.0). The total uranium and gross beta trending for Well #1336 are included with this section and are shown on Figures 5.5 and 5.6. The location (Well #1336) shows a continued downward trending in residual concentrations of total uranium. Also, starting in 1997, Tc-99 has been monitored and also has shown a continued decreasing trend from 2,590 to 1,600 pCi/L in the most recent analysis. The decrease in Tc-99 also is reflected by the gross-beta downward trend for Well #1336 (Figure 5.6).

The Seep, #1208, also was monitored for Tc-99 and showed a decreasing trend in activity from 3,960 to 2,306 pCi/L for the most recent analysis completed in March 1998. Total uranium monitored at Seep #1208 has shown a decreasing trend from 303 pCi/L in 1993 to 48.4 pCi/L in the most recent analysis in March 1998. Cimarron believes, in general, that the decreasing trends in groundwater constituents will continue and will be further mitigated now that former U-Pond #2 was further remediated and then capped, crowned and vegetated.

As discussed in Section 3.2.1.1, two wells were installed recently northeast and downgradient of former U-Pond #2 for the purpose of verifying that a semi-confining layer (Mudstone A) exists between Sandstones A and B under this area. The groundwater elevations verified that an aquitard was present between the two sandstones. Total uranium analytical results from June 1997 were 11.7 pCi/L for Well #1337 (Sandstone A) and 1.2 pCi/L for Well #1338 (Sandstone B). The analytical results demonstrate that the underlying Sandstone B located below this U-Pond has not been impacted by previous site operations.

Figure 5.5--Well 1336 Total Uranium

Linear Curve Fit

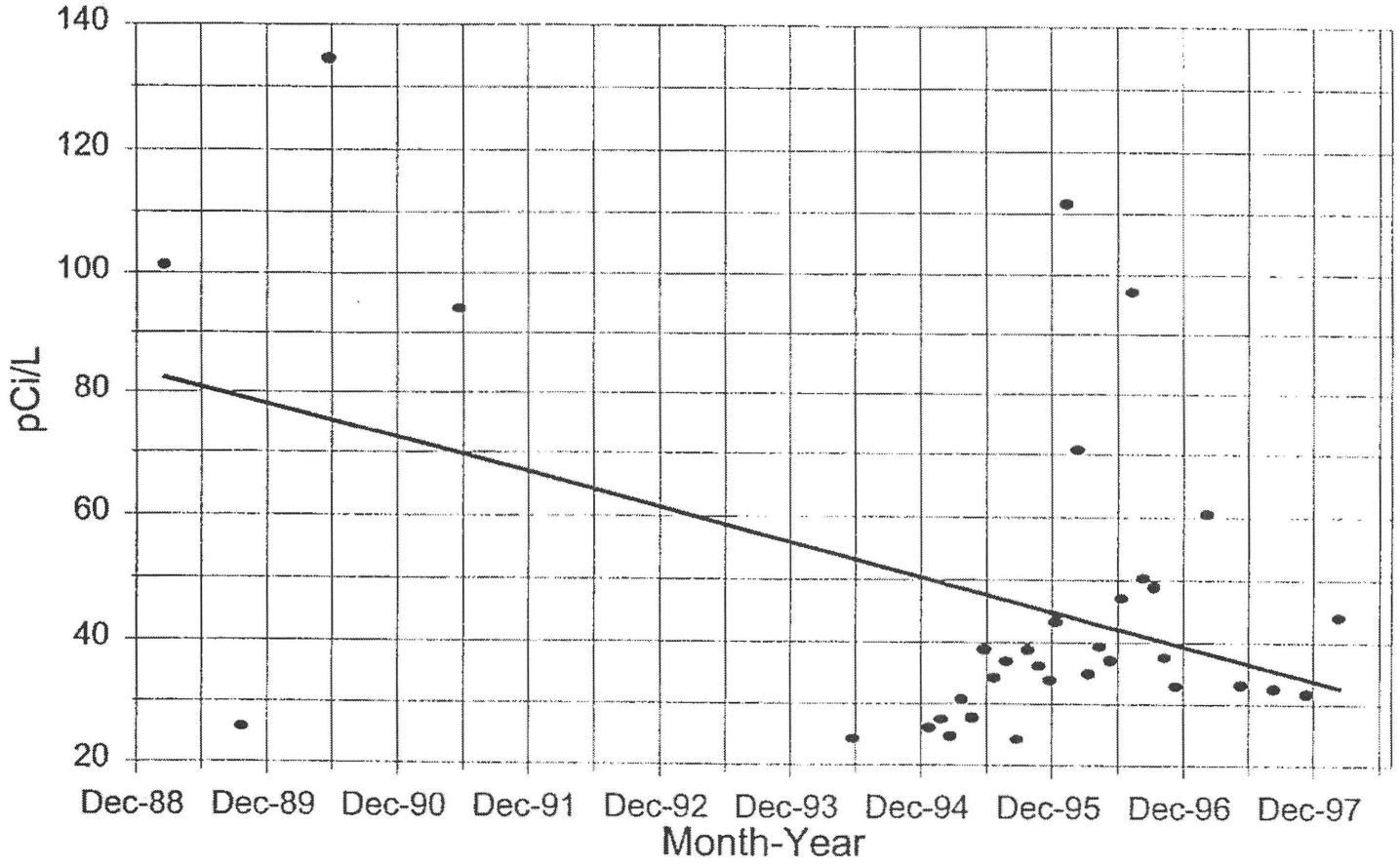
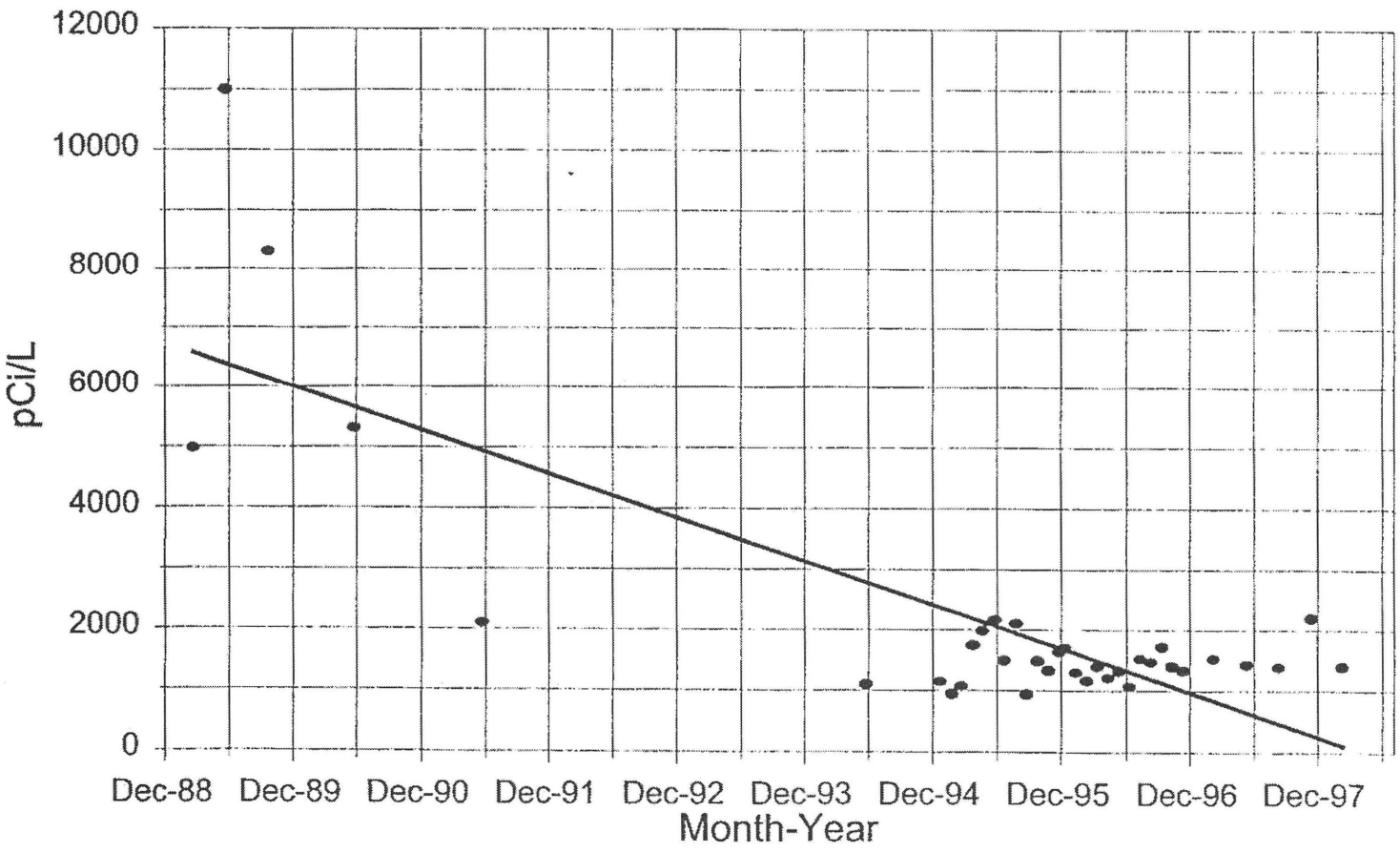


Figure 5.6--Well 1336 Gross Beta
Linear Curve Fit



Finally, Sandstone A below and downgradient of Waste Pont #2 is unsaturated due to the proximity of the seeps along the bluffs.

5.3 Uranium Waste Pond #1

This former U-pond area contains two well locations which show that groundwater has been impacted by prior site operations. Those locations are monitored by Wells #1312 and #1313. Trending for these wells for total uranium and gross beta are included with this section and are shown in Figures 5.7 through 5.10. These locations show a continued decreasing trend in residual concentrations of total uranium. Since 1997, Tc-99 has been monitored for both wells and also has shown decreases in concentration. Tc-99 for Well #1312 has decreased from a high of 3,680 to 1,856 pCi/L for the most recent analysis. Well #1313's most recent analysis for Tc-99 was 562 pCi/L. The decrease in Tc-99 also is reflected by the gross-beta downward trending for Wells #1312 and #1313 shown by Figures 5.8 and 5.10.

For Well #1312, gross alpha has decreased from a high of 2,220 pCi/L in 1985 to the most recent analysis in March of 15.8 pCi/L; total uranium for the March sample was 32.1 pCi/L. Similarly, for Well #1313, gross alpha has decreased from a high of 1,510 pCi/L in 1992 to the most recent analysis in 1998 of 30 pCi/L; total uranium for the March sample was 39.3 pCi/L. Cimarron believes that the decreasing trends in groundwater constituents will continue since additional source removal has been completed. Final backfilling and contouring of U-Pond #1 has been completed.

When the two additional wells (Nos. 1337 and 1338) were installed near U-Pond #2, two wells (Nos. 1340 and 1341) also were installed east and downgradient of former U-Pond #1. Well #1340 was completed in Sandstone A and Well #1341 in Sandstone B. Analytical results for total

Figure 5.7--Well 1312 Total Uranium
Linear Curve Fit

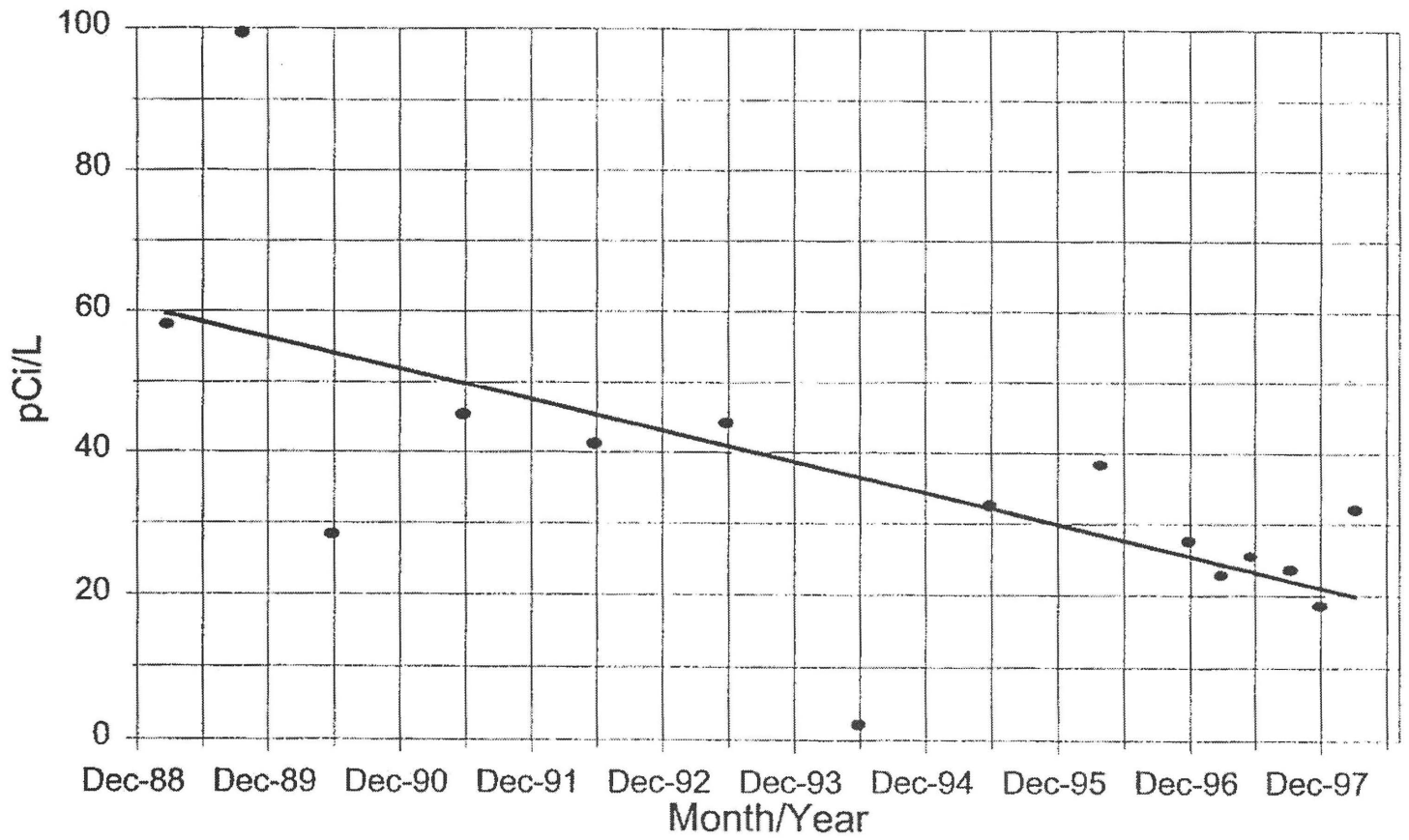


Figure 5.8--Well 1312 Total Beta
Linear Curve Fit

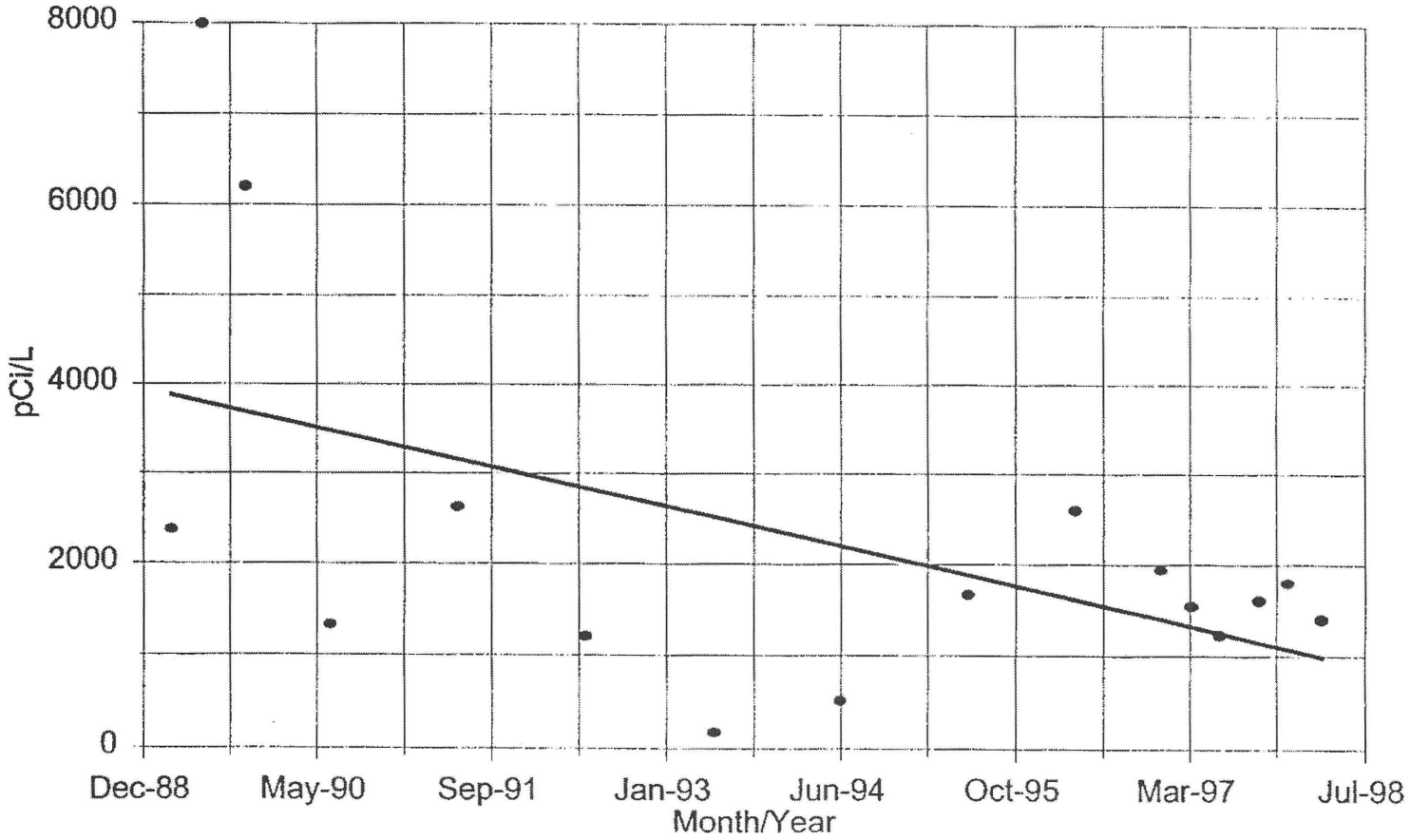


Figure 5.9-- Well 1313 Total Uranium

Linear Curve Fit

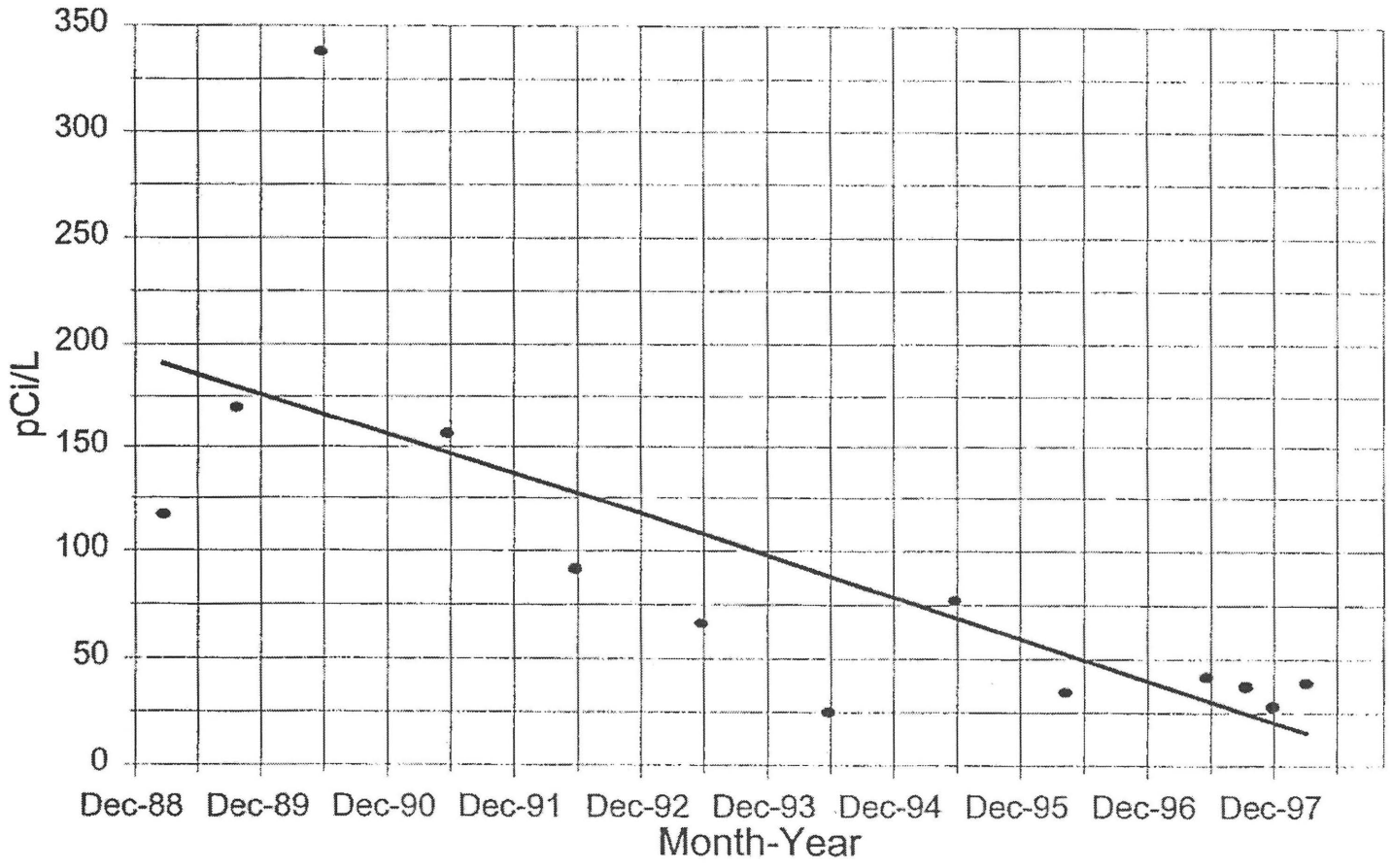
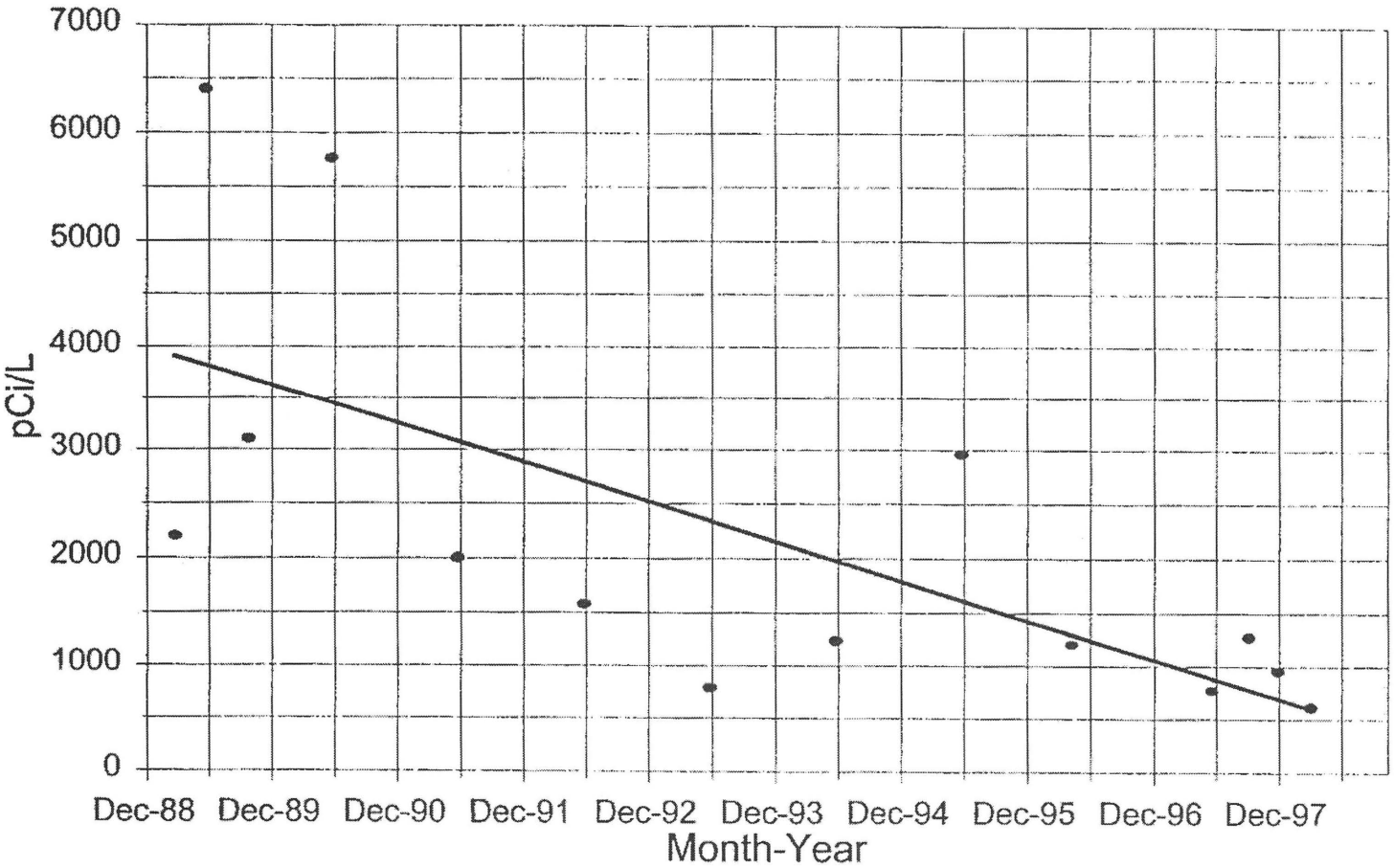


Figure 5.10-- Well 1313 Gross Beta
Linear Curve Fit



uranium from the latest sampling event, June 1997, show 3.9 pCi/L for Well #1340 and 2.2 pCi/L for Well #1341. The total uranium concentration in Well #1341 is indicative of background meaning that this zone has not been impacted by prior site operations.

5.4 Burial Area #2

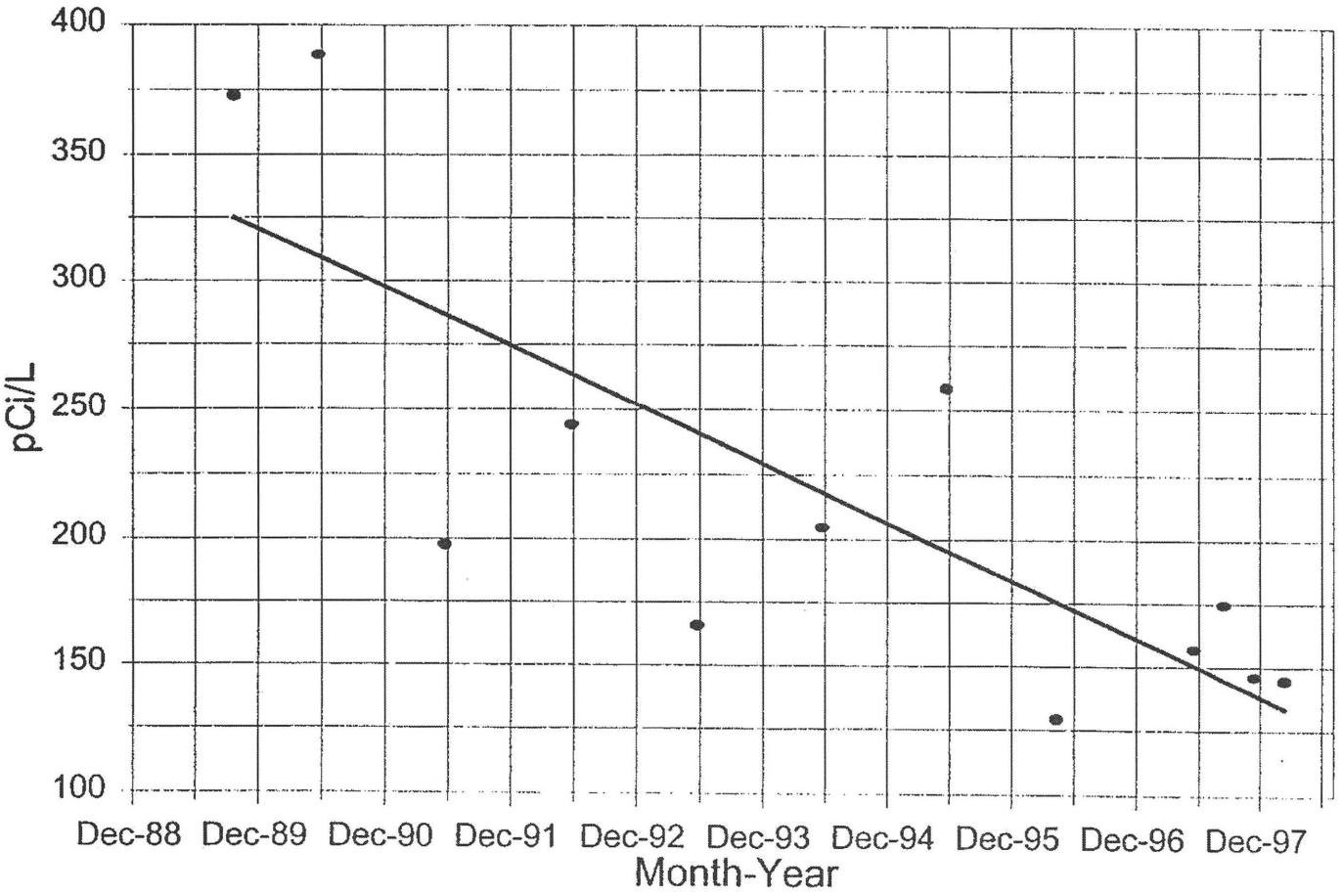
This area contains one monitoring well, Well #1331, located downgradient from former Burial Area #2 which indicates that constituents in groundwater are elevated, but are also decreasing in concentration. Figure 5.11 represents the trending for groundwater monitored for total uranium.

Recent remediation at Burial Area #2 may be influencing the constituents in this well. Cimarron has completed the removal of the buried waste and the grading, backfilling, and contouring of Burial Area #2. This remediation should mitigate any further affects upon groundwater in this area. The highest concentration of total uranium for Well #1331 was 388 pCi/L recorded in June 1990; the latest sampling results shows 145 pCi/L. This recent concentration is slightly elevated above the 129 pCi/L recorded in April 1996, but still reflects an overall decreasing trend in total uranium concentration.

5.5 All Other Monitored Locations for Shallow Groundwater

The other Sandstone A monitoring wells on-site that are located downgradient from previously closed process areas have shown minimal, if any, impact from prior site operations. The eleven monitoring wells sampled in June 1997 showed total uranium concentrations ranging from 1.2 pCi/L to 13.2 pCi/L, with the highest concentration representing Well #1333. The average total uranium concentration for these eleven wells was 6.2 pCi/L.

Figure 5.11-- Well 1331 Total Uranium
Linear Curve Fit



Three monitoring wells were installed recently adjacent to the Cimarron River for determining the thickness of the alluvium and for sampling the groundwater within this zone. Well #1342 was installed near Highway #74 as an upgradient alluvium well; and Wells #1343 and #1344 were installed north of U-Pond #2 and former Burial Area #1 (see Drawing No. 98MOST-R2 included in Section 3.0). These wells were sampled in March 1998 and show total uranium of 6.5 pCi/L for Well #1342, 18.7 pCi/L for Well #1343 and 4.5 pCi/L for Well #1344. Also, as noted in Section 3.4.3, total uranium measured for the Cimarron River was 8.1 pCi/L upstream and 7.3 pCi/L downstream. These data reflect background conditions for the Cimarron River.

5.6 Other Monitored Locations for Surface Water / Seeps

Monitored location surface drainage/seep #1206 includes a combination of collection points for both surface run-off and shallow seeps. This monitored location is shown on Drawing No. 98MOST-R2. The water monitored collects from a combination of prior waste management areas including seeps and surface runoff. These areas have subsequently been remediated, and include a former pipe line area, a surface storage area, waste ponds, and a burial area. During extreme dry periods there may be no water available for sampling this location. Also, during wet periods surface run-off affects the analytical results.

Analytical data for this location shows the downward trend for total uranium expected as a result of continued remediation and source removal. The total uranium peaked in 1994 at 517 pCi/L; the first quarter 1998 data shows a total uranium concentration decreasing to 189 pCi/L. The average concentration for total uranium is 161 pCi/L for the last four quarters when data is available; for the December 1997 sampling event, the location was dry.

The three reservoirs located on site are monitored under the sitewide environmental monitoring program. These reservoirs are recharged by a combination of surface run-off and shallow groundwater. Surface water location #1204 monitors Reservoir #1 which also is designated the West Lake. Monitoring location #1205 is for Reservoir #2, and location #1209 is for Reservoir #3. The 1997 analytical data for total uranium was 4.0 pCi/L for #1204; 0.8 pCi/L for #1205; and 2.9 pCi/L for #1209. These results show no effects from prior site operations.

5.7 Deep Monitoring Well

As discussed in Section 3.2.1, the monitoring wells located on site that monitor the deeper groundwater zones have shown total uranium concentrations ranging from 11 to 44 pCi/L. These concentrations are considered within background variances for these deeper sandstone layers. Historical data for uranium and other constituents monitored indicated that these deeper zones have not been impacted by prior site operations.

5.8 Summary

The historical and more recent groundwater and surface water investigations clearly show that groundwater radionuclide impacts have continued their decreasing trends from the levels presented in the 1989 Grant report. With additional sources removed in these areas and the site in the final phase of decommissioning, these recorded decreasing trends will continue.

5.9 References

Chase Environmental Group, Inc, 1996. Groundwater and Surface Water Assessment for Cimarron Corporation's Former Nuclear Fuel Fabrication Facility, Crescent, Oklahoma, December, 1996.

Grant, James L., 1989. Site Investigation Report for the Cimarron Corporation Facility, Logan County, Oklahoma, September 12, 1989.

6.0 DISCUSSION OF PREVIOUS PATHWAY EVALUATIONS

This section discusses previous human exposure pathway evaluations performed by the NRC and Cimarron. In addition, Cimarron performs routine monitoring of radiation workers and monitors the environment to ensure that operations are performed in a manner that conforms with all regulatory requirements and exposures are ALARA. The results of actual measurements are presented as these are generally considered to be the best data for assessment of operational impacts.

6.1 NRC Safety Evaluation Report (SER) and Environmental Assessment (EA) for Disposal of On-site BTP Option #2 Soils

This subsection provides an overview of the Safety Evaluation Report (SER) (USNRC, 1994) and Environmental Assessment (EA) (USNRC, 1994a) performed by the NRC to address health, safety, and environmental effects from an authorization for the on-site disposal of low-enriched uranium in the NRC Branch Technical Position (BTP) (USNRC, 1981) Option #2 concentration range. Although the intent of this Groundwater Report is primarily to address current groundwater issues, the SER is also relevant as it provides additional information related to the potential impacts associated with the on-site disposal of the BTP Option #2 material. The analysis is important as it evaluates conditions that present the highest soil concentrations to remain at the site. Any other remediated areas will have impacts that are significantly lower than the Option #2 disposal cell.

The SER and EA provide a significant amount of information that is directly applicable to the assessment of any other affected areas at the facility. This section lays the groundwork for determination of the relative impacts associated with former Burial Areas #1 and #2, and Uranium

Waste Ponds #1 and #2, in comparison with the impacts projected for the approved BTP Option #2 Disposal Area.

6.1.1 Discussion/Description of the NRC's SER and EA

In 1987, Cimarron requested an amendment to License No. SNM-928 to dispose on-site soils containing low concentrations of enriched uranium (i.e., BTP Option #2 materials). The original request was made in accordance with the requirements of 10 CFR 20.302 (currently 10 CFR 20.2002) (USNRC, 1998) using NRC's BTP criteria. The proposed method for disposal was to bury those soils on-site.

Pursuant to this request, the NRC prepared a SER and an EA which evaluated the health, safety, and environmental issues related to Cimarron's proposal. Based upon these evaluations, the NRC issued License Amendment No. 10 to License No. SNM-928, authorizing the burial of up to 500,000 cubic feet of soil contaminated with low-enriched uranium in the BTP Option #2 concentration range. License Condition No. 23 was issued by the NRC on November 4, 1994 and limited the maximum concentrations allowable for disposal based upon the solubility of the material. Importantly, the NRC's maximums were based upon 100 percent solubility of the uranium, which would result in the highest projected concentrations in groundwater.

The EA prepared by NRC staff provided a general description of the site and proposed BTP Option #2 Disposal Area, and presented information regarding the climate, meteorology, demographics, land and water usage, wetlands, biology, surface water hydrology, geology and hydrogeology, site geochemistry, and radiological background for the facility. This information was used to determine the expected environmental impacts

from the BTP Option #2 disposal. The environmental impacts considered included the potential for groundwater contamination, intrusion into the disposed material, direct radiation exposure, and inhalation or ingestion. The EA also considered the potential radiological doses and addressed State of Oklahoma concerns regarding non-radiological chemical impacts from the disposal of the BTP Option #2 materials. As such, the NRC analysis represents the highest exposure scenario for any soils residing at the Cimarron site.

6.1.1.1 Pathways Considered in the SER and EA

The stated purpose of the SER was "to consider the potential radiological impacts on worker health and safety associated with the movement and disposal of uranium-contaminated soil on the Cimarron site". The SER considered doses to workers from the direct exposure pathway and from the inhalation pathway. In its conclusion, the SER states that "The samples in the 0-30 picocuries/gram range (BTP Option 1) have acceptably low concentration so that the enriched uranium may be buried without restriction."

The purpose of the EA was to determine the impact of the BTP Option #2 burial on the public and the environment. The EA states that "NRC policy on on-site disposal of uranium contaminated soil pursuant to 10 CFR 20.2002 (formerly 10 CFR 20.302) is described in the 'Branch Technical Position on Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations (46 FR 52061, October, 23, 1981)."

The primary pathway considered in the EA was the groundwater pathway, as doses from this pathway were not previously considered in the NRC BTP. In the BTP, NRC staff considered the radiation doses that members

of the public could conceivably be expected to receive from direct radiation, ingestion of food raised on the site, and gamma and inhalation dose due to physical intrusion into the contaminated soil. The results of the generic calculations are used in the EA and are corrected for the average activity in the BTP Option #2 Disposal Area to present estimates of the potential dose from the disposal activity. Doses to the nearest off-site resident from earthmoving activities are also calculated in the EA. These calculated doses are presented in Section 6.1.1.4.

Based upon the results of the EA, the NRC concluded that the impact on the public and the environment would be minimal, and made a Finding of No Significant Impact (FONSI).

6.1.1.2 Assumptions/Parameters

The SER applied only to workers at the Cimarron facility, and estimated exposures that would occur during the movement of contaminated soil into the disposal cell. The activities considered in the SER also included the placement and compaction of contaminated soils in the disposal cell. The SER assumed that the soil was contaminated at 70 pCi/g, total uranium, and that workers were exposed to inhalation Class Y. The particle size chosen was 1 micron. The duration of the exposure was 6 months, and the average air concentration utilized was 2.7 E-12 μCi/mL. As discussed in Section 6.3, this assumed concentration has been shown to be very conservative, based upon the results of actual measurements performed in the field.

The SER also calculated the effective dose equivalent from exposure of radiation workers to direct radiation. The RESRAD code was used for this evaluation. For this estimate, it was assumed that workers would be

exposed continuously for one year during earthmoving and other activities. The exposure geometry used was a planar field contaminated with 70 pCi/g uranium.

The EA assumed that 500,000 cubic feet of low-enriched (3%) uranium at 70 pCi/g was buried, and that the cell would have a 4 foot cover. The source term assumed was 1.9 Ci total uranium. The solubility for the uranium was assumed to be 100 percent. In addition, the Kd value used was 339 mL/g. The solubility and Kd values used in the EA are considered to be conservative, and will result in projected estimates of exposure that are higher than reality. These parameters are addressed in more detail in Section 6.2. The well that supplied drinking water, irrigation water, and livestock water was placed at a distance of one foot from the downgradient edge of the disposal area, resulting in a travel time of 0.1 year. The groundwater flow velocity used was 10 feet/y. The porosity of the soil was assumed to be 0.33, and the soil density was 1.9 g/cm^3.

The nearest residence was chosen at the current distance of 0.8 kilometers. Uses of land in the vicinity were assumed to be row crop cultivation, grazing, or construction.

6.1.1.3 Methods

The methods used in the SER for calculation of inhalation dose involve standard health physics calculations equating the concentration of uranium contaminant in the air to the dose received. The concentration of uranium in air is multiplied by the total volume of air breathed by the worker. This result is then multiplied by a dose conversion factor to obtain the committed effective dose equivalent.

The SER also addressed the potential for exposure from direct radiation. The effective dose equivalent was determined using the RESRAD code, assuming a planar source with a uranium concentration of 70 pCi/g.

The EA used several methods to calculate doses. The leaching and subsurface migration of uranium from the BTP Option #2 Disposal Area was modeled using the simplified one-dimensional contaminant transport code TRANSS (Simmons, 1986). The TRANSS model is a convective-dispersive transport program that has been modified to allow for radioactive decay of the source and to simulate adsorption (Kd), solubility in water, and concentration or diffusion barrier controlled releases.

There were no calculations performed for direct radiation from exposure to the buried materials, since the NRC concluded in the BTP that contaminated soil buried under Option #2 conditions (i.e., at least 1.2 meters (4 feet) below the surface) would not expose any member of the public. The same 1.2 meters of cover would essentially eliminate the uptake of uranium by food or pasture crops and correspondingly reduce the amount of uranium that could be ingested by consuming food produced on-site.

The EA did consider the possibility of physical intrusion into buried contaminated soil, for the site that is released for unrestricted use. The EA made use of calculations performed for the BTP which showed that even an extreme intrusion into the buried Option #2 soil would result in an annual organ dose of no more than 170 mrem, which is equivalent to a total effective dose equivalent (TEDE) of 5 mrem for uranium soluble in lung fluid to 20 mrem for insoluble uranium.

Calculations of the potential annual dose to the nearest resident (0.8 kilometers southeast) due to blowing dust was calculated using the GENeration II (Napier, 1988) radiological pathways and dosimetry model (GENII). In addition, the toxic effects (non-radiological) due to the residual uranium activity were addressed in the EA.

6.1.1.4 Results

The SER concluded that the major radiological impact to workers would be from the inhalation of dust during earth movement activities. The calculated maximum annual exposure was 408 mrem, with 405 mrem due to dust inhalation and 3 mrem due to external occupational exposure. This projection can be compared to the actual dose received by the workers who placed the Option #2 soils into the on-site disposal cell. As of this date (through June, 1998), facility monitoring records (personnel dosimeter and lapel air monitors) show there has not been any dose assigned due to external exposures and that a single radiation worker has been assigned a dose due to intake of 0.32 mrem. The placement of materials into the BTP Option #2 disposal cell was an extensive relocation effort, with work done in close proximity or contact with the Option #2 material. Any future intruder into on-site soils containing residual activity would not create levels of airborne radioactivity as high as those produced during the placement of the soils into the Disposal Area. Therefore, based upon actual monitoring results, it is unlikely that any future intruder would receive any exposure due to the inhalation of residual Option #1 soils located within former Burial Areas #1 and #2, or from Uranium Waste Ponds #1 and #2.

The TRANSS code, which was run to determine the potential impacts due to groundwater contamination, showed that there was no calculated

impact (i.e., no measurable increase) due to the leaching of uranium from the BTP Option #2 Disposal Area for many thousands of years. The net downward movement of uranium will be much slower than the downward movement of infiltrating water because of the adsorption of uranium onto soil and rock. The TRANSS code predicted that after 1,000 years, the uranium concentration in the intruder well would still be at natural background levels. This prediction held even when the most conservative Kd value (339 mL/g at Well #1336) was input into the code. This signifies that chemical constituents, at levels such as those found in soils near the waste ponds, would not produce measurable increases in uranium concentration. All of these assumptions apply to any remaining on-site residual activity, e.g., Waste Ponds #1 and #2 and former Burial Areas #1 and #2.

As stated in Section 6.1.2.3, there were no calculations performed for direct radiation from exposure to the buried materials, due to the shielding effect of the cover materials. The same cover would essentially eliminate the uptake of uranium by food or pasture crops and correspondingly reduce the amount of uranium that could be ingested by consuming food produced on-site. Residual Option #1 materials in Uranium Waste Ponds #1 and #2 are below four feet of cover. Residual materials are present in other areas of the facility at Option #1 levels (i.e., 0 to 30 pCi/g total uranium).

The physical intrusion scenario evaluated in the EA showed that even an extreme intrusion into the buried Option #2 soil would result in an annual total effective dose equivalent (TEDE) of less than 7 mrem, without regard to solubility. The EA further states that "Such a dose is considered to be quite small compared to doses from natural background radiation...".

The potential annual TEDE to the nearest resident (0.8 kilometers southeast) due to blowing dust was calculated to be 0.67 mrem for the BTP Option #2 Disposal Area. This dose was calculated using conservative assumptions and is also insignificant in relation to background.

The EA states that "The current NRC standard for uranium exposure of occupational workers is based on a nephrotoxicity standard of 3 micrograms of uranium per gram of kidney continuously maintained for a lifetime." The EA also concluded that toxic effects from the ingestion of uranium would require groundwater concentrations in the hundreds of picocuries per liter, while the TRANSS code analysis showed that the uranium concentration will not exceed 1 pCi/L over a time period of 100,000 years. The toxicity of uranium is addressed in more detail in Section 8.0.

6.2 Adequacy of Previous Cimarron Environmental Assessments

The EA that was discussed in Section 6.1 was performed by the NRC in March 1994 and was based upon site characterization data developed by James L. Grant and Associates (Grant, 1989 and 1990) in support of Cimarron's application for on-site disposal of Option 2 soils. The pathways analysis and dose model performed by the NRC verified the earlier dose evaluation completed by Grant. The Grant evaluation can be considered a conservative representation any maximum of future exposure from residual uranium contained in media remaining at the Cimarron site.

6.2.1 Grant Analysis (1989/1990)

In the 1989 Report, Grant completed a computer simulation of the potential for leaking and migrating of contaminants from the Option #2 landfill. The simulation used the TRANSS model (Simmons, 1986). As noted in Section 6.1.2.3, the TRANSS model is a one-dimensional, convective, dispersive transport program based on Van Genuchten analytical solutions, modified to include the simultaneous decay of the source and released radionuclides. The program can model concentration or solubility limited releases, adsorption (Kd) limited releases, or diffusion beneath a barrier to the water table.

Simulations of distribution coefficient-limited releases were performed to predict uranium migration through the unsaturated zone to the water table, and through the saturated zone to the Cimarron River alluvium. For the release model, five samples of site soils, rock and groundwater were analyzed by the Kerr-McGee Technical Center to determine equilibrium distribution coefficients (Kd) for uranium. This test provides a measure of the affinity of the selected elements for soil and rock and the solubility of the material in the rock/groundwater system. The experimentally derived Kd values for the uranium range from 339 mL/g to 2,829 mL/g. This range of Kd's is representative of different conditions found on-site in groundwater due to influence from prior site operations, and for the natural background groundwater. For example, the derived Kd values of 339 mL/g was measured from aquifer matrix material collected from the installation of Well #1336 which is located within an impacted area. The higher Kd's (i.e., 2,829 mL/g) were derived from matrix material collected from upgradient non-impacted wells.

Two simulations of uranium leaching and migration to the water table directly below the proposed landfill were performed using Kd values representative of the range of aquifer matrix materials. Kd values of 2,000 mL/g and 300 mL/g were used. With a Kd of 2,000 mL/g, a maximum leachate concentration of about 4 pCi/L was seen at the end of the flowtube in approximately 237,000 years. A Kd of 300 mL/g produces a maximum leachate concentration of about 27 pCi/L at the end of the flowtube in approximately 36,000 years.

The results of the TRANSS model simulation support interpretations that leaching and migration of uranium in the subsurface of the Cimarron facility will be limited. The simulations show that the combined effects of precipitation, adsorption and dilution of uranyl complexes will prevent significant migration of uranium from the on-site disposal cell and other areas on-site when residual uranium is present.

6.2.2 Discussion of Existing Impacted Areas

The mobility of uranium at the site depends upon the chemistry of the groundwater, soils, and rocks. The stability and mobility of particular species in the subsurface depends primarily on active matrix adsorption sites, ligands available for complexation, and pH and Eh of the groundwater. Uranium has limited solubility in the slightly alkaline and oxidizing groundwater typical of the site. As demonstrated by the derived Kd's, the solubility is higher near the ponds because of the altered groundwater chemistry in these areas and the presence of complexing agents, e.g., fluoride and nitrate.

The dominant uranium species in the natural environment are uranyl complexes. Uranium exists in the hexavalent state as the uranyl ion UO_2^{+2}

in this environment (Grant, 1989). The solubility of uranium is limited by precipitation and adsorption on the aquifer matrix. Uranyl hydroxide and uranium trioxide will precipitate from slightly alkaline and oxidizing groundwater. These compounds are relatively insoluble. Uranyl ions in solution also will be sorbed onto the aquifer matrix.

The distribution coefficient (Kd) tests demonstrate that uranium will have limited solubility in the subsurface groundwater (Grant, 1989). Final concentrations of uranium in the Kd test solutions ranged from 1.2 to 9.9 pCi/L. These concentrations are consistent with naturally occurring uranium concentrations in the shallow groundwater samples from most of the monitoring wells. The combined effects of uranium precipitation and absorption on the shallow aquifer matrix materials appear to produce equilibrium concentration of uranium in Cimarron groundwater that are less than 10 pCi/L.

Concentrations of uranium above the typical equilibrium level have been detected in some on-site monitoring wells. These wells are located down-gradient from the closed uranium waste ponds and former Burial Areas #1 and #2. Materials stored in these areas have caused changes in the chemistry of the groundwater. The process wastewater discharged to the U-ponds contained dissolved uranium and was significantly different chemically from the natural groundwater, resulting in the higher uranium concentrations near the ponds. Likewise, leaching of materials stored at the former burial locations would alter the groundwater chemistry in those areas.

Uranium concentrations in the groundwater decreases rapidly with distance from the source (e.g., Uranium Waste Ponds). Uranium

complexes of fluoride, nitrate and sulfate may be more soluble than uranium carbonate salts, and the complexes often are not sorbed as strongly. Increased competition between uranium and other cations for a limited number of sorption sites increases the concentration of uranium in solution relative to the uranium sorbed on the soils. As anions are stripped from the ligands to react with matrix material (e.g., F^- with Ca^{++}), the uranium ion becomes susceptible to formation of more insoluble species and eventually sorbs on clays where it is tightly bound. The competition for exchange sites and the complexing of the uranium by other ions diminishes in importance downgradient of the former waste management areas as dilution and chemical reactions cause the modified groundwater to become more akin to the native groundwater than to the leachate.

With the closure of the former Uranium Waste Ponds and excavation of the former Burial Areas, the residual concentrations of uranium and solubilizing ligands remaining in soil will no longer possess the solubility-enhancing factors present within these former sources. Since the uranium concentrations in soil left in place will be far less than that placed into the Option #2 on-site disposal cell, the potential concentration of uranium in groundwater that leaches from the in-situ soils will be less than that predicted for the On-Site Disposal Cell. Under the remediation process, the highest concentrations of uranium and ligands in the soil went to the Option #2 On-Site Burial Area, thus making it the "worst case" scenario for the site.

6.2.3 Uranium Solubility in Soil

The previously discussed groundwater pathway models, including the EA, assumed that in-situ uranium was 100 percent soluble. This turns out to

have been a very conservative assumption. In 1997, Cimarron employed the services of an outside laboratory to perform solubility tests on representative soil samples collected from the two uranium waste pond areas and from the on-site Option 2 disposal cell. These tests were approved by the NRC via letter dated December 10, 1996 (USNRC, 1996). A total of six sample locations were included in the study, two from each location. The "yearly" solubilities were determined to range from 26.7 percent to 33.3 percent, with an average of 28.9 percent. Additionally, the average solubilities measured for the three locations were essentially the same (29.9 for Uranium Waste Pond #1, 27.7 for Uranium Waste Pond #2, and 29.2 for the On-Site Disposal Cell). Since the solubilities are similar, the three areas will perform in a similar fashion in the future with respect to constituent migration. Migration from the closed waste management areas will be much less pronounced than from the former Uranium Waste Ponds and burial grounds because the remaining impacted in-situ soils will not influence groundwater chemistry, and because only soils with low levels of uranium will be present at license termination. Leaching of the uranium will be limited by solubility and by sorptive processes in the soil. Migration of uranium that does leach will be limited by the sorption of the material in the subsurface.

Finally, since the total uranium activity permitted to be placed into the on-site disposal cell (i.e., 1.9 curies) far exceeds the residual activity estimated to be present in the two former Uranium Waste Pond areas (i.e., 0.17 Ci for Uranium Waste Pond #1 and 0.44 curies for Uranium Waste Pond #2), the pathway analysis and dose model performed for the On-site Disposal Cell represents a conservative upper boundary evaluation. Additionally, the assessment completed for the On-Site Disposal Cell assumed (Grant, 1989) a conservative solubility (i.e., 100

percent vs. 29.2 percent) and evaluated Kd's as low as 300 mL/g. These assumptions added additional conservatism to the overall evaluation.

6.3 Field Measurements

Field measurements of exposure provide a more accurate assessment of the actual exposures that may have occurred. During operations involving the movement and/or placement of BTP Option #2 materials into the disposal cell, Cimarron performed ambient environmental air monitoring, area monitoring upwind and downwind of operations, and breathing zone monitoring of radiation workers. In addition, Cimarron has a system of TLD monitors to monitor environmental exposure to direct radiation. Radiation workers are also required to wear direct radiation monitoring badges.

Results of these measurements showed that no worker received an annual exposure greater than the facility ALARA goals. The ALARA goals are set by the site ALARA Committee and are 100 mrem TEDE (individual) and 300 mrem TEDE (collective, all radiation workers) annually. The ALARA goals include doses from all operations, including the movement and placement of BTP Option #2 soils. The cumulative dose assigned to radiation workers was 3.2 mrem during the BTP Option #2 soil relocation activities. This dose was assigned to a single individual and was based upon a lapel sampler that had very low air volume. In addition, environmental monitoring results have not indicated any measurable impacts above background associated with the disposal of the BTP Option #2 materials in the on-site disposal cell (i.e., Burial Area #4).

These field results indicate that the modeling and assessments performed by the NRC were conservative. The actual doses to workers and the general public were substantially overestimated, based upon the field results.

6.4 References

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Simmons, C. S., Kincaid, C. T., and Reisenauer, A. E., 1986, "A Simplified Model for Radioactive Contaminant Transport; the TRANSS Code, Batelle Pacific Northwest Laboratory, PNL-6029.

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USNRC, 1994, "Safety Evaluation Report: Application Dated September 4, 1987, 20.2002 Burial," Docket No. 70-925, Cimarron Corporation, Crescent, OK, June 21, 1994.

USNRC, 1994a, Environmental Assessment of a Proposed Disposal of Uranium-Contaminated Soil at the Cimarron Uranium Plant," Docket No. 70-925, License No. SNM-928, March, 1994.

USNRC, 1996, letter from Mr. Kenneth L. Kalman, Project Manager, Low-Level Waste and Decommissioning Projects Branch, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, to Mr. Jess Larsen, Vice President, Cimarron Corporation, December 10, 1996.

USNRC, 1998, Code of Federal Regulations, Title 10, Part 20, "Standards for Protection Against Radiation," 1998.

7.0 DOSE ASSESSMENT FOR ALL SIGNIFICANT SOURCE AREAS ONSITE

This section discusses the impacted areas at the facility where concentrations of total uranium or Tc-99 in groundwater significantly exceed background concentrations. The BTP Option #2 Disposal Cell is not addressed in this section as it has been previously discussed in Section 6 and has not been determined to contribute to concentrations of radioactive contaminants in the groundwater. The four areas specifically addressed in this section include former Burial Areas #1 and #2, and Uranium Waste Ponds #1 and #2. In those areas the sources have been excavated and only some residual soils meeting Option #1 criteria remain.

As discussed in Section 6, the soil pathway in any affected area will not significantly influence groundwater concentrations as the concentrations are significantly below BTP Option #2 conditions which have been previously modeled. Cimarron believes that the only pathway of concern for those areas is groundwater and that any projected doses will continue to decrease with time. This section evaluates the dose from the groundwater pathway as the only significant exposure concern.

The dose conversion factors for total uranium and Tc-99 are also discussed in this section. In addition, doses are calculated for each of the wells monitored at the facility, assuming consumption of 2 liters per day by reference man.

7.1 ICRP-69 Ingestion Model for Uranium

The ICRP-69 (ICRP, 1995) Ingestion Model presents current scientific knowledge pertaining to uptake and distribution of uranium in the human

body. The uranium model is based upon biokinetic models for gastrointestinal absorption and transfer compartments within the body. A full discussion of the ICRP Gastrointestinal Model is provided in ICRP Publication 56 (ICRP, 1989). ICRP Publication 69 presents age-dependent doses to members of the public, and gives ingestion dose coefficients for uranium.

ICRP Publication 69 reviewed recent gastrointestinal absorption data for dietary forms of uranium. Based upon the data reviewed, the ICRP Committee adopted a value for gastrointestinal absorption (f_1) of 0.02. This absorption factor is consistent with the value utilized in the chemical toxicity evaluation in Section 8.0. The ICRP models also incorporate tissue weighting factors to "represent the factor by which the equivalent dose in a tissue or organ is weighted to represent the relative contributions of that tissue or organ to the total detriment resulting from uniform irradiation of the body" (ICRP, 1991).

7.1.1 Dose Conversion Factors (DCFs) for Uranium and Tc-99

ICRP Publication 69 (Part 3) presents age dependent doses to members of the public from intake of uranium. The adult DCFs for uranium are summarized in Table 7.1.

The DCF for Tc-99 is taken from EPA Federal Guidance Report No. 11 (EPA, 1988). The committed dose per unit intake is 3.95E-10 Sv/Bq (1.46E-06 mrem/pCi). The gastrointestinal absorption fraction (f_1) for Tc-99 given in the EPA guidance is 0.8. The NRC stated in a letter from Mr. Kenneth Kalman to Mr. Jess Larsen dated March 13, 1997 (USNRC, 1997) that a Tc-99 concentration of 3,790 pCi/L would result in an effective dose of 4 mrem/y (assuming consumption of 730 liters/y by

reference man). The Tc-99 DCF used by Cimarron is consistent with this value.

TABLE 7.1

DOSE CONVERSION FACTORS FOR URANIUM

	Sv/Bq Ingested	mrem/pCi Ingested
Uranium-234	5.0E-08	1.85E-04
Uranium-235	4.7E-08	1.74E-04
Uranium-238	4.5E-08	1.67E-04

Notes: 1) Values in the table represent effective dose for an adult.
2) To convert Sv/Bq to mrem/pCi, multiply Sv/Bq by 3700.

7.1.2 Calculation of an Overall DCF for the Total U Isotopic Ratios at Cimarron

The previous section presented DCFs for the individual uranium isotopes of concern at Cimarron. The DCFs for the individual isotopes range from 1.67E-04 mrem/pCi for Uranium-238 to 1.85E-04 mrem/pCi for Uranium-234. Thus, the isotopic mixture, or activity percentage of each of the three uranium isotopes will not significantly affect the hypothetical dose to a person drinking water from a well established at the Cimarron facility.

The isotopic ratios for soils at Cimarron have been previously established in the NRC's "Environmental Assessment Associated with the BTP Option #2 Onsite Disposal Cell at Cimarron" (NRC, 1994). The Environmental Assessment used activity percentages of 79% for Uranium-234, 1.7% for U-235, and 20% for Uranium-238. As stated above, the DCFs for each of the three uranium isotopes are similar. The activity percentages for soil

were used as weighting factors to determine the total uranium DCF, as shown below.

1.85E-04 mrem/pCi (0.79) + 1.74E-04 mrem/pCi (0.017) + 1.67E-04 mrem/pCi (0.20)

= 1.83E-04 mrem/pCi of total uranium.

The DCFs for Uranium-234, Uranium-235, Uranium-238, total uranium, and Tc-99 are summarized in Table 7.2 and Table 7.3 along with the concentrations that would result in an effective dose of 4 mrem/y and 100 mrem/y (Tc-99), or 25 mrem/y and 100 mrem/y (Uranium). These concentration values were selected for comparison purposes.

7.2 Dose Calculations Based Upon Well Sample Results

This section presents the hypothetical effective annual dose that could be received by a reference man drinking 2 liters every day from each of the ground water monitoring wells and surface water monitoring locations at the Cimarron facility. Of course, as discussed in Section 3.6 of this report, it is highly unlikely that an individual would use any of the on-site wells as a drinking water supply. The data presented are for calendar year 1997 and the first quarter of 1998. Tc-99 analyses were performed only when indicated based upon gross beta to gross alpha activity ratios exceeding 3:1 and gross beta activity exceeding 30 pCi/L. Those areas were around Uranium Waste Ponds #1 and #2. Total uranium is calculated by summing the isotopic uranium data for each date and location. The effective annual dose is calculated through application of the DCF to the total activity taken into the reference man. Table 7.4 presents the isotopic uranium and Technetium-99 laboratory results for each location by sampling date.

7.2.1 Burial Area #1 Dose Calculation

Burial Area #1 is surrounded by four wells. Well #1314 is upgradient of the burial area, while Wells #1315, #1316, and #1317 are within or downgradient of the burial area. As shown in Table 7.4, the total uranium concentration in Well #1314 averaged 2 pCi/L, resulting in an effective dose to the hypothetical individual of approximately 0.3 mrem/y from ingestion of uranium. There is no Tc-99 associated with Burial Area #1. (Note: As stated above, the use of a DCF for enriched uranium will not have a significant effect upon the dose calculation when naturally occurring uranium isotopic activity ratios are present).

Well #1315 (located in former Burial Area #1) had the highest concentrations of uranium for this area, and also for all monitoring wells within the Cimarron site boundary. This well averaged 1,993 pCi/L, with a resultant annual effective dose of 269 mrem calculated for the hypothetical individual.

Wells #1316 and #1317 are downgradient of former Burial Area #1. The calculated annual effective doses for the hypothetical individual were 16 mrem and 32 mrem, respectively, for the two wells.

7.2.2 Uranium Waste Pond #1 Dose Calculation

Wells #1311, #1312, and #1313, #1340, and #1341 have been used to monitor Uranium Waste Pond #1. Well #1311 is upgradient of the Pond, while Well #1312 is West of the Pond and Well #1313 is downgradient. Wells #1340 (Sandstone A) and #1341 (Sandstone B) are located side by side in an area east of the Pond.

Upgradient Well #1311 showed low levels of total uranium and Tc-99. The reported concentration for Tc-99 (March, 1997) is near the reported laboratory detection limit. The annual effective dose to the hypothetical individual for this well was calculated to be 0.53 mrem due to uranium and 0.02 mrem due to Tc-99, and is within the range of other upgradient and background wells.

Well #1312 continued to show a low level of impact from past operations. The total uranium and Tc-99 concentrations in this well averaged 26 pCi/L and 2,152 pCi/L, respectively. The concentration of Tc-99 dropped from 3,680 pCi/L in March, 1997, to 1,850 pCi/L in March, 1998. The calculated average annual effective dose for this well was 3.5 mrem (uranium) and 2.3 mrem (Tc-99).

Well #1313 had average total uranium and Tc-99 concentrations of 38 pCi/L and 1,047 pCi/L. The calculated annual effective dose to the hypothetical individual was 5.1 mrem (uranium), and 1.1 mrem (Tc-99) for this well.

The concentration of total uranium in Wells #1340 and #1341 was 3.9 pCi/L and 2.2 pCi/L, respectively, for the single sampling event in June, 1997. These concentrations correspond to annual effective doses of 0.5 mrem and 0.3 mrem for the two wells (hypothetical individual).

7.2.3 Uranium Waste Pond #2 Dose Calculation

Uranium Waste Pond #2 is monitored by one seep (#1208), four shallow groundwater wells (#1320, #1336A, #1337, and #1338), and one Sandstone C deep well (#1321). The seep is located on the bluff Northeast of the Pond. Wells #1320 and #1321 are located within the

former Pond area near the Southwest corner. Well #1336A is located downgradient of the Pond, just north of the Northwest corner. Wells #1337 (Sandstone A) and #1338 (Sandstone B) are located side by side at a location Northeast of the Pond.

Seep #1208 averaged 40 pCi/L total uranium and 2,836 pCi/L Tc-99 during 1997 and the first quarter of 1998. Tc-99 concentrations dropped from 3,960 pCi/L in March, 1997, to 2,300 pCi/L in March, 1998. It is unlikely that this seep would be used as a drinking water source on a consistent basis due to the low volumes of water available. Even so, the average annual effective dose to the hypothetical individual was calculated to be only 5.4 mrem (uranium) and 3 mrem (Tc-99).

Wells #1320 and #1321 were monitored in June, 1997. The calculated effective doses for these wells due to uranium were 0.3 mrem and 2.2 mrem, respectively. The average total uranium concentration in Well #1336A was 41 pCi/L, while the average Tc-99 concentration was 1,840 pCi/L. Tc-99 concentrations decreased from 2,590 pCi/L during March, 1997, to 1,600 pCi/L in March, 1998. The annual effective dose for this well was calculated to be 5.5 mrem (uranium), and 2 mrem (Tc-99).

Wells #1337 and #1338 had total uranium concentrations of 11.7 pCi/L and 1.2 pCi/L, respectively in June, 1997. The annual effective dose for these wells is calculated to be 1.6 mrem and 0.2 mrem, respectively.

7.2.4 Burial Area #2 Dose Calculation

Wells #1332 and #1333 are located to the east of Burial Area #2. These wells are somewhat upgradient to the Burial Area, but are also downgradient of the West Sanitary Lagoon. Well #1333 is a Sandstone C

deep well. Well #1331 is located in a draw to the northwest of the Burial Area.

Wells #1332 and #1333 had total uranium concentrations of 29 pCi/L and 13 pCi/L, respectively, during 1997. These concentrations correspond to annual effective doses of 3.9 mrem for Well #1332, and 1.8 mrem for Well #1333. The average total uranium concentration at Well #1331 was 160 pCi/L, which equates to an annual effective dose of 22 mrem to the hypothetical individual.

7.2.5 Summary of Annual Doses for Burial Area #1, Uranium Waste Ponds #1 and #2, and Burial Area #2

Table 7.5 provides a summary of the calculated annual average doses for the four operationally affected areas discussed in this section. As discussed above, the doses are hypothetical in nature and assume that reference man consumes 2 liters from the same affected well each day of the year. In all cases, the Tc-99 dose is less than 2.5 mrem, and the total uranium dose is less than 22 mrem, except at former Burial Area #1.

7.2.6 Other Areas

Well data and dose calculations for other surface water and ground water monitoring locations is presented in Table 7.4. The calculations performed for other wells at the facility do not indicate that there is the potential for any individual to receive greater than 4 mrem per year from Tc-99 or 5 mrem/y from total uranium. These calculations are very conservative and assume that an individual (i.e., reference man) continuously drinks 2 liters of water each day from the selected well.

7.3 References

EPA, 1988, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Federal Guidance Report No. 11, EPA-520/1-88-020, September, 1988.

ICRP, 1989, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 1," ICRP Publication 56, Volume 20, No. 2, 1989.

ICRP, 1991, "1990 Recommendations of the International Commission on Radiological Protection," ICRP Publication 60, Volume 21, No 1-3, 1991.

ICRP, 1995, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 3 Ingestion Dose Coefficients," ICRP Publication 69, Volume 25, No.1, 1995.

USNRC, 1994, Environmental Assessment of a Proposed Disposal of Uranium-Contaminated Soil at the Cimarron Uranium Plant," Docket No. 70-925, License No. SNM-928, March, 1994.

USNRC, 1997, letter from Mr. Kenneth L. Kalman, Project Manager, Low-Level Waste and Decommissioning Projects Branch, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, to Mr. Jess Larsen, Vice President, Cimarron Corporation, March 13, 1997.

TABLE 7.2
DOSE CONVERSION FACTORS FOR INGESTION AND CONCENTRATIONS
EQUIVALENT TO 25 and 100 mrem/year (effective dose) - URANIUM

	f1	Dose Conversion Factor CDE (Sv/Bq)	Dose Conversion Factor CDE (mrem/pCi)	Organ	Concentration equal to 25 mrem/y (pCi/L)	Concentration equal to 100 mrem/y (pCi/L)
234	0.02	5.00E-08	1.85E-04	effective	185	740
235	0.02	4.70E-08	1.74E-04	effective	197	788
238	0.02	4.50E-08	1.67E-04	effective	206	823
Total U	0.02	4.93E-08	1.82E-04	effective	188	751

1) Doses are calculated for reference man.
2) Total U DCF (based on the activity fractions used for U-234 (79%), U-235 (1.7%), and U-238 (20%) in the NRC's Option #2 Onsite Disposal Environmental Assessment), in Sv/Bq = 4.93E-08
3) Uranium data are based on ICRP Publication 69, "Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 3 Ingestion Dose Coefficients", 1995.

TABLE 7.3
DOSE CONVERSION FACTORS FOR INGESTION AND CONCENTRATIONS
EQUIVALENT TO 4 and 100 mrem/year (effective dose) - Tc-99

f1	Dose Conversion Factor CDE (Sv/Bq)	Dose Conversion Factor CDE (mrem/pCi)	Organ	Concentration equal to 4 mrem/y (pCi/L)	Concentration equal to 100 mrem/y (pCi/L)
0.8	3.95E-10	1.46E-06	effective	3749	93730

1) Tc-99 data are based on EPA Federal Guidance Report #11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA-520/1/88-020, Sept., 1988.
2) Doses are calculated for reference man.