TECHNICAL MEMORANDUM

Review of Ground-Water Contamination at Sparton Technology Inc.'s Coors Road Facility

Prepared for

City of Albuquerque Pubic Works Department
Water Resources Program

JANUARY 1996

CITY OF Albuquerque

CH2M HILL

SPARTON

SPARTON TECHNOLOGY

RECEIVED

CERTIFIED MAIL RETURN RECEIPT REQUESTED

January 30, 1997

Mr. Benito Garcia
Bureau Chief
HAZARDOUS AND RADIOACTIVE MATERIALS BUREAU
New Mexico Environment Department
PO Box 26110
Santa Fe, New Mexico 87505

Re: 1996 Annual Ground-Water Report

Dear Mr. Garcia:

Enclosed is Sparton Technology's Inc. 1996 Annual Ground-Water Report for our Coors Rd. Facility. This report is prepared in response to HWMR-5, Part IV, Section 265.94(a)(2)(ii) and (iii), and is compiled on forms provided by your office.

The Monitoring Well Identification Report Form has been modified to include the surveyed Measuring Point Elevation (MPE). This surveyed elevation is located on the wellhead vault or outer protective casing. The MPE is the reference point for all elevation data presented in this report.

If you have any questions please contact John Wakefield or me at (505) 892-5300. Thank you for your attention to this matter.

Sincerely,
SPARTON TECHNOLOGY, INC.
John Wakefield for Richard D Mico

Richard D. Mico
Vice President and General Manager

enclosure:

cc: without enclosure
Mr. J. Appel
Mr. P. Chandler
Mr. G. Richardson
Mr. J. Wakefield

004692

Sparton Technology, Inc. □ *4901 Rockaway Blvd., SE* □ *Rio Rancho, NM 87124-4469* □ *(505) 892-5300* □ *FAX (505) 892-5515*

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One Civic Plaza
Albuquerque, New Mexico

JANUARY 1996

CH2M HILL

6001 Indian School Road, NE.
Albuquerque, New Mexico
Mike Bitner

Review of Ground-Water Contamination at Sparton Technology Inc.'s Coors Road Facility

PREPARED FOR: Norman Gaume, City of Albuquerque

PREPARED BY: Mike Bitner
Amy Halloran
Sharon Minchak

COPIES: Project File
Coy Webb

DATE: January 17, 1996

This memorandum summarizes the results of a review of data and reports related to ground-water contamination at Sparton Technology, Inc.'s Coors Road facility in Albuquerque.

1. Conclusions

1.1 Nature and Extent of Contamination

Widespread and significant amounts of ground-water contamination exist at the Sparton Technology, Inc. Coors Road facility in Albuquerque. The primary hazardous constituents include trichloroethene (TCE), an industrial solvent and suspected human carcinogen, and various metals, including chromium.

The extent of the contamination has not been determined, but existing data show that TCE contamination exceeding safe drinking water standards, 5 micrograms per liter (µg/L), occurs beneath over 90 acres of land at the site and next to it.

Very high levels of TCE are found both on and off the site: concentrations approaching or exceeding 2,000 µg/L (400 times the safe drinking water standard) have been measured in two offsite wells (wells 37 and 46). Onsite TCE levels have been even higher, exceeding 17,000 µg/L. Figures 1 through 6 show estimated levels of contamination based on the most recent data available—either October 1994 or, for some wells, December 1993. The following paragraphs discuss the apparent extent of contamination.

1.1.1 Areal Extent

Figure 1 shows the apparent extent of contamination in what Sparton documents refer to as the upper flow zone. Although the Areal extent of the contamination is not known, it is clear that the contamination is spreading rapidly. Sparton's reports estimate that contamination above drinking water standards has moved at least one-half mile offsite and contaminant levels of over 700 µg/L (over 140 times greater than standards) occur at Well 61, almost 2,000 feet from the site's western boundary. Contaminants continue to move through the aquifer at relatively rapid rates. Well 61 is the most distant well directly downgradient (in the "middle" of the apparent plume). Contamination was not detected there in 1989, 1990, or 1991. But in 1993, TCE concentrations jumped to 610 µg/L in 1993 and to an average of 720 µg/L in 1994.

Sparton has estimated that the extent of TCE contamination above standards is only 700 feet downgradient of Well 61. But there are no monitoring data directly downgradient of Well 61, so the extent of these high levels of contamination is not known. Figure 1 reflects this uncertainty by showing question marks where contours of equal concentration cannot be reliably estimated. However, the ground water in this vicinity appear to be moving to the northwest at a rate of between 100 and 300 feet per year. Even if Sparton's apparently optimistic estimate of the lateral extent of the plume is correct (1,400 feet), then the areal extent of the plume is increasing at a rate of between 3 to 10 acres per year.

Wells 53 and 58 appear to be on the lateral fringe of the plume, southwest of Well 61. Contaminant levels are rising here too: no TCE was detected in Well 53 during 1989 to 1991, but 1993 sampling recorded 32 µg/L and 1994 data showed 43 µg/L; TCE in Well 58 increased from less than 30 µg/L in 1989 to 1991 to 74 µg/L in 1993.

The deeper Wells 55 (Figure 3) and 56 (Figure 2) are about 1,600 feet northwest of the site, and appear to be somewhere between the middle of the plume (suggested by well 61) and the lateral fringe (suggested by Wells 53 and 58). They too have seen significant increases in TCE concentrations: Well 56 has gone from 63.5 µg/L in 1989-1990 to 200 µg/L in 1991 to about 400 µg/L (most recent value is the average of 2 measurements) in 1994. The deeper Well 55 has gone from 10.6 µg/L in 1989-1990 to 45 µg/L in 1991 to about 555 µg/L in 1994. These are high levels of contamination indicate that the plume is spreading deeper into the aquifer as well as moving rapidly horizontally.

1.1.2 Vertical Extent

Figures 4 through 6 show TCE concentrations in cross section views. The depth of contamination has also not been determined, but concentrations over 100 times higher than safe drinking water standards have been found in Well 55 (Figures 4 an 6) at depths of over 100 feet beneath the water table and over 250 feet beneath the land surface. Figure 4 is the corss section most closely aligned with the longitudinal axis of the plume. Because Well 55 is the deepest well in the main part of the offsite plume, there are no data to define the vertical extent of the plume.

1.2 Summary of Recent Documents

Sparton claims arsenic in the local ground water would prevent its use for water supply. In fact, naturally occurring arsenic concentrations in the area are not an impediment to water supply development.

Sparton claims that diffusion is the dominant contaminant transport mechanism. In fact, the dimensions of the plume are entirely consistent with advection and dispersion driven transport mechanisms. If diffusion were the sole transport mechanism, the plume would be moving less than 1 foot per year and would not have migrated over 2,500 feet.

There is no basis for Sparton's claim that contaminant mass is decreasing. They base this claim on the large number of onsite wells, but fail to highlight the fact that concentrations are actually increasing in most of the downgradient offsite wells in the plume's path. Moreover, because the "bottom" of the plume has not been adequately delineated, the amount of contamination moving to deeper parts of the aquifer cannot be reliably estimated.

There is no basis for Sparton's assertion that pump and treat containment strategies will not be effective in diffusion-dominated plumes. In fact, pump and treat is easiest to implement when there are no opposing advective forces to counter. As noted, the transport process is largely advective and pump and treat methods are proven reliable ways to effect hydraulic control in this type of aquifer system.

2. Review of Recent Documents

As requested, CH2M HILL reviewed the following documents for the Sparton Technology, Inc.'s Corrective Action at their Coors Road facility in Albuquerque:

- Thompson & Knight's November 6, 1995, letter to US EPA Region VI
- US EPA Region VI's October 3, 1995, letter to Richard Mico/Spartan Technology
- Draft Corrective Measures Study Report, November 5, 1992
- RCRA Facility Investigation, May 1992

The review assessed the validity of the items proposed in the November 6 letter. In particular, our review focused on (1) Sparton's belief that diffusion is the dominant contaminant transport mechanism for the solvent plume from the Sparton facility, (2) Sparton's assertion that the arsenic levels in the ground water impacted by the plume make the ground water unsuitable for a source of drinking water, and (3) Sparton's claim that additional wells are not needed to further delineate the extent of the solvent plume. The following paragraphs address each of these items.

2.1 Contaminant Transport Mechanisms

The physical processes by which solutes are transported in ground water are (1) advection, (2) mechanical dispersion, and (3) molecular diffusion. Advection is the transport of a contaminant by bulk ground-water flow (i.e., as ground water moves, so do the dissolved contaminants). If advection is the dominant transport process, the distances that contaminants may travel are generally the same as the average linear distances traveled by ground water.

The mixing and spreading of contaminants as they move through the aquifer can be described by the process of dispersion. How much spreading occurs is controlled by (1) molecular diffusion of the contaminant, (2) the average velocity of the contaminant in the ground water, and (3) the dispersivity of the aquifer. In alluvial aquifers with relatively high ground-water velocities (such as in the area of the Sparton plume), the mixing caused my molecular diffusion is small relative to the mechanical mixing caused by the dispersivity in the aquifer (Neuman at el., 1987). This mechanical mixing of contaminants occurs when the flowing ground water moves on a tortuous path through heterogeneous material. Some of the water parcels encounter higher permeability materials with coarse sand and gravel and move faster than the average velocity; some flow through material with a higher clay content and move more slowly than the average. This process causes spreading or dispersion.

Thompson & Knight asserts in their cover letter to "Sparton's Reaction to the Responses of EPA..." (Sparton's Reaction) that "any expansion of impacted groundwater is at a very slow rate and caused by diffusion...". They base this assertion in Sparton's Reaction by the following three items:

1. their calculations of offsite plume velocities,
2. their calculations of the relative length and width of the plume, and
3. their estimation of a logarithmic drop-off in TCE concentrations at the leading edge of the plume.

We believe that there are several inconsistencies in these arguments, as pointed out in the following paragraphs.

2.1.1 Offsite Plume Velocities

Thompson & Knight have calculated plume velocities on the Sparton facility, at the west end of the plume, and in the area near MW-61. For these calculations they assume that K, the hydraulic conductivity, and n, the effective porosity, are constant. Yet repeatedly throughout "Sparton's Response" they assert that the aquifer is very heterogeneous. In fact they criticize EPA for what they claim is EPA's assumption that the aquifer is "homogeneous and isotropic". Therefore Thompson & Knight's assumption of a constant K and n, especially on the short distances covered by their analysis, (less than 2,500 feet) reflects the same simplifying assumption for which they criticize EPA.

CH2M HILL has compared ground-water flow characteristics in the vicinity of the Sparton facility using the recent USGS ground-water data and model for the Albuquerque basin. Based on the 1994 USGS data in the vicinity of the Sparton site, hydraulic conductivities

vary from 15 to 40 feet per day. The upper modeled layers, which coincide with the Sparton's Response flow zones, tend to exhibit higher conductivities. Localized hydraulic conductivities shown in Sparton hydrogeologic investigations appear to range from 0.1 to over 100 feet per day depending on which report is referenced. Table 1 illustrates the comparison of general hydrogeologic data between the Sparton reports and the USGS. In their response, Sparton focuses mainly on aerial differences in horizontal water movement and velocities. However, they also point out that horizontally, the aquifer zones display similar properties, but vertical discontinuities are such that they have had to refer to a single regional water bearing zone in terms of the three "flow zones". In fact, the May 1992 RCRA report alludes to a perched water zone potentially underlying the site in the upper flow zone, which causes localized gradient anomalies. This gradient differential could potentially be causing the confusion about whether ground-water velocities are increasing or decreasing as the plume leaves the site, since all other properties used to calculate velocity are assumed constant. Differences in gradient understanding and differing porosities are factors that could drive the resulting average horizontal ground-water velocities to the extreme ranges shown on Table 1.

TABLE 1
Comparison of General Hydrogeologic Data for the Sparton Site Area

Data Source	Parameter	Upper Flow Zone Values (similar to USGS layer 1)	Lower Flow Zone Values (similar to USGS layers 1-6)
Sparton Hydrogeologic Investigation Reports	Transmissivity, T	6 - 615 gpd/ft	12,000 - 18,000 gpd/ft
	Hydraulic Conductivity, K	0.1 - 8 ft/day	21 - 32 ft/day
	Hydraulic Gradient, i	0.002 - 0.025	0.003 - 0.005
	Porosity, n	0.25 - 0.4	0.25 - 0.4
	Flow Velocity, V_a	0.2 - 292 ft/yr	57 -234 ft/yr
USGS, 1994	Transmissivity, T	24,000 - 64,000 gpd/ft	24,000 - 64,000 gpd/ft
	Hydraulic Conductivity, K	15 - 40 ft/day	15 - 40 ft/day
	Hydraulic Gradient, i	0.002 - 0.003 ft/ft	0.002 - 0.003 ft/ft
	Porosity, n	0.15	0.15
	Flow Velocity, V_a	73 - 292 ft/yr	73 - 292 ft/yr

However, even if Sparton's ground-water velocities are used, the plume movement cannot be primarily due to diffusion. At the west end of the plume they calculate that the ground-water flow velocity is 39 to 94 feet per year (3.77 x 10-5 to 1.0 x 10-4 cm per second). Given the presumably low organic carbon content in the aquifer, "retardation" of contaminants by sorption/desorption phenomena should not be significant and, therefore the contaminants in the plume would be expected to be moving at approximately the same velocity. At the west end of the plume the velocity due to diffusion would be much less than these advective velocities.

If a constant source concentration is assumed (which would give the highest diffusion rates), the velocity expected from diffusion can be calculated from the following equation from Freeze and Cherry (1979):

$$C_i\,(x,t) = C_0\, erfc\, [x/\{2(D^*t)^{1/2}\}]$$

Where C_i is the concentration at distance x and time t from the source, C_0 is the initial concentration of the contaminant, *erfc* is the complementary error function, and D^* is the apparent diffusion coefficient.

If it is assumed that $C_i/C_0 = 0.5$ (i.e. the concentration at point x at time t is half as much as the initial concentration), $D^* = 8.3 \times 10^{-6}$ cm^2/sec (as given by Cohen and Mercer, 1993, for TCE), and that there is a sharp boundary or edge to the plume (which would also maximize diffusive transport), then it would take approximately 1 year for the concentration 15 cm from the plume front to equal one half of what the concentration at the center of the plume was at the beginning of the year. Or, stated another way, if the concentration at the original edge of contamination was 17,000 µg/L, then in 1 year the concentration 15 cm from that edge would reach 8,500 µg/L if diffusion is the only transport mechanism. It would take thousands of years for diffusion to transport the contaminants observed at Well 61, some 2,000 feet from the site's western boundary. The ground-water flow rates presented in Sparton's Reaction are orders of magnitude greater than this diffusion rate. Therefore, the predominant contaminant transport mechanism cannot be diffusion.

2.1.2 Plume Length and Width

Thompson & Knight further argue that the shape of the plume is evidence that the transport mechanism is diffusion-dominant. They cite the length-to-width ratios of the plume as being "well below the typical advection-dominant threshold of 10:1 L to W". This argument completely ignores the influences of mechanical dispersion. Sparton's Reaction repeatedly refers to the heterogeneous nature of the aquifer, yet they completely ignore this fact in their argument for diffusion-dominant contaminant transport. These heterogeneities likely cause some of the contaminants to migrate faster than the rate predicted by the estimated average linear ground-water flow velocities (as the ground water preferentially flows through lenses of materials with higher permeability); and some contaminants will migrate more slowly than the average. These local-scale variations in velocities and flow directions have the effect of "spreading" the plume, causing the width to become much broader than the original dimensions of the source area.

Moreover, it should be noted that localized high-permeability lenses may be quite narrow and therefore may not have a ground-water monitoring well installed in them. Therefore, the current monitoring network may not be identifying all of the offsite migration of the contaminants. Failure to include this component in a contaminant mass balance could lead to an erroneous conclusion that contaminant mass is decreasing. This may be one explanation for Thompson & Knight's assertion that the contaminant mass is decreasing.

The arguments presented for diffusion-dominant transport also do not take into consideration the seasonal changes in ground-water flow patterns or the changes in flow patterns between the regions of the aquifer. Temporal variations in flow directions are to be expected because of seasonal and annual variations in locations and rates of recharge and pumping. In addition, Sparton's data clearly document the spatial variation in flow directions at the site. As the contaminants initially migrate downward through the ground

water (TCE is heavier than water), they encounter changes in the direction of flow. This is seen in Figures 25 through 30 in the RFI report. These changes would spread out the contaminant plume, giving it a wider path than if the ground-water flow were always in one direction.

The assertion that contaminants detected in "upgradient" wells are evidence of diffusion-dominant transport also ignores (1) the potential for TCE as a dense, non-aqueous phase liquid (DNAPL) to move upgradient by being "deflected" by lower-permeability clays and silts and (2) the roles that mechanical dispersion caused by the heterogeneities of the aquifer and seasonal changes in ground-water flow patterns may play in contaminant transport. Perhaps more importantly, the assertion is inconsistent with calculations that show that transport by diffusion would amount to transport of only a foot or two upgradient, not the more than 100 feet observed.

2.1.3 Shape of Plume Front

Sparton's Reaction states that "another confirmation of the movement by diffusion is the fact that UFZ Wells MW-48, MW-58, and MW-52, which line up in the implied flow direction at the leading edge of the plume, show a logarithmic drop-off in TCE concentration." However, in cases of advective transport with increased dispersivity, the concentrations at the front of a contaminant plume slowly increase from zero to the concentration in the bulk of the plume. Samples collected from a monitoring well as a plume approaches and surrounds the well would gradually increase over time. The TCE concentrations in most of the monitoring wells from the Sparton facility have gradually increased or decreased over the monitoring period of 1989 to 1994. Only monitoring Well 61 appears to have the sharp contaminant spike indicative of advection with low dispersion (although the well was not sampled between the 1991 and 1993 sampling rounds, so a gradual increase may have occurred, but not been observed). Moreover, Wells 48, 58, and 52 do not appear to "line up in the implied flow direction at the leading edge of the plume". Rather, Sparton's water-level and contamination data suggest that the higher levels of contamination observed at Well 61 are moving to the northwest and will not pass these wells at the so-called "leading edge of the plume". Therefore, the most likely contaminant transport force is advection with dispersion.

In summary, for all of the reasons stated above, diffusion cannot be the dominant transport mechanism for the contaminants in the Sparton plume.

2.2 Arsenic Concentrations

Item three of the Sparton Reaction discusses what they refer to as "significant concentrations of naturally occurring arsenic" in ground water in the vicinity of the Sparton plume. Sparton points out that the mean concentration of arsenic in ground water pumped from the City of Albuquerque wells exceeds 15 µg/L. This statement is accurate, however, this mean arsenic concentration value takes into account all of the water produced by all of the City of Albuquerque's wells located throughout the city and does not infer anything about the arsenic concentration of water produced from proposed City wells in the vicinity of the Sparton plume. In fact, Figure C-38 (Albuquerque, 1995, p. C-57) referenced by Sparton shows that estimated arsenic levels in proposed City wells in the vicinity of the Sparton site are on the order of 10 µg/L.

Sparton also points out that three fourths of the City wells produce water with arsenic concentrations exceeding 5 µg/L. However, to date, the MCL for arsenic has not been lowered from 50 µg/L, therefore, wells with arsenic values in excess of 5 µg/L but still below 50 µg/L are not considered to have arsenic exceedances. In addition, the number of wells located throughout the city with or without elevated arsenic levels does not have any bearing on the specific arsenic levels in wells that may be proposed in the vicinity of the Sparton plume.

Sparton references ground-water sampling results for water in the Sparton plume and states that the arsenic values in the plume are "in the range of city results". There are 27 Sparton wells for which arsenic results are presented in the RFI Report. Most of these wells fall into the category referred to by Sparton as upper flow zone wells. All of the 27 wells were sampled at least twice. Of the 27 wells, 13 (48 percent) had arsenic values below the method detection level during both sampling rounds and 8 (30 percent) of the wells had arsenic values below the method detection level during one of the sampling rounds. Therefore, 78 percent of the wells had non-detectable levels of arsenic during at least one of the two sampling events. Of the 6 wells for which detectable levels of arsenic were measured during both sampling rounds, most values ranged from 4-8 µg/L. The highest arsenic levels detected in any of the 27 wells were levels of 31 µg/L and 34 µg/L in wells MW-36 and MW-37, respectively. Both of these levels are more than 30 percent less than the current MCL. Likewise, results from the second sampling round for these wells indicated an arsenic level below the method detection level in MW-36 and a level of 12 µg/L in MW-37. The reason for this dramatic decrease in arsenic levels is not clear. However, overall sampling results available show that arsenic levels in ground water from Sparton plume monitoring wells are below the drinking water standards.

Another comment made by Sparton in this section states that the "highest" concentrations of arsenic in City wells occur in wells to the west of the Rio Grande. Again, this statement is true, however, those high arsenic levels occur in City wells that are located over 5 miles to the southwest of the Sparton site. As discussed previously, estimated arsenic concentrations in proposed City wells in the vicinity of the Sparton site are on the order of 10 µg/L, which is less than the mean concentration for the City's wells.

Sparton comments on the possibility of the EPA lowering the MCL for arsenic, and the need for the City to implement ground-water treatment for arsenic if that occurs . However, as pointed out previously, the MCL for arsenic currently remains at 50 µg/L. Sparton also makes a comment regarding the fact that City management strategies do not include hydraulic containment for arsenic. Hydraulic containment is neither feasible nor possible in this case, as measurable levels of arsenic occur throughout the 3,000 square-mile Albuquerque ground-water basin, so the point of Sparton's comment is not clear.

Sparton comments that, based on the Water Management Options Study, the Sparton plume area will not be used for ground-water production, and that if it is used for drinking water in the future, wellhead treatment for TCE would be no greater impairment than wellhead treatment for arsenic.

While wellhead treatment for TCE is feasible, it would still require a separate remediation system from the arsenic treatment, since the two treatment processes are quite different. Furthermore, it cannot be assumed that arsenic treatment will be required in these areas. In such a case, TCE treatment at a City wellhead may delay use of the well, require additional

property and/or structures, and interfere with well operation and production. Also, contrary to Sparton's statement that TCE treatment does not produce hazardous waste, hazardous wastes (or even radioactive wastes) such as spent activated carbon canisters to control air emissions may be generated by the treatment process.

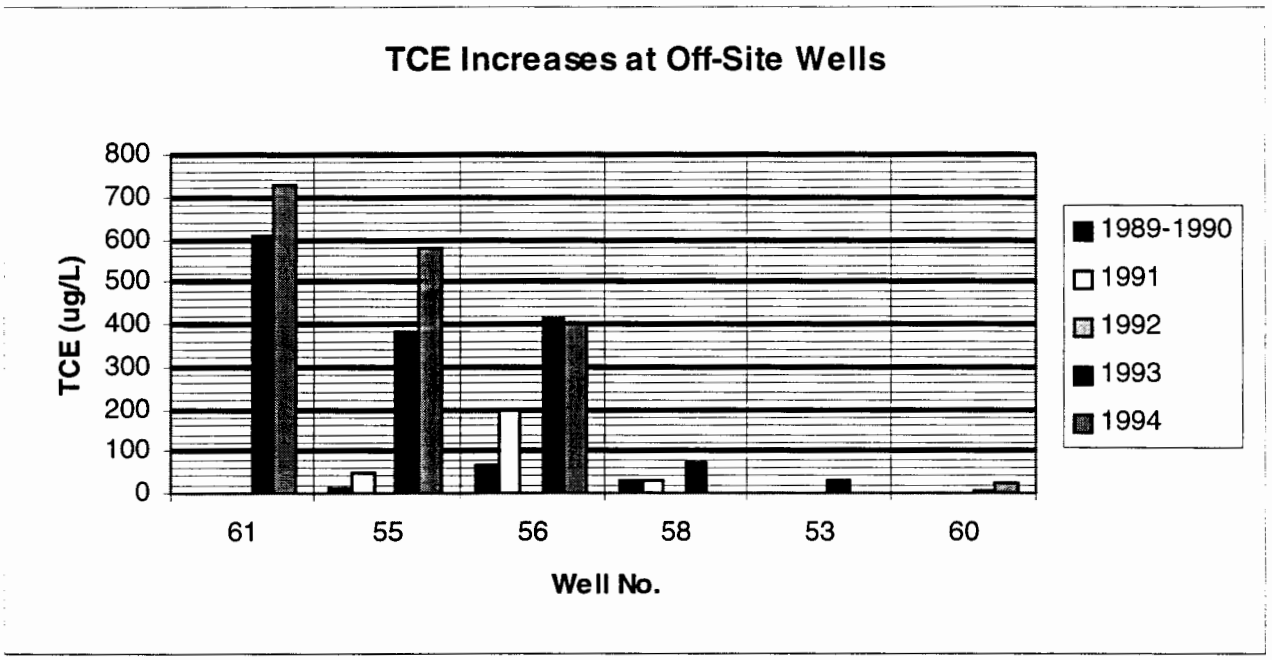
Finally, Sparton's comment regarding the fact that the Sparton plume area will not be used for ground-water production base on the City of Albuquerque's Water Management Options Study. However, that study clearly states that site-specific locations have not been identified for any of the project options and certainly not for the "conceptual future city water wells". Failure to contain the plume will certainly reduce the potential well sites available to the City. Because of the increasing difficulty of permitting new well sites, this would likely adversely impact the City's ability to continue to meet water demands in this area. Moreover, the assertion that the area will not be used for water supply ignores other non-City users. Figure 8 in the Sparton RFI Report shows an abundance of wells within a 3-mile radius of the site that were identified through State records and visual identification. These wells are not City wells and are being used for industrial, domestic, or irrigation purposes. Several of these wells appear to be located downgradient of the Sparton site and the Sparton plume may negatively impact the ground-water quality of these wells.

2.3 Additional Wells

In their documents, EPA and Thompson & Knight have differed as to whether or not TCE concentrations in the wells are increasing or decreasing. Thompson & Knight have chosen to look at all of the monitoring data, by flow zone, to present the percentage of wells where the contaminant concentrations are staying the same or decreasing. CH2M HILL agrees that the concentrations in a majority of the wells are decreasing. This is simply because the majority of the wells are close to the former source of the contamination and significant new sources of contamination may not be present.

The point that is missed in Sparton's Reaction is that the concentrations in the wells on the edge of the plume are increasing, indicating further (advective/dispersive) migration of the plume offsite. For example, as shown in Figure 1, over the sampling period (about 1989 to 1993 or 1994, depending on the well), contaminant concentrations have been increasing in Wells 53, 58, 61, and 62 in the UFZ, 56 and 60 in the ULFZ, and 55 in the LLFZ. All of these wells are on the leading edge of the plume. Therefore, the plume is continuing to migrate offsite.

FIGURE 7
TCE Contamination Increasing at Downgradient Monitoring Wells



One problem with this plume migration, is that since there are less wells on the edges of the plume, there is a greater chance that a "finger" of the plume may slip by the existing monitoring well network. These contaminant fingers are common in heterogeneous aquifers such as are found in the Albuquerque basin. Therefore, the mass reduction cited in Sparton's Reaction has a significant chance of having missed a large pocket or finger of TCE contamination. The decrease in TCE mass that they have attributed to natural attenuation may simply be evidence of a pocket of TCE that has migrated outside of the monitoring network due to channeling or other heterogeneous features or to deeper parts of the aquifer.

Thompson & Knight argue that they have "very good definition of geologic and hydrogeologic conditions" onsite and can therefore extrapolate their data to predict offsite conditions and plume migration. But, in the same document, Thompson & Knight have argued that offsite conditions are significantly different from onsite conditions, thereby causing a significant decrease in ground-water migration rates offsite. Because of these differences, mere extrapolation of the onsite data may not be sufficient to establish a lack of contaminant migration.

Because of these concerns, it seems that, at a minimum, additional monitoring wells should be installed at the edge of and beyond the plume to detect further offsite migration of the plume. In addition, deep wells closer to the center of the plume may be needed to verify that localized flow conditions are not carrying contaminants deeper into the aquifer.

3. References

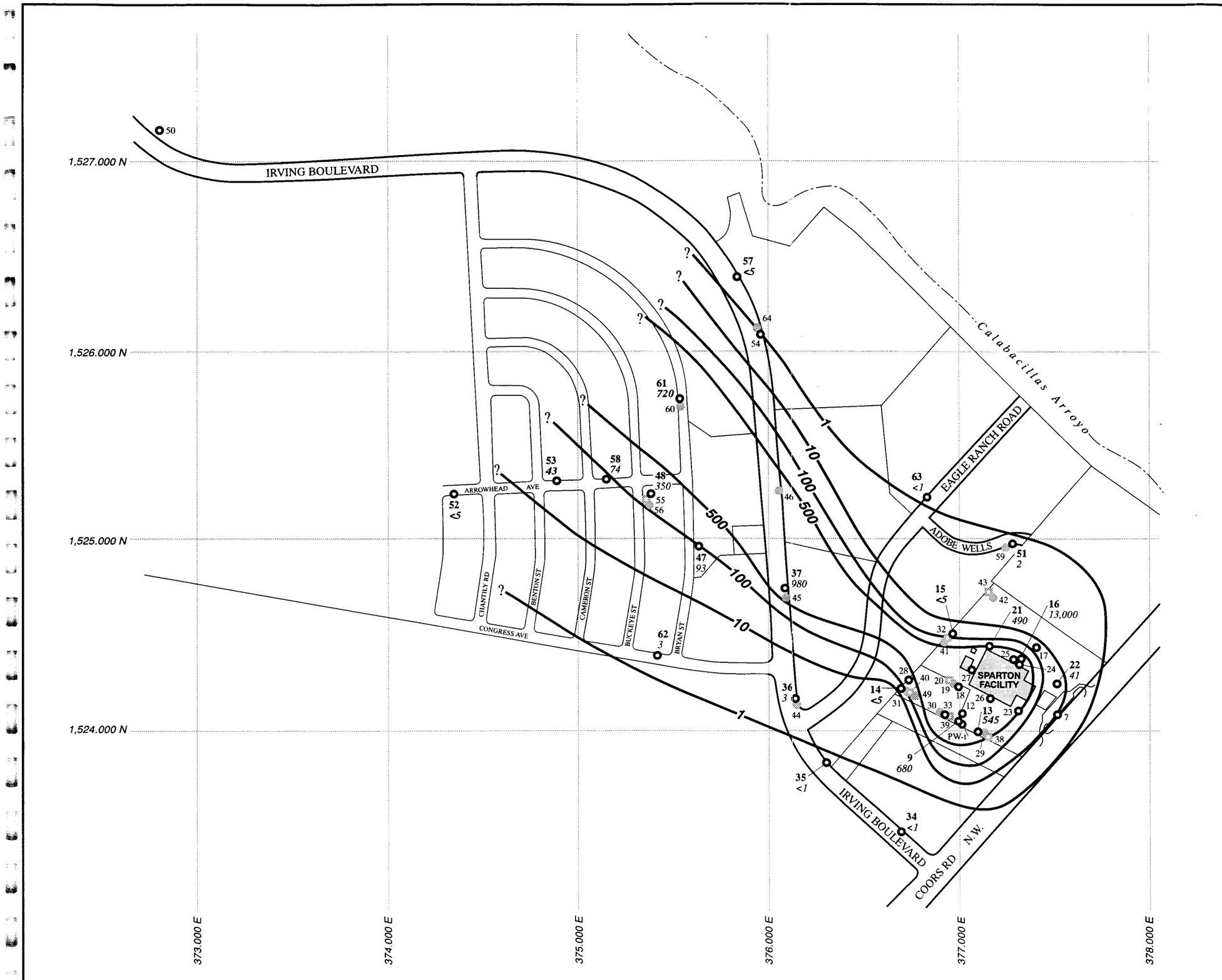
Cohen, R.M. and J.W. Mercer, 1993. DNAPL Site Evaluation, C.K. Smoley, Boca Raton, FL.

Freeze, R.A. and J.A. Cherry, 1979. Groundwater, Prentice-Hall, Englewood Cliffs, NJ.

Neuman, S.P., C.L. Winter, and C.M. Newman, 1987. Stochastic Theory of Field-Scale Fickian Dispersion in Anisotropic Porous Media. Water Resources Research, Vol 23, pp 453-466.

US EPA, Office of Solid Waste and Emergency Response, 1993. Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration, Directive 9234.2-25.

Maps and Cross Sections



LEGEND

- Upper flow zone well
- Upper lower flow zone well
- Lower lower flow zone well
- Third flow zone well
- 500 — Line of estimated equal TCE concentration (µg/L)

Well No. 58 / 74 — TCE (µg/L) October 1993

57 / <5 — TCE (µg/L) December 1994

NORTH

SCALE

0 100 250 500

Base redrawn from HDR Engineering Inc., and City of Albuquerque Zone Map pages B-12, B-13, C-12 and C13.

SPARTON TECHNOLOGY INC.
ALBUQUERQUE, NM

Upper Flow Zone TCE Concentrations, December 1993 and October 1994*

*the more recent data are shown

Folder: Sparton Tech File: UpFlw 1/96	Drawn by: JU Date: 1/10/96	Approved by: Date:

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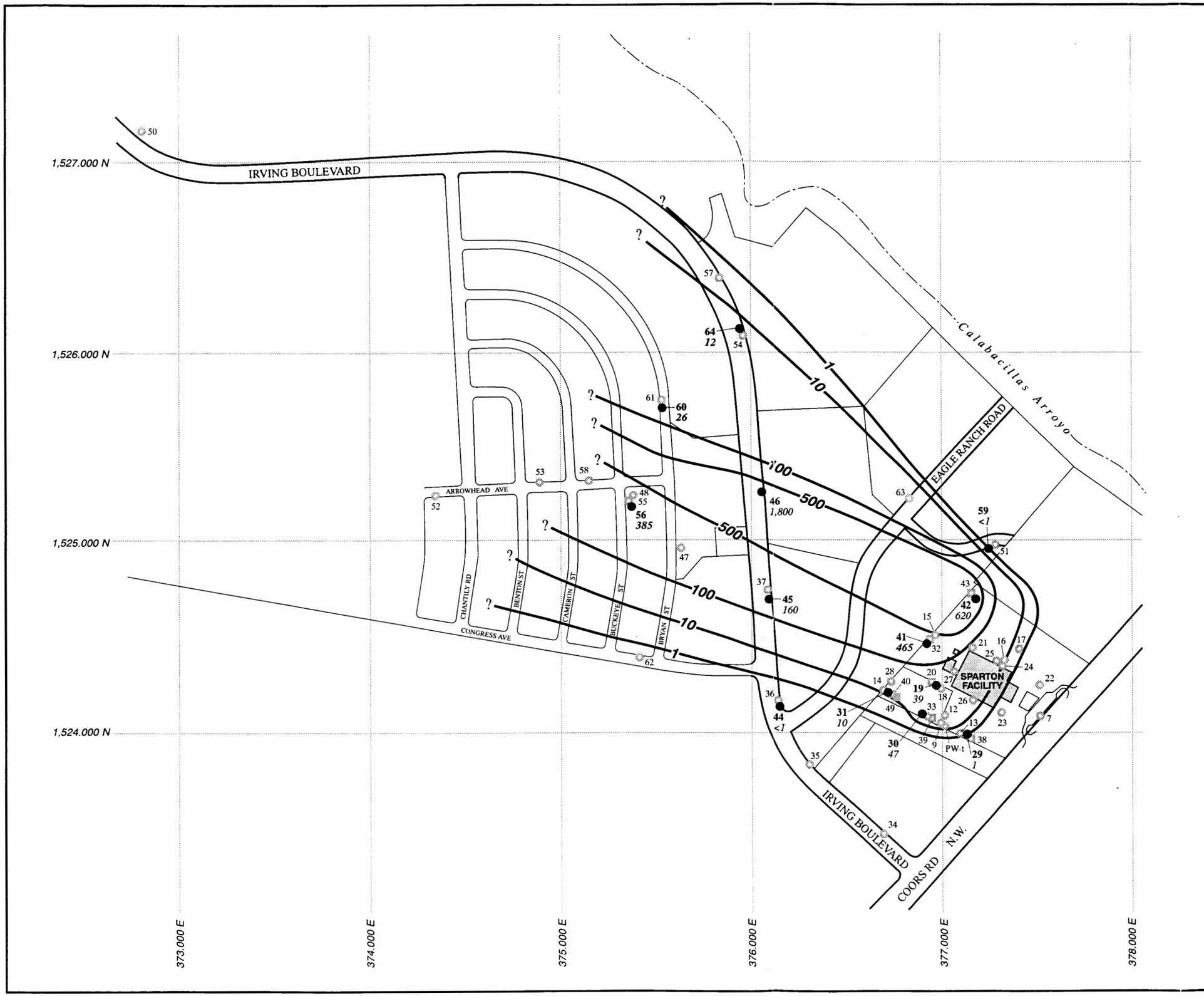
Figure 1



LEGEND

- Upper flow zone well
- Upper lower flow zone well
- Lower lower flow zone well
- Third flow zone well
- 500 — Line of estimated equal TCE concentration (µg/L)

Well No. 45 / 160 — TCE (µg/L) October 1993

Well No. 56 / 385 — TCE (µg/L) December 1994

NORTH

SCALE

0 100 250 500

Base redrawn from HDR Engineering Inc., and City of Albuquerque Zone Map pages B-12, B-13, C-12 and C13.

SPARTON TECHNOLOGY INC.
ALBUQUERQUE, NM

Upper Lower Flow Zone TCE Concentrations, December 1993 and October 1994*

*the more recent data are shown

Folder: Sparton Tech File: UpLwFlw 1/96	Drawn by: JU Date: 1/10/96	Approved by: Date:

CH2M HILL

Figure 2

LEGEND

- Upper flow zone well
- Upper lower flow zone well
- Lower lower flow zone well
- Third flow zone well
- 500 — Line of estimated equal TCE concentration (µg/L)

Well No. 43 / 150 — TCE (µg/L) October 1993

Well No. 32 / 1,400 — TCE (µg/L) December 1994

NORTH

SCALE

0 100 250 500

Base redrawn from HDR Engineering Inc., and City of Albuquerque Zone Map pages B-12, B-13, C-12 and C13.

SPARTON TECHNOLOGY INC.
ALBUQUERQUE, NM

Lower Lower Flow Zone TCE Concentrations, December 1993 and October 1994*

*the more recent data are shown

Folder: Sparton Tech File: LwLwFlw 1/96	Drawn by: JU Date: 1/10/96	Approved by: Date:

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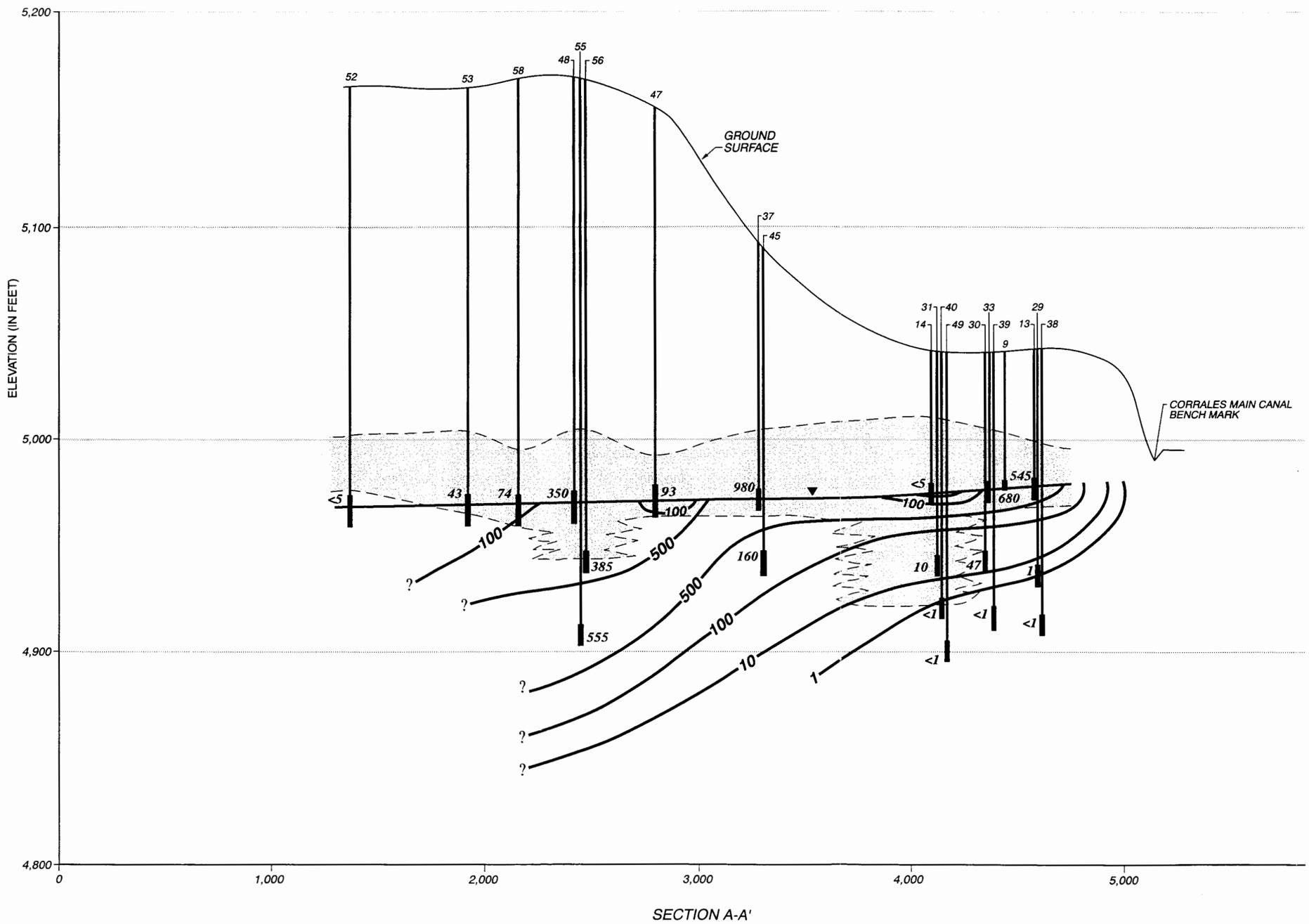
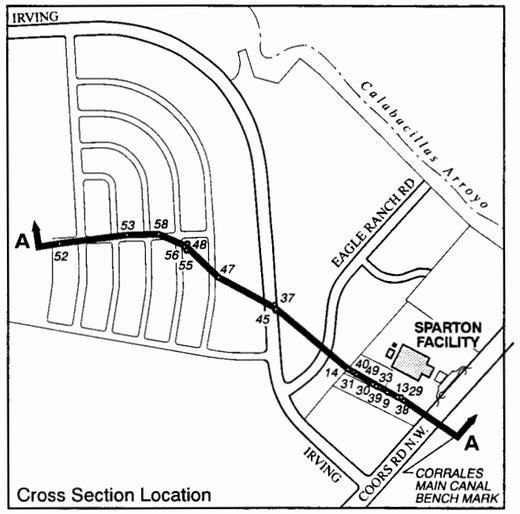
Figure 3



LEGEND

- Water table
- Gravelly zone
- 35 — Monitor well number
- Screened interval
- 43 — TCE (µg/L)
- 500 — Line of estimated equal TCE concentration (µg/L)



HORIZONTAL SCALE

0 100 250 500 FT

VERTICAL SCALE

0 10 25 50 FT

Cross-section and base map redrawn from HDR Engineering Inc.

SPARTON TECHNOLOGY INC.
ALBUQUERQUE, NM

TCE CONCENTRATION PROFILE SECTIONS A-A'

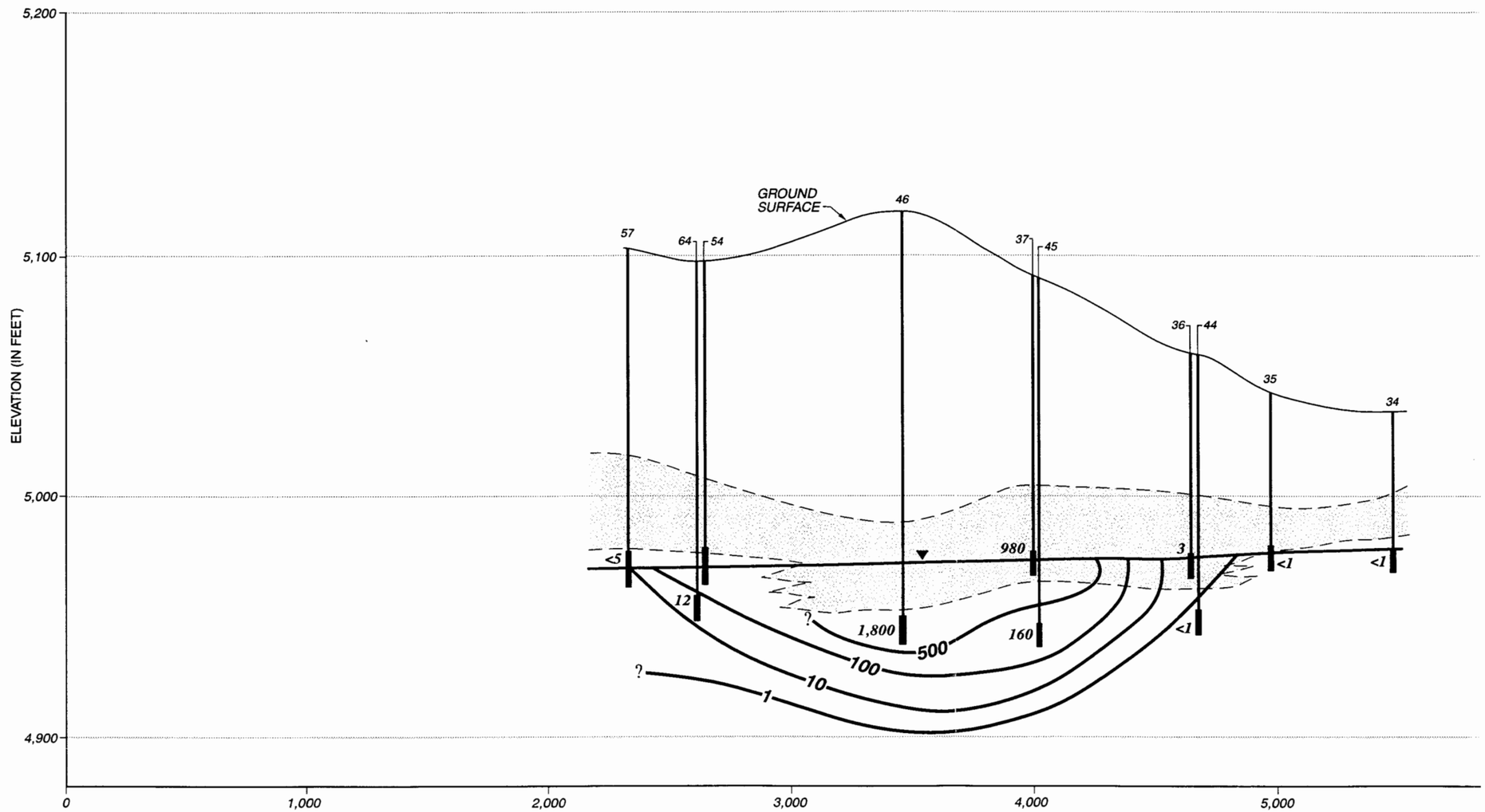
MONITORING DATES: DECEMBER 1993 AND OCTOBER 1994*

*the more recent data are shown

Folder: Sparton Tech File: X-S A-A'	Drawn by: JU Date: 1/10/96	Approved by: Date:

CH2M HILL

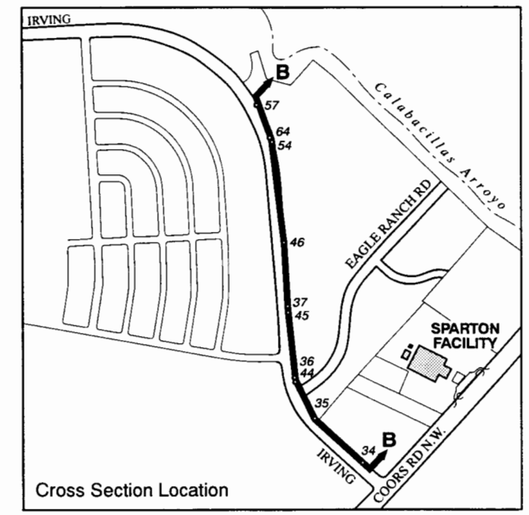
Figure 4



SECTION B-B'

LEGEND

- Water table
- Gravelly zone
- 35 — Monitor well number
- Screened interval
- 43 — TCE (µg/L)
- 500 — Line of estimated equal TCE concentration (µg/L)



Cross Section Location

HORIZONTAL SCALE
0 100 250 500 FT

VERTICAL SCALE
0 10 25 50 FT

Cross-section and base map redrawn from HDR Engineering Inc.

SPARTON TECHNOLOGY INC.
ALBUQUERQUE, NM

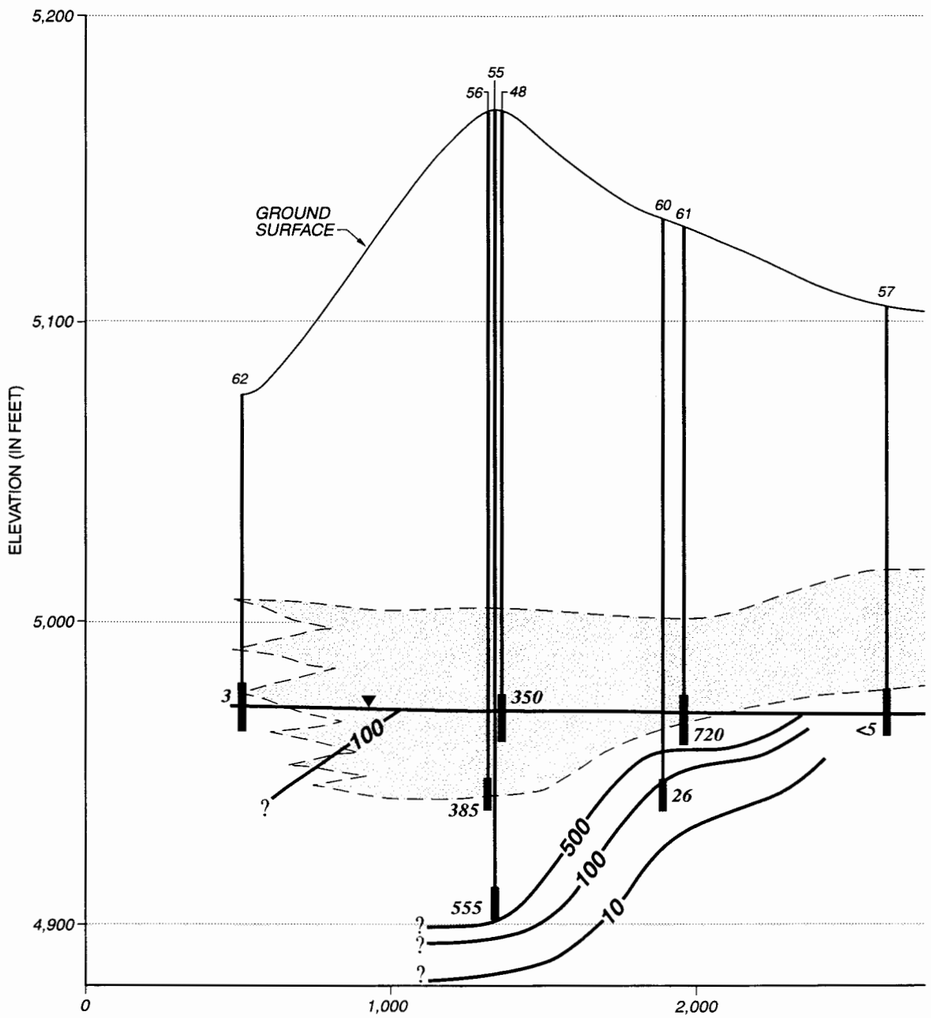
TCE CONCENTRATION PROFILE SECTIONS B-B'

MONITORING DATES: DECEMBER 1993 AND OCTOBER 1994*
*the more recent data are shown

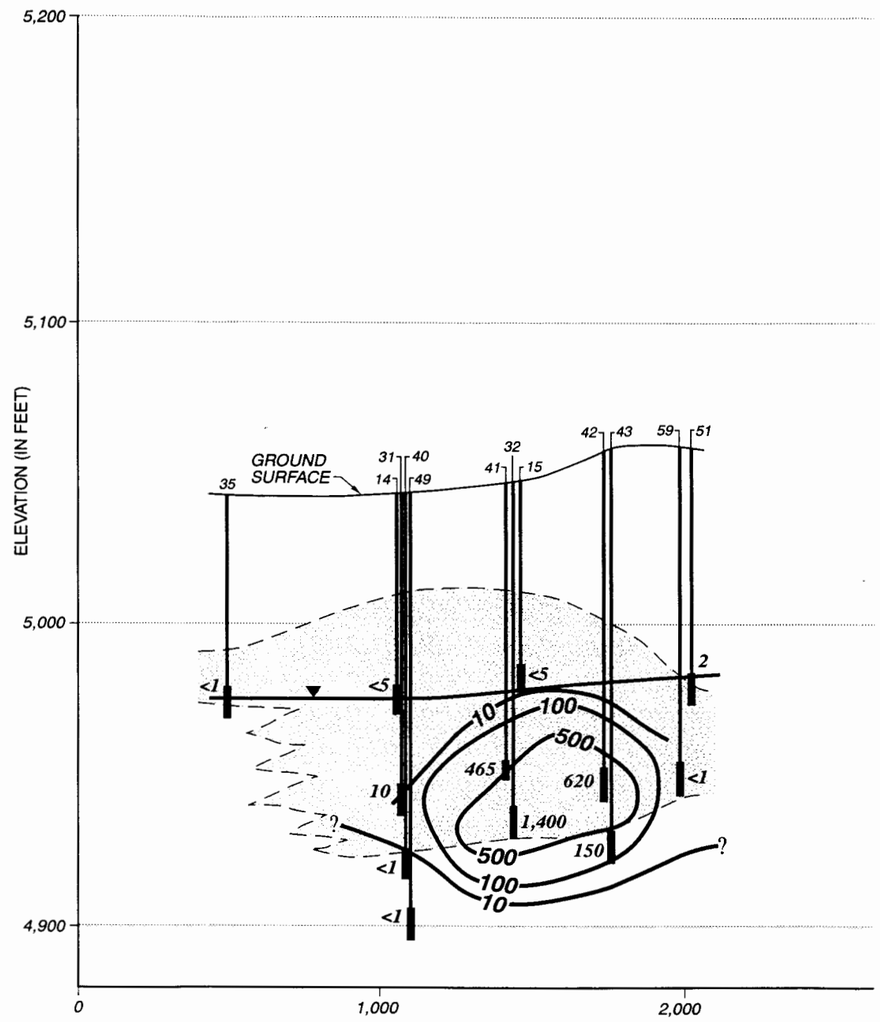
Folder: Sparton Tech File: X-S B-B'	Drawn by: JU Date: 1/10/96	Approved by: Date:

CH2M HILL

Figure 5



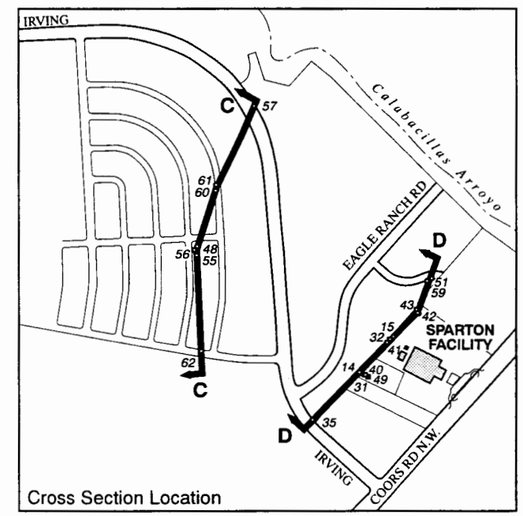
SECTION C-C'



SECTION D-D'

LEGEND

- Water table
- Gravelly zone
- 35 Monitor well number
- Screened interval
- 43 TCE (µg/L)
- 500 Line of estimated equal TCE concentration (µg/L)



Cross Section Location

HORIZONTAL SCALE

0 100 250 500 FT

VERTICAL SCALE

0 10 25 50 FT

Cross-section and base map redrawn from HDR Engineering Inc.

SPARTON TECHNOLOGY INC.
ALBUQUERQUE, NM

TCE CONCENTRATION PROFILE
SECTIONS C-C' AND D-D'

MONITORING DATES: DECEMBER 1993 AND OCTOBER 1994*
*the more recent data are shown

Folder: Sparton Tech File: X-S C-C' D-D'	Drawn by: JU Date: 1/10/96	Approved by: Date:

CH2M HILL

Figure 6