

40-6659

Petrotomics Company

P. O.-Box 8509, Shirley Basin, Wyoming 82615 - Telephone: (307) 234-9341

October 30, 1997

Mr. Joseph J. Holonich, Chief
Uranium Recovery Branch MS-T-7-J-9
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Reference: Alternate Concentration Limits Application - Response to open issues 1, 4, and 5
- Source Material License SUA-551

Dear Mr. Holonich:

Submitted herewith in triplicate is supplemental additional information in response to open issues 1, 4, and 5 (enclosed with your letter dated July 31, 1997).

As requested, proposed alternate concentration limits (ACL's) have been reviewed and revised based on utilizing more recent test data and excluding well 12-DC as a point of compliance. The revised proposed ACL's are discussed and presented in the response to open issue 1. We believe we have fully addressed the three open issues and have demonstrated that the revised ACL's are as low as reasonably achievable (ALARA). In addition, we have responded to requests for clarification, which were made during the June 18, 1997 meeting at Petrotomics site.

Please contact me if you have questions or need further information.

Sincerely,

R. A. Juday
R. A. Juday
Supervisor

NL05/1

9711050251 971030
PDR ADOCK 04006659
C PDR



Mr. Joseph J. Holonich
October 30, 1997
Page 2

Enclosure: ACL Application, Response to open issues 1, 4, and 5.

PC: Mr. Mohammad Haque - USNRC

U.S. Nuclear Regulatory Commission
Region IV
Attn: Ross Scarano, Director
Division of Radiation Safety and Safeguards
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011

Patrick C. Mackin - CNWRA

Prepared For:
Petrotomics Company
P.O. Box 8509
Shirley Basin, Wyoming 82615

PETROTOMICS TAILINGS FACILITY
APPLICATION FOR ALTERNATE
CONCENTRATION LIMITS
SOURCE MATERIAL LICENSE SUA 551
RESPONSE TO NRC OPEN ISSUES 1, 4, AND 5

Prepared By:
Shepherd Miller, Inc.
2460 West 26th Avenue, Suite 430C
Denver, Colorado 80211

October 27, 1997

**Petrotomics Tailings Facility
Application for Alternate Concentration Limits
Source Material License
SUA 551**

Response to NRC Open Issues

Prepared for:
**Petrotomics Company
P.O. Box 8509
Shirley Basin, Wyoming 82615**

Prepared by:
**Shepherd Miller, Inc.
2460 West 26th Avenue, Suite 430-C
Denver, Colorado 80211**

October 27, 1997



SHEPHERD MILLER
INCORPORATED

**PETROTOMICS TAILINGS FACILITY
APPLICATION FOR ALTERNATE CONCENTRATION LIMITS
SOURCE MATERIAL LICENSE
SUA 551**

RESPONSE TO NRC OPEN ISSUES 1, 4, AND 5

TABLE OF CONTENTS

OPEN ISSUE 1	1
OPEN ISSUE 4	19
OPEN ISSUE 5	29
REFERENCES	35

LIST OF ATTACHMENTS

Attachment for Open Issue 1	Historical Constituent Concentration Data for POC Wells 5SC, 5DC, and 51SC
	WMPLUME Transport Modeling Results
Attachment for Open Issue 5	Computer Diskette Containing Ground Water Model Files
	Calibrated Distribution of Hydraulic Conductivity and Recharge
	Summary of Aquifer Properties for Petrotomics Site Through 1991 (Hydro-Engineering, 1992)
	Summary of Main Wind River Aquifer Properties (Table 4- 1, Hydro-Engineering, 1992)
	Regional Aquifer Data North of Petrotomics (Table 3.4-4, Hydro-Engineering, 1991b)
	Transmissivity of the Lower Wind River Aquifer (Figure 2.3-9, Hydro-Engineering, 1991b)

LIST OF ATTACHMENTS, CONTINUED

Attachment for Open Issue 5, cont. Permeability and Outcrop Map of the Upper Wind River Aquifer (Exhibit 5-1, Hydro-Engineering, 1986)

Permeability and Outcrop Map of the Main Wind River Aquifer (Exhibit 5-2, Hydro-Engineering, 1986)

LIST OF TABLES

Table 1-1	Summary of Descriptive Statistics for Data from Wells 5SC, 51SC, and 5DC	15
Table 1-2	Summary of Descriptive Statistics for Chromium and Nickel Data from Wells 5SC, 51SC, and 5DC	16
Table 1-3	Computed UCL ₉₅ Values	16
Table 1-4	Proposed ACL Values Compared to Previously Proposed ACL Values.....	17
Table 1-5	Mass, Volume, and Concentration of TDS in Recovered Solution, Seepage Mitigation Program.....	17
Table 1-6	Summary of Potential Corrective Actions	18
Table 1-7	Mass, Volume, and Concentration of TDS in Recovered Solution, Corrective Action Program (CAP)	18
Table 4-1	Statistical Summary of Site-Derived Constituent Concentrations in Ground Water Samples With pH Greater Than 4 and Sulfate Concentrations Less Than 6,000 mg/L	27
Table 4-2	Summary Statistics for All Petrotonics Data from the Main and Upper Sands from Samples with pH Greater Than 4 and Sulfate Less than 6,000 mg/L	28
Table 4-3	Results of Sensitivity Testing of PHREEQC Neutralization Computations to Initial Ferrous/Ferric Ratios in the Tailings Water	28

LIST OF FIGURES

Figure 1-1	Cadmium in Proposed POC Wells
Figure 1-2	Chromium in Proposed POC Wells
Figure 1-3	Lead in Proposed POC Wells
Figure 1-4	Nickel in Proposed POC Wells

LIST OF FIGURES, CONTINUED

- Figure 1-5 Selenium in Proposed POC Wells
- Figure 1-6 Radium-226 in Proposed POC Wells
- Figure 1-7 Radium-228 in Proposed POC Wells
- Figure 1-8 Thorium-230 in Proposed POC Wells
- Figure 1-9 Uranium in Proposed POC Wells
- Figure 1-10 Sulfate in Proposed POC Wells
- Figure 1-11 Chloride in Proposed POC Wells
- Figure 1-12 pH in Proposed POC Wells
- Figure 1-13 Millions of Kg of TDS Recovered
- Figure 1-14 Millions of Gallons of Seepage Recovered

- Figure 4-1 1996 Cadmium Data
- Figure 4-2 First Quarter 1997 Cadmium Data
- Figure 4-3 1996 and 1997 Radium Data
- Figure 4-4 Ore Intercept Map
- Figure 4-5 Map of Extent of Plumes of Ground Water With $\text{pH} \leq 4$ And With Sulfate
Concentration $> 6000 \text{ mg/L}$ in Upper Sand, 4th Quarter 1990
- Figure 4-6 Map of Extent of Plumes of Ground Water With $\text{pH} \leq 4$ And With Sulfate
Concentration $> 6000 \text{ mg/L}$ in Upper Sand, 1995
- Figure 4-7 Map of Extent of Plumes of Ground Water With $\text{pH} \leq 4$ And With Sulfate
Concentration $> 6000 \text{ mg/L}$ in Upper Sand, 1st Quarter 1997
- Figure 4-8 Map of Extent of Plumes of Ground Water With $\text{pH} \leq 4$ And With Sulfate
Concentration $> 6000 \text{ mg/L}$ in Main Sand, 3rd Quarter 1992
- Figure 4-9 Map of Extent of Plumes of Ground Water With $\text{pH} \leq 4$ And With Sulfate
Concentration $> 6000 \text{ mg/L}$ in Main Sand, 1995
- Figure 4-10 Map of Extent of Plumes of Ground Water With $\text{pH} \leq 4$ And With Sulfate
Concentration $> 6000 \text{ mg/L}$ in Main Sand, 1st Quarter 1997

- Figure 5-1 Sensitivity of Sulfate Concentration to Ground Water Velocity, Upper Sand,
Northern POE.
- Figure 5-2 Sensitivity of Sulfate Concentration to Ground Water Velocity, Upper Sand,
Eastern POE.
- Figure 5-3 Sensitivity of Sulfate Concentration to Ground Water Velocity, Main Sand,
Northern POE
- Figure 5-4 Sensitivity of Sulfate Concentration to Ground Water Velocity, Main Sand,
Eastern POE
- Figure 5-5 Sensitivity of Uranium Concentration to Ground Water Velocity, Upper Sand,
RAB
- Figure 5-6 Sensitivity of Uranium Concentration to Ground Water Velocity, Main Sand,
RAB

OPEN ISSUE 1

Proposed ACLs are not consistent with "As Low As Reasonably Achievable" (ALARA) requirements.

ACTION NEEDED: Petrotomics should propose ACL values for hazardous constituents of concern which are ALARA. These values should be based on an assessment of constituent concentrations levels achieved to date. Petrotomics should use data from wells outside the tailings impoundment to select site ACLs and should exclude well 12DC from consideration as a POC.

Introductory Comment

Petrotomics held a meeting and conducted a site tour for members of the NRC staff, NRC's contractor, and the state of Wyoming DEQ on June 18, 1997. The purpose of this meeting was to familiarize NRC and DEQ staff with the site, and to discuss comments received from NRC concerning Petrotomics' Alternate Concentration Limit (ACL) application report (Petrotomics 1996). Questions were raised during this meeting, and in follow-up phone conversations with NRC staff, concerning NRCs' ALARA requirements. NRC requested that Petrotomics provide a cost/benefit analysis of remedial alternatives to satisfy ALARA requirements. Petrotomics has addressed this concern in the following response to Open Issue 1. Additional concerns expressed by NRC during the site visit are addressed in the response to Open Issue 4.

Proposed Alternate Concentration Limits (ACLs)

Petrotomics has reviewed and revised proposed ACLs to meet the requirements of ALARA. Based on results of the following analysis, Petrotomics is no longer requesting an ACL for lead, and will comply with the concentration limit specified in 10 CFR Part 40, Appendix A, criterion 5C for this constituent (0.05 mg/l).

The proposed ACLs have been recalculated using data from January 1995 to second quarter 1997. Concentrations of constituents of concern were relatively stable during this period. Well 12DC was excluded from the calculations and only data from the proposed POC wells 5SC, 51SC, and 5DC were used to recalculate the ACLs (Attachment 1). Well 5SC and 51SC are located in the Upper Sand, northwest and east of the tailings impoundment, respectively. Well 5DC is located in the Main Sand, north of the tailings impoundment. The recalculated ACL values reflect the effects of the corrective action program and are lower than the ACLs proposed in the original application (Petrotomics, 1996).

Concentrations of constituents of concern in the proposed POC wells are illustrated as a function of time in Figures 1-1 through 1-9. Sulfate concentrations, chloride concentrations, and pH were also evaluated for these wells as a function of time (Figures 1-10 through 1-12). A tabular listing of constituent concentrations for POC wells 5SC, 5DC, and 51SC is provided in Attachment 1. The concentrations of most constituents essentially stabilized by January 1995. The exceptions were chromium and nickel concentrations in well 51SC, which exhibited a temporary, sharp increase during 1996 (Figures 1-2 and 1-4).

The 95% upper confidence limit (UCL_{95}) about the mean was calculated for each constituent, using the concentration data obtained from January 1995 through second quarter 1997 (Table 1-1). The UCL_{95} for each constituent was calculated from mean and standard deviation estimates obtained using a robust log-probability regression approach (Helsel, 1990).

The 95% upper confidence limit (UCL_{95}) values calculated about the mean for chromium and nickel were anomalously high because of the previously noted concentration trend observed in well 51SC during 1996. These concentrations are unlikely to be representative of water that will be sampled by the POC wells from this time forward. Because these values are clearly anomalous and would result in higher ACLs, the statistical evaluation was repeated for chromium and nickel, excluding the three relatively high concentration values observed in 1996 (Table 1-2). Excluding the anomalously high values allows the incorporation of the most recent trends in the data, and results in lower, more conservative ACL values for chromium and nickel.

The resulting UCL₉₅ values for the mean of the constituents of concern are shown in Table 1-3. The UCL₉₅ values were selected as ACLs for the Petrotomics site for all constituents except lead (Table 1-4). Petrotomics proposes a standard of 0.05 mg/l for lead (10 CFR Part 40, Appendix A, Criterion 5C) because it is protective of human health and the environment and it is higher than the values currently observed in samples from the proposed POC wells.

In Table 1-4, the revised ACLs are compared to the previously proposed ACLs. The revised ACLs are significantly lower than the previously proposed values, except for the chromium and nickel ACLs, which decreased by only a small amount. The proposed ACL for radium is significantly smaller than the previously proposed ACL value. The proposed ACL is also much less than radium concentrations (up to 1,700 pCi/L) observed elsewhere in the Shirley Basin (Lowry, 1973). Because natural radium concentrations can be substantial in mineralized areas of the Shirley Basin, any future well locations would require close evaluation of water quality to determine the relative influence of natural radium concentrations. Proposed ACLs are consistent with ALARA, because they were derived using proposed POC wells that are outside the tailings impoundment near the toe of the reclaimed tailings dam, and the data used to determine the ACLs reflect the constituent concentrations achieved to date as a result of the site corrective action program.

Previously proposed ACLs have been shown to present acceptable risk to human health and the environment at proposed POEs (Appendix A, Petrotomics 1996). Because the revised ACLs presented in this document are lower than previously developed ACLs for all constituents of concern, it follows that the associated risk will also be acceptable (and lower than previously proposed ACLs).

Review of Historical Site Corrective Actions

In support of the determination that concentrations of constituents of concern are ALARA, Petrotomics has evaluated the 15-year tailings management and seepage recovery program. Corrective actions were implemented at the site to reduce the amount of tailings fluid in the

impoundment and minimize the spread of tailings seepage. Appendix D of Petrotomics (1996) provides a historical chronology of events at the Petrotomics facility.

Seepage Mitigation Program

Evaporation from the tailings impoundment began in 1962. Engineered evaporation methods were employed soon thereafter. The dam was raised in 1979 to increase the storage available for the tailings, and to increase the impoundment surface area to enhance evaporation. Between 1962 and 1979, the impoundment was operated without engineered seepage control of any kind. In 1979, a slurry wall was constructed concurrently with the dam raise. The slurry wall was designed to minimize the amount of recharge migrating into the tailings dam and potentially impact ground water downgradient of the impoundment.

Enhanced evaporation and the slurry wall were the first passive controls employed to reduce tailings seepage at the site. Operational reviews of these features indicated that the dam encircling the tailings impoundment had a relatively dry core, but the impact on tailings seepage was not significant. Consequently, an effort was made to manage the tailings liquid and seepage in a more aggressive fashion.

Petrotomics implemented active corrective actions in 1981, with the construction and operation of a horizontal collection drain in the Upper Sand downgradient of the northwestern toe of the tailings dam. This action was implemented to intercept seepage along the primary flow path and protect ground water resources downgradient of the tailings impoundment. This drain was instrumental in recovering seepage and controlling the movement of tailings fluid. Tailings seepage was returned to the tailings impoundment for evaporation. The horizontal collection drain was the first corrective action to yield quantitative data necessary to evaluate the effectiveness of corrective action efforts.

From 1981 to 1986, seepage mitigation efforts were responsible for the recovery of 52.3 million gallons of solution containing 5.6 million kilograms of dissolved constituents as measured by

total dissolved solids (TDS). Table 1-5 shows the volume, mass, and concentration of TDS recovered during each operational year of the seepage mitigation program. The data shown in Table 1-5 indicate that the effectiveness of seepage mitigation efforts began to decline significantly beginning in 1984. The concentration of constituents in recovered solution declined significantly at this time. The amount of seepage recovered declined beginning in 1985. The reduction in the amount of seepage collected was due to the lowering of water levels in the Upper Sand adjacent to the horizontal collection drain, and the termination of the milling process.

Corrective Action Program (CAP)

Upon evaluating water quality data associated with the seepage mitigation program, it became apparent that additional measures were necessary in order to accelerate the removal of tailings liquid from the impoundment and minimize the spread of tailings seepage. A formal corrective action program (CAP) was initiated in 1987 and remains operational. Detection and compliance monitoring programs were instituted as part of the CAP.

CAP Remedial Alternatives Analyses

During the design of the CAP, several alternative ground water corrective actions were considered. The alternatives were evaluated based upon their technical feasibility, cost/benefit ratio, potential long-term benefits, as well as the overall beneficial effects to human health and the environment. Four alternative corrective actions passed the initial screening tests and were considered to be technically feasible at the Petrotomics site:

- Pump from vertical and/or horizontal wells
- Install a containment system (e.g. slurry wall or grout curtain)
- Inject fresh water

- Inject water containing additives.

Table 1-6 summarizes these potential corrective actions and criteria used to select the preferred corrective action. Further detail regarding remedial alternative evaluation can be found in Section 3.2.2 of Petrotomics (1996).

Based on an evaluation of the various remedial alternatives, Petrotomics implemented the CAP to include the following basic elements:

- Vertical tailings liquid collection wells installed within the tailings impoundment. The collection wells were designed to reduce the amount of tailings liquid available (e.g. source reduction), and accelerate tailings dewatering for surface reclamation purposes. This system was installed in 1987, and operated between 1987 and 1996 when dewatering wells were plugged and capped due to low recovery volumes and the need to proceed with surface reclamation.
- Vertical ground water recovery wells installed in the Upper and Main Sand aquifers, downgradient of the tailings impoundment. These wells were strategically located to intercept ground water with the poorest water quality and return it to the tailings impoundment for evaporation. This system was installed in 1987 and continues to operate in spite of low recovery volumes associated with declines in aquifer water levels.
- Enhanced evaporation to eliminate recovered tailings liquid and affected ground water. Two clay-lined evaporation ponds were constructed in 1987 and 1989, and were equipped with an enhanced evaporation system consisting of a pumping station connected to misting-type sprinkler heads. The lined evaporation ponds also minimized recharge to the tailings. Enhanced evaporation was initiated in 1987 and continues to operate. In 1990, after the tails were dry enough to work, a

two-foot thick layer of compacted clay was placed over the approximate limits of the tailings area.

The selected CAP alternative had the additional advantage of dewatering the Upper Sand and reducing the saturated thickness to less than one-foot over a large area downgradient of the tailings impoundment (Figure 2-7, Petrotomics, 1996). None of the alternative corrective actions evaluated had the ease of operation, cost-effectiveness, flexibility, and benefits of the selected CAP alternative.

Evaluation of monitoring data associated with the CAP resulted in continued improvements to the CAP design. Additional recovery wells were added to the CAP on a yearly basis from 1988 through 1992. As water levels in the Upper Sand decreased and recovery well pumping rates declined, a vacuum-enhanced recovery system was installed in 1995 in order to increase ground water recovery rates. Although enhanced recovery did improve recovery rates for the short-term, continued declines in water levels have reduced pumping rates in the majority of recovery wells to less than 0.7 gallons per minute (gpm), with an average total recovery rate from all CAP wells of less than 24 gpm.

Effectiveness and Efficiency of the CAP

Implementation of the CAP resulted in an immediate increase in the amount of solution and dissolved constituents that were recovered. Table 1-7 summarizes the mass, volume, and concentration of TDS in recovered solution during the period 1987 through 1995. The seepage collection rate in 1987 was 8.6 million gallons. The first full operational year for the CAP was 1989, during which time 34.8 million gallons of solution were recovered. Continual increases in the amount of recovered solution and dissolved constituents were realized for the next several years. These increases were related to the abundance of solution that was available for recovery and the CAP design.

In spite of the aforementioned improvements to the CAP design, the amount of recovered solution began to diminish in 1992. Comparison of Tables 1-5 and 1-7 indicates that the concentration of constituents recovered during the CAP operation was similar to concentrations recovered during the latter years of the seepage mitigation program. This comparison indicates that the concentration of dissolved constituents in recovered solution has remained relatively stable for an extended period of time. This observation was one of the key factors that has led Petrotomics to conclude that concentrations of constituents of concern have been reduced to levels that are ALARA.

A further measure of the effectiveness of site corrective actions can be obtained by evaluating trends in constituent concentrations at POC wells. For example, over the last 15 years of corrective action, a significant reduction in sulfate concentration has been observed at POC well 5DC (reduced from 13,000 to 5,500 mg/l). This represents a source reduction of approximately 58 percent. Concentrations of sulfate, uranium, and other constituents of concern in POC wells have stabilized in recent years despite ongoing corrective actions (see Figures 1-1 through 1-9). This observation is another factor that has led Petrotomics to conclude that concentrations of constituents of concern have been reduced to levels that are ALARA.

Summary of Site Corrective Actions

Operation of the seepage mitigation plan and the CAP have resulted in the recovery of more than 26 million kilograms of tailings-derived constituents (Figure 1-13), and over 300 million gallons of solution (Figure 1-14). All of the recovered solution has been returned to the tailings impoundment and evaporated at the surface. Sludges and salts left behind by evaporation will be reclaimed in conjunction with the tailings reclamation.

In support of the determination that concentrations of constituents of concern are ALARA, Petrotomics has evaluated the 15-year tailings management and seepage recovery program. Recent trends observed in CAP recovery wells and at POC monitoring wells indicate concentrations of constituents of concern have stabilized despite ongoing corrective actions. As

constituent concentrations decline, the ability to achieve continued cost-effective reductions becomes increasingly difficult. Site corrective actions have clearly reached a point of diminishing return. Based on these observations, Petrotomics has concluded concentrations of constituents of concern are ALARA.

Projected Benefit of Historical Site Corrective Actions

The benefit of historical site corrective actions on constituent concentrations at proposed POEs has been estimated as part of the ALARA analysis. To this end, the long-term POE concentration was predicted given existing POC concentrations and continuous source loading assumptions. This was accomplished with the aid of a two-dimensional analytical transport model (WMPLUME). Model input and results are provided in Attachment 1. Results of this analysis indicate that the long term concentration of sulfate at the nearest POE (e.g. northern property boundary) is predicted to be 1,170 mg/l given a constant source loading of 5,500 mg/l at the POC (well 5DC). Likewise, the concentration of uranium at the nearest POE is predicted to be 0.08 mg/l given a constant source loading of 5.5 mg/l at the POC (well 5SC).

Results of this analysis are considered to be a conservative projection of conditions resulting from the termination of the CAP, because it assumes concentrations at the POC remain at existing levels and are not further reduced as a result of corrective action. Results of this analysis can be used as a baseline for comparison of the cost/benefit associated with potential alternative corrective actions.

Cost/Benefit of Corrective Actions

As previously documented, Petrotomics has evaluated many potential remedial alternatives for their ability to reduce constituent concentrations and reduce tailings seepage (Section 3, Petrotomics, 1996; Review of Historical Site Corrective Actions, this document). Of these alternatives, Petrotomics has analyzed the four most promising corrective actions that have the potential to reduce constituent concentrations at the POC and the POE. Descriptions of the

following alternatives (as well as other alternatives deemed technically infeasible or not practicable) are contained in Section 3.2 of Petrotomics' ACL Application (Petrotomics, 1996).

The alternatives analysis was conducted by considering the cost of implementing and operating the alternative versus potential reductions in constituent concentrations at the proposed POEs, or:

$$\text{Cost / Benefit} = \frac{\text{Cost of Corrective Action (dollars)}}{\text{Reduction in POE Concentration (mg / l)}}$$

The estimated cost of remedial alternatives does not include costs associated with sampling, testing, engineering, analysis, reporting, or general administrative expenses.

Alternative 1: Continuation of Existing CAP

Under this alternative, Petrotomics would continue to recover ground water from existing recovery wells in conjunction with treatment by evaporation. Because the recovered volume would slowly decrease over time, additional wells would be required to maintain the existing recovery rate. It is estimated that the system would have to operate for an additional 15 years to obtain significant constituent reductions at the POEs. The impact on constituent concentrations at the proposed POE was predicted with the aid of an analytical transport model (WMPLUME). Model input and results are provided in Attachment 1. Cost/benefit was evaluated using the following assumptions:

- Recovery would continue at the current rate (20-25 gpm)
- Estimated cost would be \$2.0 million over 15 years (capital cost of \$165,000 for up to 15 additional extraction wells, and operating costs of \$122,000/year (Petrotomics, 1996, p. 104))
- The present mass removal rate can be sustained

- Based on recent trends in concentration at POC well 5DC (Figure 1-9), sulfate concentrations at the POC could be reduced from 5,500 mg/l to approximately 5,200 mg/l as a result of continued operation of the CAP. Similarly, the concentration of uranium in POC well 5SC could be reduced from 5.5 to a approximately 4.3 mg/l.

Results of transport model simulations indicate the long-term uranium concentration at the POE will be reduced from 0.08 (baseline concentration) to 0.06 mg/l (the present site standard is 0.16 mg/l). Likewise, the concentration of sulfate at the POE will be reduced from 1,170 mg/l (baseline concentration) to 1,110 mg/l. Given the estimated cost of \$2.0 million dollars and an improvement in water quality of 0.02 mg/l for uranium and 60 mg/l sulfate, the cost/benefit associated with this alternative is \$100 million per mg/l uranium, and \$33,000 per mg/l sulfate.

Alternative 2: Modification of the Existing CAP (Additional Recovery Wells)

Under this alternative, additional ground water recovery wells would be added to the existing well network, resulting in an increased removal rate of site-derived constituents. The modified CAP would be operational for an additional 15 years. Cost/benefit of this alternative was evaluated using the following assumptions:

- Increased pumping would result in a doubling of the existing mass removal rate.
- Estimated cost would be \$3.0 million over 15 years (capital cost of \$330,000 for up to 30 additional recovery wells, operating costs of \$2.7 million).
- The decrease in concentration at the POC is proportional to the increased mass removal rate. Given this assumption, the concentration of uranium at the POC would be reduced from 5.5 to 3.1 mg/l (double the improvement of Alternative 1). Likewise, the concentration of sulfate would be reduced from 5,500 mg/l to 4,900.

- Existing evaporation facilities are adequate to handle the increased ground water extraction .

Results of transport model simulations indicate the long-term uranium concentration at the POE will be reduced from 0.08 (baseline concentration) to 0.04 mg/l (Attachment 1). Likewise, the concentration of sulfate at the POE will be reduced from 1,170 mg/l (baseline concentration) to 1,050 mg/l. Given the estimated cost of \$3.0 million dollars and an improvement in water quality of 0.04 mg/l for uranium and 120 mg/l sulfate, the cost/benefit associated with this alternative is \$75 million per mg/l uranium, and \$25,000 per mg/l sulfate.

Alternative 3: Injection of Fresh Water and Ground Water Recovery

Under this alternative, unaffected water from the Lower Wind River Aquifer would be injected through a series of injection wells and an infiltration trench into impacted areas of the Upper Wind River Aquifer. This process would slowly dilute contaminant concentrations in the affected ground water and flush affected ground water by forcing it to flow to existing recovery wells. Injection would slowly increase the pH to around 4.5 which would cause many of the heavy metals to precipitate and/or adsorb onto aquifer materials (although dissolution may also occur and prolong the mitigation effort). Cost benefit of this alternative was evaluated using the following assumptions:

- Injection would occur in the immediate vicinity of the POC for a period of six years. Ground water would be recovered from the network of existing recovery wells, and would operate for an additional nine years beyond termination of ground water injection (15 years total).
- As a result of injecting freshwater at the POC, the long-term concentration of uranium at the POC would be reduced to its lowest possible concentration. The lowest possible concentration achievable is estimated to be 2 mg/l uranium and 3,500 mg/l sulfate (Figures 2-50 and 2-69, Petrotomics, 1996). These minimum

POC concentrations are the result of steady-state source loading from the tailings to ground water previously estimated to be 13.7 kg/yr uranium and 27,600 kg/yr sulfate (Figures 2-3 and 2-4, Petrotomics, 1996).

- Injection costs have been estimated at \$1,094,400 (\$210,000 capital costs and \$884,400 operating costs for six years (ACL Application report, p 108). The cost for continuation of the CAP recovery system has been previously estimated at \$1.8 million for 15 years. The cost for additional evaporation cells is estimated at \$2.4 million (see Petrotomics, 1996, p. 111). The cost for reclamation of the additional evaporation cells and sludge disposal is not included. The total estimated cost for this action is \$5.3 million.

Results of transport model simulations for this alternative indicate the long-term uranium concentration at the POE will be reduced from 0.08 mg/l (baseline concentration) to 0.03 mg/l (Attachment 1). Likewise, the concentration of sulfate at the POE will be reduced from 1,170 mg/l (baseline concentration) to 760 mg/l (Attachment 1). Given the estimated cost of \$5.3 million dollars and an improvement in water quality of 0.05 mg/l for uranium and 410 mg/l sulfate, the cost/benefit associated with this alternative is \$106 million per mg/l uranium, and \$13,000 per mg/l sulfate.

Alternative 4: Injection of Water Containing Additives and Ground Water Recovery

This alternative is assumed to be identical to Alternative 3, with the exception that injected ground water would be amended to include reducing agents designed to precipitate dissolved metals, thus improving ground water quality. Hydrogen sulfide (H₂S), or sodium sulfide are two examples of possible reducing agents. The primary benefit of this alternative is to potentially accelerate remediation of ground water. While this alternative may result in short-term improvements in water quality relative to other alternatives, the long-term water quality at the POE will be no better than that predicted by Alternative 3, or the maximum potential benefit. The cost/benefit associated with this alternative was evaluated using the following assumptions:

- Cost of injection is \$1,593,800 (capital costs \$226,000, operating costs 1,367,800 for seven years, Petrotomics, 1996). Cost of the continued operation of the existing CAP recovery and evaporation system for 15 years has been previously estimated at \$1.8 million. Estimated cost for additional evaporation cells is \$2.4 million. The estimated total cost of this action is \$5.8 million.
- All other assumptions are identical to Alternative 3.

Predicted long-term water quality improvements at the POE are identical to those predicted by Alternative 3. The primary benefit of this action would be to decrease the time required to achieve potential benefits. Given the estimated cost of \$5.8 million dollars and an improvement in water quality of 0.05 mg/l for uranium and 410 mg/l sulfate, the cost/benefit associated with this alternative is \$116 million per mg/l uranium, and \$14,000 per mg/l sulfate.

Summary of Cost Benefit Analysis

In light of the previous analysis, the cost associated with practicable remedial alternatives is large compared to small improvements in water quality at the POE. Moreover, POE concentrations resulting from the termination of the existing CAP are very similar to concentrations resulting from any additional remedial action. Given these results, the demonstration that concentrations are ALARA, and previous findings of acceptable risk at the POE, Petrotomics believes proposed ACLs are protective of human health and the environment. Historical site corrective actions have been effective in reducing constituent concentrations to acceptable levels, and continued operation of the existing CAP is no longer warranted.

Table 1-1 Summary of Descriptive Statistics for Data from Wells 5SC, 51SC, and 5DC, Generated Using All Data Obtained from January 1995 to the Present

Constituent	Cadmium	Chromium	Lead	Nickel	Selenium	Uranium	Radium-226 (pCi/L)	Radium-228 (pCi/L)	Thorium-230 (pCi/L)
Number of Values Above Detection Limit	8	15	1	20	5	16	17	16	17
Number of Values Below Detection Limit	12	5	16	0	14	4	0	0	0
Mean	0.034	2.01	n.a.	4.05	0.003	2.17	19.75	11.64	637
Standard Deviation	0.026	3.82	n.a.	3.77	0.011	4.06	41.01	8.00	1015
Coefficient ₍₉₅₎	1.729	1.73	n.a.	1.73	1.734	1.73	1.746	1.75	1.746
UCL ₉₅	0.079	8.61	n.a.	-10.57	0.023	9.20	91.3	25.7	2,409

NOTE: All concentrations in mg/L unless otherwise noted.

n.a. = Not Applicable

Table 1-2 Summary of Descriptive Statistics for Chromium and Nickel Data from Wells 5SC, 51SC, and 5DC, Generated Using Data Obtained from January 1995 to the Present, Omitting Anomalously High Values Observed in Three Samples from 1996

Constituent	Chromium	Nickel
Number of Values Above Detection Limit	12	17
Number of Values Below Detection Limit	5	0
Mean	0.633	2.743
Standard Deviation	0.688	1.953
Coefficient ₍₉₅₎	1.746	1.746
UCL ₉₅	1.83	6.15

NOTE: All concentrations in mg/L unless otherwise noted.

Table 1-3 Computed UCL₉₅ Values

Constituent	UCL ₉₅ Values
Cadmium	0.079
Chromium	1.83
Nickel	6.15
Lead	<0.005
Radium-226 (pCi/L)	91.3
Radium-228 (pCi/L)	25.7
Thorium-230 (pCi/L)	2,409
Selenium	0.023
Uranium	9.20

NOTE: All concentrations in mg/L unless otherwise noted.

Table 1-4 Proposed ACL Values Compared to Previously Proposed ACL Values

Constituent	Proposed ACL Values	Previously Proposed ACL Values (Petrotomics, 1996)
Cadmium	0.079	0.15
Chromium	1.83	2.1
Nickel	6.15	6.2
Lead	-- ¹	0.55
Radium-226 (pCi/L)	91.3	610
Radium-228 (pCi/L)	25.7	170
Thorium-230 (pCi/L)	2,409	2,700
Selenium	0.023	0.12
Uranium	9.20	28

NOTE: All concentrations in mg/L unless otherwise noted.

Table 1-5 Mass, Volume, and Concentration of TDS in Recovered Solution, Seepage Mitigation Program

Year	1982	1983	1984	1985	1986	Total
Kg of TDS Recovered	1,748,915	1,116,335	1,100,721	723,493	922,088	5,611,552
Total Gal Pumped	14,417,000	9,202,390	10,612,000	7,757,400	10,277,000	52,265,790
Kg/Gal	0.12	0.12	0.10	0.09	0.09	0.11

¹ Petrotomics is no longer seeking an ACL for lead, and will comply with the 10 CFR Part 40, Appendix A, Criterion 5C standard, with a maximum of 0.05 mg/l.

Table 1-6 Summary of Potential Corrective Actions

Evaluated Corrective Action	Long-Term Effectiveness	Relative Cost	Adaptability/Mobility	Comments
Vertical and Horizontal Wells	Proven	Low	Very Mobile	Proven recovery technique
Expansion of Vertical and Horizontal Wells	Proven	Medium	Very Mobile	Proven recovery technique
Containment System	Questionable	Very High	Fixed Location	Modifications to this action very costly
Fresh Water Injection	Somewhat Questionable	High	Very Mobile	No constituent recovery from the aquifers
Water Injection with Additives	Somewhat Questionable	High	Very Mobile	No constituent recovery & possible remobilization

Table 1-7 Mass, Volume, and Concentration of TDS in Recovered Solution, Corrective Action Program (CAP)

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	Totals
Kg of TDS Recovered (millions)	0.73	1.49	2.23	2.31	3.34	3.51	1.82	1.90	1.49	18.82
Total Gal. Recovered (millions)	8.65	16.59	34.77	34.35	49.17	46.56	23.19	19.09	15.11	247.48
Kg/Gal	0.08	0.09	0.06	0.07	0.07	0.08	0.08	0.10	0.10	0.07

OPEN ISSUE 4

Uncertainties in Relating pH to Sulfate Concentration Need to Be Addressed.

ACTION NEEDED: Petrotomics should address the effects of dispersion and mixing with uncontaminated ground waters with respect to gypsum equilibrium. A fate and transport analysis for sulfate should be provided for the 1,000-year closure period that incorporates gypsum equilibrium, dispersion, and mixing with uncontaminated ground water. Petrotomics is requested to re-examine the pH/sulfate relationship with regard to constituent attenuation using a larger statistical database of well data to verify 1995 trends in constituent concentration, pH, and sulfate.

Response

Sulfate attenuation in the Upper and Main Sands is caused by gypsum precipitation, and the current transport model conservatively accounts for the effects of gypsum precipitation and redissolution on sulfate attenuation, as discussed below. The pH/sulfate relationship with constituent attenuation has been reexamined using a larger statistical database, and the relationship remains valid.

Effects of Gypsum Precipitation, Dispersion, and Mixing on Sulfate Attenuation

NRC (1997) observed that "the fate and transport model presented in Section 2.2.4 of the ACL application to predict future sulfate concentrations in the site aquifer does not appear to consider gypsum equilibrium as an attenuation mechanism." NRC also states that "a retardation factor for sulfate is included in the model, but it is unclear how this parameter can account for gypsum saturation in the water." Petrotomics believes that the sulfate transport model presented in the ACL application is reasonable and conservative.

The retardation factor (R_d) used for sulfate in the transport computations was derived from field injection testing (Hydro-Engineering, 1992). These tests clearly show sulfate attenuation.

Geochemical modeling has shown that ground water at the Petrotomics site is saturated with respect to gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and gypsum precipitation is the only plausible attenuation mechanism for sulfate in this system (Petrotomics, 1996, page 37). Therefore, the retardation factor used in the transport analysis does include the effects of gypsum precipitation.

The retardation factor used in the computations can be converted to the distribution coefficient value (K_d):

$$R_d = 1 + K_d(\rho/n_e)$$

where ρ is the bulk density of the sandstone and n_e is the effective porosity. Using the conservative values of bulk density (1.7 g/ml) and porosity (0.10) previously used to convert the uranium K_d value to the R_d value (Petrotomics, 1996, page 56), the K_d value for sulfate in this system is calculated to be 0.086 ml/g. A K_d value of 0.086 ml/g is extremely low and the transport computations are therefore quite conservative. Even more conservatism is added to the transport computations by using conservative estimates of source loading rate, effective porosity, and dispersivity.

Declining source loads from the tailings impoundment will eventually result in lower concentrations of sulfate in water entering the portion of the aquifer that has been affected by the plume. As sulfate concentrations decline, gypsum dissolution may occur. However, because of the saturation of native ground water with respect to gypsum, gypsum redissolution is unlikely to occur as unaffected ground water mixes with the plume. Even if water that is undersaturated with respect to gypsum comes in contact with the precipitated gypsum, gypsum redissolution will only occur until the water is once again saturated with respect to gypsum (or the gypsum is depleted). Worst-case geochemical computations presented in response to earlier comments (Petrotomics, 1997) indicated that the concentrations of sulfate in equilibrium with gypsum in this system cannot significantly exceed 6,000 mg/L.

Redissolution of gypsum, if it does occur, is unlikely to remobilize significant amounts of other constituents of concern. The only constituent that may be coprecipitated with gypsum is radium. However, because of the relatively large difference in ionic radii between Ra^{2+} and Ca^{2+} , the amount of radium that will substitute into gypsum is quite small (Langmuir and Riese, 1985). In this system, the most likely attenuation mechanism for radium is adsorption on clays and iron and manganese oxyhydroxides (Granger, 1963; Langmuir and Chatham, 1980; Ames and others, 1983).

The ACL guidance specifies that the contaminant transport estimates should be "reasonably conservative", but it does not specify that the estimates must be based upon computations that exactly simulate the attenuation mechanism (Section 3.2.3.1.2, USNRC, 1996). Transport calculations that explicitly incorporate gypsum precipitation would require the use of a coupled geochemical-advective transport modeling code such as PHREEQC (Parkhurst, 1995). Although PHREEQC is a well-documented and reliable geochemical model, the disadvantages of using PHREEQC as a transport model are considerable because of the necessary simplifying assumptions. PHREEQC only models one-dimensional transport, which is inadequate for predicting solute transport in such a hydrologically complex system. In addition, PHREEQC transport simulations could not be calibrated, given the complex hydrologic and geochemical conditions at the site. These drawbacks would cause an unreasonable amount of uncertainty in the transport simulations.

In summary, the transport computations conservatively predict the migration of sulfate in the system. These computations include sulfate attenuation through gypsum precipitation. Although these computations do not exactly simulate the attenuation mechanism for sulfate, they have been demonstrated to be quite conservative. In addition, redissolution of gypsum is unlikely, because the unaffected ground water at the site is saturated with respect to gypsum.

Relationships Between pH, Sulfate, and Concentrations of Constituents of Concern

The relationships described in the ACL application between pH, sulfate concentrations, and concentrations of constituents of concern are valid (Petrotomics, 1996). Additional explanation is provided to clarify these relationships.

Cadmium and Radium

NRC (1997) observed that “for at least some of the constituents (e.g., cadmium and radium), pH and/or sulfate may not be useful predictors of constituent attenuation.” The following discussion provides additional data to clarify the relationship between pH/sulfate concentrations and cadmium and radium concentrations.

Cadmium concentrations as a function of pH in Upper and Main Sand water samples are plotted in Figures 4-1 and 4-2 for 1996 and first quarter 1997, respectively. Above pH 4, the measured cadmium concentrations were close to or below analytical detection limits (Figures 4-1 and 4-2). The cadmium detection limit of 0.05 mg/L is also the Wyoming water quality standard for livestock (WDEQ, 1993). The low cadmium concentrations above pH 4 were not readily apparent in an earlier presentation of the 1995 data (Petrotomics, 1996) because of the much lower range of cadmium concentrations used in the diagram.

Radium concentrations during 1996 and first quarter 1997 are illustrated in Figure 4-3. Only three wells with pH above 4, 14DC, 15DC, and 16DC, had elevated radium concentrations. All of these wells are located in the ore zone (Figure 4-4). The two wells with the highest radium concentrations (14DC and 15DC) also had sulfate concentrations in excess of 6,000 mg/L. Radium concentrations in samples with pH greater than 4 and sulfate less than 6,000 mg/L do not display a simple correlation with pH or sulfate because of the naturally elevated radium concentrations caused by uranium ore. Radium concentrations in the Shirley Basin have been reported to be as high as 1,700 pCi/L (Lowry, 1973).

Relationship Between pH and Sulfate

The relationship between pH and sulfate is important, because pH and sulfate control constituent attenuation at the Petrotomics site. To illustrate the continuous nature of the pH and sulfate relationship, additional contour diagrams have been generated.

The pH equal to 4 and sulfate equal to 6,000 mg/L contours for the Upper Sand were plotted for fourth quarter 1990 (Figure 4-5), for 1995 (Figure 4-6), and for first quarter 1997 (Figure 4-7). Fourth quarter 1990 represents the earliest time at which the plumes could be defined, whereas first quarter 1997 represents more recent conditions. It is clear from comparison of Figures 4-5 through 4-7 that sulfate equal to 6,000 mg/L contour has covered a larger area than the pH 4 contour. The changes in the contours between 1990 and 1997 were caused by the corrective action program (Figures 4-5 and 4-7).

The pH 4 and sulfate equal to 6,000 mg/L contours for the Main Sand were plotted for third quarter 1992 (Figure 4-8), for 1995 (Figure 4-9), and for first quarter 1997 (Figure 4-10). Third quarter 1992 was used for the earliest contours because of the lack of complete well coverage in the Main Sand prior to this date. From these contour diagrams, it is clear that the sulfate equal to 6,000 mg/L contour has covered a larger area than the pH 4 contour throughout this time period.

The relationship between the sulfate and pH contours has remained consistent throughout the historical monitoring period because gypsum precipitation occurs as the acidic tailings seepage is neutralized by the calcite in the aquifer. Previously submitted computations (Petrotomics, 1997) have demonstrated that sufficient calcite is present in the aquifer to neutralize the acidic seepage from the tailings during the 1,000 year regulatory time frame. Therefore, the relationship between the pH and sulfate in the ground water affected by the seepage should also persist for the 1,000 year regulatory time period.

Evaluation of Predicted POE Constituent Concentrations Using A Larger Statistical Database

Because the relationship between pH, sulfate concentrations, and the concentrations of the constituents of concern are mechanistically determined, these relationships are valid throughout the time period during which ground water quality has been monitored at the Petrotomics site. To further demonstrate the relationship between pH, sulfate, and the constituents of concern, the UCL₉₅ of the mean values for each constituent of concern were calculated for samples with pH greater than 4 and sulfate less than 6,000 mg/L using the entire database (Table 4-1). The results of these calculations are compared to the results obtained using the 1995 data in Table 4-2.

For most constituents, the UCL₉₅ values calculated using the entire data set were essentially the same as the UCL₉₅ values calculated from the 1995 data (Table 4-2). Lead and thorium-230 UCL₉₅ values calculated from the entire data set, however, were somewhat greater than the values calculated from the 1995 data. Analytical problems prior to 1992 led to erroneously high lead concentrations. Therefore, statistical analyses that include these data will yield higher UCL₉₅ values than the values obtained using 1995 data. Except for lead, the UCL₉₅ values calculated using the entire data set were comparable to the values calculated using the 1995 data, and the relationship between pH greater than 4, sulfate concentrations less than 6,000 mg/L, and low concentrations of the constituents of concern remain valid.

Effects of Volume or Weight Percent Calcite on Neutralization Computations

The reported amount of calcite in the ore zone of the Upper and Main Wind River aquifers is 2.5 percent (Harshman, 1972). This value was assumed to be weight percent in the neutralization computations submitted in response to previous NRC comments (Petrotomics, 1997). It is likely that this value is weight percent, because other chemical analyses are reported as ppm, which is a weight-based unit, and it is likely that the organic and mineral carbon contents of the samples were determined by gravimetric analysis. However, if the calcite content was determined through thin-section microscopy, it is possible that the units are in fact volume percent calcite.

The following calculations were carried out to determine the effect of volume percent units on the neutralization computations.

If the aquifer material is 2.5 volume percent calcite, the grams of calcite/cm³ can be calculated:

$$2.5 \text{ volume percent calcite} = 0.025 \text{ cm}^3 \text{ calcite/cm}^3 \text{ aquifer material}$$

$$\begin{aligned} 0.025 \text{ cm}^3 \text{ calcite/cm}^3 \text{ aquifer material} &\times 2.71 \text{ g/cm}^3 \text{ calcite} \\ &= 0.0678 \text{ g calcite/cm}^3 \text{ aquifer material} \end{aligned}$$

If the units are weight percent:

$$\begin{aligned} 0.025 \text{ g calcite/g aquifer material} &\times 1.70 \text{ g aquifer material/cm}^3 \text{ aquifer material} \\ &= 0.0425 \text{ g calcite/cm}^3 \text{ aquifer material} \end{aligned}$$

Thus, if the amount of calcite in the aquifer solids is actually volume percent, the amount of calcite in the aquifer will be higher than if the reported calcite content is in weight percent. Therefore, the use of weight percent in the computations is a conservative assumption.

Effects of Initial Redox Assumptions on Neutralization Computations

The sensitivity of the neutralization computations to initial redox conditions in the tailings seepage was tested by assuming different ratios of ferrous (Fe²⁺) and ferric (Fe³⁺) iron in the initial tailings solution, which in these computations was a sample obtained from tailings well TW-4 on February 16, 1995. Neutralization computations were carried out using the PHREEQC geochemical modeling code (Parkhurst, 1995), as described in the earlier response to NRC comments (Petrotonics, 1997). The pe of a solution is an indication of its redox status. A relatively large, positive pe indicates that a solution is oxidizing, whereas a negative pe indicates that a solution is reducing. In all three test cases, the initial pe was conservatively assumed to be equal to 18.065, which represents the upper stability limit of water at the initial pH. This pe is

the highest value (most oxidizing) that can be assumed to exist at this pH. Three ferrous/ferric ratios were used to test the sensitivity of the computations by examining the final pH and pe of the solutions after neutralization was complete (Table 4-3). The three ferrous/ferric ratios were chosen by assuming: 1) all iron in solution was ferrous, 2) the amount of ferric iron in solution was equal to the amount in equilibrium with ferrihydrite, and 3) distributing the iron in solution equally between the ferrous and ferric oxidation states. The PHREEQC computations were also attempted using higher proportions of ferric iron in the initial tailings water, but these computations did not converge.

The results of the computations indicate that the initial ferrous/ferric ratio assumed in the tailings solution has minimal effects on the final pH and pe of the neutralized solution. The amount of calcite required to neutralize the tailings water increased very slightly with increasing ferric iron, because of the acidity of the ferric species. However, the additional amount of calcite required to reach a steady state pH was very small, compared to the total amount of calcite available in the aquifer solids (Petrotomics, 1997).

Table 4-1 Statistical Summary of Site-Derived Constituent Concentrations in Ground Water Samples With pH Greater Than 4 and Sulfate Concentrations Less Than 6,000 mg/L, Calculated Using All Monitoring Data From the Upper and Main Sands, Except As Noted¹

Constituent ²	Mean Concentration (Standard Deviation)	95% Upper Confidence Limit ³	Number of Values Above Detection Limit	Number of Values Below Detection Limit	Maximum Concentration and Well in Which Maximum Was Observed
Cadmium	0.011 (0.014)	0.038	153	244	0.10 (05DC)
Chromium	0.018 (0.030)	0.077	128	269	0.23 (60SC)
Lead	0.038 (0.074)	0.18	142	275	0.63 (39SC)
Nickel ⁴	0.259 (0.541)	1.32	289	115	5.06 (56SC)
Radium-226 (pCi/L)	20.1 (65.1)	148	548	4	693 (14DC)
Radium-228 (pCi/L)	11.3 (14.5)	39.9	361	28	125 (56SC)
Selenium	0.007 (0.016)	0.038	245	270	0.18 (41SC)
Thorium-230 (pCi/L)	4.2 (8.4)	20.7	369	52	109 (56SC)
Uranium	0.137 (0.566)	1.25	493	60	6.16 (PT4-4)

Notes:

¹ Well 42SC was not included in the data set, because the pH in the water samples fluctuated between 3.0 and 4.0.

² All units are mg/L unless otherwise noted.

³ 95% upper confidence limit computed from the mean, standard deviation, and K coefficient, using the equation $UCL = \text{mean} + (\text{stddev} * K_{1-0.05})$ where $K_{1-0.05}$ for 48 values = 1.68.

⁴ One erroneous nickel value (3.83 mg/L, well 10DC, 2/14/95) was removed from the data set.

Table 4-2 Summary Statistics for All Petrotonics Data from the Main and Upper Sands from Samples with pH Greater Than 4 and Sulfate Less than 6,000 mg/L Using all Data and only 1995 Data

Constituent	Mean Concentration (Standard Deviation)- All Data	UCL ₉₅ of the Mean- All Data	Mean Concentration (Standard Deviation)- 1995 Data	UCL ₉₅ of the Mean- 1995 Data
Cadmium	0.011 (0.014)	0.038	0.011 (0.017)	0.04
Chromium	0.018 (0.030)	0.077	0.022 (0.045)	0.098
Lead	0.038 (0.074)	0.18	0.003 (0.004)	0.0097
Nickel ¹	0.259 (0.541)	1.32	0.35 (0.50)	1.19
Radium-226 (pCi/L)	20.1 (65.1)	148	54 (130)	272
Radium-228 (pCi/L)	11.3 (14.5)	39.9	12 (14)	36
Selenium	0.007 (0.016)	0.038	0.002 (0.002)	0.0054
Thorium-230 (pCi/L)	4.2 (8.4)	20.7	3.9 (4.1)	11
Uranium	0.137 (0.566)	1.25	0.11 (0.48)	0.92

NOTE: All concentrations are mg/l unless otherwise noted.

Table 4-3 Results of Sensitivity Testing of PHREEQC Neutralization Computations to Initial Ferrous/Ferric Ratios in the Tailings Water (The Computations Were Carried Out Using The Composition of Tailings Solution Obtained From Well TW-04 on February 16, 1995)

Ferrous Iron (mg/L)	Ferric Iron (mg/L)	Final pH	Final pe	Calcite Required for Neutralization (moles)
2,950	0	6.16	-1.56	0.1423
2,918	32	6.16	-1.56	0.1423
1,475	1,475	6.06	-1.45	0.1660

¹ One erroneous nickel value (3.83 mg/L, well 10DC, 2/14/95) was removed from the data set.

OPEN ISSUE 5

Groundwater Flow Modeling Results Require Additional Verification.

ACTION NEEDED: Petrotomics should provide a quantitative verification that the calibrated model can predict the potentiometric contours of the site in 1996 with reasonable accuracy when initialized in 1985. The conservativeness of the modeling can be proved by showing quantitatively that during the 10-year period of 1986-1996 the model overpredicts the migration of contaminants. If the model predictions are not within the acceptable range, Petrotomics should perform sensitivity analysis to show the conservativeness of the model so that it can be successfully used for conservative predictive modeling for [the] next 1000 [years]. Additionally, Petrotomics should provide a working copy of input files for MODFLOW, basis for hydraulic conductivity values, and its distribution map, and calibrated input parameters.

Supplemental Data

Attachment 5 contains the following supplemental data requested by the NRC:

- A working copy of the MODFLOW input files for the calibration period on computer diskette
- A MODFLOW executable and a MODELCAD grid file, also contained on the computer diskette. The MODELCAD grid file should allow the reviewer to view calibrated aquifer parameters and the detailed model grid (the reviewer must possess MODELCAD or Groundwater Vistas software in order to view the grid file)
- Maps showing the model calibrated distribution of hydraulic conductivity and recharge

- A summary of site aquifer property data collected through 1991 (Hydro-Engineering, 1991a)
- A summary of site aquifer property data for the Main Wind River aquifer (Table 4-1, Hydro-Engineering, 1992)
- A summary of regional aquifer property data collected north of the Petrotomics property (Table 3.4-4, Hydro-Engineering, 1991b)
- A map showing the regional distribution of aquifer transmissivity for the Lower Wind River aquifer (Figure 2.3-9, Hydro-Engineering, 1991b)
- A map showing the permeability and outcrop pattern of the Upper Wind River aquifer at the site (Exhibit 5-1, Hydro-Engineering, 1986)
- A map showing the permeability and outcrop pattern of the Main Wind River aquifer (Exhibit 5-2, Hydro-Engineering, 1986).

A tabular listing of all calibrated model input parameters was provided in Petrotomics (1997).

Verification of the Ground Water Flow Model

NRC has requested that the calibrated ground water flow model be verified by simulating site conditions (e.g. potentiometric surface) in 1996 when initializing the flow model to conditions in 1985 (e.g. at the end of the model calibration period).

Petrotomics does not believe it is possible to simulate site conditions over this period "with reasonable accuracy." This conclusion is supported by the following lines of reasoning:

- As previously stated in Appendix F of Petrotonics (1996), and on page 36 of Petrotonics (1997), Petrotonics does not believe validation of the calibrated flow model is possible over the stated time period. This situation is not unusual, as stated by Anderson and Woessner (1992, p. 256):

“...it is often impossible to verify a model because usually only one set of field data is available. That data set, of course, is needed for calibration. If this is the case, the model cannot be verified.”

Data necessary to run the calibrated flow model over the stated 11-year period are either unavailable or would consist of gross estimates that render model simulations of poor reliability. These data include the timing, magnitude, and location of pit dewatering, pit recovery, pit backfilling, re-contouring, pit water transfers, pit expansions, remedial well pumping rates, and regional aquifer and pit water level elevations. Furthermore, the neighboring Pathfinder Mines Corporation was actively mining the area north of Petrotonics during this period, and the nature, timing, and extent of mine operations (e.g. pit dewatering, pit expansion, reclamation) during this time is not known with a reasonable degree of accuracy.

- Remedial pumping from the Upper Sand aquifer during this time frame has fully dewatered large portions of the Upper Sand, and reduced the saturated thickness to less than one foot elsewhere (see Figure 2-7, Petrotonics, 1996). Petrotonics believes it is unreasonable to expect MODFLOW or any other flow model code to reproduce the potentiometric surface “with reasonable accuracy” under these conditions. First, the data required to simulate aquifer dewatering are not sufficient to produce reliable results. These data include the timing, location, and cyclical pumping rates of dewatering wells. Second, model aquifer bottom elevations do not have sufficient resolution (e.g. one-foot accuracy) to adequately simulate very thin aquifers. Finally, even if such data were available and of

sufficient quality, numerical instability and inaccuracies are significant and unavoidable when attempting to simulate the transition from fully- to partially-saturated conditions. MODFLOW was not developed for this purpose.

The NRC has recommended that, in the event the validated model cannot produce results that are “within the acceptable range”, a sensitivity analysis of the flow model should be performed to demonstrate the conservativeness of the flow model results for predictive purposes.

Sensitivity Analysis of the Ground Water Flow Model

Petrotomics has conducted a sensitivity analysis of the ground water flow model in order to demonstrate the adequacy and conservativeness of model predictions. First, it should be noted that ground water velocities used in the original baseline transport analysis were conservative without resorting to sensitivity analyses (Petrotomics 1996). Calibrated hydraulic conductivity values are higher than average conductivities derived from site-specific testing, resulting in a conservatively rapid movement of modeled constituents. For example, the geometric mean of hydraulic conductivity for the Upper Sand is 3.7 ft/day, and 4.3 ft/day for the Main Sand (Attachment 5, Table 2-1, Hydro-Engineering, 1991a). Calibrated values of hydraulic conductivity over the site transport area vary from 5 to 40 ft/day, with an average conductivity of about 20 ft/day (see model calibrated hydraulic conductivity maps, Attachment 5). Because ground water velocity is directly proportional to hydraulic conductivity, calibrated ground water velocities are approximately 4 to 5 times higher, on the average, than velocities calculated using site-specific data. Therefore, original transport model predictions presented in Petrotomics (1996) were conducted using a highly conservative ground water velocity distribution.

The sensitivity of the ground water flow model was tested by changing the magnitude of the ground water velocity over a reasonable range of values, and comparing uranium and sulfate concentrations to “baseline” concentrations predicted by the original transport model (Petrotomics, 1996). Because ground water velocity is a function of all relevant flow model parameters (e.g. hydraulic conductivity, recharge, etc.), the sensitivity of the model to changes in

ground water velocity is equivalent to the combined sensitivity to changes in individual model parameters (e.g. sensitivity to recharge, sensitivity to hydraulic conductivity, etc.).

The sensitivity of model predictions to higher and lower ground water velocity was simulated. The baseline MODFLOW velocity files used by the RAND3D transport model were modified as part of the sensitivity analysis. Baseline velocity files included ground water velocity distributions for the years 1995, 2000, 2010, 2020, 2050, and steady-state. Ground water velocities were adjusted uniformly by a factor of two (100 percent increase in ground water velocity) for the high velocity scenario, and decreased uniformly by a factor of two (50 percent decrease in velocity) for the low velocity scenario. This range of ground water velocity is considered highly conservative, and should adequately account for uncertainties in flow model parameter values. Results of the modified transport model were then compared to the baseline predictions presented in Petrotomics (1996).

Results of the sensitivity analysis are presented on Figures 5-1 through 5-6. These results effectively illustrate the probable range of uranium and sulfate concentrations over a wide range of possible flow model conditions.

Predicted sulfate concentrations for the Upper and Main Sand POEs are provided on Figures 5-1 through 5-4. In general, sulfate concentrations are within a factor of two of the baseline concentrations for the first 100 years of the model simulation period. Variability of model predictions generally becomes larger as the model simulation time increases. More importantly, the range of predicted sulfate concentrations is consistent with findings of acceptable risk presented in the original ACL application (Petrotomics, 1996). Maximum predicted concentrations of sulfate at the proposed POEs are below 6,000 mg/l for the entire simulation period. Based on the pH/sulfate relationship described in Petrotomics (1996), Petrotomics (1997), and the response to Open Issue 4, concentrations of constituents of concern should remain below acceptable health-based risk thresholds.

Predicted uranium concentrations at the proposed POEs are below 0.1 mg/l for both high and low velocity scenarios. The sensitivity of uranium concentrations to ground water velocity at the existing Restricted Area Boundary (RAB) is provided on Figures 5-5 and 5-6 for illustrative purposes. These results are also consistent with findings of acceptable risk presented in the original ACL application report (Petrotomics, 1996).

Summary

Petrotomics has previously documented the highly conservative nature of transport modeling parameters including source loading rate, aquifer dispersivity, and constituent attenuation factors (Petrotomics, 1996; Petrotomics, 1997). In addition, calibrated hydraulic conductivity values are higher than average conductivities derived from site-specific testing, resulting in a conservatively rapid movement of modeled constituents. Because conservative estimates of these individual parameters were combined in the transport model, transport model predictions presented in Petrotomics (1996) are considered highly conservative. Results of sensitivity analyses further demonstrate the validity of the original model predictions, and are in agreement with Petrotomics's findings of acceptable risk.

REFERENCES

- Ames, L.L., J.E. McGarrah, B.A. Walker, and P.F. Salter. 1983b. "Uranium and Radium Sorption on Amorphous Ferric Oxyhydroxide." *Chemical Geology*, Vol. 40: 135-148.
- Anderson, M. P., and W. W. Woessner. 1992. *Applied Ground Water Modeling, Simulation of Flow and Advective Transport*, Academic Press, Inc., 381 p.
- Granger, H.C., 1963. *Radium Migration and Its Effect on the Apparent Age of Uranium Deposits at Ambrosia Lake, New Mexico*. U.S. Geological Survey, Professional Paper 475-B: B60-B62.
- Harshman, E.N. 1972. *Geology and Uranium Deposits, Shirley Basin Area, Wyoming*. U.S. Geological Survey, Professional Paper 745: Washington, D.C.
- Helsel, D.R. 1990. "Less than obvious, statistical treatment of data below the detection limit." *Environmental Science and Technology*, Vol. 24: 1767-1774.
- Hydro-Engineering. 1986. *Updated Ground-Water Hydrology of Petrotonics' Tailings Area*. August 1986.
- Hydro-Engineering. 1991a. *Summary of Aquifer Properties for Petrotonics Site Through 1991*. December 1991.
- Hydro-Engineering. 1991b. *Area 2/8 and 3 Permit 345C Revision, Pathfinder Mines Corporation*. November 1991.
- Hydro-Engineering. 1992. *Ground-Water Conditions and Restoration Alternatives in the Main Wind River Aquifer at Petrotonics' Tailings Area*. Prepared for Petrotonics Company, Shirley Basin, Wyoming.
- Langmuir, D. and F.R. Chatham. 1980. "Ground Water Prospecting for Sandstone-Type Uranium Deposits: A Preliminary Comparison of the Merits of Mineral-Solution Equilibria, and Single-Element Tracer Methods." *Journal of Geochemical Exploration*, Vol. 13: 201-219.
- Langmuir, D. and A. C. Riese. 1985. "The Thermodynamic Properties of Radium." *Geochimica Cosmochimica Acta*, Vol. 49: 1593-1601.
- Lowry, M.E. 1973. *Water Resources of the Laramie, Shirley, Hanna Basins and Adjacent Areas, Southeastern Wyoming*. U.S. Geological Survey, Atlas HA-471.
- Parkhurst, D.L. 1995. *User's Guide to PHREEQC: A Computer Model for Speciation, Reaction-Path, Advective-Transport, and Inverse Geochemical Calculations*. Water Resources Investigations Report 95-4227, U.S. Geological Survey.

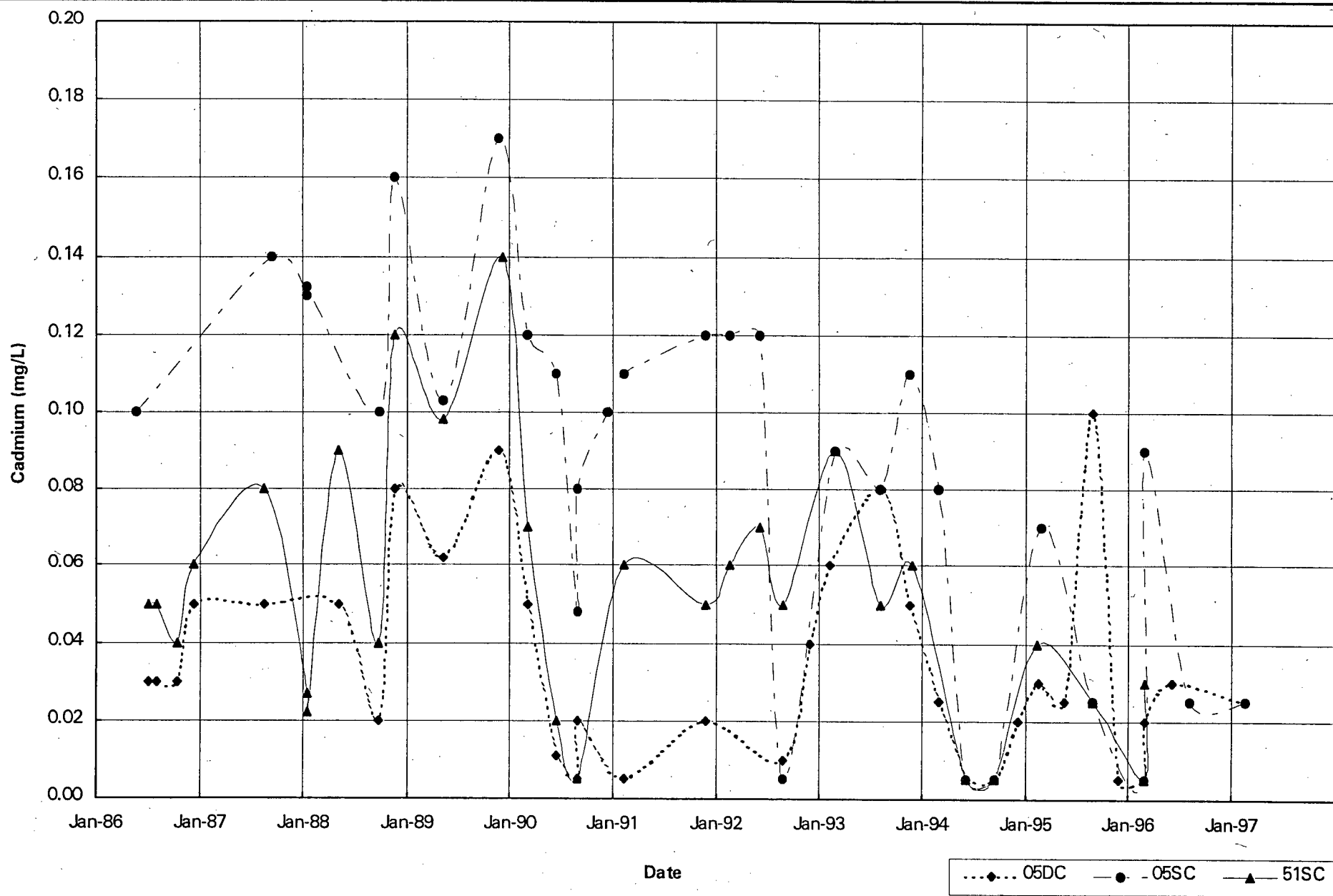
Petrotomics, 1996. *Petrotomics Tailings Facility Application for Alternate Concentration Limits to Amend USNRC Source Material License SUA 551*. Prepared by Shepherd Miller, Inc. for Petrotomics Company, Shirley Basin, Wyoming.

Petrotomics. 1997. *Petrotomics Tailings Facility Application for Alternate Concentration Limits, USNRC Source Material License SUA 551, Response to NRC Comments*. Prepared by Shepherd Miller, Inc. for Petrotomics Company, Shirley Basin, Wyoming.

USNRC. 1996. *Staff Technical Position, Alternate Concentrations Limits for Title II Uranium Mills*. U. S. Nuclear Regulatory Commission.

USNRC. 1997. *Supplemental Request for Additional Information on the Petrotomics Company Shirley Basin Wyoming Site Alternative Concentration Limit Application for Source Material License SUA-551*. July 31, 1997.

WDEQ. 1993. *Water Quality Rules and Regulations, Chapter VIII*. Wyoming Department of Environmental Quality.

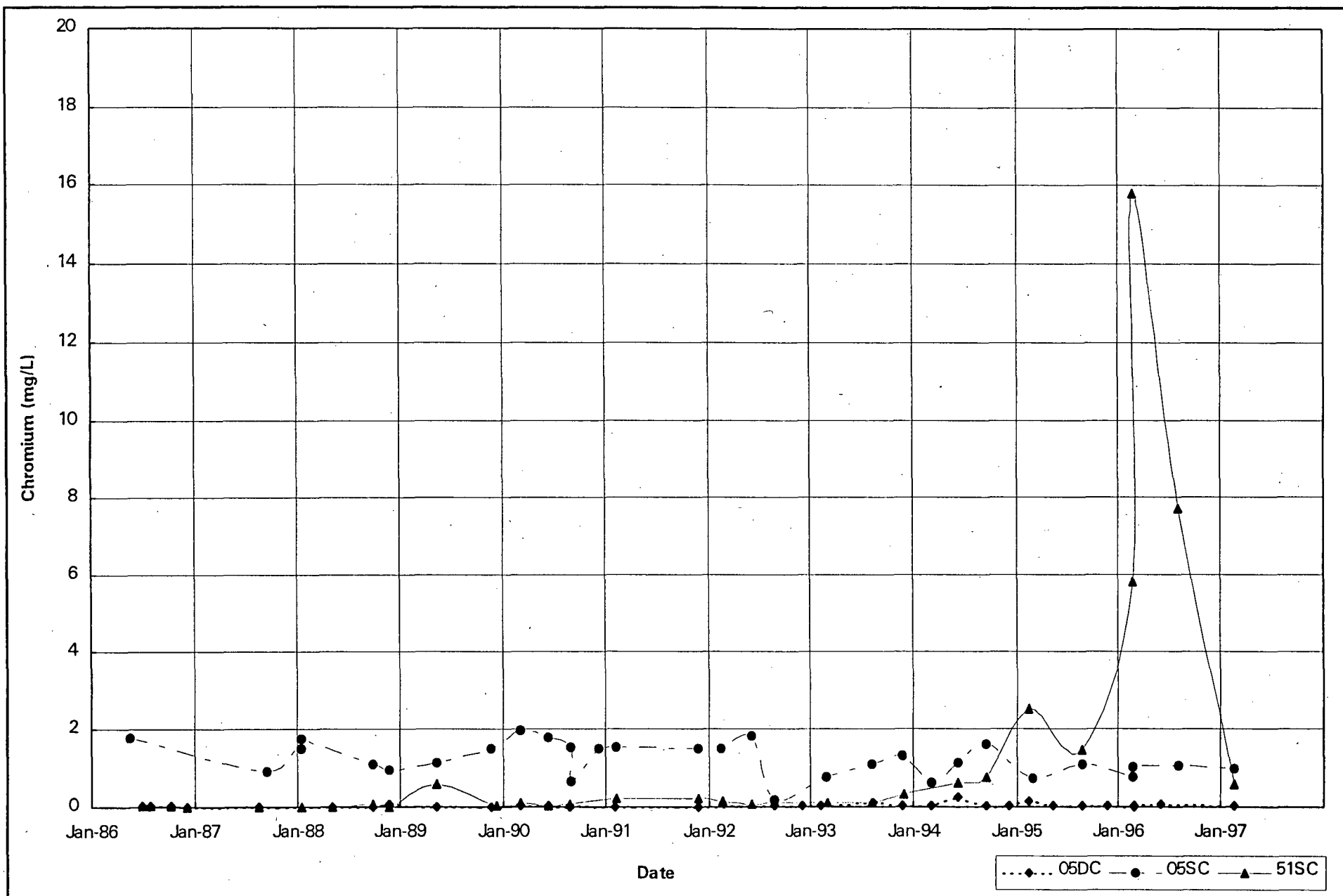


PETROTOMICS COMPANY
Figure 1-1
Cadmium in Proposed POC Wells

Date: October 1997

Project: 100053

File: wd2qtr97.ppt

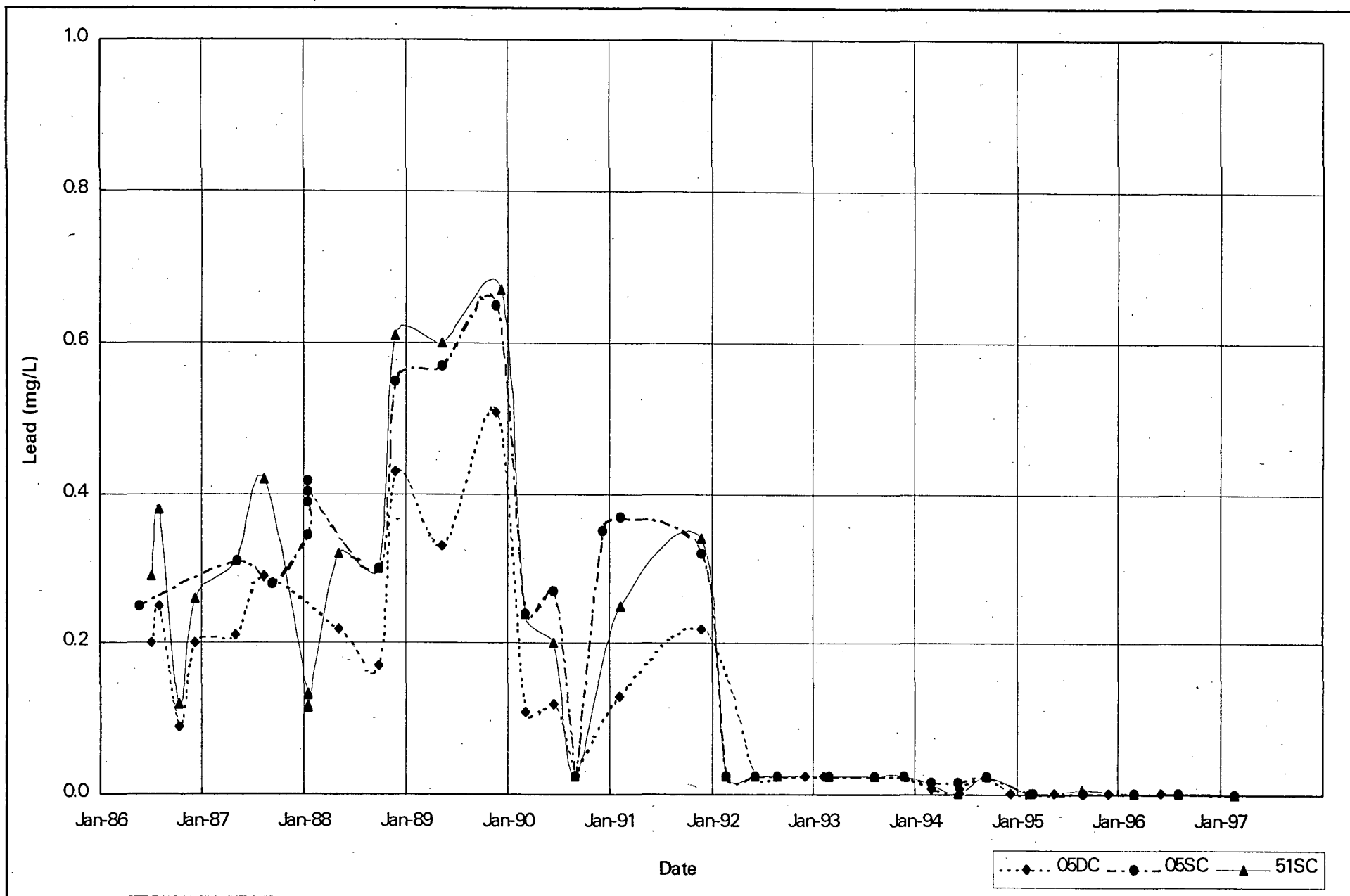


PETROTOMICS COMPANY
Figure 1-2
Chromium in Proposed POC Wells

Date: October 1997

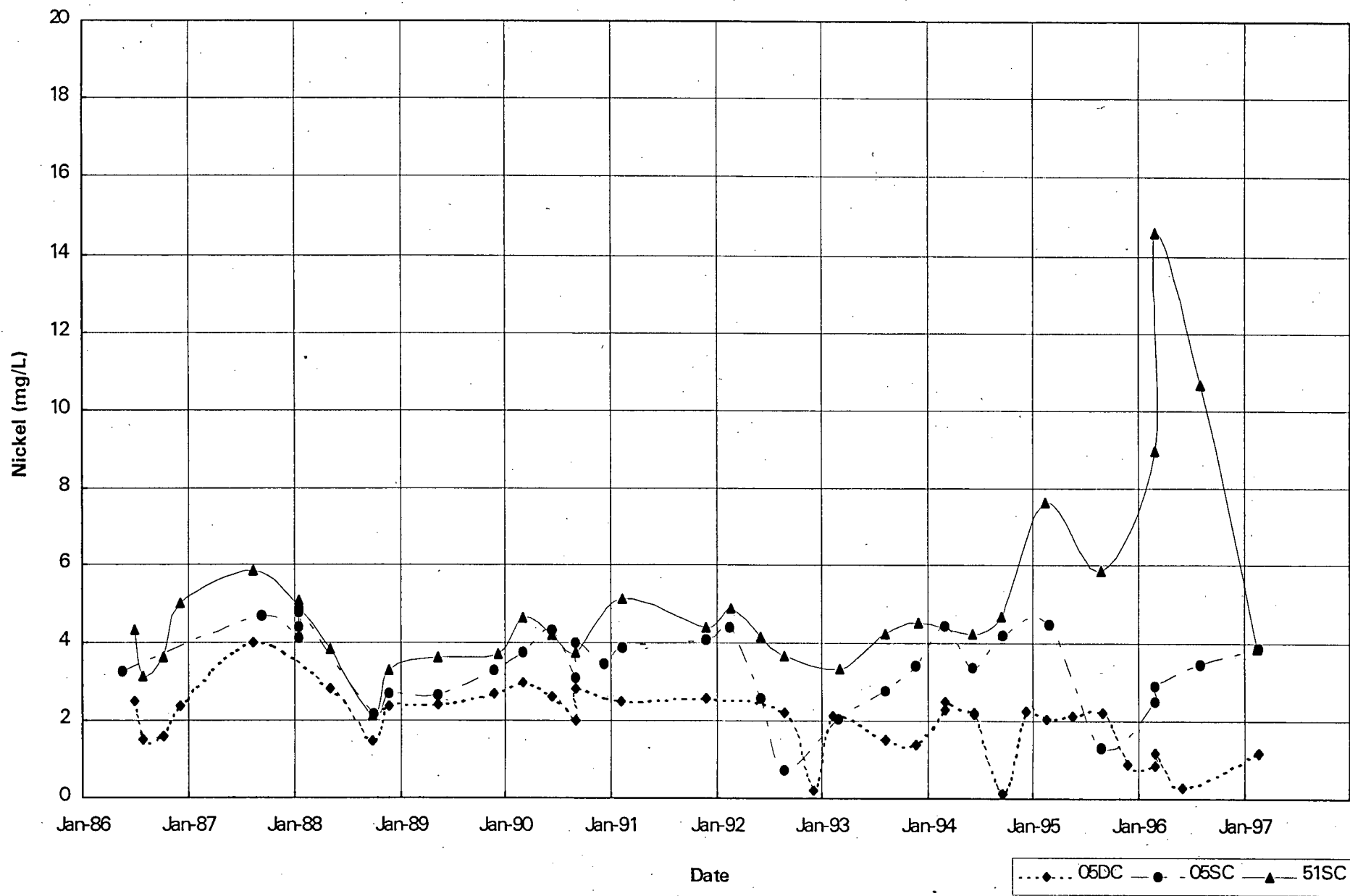
Project: 100053

File: wd2qtr97.ppt



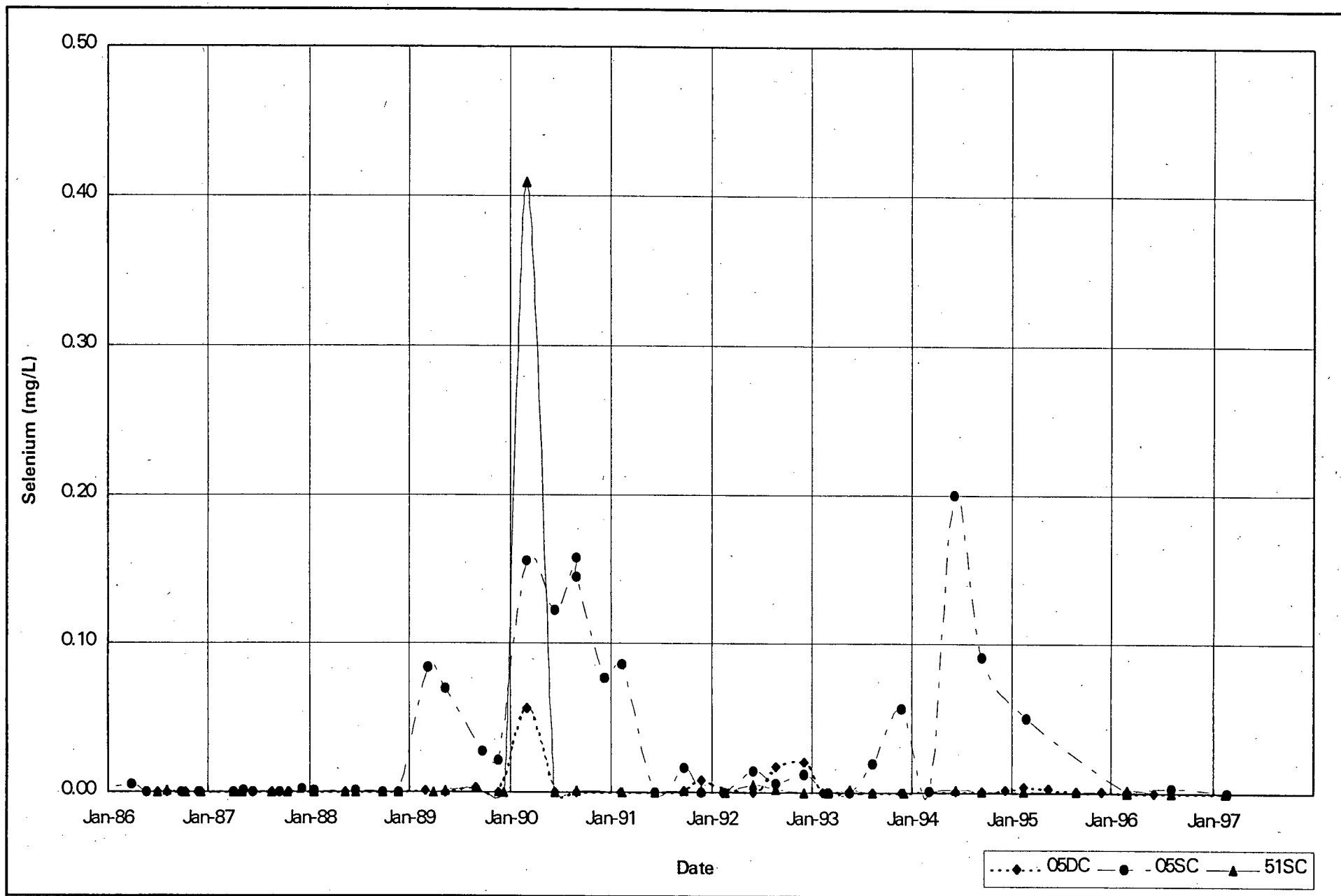
PETROTOMICS COMPANY
Figure 1-3
Lead in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt



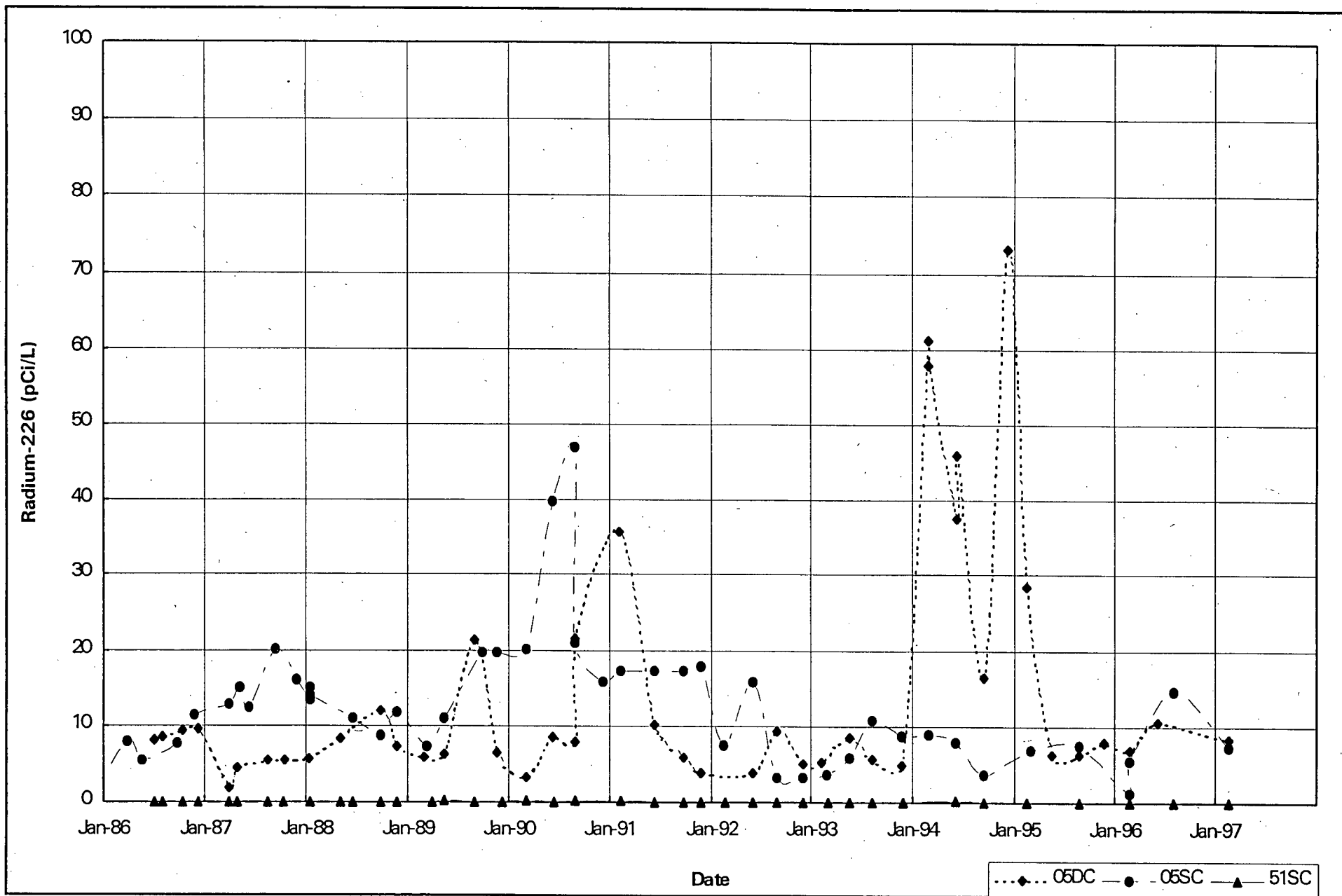
PETROTOMICS COMPANY
 Figure 1-4
 Nickel in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt



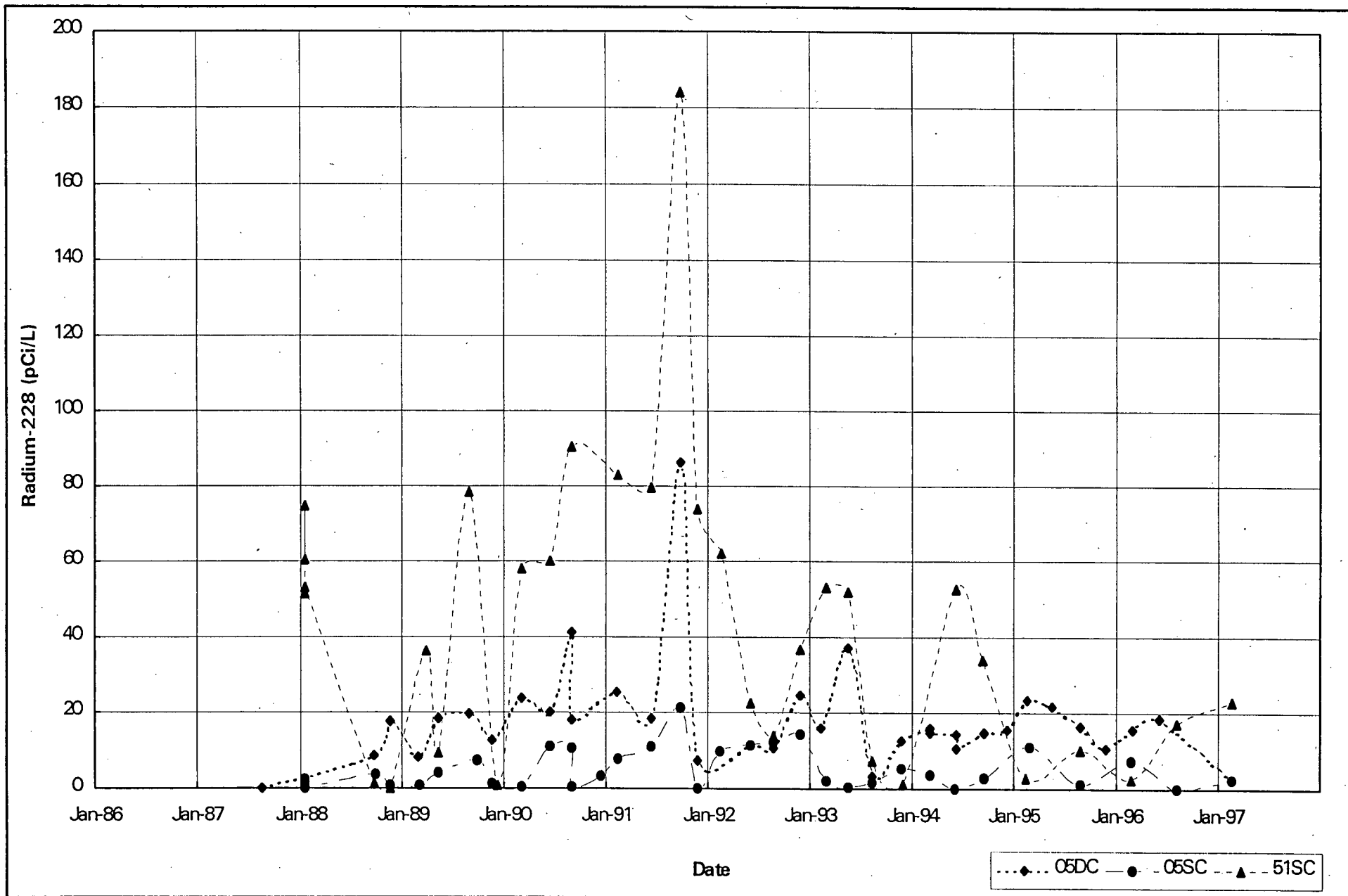
PETROTOMICS COMPANY
Figure 1-5
Selenium in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt



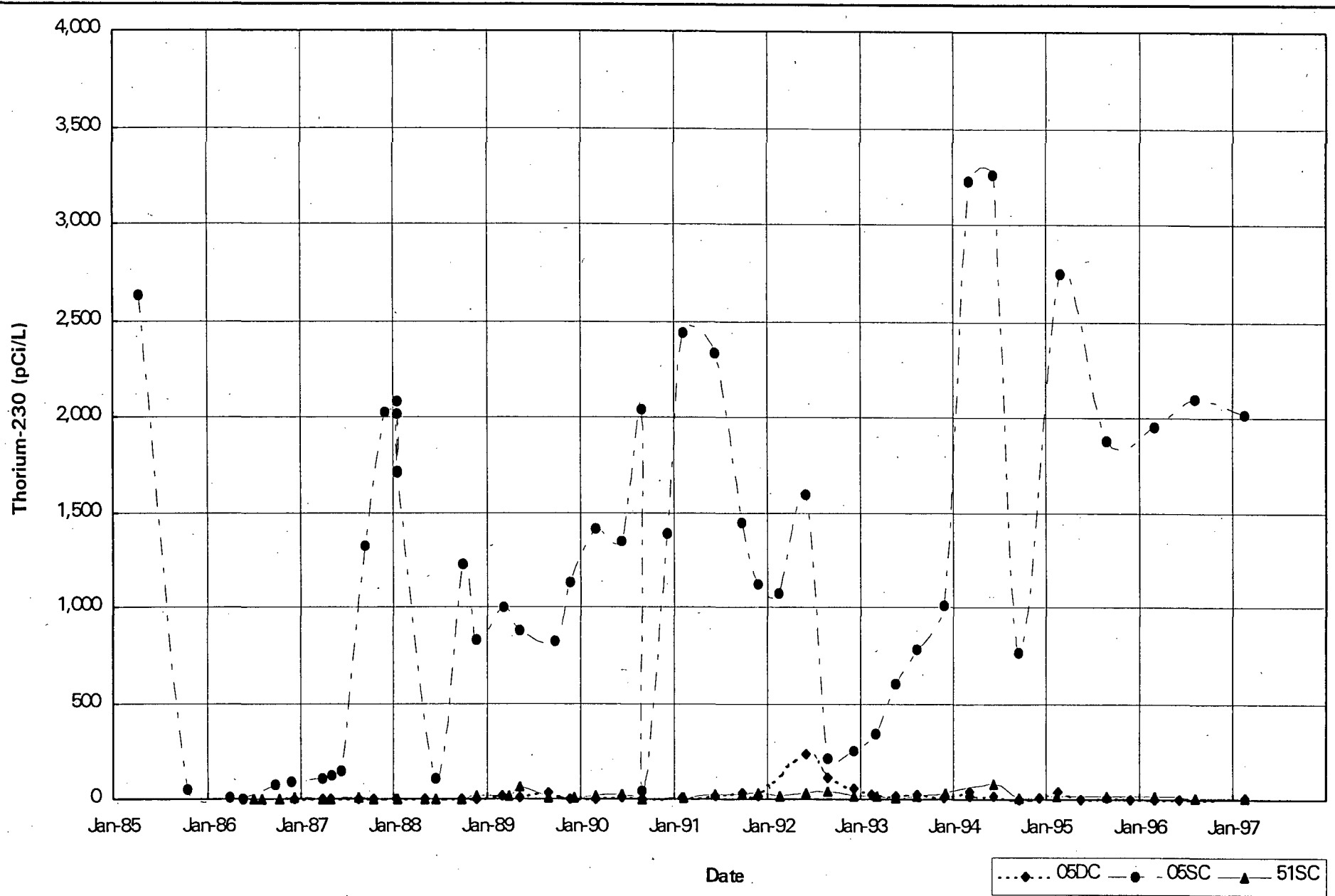
PETROTOMICS COMPANY
 Figure 1-6
 Radium-226 in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt



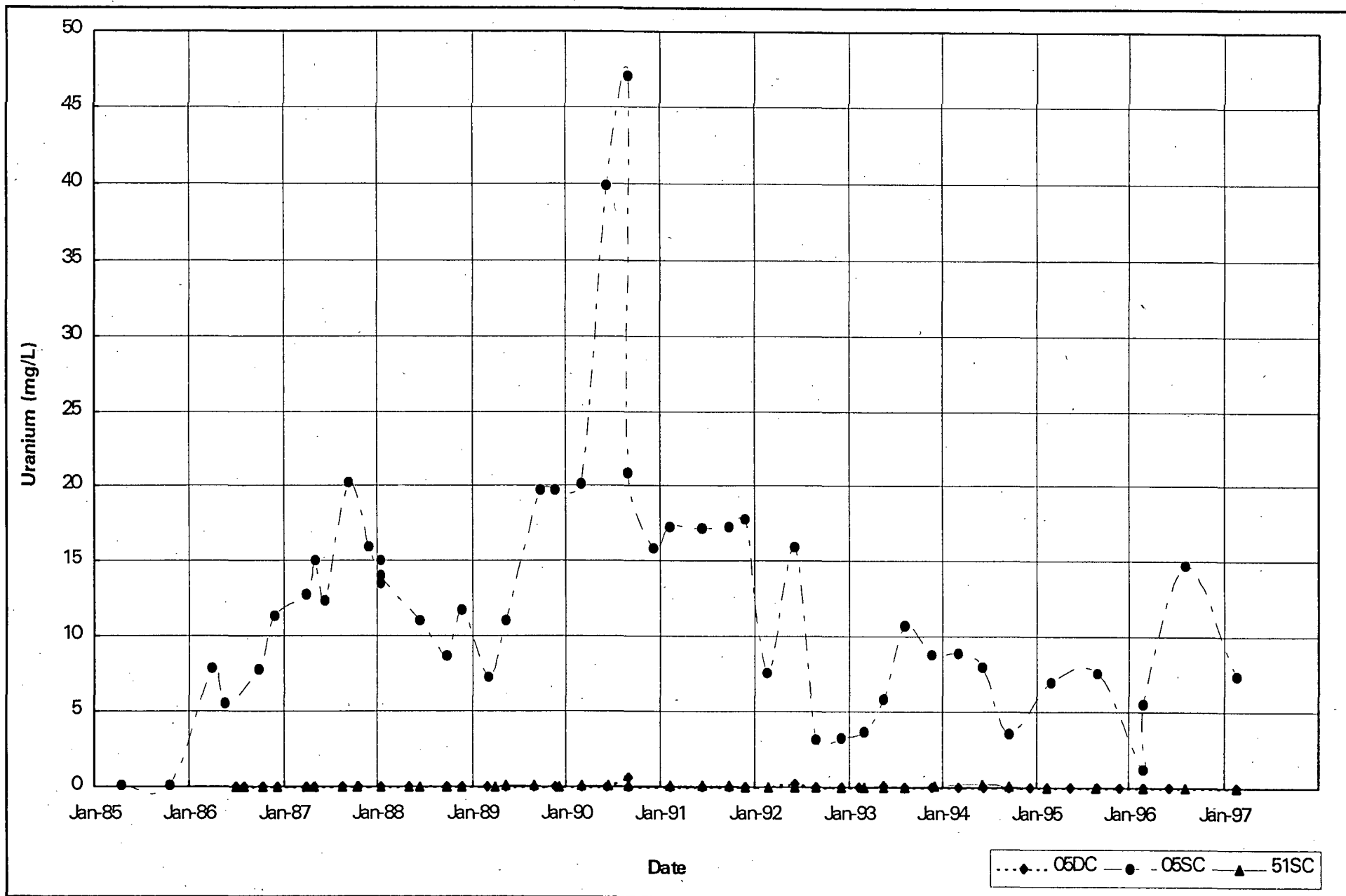
PETROTOMICS COMPANY
Figure 1-7
Radium-228 in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt



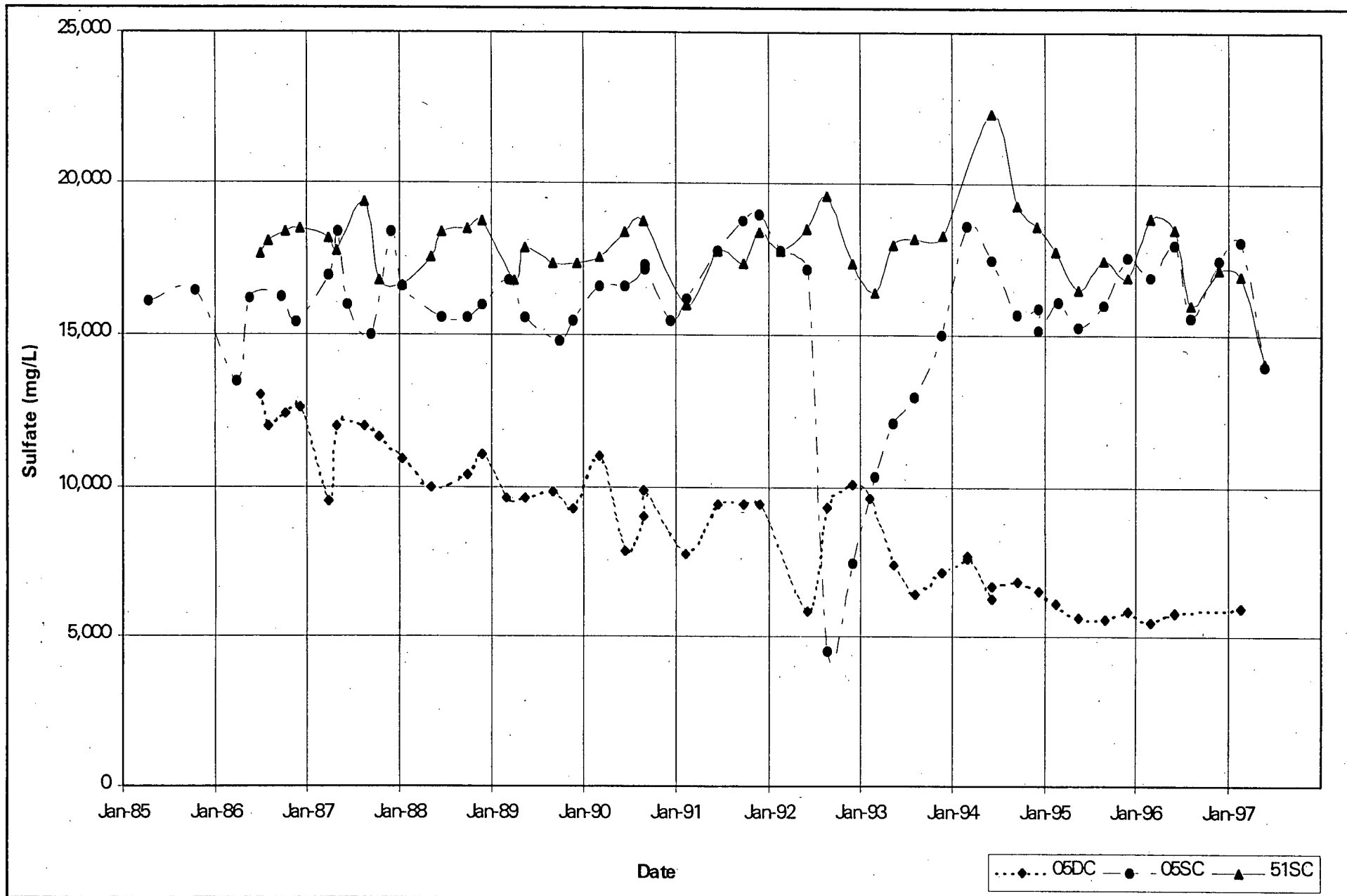
PETROTOMICS COMPANY
 Figure 1-8
 Thorium-230 in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt



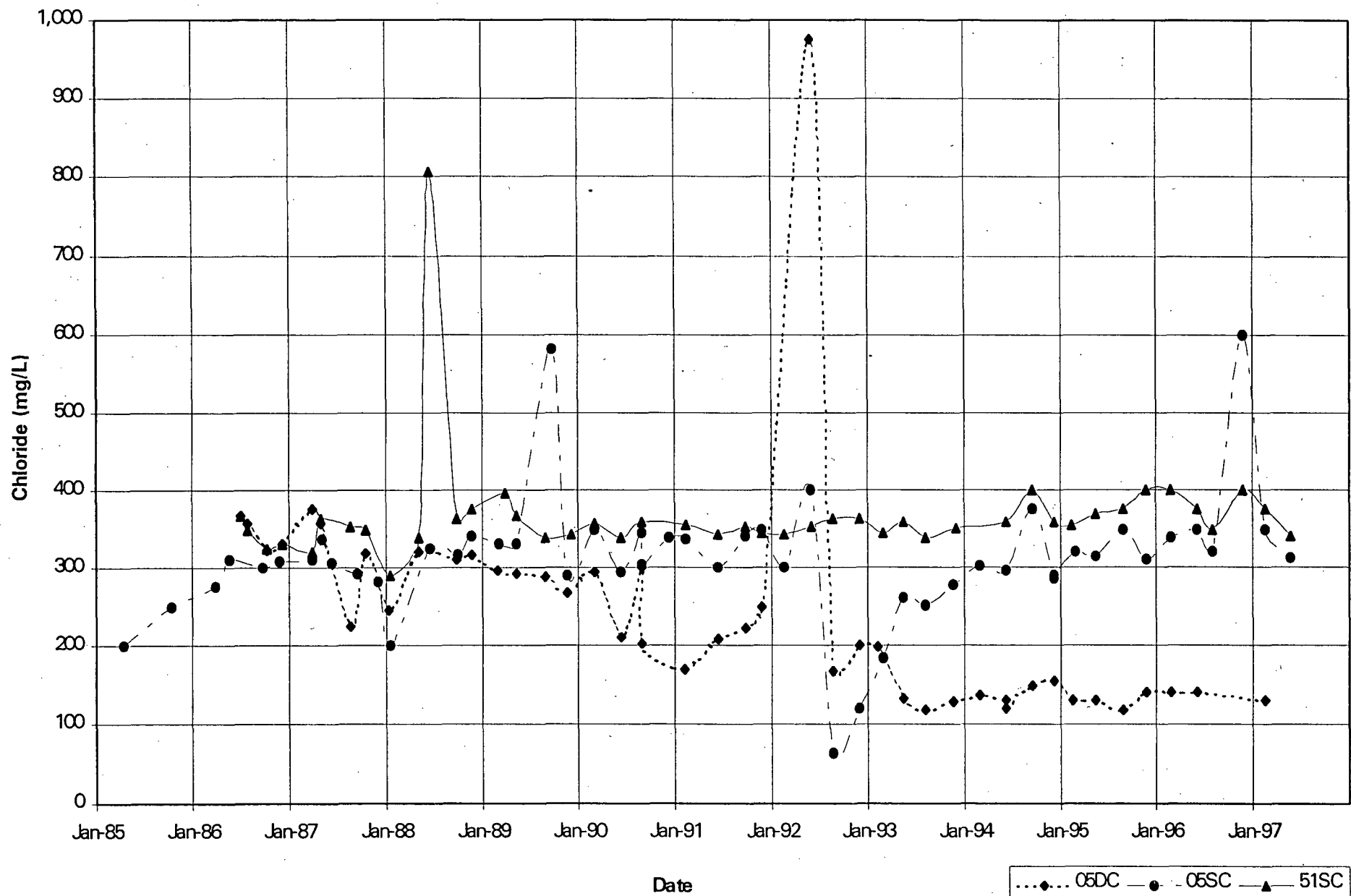
PETROTOMICS COMPANY
Figure 1-9
Uranium in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt



PETROTOMICS COMPANY
 Figure 1-10
 Sulfate in Proposed POC Wells

Date:	October 1997
Project:	100053
File:	wd2qtr97.ppt

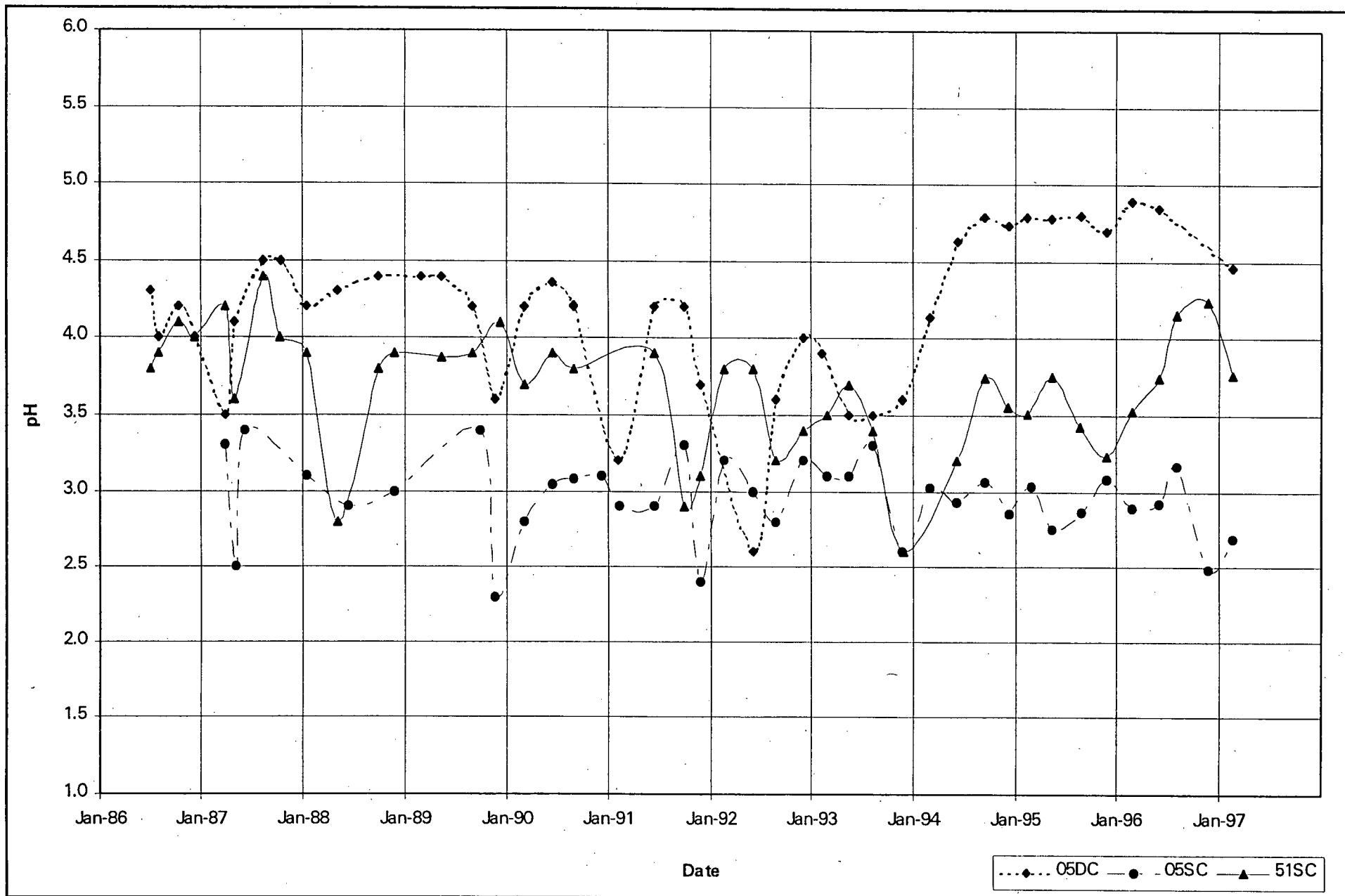


PETROTOMICS COMPANY
Figure 1-11
Chloride in Proposed POC Wells

Date: October 1997

Project: 100053

File: wd2qtr97.ppt



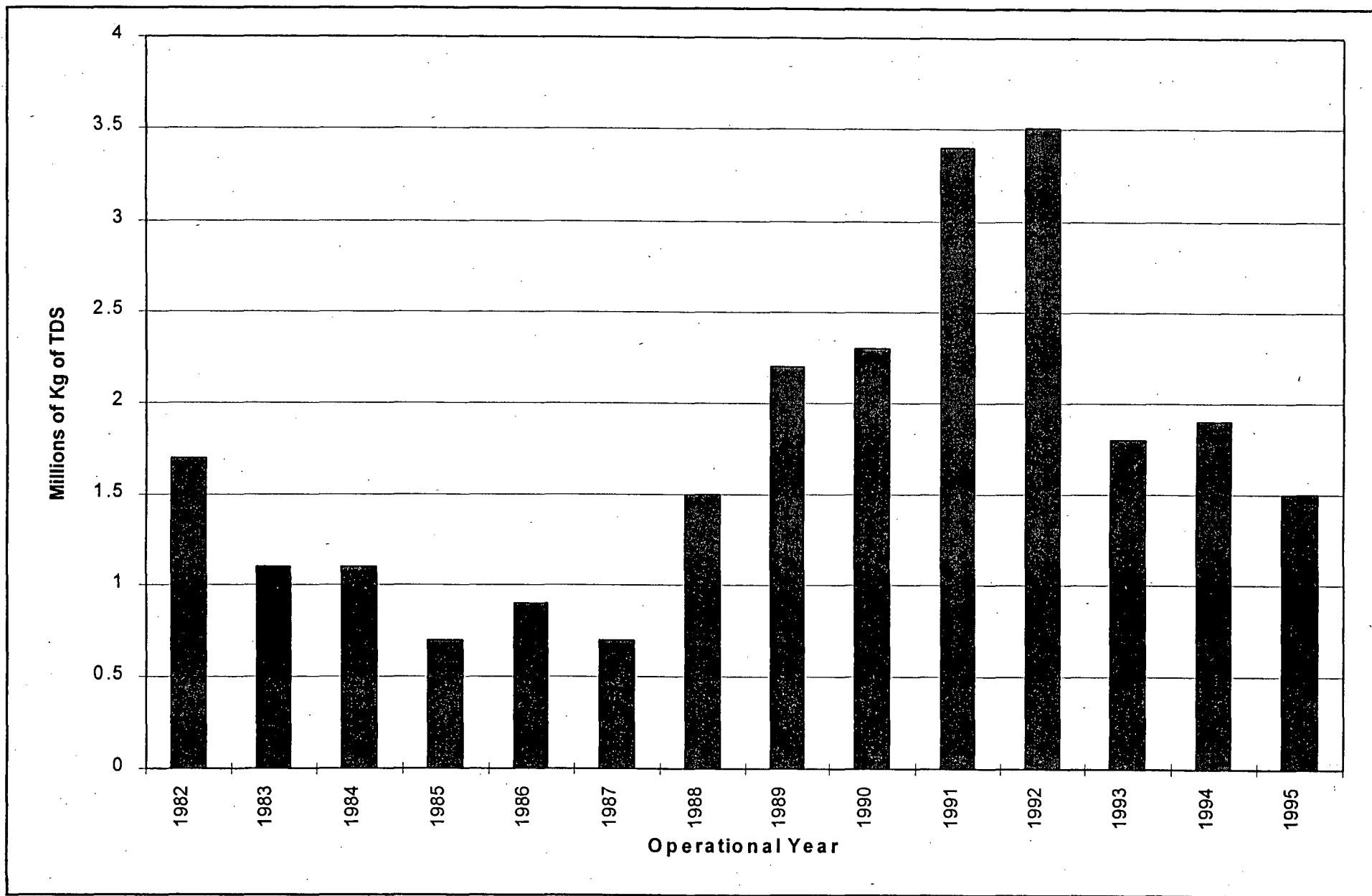
PETROTOMICS COMPANY

Figure 1-12
pH in Proposed POC Wells

Date: October 1997

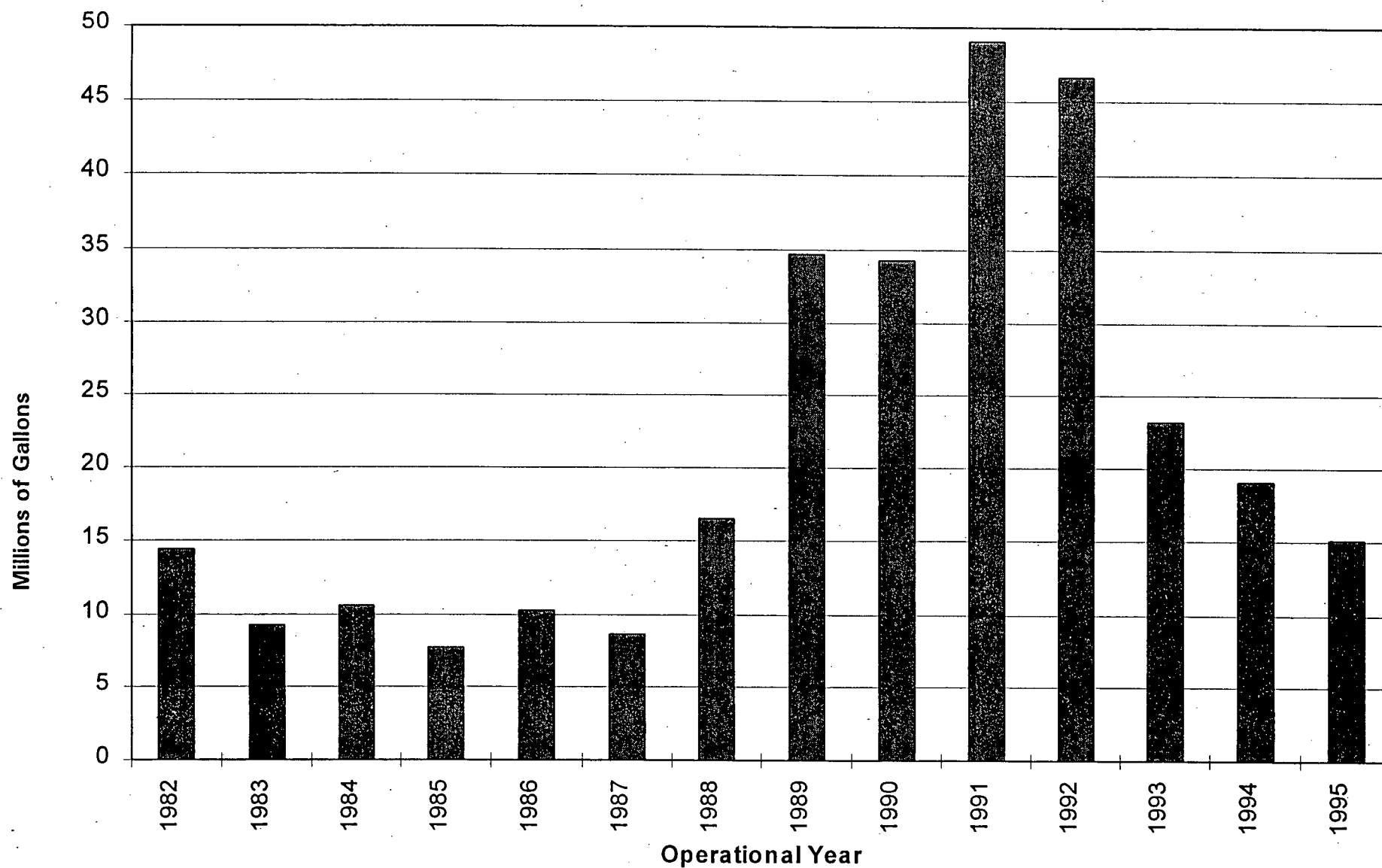
Project: 100053

File: wd2qtr97.ppt



PETROTOMICS COMPANY
Figure 1-13
Millions of Kg of TDS Recovered

Date:	October 1997
Project:	100053
File:	petro.ppt



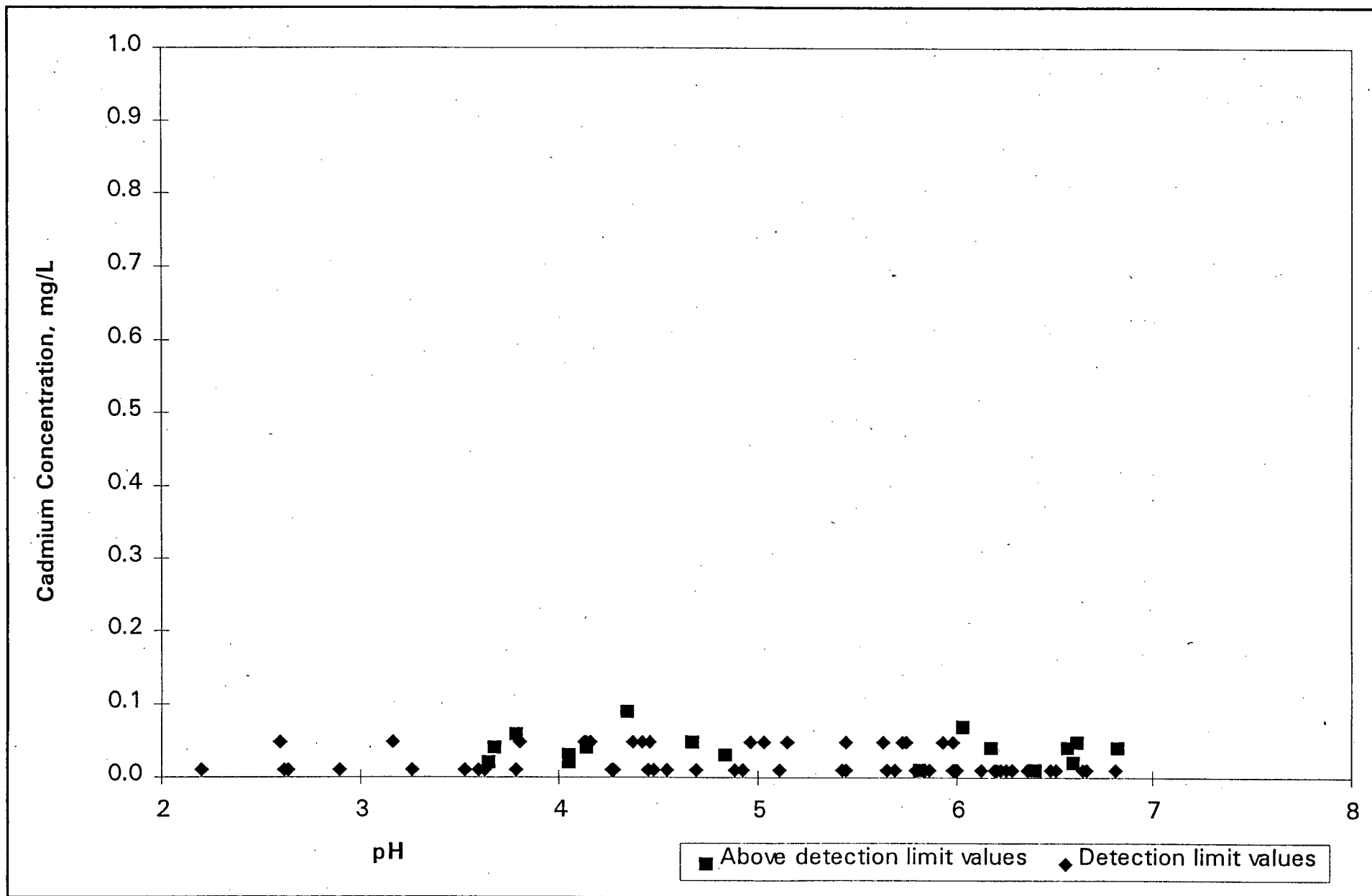
PETROTOMICS COMPANY

Figure 1-14
Millions of Gallons of Seepage Recovered

Date: October 1997

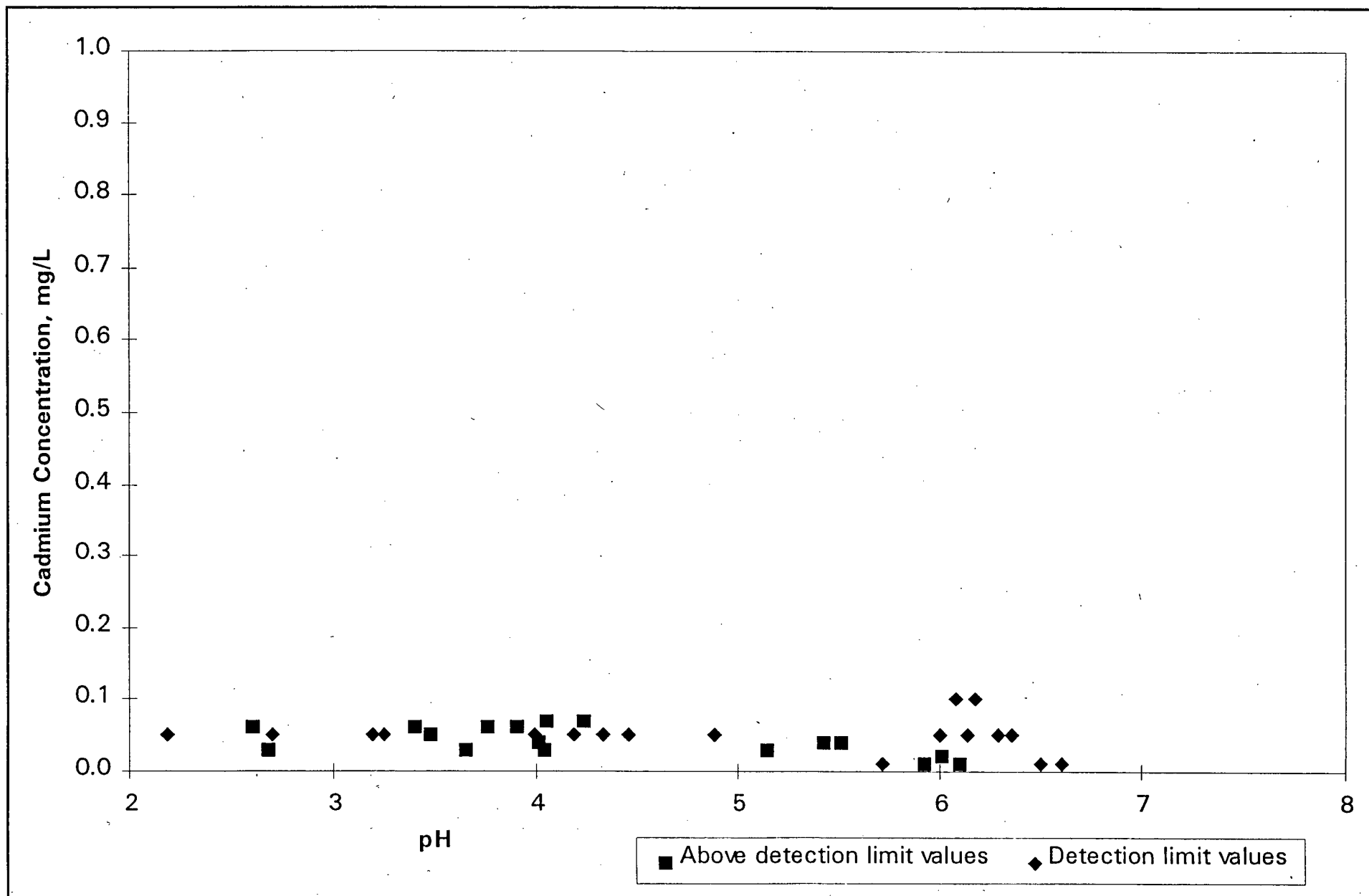
Project: 100053

File: petro.ppt



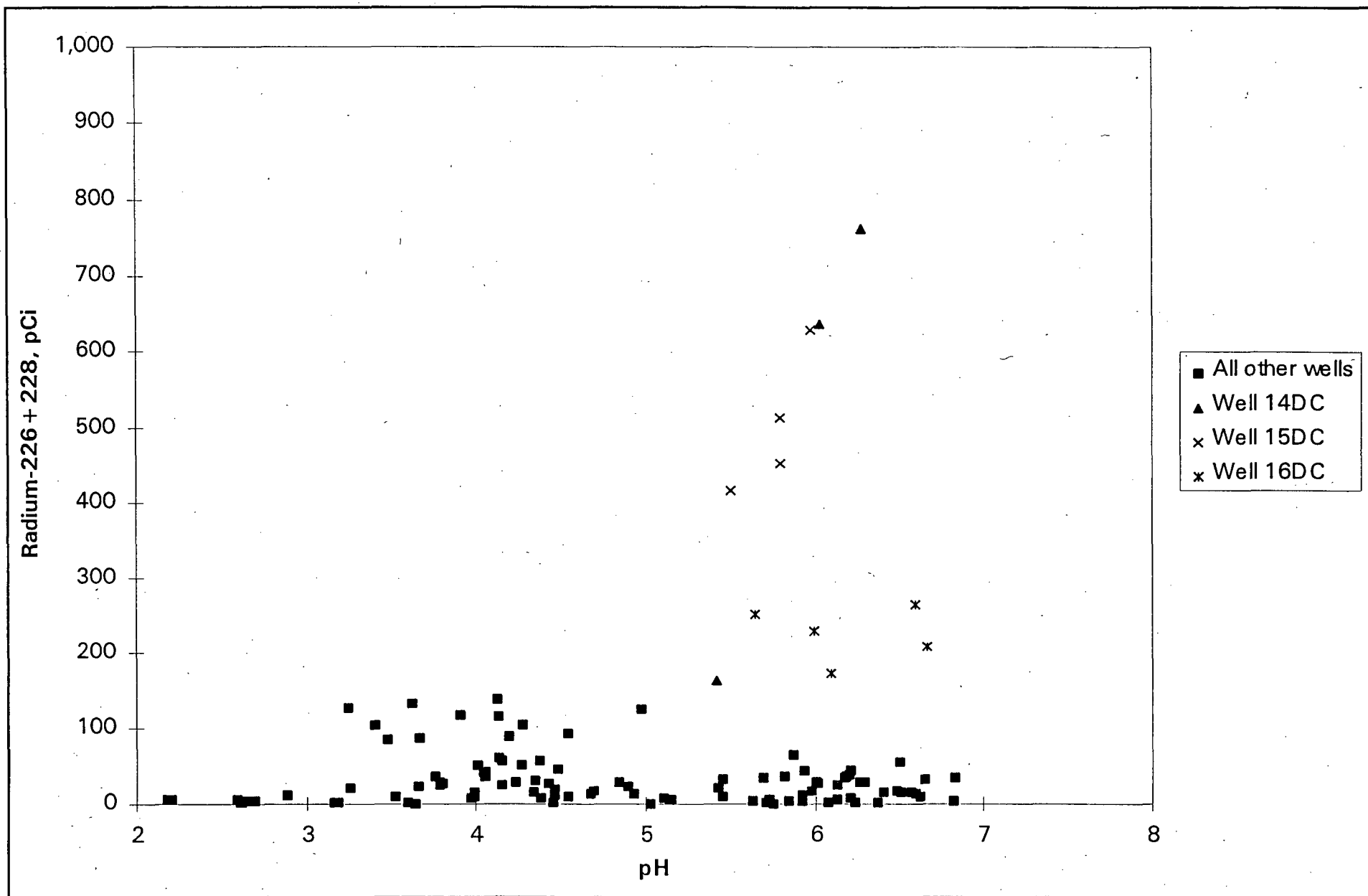
PETROTOMICS COMPANY
Figure4-1
1996 Cadmium Data

Date:	October 1997
Project:	100053
File:	figs4.ppt



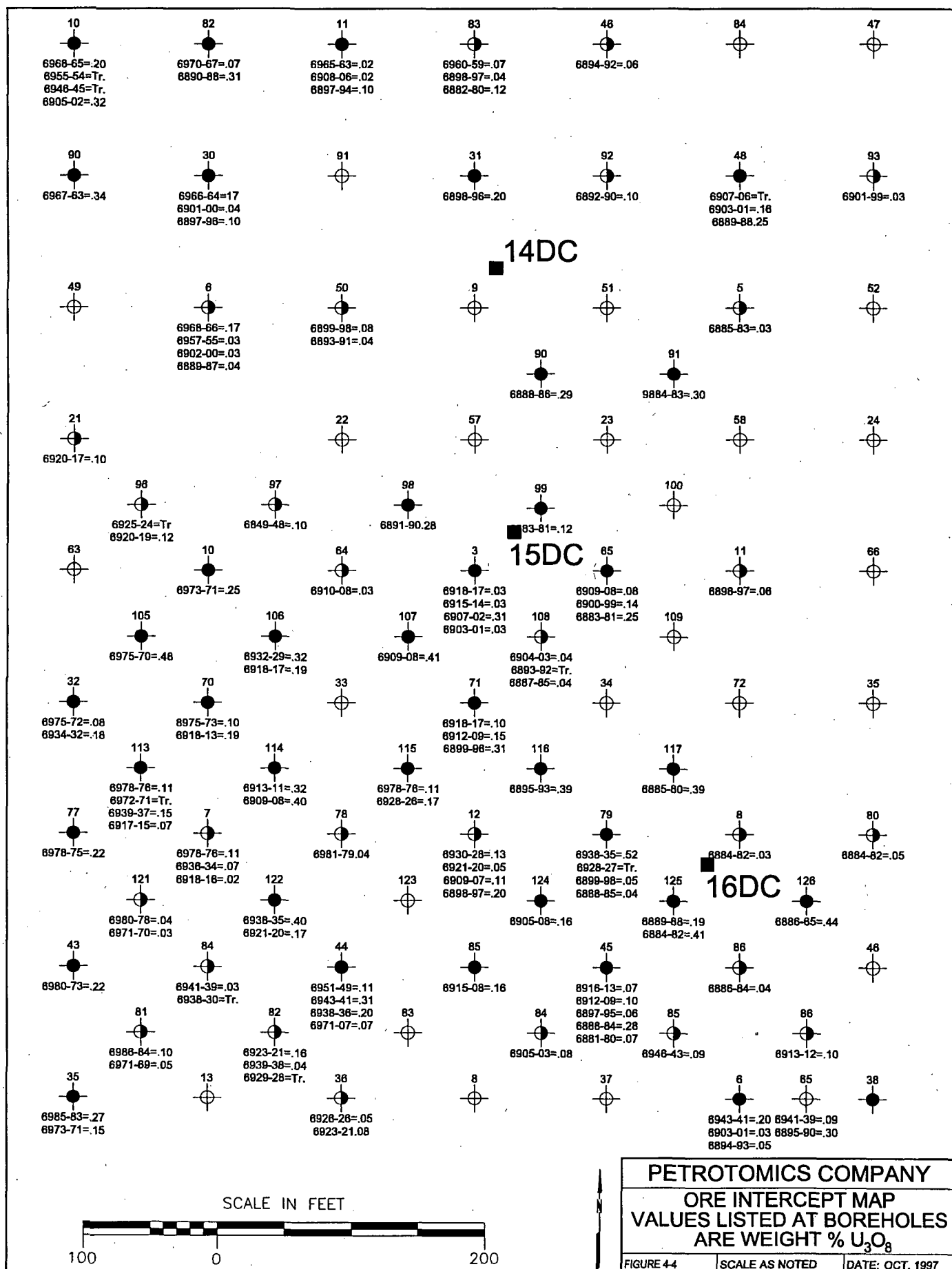
PETROTOMICS COMPANY
Figure 4-2
First Quarter 1997 Cadmium Data

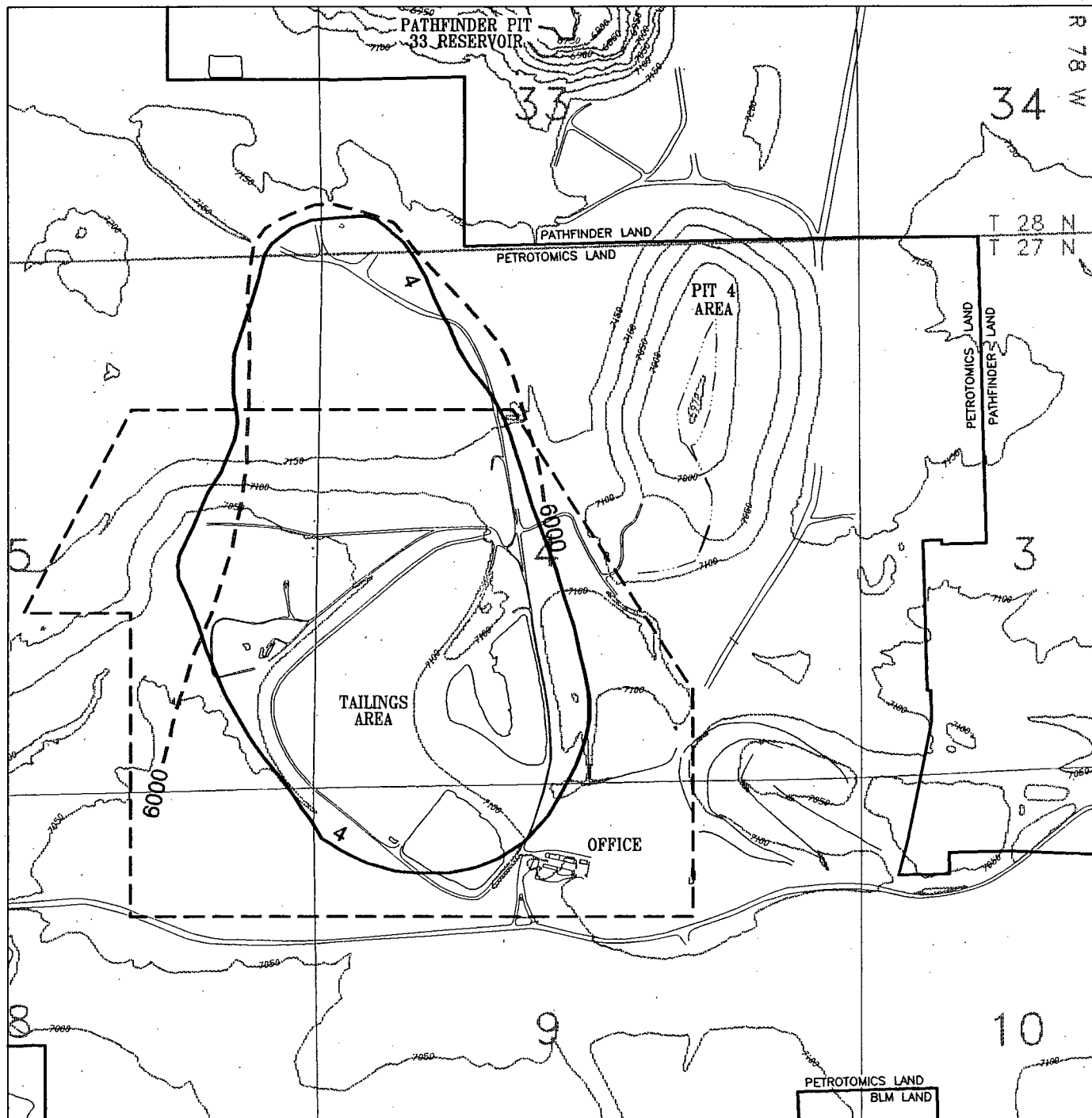
Date:	October 1997
Project:	100053
File:	figs4.ppt



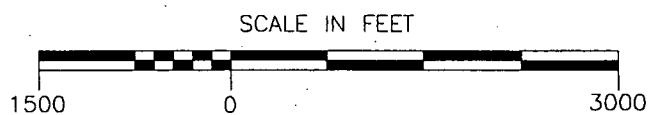
PETROTOMICS COMPANY
Figure 4-3
1996 and 1997 Radium Data

Date:	October 1997
Project:	100053
File:	figs4.ppt



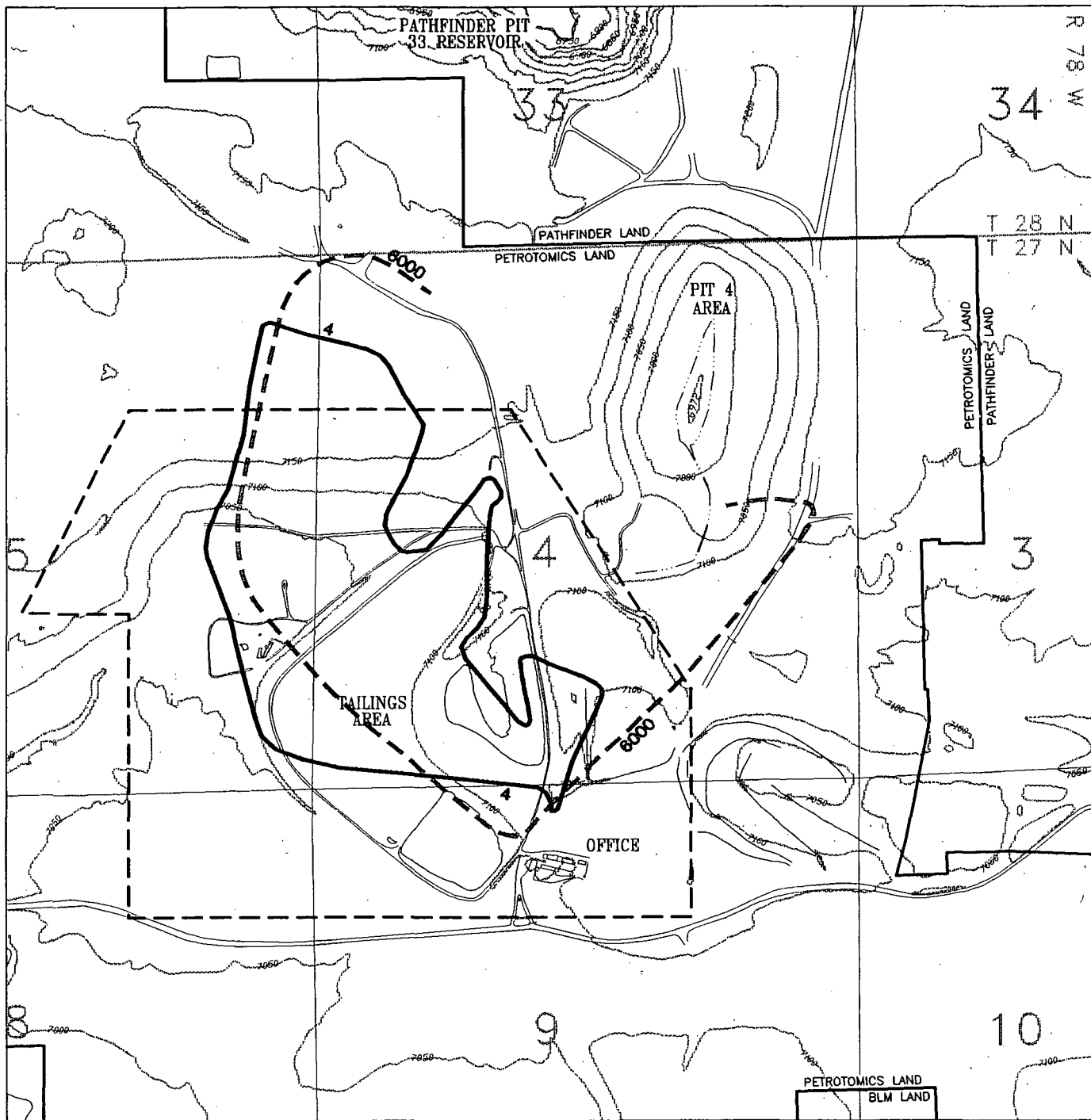


- LEGEND**
- PETROTOMICS PROPERTY BOUNDARY
 - - - - - NRC RESTRICTED AREA BOUNDARY
 - UPPER pH
 - - - - - UPPER SO₄



PETROTOMICS COMPANY
 MAP OF EXTENT OF PLUMES OF GROUND WATER
 WITH pH ≤ 4 AND WITH SULFATE
 CONCENTRATION > 6000 mg/l IN UPPER SAND,
 4th Quarter 1990

FIGURE 4-5 SCALE 1" = 1500' DATE: OCT. 1997



LEGEND

———— PETROTOMICS PROPERTY BOUNDARY

----- NRC RESTRICTED AREA BOUNDARY

———— UPPER pH

----- UPPER SO₄

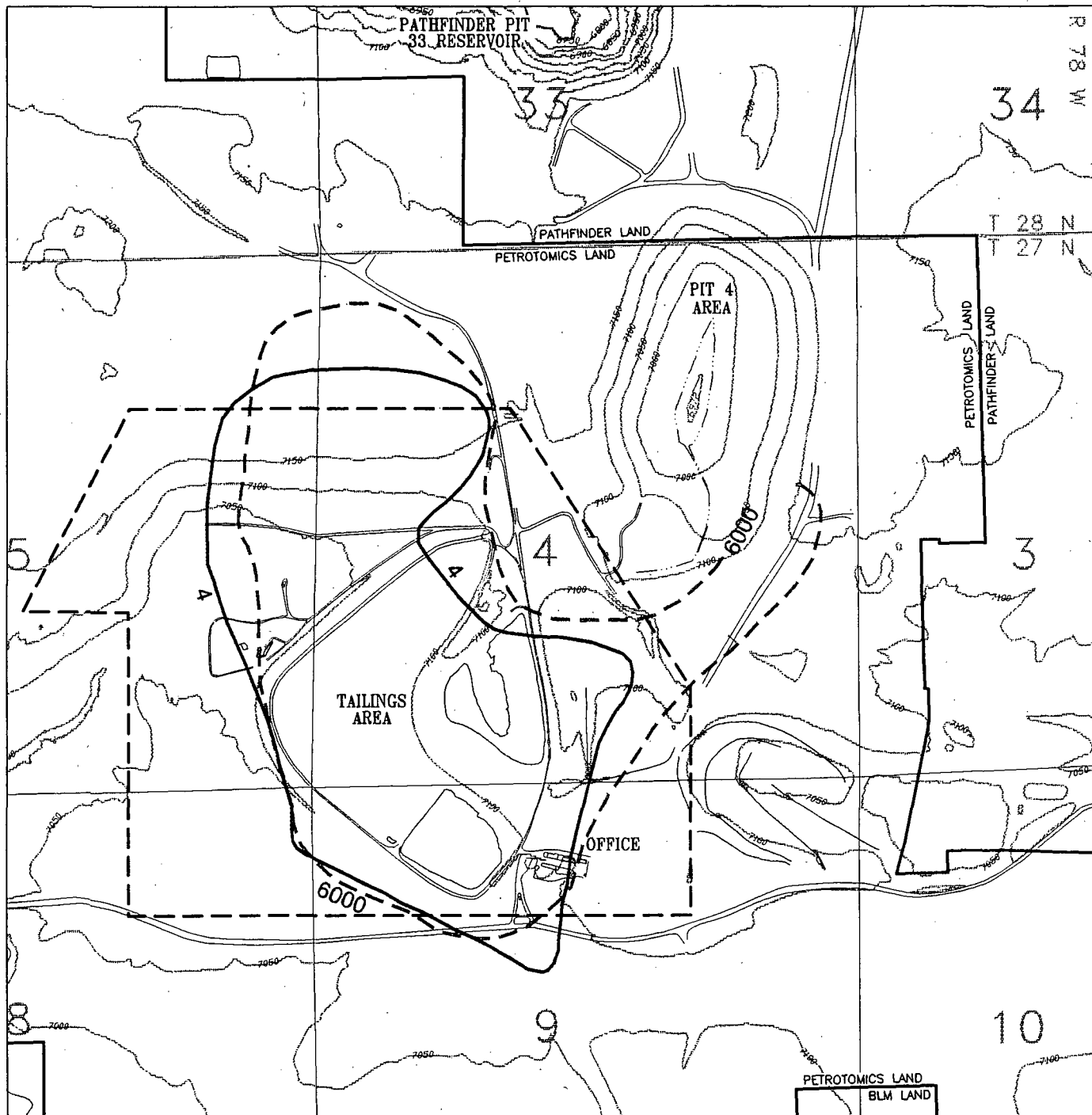
SCALE IN FEET

1500 0 3000

PETROTOMICS COMPANY

MAP OF EXTENT OF PLUMES OF GROUND WATER
WITH pH ≤ 4 AND WITH SULFATE
CONCENTRATION > 6000 mg/l IN UPPER SAND, 1995

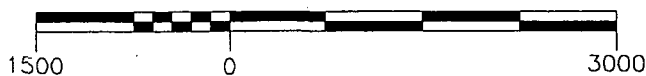
FIGURE 4-6 SCALE 1" = 1500' DATE: OCT. 1997



LEGEND

- PETROTOMICS PROPERTY BOUNDARY
- - - - - NRC RESTRICTED AREA BOUNDARY
- UPPER pH
- - - - - UPPER SO₄

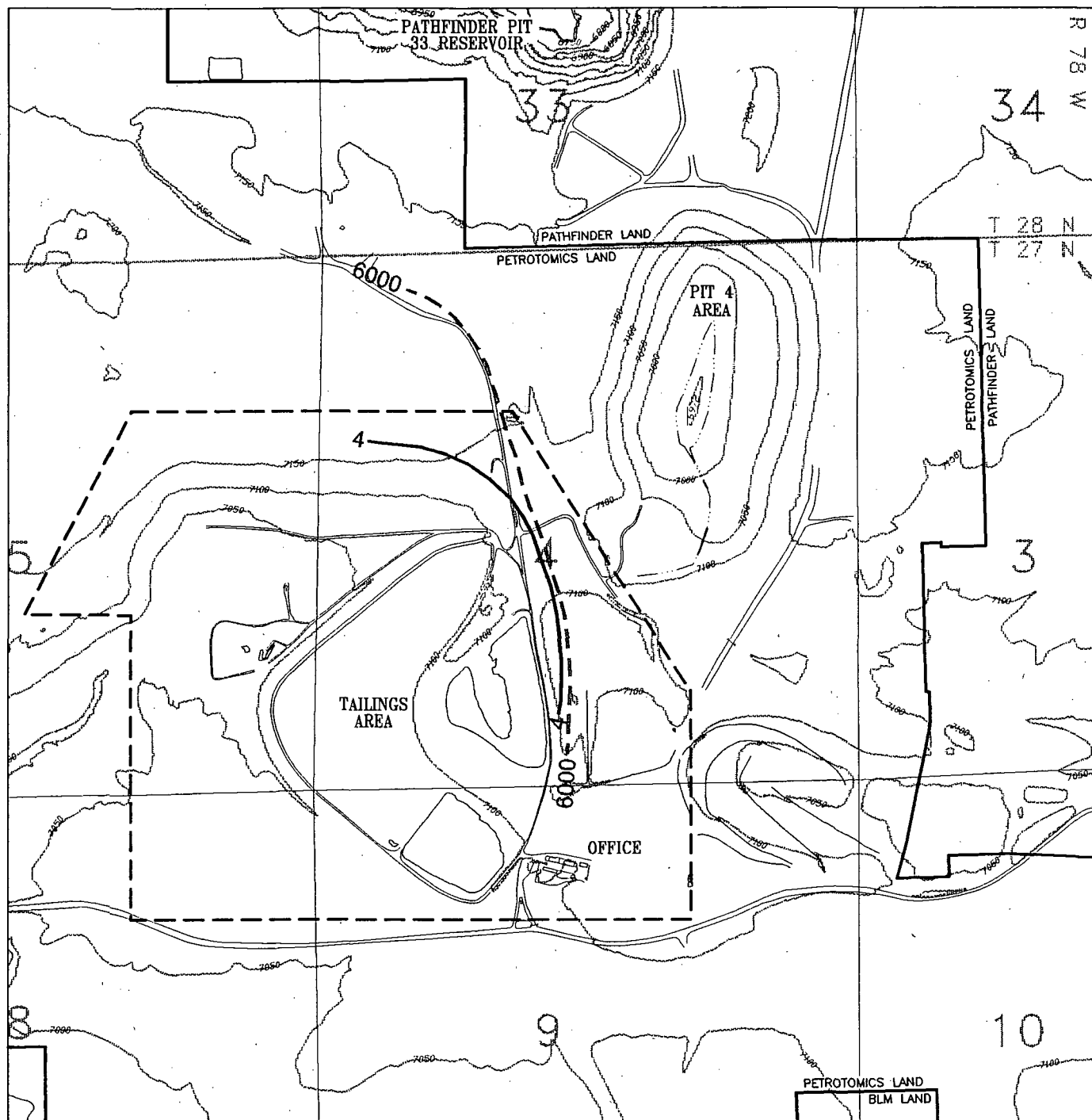
SCALE IN FEET



PETROTOMICS COMPANY

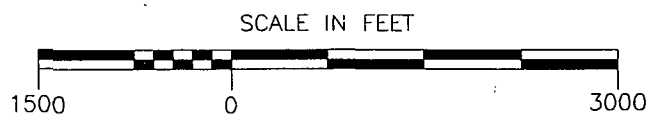
MAP OF EXTENT OF PLUMES OF GROUND WATER
WITH pH ≤ 4 AND WITH SULFATE
CONCENTRATION > 6000 mg/l IN UPPER SAND,
1st Quarter 1997

FIGURE 4-7 SCALE 1" = 1500' DATE: OCT. 1997



LEGEND

————	PETROTOMICS PROPERTY BOUNDARY
- - - -	NRC RESTRICTED AREA BOUNDARY
————	MAIN pH
- - - -	MAIN SO ₄

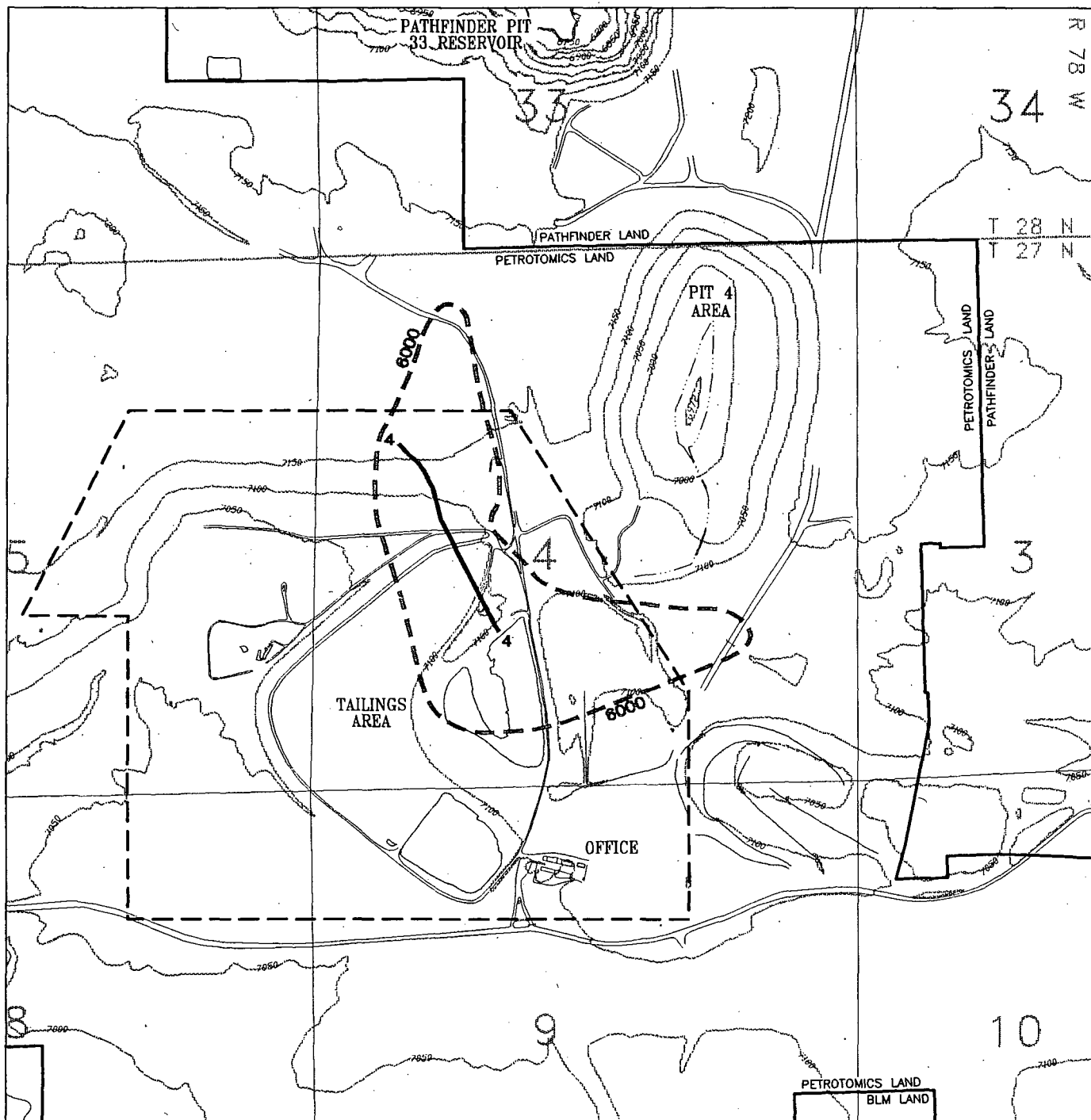


PETROTOMICS COMPANY

MAP OF EXTENT OF PLUMES OF GROUND WATER
WITH pH \leq 4 AND WITH SULFATE
CONCENTRATION $>$ 6000 mg/l IN MAIN SAND,
3rd Quarter 1992

FIGURE 4-8 SCALE 1" = 1500' DATE: OCT. 1997

100053\TASKS\PLUMES



LEGEND

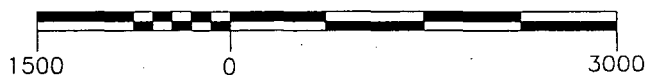
———— PETROTOMICS PROPERTY BOUNDARY

----- NRC RESTRICTED AREA BOUNDARY

———— MAIN pH

----- MAIN SO₄

SCALE IN FEET



PETROTOMICS COMPANY

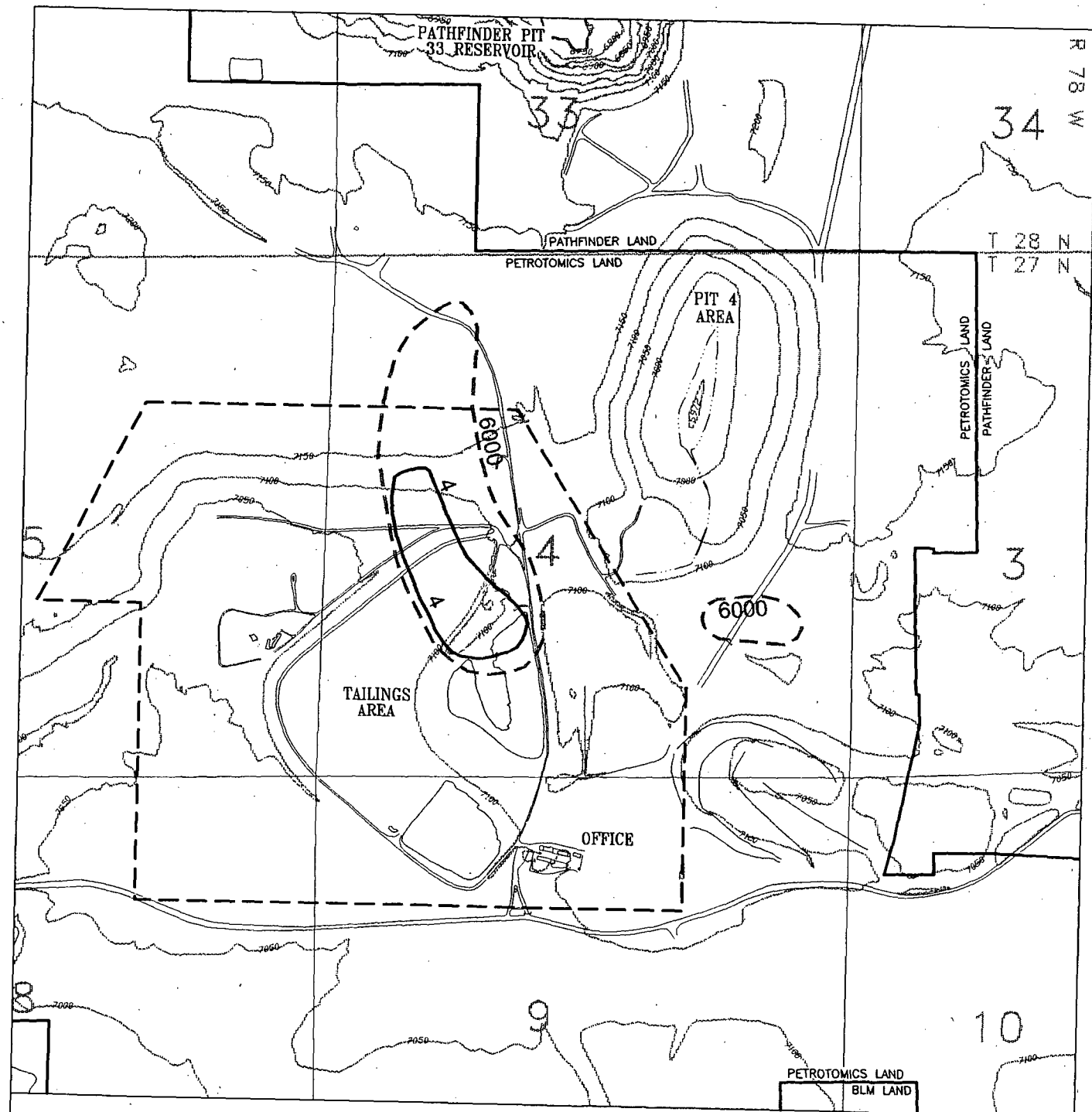
MAP OF EXTENT OF PLUMES OF GROUND WATER
WITH pH ≤ 4 AND WITH SULFATE
CONCENTRATION > 6000 mg/l IN MAIN SAND, 1995

FIGURE 4-9

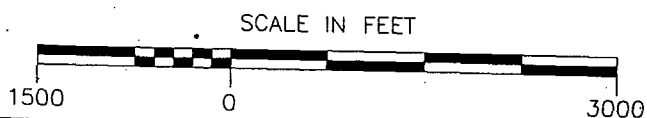
SCALE 1" = 1500'

DATE: OCT. 1997

100053/81670-0A



- LEGEND**
- PETROTOMICS PROPERTY BOUNDARY
 - - - - - NRC RESTRICTED AREA BOUNDARY
 - MAIN pH
 - - - - - MAIN SO₄



PETROTOMICS COMPANY

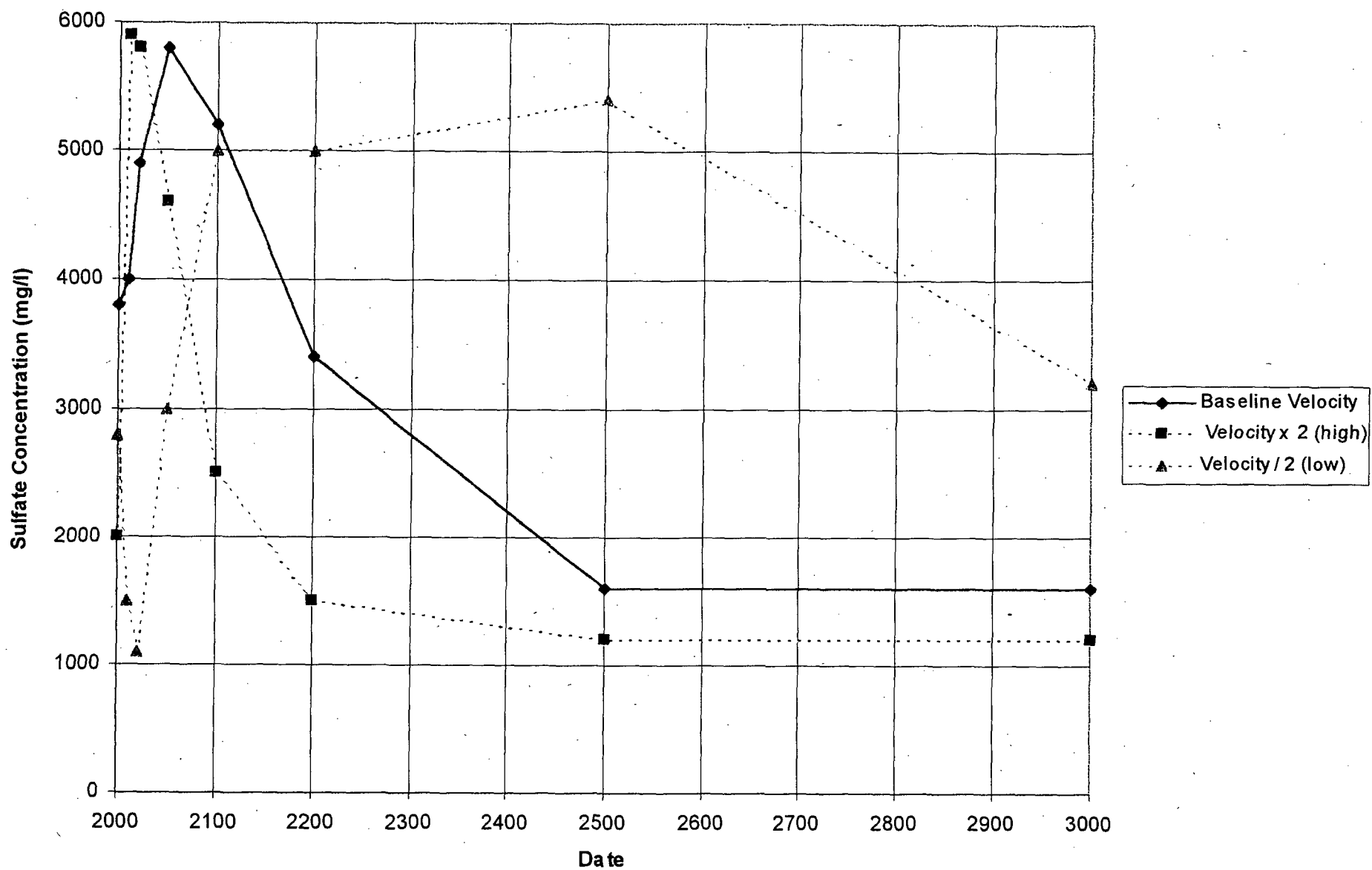
MAP OF EXTENT OF PLUMES OF GROUND WATER
WITH pH ≤ 4 AND WITH SULFATE
CONCENTRATION > 6000 mg/l IN MAIN SAND,
1st Quarter 1997

FIGURE 4-10

SCALE 1" = 1500'

DATE: OCT. 1997

100053\TASK5\PLUMES2



PETROTOMICS COMPANY

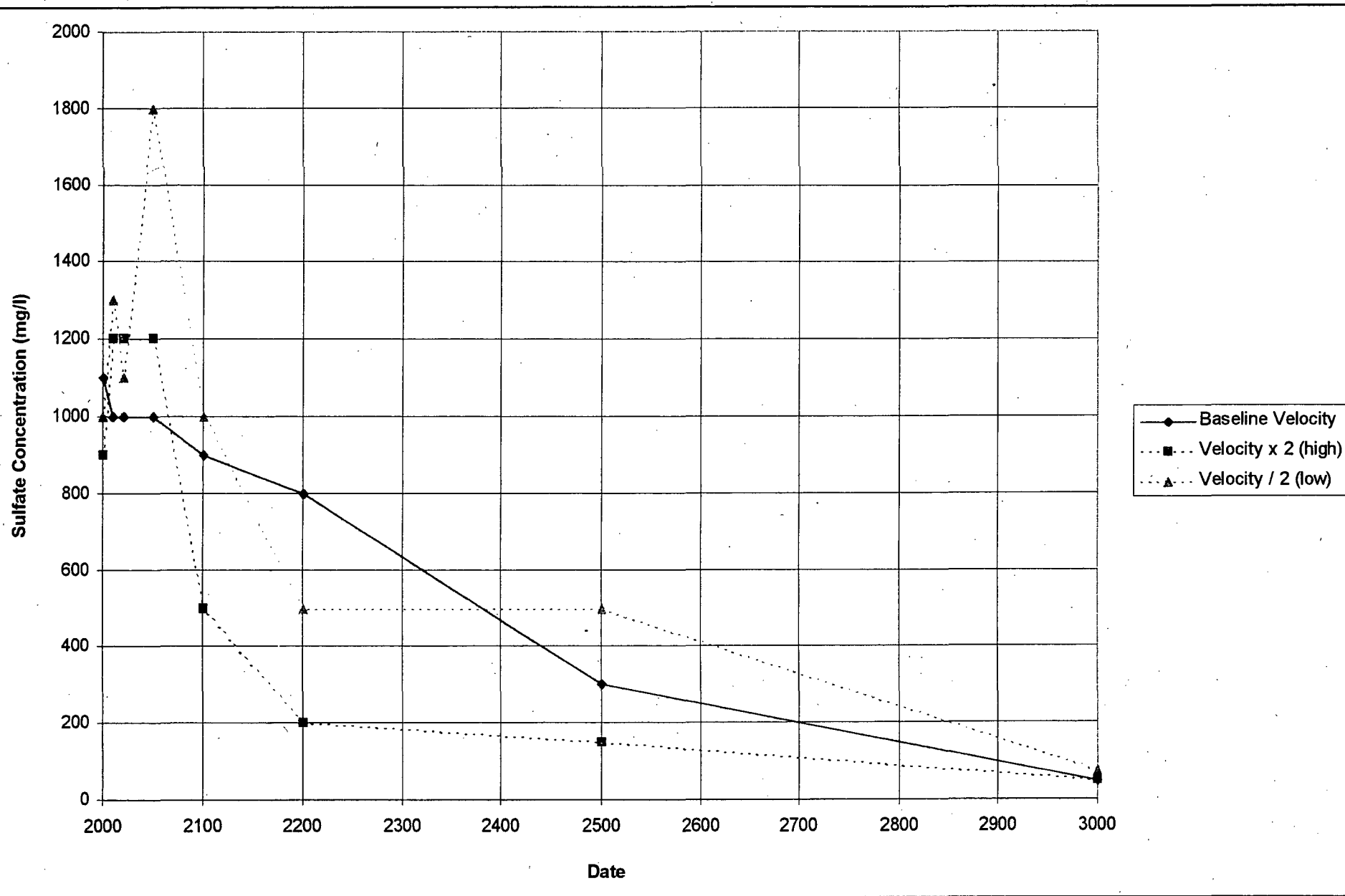
Figure 5-1

Sensitivity of Sulfate Concentration to Ground Water Velocity, Upper Sand - Northern POE

Date: October 1997

Project: 100053

File: Figs5RLL.ppt



PETROTOMICS COMPANY

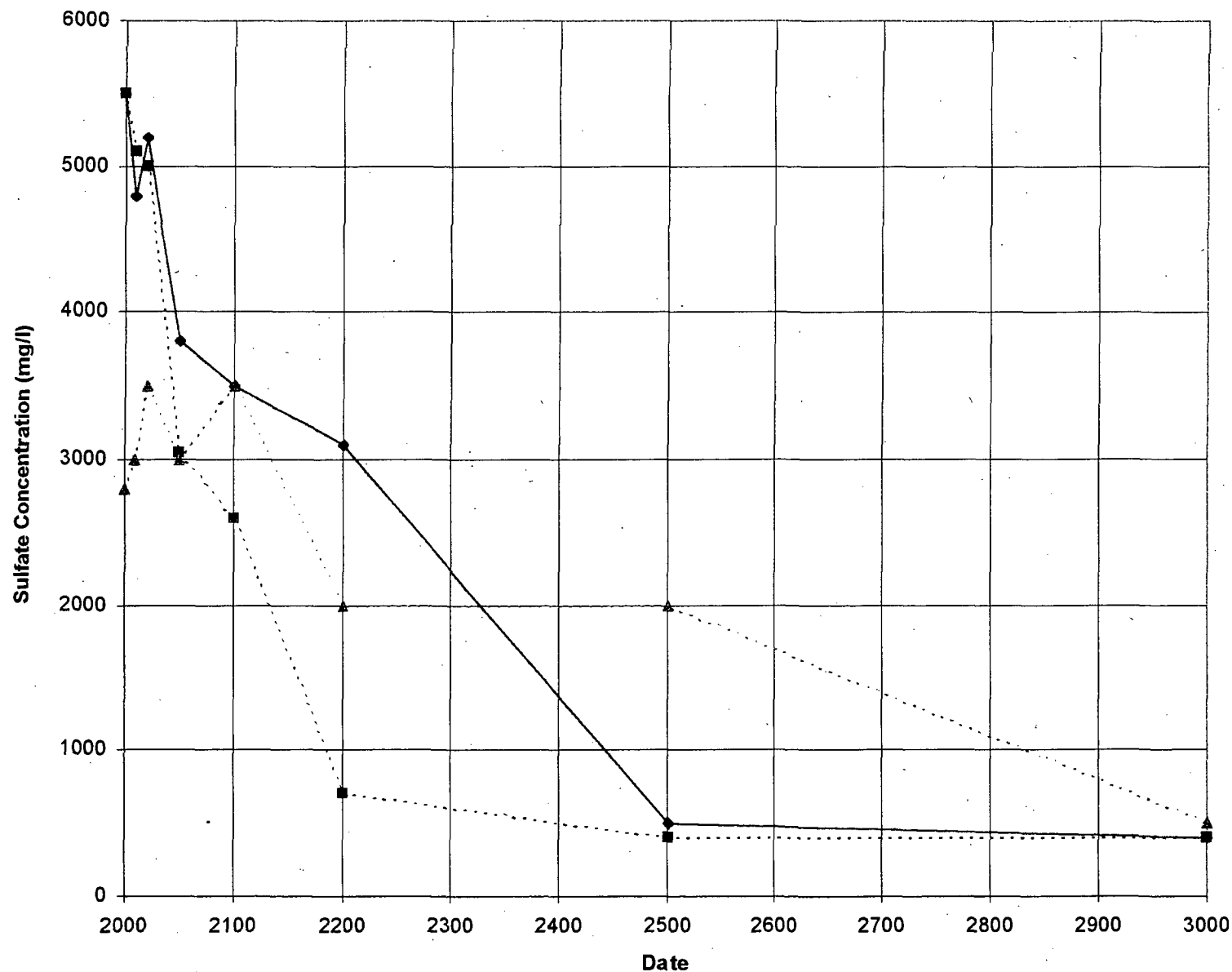
Figure 5-2

Sensitivity of Sulfate Concentration to Ground Water Velocity, Upper Sand - Eastern POE

Date: October 1997

Project: 100053

File: Figs5RLL.ppt



PETROTOMICS COMPANY

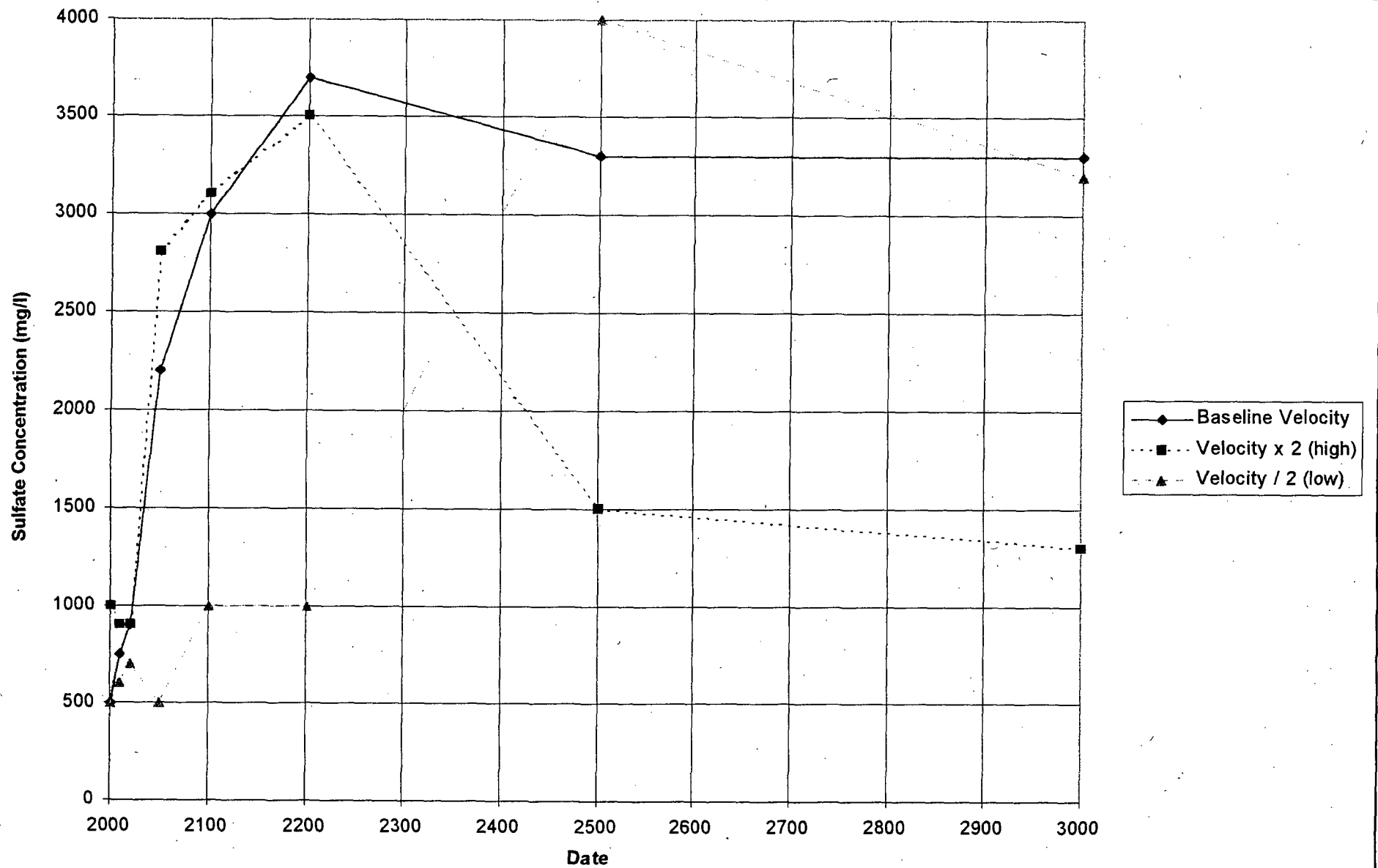
Figure 5-3

Sensitivity of Sulfate Concentration to Ground Water Velocity, Main Sand Aquifer - Northern POE

Date: October 1997

Project: 100053

File: Figs5RLL.ppt



PETROTOMICS COMPANY

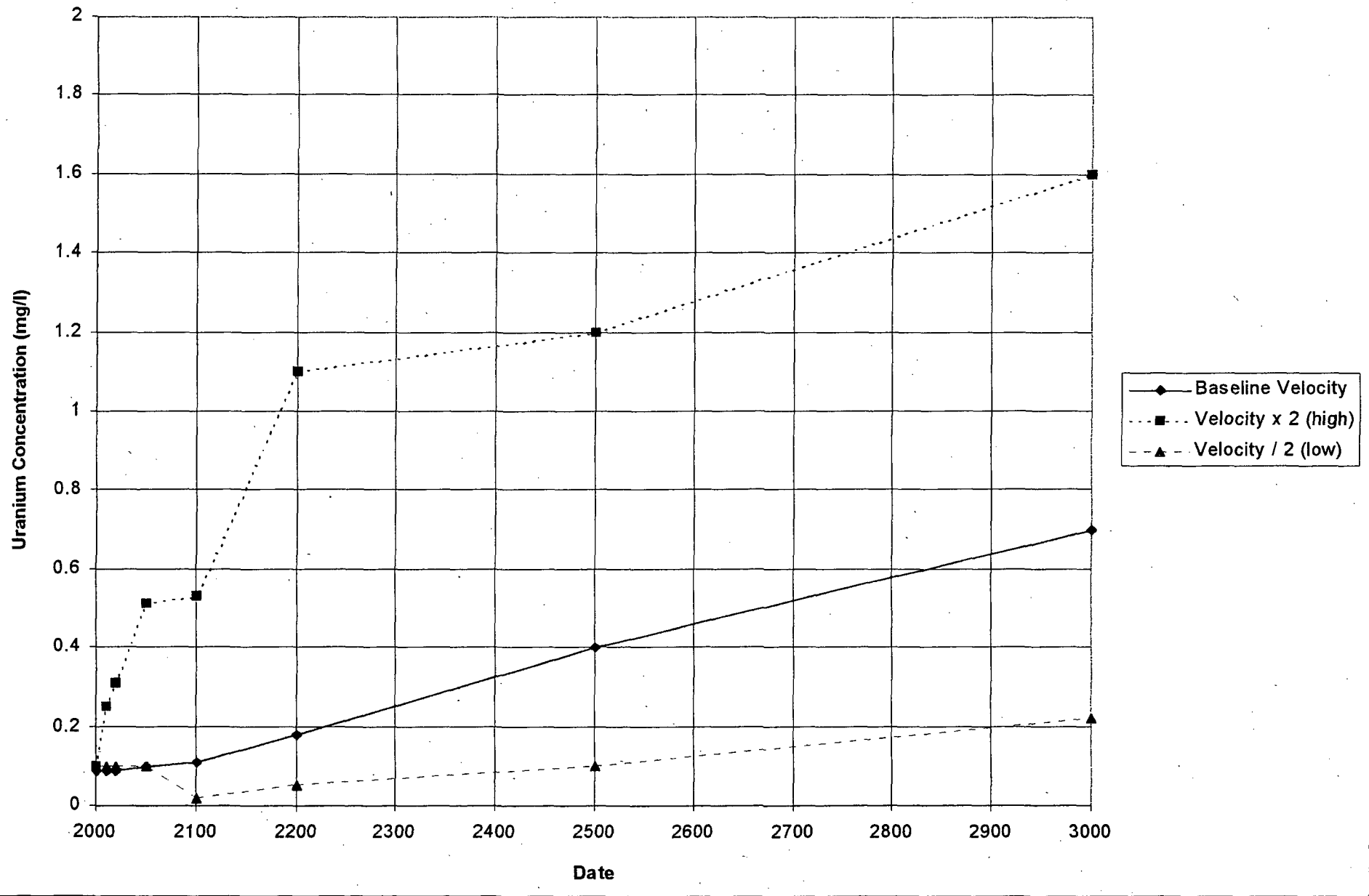
Figure 5-4

Sensitivity of Sulfate Concentration to Ground Water Velocity, Main Sand - Eastern POE

Date: October 1997

Project: 100053

File: Figs5RLL.ppt



PETROTOMICS COMPANY

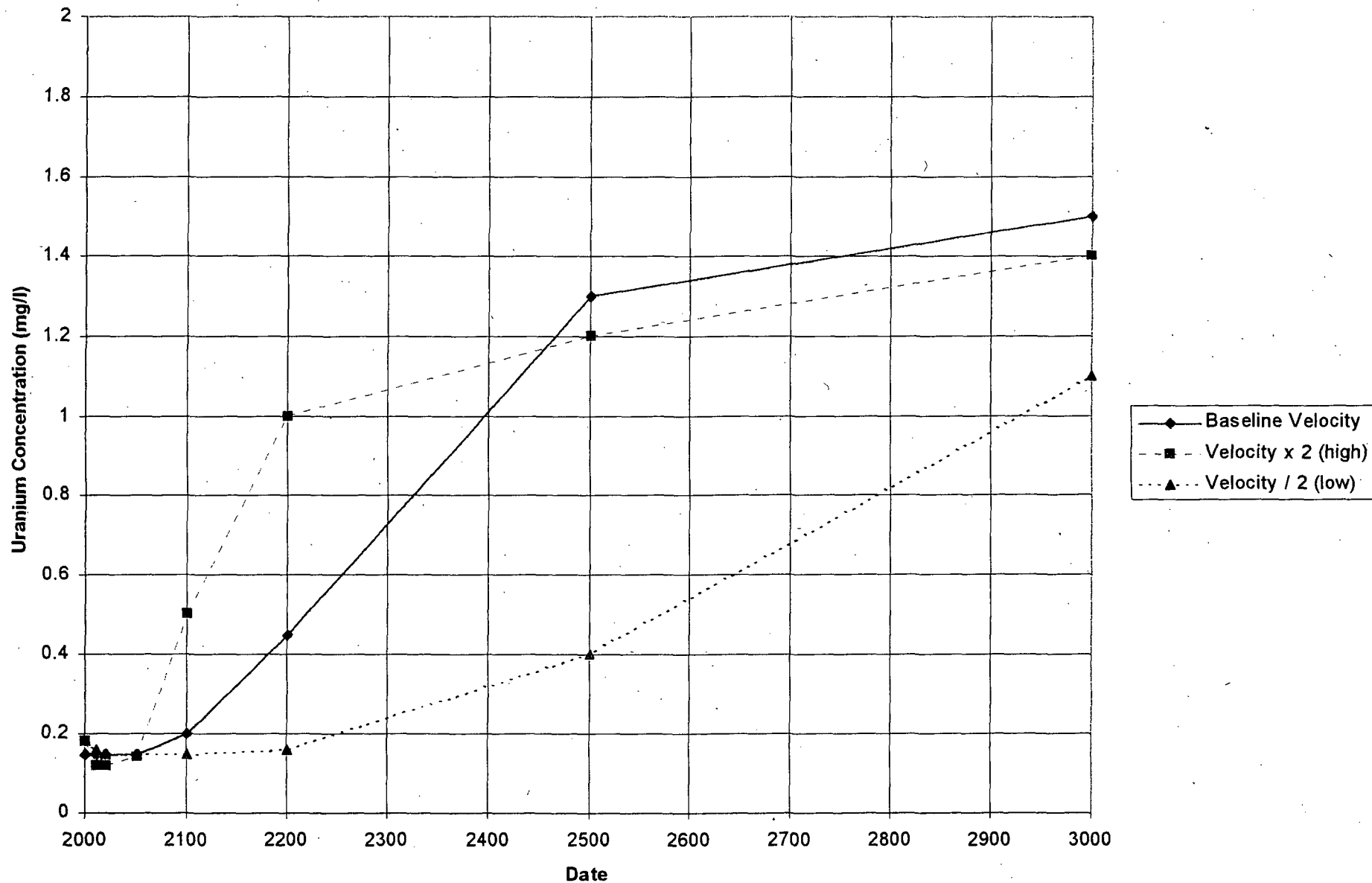
Figure 5-5

Sensitivity of Uranium Concentration to Ground Water Velocity, Upper Sand - RAB

Date: October 1997

Project: 100053

File: Figs5RLL.ppt



PETROTOMICS COMPANY

Figure 5-6

Sensitivity of Uranium Concentrations to Ground Water Velocity, Main Sand - RAB

Date: October 1997

Project: 100053

File: Figs5RLL.ppt

ATTACHMENT FOR OPEN ISSUE 1

- 1. HISTORICAL CONSTITUENT CONCENTRATION DATA FOR POC WELLS 5SC, 5DC, AND 51SC**
- 2. WMPLUME TRANSPORT MODELING RESULTS**

**HISTORICAL CONSTITUENT CONCENTRATION DATA FOR
POC WELLS 5SC, 5DC, AND 51SC**

OPEN ISSUE 1: Data (from 05DC, 05SC, and 51 SC) Used to Generate Trend Plots in Figures 1-1 Through 1-12 (Page 1 of 4)

WELL	DATE	PH (field)	CL	SO4	CD	CR	Pb	NI	Se	U	RA-226	RA-228	TH-230
05 DC	7/2/86	4.30	367	13000	0.0300	0.0250	0.2000	2.4900	0.0005	0.0240	8.2	----	----
05 DC	8/1/86	4.00	358	12000	0.0300	0.0250	0.2500	1.5200	0.0005	0.0150	8.5	----	----
05 DC	10/12/86	4.20	322	12400	0.0300	0.0200	0.0900	1.5800	0.0005	0.0260	9.3	----	----
05 DC	12/8/86	4.00	331	12581	0.0500	0.0050	0.2000	2.3500	0.0005	0.0080	9.6	----	0.1
05 DC	3/31/87	3.50	375	9500	----	----	----	----	0.0005	0.0070	1.8	----	0.4
05 DC	4/30/87	4.10	357	12000	----	----	0.2100	----	0.0005	0.0130	4.5	----	0.2
05 DC	8/18/87	4.50	224	12000	0.0500	0.0050	0.2900	3.9700	0.0005	0.0070	5.5	----	0.1
05 DC	10/19/87	4.50	319	11600	----	----	----	----	0.0005	0.0040	5.5	----	0.0
05 DC	1/15/88	4.20	244	10900	----	----	----	----	0.0005	0.0090	5.7	----	0.0
05 DC	5/6/88	4.30	321	10000	0.0500	0.0050	0.2200	2.8000	0.0005	0.0270	8.4	----	0.2
05 DC	9/26/88	4.40	310	10400	0.0200	0.0050	0.1700	1.4600	0.0005	0.0040	11.9	8.7	0.9
05 DC	11/22/88	----	316	11067	0.0800	0.0700	0.4300	2.3500	0.0005	0.0060	7.3	17.4	1.0
05 DC	3/1/89	4.40	296	9600	----	----	----	----	0.0010	0.0005	5.9	8.0	14.3
05 DC	5/11/89	4.40	292	9600	0.0620	0.0050	0.3300	2.4100	0.0005	0.0020	6.3	18.3	8.4
05 DC	8/30/89	4.20	288	9800	----	----	----	----	0.0030	0.0260	21.4	19.6	33.1
05 DC	11/21/89	3.60	267	9280	0.0900	0.0050	0.5100	2.7000	0.0005	0.0120	6.5	12.8	1.3
05 DC	3/5/90	4.20	293	11000	0.0500	0.0300	0.1100	2.9600	0.0560	0.0070	3.3	23.6	2.7
05 DC	6/12/90	4.36	211	7840	0.0110	0.0200	0.1200	2.6000	0.0005	0.0040	8.5	20.1	6.2
05 DC	8/30/90	4.21	300	9000	0.0050	0.0100	0.0250	2.0000	0.0005	0.5730	8.0	41.2	0.0
05 DC	8/30/90	4.20	202	9899	0.0200	0.0250	0.0250	2.8000	0.0005	0.0040	21.5	17.8	0.5
05 DC	2/7/91	3.20	170	7700	0.0050	0.0050	0.1300	2.4900	0.0005	0.0430	35.7	25.2	5.3
05 DC	6/13/91	4.20	209	9400	----	----	----	----	0.0005	0.0005	10.1	18.3	16.3
05 DC	9/26/91	4.20	223	9400	----	----	----	----	0.0010	0.0100	5.8	86.3	34.8
05 DC	11/27/91	3.70	250	9400	0.0200	0.0050	0.2200	2.5500	0.0080	0.0005	3.8	7.4	13.5
05 DC	6/4/92	2.60	975	5800	----	----	0.0250	----	0.0005	0.2040	3.8	11.5	236.0
05 DC	8/26/92	3.60	168	9300	0.0100	0.0400	0.0250	2.2000	0.0170	0.0510	9.3	10.5	116.0
05 DC	12/2/92	4.00	201	10100	0.0400	0.0400	0.0250	0.2200	0.0200	0.0005	5.1	24.5	58.8
05 DC	2/9/93	3.90	198	9600	0.0600	0.0400	0.0250	2.1200	0.0005	0.0040	5.4	15.9	21.4
05 DC	5/18/93	3.50	132	7360	----	----	----	----	0.0005	0.0560	8.5	37.1	20.3
05 DC	8/10/93	3.50	119	6400	0.0800	0.1000	0.0250	1.5000	0.0005	0.0340	5.6	3.4	27.1
05 DC	11/23/93	3.60	129	7100	0.0500	0.0400	0.0250	1.4000	0.0005	0.0100	4.9	12.6	5.4
05 DC	3/3/94	4.13	137	7560	0.0250	0.0250	0.0090	2.2600	0.0010	0.0060	61.1	15.9	40.3
05 DC	3/3/94	4.13	137	7680	0.0250	0.0250	0.0080	2.4800	0.0010	0.0070	57.9	14.6	17.0
05 DC	6/9/94	4.63	130	6250	0.0050	0.2500	0.0025	2.1500	0.0010	0.0020	37.6	14.4	13.6
05 DC	6/9/94	4.63	120	6640	0.0050	0.2400	0.0080	2.1800	0.0010	0.0030	46.0	10.6	19.8
05 DC	9/16/94	4.79	150	6800	0.0050	0.0250	0.0250	0.1100	0.0010	0.0240	16.5	14.6	0.9
05 DC	12/8/94	4.73	155	6480	0.0200	0.0250	0.0025	2.2400	0.0020	0.0020	73.2	15.5	5.2
05 DC	2/16/95	4.79	130	6080	0.0300	0.1300	0.0025	2.0200	0.0040	0.0005	28.5	23.4	40.5
05 DC	5/19/95	4.78	130	5620	0.0250	0.0250	0.0025	2.1300	0.0030	0.0030	6.2	21.5	1.1

OPEN ISSUE 1: Data (from 05DC, 05SC, and 51 SC) Used to Generate Trend Plots in Figures 1-1 Through 1-12 (Page 2 of 4)

WELL	DATE	PH (field)	CL	SO4	CD	CR	Pb	NI	Se	U	RA-226	RA-228	TH-230
05 DC	8/30/95	4.80	118	5580	0.1000	0.0250	0.0025	2.2000	0.0010	0.0070	6.2	16.4	7.5
05 DC	11/28/95	4.69	140	5790	0.0050	0.0250	0.0025	0.9000	0.0010	0.0020	7.9	10.6	2.7
05 DC	2/29/96	4.89	140	5440	0.0050	0.0050	0.0025	0.8700	0.0005	0.0020	7.0	15.7	2.6
05 DC	2/29/96	----	----	----	0.0200	0.0400	----	1.1800	0.0005	0.0060	----	----	----
05 DC	6/5/96	4.84	140	5760	0.0300	0.0900	0.0025	0.2800	0.0005	0.0005	10.5	18.4	2.1
05 DC	2/19/97	4.46	130	5900	0.0250	0.0250	0.0010	1.1800	0.0005	0.0005	8.4	2.3	5.4
05 SC	4/15/85	----	200	16100	----	----	----	----	0.0010	0.1360	0.5	----	2632.0
05 SC	5/27/85	----	----	----	----	----	----	----	0.0010	----	----	----	----
05 SC	6/20/85	----	----	----	----	----	----	----	0.0010	----	----	----	----
05 SC	7/22/85	----	----	----	----	----	----	----	0.0005	----	----	----	----
05 SC	8/14/85	----	----	----	----	----	----	----	0.0005	----	----	----	----
05 SC	9/26/85	----	----	----	----	----	----	----	0.0003	----	----	----	----
05 SC	10/17/85	----	250	16450	----	----	----	----	0.0005	0.0790	0.6	----	48.8
05 SC	3/31/86	----	275	13480	----	----	----	----	0.0050	7.9000	0.3	----	4.2
05 SC	5/22/86	----	310	16200	0.1000	1.7900	0.2500	3.2700	0.0005	5.5000	0.8	----	2.5
05 SC	9/26/86	----	300	16250	----	----	----	----	0.0005	7.7700	0.4	----	70.6
05 SC	11/25/86	----	309	15420	----	----	----	----	0.0005	11.4000	0.6	----	89.8
05 SC	3/31/87	3.30	311	17000	----	----	----	----	0.0005	12.8000	0.3	----	108.0
05 SC	5/7/87	2.50	336	18400	----	----	0.3100	----	0.0010	15.0000	0.5	----	125.0
05 SC	6/11/87	3.40	307	16000	----	----	----	----	0.0005	12.4000	0.5	----	146.0
05 SC	9/16/87	----	291	15000	0.1400	0.9300	0.2800	4.6700	0.0005	20.2000	0.2	----	1325.0
05 SC	12/3/87	----	281	18400	----	----	----	----	0.0020	16.0000	0.3	----	2028.0
05 SC	1/18/88	3.10	201	16600	0.1300	1.7490	0.3450	4.0900	0.0010	13.5000	0.6	1.5	2014.0
05 SC	1/18/88	----	----	----	0.1320	1.5020	0.3890	4.7700	0.0010	15.0000	0.5	2.5	1713.0
05 SC	1/18/88	----	----	----	0.1320	1.7490	0.4170	4.3900	0.0010	15.0000	0.5	1.0	2084.0
05 SC	1/18/88	----	----	----	0.1320	1.7490	0.4030	4.8400	0.0005	14.0000	0.6	0.1	1708.0
05 SC	6/16/88	2.90	324	15600	----	----	----	----	0.0010	11.0000	0.6	----	102.0
05 SC	9/28/88	----	316	15600	0.1000	1.1100	0.3000	2.1500	0.0005	8.7000	0.1	3.8	1230.0
05 SC	11/22/88	3.00	340	16000	0.1600	0.9500	0.5500	2.6800	0.0005	11.8000	0.6	1.0	827.0
05 SC	3/8/89	----	331	16800	----	----	----	----	0.0830	7.3000	0.5	1.0	1001.0
05 SC	5/11/89	----	330	15600	0.1030	1.1400	0.5700	2.6600	0.0690	11.0000	0.3	4.0	881.0
05 SC	9/26/89	3.40	581	14800	----	----	----	----	0.0270	19.7000	0.7	7.6	825.0
05 SC	11/21/89	2.30	290	15500	0.1700	1.5000	0.6500	3.3000	0.0210	19.7000	0.6	1.1	1134.0
05 SC	3/5/90	2.80	348	16600	0.1200	1.9700	0.2400	3.7400	0.1550	20.1000	1.1	0.3	1413.0
05 SC	6/12/90	3.04	293	16600	0.1100	1.8000	0.2700	4.3000	0.1220	39.9000	1.0	10.9	1348.0
05 SC	8/31/90	3.08	344	17200	0.0480	1.5500	0.0250	3.1000	0.1580	47.0000	0.6	10.7	2039.0
05 SC	8/31/90	3.08	304	17322	0.0800	0.6400	0.0250	3.9900	0.1440	20.9100	46.4	0.5	40.8
05 SC	33218	3.10	339	15500	0.1000	1.4900	0.3500	3.4400	0.0760	15.8000	0.4	3.3	1394.0

OPEN ISSUE 1: Data (from 05DC, 05SC, and 51 SC) Used to Generate Trend Plots in Figures 1-1 Through 1-12 (Page 3 of 4)

WELL	DATE	PH (field)	CL	SO4	CD	CR	Pb	NI	Se	U	RA-226	RA-228	TH-230
05 SC	2/11/91	2.90	337	16200	0.1100	1.5400	0.3700	3.8800	0.0850	17.3000	0.4	7.6	2438.0
05 SC	6/13/91	2.90	299	17800	----	----	----	----	0.0005	17.2000	1.1	11.2	2334.0
05 SC	9/26/91	3.30	341	18800	----	----	----	----	0.0160	17.3000	0.8	21.2	1444.0
05 SC	11/27/91	2.40	348	19000	0.1200	1.5000	0.3200	4.0600	0.0005	17.8000	0.2	0.0	1123.0
05 SC	2/18/92	3.20	300	17800	0.1200	1.5100	0.0250	4.4000	0.0005	7.5200	6.5	10.0	1075.0
05 SC	6/4/92	3.00	399	17200	0.1200	1.8400	0.0250	2.5800	0.0140	15.9000	0.4	11.5	1592.0
05 SC	8/26/92	2.80	64	4480	0.0050	0.2000	0.0250	0.7200	0.0060	3.2200	1.7	12.4	212.0
05 SC	12/2/92	3.20	121	7400	----	----	----	----	0.0120	3.3100	0.4	14.4	248.0
05 SC	3/1/93	3.10	184	10320	0.0900	0.7600	0.0250	2.0400	0.0005	3.7300	1.8	2.2	340.0
05 SC	5/18/93	3.10	261	12080	----	----	----	----	0.0005	5.8700	0.4	0.6	604.0
05 SC	8/9/93	3.30	252	12960	0.0800	1.1000	0.0250	2.7700	0.0190	10.7000	1.4	1.5	783.0
05 SC	11/23/93	2.60	278	15000	0.1100	1.3000	0.0250	3.4000	0.0560	8.8200	1.9	5.3	1008.0
05 SC	3/3/94	3.02	303	18600	0.0800	0.6200	0.0160	4.4400	0.0010	8.8500	156.0	3.5	3230.0
05 SC	6/6/94	2.93	295	17500	0.0050	1.1400	0.0170	3.3800	0.2000	7.9600	41.4	0.0	3260.0
05 SC	9/16/94	3.06	375	15700	0.0050	1.6000	0.0250	4.1800	0.0900	3.6100	182.0	2.8	761.0
05 SC	12/9/94	2.86	285	15900	----	----	----	----	----	----	----	----	----
05 SC	12/9/94	2.86	290	15200	----	----	----	----	----	----	----	----	----
05 SC	2/28/95	3.03	320	16100	0.0700	0.7300	0.0025	4.4800	0.0500	7.0000	175.0	11.1	2750.0
05 SC	5/17/95	2.75	315	15300	----	----	----	----	----	----	----	----	----
05 SC	8/29/95	2.87	350	16000	0.0250	1.0900	0.0025	1.3200	----	7.5600	1.4	1.1	1880.0
05 SC	11/29/95	3.08	310	17600	----	----	----	----	----	----	----	----	----
05 SC	2/28/96	2.89	338	16900	0.0050	0.7800	0.0025	2.4700	0.0005	1.2000	3.6	7.5	1950.0
05 SC	2/28/96	----	----	----	0.0900	1.0400	----	2.9000	0.0005	5.5500	----	----	----
05 SC	6/5/96	2.92	350	18000	----	----	----	----	----	----	----	----	----
05 SC	8/6/96	3.16	320	15600	0.0250	1.0600	0.0025	3.4600	0.0030	14.7000	1.7	0.0	2100.0
05 SC	11/25/96	2.48	600	17500	----	----	----	----	----	----	----	----	----
05 SC	2/19/97	2.69	350	18100	0.0250	0.9800	0.0010	3.8500	0.0005	7.3500	2.3	2.3	2020.0
05 SC	5/22/97	----	313	14000	----	----	----	----	----	----	----	----	----
51 SC	7/2/86	3.80	368	17700	0.0500	0.0250	0.2900	4.3000	0.0005	0.0140	44.8	----	0.1
51 SC	8/1/86	3.90	348	18100	0.0500	0.0250	0.3800	3.1500	0.0010	0.0190	24.3	----	0.1
51 SC	10/12/86	4.10	324	18430	0.0400	0.0200	0.1200	3.6200	0.0005	0.0160	37.3	----	0.2
51 SC	12/8/86	4.00	330	18529	0.0600	0.0050	0.2600	5.0200	0.0005	0.0130	38.8	----	4.2
51 SC	3/31/87	4.20	320	18200	----	----	----	----	0.0005	0.0005	32.8	----	3.2
51 SC	4/30/87	3.60	363	17800	----	----	0.3100	----	0.0005	0.0150	1.1	----	2.0
51 SC	8/18/87	4.40	353	19400	0.0800	0.0050	0.4200	5.8500	0.0005	0.0130	19.5	----	5.2
51 SC	10/15/87	4.00	349	16800	----	----	----	----	0.0005	0.0100	59.8	----	0.0
51 SC	1/18/88	3.90	----	----	0.0270	0.0140	0.1310	4.9200	0.0005	0.0090	44.2	60.4	1.2
51 SC	32160	----	----	----	0.0220	0.0080	0.1330	5.0000	0.0005	0.0080	45.0	74.8	0.0

OPEN ISSUE 1: Data (from 05DC, 05SC, and 51 SC) Used to Generate Trend Plots in Figures 1-1 Through 1-12 (Page 4 of 4)

WELL	DATE	PH (field)	CL	SO4	CD	CR	Pb	NI	Se	U	RA-226	RA-228	TH-230
51 SC	1/18/88	----	----	----	0.0220	0.0080	0.1170	5.0700	0.0005	0.0110	38.3	51.5	0.0
51 SC	1/18/88	----	289	16660	0.0220	0.0100	0.1150	4.9200	0.0005	0.0040	22.7	53.1	0.0
51 SC	5/6/88	2.80	339	17600	0.0900	0.0050	0.3200	3.8300	0.0005	0.0120	53.4	----	2.0
51 SC	6/16/88	----	806	18400	----	----	----	----	0.0005	0.0130	47.1	----	1.7
51 SC	9/26/88	3.80	363	18500	0.0400	0.0600	0.3000	2.1200	0.0005	0.0180	2.9	1.3	4.0
51 SC	11/22/88	3.90	375	18800	0.1200	0.0050	0.6100	3.2900	0.0005	0.0210	0.1	0.0	16.4
51 SC	3/30/89	----	396	16800	----	----	----	----	0.0005	0.0280	41.4	36.5	13.2
51 SC	5/11/89	3.87	368	17900	0.0980	0.5800	0.6000	3.6300	0.0010	0.1200	0.4	9.3	62.1
51 SC	8/30/89	3.90	339	17400	----	----	----	----	0.0030	0.0570	65.6	78.7	11.8
51 SC	12/8/89	4.10	343	17400	0.1400	0.0500	0.6700	3.7000	0.0005	0.0110	1.4	0.7	11.1
51 SC	3/5/90	3.70	358	17600	0.0700	0.1200	0.2400	4.6500	0.4100	0.1030	33.0	57.9	18.5
51 SC	6/13/90	3.90	339	18400	0.0200	0.0500	0.2000	4.2000	0.0005	0.1010	29.0	60.2	23.5
51 SC	8/30/90	3.80	359	18800	0.0050	0.0600	0.0250	3.7400	0.0010	0.1440	45.8	90.5	3.8
51 SC	2/11/91	----	355	16000	0.0600	0.2300	0.2500	5.1200	0.0005	0.1080	38.3	83.1	11.8
51 SC	6/13/91	3.90	342	17800	----	----	----	----	0.0005	0.0880	52.1	79.6	27.6
51 SC	9/26/91	2.90	354	17400	----	----	----	----	0.0010	0.0920	38.1	184.0	24.8
51 SC	11/27/91	3.10	345	18400	0.0500	0.2100	0.3400	4.4100	0.0010	0.0380	11.9	74.2	31.1
51 SC	2/20/92	3.80	342	17800	0.0600	0.1500	0.0250	4.8600	0.0005	0.0390	13.3	62.2	12.3
51 SC	6/4/92	3.80	354	18500	0.0700	0.0900	0.0250	4.1300	0.0050	0.0160	19.7	22.5	31.1
51 SC	8/26/92	3.20	364	19600	0.0500	0.1000	0.0250	3.6400	0.0020	0.0170	7.7	14.1	41.8
51 SC	12/2/92	3.40	363	17400	----	----	----	----	0.0005	0.0005	11.5	36.7	19.0
51 SC	3/2/93	3.50	345	16400	0.0900	0.1000	0.0250	3.3200	0.0005	0.0200	1.3	53.3	16.9
51 SC	5/18/93	3.70	359	18000	----	----	----	----	0.0020	0.0090	14.3	51.8	8.4
51 SC	8/9/93	3.40	338	18200	0.0500	0.1200	0.0250	4.2400	0.0005	0.0220	0.9	7.5	13.6
51 SC	11/30/93	2.60	352	18300	0.0600	0.3200	0.0250	4.5000	0.0005	0.0630	4.8	1.1	30.2
51 SC	6/7/94	3.20	360	22300	0.0050	0.6100	0.0025	4.2200	0.0020	0.2120	99.6	52.7	83.2
51 SC	9/15/94	3.74	400	19300	0.0050	0.7800	0.0250	4.6800	0.0010	0.0630	98.4	33.9	7.7
51 SC	12/6/94	3.56	360	18600	----	----	----	----	----	----	----	----	----
51 SC	2/14/95	3.51	355	17800	0.0400	2.5200	0.0025	7.6500	0.0010	0.0300	35.0	2.9	20.3
51 SC	5/18/95	3.75	370	16500	----	----	----	----	----	----	----	----	----
51 SC	8/28/95	3.43	375	17500	0.0250	1.4600	0.0060	5.8600	0.0010	0.0220	13.1	10.4	17.2
51 SC	11/28/95	3.23	400	16900	----	----	----	----	----	----	----	----	----
51 SC	2/28/96	3.53	400	18900	0.0050	5.8000	0.0025	9.0000	0.0005	0.0005	7.1	2.4	14.7
51 SC	2/28/96	----	----	----	0.0300	15.8000	----	14.6000	0.0020	0.0140	----	----	----
51 SC	6/5/96	3.74	375	18500	----	----	----	----	----	----	----	----	----
51 SC	8/6/96	4.15	350	16000	0.0250	7.7300	0.0025	10.7000	0.0005	0.0040	7.3	17.2	11.1
51 SC	11/26/96	4.24	400	17200	----	----	----	----	----	----	----	----	----
51 SC	2/18/97	3.76	375	17000	0.0600	0.6000	0.0010	3.8800	0.0005	0.0190	14.6	23.1	8.7
51 SC	35572	----	341	14100	----	----	----	----	----	----	----	----	----

WMPLUME TRANSPORT MODELING RESULTS


```

*****
*
* SOLUTE TRANSPORT FROM POINT SOURCES
* IN TWO-DIMENSIONAL UNIFORM FLOW
*
* MODEL: WMPLUME
*
*****

```

USER: SMI, Inc - Baseline Simulation

(Sulfate)

LOCATION: Denver, CO

DATE: 9/27/97

INPUT DATA:

```

DARCY VELOCITY.....: 0.01 ft/d
EFFECTIVE POROSITY.....: .1
AQUIFER THICKNESS.....: 20.00 ft
LONGITUDINAL DISPERSIVITY.....: 160.00 ft
LATERAL DISPERSIVITY.....: 16.00 ft
RETARDATION FACTOR.....: 2.47
DECAY CONSTANT (lambda).....: 0 1/d
NUMBER OF POINT SOURCES.....: 1

```

SOURCE DATA:

SOURCE NO. 1

```

X-COORDINATE OF THE SOURCE.....: 0.00 ft
Y-COORDINATE OF THE SOURCE.....: 0.00 ft
THE SOURCE STRENGTH.....: 9.70 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY....: 365000.00 d

```

GRID DATA:

```

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
DISTANCE INCREMENT DELX.....: 100.00 ft
DISTANCE INCREMENT DELY.....: 100.00 ft
NUMBER OF NODES IN X-DIRECTION.....: 24
NUMBER OF NODES IN Y-DIRECTION.....: 10

```

***** RESULTS *****

-----> X-direction CONCENTRATION in mg/l (ppm)

POC

	0.00 ft	100.00 ft	200.00 ft	300.00 ft	400.00 ft
0.00 ft	-1.0000	5478.9210	3874.1820	3163.2560	2739.4610
100.00 ft	1146.8860	1458.6170	1643.5790	1716.2510	1721.0600
200.00 ft	301.8771	400.1318	500.0587	593.3049	674.3773
300.00 ft	91.7508	123.0251	158.8626	197.9566	238.7506
400.00 ft	29.5778	39.8703	52.2868	66.7656	83.1180
500.00 ft	9.8477	13.3147	17.6176	22.8225	28.9644
600.00 ft	3.3463	4.5333	6.0331	7.8895	10.1418
700.00 ft	1.1532	1.5644	2.0904	2.7519	3.5698
800.00 ft	0.4016	0.5453	0.7308	0.9668	1.2627
900.00 ft	0.1409	0.1915	0.2573	0.3416	0.4485

	500.00 ft	600.00 ft	700.00 ft	800.00 ft	900.00 ft
0.00 ft	2450.2480	2236.7600	2070.8370	1937.0910	1826.3070
100.00 ft	1691.8050	1647.5180	1597.8610	1547.5380	1498.7530
200.00 ft	741.0820	793.6705	833.7095	863.2277	884.2284
300.00 ft	279.7066	319.5102	357.1743	392.0550	423.8076
400.00 ft	101.0499	120.1973	140.1649	160.5621	181.0294
500.00 ft	36.0441	44.0274	52.8481	62.4147	72.6167
600.00 ft	12.8220	15.9529	19.5468	23.6051	28.1178
700.00 ft	4.5648	5.7560	7.1608	8.7934	10.6647
800.00 ft	1.6284	2.0743	2.6107	3.2476	3.9945
900.00 ft	0.5823	0.7476	0.9496	1.1934	1.4845

	1000.00 ft	1100.00 ft	1200.00 ft	1300.00 ft	1400.00 ft
0.00 ft	1732.5870	1651.9570	1581.6280	1519.5790	1464.3030
100.00 ft	1452.4620	1409.0030	1368.4060	1330.5560	1295.2710
200.00 ft	898.4785	907.4438	912.3042	913.9899	913.2312
300.00 ft	452.3210	477.6481	499.9471	519.4367	536.3629
400.00 ft	201.2569	220.9907	240.0345	258.2459	275.5288
500.00 ft	83.3326	94.4375	105.8082	117.3288	128.8935
600.00 ft	33.0651	38.4184	44.1420	50.1950	56.5333
700.00 ft	12.7820	15.1483	17.7627	20.6207	23.7141
800.00 ft	4.8602	5.8521	6.9766	8.2383	9.6406
900.00 ft	1.8283	2.2300	2.6949	3.2276	3.8325

	1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
0.00 ft	1414.6510	1369.7300	1328.8330	1291.3940	1256.9510
100.00 ft	1262.3530	1231.5990	1202.8170	1175.8330	1150.4840
200.00 ft	910.5960	906.5266	901.3666	895.3859	888.7941
300.00 ft	550.9785	563.5285	574.2432	583.3353	590.9960
400.00 ft	291.8265	307.1136	321.3887	334.6689	346.9847

500.00	ft	140.4083	151.7927	162.9784	173.9101	184.5436
600.00	ft	63.1109	69.8818	76.8010	83.8255	90.9153
700.00	ft	27.0315	30.5593	34.2815	38.1808	42.2388
800.00	ft	11.1851	12.8718	14.6992	16.6645	18.7636
900.00	ft	4.5134	5.2737	6.1159	7.0419	8.0530

POE

	2000.00 ft	2100.00 ft	2200.00 ft	2300.00 ft
--	------------	------------	------------	------------

0.00	ft	1225.1240	1195.5980	1168.1100	1142.4340
100.00	ft	1126.6250	1104.1250	1082.8700	1062.7530
200.00	ft	881.7552	874.3986	866.8258	859.1178
300.00	ft	597.3953	602.6871	607.0061	610.4693
400.00	ft	358.3748	368.8844	378.5612	387.4551
500.00	ft	194.8446	204.7886	214.3587	223.5437
600.00	ft	98.0329	105.1450	112.2217	119.2362
700.00	ft	46.4366	50.7549	55.1749	59.6780
800.00	ft	20.9911	23.3408	25.8056	28.3779
900.00	ft	9.1499	10.3323	11.5996	12.9505

```

*****
*
* SOLUTE TRANSPORT FROM POINT SOURCES
* IN TWO-DIMENSIONAL UNIFORM FLOW
*
* MODEL: WMPLUME
*
*****

```

USER: SMI, Inc. - Continued CAP Simulation (Sulfate)

LOCATION: Denver, CO

DATE: 9/27/97

INPUT DATA:

```

DARCY VELOCITY.....: 0.01 ft/d
EFFECTIVE POROSITY.....: .1
AQUIFER THICKNESS.....: 20.00 ft
LONGITUDINAL DISPERSIVITY.....: 160.00 ft
LATERAL DISPERSIVITY.....: 16.00 ft
RETARDATION FACTOR.....: 2.47
DECAY CONSTANT (lambda).....: 0 1/d
NUMBER OF POINT SOURCES.....: 1

```

SOURCE DATA:

SOURCE NO. 1

```

X-COORDINATE OF THE SOURCE.....: 0.00 ft
Y-COORDINATE OF THE SOURCE.....: 0.00 ft
THE SOURCE STRENGTH.....: 9.20 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...: 365000.00 d

```

GRID DATA:

```

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
DISTANCE INCREMENT DELX.....: 100.00 ft
DISTANCE INCREMENT DELY.....: 100.00 ft
NUMBER OF NODES IN X-DIRECTION.....: 24
NUMBER OF NODES IN Y-DIRECTION.....: 10

```

***** RESULTS *****

+-----> X-direction CONCENTRATION in mg/l (ppm)

	0.00 ft	100.00 ft	200.00 ft	300.00 ft	400.00 ft
0.00 ft	-1.0000	5196.5030	3674.4820	3000.2020	2598.2510
100.00 ft	1087.7680	1383.4310	1558.8580	1627.7850	1632.3460
200.00 ft	286.3164	379.5065	474.2825	562.7222	639.6156
300.00 ft	87.0213	116.6836	150.6738	187.7526	226.4438
400.00 ft	28.0531	37.8151	49.5916	63.3241	78.8336
500.00 ft	9.3401	12.6284	16.7095	21.6460	27.4714
600.00 ft	3.1738	4.2996	5.7221	7.4828	9.6190
700.00 ft	1.0938	1.4838	1.9827	2.6100	3.3858
800.00 ft	0.3809	0.5172	0.6931	0.9169	1.1976
900.00 ft	0.1337	0.1816	0.2440	0.3240	0.4254

	500.00 ft	600.00 ft	700.00 ft	800.00 ft	900.00 ft
0.00 ft	2323.9460	2121.4630	1964.0930	1837.2410	1732.1670
100.00 ft	1604.5990	1562.5940	1515.4970	1467.7680	1421.4970
200.00 ft	702.8818	752.7596	790.7348	818.7313	838.6497
300.00 ft	265.2887	303.0406	338.7633	371.8460	401.9618
400.00 ft	95.8412	114.0016	132.9399	152.2857	171.6980
500.00 ft	34.1862	41.7579	50.1240	59.1975	68.8736
600.00 ft	12.1610	15.1306	18.5393	22.3883	26.6684
700.00 ft	4.3295	5.4593	6.7917	8.3401	10.1150
800.00 ft	1.5445	1.9674	2.4761	3.0802	3.7886
900.00 ft	0.5523	0.7091	0.9006	1.1319	1.4080

	1000.00 ft	1100.00 ft	1200.00 ft	1300.00 ft	1400.00 ft
0.00 ft	1643.2780	1566.8040	1500.1010	1441.2500	1388.8240
100.00 ft	1377.5930	1336.3740	1297.8700	1261.9700	1228.5040
200.00 ft	852.1653	860.6684	865.2782	866.8771	866.1576
300.00 ft	429.0055	453.0271	474.1767	492.6616	508.7154
400.00 ft	190.8829	209.5994	227.6616	244.9343	261.3263
500.00 ft	79.0371	89.5696	100.3541	111.2809	122.2495
600.00 ft	31.3607	36.4381	41.8667	47.6077	53.6192
700.00 ft	12.1231	14.3674	16.8471	19.5578	22.4917
800.00 ft	4.6097	5.5505	6.6170	7.8137	9.1437
900.00 ft	1.7340	2.1151	2.5559	3.0612	3.6349

	1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
0.00 ft	1341.7310	1299.1250	1260.3370	1224.8270	1192.1590
100.00 ft	1197.2830	1168.1150	1140.8160	1115.2230	1091.1810
200.00 ft	863.6581	859.7984	854.9043	849.2320	842.9800
300.00 ft	522.5775	534.4806	544.6430	553.2665	560.5323
400.00 ft	276.7839	291.2830	304.8222	317.4179	329.0989

500.00	ft	133.1708	143.9683	154.5774	164.9456	175.0310
600.00	ft	59.8578	66.2797	72.8422	79.5046	86.2289
700.00	ft	25.6382	28.9841	32.5144	36.2128	40.0616
800.00	ft	10.6085	12.2083	13.9415	15.8055	17.7964
00	ft	4.2808	5.0018	5.8006	6.6789	7.6379

→ POE

	2000.00 ft	2100.00 ft	2200.00 ft	2300.00 ft
0.00 ft	1161.9730	1133.9700	1107.8980	1083.5460
100.00 ft	1068.5510	1047.2120	1027.0520	1007.9720
200.00 ft	836.3040	829.3265	822.1441	814.8334
300.00 ft	566.6017	571.6208	575.7172	579.0018
400.00 ft	339.9018	349.8697	359.0478	367.4832
500.00 ft	184.8011	194.2325	203.3092	212.0208
600.00 ft	92.9797	99.7252	106.4371	113.0900
700.00 ft	44.0429	48.1386	52.3308	56.6018
800.00 ft	19.9091	22.1376	24.4755	26.9151
900.00 ft	8.6782	9.7997	11.0017	12.2829

 *
 * SOLUTE TRANSPORT FROM POINT SOURCES *
 * IN TWO-DIMENSIONAL UNIFORM FLOW *
 *
 * MODEL: WMPLUME *
 *

USER: SMI, Inc. - Modified CAP (Double Existing Pumping Rate)

(Sulfate)

LOCATION: Denver, CO

DATE: 9/27/97

INPUT DATA:

DARCY VELOCITY.....: 0.01 ft/d
 EFFECTIVE POROSITY.....: .1
 AQUIFER THICKNESS.....: 20.00 ft
 LONGITUDINAL DISPERSIVITY.....: 160.00 ft
 LATERAL DISPERSIVITY.....: 16.00 ft
 RETARDATION FACTOR.....: 2.47
 DECAY CONSTANT (lambda).....: 0 1/d
 NUMBER OF POINT SOURCES.....: 1

SOURCE DATA:

SOURCE NO. 1

X-COORDINATE OF THE SOURCE.....: 0.00 ft
 Y-COORDINATE OF THE SOURCE.....: 0.00 ft
 THE SOURCE STRENGTH.....: 8.70 lb/d
 ELAPSED TIME OF THE SOURCE ACTIVITY...: 365000.00 d

GRID DATA:

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
 Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
 DISTANCE INCREMENT DELX.....: 100.00 ft
 DISTANCE INCREMENT DELY.....: 100.00 ft
 NUMBER OF NODES IN X-DIRECTION.....: 24
 NUMBER OF NODES IN Y-DIRECTION.....: 10

***** RESULTS *****

-----> X-direction CONCENTRATION in mg/l (ppm)

	0.00 ft	100.00 ft	200.00 ft	300.00 ft	400.00 ft
0.00 ft	-1.0000	4914.0830	3474.7820	2837.1470	2457.0420
100.00 ft	1028.6500	1308.2440	1474.1370	1539.3180	1543.6310
200.00 ft	270.7557	358.8811	448.5062	532.1394	604.8538
300.00 ft	82.2919	110.3421	142.4850	177.5487	214.1371
400.00 ft	26.5285	35.7600	46.8964	59.8826	74.5491
500.00 ft	8.8325	11.9421	15.8014	20.4696	25.9784
600.00 ft	3.0014	4.0659	5.4111	7.0762	9.0963
700.00 ft	1.0344	1.4031	1.8749	2.4682	3.2018
800.00 ft	0.3602	0.4891	0.6555	0.8671	1.1325
900.00 ft	0.1264	0.1718	0.2307	0.3064	0.4023

	500.00 ft	600.00 ft	700.00 ft	800.00 ft	900.00 ft
0.00 ft	2197.6450	2006.1660	1857.3490	1737.3910	1638.0280
100.00 ft	1517.3920	1477.6710	1433.1330	1387.9980	1344.2420
200.00 ft	664.6816	711.8487	747.7601	774.2351	793.0708
300.00 ft	250.8708	286.5710	320.3522	351.6369	380.1160
400.00 ft	90.6324	107.8059	125.7149	144.0093	162.3666
500.00 ft	32.3283	39.4885	47.3999	55.9802	65.1304
600.00 ft	11.5001	14.3082	17.5317	21.1716	25.2190
700.00 ft	4.0942	5.1626	6.4225	7.8868	9.5652
800.00 ft	1.4605	1.8604	2.3415	2.9128	3.5827
900.00 ft	0.5222	0.6705	0.8517	1.0704	1.3314

	1000.00 ft	1100.00 ft	1200.00 ft	1300.00 ft	1400.00 ft
0.00 ft	1553.9700	1481.6520	1418.5740	1362.9210	1313.3440
100.00 ft	1302.7240	1263.7450	1227.3330	1193.3850	1161.7380
200.00 ft	805.8518	813.8928	818.2522	819.7641	819.0838
300.00 ft	405.6899	428.4060	448.4062	465.8864	481.0677
400.00 ft	180.5088	198.2081	215.2887	231.6226	247.1238
500.00 ft	74.7416	84.7016	94.9001	105.2330	115.6055
600.00 ft	29.6563	34.4577	39.5913	45.0203	50.7051
700.00 ft	11.4642	13.5866	15.9315	18.4949	21.2693
800.00 ft	4.3592	5.2488	6.2574	7.3890	8.6467
900.00 ft	1.6398	2.0001	2.4170	2.8948	3.4374

	1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
0.00 ft	1268.8110	1228.5210	1191.8400	1158.2610	1127.3680
100.00 ft	1132.2140	1104.6300	1078.8160	1054.6130	1031.8770
200.00 ft	816.7201	813.0703	808.4421	803.0780	797.1659
300.00 ft	494.1765	505.4328	515.0428	523.1977	530.0685
400.00 ft	261.7413	275.4524	288.2558	300.1669	311.2131

00.00	ft	125.9332	136.1440	146.1765	155.9812	165.5185
100.00	ft	56.6047	62.6775	68.8834	75.1837	81.5426
200.00	ft	24.2448	27.4089	30.7474	34.2447	37.8843
300.00	ft	10.0320	11.5448	13.1838	14.9465	16.8292
400.00	ft	4.0481	4.7300	5.4854	6.3159	7.2228

	2000.00 ft	2100.00 ft	2200.00 ft	2300.00 ft
--	------------	------------	------------	------------

0.00	ft	1098.8220	1072.3410	1047.6860	1024.6570
100.00	ft	1010.4780	990.2978	971.2336	953.1905
200.00	ft	790.8526	784.2543	777.4623	770.5489
300.00	ft	535.8081	540.5544	544.4281	547.5343
400.00	ft	321.4289	330.8551	339.5343	347.5112
500.00	ft	174.7575	183.6764	192.2598	200.4979
600.00	ft	87.9264	94.3053	100.6524	106.9438
700.00	ft	41.6493	45.5224	49.4867	53.5256
800.00	ft	18.8271	20.9345	23.1453	25.4523
900.00	ft	8.2066	9.2671	10.4038	11.6154

POE

```

*****
*
* SOLUTE TRANSPORT FROM POINT SOURCES
* IN TWO-DIMENSIONAL UNIFORM FLOW
*
* MODEL: WMPLUME
*
*****

```

USER: SMI, Inc. - Freshwater Injection (Source ³⁵⁰⁰3000 mg/l) (Sulfate)

LOCATION: Denver,, CO

DATE: 9/27/97

INPUT DATA:

```

DARCY VELOCITY.....: 0.01 ft/d
EFFECTIVE POROSITY.....: .1
AQUIFER THICKNESS.....: 20.00 ft
LONGITUDINAL DISPERSIVITY.....: 160.00 ft
LATERAL DISPERSIVITY.....: 16.00 ft
RETARDATION FACTOR.....: 2.47
DECAY CONSTANT (lambda).....: 0 1/d
NUMBER OF POINT SOURCES.....: 1

```

SOURCE DATA:

SOURCE NO. 1

```

X-COORDINATE OF THE SOURCE.....: 0.00 ft
Y-COORDINATE OF THE SOURCE.....: 0.00 ft
THE SOURCE STRENGTH.....: 6.30 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY....: 365000.00 d

```

GRID DATA:

```

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
DISTANCE INCREMENT DELX.....: 100.00 ft
DISTANCE INCREMENT DELY.....: 100.00 ft
NUMBER OF NODES IN X-DIRECTION.....: 24
NUMBER OF NODES IN Y-DIRECTION.....: 10

```

***** RESULTS *****

+-----> X-direction CONCENTRATION in mg/l (ppm)

POC

	0.00 ft	100.00 ft	200.00 ft	300.00 ft	400.00 ft
0.00 ft	-1.0000	3558.4740	2516.2210	2054.4860	1779.2370
100.00 ft	744.8845	947.3496	1067.4790	1114.6790	1117.8020
200.00 ft	196.0645	259.8794	324.7804	385.3424	437.9977
300.00 ft	59.5907	79.9029	103.1788	128.5697	155.0648
400.00 ft	19.2103	25.8951	33.9595	43.3633	53.9839
500.00 ft	6.3959	8.6477	11.4424	14.8228	18.8120
600.00 ft	2.1734	2.9443	3.9184	5.1241	6.5870
700.00 ft	0.7490	1.0161	1.3577	1.7873	2.3185
800.00 ft	0.2608	0.3541	0.4746	0.6279	0.8201
900.00 ft	0.0915	0.1244	0.1671	0.2219	0.2913

	500.00 ft	600.00 ft	700.00 ft	800.00 ft	900.00 ft
0.00 ft	1591.3980	1452.7410	1344.9770	1258.1110	1186.1580
100.00 ft	1098.8010	1070.0380	1037.7860	1005.1020	973.4165
200.00 ft	481.3213	515.4768	541.4814	560.6530	574.2928
300.00 ft	181.6651	207.5170	231.9792	254.6337	275.2565
400.00 ft	65.6304	78.0663	91.0349	104.2826	117.5758
500.00 ft	23.4101	28.5951	34.3240	40.5374	47.1634
600.00 ft	8.3277	10.3611	12.6954	15.3311	18.2621
700.00 ft	2.9647	3.7385	4.6508	5.7111	6.9266
800.00 ft	1.0576	1.3472	1.6956	2.1092	2.5944
900.00 ft	0.3782	0.4856	0.6167	0.7751	0.9642

	1000.00 ft	1100.00 ft	1200.00 ft	1300.00 ft	1400.00 ft
0.00 ft	1125.2890	1072.9200	1027.2430	986.9432	951.0422
100.00 ft	943.3520	915.1258	888.7586	864.1754	841.2584
200.00 ft	583.5480	589.3708	592.5275	593.6224	593.1296
300.00 ft	293.7755	310.2251	324.7079	337.3661	348.3594
400.00 ft	130.7133	143.5301	155.8987	167.7267	178.9517
500.00 ft	54.1233	61.3357	68.7208	76.2032	83.7143
600.00 ft	21.4753	24.9522	28.6696	32.6009	36.7175
700.00 ft	8.3017	9.8386	11.5366	13.3928	15.4019
800.00 ft	3.1566	3.8009	4.5312	5.3507	6.2614
900.00 ft	1.1874	1.4484	1.7503	2.0962	2.4891

	1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
0.00 ft	918.7941	889.6185	863.0568	838.7405	816.3699
100.00 ft	819.8790	799.9046	781.2114	763.6852	747.2215
200.00 ft	591.4181	588.7751	585.4237	581.5393	577.2581
300.00 ft	357.8520	366.0031	372.9621	378.8673	383.8427
400.00 ft	189.5368	199.4656	208.7370	217.3623	225.3612

500.00	ft	91.1930	98.5870	105.8520	112.9519	119.8582
600.00	ft	40.9896	45.3872	49.8811	54.4434	59.0481
700.00	ft	17.5566	19.8478	22.2653	24.7979	27.4335
800.00	ft	7.2645	8.3600	9.5469	10.8233	12.1867
900.00	ft	2.9314	3.4252	3.9722	4.5736	5.2303

2000.00 ft 2100.00 ft 2200.00 ft 2300.00 ft

↗ POE

0.00	ft	795.6990	776.5227	758.6693	741.9932
100.00	ft	731.7253	717.1124	703.3072	690.2415
200.00	ft	572.6864	567.9084	562.9900	557.9838
300.00	ft	387.9990	391.4360	394.2411	396.4904
400.00	ft	232.7589	239.5847	245.8697	251.6461
500.00	ft	126.5486	133.0071	139.2226	145.1882
600.00	ft	63.6709	68.2901	72.8863	77.4421
700.00	ft	30.1598	32.9645	35.8352	38.7599
800.00	ft	13.6334	15.1595	16.7604	18.4310
900.00	ft	5.9427	6.7107	7.5338	8.4111

```

*****
*
* SOLUTE TRANSPORT FROM POINT SOURCES
* IN TWO-DIMENSIONAL UNIFORM FLOW
*
* MODEL: WMPLUME
*
*****

```

USER: SMI, Inc. - Baseline Simulation

(Uranium)

LOCATION: Denver, CO

DATE: 7/27/97

INPUT DATA:

```

DARCY VELOCITY.....: 0.01 ft/d
EFFECTIVE POROSITY.....: .1
AQUIFER THICKNESS.....: 20.00 ft
LONGITUDINAL DISPERSIVITY.....: 160.00 ft
LATERAL DISPERSIVITY.....: 16.00 ft
RETARDATION FACTOR.....: 30.00
DECAY CONSTANT (lambda).....: 0 1/d
NUMBER OF POINT SOURCES.....: 1

```

SOURCE DATA:

SOURCE NO. 1

```

X-COORDINATE OF THE SOURCE.....: 0.00 ft
Y-COORDINATE OF THE SOURCE.....: 0.00 ft
THE SOURCE STRENGTH.....: 0.01 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY....: 365000.00 d

```

⇒ 0.011 lb/d

GRID DATA:

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
DISTANCE INCREMENT DELX.....: 100.00 ft
DISTANCE INCREMENT DELY.....: 100.00 ft
NUMBER OF NODES IN X-DIRECTION.....: 24
NUMBER OF NODES IN Y-DIRECTION.....: 10

***** RESULTS *****

+-----> X-direction CONCENTRATION in mg/l (ppm)

|
v Y

POC

	0.00 ft	100.00 ft	200.00 ft	300.00 ft	400.00 ft
0.00 ft	-1.0000	5.5000	3.8291	3.0628	2.5829
100.00 ft	1.1062	1.4015	1.5613	1.6000	1.5628
200.00 ft	0.2597	0.3428	0.4234	0.4923	0.5436
300.00 ft	0.0637	0.0850	0.1083	0.1318	0.1537
400.00 ft	0.0145	0.0194	0.0250	0.0311	0.0373
500.00 ft	0.0029	0.0039	0.0050	0.0063	0.0076
600.00 ft	0.0005	0.0006	0.0008	0.0011	0.0013
700.00 ft	0.0001	0.0001	0.0001	0.0001	0.0002
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	500.00 ft	600.00 ft	700.00 ft	800.00 ft	900.00 ft
0.00 ft	2.2334	1.9546	1.7182	1.5097	1.3211
100.00 ft	1.4841	1.3837	1.2720	1.1549	1.0358
200.00 ft	0.5751	0.5871	0.5815	0.5612	0.5291
300.00 ft	0.1724	0.1865	0.1951	0.1979	0.1952
400.00 ft	0.0431	0.0482	0.0521	0.0547	0.0557
500.00 ft	0.0090	0.0103	0.0113	0.0121	0.0126
600.00 ft	0.0016	0.0018	0.0020	0.0022	0.0023
700.00 ft	0.0002	0.0003	0.0003	0.0003	0.0003
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	1000.00 ft	1100.00 ft	1200.00 ft	1300.00 ft	1400.00 ft
0.00 ft	1.1480	0.9885	0.8417	0.7077	0.5867
100.00 ft	0.9174	0.8017	0.6909	0.5865	0.4901
200.00 ft	0.4882	0.4413	0.3911	0.3399	0.2896
300.00 ft	0.1875	0.1756	0.1604	0.1432	0.1249
400.00 ft	0.0551	0.0531	0.0498	0.0456	0.0406

500.00	ft	0.0128	0.0126	0.0120	0.0112	0.0102
600.00	ft	0.0024	0.0024	0.0023	0.0022	0.0020
700.00	ft	0.0003	0.0003	0.0003	0.0003	0.0003
800.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000

		1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
0.00	ft	0.4790	0.3847	0.3037	0.2354	0.1791
100.00	ft	0.4027	0.3252	0.2579	0.2007	0.1532
200.00	ft	0.2419	0.1981	0.1590	0.1250	0.0963
300.00	ft	0.1065	0.0888	0.0724	0.0577	0.0450
400.00	ft	0.0353	0.0300	0.0248	0.0201	0.0158
500.00	ft	0.0090	0.0077	0.0065	0.0053	0.0043
600.00	ft	0.0018	0.0016	0.0013	0.0011	0.0009
700.00	ft	0.0003	0.0002	0.0002	0.0002	0.0001
800.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000

		2000.00 ft	2100.00 ft	2200.00 ft	2300.00 ft
0.00	ft	0.1336	0.0977	0.0700	0.0491
100.00	ft	0.1146	0.0840	0.0603	0.0424
200.00	ft	0.0726	0.0536	0.0387	0.0273
300.00	ft	0.0343	0.0255	0.0186	0.0132
400.00	ft	0.0122	0.0092	0.0068	0.0048
500.00	ft	0.0033	0.0025	0.0019	0.0014
600.00	ft	0.0007	0.0005	0.0004	0.0003
700.00	ft	0.0001	0.0001	0.0001	0.0000
800.00	ft	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000

POE
↖


```

*****
*
* SOLUTE TRANSPORT FROM POINT SOURCES
* IN TWO-DIMENSIONAL UNIFORM FLOW
*
* MODEL: WMPLUME
*
*****

```

USER: SMI, Inc. - Continued CAP for 15 years (Uranium)

LOCATION: Denver, CO

DATE: 7/27/97

INPUT DATA:

```

DARCY VELOCITY.....: 0.01 ft/d
EFFECTIVE POROSITY.....: .1
AQUIFER THICKNESS.....: 20.00 ft
LONGITUDINAL DISPERSIVITY.....: 160.00 ft
LATERAL DISPERSIVITY.....: 16.00 ft
RETARDATION FACTOR.....: 30.00
DECAY CONSTANT (lambda).....: 0 1/d
NUMBER OF POINT SOURCES.....: 1

```

SOURCE DATA:

SOURCE NO. 1

```

X-COORDINATE OF THE SOURCE.....: 0.00 ft
Y-COORDINATE OF THE SOURCE.....: 0.00 ft
THE SOURCE STRENGTH.....: 0.01 lb/d => 0.0078 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY....: 365000.00 d

```

GRID DATA:

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
DISTANCE INCREMENT DELX.....: 100.00 ft
DISTANCE INCREMENT DELY.....: 100.00 ft
NUMBER OF NODES IN X-DIRECTION.....: 24
NUMBER OF NODES IN Y-DIRECTION.....: 10

***** RESULTS *****

+-----> X-direction CONCENTRATION in mg/l (ppm)

|
v Y

0.00 ft 100.00 ft 200.00 ft 300.00 ft 400.00 ft

0.00 ft	-1.0000	4.3167	3.0053	2.4039	2.0272
100.00 ft	0.8682	1.0999	1.2254	1.2558	1.2266
200.00 ft	0.2038	0.2691	0.3323	0.3864	0.4267
300.00 ft	0.0500	0.0667	0.0850	0.1034	0.1207
400.00 ft	0.0114	0.0152	0.0196	0.0244	0.0292
500.00 ft	0.0023	0.0030	0.0039	0.0049	0.0060
600.00 ft	0.0004	0.0005	0.0007	0.0008	0.0010
700.00 ft	0.0001	0.0001	0.0001	0.0001	0.0001
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

500.00 ft 600.00 ft 700.00 ft 800.00 ft 900.00 ft

0.00 ft	1.7529	1.5341	1.3486	1.1849	1.0369
100.00 ft	1.1648	1.0860	0.9984	0.9064	0.8129
200.00 ft	0.4514	0.4608	0.4564	0.4405	0.4153
300.00 ft	0.1353	0.1463	0.1531	0.1554	0.1532
400.00 ft	0.0338	0.0378	0.0409	0.0429	0.0437
500.00 ft	0.0071	0.0080	0.0089	0.0095	0.0099
600.00 ft	0.0012	0.0014	0.0016	0.0017	0.0018
700.00 ft	0.0002	0.0002	0.0002	0.0002	0.0003
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

1000.00 ft 1100.00 ft 1200.00 ft 1300.00 ft 1400.00 ft

0.00 ft	0.9010	0.7758	0.6606	0.5554	0.4605
100.00 ft	0.7200	0.6293	0.5422	0.4603	0.3846
200.00 ft	0.3832	0.3464	0.3070	0.2667	0.2273
300.00 ft	0.1472	0.1378	0.1259	0.1124	0.0981
400.00 ft	0.0433	0.0417	0.0391	0.0358	0.0319

500.00	ft	0.0100	0.0099	0.0094	0.0088	0.0080
600.00	ft	0.0019	0.0018	0.0018	0.0017	0.0016
700.00	ft	0.0003	0.0003	0.0003	0.0003	0.0002
800.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000

1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
------------	------------	------------	------------	------------

0.00	ft	0.3759	0.3019	0.2383	0.1848	0.1406
100.00	ft	0.3161	0.2552	0.2024	0.1575	0.1202
200.00	ft	0.1899	0.1555	0.1248	0.0981	0.0756
300.00	ft	0.0836	0.0697	0.0568	0.0453	0.0353
400.00	ft	0.0277	0.0235	0.0195	0.0157	0.0124
500.00	ft	0.0071	0.0061	0.0051	0.0042	0.0033
600.00	ft	0.0014	0.0012	0.0010	0.0009	0.0007
700.00	ft	0.0002	0.0002	0.0002	0.0001	0.0001
800.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000

2000.00 ft	2100.00 ft	2200.00 ft	2300.00 ft
------------	------------	------------	------------

0.00	ft	0.1049	0.0767	0.0550	0.0386
100.00	ft	0.0900	0.0659	0.0474	0.0333
200.00	ft	0.0570	0.0420	0.0304	0.0215
300.00	ft	0.0269	0.0200	0.0146	0.0104
400.00	ft	0.0096	0.0072	0.0053	0.0038
500.00	ft	0.0026	0.0020	0.0015	0.0011
600.00	ft	0.0005	0.0004	0.0003	0.0002
700.00	ft	0.0001	0.0001	0.0001	0.0000
800.00	ft	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000

POE

 *
 * / SOLUTE TRANSPORT FROM POINT SOURCES *
 * IN TWO-DIMENSIONAL UNIFORM FLOW *
 *
 * MODEL: WMPLUME *
 *

USER: SMI, Inc. - Modified CAP (Double Existing Pumping Rate) (Uranium)

LOCATION: Denver, CO

DATE: 9/17/97

INPUT DATA:

DARCY VELOCITY.....: 0.01 ft/d
 EFFECTIVE POROSITY.....: .1
 AQUIFER THICKNESS.....: 20.00 ft
 LONGITUDINAL DISPERSIVITY.....: 160.00 ft
 LATERAL DISPERSIVITY.....: 16.00 ft
 RETARDATION FACTOR.....: 30.00
 DECAY CONSTANT (lambda).....: 0 1/d
 NUMBER OF POINT SOURCES.....: 1

SOURCE DATA:

SOURCE NO. 1

X-COORDINATE OF THE SOURCE.....: 0.00 ft
 Y-COORDINATE OF THE SOURCE.....: 0.00 ft
 THE SOURCE STRENGTH.....: 0.01 lb/d $\Rightarrow 0.0058 \text{ lb/d}$
 ELAPSED TIME OF THE SOURCE ACTIVITY....: %365000.00 d

GRID DATA:

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
 Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
 DISTANCE INCREMENT DELX.....: 100.00 ft
 DISTANCE INCREMENT DELY.....: 100.00 ft
 NUMBER OF NODES IN X-DIRECTION.....: 24
 NUMBER OF NODES IN Y-DIRECTION.....: 10

***** RESULTS *****

+-----> X-direction CONCENTRATION in mg/l (ppm)

POC

	0.00 ft	100.00 ft	200.00 ft	300.00 ft	400.00 ft
0.00 ft	-1.0000	3.1556	2.1969	1.7573	1.4819
100.00 ft	0.6347	0.8041	0.8958	0.9180	0.8967
200.00 ft	0.1490	0.1967	0.2429	0.2825	0.3119
300.00 ft	0.0365	0.0488	0.0621	0.0756	0.0882
400.00 ft	0.0083	0.0111	0.0144	0.0178	0.0214
500.00 ft	0.0016	0.0022	0.0029	0.0036	0.0044
600.00 ft	0.0003	0.0004	0.0005	0.0006	0.0007
700.00 ft	0.0000	0.0001	0.0001	0.0001	0.0001
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	500.00 ft	600.00 ft	700.00 ft	800.00 ft	900.00 ft
0.00 ft	1.2814	1.1214	0.9859	0.8662	0.7580
100.00 ft	0.8515	0.7939	0.7298	0.6626	0.5943
200.00 ft	0.3300	0.3368	0.3336	0.3220	0.3036
300.00 ft	0.0989	0.1070	0.1119	0.1136	0.1120
400.00 ft	0.0247	0.0276	0.0299	0.0314	0.0320
500.00 ft	0.0052	0.0059	0.0065	0.0070	0.0073
600.00 ft	0.0009	0.0010	0.0011	0.0012	0.0013
700.00 ft	0.0001	0.0001	0.0002	0.0002	0.0002
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	1000.00 ft	1100.00 ft	1200.00 ft	1300.00 ft	1400.00 ft
0.00 ft	0.6587	0.5671	0.4829	0.4060	0.3366
100.00 ft	0.5263	0.4600	0.3964	0.3365	0.2812
200.00 ft	0.2801	0.2532	0.2244	0.1950	0.1662
300.00 ft	0.1076	0.1007	0.0921	0.0822	0.0717
400.00 ft	0.0316	0.0305	0.0286	0.0261	0.0233
500.00 ft	0.0073	0.0072	0.0069	0.0064	0.0058
600.00 ft	0.0014	0.0014	0.0013	0.0012	0.0011
700.00 ft	0.0002	0.0002	0.0002	0.0002	0.0002
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
0.00 ft	0.2748	0.2207	0.1742	0.1351	0.1028
100.00 ft	0.2310	0.1866	0.1480	0.1151	0.0879
200.00 ft	0.1388	0.1137	0.0912	0.0717	0.0552
300.00 ft	0.0611	0.0510	0.0415	0.0331	0.0258
400.00 ft	0.0203	0.0172	0.0142	0.0115	0.0091

500.00	ft	0.0052	0.0044	0.0037	0.0031	0.0024
600.00	ft	0.0010	0.0009	0.0008	0.0006	0.0005
700.00	ft	0.0002	0.0001	0.0001	0.0001	0.0001
800.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000
00	ft	0.0000	0.0000	0.0000	0.0000	0.0000

2000.00 ft 2100.00 ft 2200.00 ft 2300.00 ft

0.00	ft	0.0767	0.0561	0.0402	0.0282
100.00	ft	0.0658	0.0482	0.0346	0.0243
200.00	ft	0.0416	0.0307	0.0222	0.0157
300.00	ft	0.0197	0.0146	0.0107	0.0076
400.00	ft	0.0070	0.0053	0.0039	0.0028
500.00	ft	0.0019	0.0014	0.0011	0.0008
600.00	ft	0.0004	0.0003	0.0002	0.0002
700.00	ft	0.0001	0.0000	0.0000	0.0000
800.00	ft	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000

POE

```

*****
*
* SOLUTE TRANSPORT FROM POINT SOURCES
* IN TWO-DIMENSIONAL UNIFORM FLOW
*
* MODEL: WMLPUME
*
*****

```

USER:

SMI, Inc. - Freshwater Injection (Source Reduced to 2.0 mg/l) (Uranium)

LOCATION: Denver, CO

DATE: 9/27/97

INPUT DATA:

```

DARCY VELOCITY.....: 0.01 ft/d
EFFECTIVE POROSITY.....: .1
AQUIFER THICKNESS.....: 20.00 ft
LONGITUDINAL DISPERSIVITY.....: 160.00 ft
LATERAL DISPERSIVITY.....: 16.00 ft
RETARDATION FACTOR.....: 30.00
DECAY CONSTANT (lambda).....: 0 1/d
NUMBER OF POINT SOURCES.....: 1

```

SOURCE DATA:

SOURCE NO. 1

```

X-COORDINATE OF THE SOURCE.....: 0.00 ft
Y-COORDINATE OF THE SOURCE.....: 0.00 ft
THE SOURCE STRENGTH.....: 0.00 lb/d => 0.0038 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY....: 365000.00 d

```

GRID DATA:

```

X-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.....: 0.00 ft
DISTANCE INCREMENT DELX.....: 100.00 ft
DISTANCE INCREMENT DELY.....: 100.00 ft
NUMBER OF NODES IN X-DIRECTION.....: 24
NUMBER OF NODES IN Y-DIRECTION.....: 10

```


***** RESULTS *****

+-----> X-direction CONCENTRATION in mg/l (ppm)

POC

	0.00 ft	100.00 ft	200.00 ft	300.00 ft	400.00 ft
0.00 ft	-1.0000	2.0675	1.4394	1.1513	0.9709
100.00 ft	0.4158	0.5268	0.5869	0.6015	0.5875
200.00 ft	0.0976	0.1289	0.1592	0.1851	0.2044
300.00 ft	0.0239	0.0320	0.0407	0.0495	0.0578
400.00 ft	0.0054	0.0073	0.0094	0.0117	0.0140
500.00 ft	0.0011	0.0014	0.0019	0.0024	0.0029
600.00 ft	0.0002	0.0002	0.0003	0.0004	0.0005
700.00 ft	0.0000	0.0000	0.0000	0.0001	0.0001
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	500.00 ft	600.00 ft	700.00 ft	800.00 ft	900.00 ft
0.00 ft	0.8396	0.7347	0.6459	0.5675	0.4966
100.00 ft	0.5579	0.5201	0.4782	0.4341	0.3894
200.00 ft	0.2162	0.2207	0.2186	0.2110	0.1989
300.00 ft	0.0648	0.0701	0.0733	0.0744	0.0734
400.00 ft	0.0162	0.0181	0.0196	0.0206	0.0209
500.00 ft	0.0034	0.0039	0.0043	0.0046	0.0048
600.00 ft	0.0006	0.0007	0.0008	0.0008	0.0009
700.00 ft	0.0001	0.0001	0.0001	0.0001	0.0001
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	1000.00 ft	1100.00 ft	1200.00 ft	1300.00 ft	1400.00 ft
0.00 ft	0.4315	0.3716	0.3164	0.2660	0.2205
100.00 ft	0.3448	0.3014	0.2597	0.2205	0.1842
200.00 ft	0.1835	0.1659	0.1470	0.1278	0.1089
300.00 ft	0.0705	0.0660	0.0603	0.0538	0.0470
400.00 ft	0.0207	0.0200	0.0187	0.0171	0.0153
500.00 ft	0.0048	0.0047	0.0045	0.0042	0.0038
600.00 ft	0.0009	0.0009	0.0009	0.0008	0.0007
700.00 ft	0.0001	0.0001	0.0001	0.0001	0.0001
800.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
900.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	1500.00 ft	1600.00 ft	1700.00 ft	1800.00 ft	1900.00 ft
100.00 ft	0.1800	0.1446	0.1142	0.0885	0.0673
200.00 ft	0.0909	0.0745	0.0598	0.0470	0.0362
300.00 ft	0.0400	0.0334	0.0272	0.0217	0.0169
400.00 ft	0.0133	0.0113	0.0093	0.0075	0.0060

500.00	ft	0.0034	0.0029	0.0024	0.0020	0.0016
600.00	ft	0.0007	0.0006	0.0005	0.0004	0.0003
700.00	ft	0.0001	0.0001	0.0001	0.0001	0.0001
800.00	ft	0.0000	0.0000	0.0000	0.0000	0.0000
00	ft	0.0000	0.0000	0.0000	0.0000	0.0000

2000.00 ft	2100.00 ft	2200.00 ft	2300.00 ft
------------	------------	------------	------------

0.00	ft	0.0502	0.0367	0.0263	0.0185
100.00	ft	0.0431	0.0316	0.0227	0.0159
200.00	ft	0.0273	0.0201	0.0145	0.0103
300.00	ft	0.0129	0.0096	0.0070	0.0050
400.00	ft	0.0046	0.0035	0.0025	0.0018
500.00	ft	0.0012	0.0009	0.0007	0.0005
600.00	ft	0.0003	0.0002	0.0001	0.0001
700.00	ft	0.0000	0.0000	0.0000	0.0000
800.00	ft	0.0000	0.0000	0.0000	0.0000
900.00	ft	0.0000	0.0000	0.0000	0.0000

POE

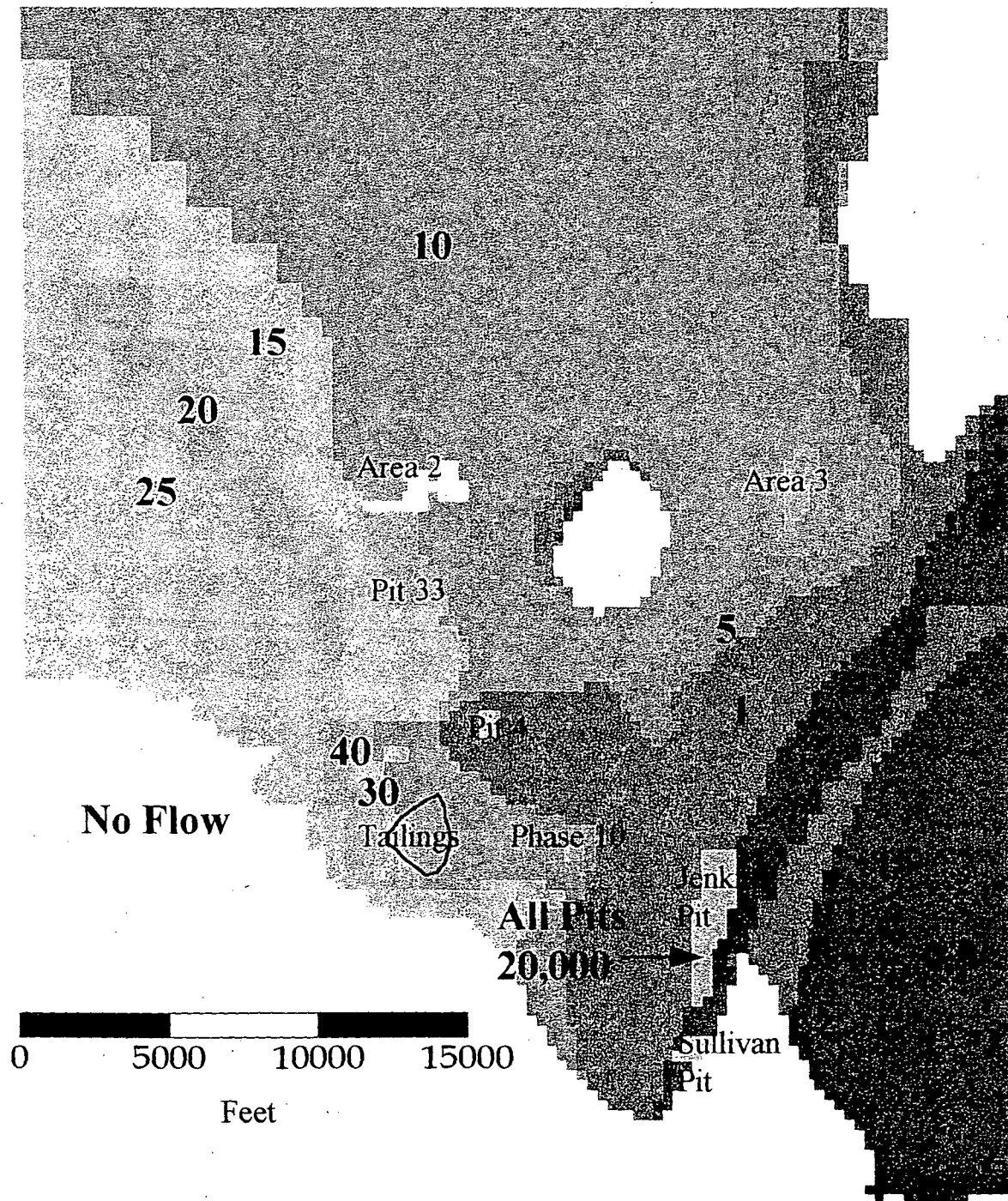
ATTACHMENT FOR OPEN ISSUE 5

- 1. COMPUTER DISKETTE CONTAINING GROUND WATER MODEL FILES**
- 2. CALIBRATED DISTRIBUTION OF HYDRAULIC CONDUCTIVITY AND RECHARGE**
- 3. SUMMARY OF AQUIFER PROPERTIES FOR PETROTOMICS SITE THROUGH 1991 (HYDRO-ENGINEERING, 1991a)**
- 4. SUMMARY OF MAIN WIND RIVER AQUIFER PROPERTIES (TABLE 4-1, HYDRO-ENGINEERING, 1992)**
- 5. REGIONAL AQUIFER DATA NORTH OF PETROTOMICS (TABLE 3.4-4, HYDRO-ENGINEERING, 1991b)**
- 6. TRANSMISSIVITY OF THE LOWER WIND RIVER AQUIFER (FIGURE 2.3-9, HYDRO-ENGINEERING, 1991b)**
- 7. PERMEABILITY AND OUTCROP MAP OF THE UPPER WIND RIVER AQUIFER (EXHIBIT 5-1, HYDRO-ENGINEERING, 1986)**
- 8. PERMEABILITY AND OUTCROP MAP OF THE MAIN WIND RIVER AQUIFER (EXHIBIT 5-2, HYDRO-ENGINEERING, 1986)**

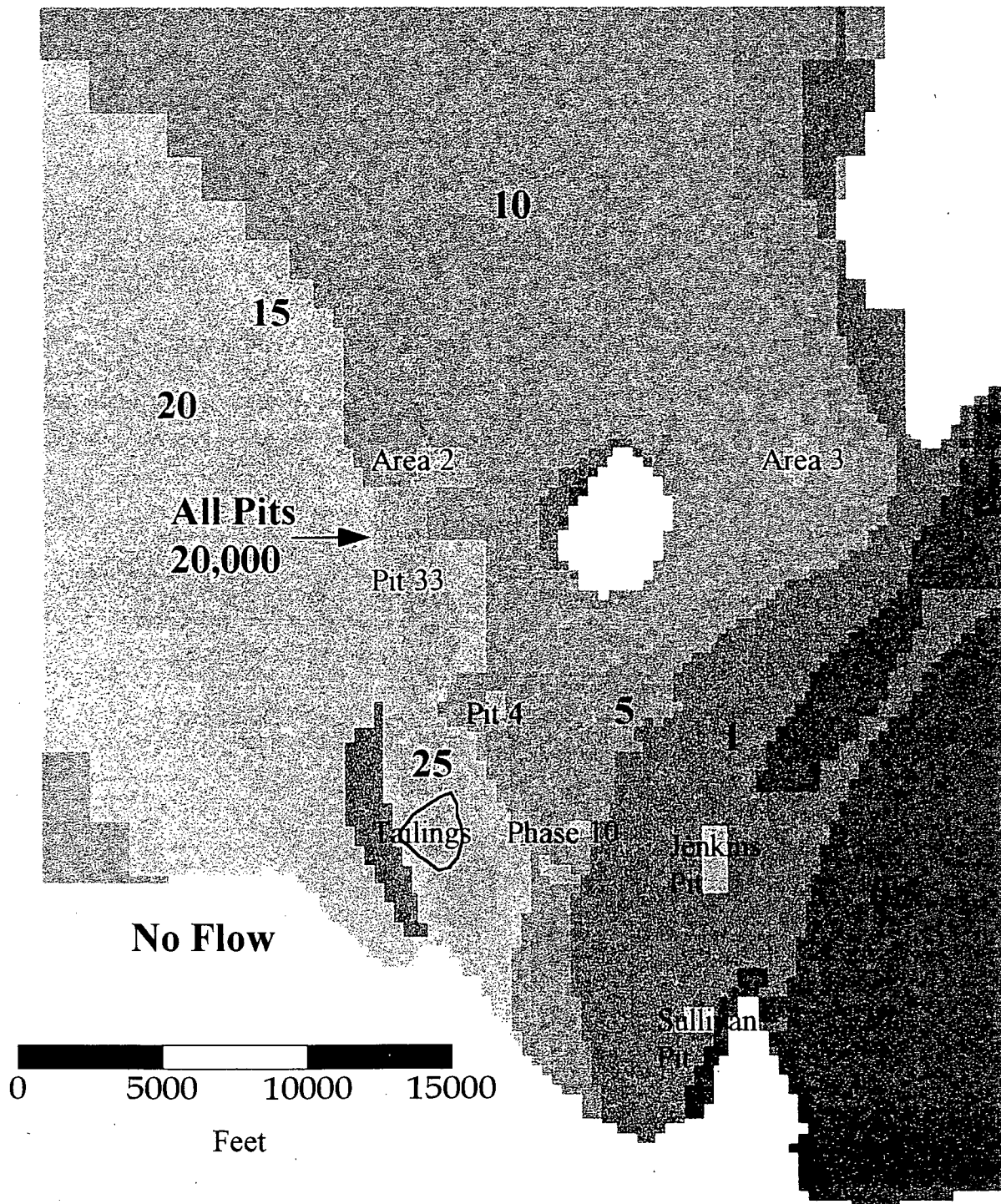
COMPUTER DISKETTE CONTAINING GROUND WATER MODEL FILES

CALIBRATED DISTRIBUTION OF HYDRAULIC CONDUCTIVITY AND RECHARGE

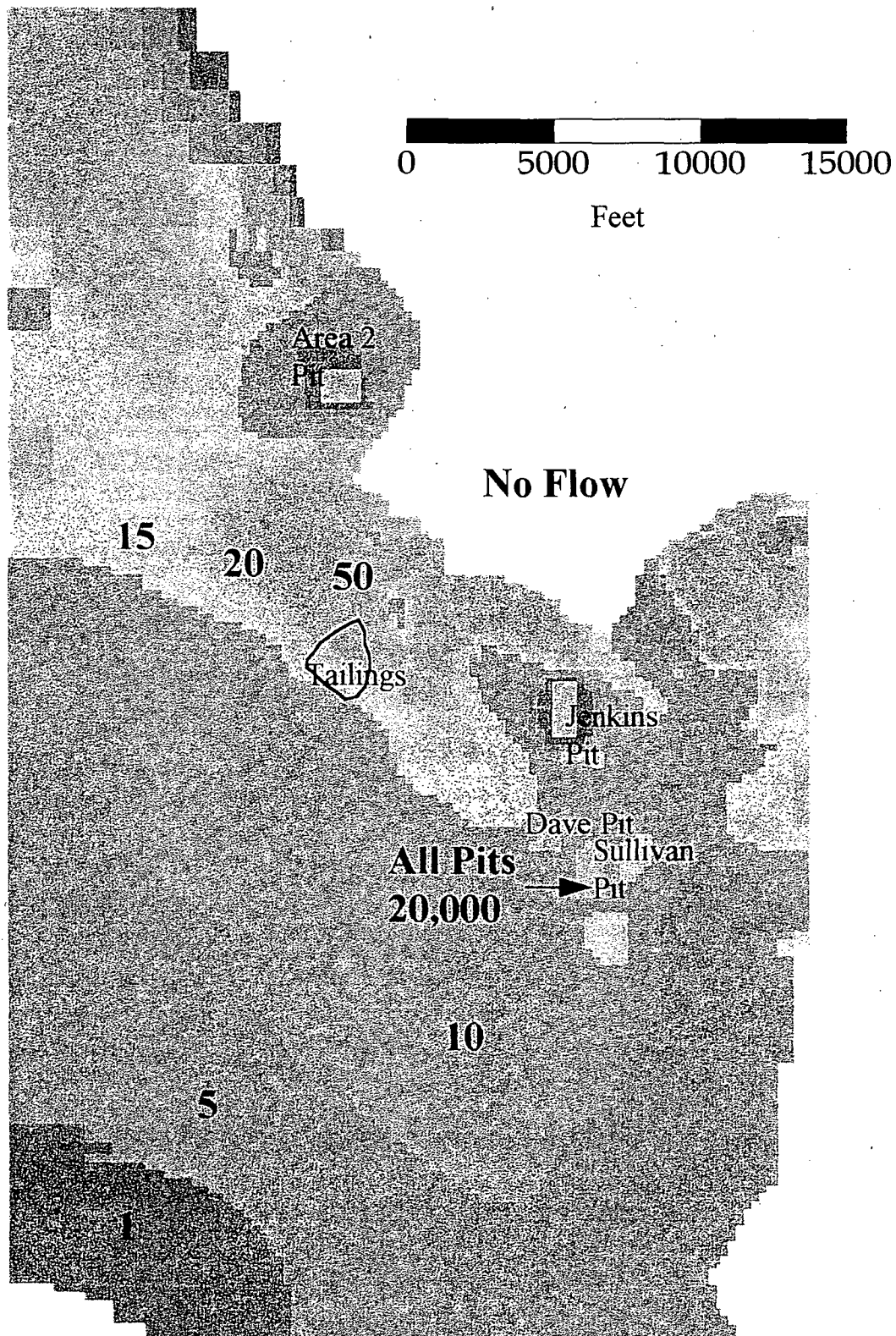
Calibrated Hydraulic Conductivity Distribution (ft/day),
Layer 1 (Upper Sand), 1985



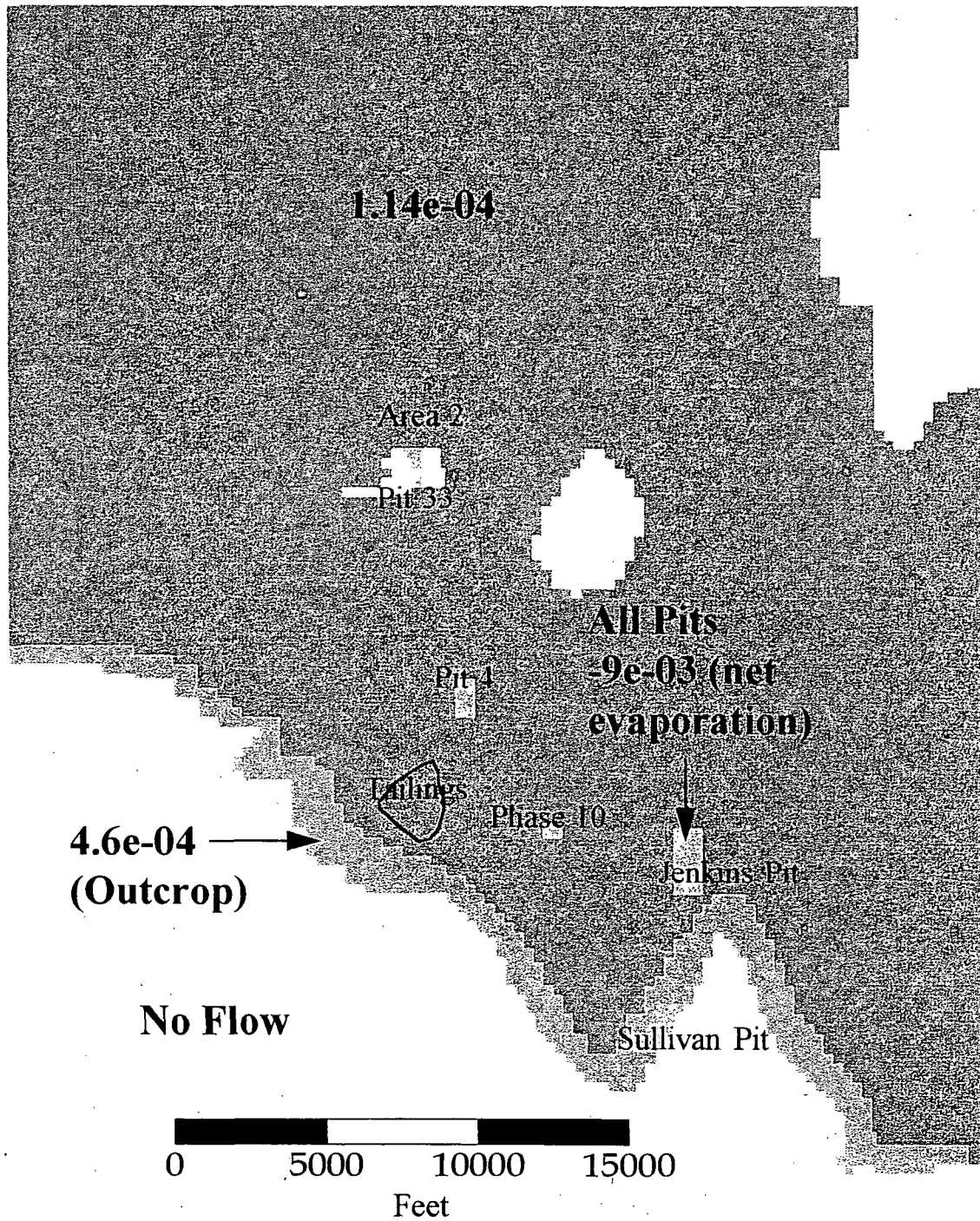
Calibrated Hydraulic Conductivity Distribution (ft/day), Layer 2 (Main Sand), 1985



Calibrated Hydraulic Conductivity, Layer 3,
Lower Sand, 1985



Calibrated Recharge, 1985



**SUMMARY OF AQUIFER PROPERTIES FOR PETROTOMICS SITE THROUGH 1991
(HYDRO-ENGINEERING, 1991a)**

SUMMARY OF AQUIFER PROPERTIES
FOR PETROTOMICS SITE
THROUGH 1991

FOR:

PETROTOMICS COMPANY

BY:

HYDRO-ENGINEERING

DECEMBER, 1991


GEORGE L. HOFFMAN, P.E.
HYDROLOGIST

TABLE OF CONTENTS

	PAGE N
1.0 INTRODUCTION	1
2.0 SUMMARY OF AQUIFER PROPERTIES	2
3.0 REFERENCES	5
APPENDIX A: UPPER WIND RIVER SAND PUMP TESTS	
APPENDIX B: MAIN WIND RIVER AND BACKFILL AQUIFER PUMP TESTS	
APPENDIX C: LOWER WIND RIVER AQUIFER PUMP TESTS	
APPENDIX D: OTHER AQUIFER PUMP TESTS	

TABLE OF CONTENTS - TABLES

2-1 SUMMARY OF AQUIFER PROPERTIES	4
---	---

1.0 INTRODUCTION

This report presents the pump tests that have been conducted on wells completed in the Upper Wind River, Main Wind River, Backfill and Lower Wind River aquifers through 1991 on the Petrotomics property. Appendix A presents the drawdown and recovery curves and the data tables for the Upper Wind River pump tests. Appendices B and C present the pump test data for the Main and Lower Wind River aquifers, respectively. Appendix D presents the pump tests conducted on some additional units. A pump test is presented for well 3-SC, which is completed in a sand that exists above the Upper Wind River sand. A pump test on alluvial well 1-AC and two constant head permeability tests on two clay zones between the Upper and Main Wind River sands are also presented.

2.0 SUMMARY OF AQUIFER PROPERTIES

Numerous pump tests have been conducted on the Upper Wind River sands and these tests show that the permeability varies significantly from less than 1.0 to greater than 30 ft/day. Permeabilities to the north, on the west side of the tailings, are higher than permeabilities north of the tailings on the east side. These permeabilities extend back into the tailings area in the area of well PT-6. A zone of permeabilities of greater than 30 ft/day exists in this area. Permeabilities are slightly smaller, but similar, west of the tailings in the area of wells 1-SC, 2-SC and 41-SC. The PT wells on the southwest and southeast sides of the tailings indicate that in this area the permeabilities of the Upper Wind River sands are much lower. All of these values were less than 1.0 ft/day.

Several pump tests have also been conducted on the Main Wind River sands. Pump tests on the P4 wells indicated that the permeabilities in this area vary from slightly greater than 30 ft/day at well P4-7 to 3.0 ft/day at P4-2. The two backfill wells, P4-5 and P4-4, contain a permeability of approximately 8.0 ft/day. The pump test results are presented for the Pathfinder 3A area east of Petrotonics site because a specific yield value was obtained from this pump test. Table 2-1 also presents pump test data from one alluvial well, the sand above the Upper, and two clay constant head permeability tests. Three pump tests were also presented for the Lower Wind River aquifer. The Lower Wind River aquifer is generally a very permeable system, with permeabilities of roughly

30 ft/day. The Old Salvage Yard well, 373, contains a much lower permeability than the remainder of the Lower Wind River wells.

TABLE 2-1. SUMMARY OF AQUIFER PROPERTIES.

WELL DESIGNATION	TRANSMISSIVITY (GAL/DAY/FT)						AQUIFER THICKNESS (FT)	PERMEABILITY (FT/DAY)		SPECIFIC YIELD (BEST VALUE)	
	STRAIGHT LINE		JACOB METHOD	STRELTSOVA METHOD	THEIS METHOD	CONSTANT HEAD METHOD					
	RECOVERY METHOD					BEST VALUE		HORIZONTAL	VERTICAL		
UPPER WIND RIVER SAND											
1-SC	5140	2680	—	—	—	2680	14 28	26	—	—	
2-SC	3350	1100	—	—	—	1100	6.5 8	23	—	—	
4-SC	1700	—	—	—	—	1700	8 15+	28	—	—	
5-SC	930	446	—	—	—	446	20 15+	3	—	—	
8-SC	780	—	—	—	—	780	10 10	10	—	—	
42-SC	4400	4000	—	—	—	4000	14 25	38	—	—	
43-SC	5800	1510	—	—	—	1510	5 13	40	—	—	
43-SC*	—	300	—	—	—	300	5 20	8	—	—	
44-SC	—	(7720, 1600)	—	—	—	—?	17 25	—	—	—	
45-SC	1100	300	—	—	—	300	8 13	5	—	—	
46-SC	0.8	—	—	—	—	—	18 ?	—	—	—	
49-SC	—	(42, 34)	—	—	—	217	42	5 0.15	1.1	—	
50-SC	—	—	—	—	—	40	40	31 30	0.17	—	
51-SC	—	340	—	—	—	340	11 0.5	4.3	—	—	
53-SC	—	—	—	—	—	120	120	20 28	0.80	—	
54-SC	—	—	—	—	—	880	880	13 50	9.1	—	
55-SC	1.9	—	—	—	—	1.9	1.7	0.15	—	—	
56-SC	—	3.5	—	—	—	3.5	5.2 30	0.09	—	—	
57-SC	8	—	—	—	—	8	— 14	—	—	—	
58-SC	—	150	—	—	—	150	8.4 31+	2.4	—	—	
59-SC	—	—	—	—	—	270	3.6 23	10	—	—	
60-SC	0.1	—	—	—	—	0.1	7.8 ? 30	0.002	—	—	
61-SC	—	171	—	—	—	171	6.9 25	3.3	—	—	
62-SC	—	990	—	—	—	990	4.9 22	27	—	—	
63-SC	—	6970	—	—	—	6970	6.9 39	135	—	—	
64-SC	2240	—	—	—	—	2240	2.9 21	103	—	—	
1-OC	—	(11000, 2870)	4350	—	—	4000	17 33	31	0.31	0.05	
2-OC	—	(7170, 5140)	3960	—	—	4000	17 28	31	0.31	0.05	
3-OC	1300	1120	970	1150	—	970	7 10+	18	4.8	0.05	
4-OC	1260	850	960	760	—	760	13 8	7.8	2.3	0.011	
PT-6	—	9210	—	—	—	9210	20.5 35	60	—	—	
PT-8	—	32	—	—	—	32	13.2 24	0.32	—	—	
PT-9	—	10	—	—	—	10	18.4 20	0.07	—	—	
PT-10	—	75	—	—	—	75	33.5 10	0.30	—	—	
PT-11	—	24	—	—	—	24	17.1 20+	0.19	—	—	

Geom \bar{x} = 3.7

MAIN WIND RIVER AQUIFER

1-DC	12	—	—	—	—	12	12	0.13	—	—
5-DC	—	17300	—	—	—	17300	41	56	—	—
6-DC	—	37	—	—	—	37	32	0.15	—	—
7-DC	—	83	—	—	590	83	29	0.38	—	—

TABLE 2-1. SUMMARY OF AQUIFER PROPERTIES (CONTINUED).

WELL DESIGNATION	TRANSMISSIVITY (GAL/DAY/FT)						AQUIFER THICKNESS (FT)	PERMEABILITY (FT/DAY)		SPECIFIC YIELD (BEST VALUE)
	STRAIGHT LINE	JACOB METHOD	STRELTSOVA METHOD	THEIS METHOD	CONSTANT	BEST VALUE		HORIZONTAL	VERTICAL	
	RECOVERY METHOD				HEAD METHOD					
<u>MAIN WIND RIVER AQUIFER - CONTINUED</u>										
52-SC	--	2700	--	--	--	2700	15	24	--	--
P4-1	3200	2900	--	--	--	2900	47	8.2	--	--
P4-2	3410	1670	--	--	--	1670	70	3.2	--	--
P4-3	3980	3060	--	--	--	3060	25	16	--	--
P4-6	9100	4030	--	--	--	4030	31	17	--	--
P4-7	6790	9240	--	--	--	9240	37	33	--	--
3A-2	--	--	1790	--	--	1790	59	4.1	0.053	0.14
3A-3	--	--	--	--	--	--	--	--	--	--
Geom. $\bar{x} = 4.3$										
<u>SAND DRAW ALLOVIUM</u>										
1-AC	360	34	--	--	--	360	5.5	8.7	--	--
<u>SAND ABOVE UPPER</u>										
3-SC	1100	1100	--	--	--	1100	15	9.8	--	--
<u>CLAY STRATUM</u>										
7-C	--	--	--	--	0.80	0.80	12	8.9×10^{-3}	--	--
9-C	--	--	--	--	0.303	0.303	13	3.1×10^{-3}	--	--
<u>BACKFILL</u>										
P4-4	6140	5260	--	--	--	5260	80	8.8	--	--
P4-5	--	4040	--	--	--	4040	75	7.2	--	--
<u>LOWER WIND RIVER AQUIFER</u>										
373	990	--	--	--	--	990	50	2.6	--	--
2205 (1)	16000	18300	--	--	--	18300	60	41	--	--
2205 (2)	16000	17000	--	--	--	16500	60	36	--	--
31943	14000	19000	--	--	--	16500	--	--	--	--

NOTE: * = REPLACEMENT WELL

3.0 REFERENCES

Budo, Shoro. 1968. Pump test of well 2205. In-house report for Petrotomics Company. (Pump test on well 2205, Lower Wind River aquifer.)

Hydro-Engineering, 1980. (Appendix D-6) Hydrology of the KGS Project, Consulting Report for Petrotomics Company. (Recovery test for 373 and drawdown and recovery test for well 2205.)

Hydro-Engineering, 1979. Mine Hydrology for Pit 3A for Pathfinder's Shirley Basin Mine, Consulting Report for Pathfinder Mines Corporation. (Pump tests on well 3A-3 and observation well 3A-2.)

Hydro-Engineering, 1981. Preliminary Report on the Evaluation of the Ground-Water Hydrology in the Vicinity of Petrotomics Tailings Reservoir, Shirley Basin, Wyoming, Consulting Report for Petrotomics Company. (Tests conducted in this report are wells 1-SC through 46-SC in the Upper Wind River Aquifer, 1-DC in the Main Wind, 3-AC in the sand above the Upper, 1-AC in the alluvium, 7-C and 9-C in the aquitard below the Upper.)

Hydro-Engineering, 1986. Updated Ground-Water Hydrology of Petrotomics Tailings Area, Consulting Report for Petrotomics Company. (Second test on Upper well 43-SC, pumping and injection test on 49-SC, injection test 50-SC, pump test 51-SC, injection test 53-SC, pump test 54-SC and, for Main wells, 5-DC and 52-SC pump tests, 6-DC and 7-DC injection tests.)

**SUMMARY OF MAIN WIND RIVER AQUIFER PROPERTIES
(TABLE 4-1, HYDRO-ENGINEERING, 1992)**

Table from Hydro-Engineering (1992)

TABLE 4-1. SUMMARY OF MAIN WIND RIVER AQUIFER PROPERTIES.

WELL NAME	TRANSMISSIVITY (GAL/DAY/FOOT)				AQUIFER THICKNESS (FT)	PERMEABILITY (FT/DAY) HORIZONTAL	SPECIFIC YIELD (BEST VALUE)
	STRAIGHT-LINE	JACOB METHOD	CONSTANT				
	RECOVERY METHOD		HEAD METHOD	BEST VALUE			

MAIN WIND RIVER AQUIFER TESTS - 1992

12DC	--	14800	--	14800	32	58	--
SDC	--	785	--	--	--	--	--
P4-1	--	1560	--	--	--	--	--
11DC	--	16600	--	16600	54	41	0.15
SDC	--	23300	--	23300	36	86	0.834
8DC	--	10.5	--	--	14	--	--
8DC (2ND)	--	12.7	--	12.7	14	8.12	--
9DC	--	551	--	551	46	1.6	--
18DC	--	13500	--	13500	54	33	--
11DC	--	15700	--	15700	54	39	--

MAIN WIND RIVER AQUIFER TESTS - PRIOR TO 1992

SDC	--	17300	--	17300	41	56	--
6DC	--	37	--	37	32	0.15	--
7DC	--	83	590	83	29	0.38	--
S2SC	--	2700	--	2700	15	24	--
P4-1	3200	2900	--	2900	47	0.2	--
P4-2	3410	1670	--	1670	70	3.2	--
P4-3	3900	3060	--	3060	25	16	--
P4-6	9100	4030	--	4030	31	17	--
P4-7	6790	9240	--	9240	37	33	--
1DC	12	--	--	12	12	0.13	--

BACKFILL AQUIFER TESTS

P4-4	6140	5260	--	5260	80	8.8	--
P4-5	--	4040	--	4040	75	7.2	--

NOTE: DISCUSSION OF JACOB METHOD CAN BE FOUND IN APPENDIX B.

**REGIONAL AQUIFER DATA NORTH OF PETROTOMICS
(TABLE 3.4-4, HYDRO-ENGINEERING, 1991b)**

Regional Aquifer Data North of Petrotoomics

Table from Hydro-Engineering (1991b)

TABLE 3.4-4. MAIN WIND RIVER AQUIFER PROPERTIES.

WELL NO.	AQUIFER THICKNESS (D)	LOG-LOG PLOT				SEMI-LOG PLOT			RECOVERY PLOT	
		T	K	S	Sy	T	K	S	T	K
WI1	35	3200	12	1.9E-4	-	3400	13	1.7E-4	-	-
		3460	13	1.0E-4	-	3630	14	1.6E-4	2800	11
		3220	12	2.0E-4	-	3400	13	2.0E-4	-	-
WI2	56	2520	6.0	1.8E-4	-	2700	6.4	1.5E-4	-	-
		2620	6.3	1.9E-4	-	2560	6.1	1.7E-4	-	-
WI3	82	5140	8.4	2.6E-4	-	3100	5.1	-	2300	3.7
		5090	8.3	2.8E-4	-	-	-	-	-	-
WI9	--	3670	-	1.8E-4	-	3810	-	1.7E-4	-	-
WI10	--	-	-	-	-	3400	-	-	-	-
		-	-	-	-	3490	-	-	-	-
*S5	--	1700	-	2.0E-4	-	-	-	-	-	-
		2860	-	1.4E-4	-	-	-	-	-	-
		2410	-	1.5E-4	-	-	-	-	-	-
*N6	--	1500	-	1.5E-4	-	-	-	-	-	-
		2570	-	1.1E-4	-	-	-	-	-	-
		2210	-	1.1E-4	-	-	-	-	-	-
*M1	--	1300	-	1.2E-4	-	-	-	-	-	-
		2570	-	9.9E-4	-	-	-	-	-	-
		1970	-	9.8E-5	-	-	-	-	-	-
WI11	26	-	-	-	-	2460	13	-	-	-
BF1	90	-	-	-	-	950	1.4	-	-	-
(Backfill in contact with Main)										
WIM1	81	-	-	-	-	10000	16.5	-	-	-
WIM2	47	-	-	-	-	6000	17	-	-	-
WIM2A	47	5060	14*	1.3E-3	0.13	6000	17	1.0E-3	-	-
WIM3	47	-	-	-	-	1970	5.7	-	-	-
WIM4	90	-	-	-	-	16000	24	-	-	-
P4-2	70	-	-	-	-	1670	3.2	-	3410	6.5
P4-3	25	-	-	-	-	3060	16	-	3980	21
P4-6	31	-	-	-	-	4030	17	-	9100	39
SX816	87	-	-	-	-	1830	2.8	-	-	-

NOTES:

T = Transmissivity, gal/day/ft
K = Hydraulic Conductivity, ft/day
S = Storage Coefficient, dimensionless
Sy = Specific Yield, dimensionless
D = Aquifer Thickness, ft

* = Vertical Hydraulic Conductivity at WIM2A = 7 ft/day

Table from Hydro-Engineering (1991b)

TABLE 3.4-5. LOWER WIND RIVER AQUIFER PROPERTIES.

WELL NO.	AQUIFER THICKNESS (D)	LOG-LOG PLOT				SEMI-LOG PLOT			RECOVERY PLOT	
		T	K	S	Sy	T	K	S	T	K
UW31943	70	-	-	-	-	19000	36	-	14000	27
WIL1	32	-	-	-	-	1080	4.51	-	-	-
WIL2	59	-	-	-	-	8100	18.4	-	-	-
WIL2A	60	9600	21.4	1.9E-4	-	7470	16.6	-	-	-
WIL4	33	-	-	-	-	22400	90.7	-	-	-

NOTES:

T = Transmissivity, gal/day/ft
 K = Hydraulic Conductivity, ft/day
 S = Storage Coefficient, dimensionless
 Sy = Specific Yield, dimensionless
 D = Aquifer Thickness, ft

**THIS PAGE IS AN
OVERSIZED DRAWING OR
FIGURE,
THAT CAN BE VIEWED AT THE RECORD
TITLED:
“LOWER WIND RIVER
TRANSMISSIVITY MAP,
EXHIBIT 2.3-9. ”**

**WITHIN THIS PACKAGE... OR
BY SEARCHING USING THE**

D-01

**TRANSMISSIVITY OF THE LOWER WIND RIVER AQUIFER
(FIGURE 2.3-9, HYDRO-ENGINEERING, 1991b)**

**THIS PAGE IS AN
OVERSIZED DRAWING OR
FIGURE,
THAT CAN BE VIEWED AT THE RECORD
TITLED:
“PERMEABILITY AND OUTCROP MAP
OF THE UPPER WIND RIVER
AQUIFER, EXHIBIT 5-1.”**

**WITHIN THIS PACKAGE... OR
BY SEARCHING USING THE**

D-02

**PERMEABILITY AND OUTCROP MAP OF THE UPPER WIND RIVER AQUIFER
(EXHIBIT 5-1, HYDRO-ENGINEERING, 1986)**

**THIS PAGE IS AN
OVERSIZED DRAWING OR
FIGURE,
THAT CAN BE VIEWED AT THE RECORD
TITLED:
“PERMEABILITY AND OUTCROP MAP
OF THE MAIN WIND RIVER
AQUIFER, EXHIBIT 5-2.”**

**WITHIN THIS PACKAGE... OR
BY SEARCHING USING THE**

D-03X

**PERMEABILITY AND OUTCROP MAP OF THE MAIN WIND RIVER AQUIFER
(EXHIBIT 5-2, HYDRO-ENGINEERING, 1986)**