THE FATE OF ALDICARB RESIDUE IN GROUNDWATER AT A CENTRAL SAND PLAIN FARM, WAUSHARA COUNTY, WISCONSIN

by

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ABSTRACT

Groundwater is depended upon by a large proportion of the people of Wisconsin, as well as America, for drinking and many other domestic, agricultural, and industrial purposes. In spite of this dependence, groundwater statewide and nationwide is being extensively contaminated with low levels of toxic chemicals which may impact to some degree on human and animal health. Therefore, groundwater should be studied so we may better understand the fate of potentially harmful chemicals.

Aldicarb is an insecticide which has been widely used on potatoes in the Central Sand Plain of Wisconsin and which has leached into groundwater in many parts of that region and the U.S. In Wisconsin, an administrative rule, pesticide label restrictions, and legislation were made to limit aldicarb leaching but some doubt their effectiveness.

Groundwater at a Central Wisconsin farm was monitored for residues of aldicarb and for certain inorganic chemicals. 42 multi-level and standard PVC groundwater sampling devices were constructed and installed at 26 sites for this and other related studies. Groundwater samples were collected at 1-3 month intervals from November 1981 to April 1984. An additional study was conducted to determine if aldicarb degrades under laboratory conditions.

Aldicarb occurred in the groundwater in a distinct plume characterized by a high aldicarb concentration layer in its mid-section and decreasing aldicarb concentrations above and below that layer. Observations indicated the plume was traveling at a rate of 1.4 ft/day, and that it had traveled a total of 1956 ft by the end of the study.

The depth of the maximum aldicarb concentration layer increased 5-10 ft below both the ground level and the water table over the study period. The maximum depth of the plume was 18.3 ft in October 1983. The plume thickness was 6 ft in May 1982, 12 ft in October 1982 and between 2 and 8 ft in February 1984. The highest aldicarb concentration in February 1982 was 114 ppb whereas it was 8 ppb in February 1984. The half-life for aldicarb in the groundwater was calculated to be 206 days.

In a laboratory study aldicarb half-lives in three samples were calculated to be 1916, 1520, and 478 days. Half-lives were inversely related to pH and alkalinity concentrations.

Concentration zones of certain inorganic chemicals tracked with the maximum aldicarb concentration layer over time. This indicated that these chemicals move similar to aldicarb in groundwater.

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INTRODUCTION

Groundwater is water occurring beneath the land surface in a saturated zone, the top of which is the water table. This water evaporated from the oceans, was transported overland as water vapor, fell to the land as precipitation, infiltrated into and percolated through soil, is supported by largely impervious geologic formations, and is for the most part moving slowly towards rivers and ultimately back to the oceans.

Like most natural resources, groundwater is essential to our way of life. Nearly 70% of the people of Wisconsin use and depend on it for drinking and other domestic purposes (Wis. DNR, 1983). Further, it is the water supply of 94% of Wisconsin cities and villages and is a major water source for agriculture and the food processing industry. Nationwide, 50% of all people, 80% of rural Americans, and 80% of livestock use groundwater as their primary drinking water supply (OTA, 1984). Virtually all people depend on groundwater in one way or another and its use will likely remain essential in the future.

Most people would agree that groundwater currently in use or intended for future use should not become polluted. But many disagree on the acceptable level of contamination. Concerns exist that consumption of low levels of toxic chemicals may result in adverse health effects. In areas where groundwater contamination has occurred, is occurring, or may occur, these concerns prompt us to monitor the groundwater to determine the extent of contamination and the potential for the contaminants to contact people and livestock.

Groundwater in America has been and is being contaminated locally, regionally, and nationwide with a wide variety of toxic organic chemicals (synthetic and natural) which include pesticides, organic solvents, and petrochemicals. Groundwaters are seriously contaminated with some or all of these chemical groups in each of the 50 states. But, as of 1984 there was no conclusive information on the total extent of the contamination and there likely won't be any in the foreseeable future (OTA, 1984).

The potential for groundwater contamination is indicated in the following. There were 1.4 to 1.5 billion pounds of pesticides (active ingredient) produced in the U.S. in 1982, of which 552 million pounds were applied to about 280 million acres of major field crops (OTA, 1984). Farm pesticide use was believed to be leveling off in 1982 (U.S.D.A., 1982).

In 1978, 57 million tons of hazardous industrial wastes were generated in the U.S., most of which were disposed of in landfills that did not meet new federal waste disposal guidelines. In 1980 there were 376,000 known landfills, unauthorized dumps, and liquid waste disposal pits, ponds, and lagoons leaking some estimated hundreds of billions of gallons of waste water (CEQ, 1981).

In 1983 there were an estimated 2.4 million underground steel storage tanks containing petrochemicals, 25% to 30% of which are probably leaking, and 120,000 of which are likely contaminating groundwater (OTA, 1984). It is estimated that by 1989 75% of the tanks will be leaking.

Volatile organic chemicals contaminate groundwaters in many if not all states in the nation. In Wisconsin in 1982, 51 community water wells out of 208 sampled were contaminated with VOC's (Wis. DNR, 1983).

Once in the soil many such chemicals can be transported with soil water to groundwater. The degree of this depends largely on characteristics of the chemicals and the soil. In soil, groundwater, or the environment in general these chemicals are diluted to lower concentrations over time. Some chemicals are degraded to other compounds. But many persist in their original form and occur in all parts of our environment.

Concerns exist about these and other chemicals in groundwater because of their toxicity. Many of these chemicals are acutely toxic when consumed in relatively high concentrations and chronically toxic when consumed in lower concentrations over a period of time. And many are likely to cause adverse physiological effects when consumed over time in the relatively low concentrations found in groundwater (OTA, 1984; Wis. DHSS, 1984).

Chemical manufacturing firms and the Environmental Protection Agency have undertaken extensive programs to determine the quantity of toxic chemicals that can be consumed without causing "significant deleterious effects" to human health. This quantity, or concentration, is called among other things a Safety Standard (SS), a Maximum Contaminant Level (MCL), or a Suggested No Adverse Response Level (SNARL), depending largely on how much is known about its health effects.

It is probable that people will not suffer obvious, immediate effects from a single dose of a toxic chemical at its SS, MCL, or SNARL. But the nature of these compounds indicates that physiological effects are occurring and that the effects occur to greater degrees with increasing time of consumption and with increasing numbers of compounds consumed. And whether or not the effects are significant should be up to each person to decide.

Unfortunately, the ability to realize and understand all the effects of low levels of toxic chemicals on our bodies has been far outpaced by our ability to produce toxic chemicals, by our tendency to contaminate our environment with them, and by the likelihood of our coming in contact with them. Perhaps someday we will know all the bodily effects produced by a single toxic chemical or by many working together. But it is questionable if they will ever be totally prevented from entering our environment. And it is doubtful anyone will ever be able to prove that consumption of low levels of a given toxic chemical at a given time produced at some future time a given health effect - "significant" or insignificant. Therefore, people should be aware when, where, with what, and how much their environment is being contaminated so they may exercise any precautions they might have.

Aldicarb, manufactured by the Union Carbide Corporation and marketed in the trade formulation TEMIK, is a systemic, carbamate insecticide used in many parts of the U.S. on many crops to eliminate many different insect pests. In Wisconsin it is used extensively in the Central Sands region on potato crops for control of the Colorado Potato Beetle and leaf hoppers, and as a preventative measure against the golden nematode. It is estimated that in 1981 as many as 130,000 pounds of aldicarb may have been used on as many as 43,000 acres in Wisconsin, much of it in the Central Sands area (Wis. DATCP, 1982).

Aldicarb is designed to break down in soil but its solubility, combined with various sand plain characteristics including sandy soils, high water inputs, and a high water table, make it likely to leach through soil and enter groundwater before complete breakdown can occur. It is the most toxic pesticide registered by the EPA and kills insects by inhibiting the neural enzyme cholinesterase, an enzyme also vital in the human nervous system.

Aldicarb (residue) has been found in groundwaters of at least 15 states including Wisconsin, New York, Maine, Virginia, Florida, Texas, California, and Missouri and is present in numerous drinking water wells in these states (Science, 1985; Harkin, et. al., 1984). In Wisconsin in a groundwater sampling program, 210 wells out of 944 sampled were contaminated, 70 of which had aldicarb in concentrations above the 10 ppb SNARL (Wis. DNR, 1985). In Long Island, New York over 2000 wells have been contaminated, of which over 1000 had aldicarb in concentrations above New York's 7 ppb SNARL (Baier, 1982a and 1982b). Aldicarb use in Long Island was discontinued in 1981. In Wisconsin, an administrative rule and pesticide label changes were made for aldicarb in 1982, and legislation was adopted in 1984, to limit aldicarb leaching. But the effectiveness of these in preventing further groundwater contamination in the sand plain is limited (Wis. DATCP, 1985; Harkin, et. al., 1984).

The fate of aldicarb in soils depends largely on soil physical, chemical, and biological properties and on water inputs to the soil. Researchers have found aldicarb will leach through sandy, loamy, or clay soils when sufficient amounts of water are applied (Coppedge, 1977; Leistra, 1976; Quraishi, 1972). Others found it is relatively immobile and likely to degrade in clay and loam soils under field conditions (Bull, 1970; Bromilow, 1980). The fact remains that aldicarb residues occur in and continue to enter groundwater in many parts of the country.

Chesters et. al. (1982), working at five Central Wisconsin farms from December 1980 to November 1981, found aldicarb in groundwater in roughly a 5-10 ft thick zone near the water table. Manser (1983), working at one of the sites in the above study (the site of this study), observed that the aldicarb occurred in a 6 ft thick plume with a high concentration zone occurring about 6-8 ft below the water table. Harkin, et. al. (1984) worked at this study site through 1983 and found aldicarb was moving lower into the groundwater and that aldicarb concentrations were being reduced.

In another Wisconsin study aldicarb was found up to 75 ft below the water table (P.C. CHS, 1984). Baier (1982b) found aldicarb widely dispersed in groundwater in potato farming areas of Long Island, N.Y. and at depths up to 100 ft below the water table.

Information has been collected on aldicarb in groundwater but more remains to be known about the fate of such chemicals in groundwater. The objectives of this study were to:

1. observe the occurrence of aldicarb in groundwater under a given field over time and space and determine the extent of aldicarb advection (horizontal and vertical), dispersion, and concentration reduction;

2. observe the occurrence of certain inorganic chemicals in groundwater over time and determine if some act to reduce aldicarb concentrations, and if others are indicators of aldicarb movement in groundwater;

3. determine if aldicarb degrades in groundwater samples under laboratory conditions.

STUDY SITE

The study site is a 320 acre farm located on the Central Sand Plain of Wisconsin, in Waushara County (Fig. 1). The soil is predominantly Plainfield Sand and the land surface is relatively flat. The depth of the water table averages about 6 ft below ground surface, and varies with the seasons and with local topography. The aquifer materials are unconsolidated sediments and are composed largely of medium to coarse grained sands with localized zones of gravel and silt. Sandstone bedrock occurs between 70 and 130 ft below the ground surface (Manser, 1983).

Precipitation averaged 31 inches per year from 1979 to to 1983 (NOAA, 1979 to 1983). Precipitation during the growing seasons of 1979 and 1980 amounted to 18 and 24 inches, respectively (NOAA, 1979 and 1980). Irrigation amounted to 2.5 inches in 1982 and 12.5 inches in 1983 (Corneli, K., 1985). Groundwater recharge in Central Wisconsin is believed to be about 10 inches per year (Holt, C.R.L., 1965). Air temperatures for the growing seasons of 1979 to 1983 averaged 65 F (NOAA, 1979 and 1980).

The study site is divided into two fields: the 115 acre field to the east is referred to as Field A, while the west field is referred to as Field B. TEMIK 15G (15% granular aldicarb) was applied to potatoes at planting on the eastern half of Field A in May 1979, on the entire Field A in May 1980, and on a 90 ft strip in Field B in 1981 (Fig. 2) (Corneli, S., 1984). The application rate was 15-20 pounds

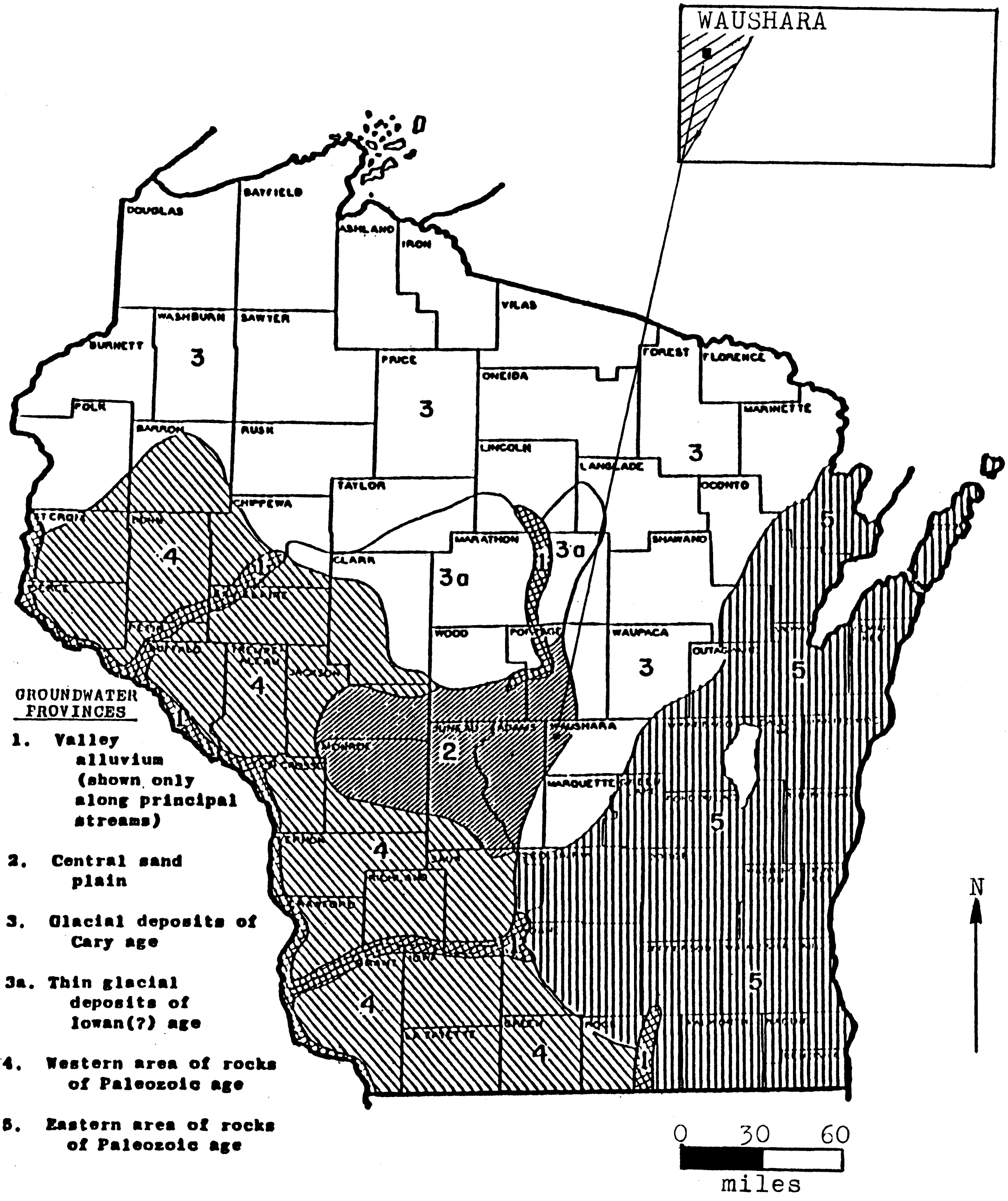


Figure 1. Location of study site in the Central Sand Plain of Wisconsin (adapted from Drescher, 1956).

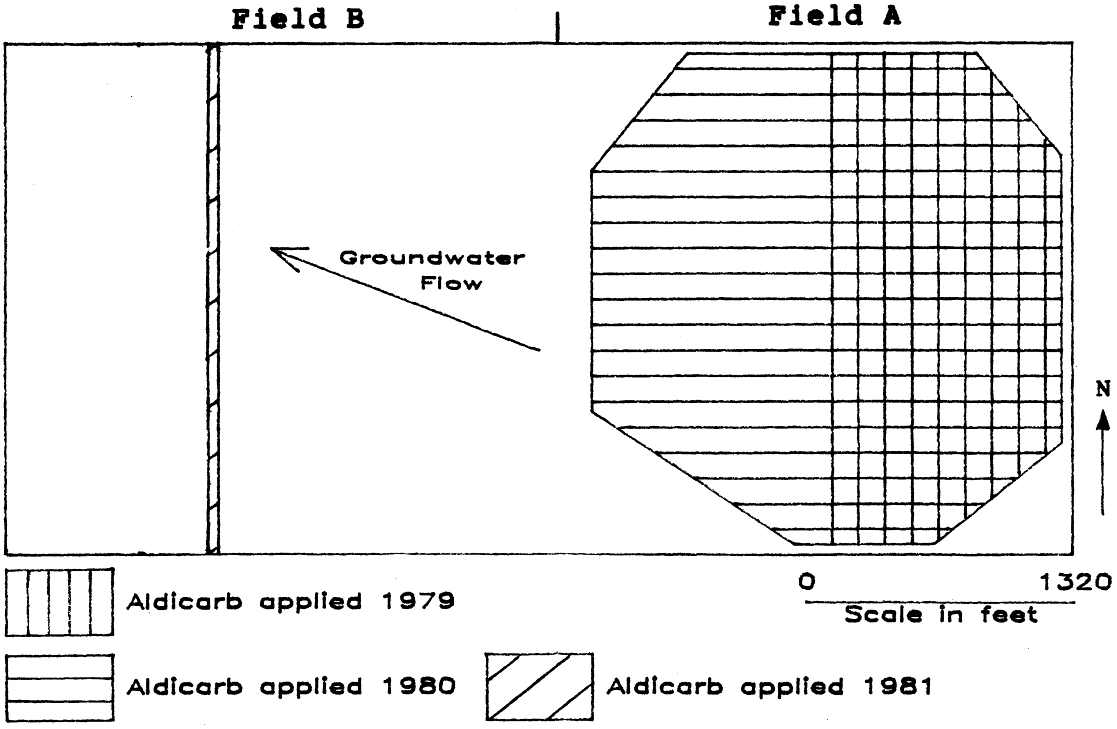


Figure 2. Aldicarb application areas at study site.

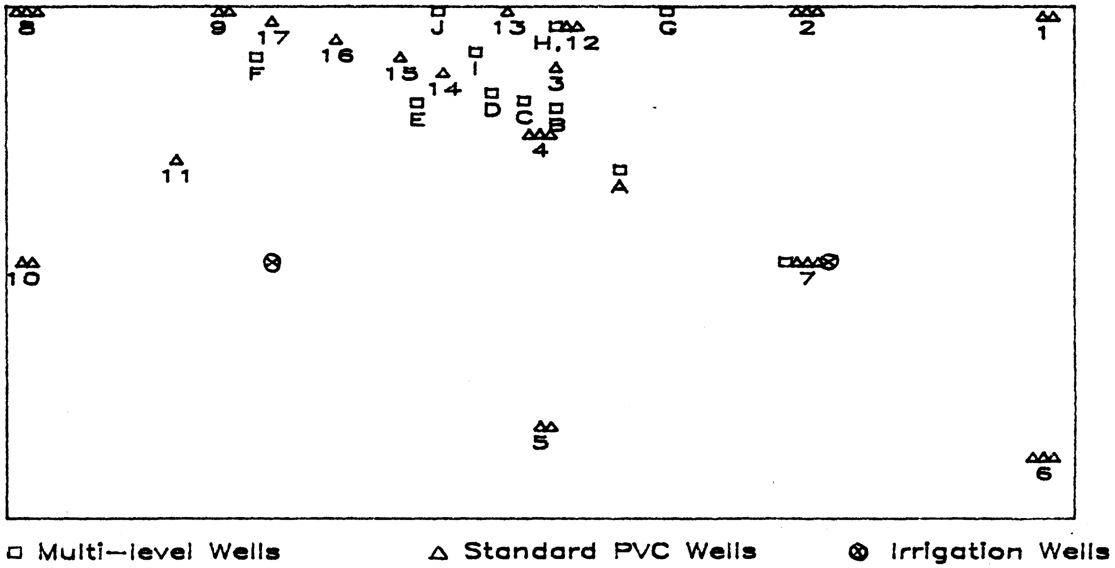


Figure 3. Location of wells at study site. The number of wells at each well site is indicated by the number of symbols (the multi-level wells each contain 9 to 12 individual wells in a bundle).

of TEMIK (2.2 to 2.3 pounds aldicarb) per acre with the 15 lbs/acre rate being prevalent.

The study site is located in a groundwater recharge area. Groundwater flows in a northwesterly direction at a rate of 1.1 to 1.5 ft/day (Manser, 1983).

MATERIALS AND METHODS

Groundwater sampling devices were constructed and installed at the study site and groundwater was sampled and analyzed at 1-3 month intervals from November 1981 to April 1984. The water samples were analyzed for aldicarb residues, temperature, pH, conductivity, alkalinity, total hardness, nitrate+nitrite-N, sulfate, and chloride. A laboratory study was performed to determine the extent of aldicarb residue degradation under set conditions.

Monitoring Network

The network of wells at the study site is shown in Figure 3. The wells are of two basic types: standard PVC and multi-level (Fig. 4). Appendix A gives information about the wells including depths, elevations, and screen lengths. Appendix B indicates the numerical alterations in ground elevation for each well nest so that the water table level at each nest could be referenced to one ground level. Appendix C gives the distance of the wells from the areas of aldicarb application in Field A.

The standard PVC wells consist of 1-1/4 in ID PVC pipe Sch. 40 or 80, with a 1 or 3 ft water intake screen with 3 rows of 0.006 inch slits at 3/16 intervals. There are 32 such wells and they occur singly or in nests of two or three. The standard PVC well sites are numbered 1 to 17 to show their position in the study site and are lettered 'a' to 'd' to indicate their approximate depth below the water

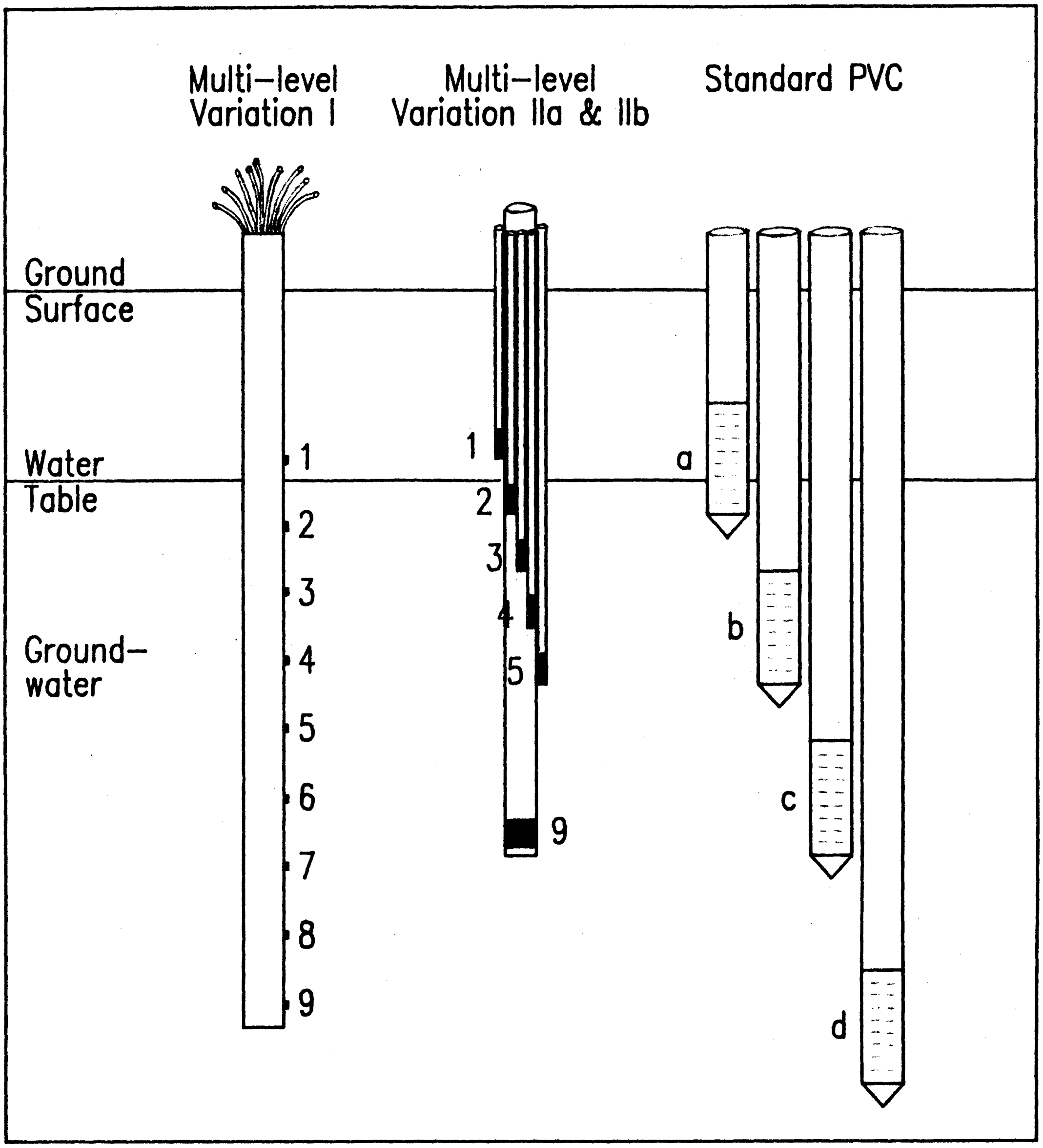


Figure 4. General appearance of wells at study site.

table. The bottom of the well screens ranged in depth below the water table as follows: 'a' wells - 0-2 ft; 'b' wells - 2.5-6.5 ft; 'b2' wells - 3-7 ft; 'c' wells - 7-11 ft; 'd' wells - 19-23 ft.

Standard PVC wells were installed in the aquifer using a bucket auger for shallow wells and an engine driven auger for deeper wells. The wells were pushed into the auger holes by one or two people. Most of the standard PVC wells (No.'s 1-11) were installed for a previous study at this site during Fall 1980/Spring 1981 by personnel from Wisconsin Geological and Natural History Survey and from the UW-SP Environmental Task Force. A bentonite seal was made for each well about 2-3 ft below ground level to prevent seepage of surface water down along the pipe. Wells 12 and 13 were installed on July 1, 1983, and wells 14 to 17 on November 17 and 22, 1983.

Multi-level wells are of three variations in design and consist basically of PVC pipe and a number of tubes (Fig. 4). The tubes are of various length and extend from the top of the pipe at the ground surface down through the center of the pipe, or down the outside of the pipe, to regularly spaced positions in the aquifer. This allows groundwater samples to be collected from many depths below the water table in one vertical column. The end of the pipe and tubes in the aquifer are referred to as sample points and are wrapped to keep sediment out. Multi-level wells are lettered A to J to show their position in the study site and the sample points are numbered sequentially to indicate their position below the ground surface.

The multi-level wells were installed using an engine driven hollow core auger operated by personnel from Wisconsin Geological and Natural History Survey. Installation involved plugging the bottom of the auger with a rubber stopper, drilling to a pre-determined depth, inserting the well down the inside of the auger, popping out the stopper by pounding down on the well, and pulling the auger up around the outside of the well. Sand was filled in the hole left by the auger to secure the well in the ground. Wells I and J were installed on October 25, 1981, Wells A, E and F on April 21, 1982, and Wells C and D on August 5, 1983. Wells B, G and H were installed on October 24, 1981 by Manser (1983) and Rothschild (1982).

Multi-level well var. I was described by Pickens, et. al. (1978) and consists of a 25 ft long, 1-1/4 in Sch. 80 PVC pipe and nine or ten 1/32 in ID Tygon tubes. The tubes run from the top of the PVC pipe down the inside of the pipe and emerge in the aquifer at two foot intervals through AA single hole stoppers. The stoppers are plugged into 1/4 inch holes in the pipe and sealed with silicone rubber cement. These sample points are covered with glass wool and wrapped with fiberglass cloth. There are 5 such wells and they are lettered A, E, F, I and J.

Multi-level well var. IIa was devised and described by Manser (1983) and Rothschild (1982). It consists of a 20 ft long, 3/4 in PVC pipe and nine 3/8 in ID, 1/2 in OD polyethylene tubes. The tubes are taped to the outside of the pipe and run from the top to lower on the pipe where they emerge in the aquifer at 1-1/2 ft intervals. The sample points are 6 inch sections of 3/8 in ID, 1/2 in OD polyethylene tubing drilled at length with many 1/8 inch holes. The points are connected to the main tubing with a 1 inch piece of 3/8 in OD polyethylene tubing and secured with silicon rubber cement. The bottom 6 inches of the PVC pipe is also drilled with many holes making this the deepest sampling point. The pipe is also where groundwater depth is checked. The bottom opening of the tubes and the pipe is filled with silicon rubber cement and all the points are wrapped several times with fine mesh "no-see-um" netting. There are 3 such wells and they are lettered B, G and H.

Multi-level well var. IIb is similar to multi-level well var. IIA. The following are the alterations made in order to extend the depth, simplify the design, and reduce the cost of the well. Four sections of 10 ft long, 3/4 in ID PVC were used for the center pipe. The sample tubes are 1/4 in ID, 3/8 in OD polypropylene tubes. About thirty 1/8 inch holes were drilled in the bottom 4 inch section of each tube and the center pipe. The upper sample points were finished at 2 ft intervals and the bottom two points at 3 or 5 ft intervals. Each sample point was wrapped about 6 times with a fine mesh "mosquito" netting. There are 2 such wells and they are lettered C and D .

Groundwater Sampling Procedure

The groundwater sampling procedure generally followed the methods described by EPA (1979a) and by Shaw (1982). Groundwater depth below ground was determined using a measuring tape with a "popper" at the end. Groundwater was drawn from the wells using a peristaltic pump powered by a 12 volt battery. An ISCO pump was used to collect groundwater from the standard PVC wells and from the multi-level well center pipes. A 3/8 in ID, 1/2 in OD teflon tube was connected to the pump and extended down the inside of the pipe to the water table. A Cole-Parmer Masterflex pump was used to collect groundwater from the multi-level well tubes by connecting the silicone rubber tube in the pump individually to each well tube. Three retention volumes of water were pumped from each well to ensure a fresh sample. Two 500 ml polypropylene bottles, one for aldicarb analysis and one for inorganic analysis, were rinsed three times with fresh groundwater and filled to the top.

After each sample was collected the groundwater temperature was measured using a -30 to 50 C Ertco thermometer. If the air temperature was above 70 F the sample bottles were placed in a cooler and stored in a shaded area. During sampling a record was made of groundwater depths and temperatures, air temperatures, and time of sampling. Groundwater depths were measured at each sampled well to determine the depth of the water table below ground and the depth of the samples below the water table. Water elevations were taken in additional wells so the water table elevation could be determined.

After the samples were collected they were transported to the CNR lab. There the samples for inorganic analysis were refrigerated and analyzed within a few days. The samples for aldicarb analysis were also refrigerated unless analysis was not to occur within two weeks, in which case they were frozen.

Groundwater Analyses

Methods for inorganic analyses generally followed those in Standard Methods for Water and Waste-water Analysis (1980). Conductivity was determined using a Labline Lectro mho-meter earlier in the study and a YSI Model 32 Conductance meter later in the study. pH was determined using a Corning Digital 110 pH meter. Alkalinity and total hardness were determined by titration. Nitrate+nitrite-N and sulfate concentrations were determined using a Technicon Auto-Analyzer II upon filtration of the samples. Chloride concentrations were determined using a specific ion electrode (Corning Model 12 Research pH meter). I analyzed the samples for pH, conductivity, alkalinity, and total hardness while employees of the Environmental Task Force lab analyzed them for nitrate+nitrite-N, sulfate, and chloride.

Aldicarb was extracted from the groundwater samples using a method developed by Union Carbide Agricultural Products Company, Inc. (UCC, 1981). Quality control methods involved performing 1 blank, 1 duplicate, and 1 spike for each extraction run which usually involved between 5 and 9 samples (EPA, 1979a; Shaw, 1982). Spike solutions were combinations of aldicarb, aldicarb sulfoxide, and aldicarb sulfone in acetone at concentrations between 0.7 and 1.4 parts per million. In most cases groundwater samples were spiked rather than distilled water. Thus the spike solution became a spike+sample solution. The determination of spike recovery is discussed below. I performed all aldicarb analyses.

The aldicarb extraction involved the following procedure. 100 ml of a groundwater sample was poured into a 250 ml separatory funnel and oxidized with 2 ml of peracetic acid for 30 minutes. This length of time allowed complete oxidation of pure aldicarb (in spikes) and aldicarb sulfoxide to aldicarb sulfone. 40 ml of sodium bicarbonate was added and let stand 15 minutes to stop the oxidation reaction and to "salt out" aldicarb sulfone from solution. 100 ml dichloromethane (PRA or ACS grade) was added and the funnel was shaken vigorously for 1 minute. The dichloromethane was drained through about 10 grams of anhydrous sodium sulfate crystals into a 300 ml dissolved oxygen (D.O.) bottle. The groundwater sample was then re-extracted with another 100 ml of dichloromethane and drained as before into the same bottle. The sodium sulfate was washed with 25 ml dichloromethane which was drained into the same D.O. bottle. After the samples were extracted they were concentrated.

The concentration procedure involved placing the D.O. bottles containing the dichloromethane/aldicarb sulfone solution in a 40 C water bath and blowing a gentle stream of air over them. After the bottles appeared to be dry, air was blown into them for an additional 15 minutes to ensure complete dichloromethane evaporation. The bottles were then removed from the water bath and placed in ice. 2 ml of acetone was added to each bottle, swirled around inside the bottle at least 3 times, and transferred to a 3.8 dram vial with a teflon lined cap.

Analysis for aldicarb involved injecting 4 ul of the aldicarb extract into a Tracor Model 560 gas chromatograph equipped with a flame photometric detector which contained a sulfur filter (394 nanometer). The operating conditions of the gas chromatograph are listed in Appendix D.

Positive response for aldicarb sulfone was marked by a deflection, or peak, on the chart recorder. Standard concentrations of aldicarb sulfone were injected into the GC and peak height vs. concentration was plotted on log/log graph paper. The peak heights for the aldicarb samples were compared to the standard curve, the concentration of the extract was determined, the concentration factor was applied, and the concentration in the original groundwater sample was determined. The concentration of the spiked sample extract was determined in the same manner. To get the concentration of the spike recovered, the concentration of the corresponding sample was subtracted from the concentration of the spiked sample extract. Then the percent recovery of the spike was determined by dividing the spike concentration recovered by the original spike concentration.

Laboratory Study on Aldicarb Degradation

An experiment was done to determine if aldicarb residues degrade in groundwater samples under laboratory conditions. 1 gallon groundwater samples were collected from well points B6 and B7 on March 27, 1982 and from B8 on March 13, 1983. Each 1 gallon sample was distributed to twelve 300 ml dissolved oxygen bottles. These bottles were then stoppered with glass stoppers, water sealed, and capped with polyethylene caps or cellophane to make them air tight. They were then stored in a controlled temperature refrigerator in darkness at 10 C. Two bottles from each sample set were analyzed soon after sampling to determine the initial aldicarb residue concentrations. Thereafter, one or two samples from each set were analyzed at 2 to 4 month intervals to determine subsequent concentrations. This study lasted until September 28, 1984, a period of 2.5 years.

Statistical Analyses

All statistical analyses and other data processing were performed on personal computers using Lotus 1-2-3 (Lotus Development Corp., 1983).

RESULTS AND DISCUSSION

Occurrence of Aldicarb in Groundwater

Pure aldicarb in the soil environment is oxidized to sulfoxide and sulfone forms. These forms occur in roughly a 50:50 mix and retain the insecticidal properties of pure aldicarb. It is these oxidation products which enter and occur in groundwater. They are referred to in this study as aldicarb or aldicarb residues.

Aldicarb concentrations in groundwater, and changes in them over time and space, were used to determine the extent of aldicarb advection (both horizontal and vertical), dispersion, concentration reduction, and relationships with inorganic chemicals. The results of the groundwater analyses and the depths of the groundwater samples below the water table are listed in Appendix E.

Quality control information for the aldicarb analyses is listed in Appendix F. All aldicarb concentrations were corrected for spike recovery. Spike recoveries ranged mostly from 70 to 100 percent.

Aldicarb was present in the groundwater at the study site throughout the study period of November 1981 to April 1984. Figure 5 shows which wells were contaminated during the period. Figure 6 shows the groundwater flow direction. Figure 7 shows water table elevations. The depths of the water table below ground and the water table elevation for each well on each sampling date are listed in Appendices G and H, respectively.

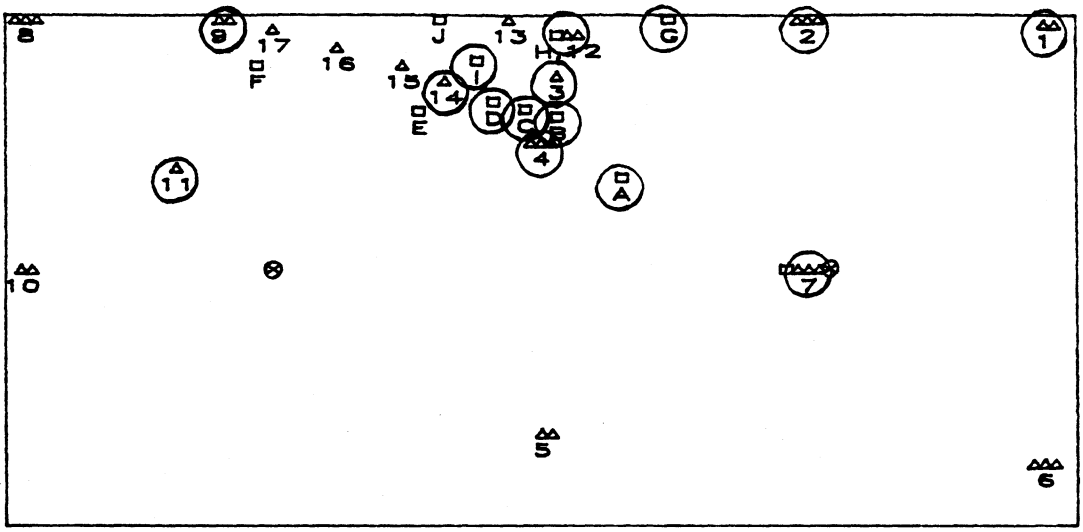


Figure 5. Wells at study site showing those contaminated with aldicarb residues (circled wells).

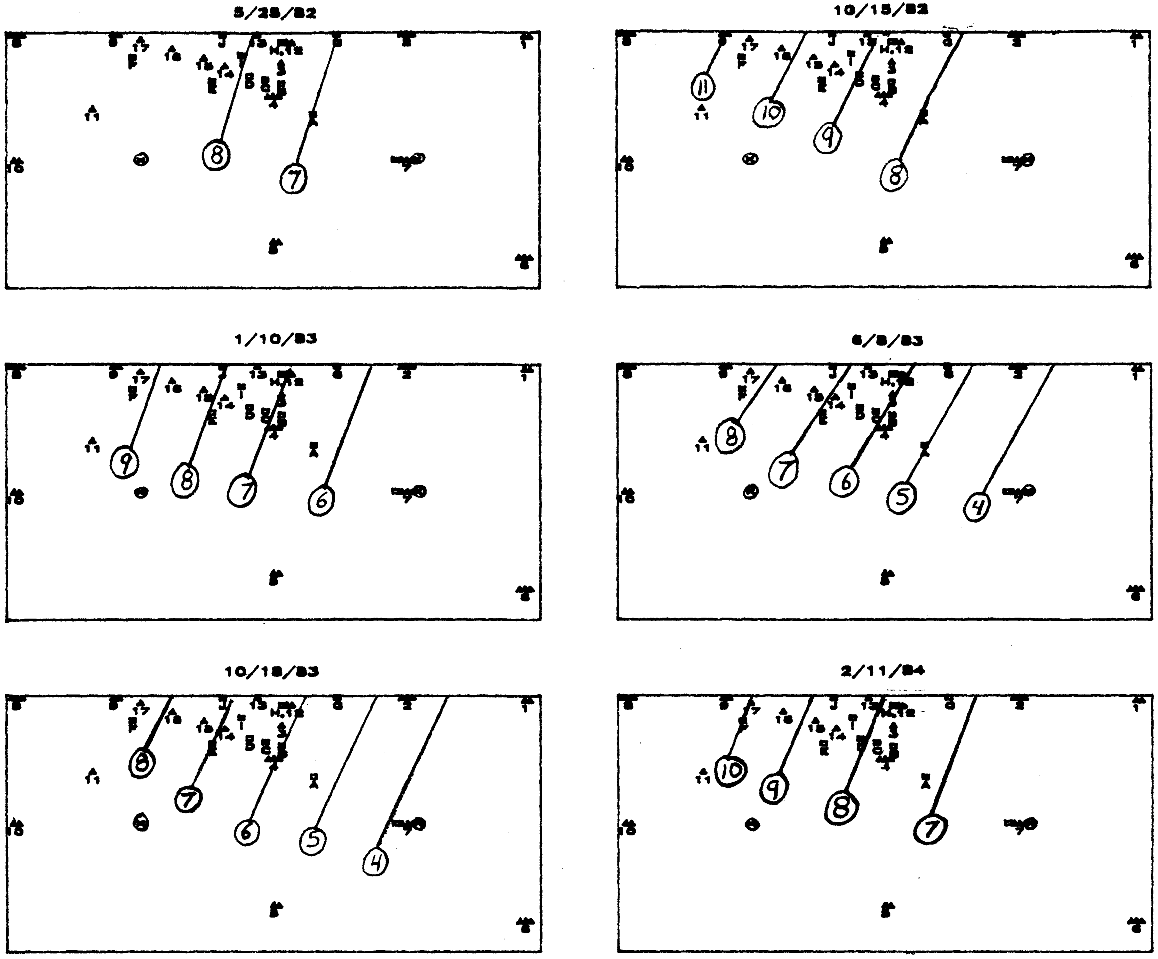


Figure 6. Water table contours at study site on various dates (feet below ground level at Well 4).

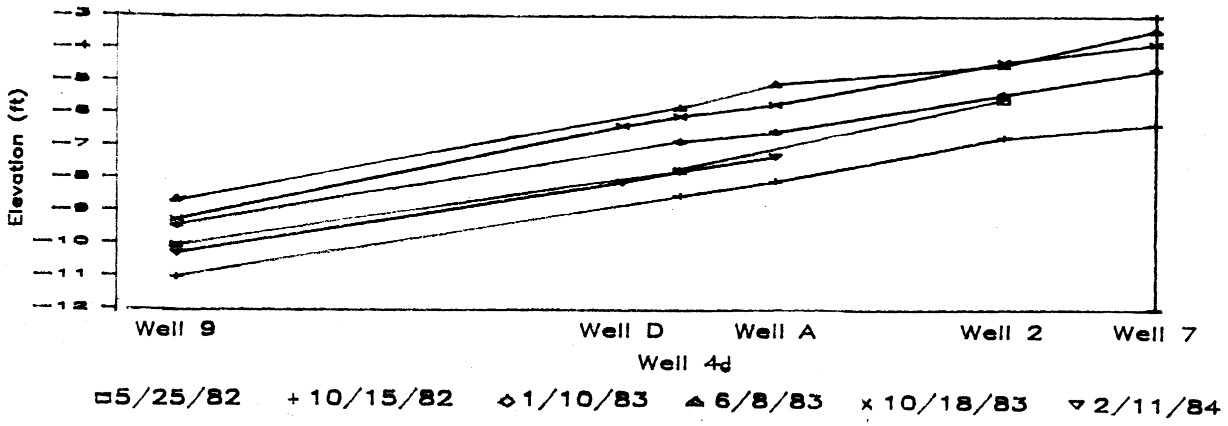


Figure 7. Water table elevations at study site on various dates (feet below ground level at Well 4).

The wells contaminated with aldicarb were beneath and and to the northwest of the aldicarb treated fields, as would be expected given the northwesterly groundwater flow. Well contamination was not entirely consistent however. Aldicarb occurred in Wells 14, 11, and 9b, among the others, but not at all in Wells E, F, J, 15, 16 and 17 - wells between and generally on a groundwater flow line with the mentioned contaminated wells.

Well E functioned improperly as only well points 3, 5 and 6 would draw water. Well points A1, A2, A3 and J8 did not draw water for part or all of the study. The rest of the wells functioned adequately.

Well 11 was installed to determine if aldicarb was leaching from the 1981 aldicarb application area (Fig. 2). The aldicarb detected in this well in May 1982 probably originated from that area. It is possible that the aldicarb contaminating Well 9b also originated in that area. The source of aldicarb in the wells and the extent of aldicarb contamination in the groundwater are considered further in the section on horizontal advection.

Figures 8, 9 and 10 show the aldicarb concentrations which occurred in Wells A, B, C and D. Note the non-uniformity of the time scale in these graphs. These graphs will be referred to often during the work.

The multi-level wells allow observation of vertical cross-sections of the aldicarb in the groundwater. This cross-section reveals aldicarb occurs in a distinct plume which is characterized by a high aldicarb concentration

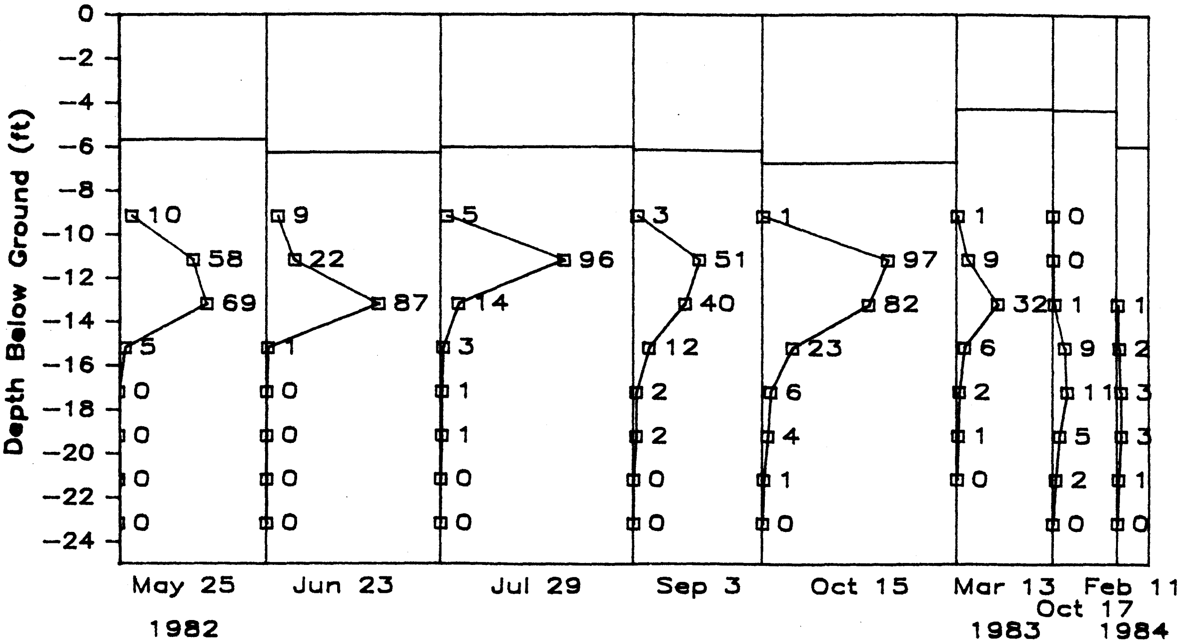


Figure 8. Depth distribution of aldicarb residue concentrations (ppb), and water table level (———), below ground level in Well A.

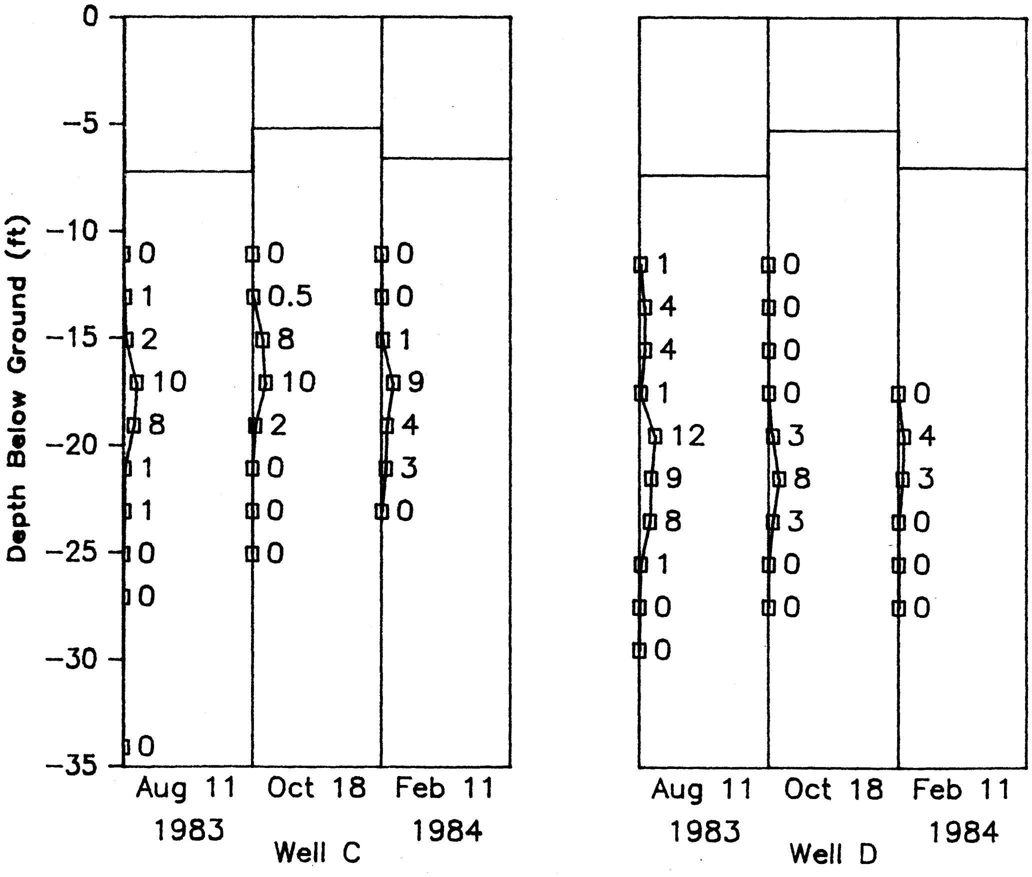


Figure 9. Depth distribution of aldicarb residue concentrations (ppb), and water table level (———), below ground level in Wells C and D.

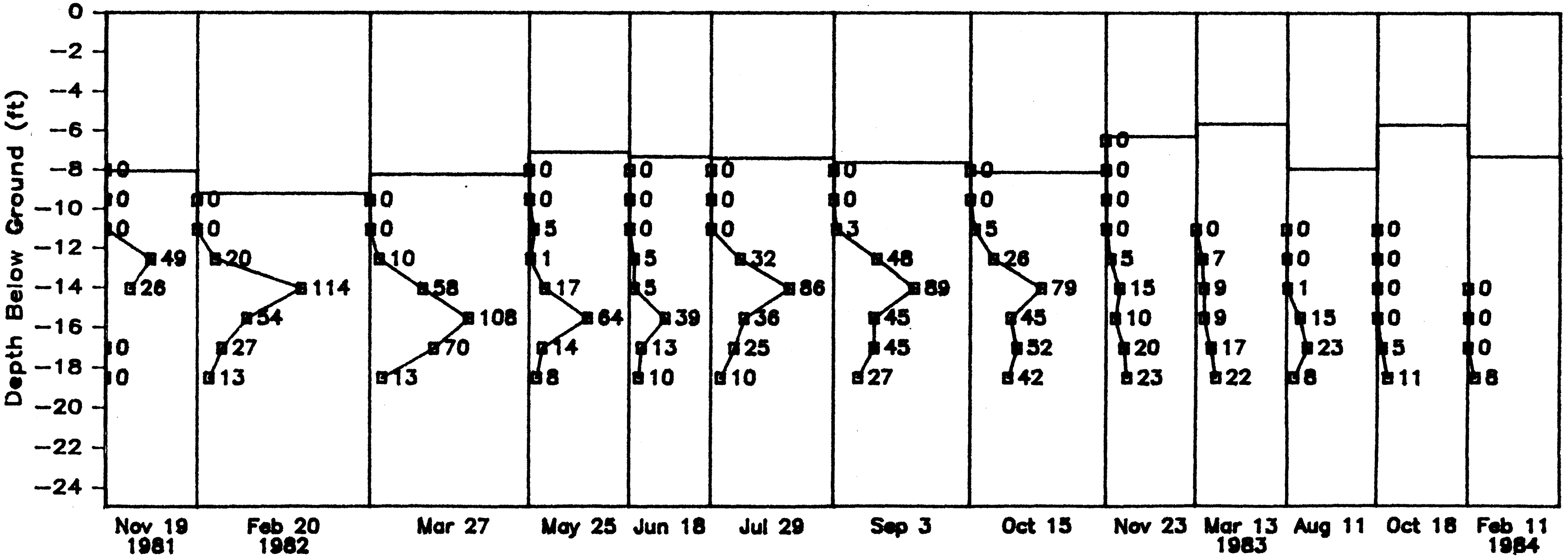


Figure 10. Depth distribution of aldicarb residue concentrations (ppb), and water table level (———), below ground level in Well B.

layer in its mid-section, and lesser concentrations which decrease to 0 ppb, above and below this layer. This concentration pattern occurred consistently throughout the study period though the plume varied in size, shape, concentration, and in depth below the water table, from well to well and from date to date. Wells H and I contained aldicarb but not in the same concentration pattern observed in the above cases. Reasons for this are explored in the section concerning these wells.

Aldicarb was applied in two consecutive years on Field A (Fig. 2) and two layers of aldicarb are apparently present in the groundwater. Evidence of this is seen in Well B from May to November 1982 (Fig. 10) and in Well D in August 1983 (Fig. 9). Note that the sample points in Well A are spaced too far apart to reveal the presence of two plumes. Similarly, if the sample points in Well B were spaced 2 ft apart two distinct layers would not have been evident.

Horizontal Advection of the Aldicarb Plume

The rate of advection of a contaminant plume, and the groundwater flow direction, determine the areal location of the plume over time and determine when the contaminant will enter and/or exit a given well. The factors which determine the rate of advection and contaminant travel distance are the groundwater flow rate, and contaminant solubility, adsorptivity, and reactivity.

Owing to advection, non-reactive solutes in groundwater are carried at an average rate equal to the average linear velocity of the water (Freeze and Cherry, 1979). Aldicarb is sufficiently soluble in water, has a low partition coefficient, and is relatively stable in buffer solutions at pH 5 to 7 at 25 C (Bromilow, 1973; Khasawinah, 1977). Therefore, aldicarb is expected to be carried for some distance in this groundwater at the observed groundwater flow rate. Direct measurement of aldicarb's rate of movement would be desirable in order to confirm or disprove this and to determine if other factors, such as variations in hydraulic conductivity, may be affecting groundwater flow and aldicarb movement in any way.

Attempts were made to locate the leading edge of the Field A aldicarb plume (the plume front) and to directly measure the rate of plume movement. The exact location of the plume front was not determined. The following is an account of what was found.

As of June 1983 aldicarb had been detected consistently in Well B, 200 ft from the field edge, but not in any of the wells down-gradient from this well at that time (Wells E, F, I and J)(Fig. 5). Aldicarb had been found in Well 11 in May 1982 but the source of this is believed the 1981 aldicarb application (Fig. 2). This led to the deduction that either the plume front was between Wells B and I, or the plume had moved beneath the wells down-gradient from Well B.

Then new information was obtained. In July 1983 it was learned that Manser (1983) had found aldicarb in Well 9c on November 11, 1981. This was confirmed by the finding of aldicarb in a Well 9c groundwater sample which was collected on March 27, 1982, and which had been frozen since that time. Well 9 was being avoided, as were Wells 8 and 10, because of the absence of aldicarb from Wells E, F, I and J. In addition to this information, in October 1984, trace concentrations of aldicarb were confirmed to have occurred in Well I from July 1982 to at least July 1983.

This new information indicates that aldicarb might have been carried in the groundwater from Field A to Well 9. But much evidence suggests that the aldicarb in Well 9 originated somewhere besides Field A. The following is an account of this evidence.

The groundwater flow rate at this site was calculated to be between 1.1 and 1.5 ft/day (Manser, 1983). This rate was within the range used by Chesters, et. al. (1982) for this site of 1-2 ft/day.

If aldicarb was carried to Well 9 from Field A at a rate of 1.1 to 1.5 ft/day it would not have reached Well 9 until November 1983 (Appendix I). But aldicarb was present in this well by November 1981. If aldicarb was carried from Field A to Well 9 by November 1981 the groundwater flow rate would have to be at least 3.7 ft/day. At 3.7 ft/day aldicarb would have left Wells 2 and 7 by September 1981 and Well D by March 1983, and it would have reached Well 8 by February 1983 (Appendix I). And because the distance from Well 2 to Well 9 is greater than the anticipated length of the Field A plume, the back end of the plume would logically leave Wells 2 and 7 before the front end entered Well 9. But none of these conditions were observed.

Aldicarb from Field A could have occurred in Well 9 before November 1983 if groundwater was being channeled from Field A to Well 9 in a course sediment layer. But, Manser (1983) determined that variations in aquifer hydraulic conductivity at this site were too subtle to allow for such groundwater channeling. Chesters, et. al. (1982) encountered course gravel layers at this site but believed they were not extensive in either the horizontal or the vertical directions.

Another conceivable reason for the simultaneous presence of aldicarb in Field A wells and Well 9 is that this aldicarb could have originated wholly or in part from fields up-gradient of the study site (it is unknown if aldicarb was ever used on up-gradient fields). But aldicarb was never detected in up-gradient Wells 1, 5 or 6 except for one apparent detection in Well 1 in November 1981 at a concentration of 1 ppb (Chesters, et. al. 1982). Aldicarb could have occurred beneath Wells 1, 5 and 6 but then it likely would have occurred beneath Wells 2, 7 and 9 as well. And there were no observed vertical groundwater flow gradients that would have moved aldicarb from beneath up-gradient wells into the down-gradient wells. It is unlikely an older plume had passed by Field A by 1981 and was passing by Well 9 from 1981 to 1984 given apparent rates of aldicarb downward advection and degradation (see sections on these).

The above evidence suggests that the aldicarb in Well 9 originated at the study site but somewhere besides Field A. The source would seem to be the 1981 aldicarb application area. Evidence against this is that Well 9 apparently occurred near the up-gradient end of this area. The apparent continuity of the presence of aldicarb in Well 9 from November 1981 to at least April 1984 indicates the aldicarb source for this well was large. It is conceivable that the aldicarb in Well 9 could have originated in an aldicarb spill in the vicinity of this well.

The preceding evidence strengthens the belief that the front of the Field A aldicarb plume was somewhere between Wells B and 9. Wells were drilled between these two wells to try and locate it.

Wells C and D were installed in August 1983 and aldicarb was detected in each (Figs. 5 and 9). This fairly well put to rest the idea that the aldicarb plume had perhaps moved beneath Well I.

Then four standard PVC wells numbered 14 to 17, with 3 ft well screens, were installed at 200 to 500 ft intervals between Wells D and 9 (Fig. 5). Aldicarb was detected consistently in Well 14 but not at all in Wells 15, 16 or 17.

The screens of wells 14 to 17 were located at about the same depth below the water table as the maximum aldicarb concentration layer in Well D in August 1983 (Appendix E). Unfortunately, the October 1983 samples for Well D were analyzed after Wells 14 to 17 were installed. Analysis of the October samples revealed that the plume occurred at a considerably lower level in the groundwater by that time.

In April 1984, after Wells 14 to 17 were sampled, the screens of these wells were pulled up to the depth where aldicarb was detected in Well 9c in February 1984, and the wells were sampled. No aldicarb was detected in any of these except Wells 14c and 9c (Fig. 11). Figure 11 indicates that Field A aldicarb is probably not in Well 9 as no aldicarb was detected between Wells 14 and 17 at the depth where it occurred in Well 9. Figure 11 also indicates that the plume may have been below Wells 15, 16, 17, and 9.

Observation of an apparent second plume in the groundwater (see Fig. 10) may shed some light on the plume advection rate. The 1979 aldicarb application was made on the east half of Field A whereas the 1980 application was made on all of Field A. The 1979 plume would logically occur beneath the 1980 plume and the 1980 plume would logically enter wells down-gradient of Field A before the 1979 plume. At a groundwater flow rate of 1.4 ft/day the 1980 plume would reach Well B in December 1980 and the 1979 plume would reach it in June 1982. This corresponds well with what was actually observed in Well B where only one plume was observed from November 1981 until July 1982 when a second plume was observed to enter the well.

The leading edge of the aldicarb plume from the 1980 application was not found. But observation of the aldicarb plume from the 1979 application indicated that the plume advection rate is within the expected groundwater flow range of 1.1 to 1.5 ft/day, that is, about 1.4 ft/day. At this flow rate the 1980 plume would have been transported 1950 ft from July 1980 (the date used by Manser (1983)) to April

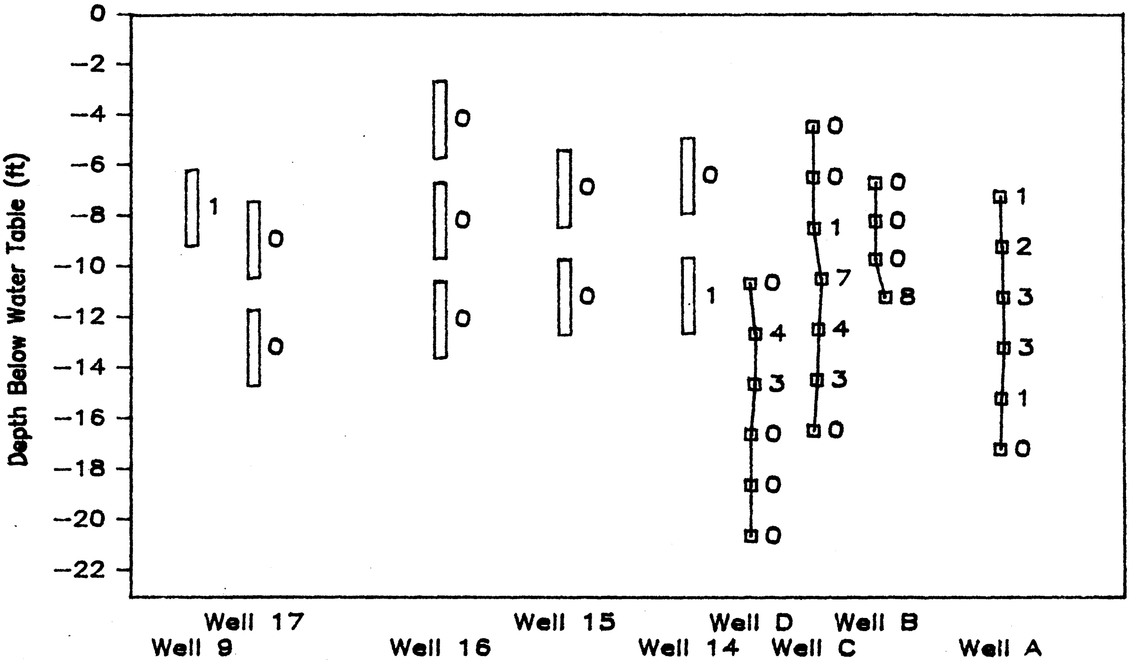


Figure 11. Depth distribution of aldicarb residue concentrations (ppb) below water table between wells A and 9. Wells A,B,C and D were sampled on February 11, 1984; Wells 9,14,15,16 and 17 were sampled on April 18, 1984.

1984. The leading edge of the 1980 aldicarb plume would then have been about 120 ft down-gradient of Well 9, and the back end of the plume would have been about 300 ft up-gradient of Well G (see Figure 5).

Vertical Advection of the Aldicarb Plume

Upon groundwater discharge, water near the water table in groundwater recharge areas moves in a downward direction, and substances dissolved in the water move downward as well. Groundwater is replenished, or recharged, by varying amounts of rainfall and snow melt. Subsequently, dissolved substances occur further below the existing water table a distance about equal to the depth of the recharge water. Thus over time, dissolved substances occur lower and lower beneath both the ground surface and the water table.

Aldicarb occurred at successively lower levels in the groundwater during this study. Figure 12 shows the position of the plume below the water table in Wells A, B, C and D over time. Refer to figures 8, 9 and 10 for the position of the plume below ground level in these wells.

Table 1 gives aldicarb concentrations and their depths below the water table in nested Wells 2 and 7. Aldicarb concentrations in these wells increased in the deeper wells and decreased in the shallower wells over time becoming absent from most of them by October 1983. This indicates at least in part that aldicarb was moving downward in these wells. Similar observations were made by Chesters, et. al. (1982) and by Manser (1983).

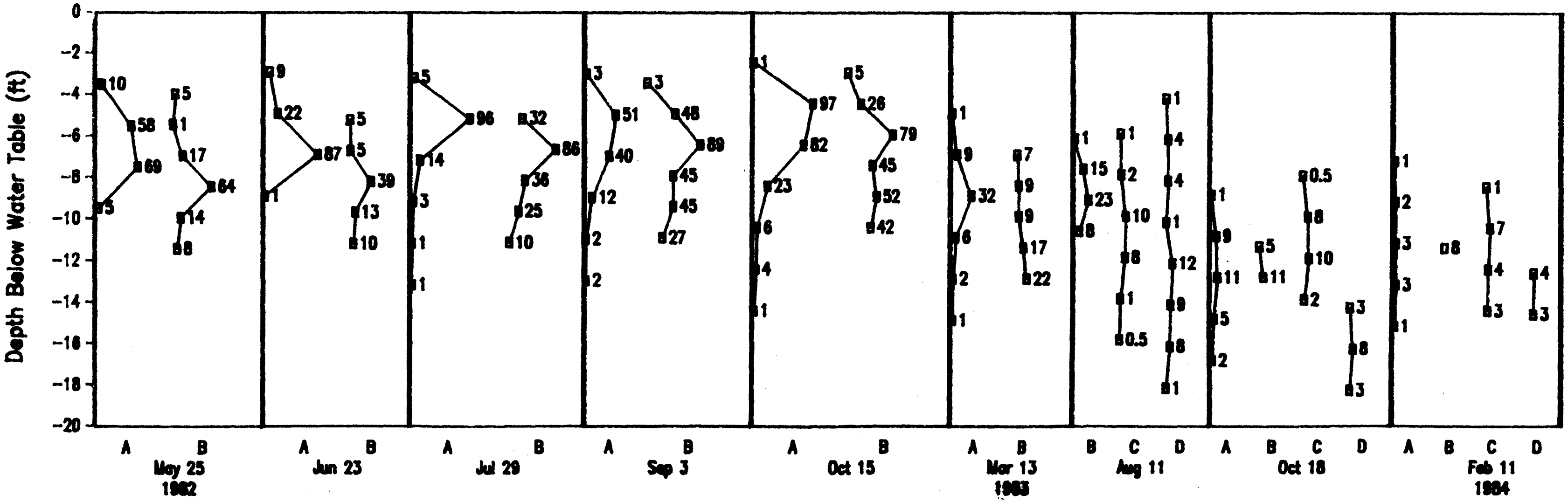


Figure 12. Depth distribution of aldicarb residue concentrations (ppb) below water table in Wells A,B,C and D.

Table 1. Aldicarb residue concentrations in Wells 2 and 7, and depths of water samples below the water table, from February 1982 to October 1983.

Well	1982					1983
No.	2/20	7/29	9/3	10/15	3/13	10/18
2b		--	5(4.3)	-	0(6.4)	0(6.1)
2b2		23(4.9)	23(4.7)	3(4.3)	0(6.8)	0(6.6)
2c		62(8.7)	48(8.6)	24(8.1)	44(10.6)	tr(10.4)
7b	--	7(3.2)	0(3.4)	8(3.2)	tr(5.7)	0(5.6)
7b2	45(2.8)	10(4.4)	4(3.9)	tr(3.6)	tr(6.2)	0(6.1)
7c	2(7.7)	7(9.0)	13(8.5)	7(8.3)	3(10.9)	0(10.8)

(eg. 45(2.8): 45 = aldicarb residue concentration (ppb); (2.8) = depth below water table (ft)).

For determining the extent of vertical advection the maximum aldicarb concentration layer is the most reliable point of reference. The depth of the middle of this layer below the water table over time is shown in Figure 13 and was determined using the concentration weighted formula:

$$\text{Depth (ft)} = \frac{\sum(C*D)}{(C)}$$

where C is the aldicarb concentration of each sample for each multi-level well, and D is the depth of each sample below the water table. The effects of groundwater recharge on the depths of the water table and the maximum aldicarb concentration layer below ground level is shown in Figure 14. Recharge was determined using the formula:

$$R = WI - ET$$

where R is recharge, WI is water input in the form of rainfall and snowmelt (NOAA, 1982 and 1983) and irrigation water (Corneli, K., 1985), and ET is evapotranspiration

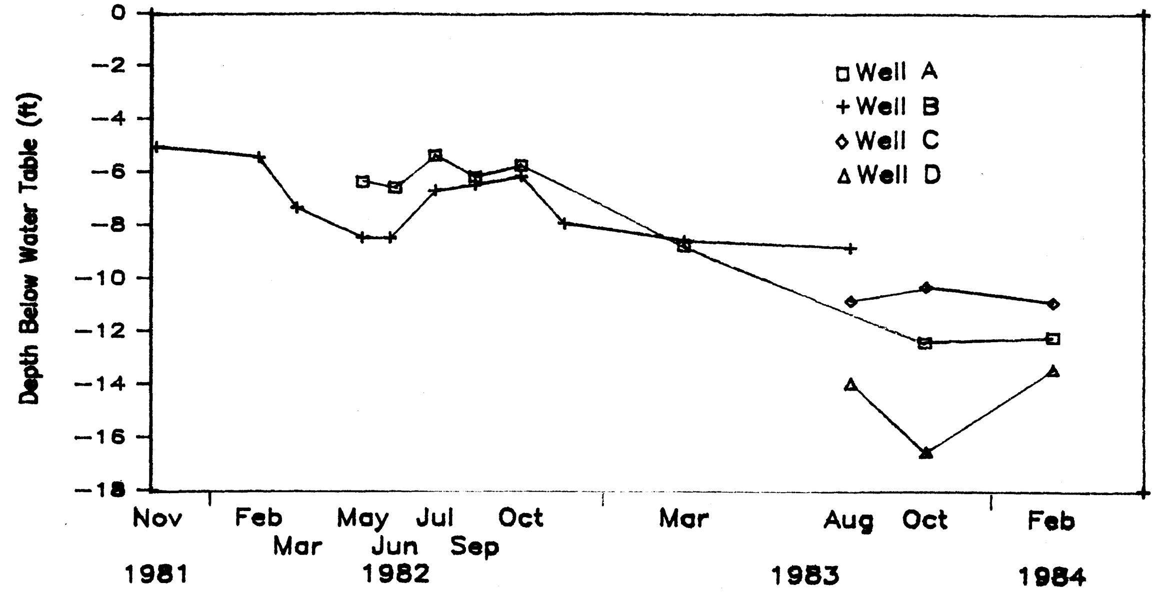


Figure 13. Depth of maximum aldicarb residue concentration layer below water table in Wells A,B,C and D.

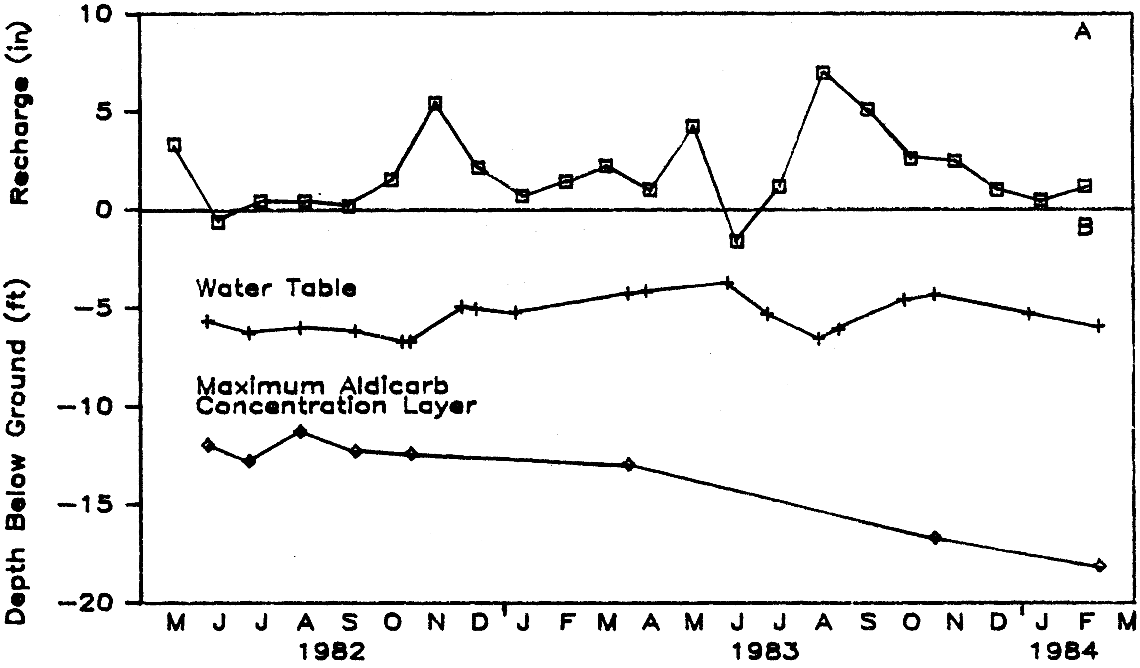


Figure 14. Amount of groundwater recharge over time (Graph A) and its relationship to depths of the water table and maximum aldicarb concentration layer below ground level (Graph B) from May 1982 to February 1984.

Table 2. Water input (WI), evapotranspiration (ET), recharge (R), and vertical depth of recharge water in the aquifer (Rd = R * 2.5) in 1982 and 1983 (2.5 = inches of saturated aquifer (sand) per inch of water).

	WI (in)	ET (in)	R (in)	Rd (ft)
1982	36.4	17.1	19.3	4.0
1983	46.8	19.8	27.0	5.6

(HES, 1982 and 1983).

Table 2 gives the quantity of water input, evapotranspiration, recharge, and the vertical depth of the recharge water in the aquifer, at the study site in 1982 and 1983. The recharge quantity corresponds fairly well with the observed 5-7 ft increase in depth below ground level of the maximum aldicarb concentration layer from March 1983 to February 1984 (Fig. 14). The depth of this aldicarb layer below the water table increased 5-10 ft from May 1982 to February 1984 (Fig. 13, and Tabs. 3 and 4).

The aldicarb maximum concentration layer remains at about the same depth below the ground level from at least May 1982 to March 1983, and then moves downward 5-7 ft over the next 11 months (Fig. 14). The hydraulic gradient increased significantly in November 1982 and remained high until June 1983 (Fig. 14). This probably resulted in increases in the groundwater discharge rate and the downward rate of groundwater movement. This could then explain the irregular downward movement of the aldicarb plume over time.

Approximate depths of the upper and lower boundaries of

Table 3. Depth (ft) below water table of the maximum concentration layer and upper and lower boundaries of the aldicarb plume during the study period.

Well Number	Date	Maximum Conc. Layer	Upper Boundary	Lower Boundary
A	5/25	6.3	--	9.5
	6/23	6.5	--	8.9
	7/29	5.3	--	13.2
	9/3	6.1	--	13.0
	10/15	5.7	--	14.4
	3/13	8.7	--	14.9
	10/18	12.4	8.8	16.8
	2/11	12.2	--	15.2
B	11/19	5.0	4.4	--
	2/20	5.4	3.3	--
	3/27	7.3	4.2	--
	5/25	8.4	3.9	--
	6/18	8.4	5.2	--
	7/29	6.6	5.1	--
	9/3	6.4	3.4	--
	10/15	6.1	2.9	--
	11/23	7.9	6.2	--
	3/13	8.5	6.9	--
	8/11	8.9	4.6	--
	10/18	--	11.3	--
	2/11	--	11.2	--
C	8/11	10.8	5.8	15.8
	10/18	10.3	7.9	13.9
	2/11	10.9	8.4	14.4
D	8/11	13.9	--	18.2
	10/18	16.5	14.3	18.3
	2/11	13.4	12.6	14.6

Table 4. Average depths (ft) below water table of aldicarb maximum concentration layer during two time periods.

Date	Well A	Well B	Well C	Well D
5/25/82 to 10/15/82	6.4	7.2	--	--
10/18/83 to 2/11/84	12.3	--	10.7	14.6

the plume, as well as the maximum concentration layer, are listed in Table 3. Average depths of the maximum concentration layer are given in Table 4.

The depth of the maximum concentration layer below the water table averaged 6.7 ft in mid 1982 and 12.7 ft in late 1983/early 1984 (Table 4). Its maximum depth was 16.5 ft in Well D in October 1983 (Table 3). It is not known for certain if this layer in Well D was part of the 1979 or the 1980 plume. The maximum depths of the upper and lower boundaries of the plume below the water table also occurred in Well D and were 14.3 ft and 18.3 ft, respectively, also in October 1983.

The plume appeared to increase in depth below the water table with distance from Field A (Figure 12). The consistency of this occurrence seems to indicate that something beyond chance may be responsible. However, in February 1984 the plume from Well A to Well D appeared to be generally at one depth below the water table.

Vertical advection of solutes occurs as groundwater is discharged and recharged. The vertical depth of the recharge water in 1982-83 was about 9.6 ft, and the depth of the maximum aldicarb concentration layer below both the ground level and the water table increased 5-10 ft.

Hydrodynamic Dispersion of Aldicarb

Non-reactive solutes in groundwater will be mechanically dispersed as they are carried through the aquifer (Freeze and Cherry, 1979). Solutes in water will also move (diffuse) under the influence of their kinetic activity in the direction of their concentration gradient. Together these two processes are referred to as hydrodynamic dispersion. Both are likely occurring in this groundwater but no attempt is made to determine the extent to which each occurs individually. Rather, what is stressed is increases in plume thickness, that is, the vertical (transverse) expansion of the plume. Hydrodynamic dispersion will be referred to simply as dispersion.

Dispersion can occur both longitudinally and transversely. I did not attempt to determine longitudinal dispersion. Manser (1983), Rothschild (1982), and Chesters, et. al. (1982) used a maximum longitudinal dispersivity for aldicarb at this site of 70 ft in computer simulations. They also used a transverse dispersivity of 14 ft.

Transverse dispersion observed in this study was indicated by the classic solute dispersion pattern in which low aldicarb concentrations occurred above and below high aldicarb concentrations, and by the mere thickness of plume on many dates (Figure 12). This apparently reveals that the aldicarb is dispersing away from a concentrated mass. Dispersion was also indicated by the increasing numbers on sample points in the multi-level wells which contained aldicarb on succeeding sampling dates. For example, in Well A the lower boundary of the plume occurred between points 5 and 6 in May 1982, whereas it occurred between points 8 and 9 in October 1982 (Fig. 8). On both of these dates the high concentration layer occurred at about the same depth below the water table. The distance from the high concentration layer to the lower boundary increased significantly and apparently due to dispersive processes.

Many considerations must be taken into account when trying to determine the extent of vertical aldicarb dispersion that had occurred in this groundwater. First, the upper or lower boundary of the plume was not visible in some of the multi-level wells on some of the sampling dates. This is dealt with by observing changes in the thickness between the maximum concentration layer and the deepest (or shallowest) contaminated sample point in each well over time. Second, the thickness of the plume observed in each well is a minimum value as its boundaries occur between two sample points. Each boundary could be as much as 1.5 feet further from the center of the plume in Well B, and two feet further from center in Wells A, C and D. Third, the thickness of the plume in the groundwater just after the aldicarb had finally and completely left the unsaturated zone is not known. Thus an accurate determination of the total extent of plume dispersion cannot be made. Aldicarb does appear to have spread out around a relatively high aldicarb concentration zone which is probably the remnant of the original aldicarb plume. Thus the maximum concentration layer in the plume as it currently exists may be roughly the same thickness as was the entire plume before it began to disperse. The thickness of the maximum concentration layer in February 1982 and beyond that date in Well B appears to be 3 ft or even less. Therefore, 3 ft seems to be a fair approximation of the original plume thickness. This was the value used by Manser (1983) in computer simulations for this thickness.

A fourth consideration in trying to determine the extent of aldicarb dispersion is that two aldicarb plumes are probably present in the groundwater. The upper and lower plumes are probably expanding primarily in the upward and downward directions, respectively, because the lack of concentration gradient where they meet. In Well A the juncture of the two plumes would be in the maximum concentration layer. This is also reason for measuring the dispersion from this layer to the lower boundary. The total extent of dispersion for the two plumes would likely be somewhat greater than that for a single plume because of the greater quantity of aldicarb. Fifth, the aldicarb plume may be of variable thicknesses thereby creating a perception of expansion and contraction as it passes the wells. But the thickness of the plume increases consistently early in the study, and later decreases consistently, seeming to indicate the plume itself expands and then contracts (Figs. 15 and 16). Sixth, the plume does not expand in thickness until the concentration gradient is gone as would be expected, but declines in size after a time. This indicates aldicarb is degrading at the same time the plume is expanding and eventually the degradation rate exceeds the expansion rate. Finally, the detection limit for aldicarb is roughly 1 ppb prohibiting observation of aldicarb concentrations below this limit beyond the boundaries of the plume. But aldicarb

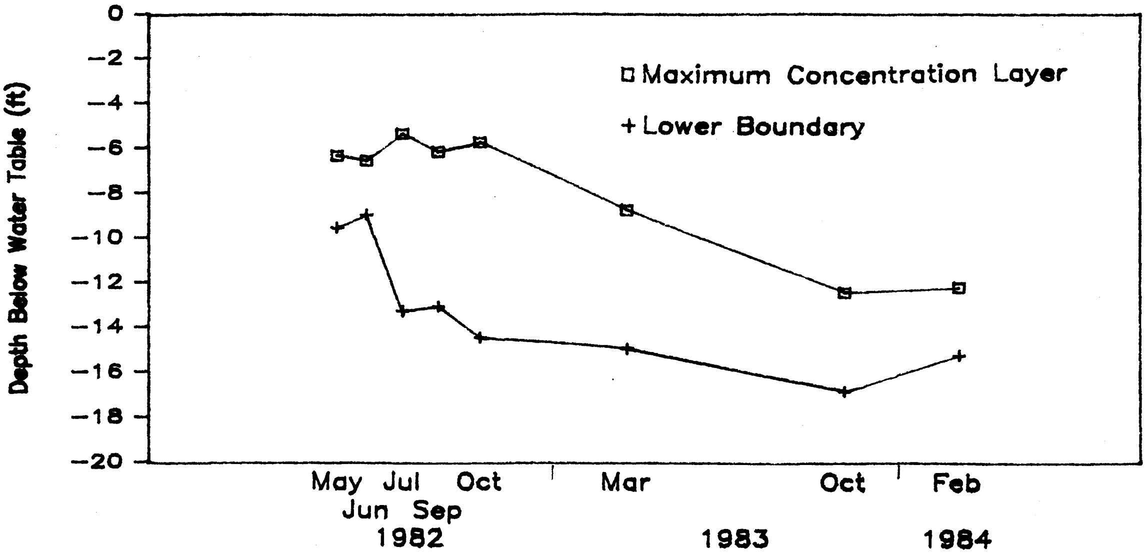


Figure 15. Depth of maximum concentration layer and lower boundary of aldicarb plume below water table Well A.

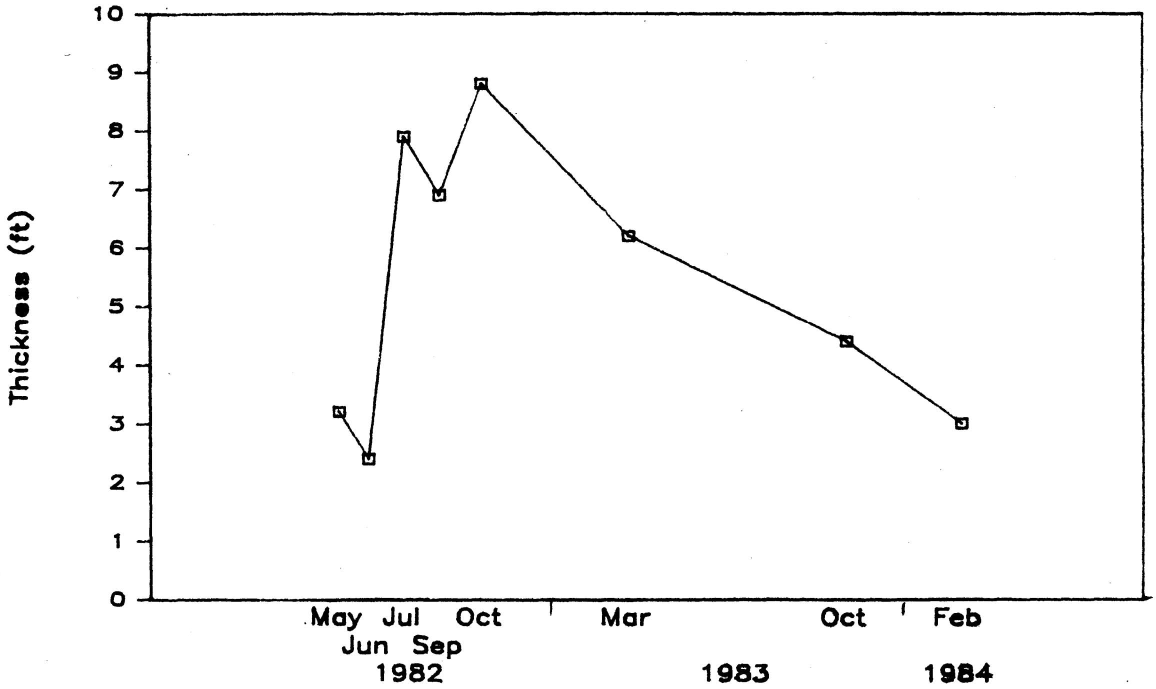


Figure 16. Changes in thickness of aldicarb plume in Well A measuring from the maximum aldicarb concentration layer to the lower boundary.

at this concentration would have to disperse a considerable distance before the high aldicarb concentrations would be significantly reduced.

With these considerations in mind it appears the aldicarb has dispersed in the groundwater. The plume in Well A seems to have definitely increased in size by October 1982 (Fig. 8). Figures 15 and 16 reveal the change in the plume thickness in this well over time.

The distance from the high concentration layer to the lower boundary in Well A was 3.2 ft in May 1982, 8.7 ft in October 1982, and 3.0 ft in February 1984. By October 1982 the thickness of the expected lower plume was observed to increase 3-fold. It eventually decreased by 3-fold to a thickness of 3 ft by February 1984. This occurrence is discussed further in the next section.

In Well B, the distance from the upper high concentration layer to the upper boundary did not vary greatly. It increased from 1.5 ft in November 1981 to 3 ft in September 1982 (Fig. 10).

In Well C the plume had a thickness of 10 ft in August 1983, and 6 ft in October 1983 and February 1984 (Figure 9). The plume in this well apparently increased in thickness over 3-fold by August 1983. Two plumes were not evident in this well.

The plume in Well D had a thickness of 14 ft in August 1983 (Fig. 9). This would amount to a 5-fold increase in thickness. But two plumes appeared to be present in this well at that time. The lower plume would have expanded vertically about 3-fold by August 1983. The plume thickness decreased substantially in this well by February 1984 when it was observed to be 2 ft. Overall, plume thickness appeared to increase by about 3-fold from its initial 3 ft before beginning to decrease in size after October 1982.

Reduction of Aldicarb Concentrations

Solute concentrations in groundwater can be reduced in concentration in three ways - adsorption, dilution, and degradation. Aldicarb has a low adsorption coefficient (Bromilow, 1973) and therefore is not expected to adsorb to aquifer materials.

As indicated in the previous section, aldicarb has dispersed in the groundwater. It follows then that it has also been diluted to lower concentrations.

Degradation of some solutes will occur in groundwater depending on molecular characteristics of the solute, and on the physical, chemical, and biological characteristics of the groundwater. Aldicarb, being a carbamate, will break down in an alkaline environment, above pH 7, via alkali catalyzed hydrolysis of its ester bond. Aldicarb sulfoxide in sterile buffered solutions at 25 C has an estimated half-life of 350 days at pH 7, is stable at pH 5, and is unstable (half-life 2.3 days) at pH 9 (Khasawinah, 1977). Aldicarb is relatively unstable at pH 6 to 8 at 80-100 C (Lykins, 1971). Bacteria are also believed to degrade aldicarb (Back, 1981).

Of the groundwater contaminated with aldicarb, the pH was observed to range from 5 to 8.5, alkalinity ranged from 2 to 100 ppm, and their average values were 7.6 and 45 ppm, respectively. Bacteria were not analyzed for in this study but were observed by Chesters et. al. (1982) to range from 80 counts to 1.12 million counts per 100 ml in Wells 2 and 7. This was considered a high bacteria concentration. Harkin, et. al. (1984) believed bacteria were significantly degrading aldicarb in this groundwater. Thus, alkalinity and bacteria may be reducing aldicarb concentrations at this site.

Aldicarb concentrations have been greatly reduced in this groundwater. The highest observed concentration in this study was 114 ppb in February 1982. The highest concentration in February 1984 was 8 ppb. A gradual decline in concentrations occurred between these two dates, although a new slug of aldicarb apparently came through in October 1982. Over 24 months there was roughly a 15-fold, 93% decline in the highest aldicarb concentration.

Figure 17 shows the highest aldicarb concentrations in Wells A to D for each sampling date. Figure 18 shows estimates of aldicarb quantities in the groundwater over time. The aldicarb quantity was determined using the formula:

$$Q = m/v * DI * A * 0.4$$

where Q is aldicarb quantity (lbs) per acre, m/v is the aldicarb concentration (ug/l), DI is the depth increment of multi-level sample points (2 ft), A is area per acre (cm^2), and 0.4 is the porosity of sand (Conversions: ug/l =

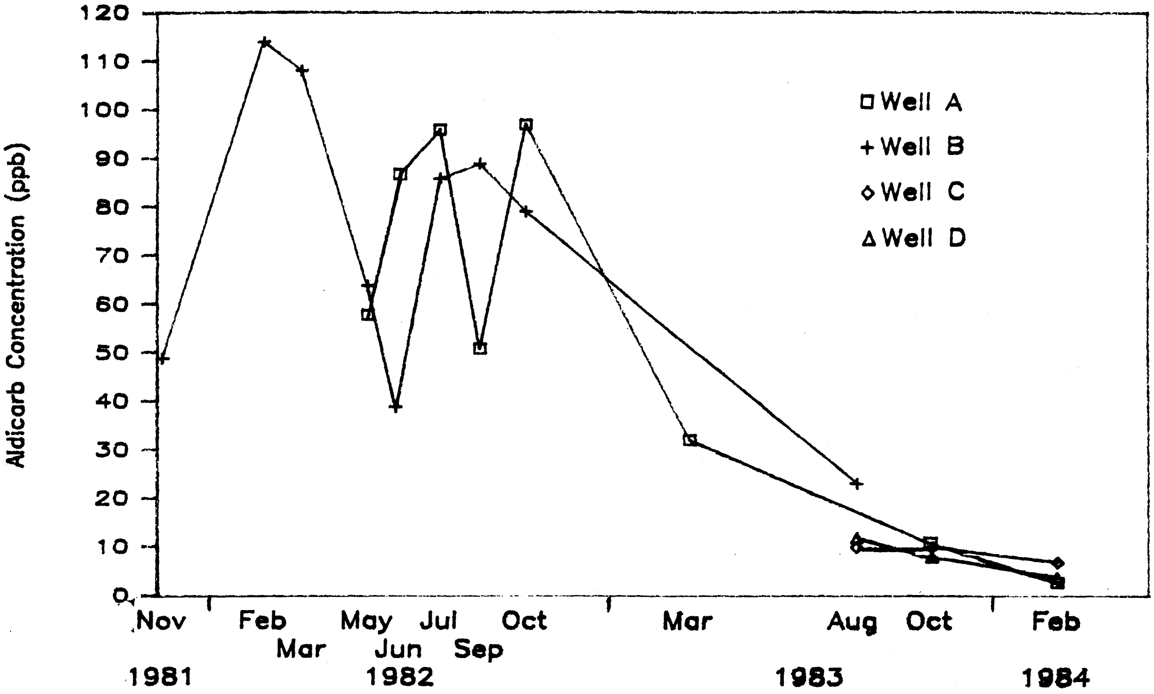


Figure 17. Maximum aldicarb concentrations in Wells A,B,C, and D over time.

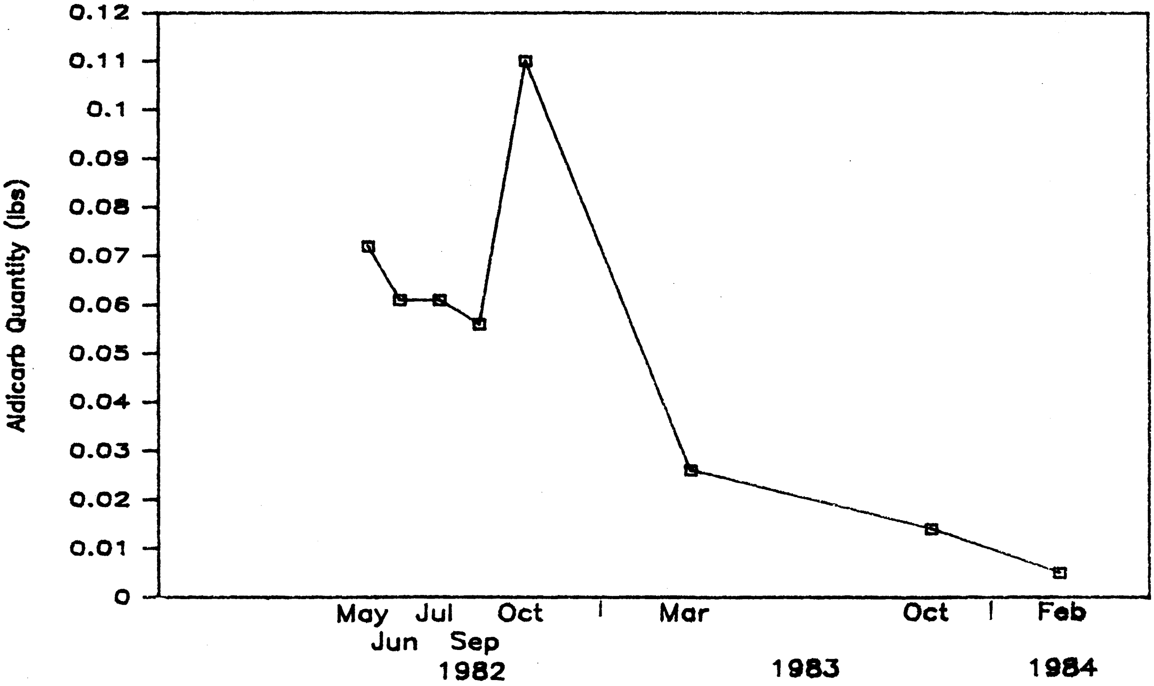


Figure 18. Aldicarb residue quantities that would occur in groundwater beneath one acre of field over time based on Well A aldicarb concentrations.

ng/cm^3; 1 lb = 2.2*10^{12}ng; 1 ft = 30.5 cm; 1 acre = 4.6*10^{7}cm^2).

The preceding information shows the extent of decline in aldicarb concentrations during this study. But it is evident the highest aldicarb concentrations which occurred in this groundwater were substantially greater than 114 ppb. Manser (1983) observed an aldicarb concentration of 242 ppb in well point G5 in March 1982. This would amount to roughly a 35-fold, 97% decline in concentration over 23 months.

Harkin and McWilliams (1982) estimated that under conditions similar to those at this site the highest concentration of aldicarb in groundwater would be 300 ppb. This was also the highest concentration they had observed in groundwater samples taken from monitoring wells in aldicarb treated fields in Central Wisconsin. This indicates that there was roughly a 43-fold, 97% decline in aldicarb concentrations over 43 months.

Aldicarb concentration reduction rates were highly variable in these three examples. When using the initial concentration values of 114, 242, and 300 ppb, the reduction rates were 57, 123, and 81 ppb/year, respectively. The average of these is 87 ppb/year.

Aldicarb degradation is believed to follow 1st order kinetics. The half-life calculated for aldicarb during this study averaged 206 days (Table 5). The aldicarb quantity for October 1982 was not used in the calculations as it is believed part of a slug of aldicarb which deviated from the

Table 5. Half-life values for aldicarb in groundwater, using aldicarb quantities that would occur beneath one acre of field based on Well A aldicarb concentrations.

Date	Number of Days	Aldicarb Quantity lbs	Half-life (days)
5-25-82	0	0.072	
6-23-82	29	0.06	110
7-29-82	65	0.061	272
9-3-82	101	0.056	278
3-13-83	292	0.026	199
10-17-83	510	0.014	216
2-11-84	627	0.005	163
			206 mean

regular set of conditions. The variation in the half-lives is probably due to variations in alkalinity and bacteria concentrations, and to areal variations in aldicarb concentrations which resulted from varying aldicarb loading rates. Harkin, et. al., (1984) estimated the half-life of aldicarb in groundwater at this site would be 1.3 years (475 days).

With a half-life of 206 days it would have taken 4.5 years (until January 1985) before the highest aldicarb concentration in the groundwater was 1 ppb. During that time the plume would have traveled 2300 ft.

By comparing the extents of degradation and dispersion it is possible to determine their relative importance in reducing aldicarb concentrations. Used here are the distances from the maximum concentration layer to the lower boundary, and the maximum aldicarb concentrations, in Well A. July 1980 is taken to be the date aldicarb first entered the groundwater, and 300 ppb is taken to be the initial aldicarb concentration.

By October 1982 (27 months) the plume thickness had increased 2.9-fold while the maximum aldicarb concentration decreased 3.1-fold. By March 1983 (32 months) the plume thickness was only 2.1-fold greater than the initial 3 ft with a coinciding decrease in the maximum aldicarb concentration of 9.4-fold. By February 1984 (43 months) the plume thickness was declining further and the maximum aldicarb concentration had decreased 100-fold. This indicates that degradation was the primary factor by which aldicarb concentrations were reduced in the groundwater. It is probable, however, that dispersion occurred to a significant degree but was masked by subsequent degradation.

Laboratory Study on Aldicarb Degradation

The results of this experiment are listed in Appendix J. Quality control information is listed in Appendix K. The variability of some spike recoveries indicated that some of the spike solutions may have been faulty. Uncorrected aldicarb concentrations were used as their concentration declines were fairly consistent over time, and because duplicate concentrations were usually quite similar. The initial uncorrected aldicarb concentrations in the water samples taken from Well points B6, B7, and B8 in this experiment were 54 ppb, 90 ppb and 12 ppb, respectively. The aldicarb concentrations, corrected for spike recovery, for regular field samples taken from Well points B6 and B7 on 3/27/82, and from B8 on 3/13/83, were 58 ppb, 108 ppb and 17 ppb, respectively.

The extent of aldicarb concentration reduction in this experiment varied from that seen in the groundwater at the study site. Aldicarb concentrations declined about 25% in the Well point B6 and B7 samples over 30 months, and 67% in the Well point B8 sample over 18 months. The half-lives for the B6, B7 and B8 samples were 1916, 1520 and 478 days, respectively.

Figure 19 shows the extent of aldicarb concentration decline in the samples over time. Figure 20 shows the relationship between the half-lives of aldicarb and original alkalinities of the samples.

The pH and alkalinities of the water samples were inversely related with the aldicarb concentration reduction rates. This reinforces the belief that these chemical characteristics degrade the aldicarb molecule in groundwater. Any bacteria present in the samples may also have contributed to aldicarb degradation.

The relatively slow rate of aldicarb concentration reduction indicates that dispersion may have played a more significant role in reducing aldicarb concentrations at the study site than what was observed. Dispersive effects would have been obscured if the aldicarb was being degraded faster than it was being dispersed. It is likely that alkaline hydrolysis, bacteria, and dispersive effects combined in the groundwater at the study site to produce the observed concentration reduction rate (half-life - 206 days).

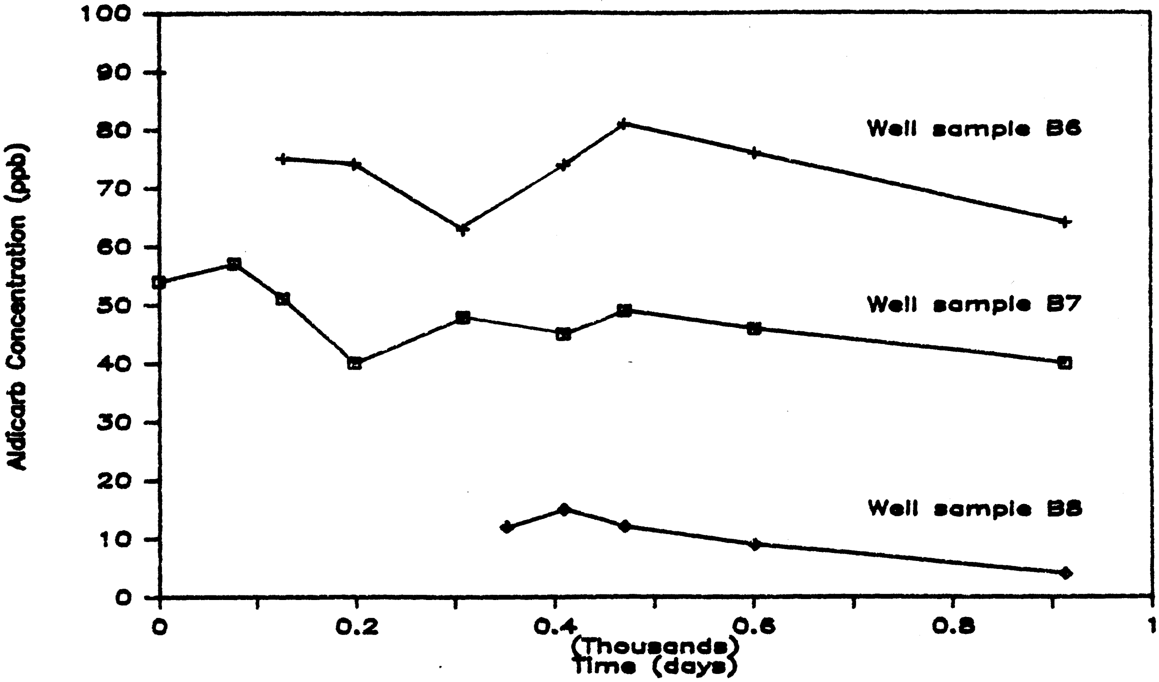


Figure 19. Aldicarb concentrations over time in samples for laboratory study on aldicarb degradation.

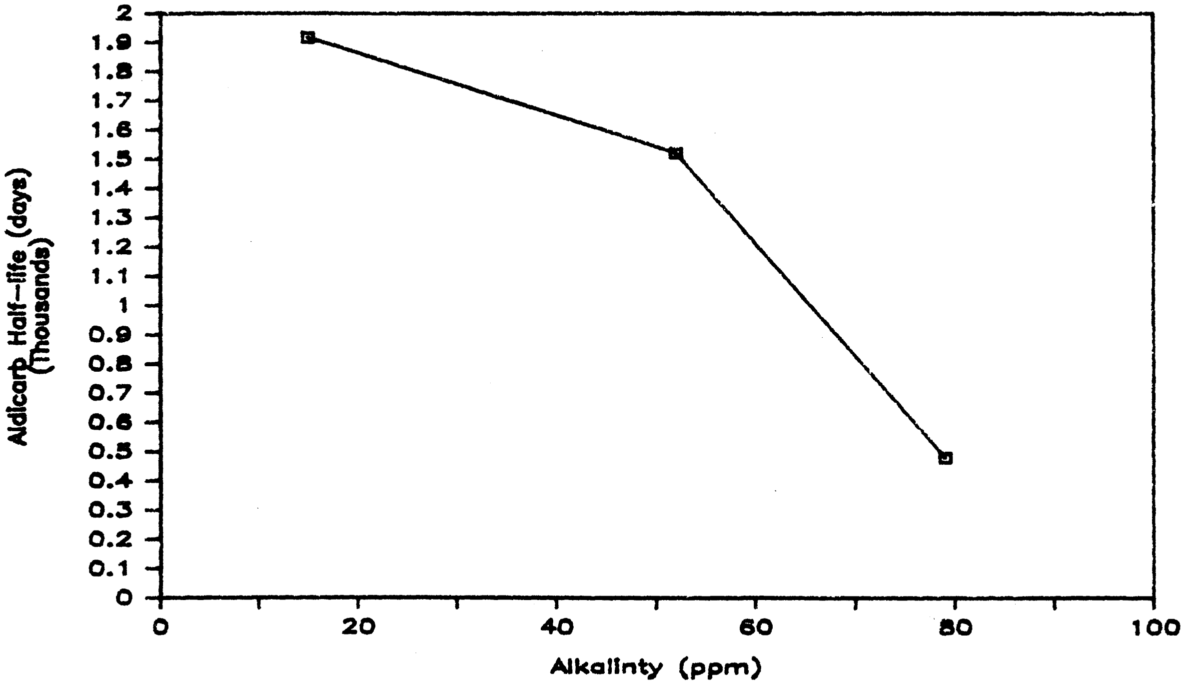


Figure 20. Relationship between aldicarb half-life and alkalinity concentrations in samples for laboratory study on aldicarb degradation.

Anomaly at Wells H and I

Aldicarb concentrations in Wells H and I were different in magnitude and depth below the water table than those occurring in Wells A, B, C, D and G (Fig. 19). Well H had aldicarb in only the 2 to 3 lowest sample points (11-13 ft below water table) at concentrations between 1 and 10 ppb from September 1982 to at least March 1983. In Well I, aldicarb occurred only in trace concentrations from July 1982 to at least July 1983. Well H is 505 ft and Well I 626 ft down-gradient from Field A. This occurrence indicates that aldicarb does not naturally occur in the same general concentrations and at the same depths throughout the plume.

In Well I, samples collected after February 1982 were taken from every other sampling point. In October 1984 the 2 ml aldicarb extracts for all samples collected were further concentrated by a factor of 2 to 3. Aldicarb was detected consistently in samples taken between 9.6 and 15.9 feet below the water table, but only in two sample points at any one time. Even though the points sampled were 4 feet apart it is doubtful that significantly higher aldicarb concentrations occurred between them.

The most logical explanation for the anomaly is that the distance of Wells H and I from Field A allowed more time for recharge water to push the plume to deeper depths in the groundwater. But, in September 1982 the upper boundary of the plume in Well H occurred 8 feet below the level of the upper boundary in Well B. Considering how much the plume

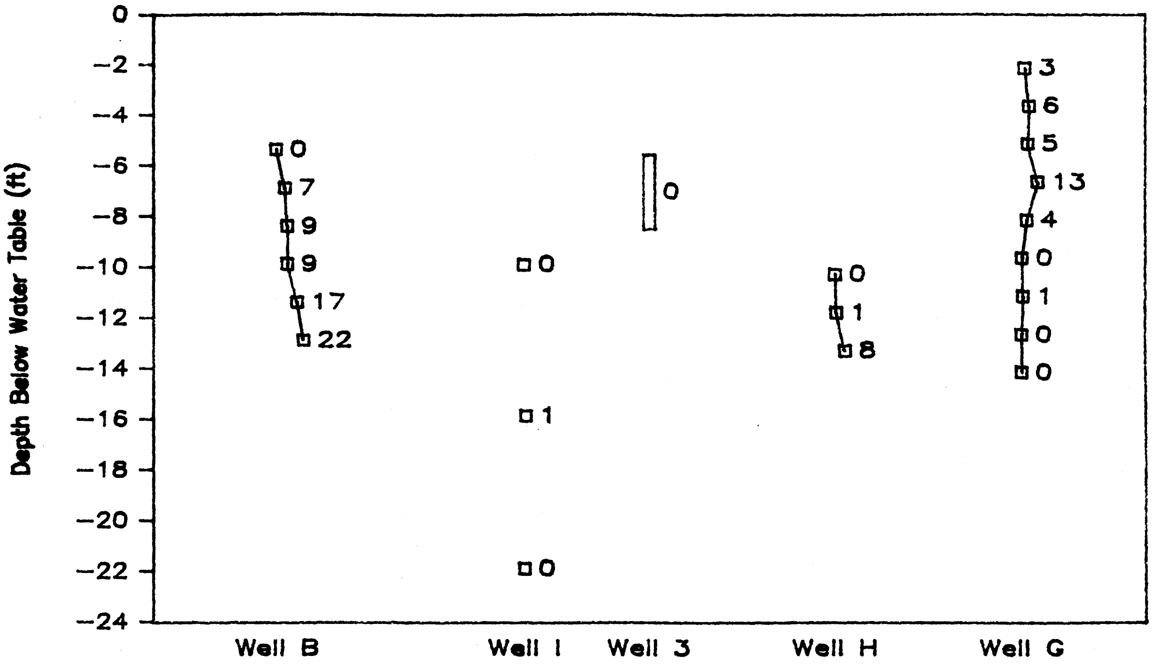


Figure 21. Depth distribution of aldicarb residue concentrations below water table between Wells B and G on March 13, 1983.

was observed to move downward per year this 8 foot difference appears much too great to be due to differences in the distance from Field A.

Groundwater conditions in this area may vary from those occurring in other areas. While pH and alkalinity concentrations were not significantly higher than those occurring in other contaminated wells perhaps bacteria concentrations were higher. Or perhaps a lesser amount of aldicarb leached up-gradient of Wells I and H. If these wells occurred in relatively denser aquifer materials, contaminated water would probably have largely bypassed them.

A lesser possibility is that a bedrock mound may be altering the groundwater flow in the vicinity of Wells H and I, thus disrupting the aldicarb plume in that vicinity. Manser (1983), upon conducting a seismic survey, discovered such a mound about 100 ft up-gradient and about 35 ft below Well 9, but concluded it would not have a significant effect on groundwater flow.

Relationship Between Certain Inorganic Chemicals and Aldicarb

Various physical, chemical, and biological characteristics in groundwater can break down the aldicarb molecule. Also, some inorganic chemicals may behave (eg. move, disperse) similar to aldicarb in groundwater. By observing the occurrence of aldicarb together with various chemicals in groundwater over time it is possible to determine which, if any, are acting to reduce aldicarb concentrations and which are indicators of aldicarb.

Observed in the groundwater along with aldicarb were temperature, pH, conductivity, alkalinity, total hardness, nitrate+nitrite-N, sulfate, and chloride. Averages of these in the observed portions of the aldicarb plume are listed in Table 6.

Aldicarb sulfoxide is known to break down in neutral to alkaline environments over time (Khasawinah, 1977). Evidence that alkalinity is degrading aldicarb at this site was indicated in the laboratory study, where aldicarb degradation was inversely related to pH and to alkalinity concentrations. Therefore, potential for aldicarb degradation might be indicated by relatively high values for alkalinity, pH, and total hardness. Aldicarb also breaks down in high temperatures so groundwater temperature was observed. Bacteria may be degrading aldicarb in groundwater at this site (Harkin, et. al., 1984) but were not analyzed

Table 6. Averages for aldicarb and inorganic chemical concentrations during the study period.

	Mean	SD	N
Aldicarb (ppb)	17	24	188
Temperature (C)	11.3	3.3	162
Conductivity (umhos)	410	85	188
pH	7.57	0.74	188
Alkalinity (ppm)	45	21	188
Total Hardness (ppm)	181	41	188
Nitrate+nitrite-N (ppm)	26	6	187
Sulfate (ppm)	21	7	187
Chloride (ppm)	28	12	186

for in this study.

Concentrations of nitrate+nitrite-N, sulfate, and chloride in the groundwater were compared to those of aldicarb to determine if they behave similarly in the groundwater over time. They were observed because they were applied in fertilizers generally at the same time aldicarb was applied and because they are highly water soluble and relatively non-reactive. Thus they may be indicators of aldicarb's location, movement, and dispersion in the groundwater.

Figures 22 to 24 show concentration profiles for the chemicals and aldicarb in multi-level wells A, B, C and D over time. Figure 25 shows the average concentrations of aldicarb and chemicals in Wells A and B over time.

The average alkalinity of the groundwater contaminated with aldicarb was 45 ppm (SD 21 ppm). Degradation of aldicarb via alkaline hydrolysis was indicated in the laboratory study and probably occurs slowly over long time periods.

Certain chemicals may be indicators of aldicarb's movement in groundwater. Various concentration zones of the chemicals occurred and moved with the aldicarb maximum concentration layer over time. A good example of this is seen with sulfate in Wells A, B, C and D (Figs. 22i, 23i, and 24i). In Well B (Fig. 23i) in February 1982 the sulfate concentration occurring in the maximum aldicarb concentration layer was about 12 ppm. This concentration zone tracked with the aldicarb layer for most of the study

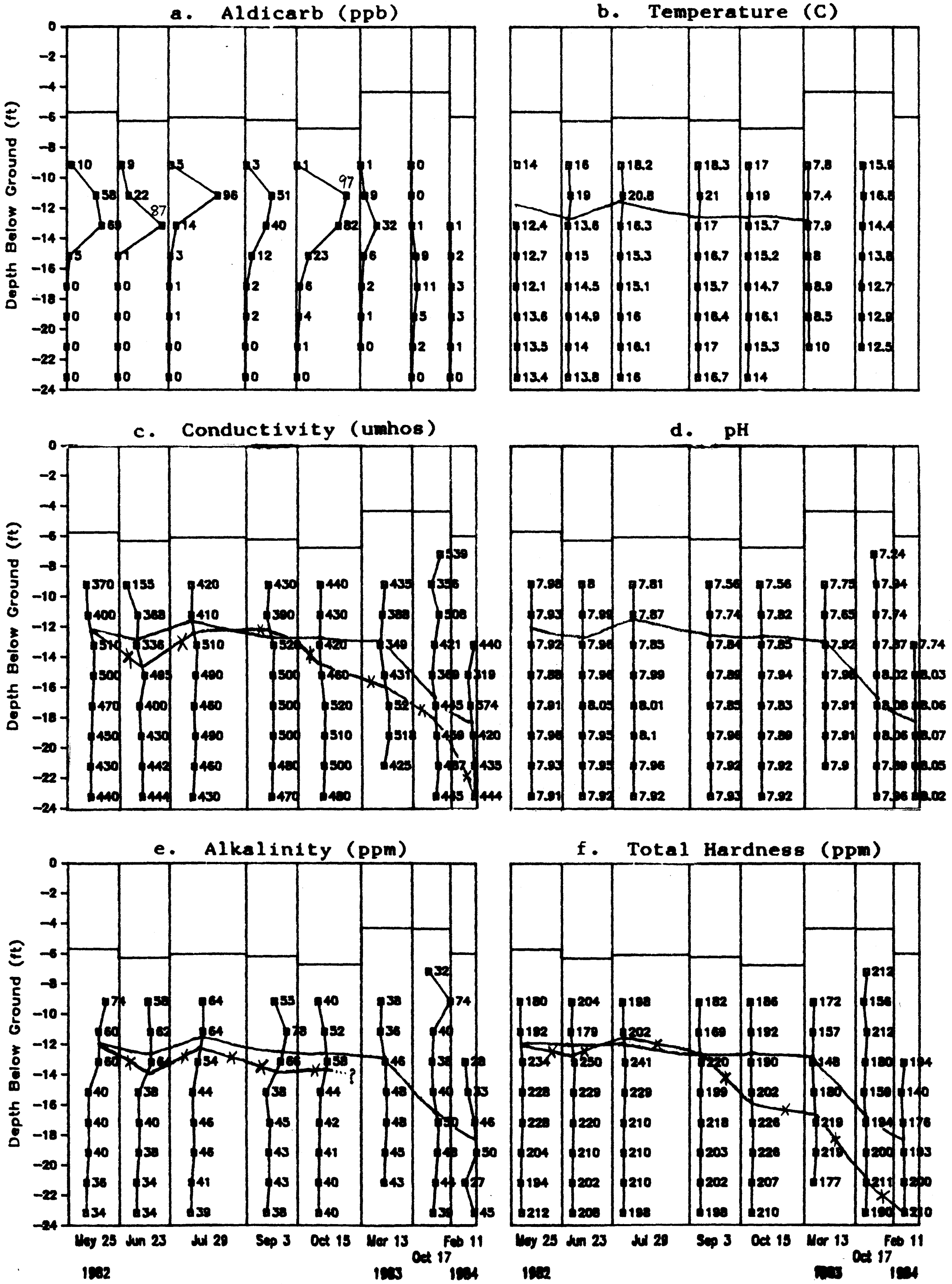


Figure 22a-i. Depth distribution of aldicarb residue and chemical concentrations, and water table level (———), below ground level in Well A. The plain curve (⁀‿) marks the level of the aldicarb maximum concentration layer. The x'ed curve (‿x‿x⁀) marks the level of the chemical concentration zone which tracked with the aldicarb layer.

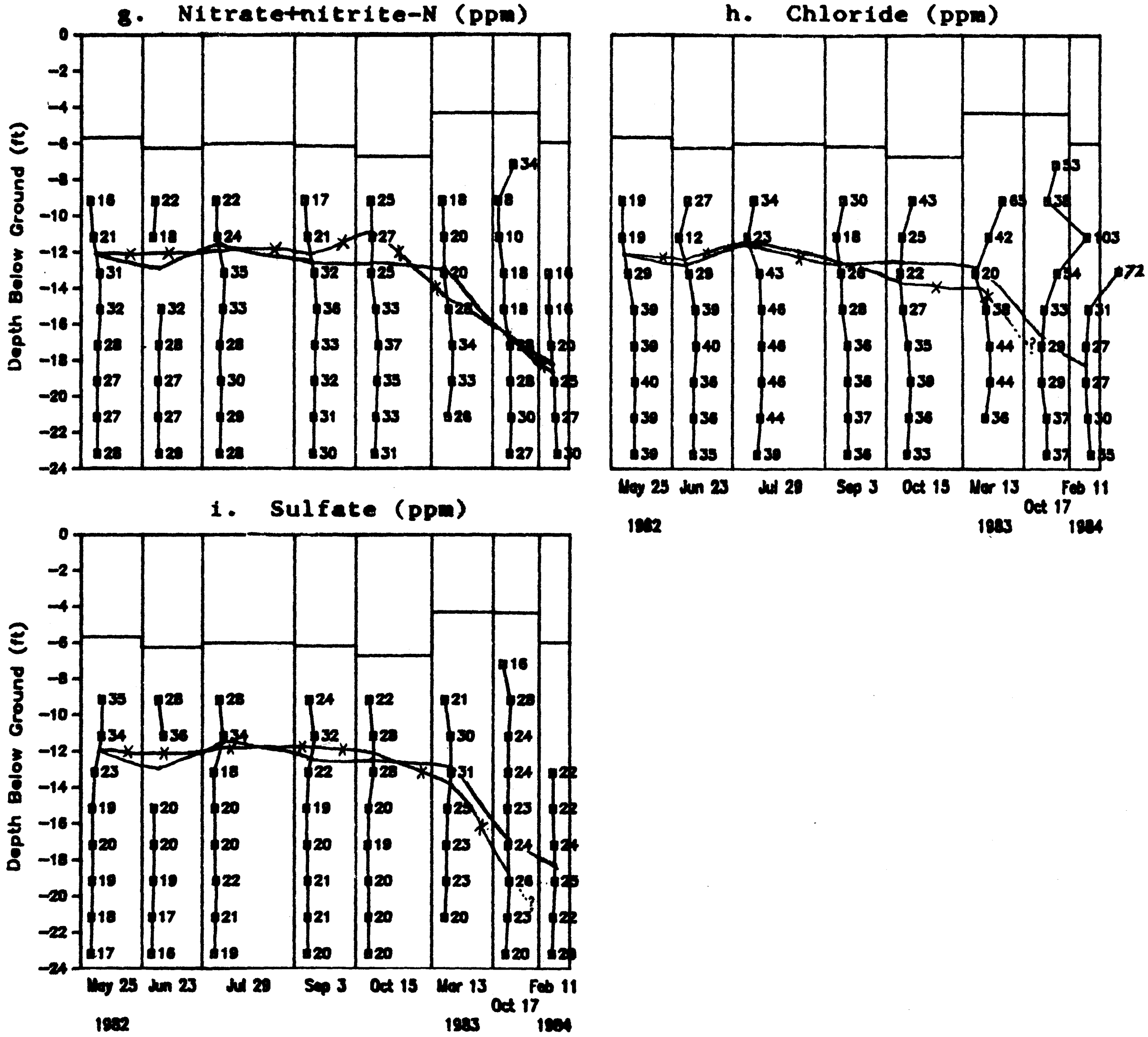


Figure 22a-i. Depth distribution of aldicarb residue and chemical concentrations, and water table level (———), below ground level in Well A. The plain curve (⁀‿) marks the level of the aldicarb maximum concentration layer. The x'ed curve (⁀x‿x⁀) marks the level of the chemical concentration zone which tracked with the aldicarb layer.

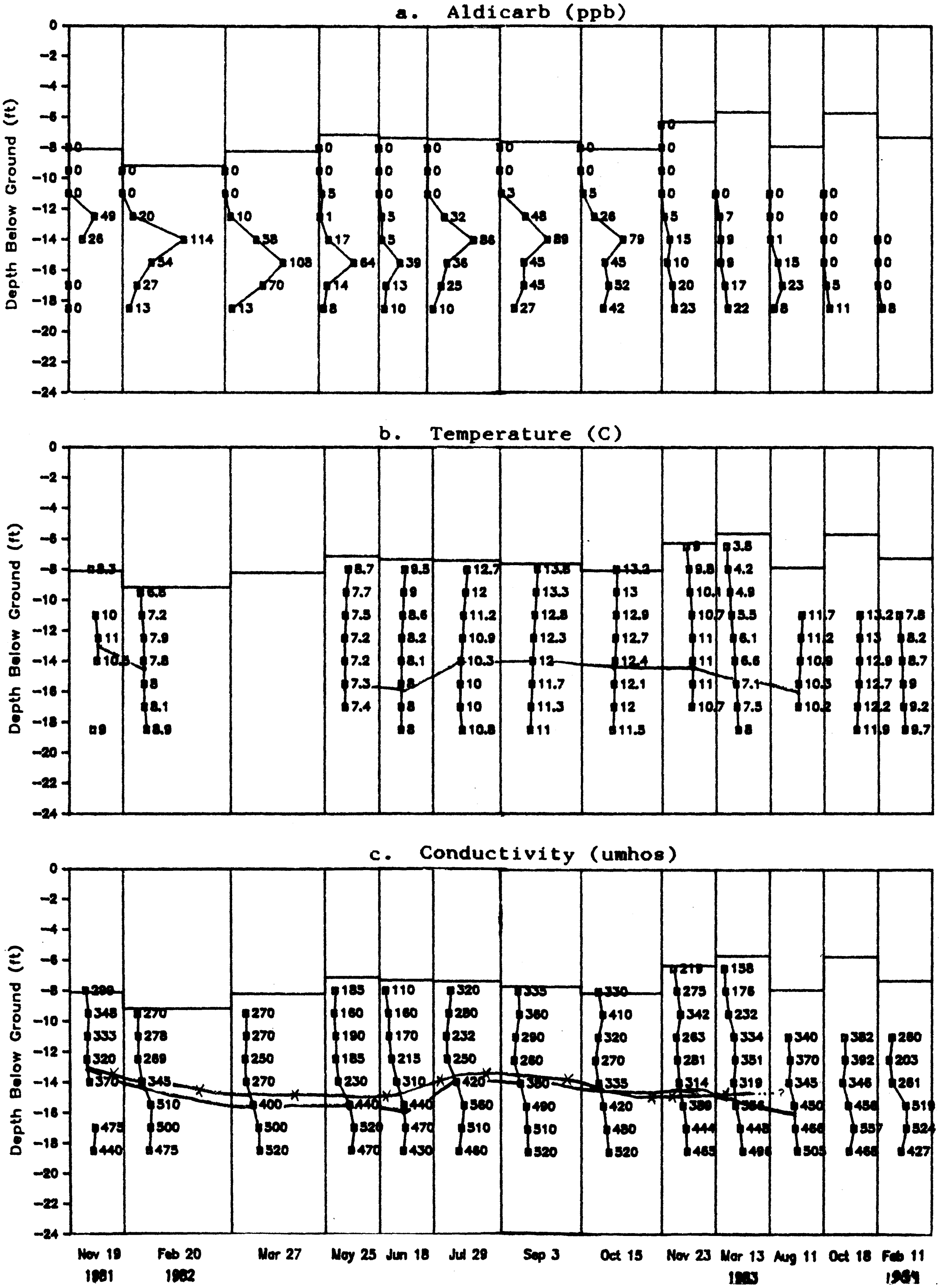


Figure 23a-i. Depth distribution of aldicarb residue and chemical concentrations, and water table level (———), below ground level in Well B. The plain curve (⁀) marks the level of the aldicarb maximum concentration layer. The x'ed curve (-x-x-) marks the level of the chemical concentration zone which tracked with the aldicarb layer.

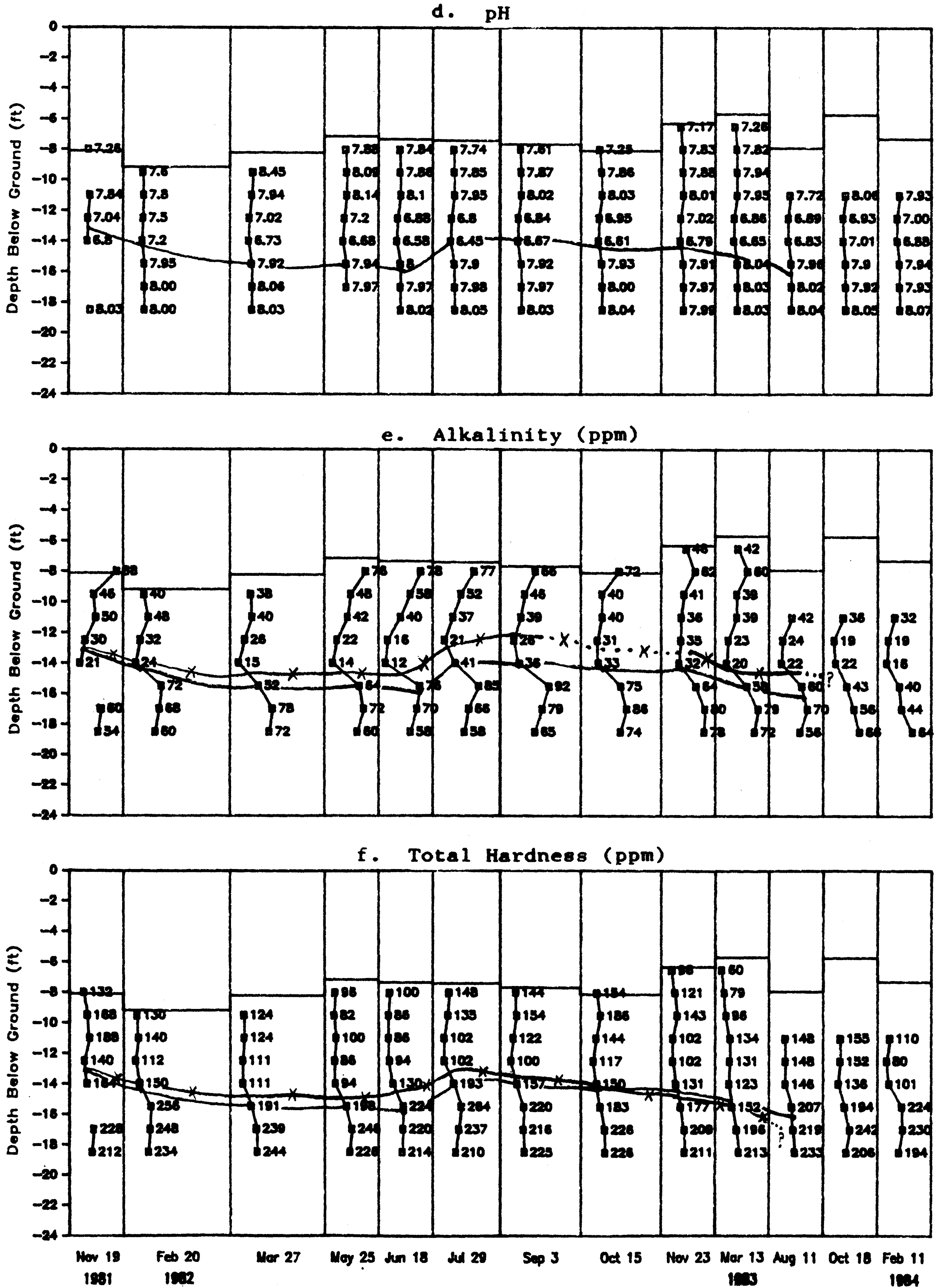
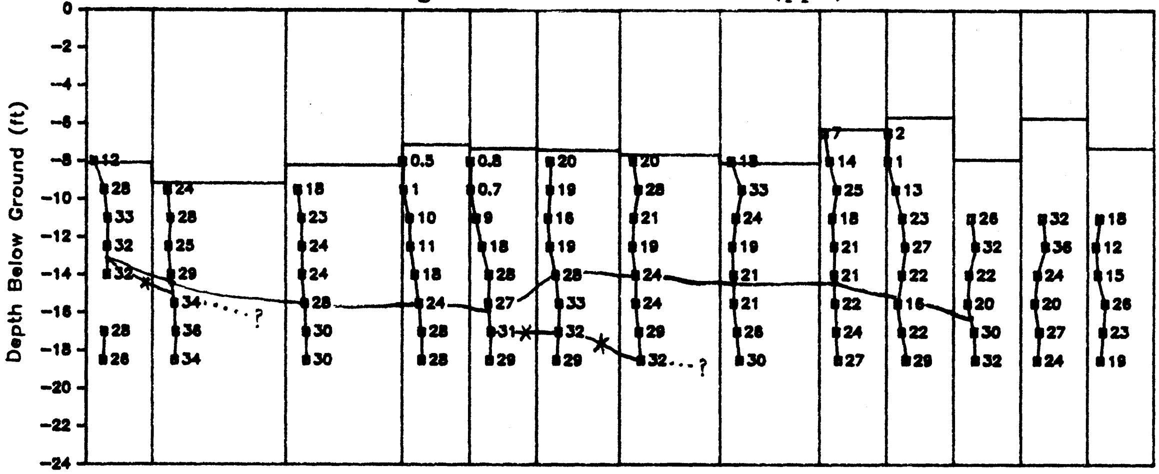
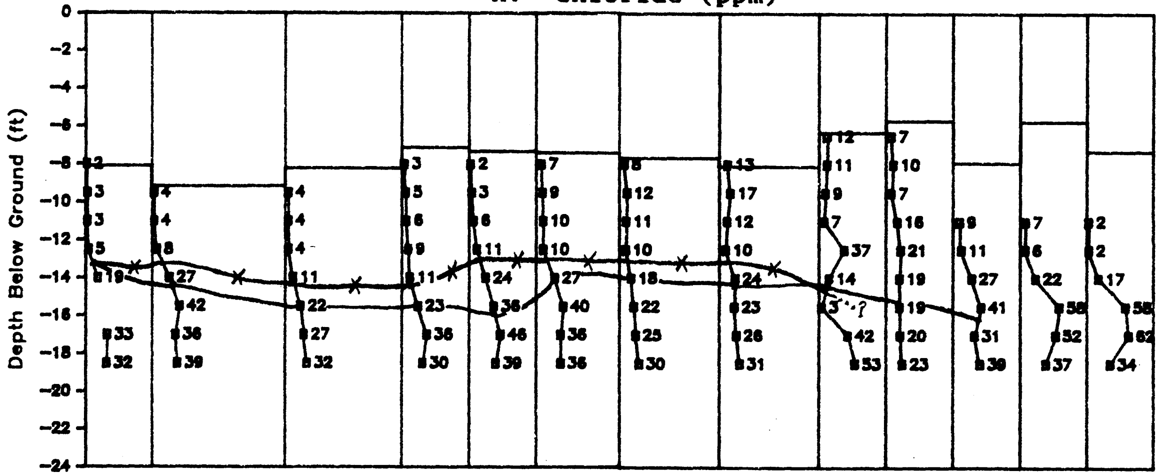


Figure 23a-i. Depth distribution of aldicarb residue and chemical concentrations, and water table level (———), below ground level in Well B. The plain curve (⁀‿) marks the level of the aldicarb maximum concentration layer. The x'ed curve (⁀x‿x⁀) marks the level of the chemical concentration zone which tracked with the aldicarb layer.

g. Nitrate+nitrite-N (ppm)



h. Chloride (ppm)



i. Sulfate (ppm)

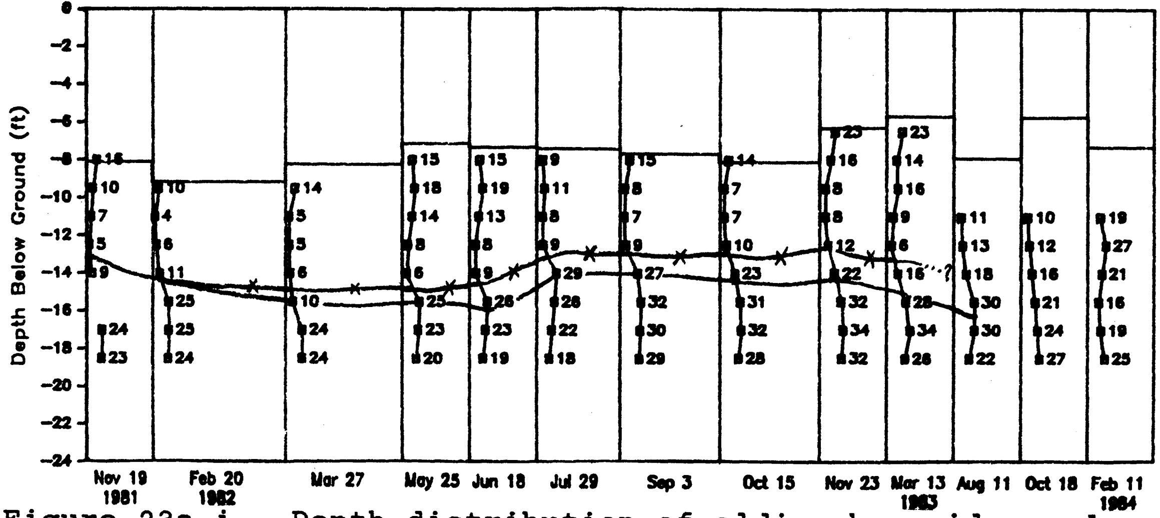


Figure 23a-i. Depth distribution of aldicarb residue and chemical concentrations, and water table level (———), below ground level in Well B. The plain curve (⁀) marks the level of the aldicarb maximum concentration layer. The x'ed curve (—x—x—) marks the level of the chemical concentration zone which tracked with the aldicarb layer.

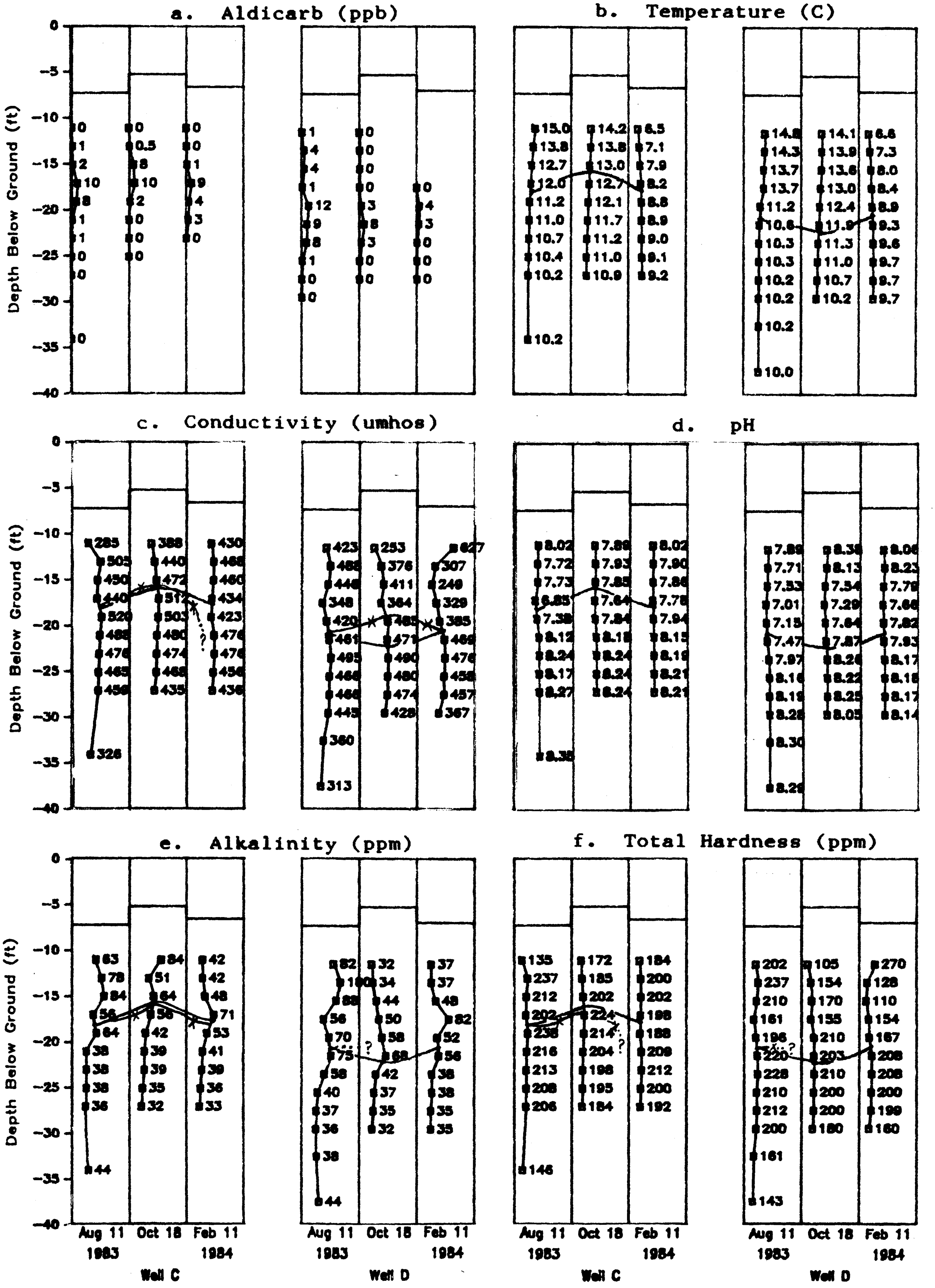
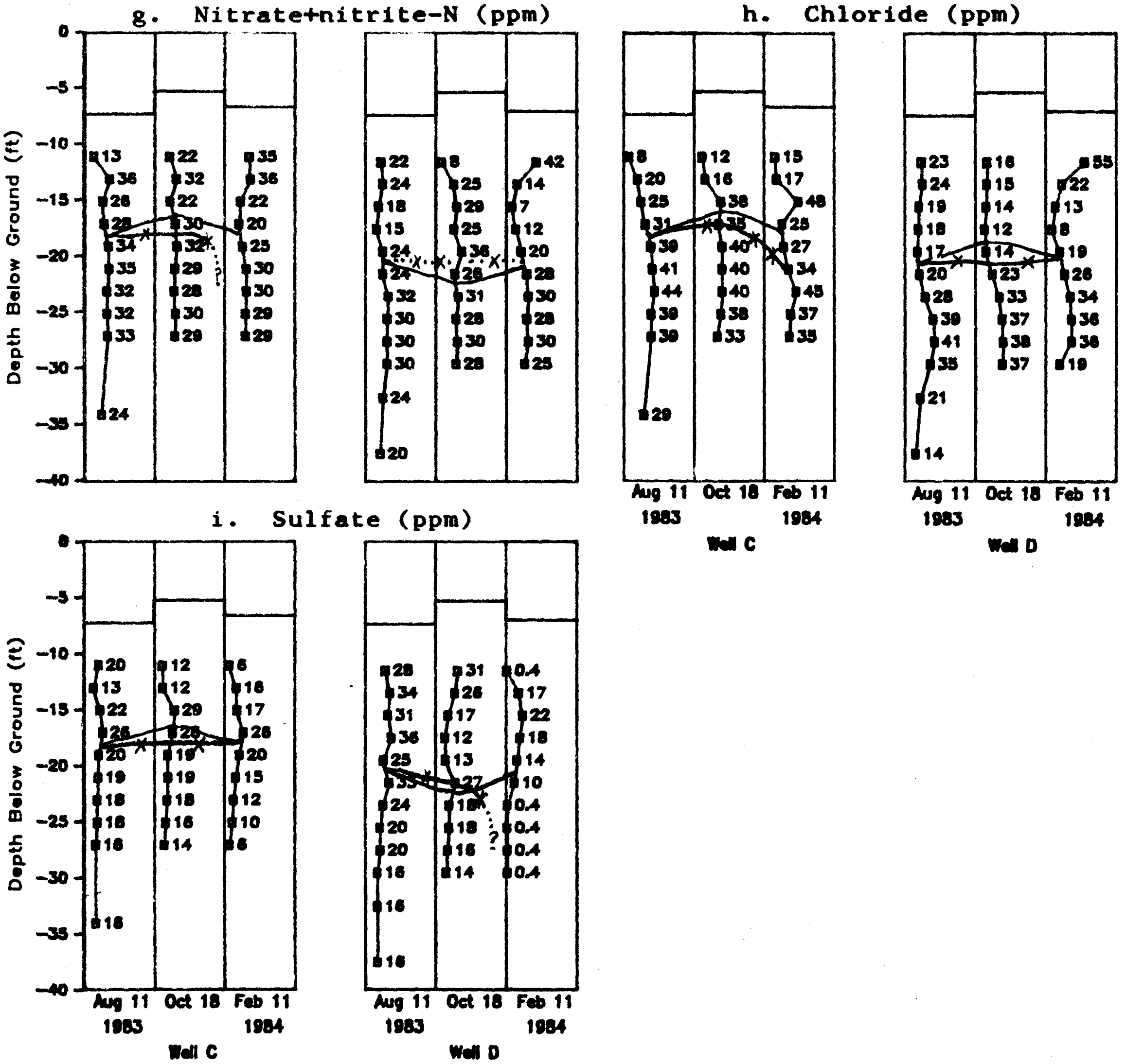


Figure 24a-i. Depth distribution of aldicarb residue and chemical concentrations, and water table level (———), below ground level in Wells C and D. The plain curve (⁀) marks the level of the aldicarb maximum concentration layer. The x'ed curve (-x-x-) marks the level of the chemical concentration zone which tracked with the aldicarb layer.



g. Nitrate+nitrite-N (ppm)

h. Chloride (ppm)

i. Sulfate (ppm)

Figure 24a-i. Depth distribution of aldicarb residue and chemical concentrations, and water table level (———), below ground level in Wells C and D. The plain curve (⁀) marks the level of the aldicarb maximum concentration layer. The x'ed curve (⁀x⁀x⁀) marks the level of the chemical concentration zone which tracked with the aldicarb layer.

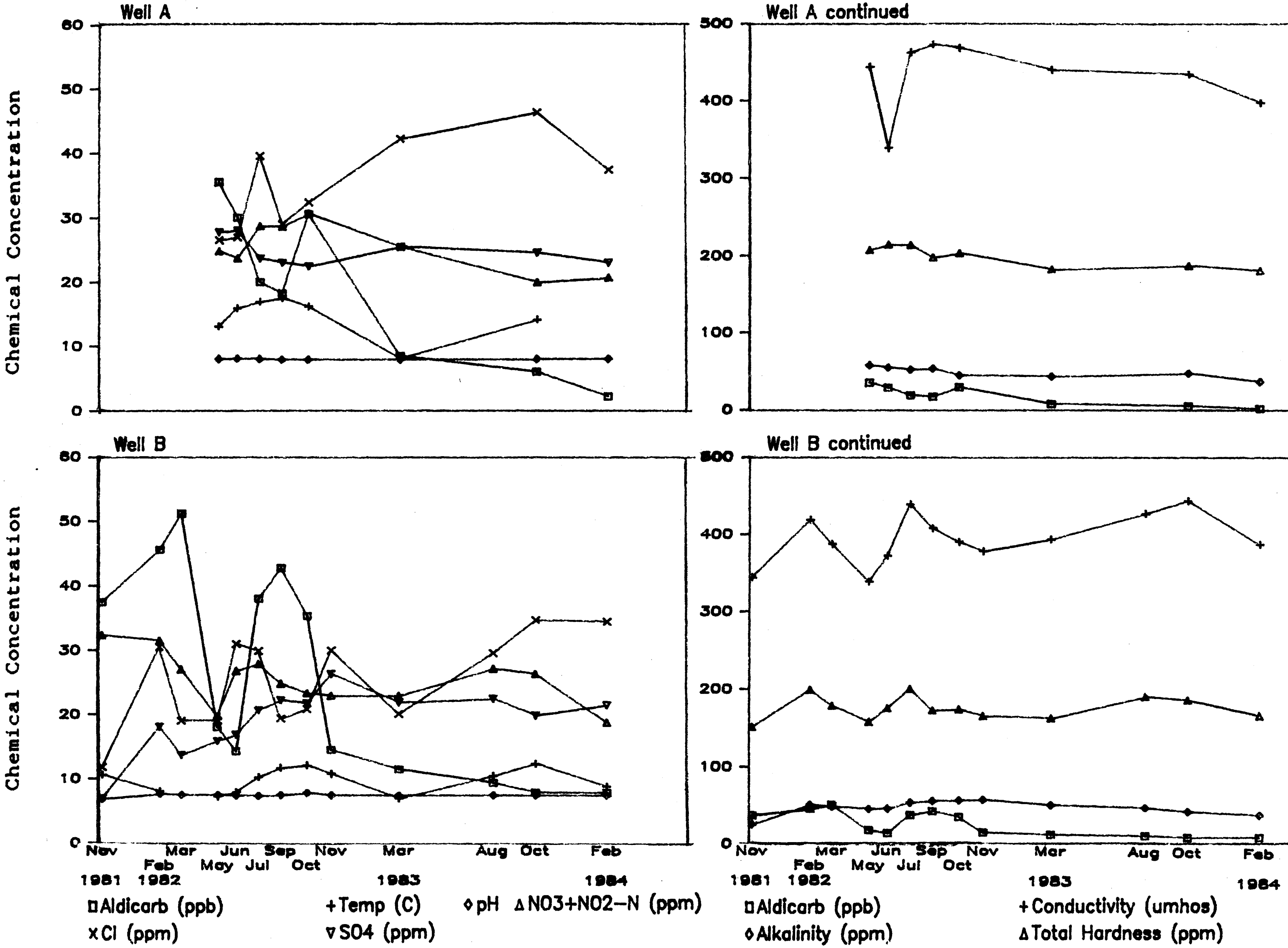


Figure 25. Average values for aldicarb residue and parameter concentrations within the observed portion of the plume in Wells A and B.

period in this well. Similar relationships were observed for aldicarb and chloride in Well B (Fig. 23h) and with nitrate in Well A (Fig. 22g). Conductivity tracked very well with aldicarb in Wells A (Fig. 22c) and B (Fig. 23c). Alkalinity and total hardness concentration zones also appear to track well with the aldicarb layer (Figs. 22 and 23 - e and f). Table 7 shows there were high positive correlations for the depths of aldicarb vs. conductivity and sulfate in both Wells A and B, and vs. total hardness and nitrate+nitrite-N in Well A only.

Note again that the last quarter of the sampling dates for Wells A and B (Figs. 22 and 23) span a time period of about one year, as do the first three-quarters of the sampling dates for those wells. This variability should account for the apparent sudden downward movement of aldicarb later in the study period. Likewise, the disappearance of some chemical concentration zones later in the study probably resulted as the zones moved beneath the

Table 7. Correlations (r) between depths below ground level (ft) of the aldicarb maximum concentration layer and the chemical concentration zones that tracked with the aldicarb layer in Wells A and B during the study period.

	Well A	Well B
Conductivity	.95**	.85**
Alkalinity	.74	.82*
Total Hardness	.95**	.72*
Nitrate+nitrite-N	.95**	--
Chloride	.84*	.54
Sulfate	.98*	.86**

** Significant at .01 level
* Significant at .05 level

lowest well sample points.

Though there are high positive correlations between the depths of the aldicarb maximum concentration layer and the depths of certain chemical concentration zones, this seems an unlikely occurrence. This because of varying quantities of these materials applied on the land, varying solubilities of these materials, and varying depths to the water table over the study site. But the chemical concentrations were usually quite similar from well to well (Table 8), and the concentrations that tracked with aldicarb in one well usually tracked with it in another, even though the initial concentrations at times varied considerably (Figs. 22 and 23).

Groundwater temperatures apparently followed seasonal

Table 8. Averages for the chemical concentrations which occurred with the maximum aldicarb concentration in the multi-level wells during the study period.

Well		Cond ppm	Alk ppm	THard ppm	$NO_{2,3}$ ppm	Cl ppm	SO_4 ppm
A	Mean	406	57.5	195.6	25.6	25.0	28.0
	S.D.	53	10.4	31.3	3.8	4.0	4.1
	N	8	8	8	7	8	7
B	Mean	385	45.8	175.3	26.4	22.7	20.8
	S.D.	51	17.5	31.9	3.6	8.3	8.4
	N	10	10	10	10	10	10
C	Mean	462	61.0	208.0	26.0	30.3	26.0
	S.D.	35	7.1	11.4	4.3	4.1	0.0
	N	3	3	3	3	3	3
D	Mean	425	63.3	188.7	26.0	19.7	22.0
	S.D.	35	8.1	15.6	1.6	2.5	5.7
	N	3	3	3	3	3	3

air temperatures, being generally higher near the water table and decreasing with depth in summer and fall, and being lower near the water table and increasing with depth in winter and spring (Figs. 23b and 24b). The highest observed groundwater temperature was 13.8 C (Fig. 24b). Temperatures for Wells A, E, F, I and J were not considered accurate as the sections of tubing above ground were long and groundwater moved through them slowly giving the water time to absorb or lose heat. Temperature apparently levels off at about 10.0 C about 30 ft below the water table (38 ft below ground) (Fig. 24b). There was no apparent relationship between groundwater temperature and aldicarb concentrations.

Alkalinity, pH, and total hardness appeared to correlate highly and positively with each other, as expected. In Well B a low concentration layer of these materials occurred consistently in the groundwater between 12 and 14 ft below ground level (Fig. 23d, e and f). Considerably higher values occurred above and below this layer. The consistency in depth of these layers below the ground surface seems to suggest they are a function of the aquifer materials, perhaps alternating layers of carbonate and non-carbonate bearing materials, rather than a result of solute inputs to the groundwater. But this occurrence is not observed in Wells A, C and D (Figs. 22 and 24 - d, e, and f). And in Well B the lower level high alkalinity layer appears to be moving lower into the groundwater in October 1983. The low alkalinity concentration layer in Well B remains at the same level, however. This occurrence conceivably could have been caused by restriction of liming during the 1980 growing season.

It is evident that conservative chemicals like nitrate+nitrite-N, chloride, and sulfate in groundwater move at the same rate as aldicarb. This indicates that these materials, after entering groundwater with aldicarb or similar pesticides, may indicate the position and movement of the pesticides in the groundwater.

CONCLUSIONS

1. Aldicarb (residue) was present in the groundwater throughout the study period of November 1981 to April 1984. It occurred in a distinct plume characterized by a high aldicarb concentration in its mid-section, and lesser aldicarb concentrations which decreased to 0 ppb above and below this layer.

2. At the expected groundwater flow rate for this site of between 1.1 to 1.5 ft/day the aldicarb plume would have been carried between 1537 and 2096 ft, respectively. Observation of a second aldicarb plume in the groundwater indicated the plume was traveling at a rate of 1.4 ft/day. At this flow rate the plume would have traveled 1956 ft by April 1984.

3. Vertical advection of the aldicarb plume was observed to occur. The aldicarb maximum concentration layer remained at a relatively constant depth over at least an 11 month period and then moved downward 5-10 ft during the next year. The depth of this layer below the water table averaged 6.7 ft early in the study and 12.7 ft later in the study. The shallowest depth of the plume upper boundary was 4.4 ft, whereas the deepest depth of the lower boundary was 18.3 ft. Vertical advection probably resulted from the combined effects of groundwater recharge and discharge.

4. Plume thickness increased and then decreased. The maximum thickness was 14 ft but was probably the result of two aldicarb plumes combining. The maximum thickness of a

single plume was observed to be 9 ft. The decrease in thickness was believed due to aldicarb degradation which eventually exceeded the rate of dispersion.

5. Aldicarb concentrations in the groundwater were reduced by about 97% from the highest aldicarb concentrations. The half-life of aldicarb was calculated to be 206 days. This reduction is believed to be caused by a combination of dispersion, alkaline hydrolysis, and bacteria in the groundwater.

Aldicarb concentrations in a laboratory study had half-lives between 1915 and 479 days, respectively. Alkalinity concentrations were inversely related to aldicarb degradation and were apparently a major degradation factor.

6. The observed aldicarb dispersion pattern did not occur in all of the contaminated wells. This indicates that this pattern can not be expected to be the same throughout the plume, and that the plume may be disrupted by various, albeit unknown, factors in the groundwater.

7. Aldicarb appears to move similarly with various inorganic chemicals in the groundwater. This supports the idea that conservative anions may indicate the position and movement of aldicarb and similar pesticides in groundwater.

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APPENDIX A

Information on Wells A,B,C and D.

Well No.	Casing Top to Sample Point (ft)	Casing Top to Ground (ft)	Grd to Sample Point (ft)	Screen Length (ft)	Casing Inside Diameter (in)	Elev. Casing Top (ft)	Elev. of Ground (ft)	Elev. Screen (ft)
A1	5.56	(1.6)	7.16	0.005	0.06	(2.92)	(1.32)	8.48
A2	7.56		9.16	0.005	0.06			10.48
A3	9.59		11.16	0.005	0.06			12.48
A4	11.56		13.16	0.005	0.06			14.48
A5	13.56		15.16	0.005	0.06			16.48
A6	15.56		17.16	0.005	0.06			18.48
A7	17.56		19.16	0.005	0.06			20.48
A8	19.56		21.16	0.005	0.06			22.48
A9	21.56		23.16	0.005	0.06			24.48
B1	8.0	(+1.5)	6.5	0.5	0.5	(+1.12)	(+0.38)	6.88
B2	9.5		8.0	0.5	0.5			8.38
B3	11.0		9.5	0.5	0.5			9.88
B4	12.5		11.0	0.5	0.5			11.38
B5	14.0		12.5	0.5	0.5			12.88
B6	15.5		14.0	0.5	0.5			14.38
B7	17.0		15.5	0.5	0.5			15.88
B8	18.5		17.0	0.5	0.5			17.38
B9	20.0		18.5	0.5	0.5			18.88
C1	9.60	(1.5)	11.10	0.3	0.25	(2.66)	(1.16)	12.26
C2	11.60		13.10	0.3	0.25			14.26
C3	13.60		15.10	0.3	0.25			16.26
C4	15.60		17.10	0.3	0.25			18.26
C5	17.60		19.10	0.3	0.25			20.26
C6	19.60		21.10	0.3	0.25			22.26
C7	21.60		23.10	0.3	0.25			24.26
C8	23.60		25.10	0.3	0.25			26.26
C9	25.60		27.10	0.3	0.25			28.26
C10	32.60		34.10	0.3	0.25			35.26
C11	37.60		39.10	0.3	0.25			38.26
D1	10.06	(1.5)	11.56	0.3	0.25	(2.63)	(1.13)	12.69
D2	12.06		13.56	0.3	0.25			14.69
D3	14.06		15.56	0.3	0.25			16.69
D4	16.06		17.56	0.3	0.25			18.69
D5	18.06		19.56	0.3	0.25			20.69
D6	20.06		21.56	0.3	0.25			22.69
D7	22.06		23.56	0.3	0.25			24.69
D8	24.06		25.56	0.3	0.25			26.69
D9	26.06		27.56	0.3	0.25			28.69
D10	28.06		29.56	0.3	0.25			30.69
D11	31.06		32.56	0.3	0.25			33.69
D12	36.06		37.56	0.3	0.25			38.69

Information on Wells E,F,G and H.

Well No.	Casing Top to Sample Point (ft)	Casing Top to Ground (ft)	Grd to Sample Point (ft)	Screen Length (ft)	Casing Inside Diameter (in)	Elev. Casing Top (ft)	Elev. of Ground (ft)	Elev. Screen (ft)
E1	1.94	(1.7)	3.64	0.005	0.06	(3.21)	(1.51)	5.15
E2	3.94		5.64	0.005	0.06			7.15
E3	5.94		7.64	0.005	0.06			9.15
E4	7.94		9.64	0.005	0.06			11.15
E5	9.94		11.64	0.005	0.06			13.15
E6	11.94		13.64	0.005	0.06			15.15
E7	13.94		15.64	0.005	0.06			17.15
E8	15.94		17.64	0.005	0.06			19.15
E9	17.94		19.64	0.005	0.06			21.15
E10	19.94		21.64	0.005	0.06			23.15
F1	5.39	(1.4)	6.79	0.005	0.06	(5.04)	(4.44)	11.23
F2	7.39		8.79	0.005	0.06			13.23
F3	9.39		10.79	0.005	0.06			15.23
F4	11.39		12.79	0.005	0.06			17.23
F5	13.39		14.79	0.005	0.06			19.23
F6	15.39		16.79	0.005	0.06			21.23
F7	17.39		18.79	0.005	0.06			23.23
F8	19.39		20.79	0.005	0.06			25.23
F9	21.39		22.79	0.005	0.06			27.23
F10	23.39		24.79	0.005	0.06			29.23
G1	8.0	(+0.88)	7.12	0.5	0.5	(+0.33)	(+0.55)	7.67
G2	9.5		8.62	0.5	0.5			9.17
G3	11.0		10.12	0.5	0.5			10.67
G4	12.5		11.62	0.5	0.5			12.17
G5	14.0		13.12	0.5	0.5			13.67
G6	15.5		14.62	0.5	0.5			15.17
G7	17.0		16.12	0.5	0.5			16.67
G8	18.5		17,62	0.5	0.5			18.17
G9	20.0		19.12	0.5	0.5			19.67
H1	8.0	(+1.6)	6.4	0.5	0.5	(+0.45)	(1.15)	7.55
H2	9.5		7.9	0.5	0.5			9.05
H3	11.0		9.4	0.5	0.5			10.55
H4	12.5		10.9	0.5	0.5			12.05
H5	14.0		12.4	0.5	0.5			13.55
H6	15.5		13.9	0.5	0.5			15.05
H7	17.0		15.4	0.5	0.5			16.55
H8	18.5		16.9	0.5	0.5			18.05
H9	20.0		18.4	0.5	0.5			19.55

APPENDIX A, continued

Information on Wells I and J.

Well No.	Casing Top to Sample Point (ft)	Casing Top to Ground (ft)	Grd to Sample Point (ft)	Screen Length (ft)	Casing Inside Diameter (in)	Elev. Casing Top (ft)	Elev. of Ground (ft)	Elev. Screen (ft)
I1	5.81	(1.6)	7.41	0.005	0.06	(4.74)	(3.14)	10.55
I2	7.81		9.41	0.005	0.06			12.55
I3	9.81		11.41	0.005	0.06			14.55
I4	11.81		13.41	0.005	0.06			16.55
I5	13.81		15.41	0.005	0.06			18.55
I6	15.81		17.41	0.005	0.06			20.55
I7	17.81		19.41	0.005	0.06			22.55
I8	19.81		21.41	0.005	0.06			24.55
I9	21.81		23.41	0.005	0.06			26.55
I10	23.81		25.41	0.005	0.06			28.55
J1	9.98	(1.00)	8.98	0.005	0.06	(+1.67)	(+0.67)	8.31
J2	11.98		10.98	0.005	0.06			10.31
J3	13.98		12.98	0.005	0.06			12.31
J4	15.98		14.98	0.005	0.06			14.31
J5	17.98		16.98	0.005	0.06			16.31
J6	19.98		18.98	0.005	0.06			18.31
J7	21.98		20.98	0.005	0.06			20.31
J8	23.98		22.98	0.005	0.06			22.31
J9	25.98		24.98	0.005	0.06			24.31
J10	27.98		26.98	0.005	0.06			26.31

Information on Standard PVC wells.

Well No.	Casing Top to Sample Point (ft)	Casing Top to Ground (ft)	Grd to Sample Point (ft)	Screen Length (ft)	Casing Inside Diameter (in)	Elev. Casing Top (ft)	Elev. of Ground (ft)	Elev. Screen (ft)
1b	9.63	+0.66	8.97	3.00	1.25	+0.51	0.15	9.12
1c	14.59	+1.24	13.35	3.00	1.25	+1.09	0.15	13.50
2b	10.97	+1.26	9.71	3.00	1.25	+0.31	0.95	10.66
2b2	11.85	+1.78	10.07	3.00	1.25	+0.83	0.95	11.02
2c	15.65	+1.75	13.90	3.00	1.25	+0.00	0.95	14.85
3c	16.40	+3.05	13.35	3.00	1.25	+0.49	2.56	15.91
4a	10.50	+2.72	7.78	3.00	1.25	+2.72	0.00	7.78
4c	17.85	+3.91	13.94	3.00	1.25	+3.91	0.00	13.94
4d	33.00	+4.00	29.00	3.00	1.25	+4.00	0.00	29.00
5a	12.79	+3.13	9.66	3.00	1.25	+5.63	+2.50	7.16
5b	17.77	+3.52	14.25	3.00	1.25	+6.02	+2.50	11.75
6a	11.97	+2.38	9.59	3.00	1.25	+7.41	+5.03	4.56
6c	15.10	+1.72	13.33	3.00	1.25	+6.80	+5.03	8.30
6d	32.98	+2.79	30.19	3.00	1.25	+7.82	+5.03	25.16
7b	13.15	+0.40	12.75	3.00	1.25	+3.69	+3.29	9.46
7b2	15.01	+1.88	13.21	3.00	1.25	+5.09	+3.29	9.92
7c	20.34	+2.46	17.88	3.00	1.25	+5.75	+3.29	14.59
8b	9.59	+2.92	6.54	3.00	1.25	5.43	8.35	15.02
8c	15.07	+1.20	13.87	3.00	1.25	7.15	8.35	21.79
8d	33.02	+1.63	31.39	3.00	1.25	6.72	8.35	40.17
9b	10.99	+2.20	8.79	3.00	1.25	2.45	4.65	13.44
9c	15.63	+2.22	13.02	3.00	1.25	2.43	4.65	18.08
10b	13.13	+3.58	9.55	3.00	1.25	1.36	4.94	14.49
10c	16.07	+2.77	13.30	3.00	1.25	2.17	4.94	18.24
11b	--	--	--	3.00	1.25	--	--	--
12c	23.66	+0.32	23.34	1.00	1.25	0.03	1.15	24.57
12d	29.40	+1.27	28.13	1.00	1.25	+0.12	1.15	29.43
13d	27.70	+1.40	26.30	3.00	1.25	--	--	--
14b	21.78	+7.40	14.38	3.00	1.25	+6.89	0.51	14.89
14c	21.78	+2.65	19.13	3.00	1.25	+2.14	0.51	19.64
15b	20.63	+5.55	15.08	3.00	1.25	+4.90	0.65	15.73
15c	20.92	+1.50	19.42	3.00	1.25	+0.85	0.65	20.07
16b	13.12	+2.29	10.83	3.00	1.25	0.41	2.70	13.53
16b2	22.97	+0.14	14.83	3.00	1.25	+5.44	2.70	17.53
16c	23.25	+4.43	18.82	3.00	1.25	+1.73	2.70	21.52
17b	17.02	+1.62	15.40	3.00	1.25	1.94	3.56	18.96
17c	24.33	+4.67	19.66	3.00	1.25	+0.67	3.56	23.66

APPENDIX B

Numerical alteration of nested well dimensions to accomodate differences in ground elevation at each site.

Well No.	Casing Top to Ground (ft)	Ground Elevation (ft)	Ground Elevation Altered (ft)	Ground Elevation Dif. (ft)	Casing Top to Ground-Altered (ft)	Ground to sample Point (ft)	Ground to Sample Point-Altered (ft)
1b	+0.66	0.15	0.15	0.00	+0.66	8.97	8.97
1c	+1.19	0.10	0.15	+0.05	+1.24	13.40	13.35
2b	+1.30	0.99	0.95	0.04	+1.26	9.67	9.71
2b2	+1.60	0.77	0.95	+0.18	+1.78	10.25	10.07
2c	+1.75	0.95	0.95	0.00	+1.75	13.90	13.90
4a	+2.45	+0.27	0.00	+0.27	+2.72	8.05	7.78
4c	+3.95	0.04	0.00	0.04	+3.91	13.90	13.94
4d	+4.00	0.00	0.00	0.00	+4.00	29.00	29.00
5a	+3.20	+2.43	+2.50	0.07	+3.13	9.59	9.66
5b	+3.52	+2.50	+2.50	0.00	+3.52	14.25	14.25
6a	+2.28	+5.13	+5.03	+0.10	+2.38	9.69	9.59
6b	+1.65	+5.15	+5.03	+0.12	+1.77	13.45	13.33
6d	+2.79	+5.03	+5.03	0.00	+2.79	30.19	30.19
7a	+0.40	+3.29	+3.29	0.00	+0.40	12.75	12.75
7b	+1.40	+3.69	+3.29	+0.40	+1.80	13.61	13.21
7c	+2.00	+3.75	+3.29	+0.46	+2.46	18.34	17.88
8b	+2.92	8.35	8.35	0.00	+2.92	6.54	6.54
8c	+1.17	8.32	8.35	+0.03	+1.20	13.90	13.87
8d	+1.78	8.50	8.35	0.15	+1.63	31.24	31.39
9b	+2.20	4.65	4.65	0.00	+2.20	8.79	8.79
9c	+1.81	4.24	4.65	+0.41	+2.22	13.43	13.02
10b	+3.33	4.69	4.94	+0.25	+3.58	9.80	9.55
10c	+2.77	4.94	4.94	0.00	+2.77	13.30	13.30
12c	+0.60	1.43	1.15	0.28	+0.32	23.06	23.34
12d	+1.50	1.38	1.15	0.23	+1.27	27.90	28.13
H	+1.60	1.15	1.15	0.00	+1.60	6.40	6.40

APPENDIX C

Distances of wells from areas of aldicarb application and from well 7.

Well No.	Distance From Well No. 7 (ft)	Distance From Field Treated in 1979 (ft)	Distance From Field Treated in 1980 (ft)	Length of Aldicarb Plume Passing Well (ft)
A	1226	1236	0	2490
B	1523	1454	200	2515
C	1622	1553	299	2515
D	1719	1650	396	2515
E	2194	2204	919	2540
F	2796	2806	1504	2540
G	1234	888	136	2120
H	1701	1454	505	2318
I	1879	1740	626	2416
J	2296	2071	1048	2342
1	-592	--	--	0
2	493	70	70	962
3	1677	1454	431	2367
4	1533	1463	210	2564
5	957	1480	1282	1479
6	-1381	--	--	0
7	0	10	10	1257
8	4019	4167	2885	2293
9	3156	3156	1835	2589
10	3600	4019	2712	1972
11	3082	3501	2194	1751
12	1701	1454	505	2318
13	1781	1549	600	2268
14	1906	1837	593	2540
15	2149	2080	836	2540
16	2459	2380	1136	2564
17	2950	2871	1627	2589

APPENDIX D

Operating conditions of Tracor Model 560 gas chromatograph.

Operating temperatures, C	
Oven (column)	175
Detector	200
Injector	200
Gas flow rates, ml/min	
Nitrogen	5
Air	100
Hydrogen	50
Glass column	
Length, cm	100
Inside diameter, mm	2
Packing	
stationary phase	5% SP-1000
support	Supel coport 100/120
Injection volume, ul	4
Input current, amps	4×10^{-10} to 5×10^{-9}
Detection limit, ppb	1

APPENDIX E

Groundwater chemistry data for wells sampled November 15, 1981.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
B3	11-15-81	--	--	7.97	370	57.8	169	27.8	4.1	14	0
B4	11-15-81	--	--	8.05	410	57.8	180	32.5	4.7	8	0
B5	11-15-81	--	9.8	7.58	340	58.0	156	29.0	6.5	5	0
B6	11-15-81	--	11.1	7.32	385	38.0	170	29.8	26.3	9	?
B7	11-15-81	--	--	7.65	540	60.0	252	34.0	45.6	23	?
B8	11-15-81	--	12.2	8.14	480	62.4	220	27.5	42.4	24	0
I1	11-15-81	1.53	--	8.09	605	40.0	280	67.0	21.2	15	0
I2	11-15-81	3.53	--	8.15	400	40.0	176	28.0	22.6	18	0
I3	11-15-81	5.53	--	7.85	298	32.2	120	5.0	58.1	18	0
I4	11-15-81	7.53	--	8.08	480	58.0	212	21.2	77.2	13	0
I5	11-15-81	9.53	13.8	8.26	461	42.0	208	20.5	68.5	14	0
I6	11-15-81	11.53	--	8.36	340	67.6	128	12.2	39.8	10	0
I7	11-15-81	13.53	--	8.43	350	36.4	132	14.2	55.9	6	0
I8	11-15-81	15.53	--	8.31	400	33.8	176	27.7	35.5	19	0
I9	11-15-81	17.53	--	8.28	410	32.0	168	28.5	32.3	21	0
I10	11-15-81	19.53	--	8.19	461	34.0	320	30.0	45.1	14	0
J3	11-15-81	2.61	14.6	8.01	470	45.8	204	27.2	44.0	22	0
J4	11-15-81	4.61	13.4	7.83	383	27.6	164	21.5	32.3	22	0
J5	11-15-81	6.61	13.8	8.26	367	50.8	172	22.2	23.5	22	0
J6	11-15-81	8.61	13.8	8.37	420	59.4	200	27.4	21.4	12	0
J7	11-15-81	10.61	15.0	8.33	381	54.6	164	20.5	31.2	14	0
J8	11-15-81	12.61	15.0	8.40	267	52.0	128	10.0	22.3	12	0
J10	11-15-81	16.61	14.0	8.46	190	51.0	88	6.2	7.4	11	0

Groundwater chemistry data for wells sampled November 19, 1981.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
B2	11-19-81	-0.07	8.3	7.26	299	88.4	132	11.6	2.0	16	0
B3	11-19-81	1.43	--	7.82	348	46.0	168	27.5	3.0	10	0
B4	11-19-81	2.93	10.0	7.84	333	50.0	188	33.2	2.9	7	0
B5	11-19-81	4.43	11.0	7.04	320	29.6	140	32.5	4.9	5	49
B6	11-19-81	5.93	10.5	6.80	370	20.8	164	32.2	18.8	9	26
B8	11-19-81	8.93	--	7.75	475	60.2	228	28.2	33.2	24	0
B9	11-19-81	10.43	9.0	8.03	440	54.4	212	26.5	31.5	23	0

Groundwater chemistry data for wells sampled January 31, and February 1 and 20, 1982.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
B3	2-20-82	0.33	6.8	7.60	270	40	130	24.2	3.7	10	0
B4	2-20-82	1.83	7.2	7.80	278	48	140	28.0	3.8	4	0
B5	2-20-82	3.33	7.9	7.50	269	32	112	24.8	8.1	6	20
B6	2-20-82	4.83	7.8	7.20	345	24	150	29.0	27.3	11	114
B7	2-20-82	6.33	8.0	7.95	510	72	256	34.2	41.8	25	54
B8	2-20-82	7.83	8.1	8.00	500	68	248	36.0	36.2	25	27
B9	2-20-82	9.33	8.9	8.00	475	60	234	33.6	39.3	24	13
H9	2-20-82	9.71	--	8.20	320	40	150	21.7	33.3	8	--
I1	2-1-82	0.66	8.5	7.14	200	28	268	62.5	16.3	--	0
I2	2-1-82	2.66	9.0	7.23	134	56	212	31.0	27.4	--	0
I3	2-1-82	4.66	8.6	6.97	690	24	280	66.0	22.8	--	0
I4	2-1-82	6.66	--	7.35	320	56	248	43.6	28.0	--	0
I5	2-1-82	8.66	--	7.57	400	48	172	15.5	44.1	--	0
I6	2-1-82	10.66	8.8	7.47	465	40	196	21.4	40.2	--	0
I7	2-1-82	12.66	12.0	7.45	465	40	200	24.5	40.2	--	0
I8	2-1-82	14.66	12.8	7.44	440	36	192	25.0	32.6	--	0
I9	2-1-82	16.66	12.0	7.32	448	32	196	26.6	32.6	--	0
I10	2-1-82	18.66	12.1	7.34	519	36	212	30.0	40.2	--	0
J3	1-31-82	1.77	11.2	7.15	430	44	204	27.0	35.9	--	0
J4	1-31-82	3.77	11.5	7.06	460	48	208	20.0	65.2	--	0
J5	1-31-82	5.77	12.0	7.45	420	56	224	24.0	43.5	--	0
J6	1-31-82	7.77	11.9	7.47	390	44	180	25.0	26.9	--	0
J7	1-31-82	9.77	11.6	7.54	330	52	176	15.5	32.3	--	0
J8	1-31-82	11.77	12.0	7.86	220	60	104	4.7	16.0	--	0
J10	1-31-82	15.77	12.5	7.39	170	56	88	3.2	5.1	--	0
3c	2-20-82	6.00	--	8.05	350	40	166	23.2	34.4	18	--
4c	2-20-82	4.45	--	7.00	250	16	108	21.2	20.4	11	55
4d	2-20-82	19.40	8.8	7.85	370	36	160	25.2	26.3	13	0
7b	2-20-82	2.81	--	6.85	335	4	144	31.4	18.3	24	45
7c	2-20-82	7.74	--	7.70	355	24	160	29.2	30.1	12	2

APPENDIX E, continued

Groundwater chemistry data for wells sampled March 27, 1982.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	ppm					ppb
B3	3-27-82	1.23	--	8.45	270	38.0	124	18.5	4.2	14	0
B4	3-27-82	2.73	--	7.94	270	39.6	124	23.0	3.7	5	0
B5	3-27-82	4.23	--	7.02	250	26.0	111	23.5	4.2	5	10
B6	3-27-82	5.73	--	6.73	270	15.0	111	24.0	11.2	6	58
B7	3-27-82	7.23	--	7.92	400	52.2	191	27.5	21.5	10	108
B8	3-27-82	8.73	--	8.06	500	78.4	239	30.0	27.2	24	70
B9	3-27-82	10.23	--	8.03	520	72.0	244	30.2	31.5	24	13
I1	3-27-82	1.37	--	7.60	480	20.8	202	44.5	20.6	13	--
I2	3-27-82	3.37	--	7.80	600	36.4	269	60.0	18.7	13	--
I3	3-27-82	5.37	--	7.05	600	20.4	248	62.5	22.0	12	--
I4	3-27-82	7.37	--	7.93	500	33.2	231	39.5	41.3	13	--
I5	3-27-82	9.37	--	8.10	360	56.0	168	19.5	30.6	9	--
I6	3-27-82	11.37	--	8.03	400	40.8	187	24.0	32.2	21	--
I7	3-27-82	13.37	--	7.96	400	40.0	187	24.5	32.8	21	--
I8	3-27-82	15.37	--	7.96	380	34.4	172	24.0	28.0	21	--
I9	3-27-82	17.37	--	7.88	385	32.0	176	25.0	30.6	21	--
I10	3-27-82	19.37	--	7.89	440	37.2	202	30.0	35.9	17	--
J2	3-27-82	0.41	--	7.67	340	40.8	141	20.0	21.0	24	--
J3	3-27-82	2.41	--	7.85	440	52.8	197	52.5	30.4	23	--
J4	3-27-82	4.41	--	7.00	490	24.4	208	23.0	81.5	19	--
J5	3-27-82	6.41	--	7.83	400	56.8	193	21.5	34.4	18	--
J6	3-27-82	8.41	--	8.03	320	58.0	151	15.5	23.6	11	--
4c	3-27-82	5.25	--	6.14	170	10.0	82	10.5	15.3	14	--
4d	3-27-82	20.30	--	8.17	420	34.4	189	27.8	40.2	14	--
8b	3-27-82	1.96	--	5.85	47	4.0	15	0.5	1.0	12	--
8c	3-27-82	9.17	--	6.43	310	11.8	128	19.0	34.4	12	--
8d	3-27-82	26.68	--	8.35	330	39.6	158	23.0	19.4	14	--
9b	3-27-82	2.09	--	6.65	150	2.6	61	10.8	10.5	26	--
9c	3-27-82	6.83	--	6.97	430	29.4	172	29.5	31.0	21	25

Groundwater chemistry data for wells sampled May 6, 1982.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	ppm					ppb
B2	5-6-82	--	--	7.74	150	70	90	1.4	1.6	14	--
B3	5-6-82	--	--	7.82	160	52	82	2.6	1.9	19	--
B4	5-6-82	--	--	7.81	170	36	76	5.2	4.9	19	--
B5	5-6-82	--	--	7.16	210	20	96	19.0	5.0	6	--
B6	5-6-82	--	--	7.13	220	16	90	19.6	6.8	6	--
B7	5-6-82	--	--	7.90	330	44	154	22.4	17.7	14	--
B8	5-6-82	--	--	8.00	405	68	204	24.8	25.8	24	--
B9	5-6-82	--	--	8.08	500	84	252	29.5	34.8	27	--

Groundwater chemistry data for wells sampled May 25, 1982.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	ppm					ppb
A2	5-25-82	3.48	14.0	7.98	370	74	180	15.7	18.8	35	10
A3	5-25-82	5.48	--	7.93	400	60	192	20.6	19.4	34	58
A4	5-25-82	7.48	12.4	7.92	510	60	234	30.9	29.4	23	69
A5	5-25-82	9.48	12.7	7.88	500	40	228	32.0	38.6	19	5
A6	5-25-82	11.48	12.1	7.91	470	40	228	28.3	38.6	20	0
A7	5-25-82	13.48	13.6	7.96	450	40	204	26.8	40.2	19	0
A8	5-25-82	15.48	13.5	7.93	430	36	194	27.0	38.6	18	0
A9	5-25-82	17.48	13.4	7.91	440	34	212	28.3	38.6	17	0
B2	5-25-82	0.94	8.7	7.88	185	76	96	0.5	2.5	15	0
B3	5-25-82	2.44	7.7	8.09	160	48	82	1.4	5.2	18	0
B4	5-25-82	3.94	7.5	8.14	190	42	100	10.1	5.8	14	5
B5	5-25-82	5.44	7.2	7.20	185	22	86	11.4	9.3	8	1
B6	5-25-82	6.94	7.2	6.68	230	14	94	18.2	10.6	6	17
B7	5-25-82	8.44	7.3	7.94	440	64	198	23.7	22.8	25	64
B8	5-25-82	9.94	7.4	7.97	520	72	246	27.7	35.9	23	14
B9	5-25-82	11.44	--	7.59	470	60	226	27.6	30.4	20	8
E3	5-25-82	0.51	14.9	7.75	395	40	178	25.3	15.4	25	0
E5	5-25-82	4.51	14.5	7.64	430	28	188	18.9	57.6	24	0
E6	5-25-82	6.51	15.4	8.03	510	40	230	33.6	40.2	22	0
F1	5-25-82	1.74	13.2	7.64	270	64	130	8.0	5.0	38	0
F3	5-25-82	5.74	--	7.83	540	40	224	22.0	76.9	16	0
F5	5-25-82	9.74	13.8	7.64	390	32	186	23.9	32.3	19	0
F7	5-25-82	13.74	13.4	7.94	540	26	236	24.3	70.9	32	0
F10	5-25-82	19.74	14.0	7.97	460	34	212	27.2	32.6	30	0
I1	5-25-82	2.53	11.9	8.23	245	18	106	14.2	8.3	28	0
I3	5-25-82	6.53	12.2	7.39	430	20	176	35.2	16.3	21	0
I5	5-25-82	10.53	13.0	8.08	340	60	152	17.5	17.2	8	0
I7	5-25-82	14.53	13.2	8.04	420	36	194	25.9	32.6	23	0
I10	5-25-82	20.53	14.0	8.00	410	36	200	28.7	33.9	17	0
J3	5-25-82	3.61	15.8	7.92	410	50	174	23.6	22.6	22	0
J6	5-25-82	9.61	--	8.33	340	72	176	10.6	31.2	15	0
2c	5-25-82	9.26	--	7.34	450	42	206	30.6	21.2	18	90
4d	5-25-82	21.51	--	8.33	400	32	180	26.1	35.5	15	0
13b	5-25-82	--	--	5.18	620	2	238	62.0	18.5	15	15

APPENDIX E, continued

Groundwater chemistry data for wells sampled June 18 and 23, 1982.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	-----------ppm-----------					ppb
A2	6-23-82	2.88	16.0	8.00	155	58	204	21.7	27.4	28	9
A3	6-23-82	4.88	19.0	7.99	368	62	179	17.6	12.4	36	22
A4	6-23-82	6.88	13.6	7.96	338	64	250	--	29.0	--	87
A5	6-23-82	8.88	15.0	7.96	495	38	229	31.8	39.0	20	1
A6	6-23-82	10.88	14.5	8.05	400	40	220	27.7	40.2	20	0
A7	6-23-82	12.88	14.9	7.95	430	38	210	27.2	35.9	19	0
A8	6-23-82	14.88	14.0	7.95	442	34	202	27.3	35.9	17	0
A9	6-23-82	16.88	13.8	7.92	444	34	208	29.0	34.7	16	0
B2	6-18-82	0.69	9.5	7.84	110	78	100	0.8	1.8	15	0
B3	6-18-82	2.19	9.0	7.86	160	58	86	0.7	2.5	19	0
B4	6-18-82	3.69	8.6	8.10	170	40	86	9.0	5.6	13	0
B5	6-18-82	5.19	8.2	6.88	215	16	94	18.5	10.6	8	5
B6	6-18-82	6.69	8.1	6.58	310	12	130	28.5	23.7	9	5
B7	6-18-82	8.19	8.0	8.00	440	76	224	27.2	35.9	26	39
B8	6-18-82	9.69	8.0	7.97	470	70	220	30.8	45.7	23	13
B9	6-18-82	11.19	8.0	8.02	430	58	214	29.2	39.1	19	10
E3	6-18-82	0.00	14.5	7.78	562	38	245	40.5	28.6	20	--
E5	6-18-82	4.00	14.0	7.71	462	38	208	24.4	52.2	24	--
E6	6-18-82	6.00	15.0	8.06	521	44	235	29.5	44.0	24	--
F1	6-18-82	1.26	15.5	7.97	283	46	125	12.6	3.9	33	--
F3	6-18-82	5.26	14.2	7.86	538	40	233	24.0	67.0	15	--
F5	6-18-82	9.26	13.6	7.76	385	28	171	25.8	24.7	21	--
F7	6-18-82	13.26	13.2	7.72	540	28	241	--	69.2	--	--
F10	6-18-82	19.26	14.4	7.90	460	36	260	28.8	29.3	27	--
I1	6-18-82	1.98	15.2	7.66	272	18	123	17.7	9.6	36	0
I3	6-18-82	5.98	15.0	7.19	585	18	243	52.5	18.9	16	0
I5	6-18-82	9.98	14.5	8.13	335	60	156	--	15.8	--	0
I7	6-18-82	13.98	16.0	8.06	450	38	200	28.3	33.2	23	0
I10	6-18-82	19.98	18.9	7.99	450	26	206	--	33.2	--	0
J3	6-18-82	3.11	14.7	7.88	368	40	152	17.0	28.0	24	0
J5	6-18-82	7.11	14.7	8.14	339	58	210	19.0	37.0	24	0
J7	6-18-82	11.11	15.0	8.27	158	66	108	4.2	14.3	10	0
J10	6-18-82	17.11	16.0	8.06	152	38	92	5.8	14.9	7	0
7a	6-18-82	3.43	--	6.19	295	6	127	23.2	15.8	25	7
7b	6-18-82	3.91	--	6.10	173	6	135	25.4	15.5	24	5
7c	6-18-82	8.56	--	8.17	385	34	173	27.2	24.7	15	12

Groundwater chemistry data for wells sampled July 29, 1982.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	-----------ppm-----------					ppb
A2	7-29-82	3.16	18.2	7.81	420	64.2	198	22.2	33.7	28	5
A3	7-29-82	5.16	20.8	7.87	410	64.2	202	24.4	22.6	34	96
A4	7-29-82	7.16	16.3	7.85	510	53.8	241	34.8	42.7	18	14
A5	7-29-82	9.16	15.3	7.99	490	43.5	229	33.0	46.1	20	3
A6	7-29-82	11.16	15.1	8.01	460	45.5	210	28.0	46.1	20	1
A7	7-29-82	13.16	16.0	8.10	490	45.5	210	30.0	46.1	22	1
A8	7-29-82	15.16	15.1	7.96	460	41.4	210	29.0	44.3	21	0
A9	7-29-82	17.16	16.0	7.92	430	39.3	198	28.0	39.2	19	0
B2	7-29-82	0.63	12.7	7.74	320	76.6	148	19.5	6.7	9	0
B3	7-29-82	2.13	12.0	7.85	280	51.8	135	19.2	9.0	11	0
B4	7-29-82	3.63	11.2	7.95	232	37.3	102	15.8	10.5	8	0
B5	7-29-82	5.13	10.9	6.80	250	20.7	102	19.2	10.5	9	32
B6	7-29-82	6.63	10.3	6.45	420	41.4	193	27.5	26.6	29	86
B7	7-29-82	8.13	10.0	7.90	560	84.9	264	32.6	39.7	26	36
B8	7-29-82	9.63	10.0	7.98	510	66.2	237	31.5	36.4	22	25
B9	7-29-82	11.13	10.8	8.05	460	58.0	210	28.8	36.4	18	10
I1	7-29-82	2.21	--	8.06	245	22.8	100	14.0	8.7	32	0
I3	7-29-82	6.21	--	7.11	460	22.8	189	41.2	21.0	15	0
I5	7-29-82	10.21	--	8.09	350	68.3	166	19.5	27.5	8	0
I7	7-29-82	14.21	15.1	8.09	450	41.4	208	28.2	38.0	24	tr
I9	7-29-82	18.21	14.7	7.94	440	37.3	204	29.4	38.0	20	0
2b	7-29-82	4.90	13.3	5.14	370	2.1	146	32.4	14.6	23	23
2c	7-29-82	8.70	12.5	7.30	420	41.4	185	28.0	30.2	18	63
4d	7-29-82	21.20	10.9	8.21	440	35.2	198	28.5	41.2	15	0
7a	7-29-82	3.15	13.3	5.90	340	4.1	137	27.2	20.0	22	7
7b	7-29-82	4.36	13.2	5.83	340	6.2	131	26.2	18.5	23	10
7c	7-29-82	9.04	12.1	8.26	410	37.3	175	28.4	29.9	14	7

APPENDIX E, continued

Groundwater chemistry data for wells sampled September 3, 1982.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
A2	9-3-82	2.97	18.3	7.56	430	54.6	182	17.3	30.4	24	3
A3	9-3-82	4.97	21.0	7.74	390	78.0	169	21.2	17.5	32	51
A4	9-3-82	6.97	17.0	7.84	520	66.4	220	32.4	26.1	22	40
A5	9-3-82	8.97	16.7	7.89	500	38.0	199	35.5	28.3	19	12
A6	9-3-82	10.97	15.7	7.85	500	44.8	218	33.2	35.9	20	2
A7	9-3-82	12.97	16.4	7.96	500	43.0	203	32.1	35.9	21	2
A8	9-3-82	14.97	17.0	7.92	480	42.6	202	30.5	37.0	21	0
A9	9-3-82	16.97	16.7	7.93	470	38.4	198	29.8	35.9	20	0
B2	9-3-82	0.41	13.8	7.61	335	66.0	144	20.5	8.0	15	0
B3	9-3-82	1.91	13.3	7.87	360	45.6	154	27.5	12.4	8	0
B4	9-3-82	3.41	12.8	8.02	290	39.4	122	21.2	11.4	7	3
B5	9-3-82	4.91	12.3	6.84	260	26.4	100	19.2	9.9	9	48
B6	9-3-82	6.41	12.0	6.67	380	35.6	157	23.5	18.3	27	89
B7	9-3-82	7.91	11.7	7.92	490	92.2	220	24.0	21.7	32	45
B8	9-3-82	9.41	11.3	7.97	510	78.6	216	28.8	25.2	30	45
B9	9-3-82	10.91	11.0	8.03	520	64.6	225	32.3	30.4	29	27
G6	9-3-82	7.78	13.2	7.42	300	32.0	118	17.0	11.3	33	8
G7	9-3-82	9.28	13.9	8.12	320	44.0	120	19.4	74.7	31	8
H2	9-3-82	0.91	13.8	7.29	260	124.6	131	1.0	4.0	8	0
H3	9-3-82	2.41	13.2	7.93	175	44.8	74	6.0	11.7	4	0
H4	9-3-82	3.91	12.8	7.91	185	38.2	76	9.7	9.8	4	0
H5	9-3-82	5.41	12.3	7.51	260	37.0	106	16.0	19.7	3	0
H6	9-3-82	6.91	12.0	7.88	350	28.6	142	20.5	34.2	8	0
H7	9-3-82	8.41	11.8	8.41	390	37.0	164	25.0	30.9	16	0
H8	9-3-82	9.91	11.3	8.34	420	46.0	174	27.0	29.3	17	0
H9	9-3-82	11.41	--	8.26	440	47.2	180	29.2	30.4	18	9
I1	9-3-82	2.11	18.4	7.95	215	28.0	82	11.0	40.0	33	0
I3	9-3-82	6.11	17.2	7.38	380	30.0	142	18.6	36.0	27	0
I5	9-3-82	10.11	17.2	8.11	380	70.2	167	19.1	26.9	12	0
I7	9-3-82	14.11	17.7	8.04	450	42.0	184	28.4	30.4	23	0
I10	9-3-82	20.11	18.0	7.92	450	36.6	191	29.0	34.6	19	0
2a	9-3-82	4.30	14.8	4.76	260	3.0	90	22.0	7.7	21	5
2b	9-3-82	4.70	14.2	4.94	350	3.0	122	29.2	11.8	22	23
2c	9-3-82	8.56	13.1	7.32	380	40.4	159	25.2	21.5	20	48
3c	9-3-82	7.54	12.7	8.43	350	44.6	150	24.0	22.3	8	3
4c	9-3-82	5.88	12.5	6.38	370	20.0	141	29.2	14.2	20	34
4d	9-3-82	20.98	9.8	8.18	460	34.4	196	30.8	40.2	16	0
7a	9-3-82	3.45	13.6	6.17	340	6.0	122	24.0	30.1	17	0
7b	9-3-82	3.93	13.4	6.19	380	7.6	138	26.2	32.7	18	4
7c	9-3-82	8.52	11.9	8.26	360	37.0	148	23.1	19.0	24	13

Groundwater chemistry data for wells sampled October 12 and 15, 1982.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
A2	10-15-82	2.42	17.0	7.56	440	40.2	186	24.8	42.7	22	1
A3	10-15-82	4.42	19.0	7.82	430	52.0	192	26.7	25.0	28	97
A4	10-15-82	6.42	15.7	7.85	420	58.4	190	25.2	21.7	28	82
A5	10-15-82	8.42	15.2	7.94	460	44.0	202	32.8	26.8	20	23
A6	10-15-82	10.42	14.7	7.83	520	41.8	226	36.6	34.8	19	6
A7	10-15-82	12.42	16.1	7.89	510	40.8	226	35.1	39.3	20	4
A8	10-15-82	14.42	15.3	7.92	500	40.4	207	33.2	36.1	20	1
A9	10-15-82	16.42	14.0	7.92	480	40.4	210	31.2	33.3	20	0
B2	10-15-82	-0.08	13.2	7.25	330	72.4	154	18.5	12.6	14	0
B3	10-15-82	1.42	13.0	7.86	410	40.4	186	33.0	16.7	7	0
B4	10-15-82	2.92	12.9	8.03	320	40.4	144	23.7	11.6	7	5
B5	10-15-82	4.42	12.7	6.95	270	30.6	117	19.2	9.6	10	26
B6	10-15-82	5.92	12.4	6.61	335	33.2	150	20.7	24.2	23	79
B7	10-15-82	7.42	12.1	7.93	420	75.4	183	20.8	23.3	31	45
B8	10-15-82	8.92	12.0	7.97	480	86.2	226	26.2	26.3	32	52
B9	10-15-82	10.42	11.5	8.04	520	74.4	226	29.7	30.8	28	42
I1	10-12-82	1.61	14.7	7.64	230	22.2	100	12.0	5.7	30	0
I3	10-12-82	5.61	14.6	7.00	355	20.2	146	26.0	17.4	22	0
I5	10-12-82	9.61	14.4	7.90	370	62.4	187	20.0	28.5	7	tr
I7	10-12-82	13.61	14.0	8.06	440	37.6	204	29.2	30.6	21	tr
I10	10-12-82	19.61	15.3	7.86	440	34.0	202	29.3	43.5	18	0
2b	10-15-82	4.33	14.0	4.87	350	4.0	130	29.6	12.4	18	3
2c	10-15-82	8.14	13.2	7.33	370	40.4	164	23.7	22.2	20	24
3c	10-15-82	7.03	12.3	8.42	355	40.6	158	25.0	22.0	7	tr
4d	10-15-82	20.49	10.2	8.15	470	33.4	206	31.5	47.5	14	0
7a	10-15-82	3.15	12.7	5.79	340	6.0	124	20.2	33.1	22	8
7b	10-15-82	3.63	12.8	5.79	345	8.0	123	20.2	36.6	20	tr
7c	10-15-82	8.27	12.0	8.31	370	38.4	156	24.0	22.6	21	7

APPENDIX E, continued

Groundwater chemistry data for wells sampled November 23 and December 3, 1982.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	ppm					ppb
A2	12-3-82	4.09	10.2	7.62	369	39.4	159	17.0	44.1	22	--
A3	12-3-82	6.09	10.3	7.62	360	51.6	172	21.0	19.4	34	--
A4	12-3-82	8.09	10.6	7.62	345	42.8	165	22.5	17.7	30	--
A5	12-3-82	10.09	9.8	7.68	441	42.6	202	33.6	27.2	19	--
A6	12-3-82	12.09	10.1	7.65	474	44.4	221	35.2	35.9	19	--
A7	12-3-82	14.09	10.0	7.66	480	40.6	227	33.5	37.0	20	--
A8	12-3-82	16.09	9.7	7.68	467	39.0	207	30.7	35.9	19	--
A9	12-3-82	18.09	9.8	7.63	437	38.4	200	29.5	34.8	19	--
B1	11-23-82	0.17	9.0	7.17	219	46.4	96	7.0	12.3	23	0
B2	11-23-82	1.67	9.8	7.83	275	62.4	121	13.5	11.2	16	0
B3	11-23-82	3.17	10.1	7.88	342	41.4	143	25.2	8.6	8	0
B4	11-23-82	4.67	10.7	8.01	263	36.2	102	18.2	7.2	8	0
B5	11-23-82	6.17	11.0	7.02	281	34.6	102	21.2	36.7	12	5
B6	11-23-82	7.67	11.0	6.79	314	32.0	131	21.0	14.5	22	15
B7	11-23-82	9.17	11.0	7.91	389	63.6	177	21.5	3.2	32	10
B8	11-23-82	10.67	10.7	7.97	444	80.0	209	24.2	42.4	34	20
B9	11-23-82	12.17	--	7.99	465	77.8	211	27.0	53.3	32	23
B6	12-3-82	7.58	11.0	7.40	324	22.0	146	25.0	18.8	18	--
B8	12-3-82	10.58	11.1	7.92	431	80.4	202	25.0	18.5	33	--
I1	11-23-82	3.23	8.7	7.90	230	27.6	96	12.5	89.3	34	0
I3	11-23-82	7.23	9.8	7.25	281	17.0	108	18.0	11.0	32	0
I5	11-23-82	11.23	9.2	8.10	345	65.0	154	17.4	34.9	8	tr
I7	11-23-82	15.23	9.0	8.01	473	54.4	204	32.0	35.3	23	2
I10	11-23-82	21.23	7.0	7.85	446	36.6	192	29.3	40.2	18	0
I6	12-3-82	13.06	10.0	7.90	380	64.0	184	25.0	25.8	11	--
I7	12-3-82	15.06	9.0	7.71	448	46.0	207	31.4	32.6	22	--
I8	12-3-82	17.06	9.0	7.69	432	40.4	215	31.2	34.8	21	--
2a	12-3-82	5.59	9.7	5.12	348	5.4	136	35.6	10.8	17	--
2b	12-3-82	6.03	10.0	5.17	299	3.2	119	28.3	12.9	21	--
2c	12-3-82	9.84	10.8	7.25	320	42.0	140	22.0	16.8	24	--
4d	12-3-82	22.24	--	8.24	450	32.0	189	31.6	42.1	16	0
7a	12-3-82	4.78	10.0	6.28	288	7.8	111	18.2	27.6	23	--
7b	12-3-82	5.26	10.0	6.30	282	8.0	113	17.7	27.6	24	--
7c	12-3-82	9.90	10.7	7.64	356	41.2	154	26.0	21.5	22	--

Groundwater chemistry data for wells sampled January 10 and 11, 1983.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	ppm					ppb
A3	1-11-83	5.93	--	7.57	384	40.0	168	20.0	33.8	30	--
A4	1-11-83	7.93	--	7.75	382	44.0	172	24.2	21.2	29	--
A5	1-11-83	9.93	8.7	7.71	450	48.4	196	31.5	29.0	23	--
A6	1-11-83	11.93	8.8	7.40	507	44.0	224	36.6	37.0	20	--
A7	1-11-83	13.93	8.0	7.52	501	42.0	220	35.0	39.1	21	--
A8	1-11-83	15.93	7.6	7.51	461	46.4	204	30.5	37.5	20	--
B1	1-10-83	0.08	5.7	7.52	159	60.3	78	2.8	8.6	9	--
B2	1-10-83	1.58	6.8	7.85	232	56.1	110	12.4	5.0	17	--
B3	1-10-83	3.08	7.4	7.97	335	38.4	154	26.0	21.2	6	--
B4	1-10-83	4.58	8.2	8.04	303	36.6	136	22.8	20.9	5	--
B5	1-10-83	6.08	8.7	6.94	320	24.1	130	26.0	22.8	5	--
B6	1-10-83	7.58	9.1	6.63	399	21.5	178	34.5	24.5	17	--
B7	1-10-83	9.08	9.4	8.00	383	67.1	186	21.5	19.4	31	--
B8	1-10-83	10.58	9.7	8.02	431	80.4	212	24.0	22.3	33	--
B9	1-10-83	12.08	10.0	8.05	473	73.4	228	30.5	26.6	28	--
H7	1-10-83	9.46	8.7	8.25	360	36.4	164	26.0	31.2	9	--
H8	1-10-83	10.96	8.7	8.21	399	39.6	184	23.2	34.4	14	--
H9	1-10-83	12.46	8.8	8.28	426	42.2	196	30.5	35.9	15	--
I2	1-11-83	4.86	7.2	7.73	411	30.8	176	36.4	17.0	17	--
I3	1-11-83	6.86	7.7	7.26	228	14.8	98	11.5	9.9	40	--
I6	1-11-83	12.86	8.7	8.01	416	61.0	192	27.8	23.9	15	--
I8	1-11-83	16.86	8.1	7.92	458	42.2	210	30.5	37.5	20	--
I10	1-11-83	20.86	7.2	7.88	446	36.2	204	30.0	37.0	17	--
2a	1-10-83	5.27	5.2	4.90	346	2.0	136	29.0	24.5	19	--
2b	1-10-83	5.70	7.0	5.13	317	3.8	122	23.4	15.5	21	--
2c	1-10-83	9.51	8.2	7.40	320	38.8	146	41.8	19.6	22	--
4d	1-10-83	22.15	10.0	8.25	414	34.4	190	30.8	37.0	14	--
7a	1-10-83	4.82	7.2	5.87	340	8.0	136	21.0	40.0	22	--
7b	1-10-83	5.30	--	5.83	339	6.0	136	20.0	39.2	23	--
7c	1-10-83	9.94	8.7	8.27	364	39.8	160	25.6	26.3	20	--

APPENDIX E, continued

Groundwater chemistry data for wells sampled March 13, 1983.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	-----------ppm-----------					ppb
A2	3-13-83	4.88	7.8	7.75	435	38.2	172	17.8	65.0	21	1
A3	3-13-83	6.88	7.4	7.65	388	36.0	157	19.8	42.0	30	9
A4	3-13-83	8.88	7.9	7.92	349	46.4	148	19.5	20.0	31	32
A5	3-13-83	10.88	8.0	7.98	431	48.0	180	27.6	38.0	25	6
A6	3-13-83	12.88	8.9	7.91	521	48.0	219	34.5	44.0	23	2
A7	3-13-83	14.88	8.5	7.91	518	44.6	219	33.4	44.0	23	1
A8	3-13-83	16.88	10.0	7.90	425	43.0	177	25.5	35.5	20	0
B1	3-13-83	0.88	3.8	7.26	158	42.2	60	2.0	6.6	23	--
B2	3-13-83	2.38	4.2	7.82	176	60.0	79	1.2	9.6	14	--
B3	3-13-83	3.88	4.9	7.94	232	39.0	96	13.0	6.9	16	--
B4	3-13-83	5.38	5.5	7.95	334	39.0	134	23.2	16.5	9	0
B5	3-13-83	6.88	6.1	6.86	351	23.4	131	26.8	21.0	6	7
B6	3-13-83	8.38	6.6	6.65	319	20.4	123	21.5	18.7	16	9
B7	3-13-83	9.88	7.1	8.04	356	58.4	152	15.8	18.7	28	9
B8	3-13-83	11.38	7.5	8.03	448	78.6	196	21.8	20.0	34	17
B9	3-13-83	12.88	8.0	8.03	496	72.0	213	29.0	22.6	26	20
G1	3-13-83	2.13	4.2	7.37	149	34.4	61	6.2	4.2	14	2
G2	3-13-83	3.63	4.8	7.38	337	55.0	142	14.2	4.2	34	6
G3	3-13-83	5.13	5.1	8.04	466	54.5	190	37.6	5.1	24	6
G4	3-13-83	6.63	6.0	7.42	356	22.2	132	18.4	35.5	24	12
G5	3-13-83	8.13	6.3	6.84	327	14.1	123	17.6	27.0	23	3
G6	3-13-83	9.63	6.8	7.44	316	26.3	123	18.4	18.0	26	0
G7	3-13-83	11.13	7.2	8.09	388	40.4	157	24.2	16.5	27	tr
G8	3-13-83	12.63	7.5	8.20	486	40.4	202	33.0	25.0	23	0
G9	3-13-83	14.13	8.1	8.24	482	36.4	198	33.6	30.8	18	0
H7	3-13-83	10.26	6.5	8.38	380	36.4	156	26.5	29.5	8	0
H8	3-13-83	11.76	7.2	8.28	422	38.4	173	29.5	29.5	10	tr
H9	3-13-83	13.26	8.0	8.23	468	46.5	196	31.0	30.8	16	8
I4	3-13-83	9.86	7.4	8.08	418	70.0	177	25.6	18.7	13	0
I7	3-13-83	15.86	8.5	8.04	498	54.8	211	30.6	31.0	22	1
I10	--	--	--	--	--	--	--	--	--	--	0
2a	3-13-83	6.42	3.7	5.14	171	2.0	58	13.0	9.0	10	0
2b	3-13-83	6.77	4.2	4.92	457	2.0	157	38.0	22.5	16	0
2c	3-13-83	10.56	5.7	7.45	340	40.4	138	19.8	16.0	24	44
3c	3-13-83	8.50	6.0	8.09	264	34.4	109	19.8	8.3	7	tr
4d	3-13-83	22.95	9.1	8.11	431	34.4	190	29.8	27.0	14	0
7a	3-13-83	5.72	5.8	6.00	354	6.1	143	20.0	37.0	22	tr
7b	3-13-83	6.23	5.8	6.05	355	4.04	137	18.5	35.5	24	tr
7c	3-13-83	10.89	7.1	8.05	380	38.4	161	26.2	18.0	20	3

Groundwater chemistry data for wells sampled April 14, 1983.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	-----------ppm-----------					ppb
B3	4-12-83	3.97	4.8	7.85	203	45	90	7.6	6.2	26	--
B4	4-12-83	5.47	5.3	7.73	362	34	154	27.8	20.1	10	--
B5	4-12-83	6.97	5.8	6.76	352	20	140	29.0	20.1	20	--
B6	4-12-83	8.47	6.2	6.54	318	13	130	22.5	21.5	20	--
B7	4-12-83	9.97	6.6	7.97	394	54	180	17.0	27.4	29	--
B8	4-12-83	11.47	6.9	7.99	484	60	224	28.5	27.2	34	--
I4	4-12-83	9.92	--	7.92	334	0	136	22.5	10.2	39	0
I7	4-12-83	15.92	--	8.09	521	0	222	31.0	33.7	32	1
I10	--	--	--	--	--	--	--	--	--	--	0

APPENDIX E, continued

Groundwater chemistry data for wells sampled June 2 and 8, 1983.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
A1	6-2-83	3.42	16.6	7.35	338	25	125	5.0	62.4	20	--
A2	6-2-83	5.42	19.7	7.78	538	44	230	21.8	86.8	19	--
A3	6-2-83	7.42	19.5	7.60	402	36	172	19.8	41.9	30	--
A4	6-2-83	9.42	--	7.78	394	31	174	19.0	41.9	26	--
A5	6-2-83	11.42	--	8.01	440	46	192	28.0	29.9	23	--
A6	6-2-83	13.42	--	8.03	490	43	220	31.5	43.5	20	--
A7	6-2-83	15.42	--	8.08	434	45	192	27.0	41.3	20	--
A8	6-2-83	17.42	--	8.08	400	37	180	24.2	37.6	18	--
B1	6-2-83	1.17	8.7	7.63	173	78	90	2.2	2.8	4	--
B2	6-2-83	2.67	8.2	7.76	250	48	118	14.7	3.1	15	--
B3	6-2-83	4.17	8.0	7.95	280	49	127	18.7	8.1	12	--
B4	6-2-83	5.67	7.5	7.76	374	41	166	30.7	13.9	6	--
B5	6-2-83	7.17	7.3	6.84	415	20	172	38.0	18.5	8	--
B6	6-2-83	8.67	7.4	6.66	345	25	144	16.5	39.7	18	--
B7	6-2-83	10.17	7.6	7.96	413	71	192	18.5	27.2	30	--
B8	6-2-83	11.67	7.6	7.97	490	72	226	29.0	26.1	26	--
B9	6-2-83	13.17	8.0	7.98	506	50	225	33.0	35.3	18	--
G1	6-8-83	2.42	9.0	7.00	140	46	68	3.8	1.6	12	--
G2	6-8-83	3.92	8.6	7.34	268	56	120	11.5	2.2	30	--
G3	6-8-83	5.42	8.6	7.80	375	62	166	21.5	6.5	31	--
G4	6-8-83	6.92	8.3	7.34	480	28	198	32.5	42.4	22	--
G5	6-8-83	8.42	8.0	6.86	478	11	188	30.6	57.6	18	--
G6	6-8-83	9.92	8.0	7.20	360	14	142	21.4	40.9	20	--
G7	6-8-83	11.42	8.0	7.95	340	34	142	19.0	23.7	28	--
G8	6-8-83	12.92	8.0	8.02	370	45	164	21.0	23.7	28	--
G9	6-8-83	14.42	8.2	7.96	418	46	190	26.8	31.5	24	--
H7	6-8-83	10.55	8.0	8.16	278	36	122	19.6	20.2	6	--
H8	6-8-83	12.05	8.2	8.18	368	38	162	26.8	29.0	7	--
H9	6-8-83	13.55	8.2	8.18	422	44	186	30.5	27.7	10	--
I5	6-2-83	12.26	12.3	8.13	343	74	157	18.0	14.5	10	0
I8	6-2-83	18.26	13.5	8.08	480	41	210	30.5	5.6	18	0
I10	6-2-83	22.26	20.5	7.86	430	38	189	28.5	30.4	16	0
2a	6-8-83	6.13	9.1	5.10	320	4	114	25.5	16.8	17	--
2b	6-8-83	6.60	8.9	5.32	299	4	108	22.4	16.8	23	--
2c	6-8-83	10.37	8.4	7.47	373	43	156	21.2	25.3	24	--
4a	6-8-83	1.99	9.3	6.84	164	54	74	2.0	3.6	16	--
4c	6-8-83	8.15	8.2	6.35	339	10	130	25.8	21.5	14	--
4d	6-8-83	23.24	9.1	8.04	440	34	192	32.5	31.0	14	--
7a	6-8-83	6.04	8.3	5.97	383	6	146	29.5	30.6	16	--
7b	6-8-83	6.51	8.0	5.79	392	6	150	29.0	30.6	18	--
7c	6-8-83	11.16	7.9	8.05	317	28	126	16.0	25.3	24	--

Groundwater chemistry data for wells sampled July 6, 1983.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
B4	7-6-83	4.30	9.7	7.75	380	48.0	164	31.2	15.4	8	--
B5	7-6-83	5.80	9.2	6.79	362	32.8	143	30.6	14.5	14	--
B6	7-6-83	7.30	9.0	6.72	318	24.0	131	16.5	30.1	19	--
B7	7-6-83	8.80	8.7	8.05	403	60.6	183	17.0	30.1	28	--
B8	7-6-83	10.30	8.7	8.01	476	78.6	221	26.0	19.6	30	--
B9	7-6-83	11.80	8.4	8.06	484	42.4	215	31.0	24.5	23	--
H8	7-6-83	10.68	9.1	8.38	320	41.4	140	22.5	17.7	8	--
H9	7-6-83	12.18	8.8	8.20	430	45.6	190	30.4	19.6	11	--
I6	7-6-83	12.87	--	8.04	500	54.4	222	30.5	30.4	22	1
4d	7-6-83	21.87	9.0	8.28	446	36.2	194	31.2	35.9	14	0
12c	7-6-83	16.46	8.8	8.27	432	48.4	191	28.2	23.7	19	1
12d	7-6-83	21.37	9.1	8.14	430	40.2	188	27.0	30.4	19	1
13d	7-6-83	20.46	8.5	8.01	412	36.4	180	24.5	27.7	19	tr

APPENDIX E, continued

Groundwater chemistry data for wells sampled August 11, 1983.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	ppm					ppb
B4	8-11-83	3.07	11.7	7.72	340	42.4	148	26.0	9.0	11	0
B5	8-11-83	4.57	11.2	6.89	370	23.8	148	32.0	10.8	13	0
B6	8-11-83	6.07	10.9	6.83	345	22.4	146	22.5	26.9	18	1
B7	8-11-83	7.57	10.3	7.96	450	60.4	207	20.0	40.7	30	15
B8	8-11-83	9.07	10.2	8.02	466	70.4	219	29.5	30.7	30	23
B9	8-11-83	10.57	--	8.04	505	56.0	233	32.0	39.1	22	8
C1	8-11-83	3.84	15.0	8.02	285	62.6	135	13.0	8.0	20	0
C2	8-11-83	5.84	13.8	7.72	505	78.0	237	35.5	20.1	13	1
C3	8-11-83	7.84	12.7	7.73	450	84.0	212	26.0	25.2	22	2
C4	8-11-83	9.84	12.0	6.85	440	56.0	202	27.5	30.7	26	10
C5	8-11-83	11.84	11.2	7.38	520	64.0	238	34.5	39.1	20	8
C6	8-11-83	13.84	11.0	8.12	488	38.0	216	35.0	40.7	19	1
C7	8-11-83	15.84	10.7	8.24	476	38.0	213	32.4	43.5	18	tr
C8	8-11-83	17.84	10.4	8.17	465	38.0	208	31.8	39.1	18	0
C9	8-11-83	19.84	10.2	8.27	459	36.0	206	32.8	39.1	16	0
C10	8-11-83	26.84	10.2	8.35	326	44.0	146	23.5	28.8	16	0
D1	8-11-83	4.15	14.8	7.89	423	82.0	202	22.0	23.3	28	1
D2	8-11-83	6.15	14.3	7.71	488	100.0	237	23.5	23.9	34	4
D3	8-11-83	8.15	13.7	7.53	446	88.0	210	18.0	19.0	31	4
D4	8-11-83	10.15	13.7	7.01	348	55.8	161	15.0	18.1	36	1
D5	8-11-83	12.15	11.2	7.15	420	69.8	196	23.6	16.8	25	12
D6	8-11-83	14.15	10.6	7.47	461	75.0	220	24.5	20.5	33	9
D7	8-11-83	16.15	10.3	7.97	495	58.0	228	31.5	28.3	24	8
D8	8-11-83	18.15	10.3	8.16	466	40.0	210	29.5	39.1	20	1
D9	8-11-83	20.15	10.2	8.19	466	37.0	212	29.5	40.7	20	0
D10	8-11-83	22.15	10.2	8.28	445	36.0	200	29.5	34.8	16	0
D11	8-11-83	25.15	10.2	8.30	360	38.0	161	24.0	21.3	16	--
D12	8-11-83	30.15	10.0	8.29	313	44.0	143	19.6	14.2	16	--
4c	8-11-83	5.59	11.8	5.81	475	8.0	205	30.0	54.3	16	0
4d	8-11-83	20.57	9.7	8.25	445	32.0	200	30.6	42.4	14	0

Groundwater chemistry data for wells sampled August 25, 1983.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	ppm					ppb
E5	8-25-83	4.16	--	7.68	299	22.0	126	17.4	8.8	39	0
E6	8-25-83	6.16	21.0	7.92	478	36.0	209	37.8	19.6	15	0
F1	8-25-83	1.47	22.2	7.80	180	33.6	69	4.6	8.9	20	0
F2	8-25-83	3.47	21.0	7.53	367	35.6	144	23.5	14.9	26	0
F3	8-25-83	5.47	21.3	7.57	440	34.4	180	30.5	20.1	20	0
F4	8-25-83	7.47	19.9	7.78	485	38.4	201	33.5	22.1	20	0
F5	8-25-83	9.47	20.7	7.65	396	37.2	158	25.0	24.7	17	0
F6	8-25-83	11.47	--	7.71	421	23.8	173	33.6	16.3	13	0
F7	8-25-83	13.47	18.8	7.72	493	24.6	210	35.5	30.4	14	0
F8	8-25-83	15.47	--	7.90	489	28.2	210	29.5	39.1	16	0
F9	8-25-83	17.47	--	7.99	467	46.0	206	23.0	41.3	22	0
F10	8-25-83	19.47	--	7.99	476	46.2	217	23.8	39.1	26	0
8b	8-25-83	2.48	18.0	5.70	58	5.0	19	1.8	1.0	10	0
8c	8-25-83	9.69	13.9	6.46	222	8.0	64	6.2	27.1	14	0
8d	8-25-83	27.18	10.2	8.10	454	32.6	200	32.5	23.4	14	0
9b	8-25-83	3.14	16.5	6.22	206	26.0	79	7.2	8.2	27	0
9c	8-25-83	7.78	14.4	6.68	424	14.0	172	34.2	16.3	20	15
10a	8-25-83	3.76	15.6	5.53	168	4.0	63	4.8	7.1	39	0
10b	8-25-83	7.50	13.2	6.61	491	13.6	200	40.5	23.9	16	0

APPENDIX E, continued

Groundwater chemistry data for wells sampled October 17 and 18, 1983.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
A1	10-17-83	2.82	--	7.24	539	31.6	212	34.5	52.7	16	--
A2	10-17-83	4.82	15.9	7.94	356	74.0	156	7.5	37.6	28	0
A3	10-17-83	6.82	16.8	7.74	508	40.4	212	10.0	103.3	24	0
A4	10-17-83	8.82	14.4	7.87	421	38.0	180	18.0	54.3	24	1
A5	10-17-83	10.82	13.8	8.02	369	39.8	159	18.5	33.3	23	9
A6	10-17-83	12.82	12.7	8.08	445	50.0	194	27.5	29.3	24	11
A7	10-17-83	14.82	12.9	8.06	459	48.4	200	28.0	29.3	26	5
A8	10-17-83	16.82	12.5	7.89	487	44.0	211	30.5	36.9	23	2
A9	10-17-83	18.82	--	7.96	445	38.8	190	27.0	36.9	20	0
B4	10-18-84	5.30	13.2	8.06	382	36.0	155	32.5	6.9	10	0
B5	10-18-84	6.80	13.0	6.93	392	19.4	152	36.5	6.5	12	0
B6	10-18-84	8.30	12.9	7.01	346	22.0	136	24.0	21.5	16	0
B7	10-18-84	9.80	12.7	7.90	456	42.6	194	20.0	57.6	21	0
B8	10-18-84	11.30	12.2	7.92	557	56.0	242	27.0	51.6	24	5
B9	10-18-84	12.80	11.9	8.05	468	66.0	206	24.5	36.6	27	11
C1	10-18-84	5.89	14.2	7.89	388	84.0	172	22.0	11.8	12	0
C2	10-18-84	7.89	13.8	7.93	440	50.8	185	32.0	16.3	12	tr
C3	10-18-84	9.89	13.0	7.85	472	64.0	202	22.5	38.0	29	8
C4	10-18-84	11.89	12.7	7.64	512	56.0	224	30.5	35.3	26	10
C5	10-18-84	13.89	12.1	7.84	503	42.0	214	32.0	40.2	19	1
C6	10-18-84	15.89	11.7	8.18	480	39.0	204	29.0	40.2	19	0
C7	10-18-84	17.89	11.2	8.24	474	39.0	198	28.5	40.2	18	0
C8	10-18-84	19.89	11.0	8.24	468	35.0	195	29.5	38.0	16	0
C9	10-18-84	21.89	10.9	8.24	435	32.0	184	29.0	32.6	14	--
D1	10-18-84	6.27	14.1	8.38	253	32.0	105	8.5	15.9	31	0
D2	10-18-84	8.27	13.9	8.13	376	34.0	154	25.0	14.7	26	0
D3	10-18-84	10.27	13.6	7.54	411	44.4	170	29.0	14.1	17	0
D4	10-18-84	12.27	13.0	7.29	364	49.6	155	25.0	11.8	12	0
D5	10-18-84	14.27	12.4	7.64	485	58.0	210	35.5	13.6	13	3
D6	10-18-84	16.27	11.9	7.87	471	68.0	203	25.5	22.8	27	8
D7	10-18-84	18.27	11.3	8.26	490	42.4	210	31.0	32.6	18	3
D8	10-18-84	20.27	11.0	8.22	480	37.2	200	28.5	36.9	18	0
D9	10-18-84	22.27	10.7	8.25	474	34.6	200	29.5	38.0	16	0
D10	10-18-84	24.27	10.2	8.05	428	31.6	180	28.0	36.9	14	--
2a	10-18-84	6.14	14.6	4.89	308	2.6	104	18.5	27.9	18	0
2b	10-18-84	6.62	14.5	5.00	391	3.0	139	15.0	55.9	20	0
2c	10-18-84	10.45	13.9	7.45	527	44.8	220	22.0	70.6	20	1
4a	10-18-84	1.69	--	6.60	222	67.0	101	5.0	3.2	21	--
4c	10-18-84	7.85	13.1	6.15	418	7.0	160	28.5	36.9	23	0
4d	10-18-84	22.93	10.3	8.15	430	32.6	190	28.5	30.9	14	0
7a	10-18-84	5.62	15.0	6.48	425	34.0	168	25.5	30.9	21	0
7b	10-18-84	6.10	15.0	6.51	462	40.8	184	28.0	30.9	22	0
7c	10-18-84	10.75	14.2	8.01	456	58.0	190	11.0	67.4	30	0

Groundwater chemistry data for wells sampled January 6, 1984.

Well No.	Date	Depth ft	Temp C	pH	Cond umhos	Alk	THard	NO3,2	Cl	SO4	Ald ppb
						ppm					
9b	1-6-84	3.73	7.0	5.95	452	10.4	190	41.5	20.7	12	--
9c	1-6-84	8.35	9.0	6.83	428	18.8	182	32.5	23.9	27	4
14c	1-6-84	11.79	10.0	8.16	340	42.0	156	21.5	17.2	19	1
15c	1-6-84	11.85	10.0	8.10	440	50.2	197	32.4	27.9	16	0
16c	1-6-84	12.73	9.9	8.15	453	36.0	206	24.4	45.7	18	0
17c	1-6-84	14.15	10.2	8.14	455	30.0	195	34.5	30.4	15	0

APPENDIX E, continued

Groundwater chemistry data for wells sampled February 10 and 11, 1984.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	-----------ppm-----------					ppb
A4	2-10-84	7.18	--	7.74	440	28.4	194	16.0	71.7	22	1
A5	2-10-84	9.18	--	8.03	319	32.8	140	15.5	31.2	22	2
A6	2-10-84	11.18	--	8.06	374	45.8	176	19.8	27.4	24	3
A7	2-10-84	13.18	--	8.07	420	49.6	193	25.0	26.6	25	3
A8	2-10-84	15.18	--	8.05	435	27.4	200	27.0	29.9	22	1
A9	2-10-84	17.18	--	8.02	444	44.6	201	27.5	34.8	20	0
B4	2-11-84	3.68	7.8	7.93	260	32.0	110	18.5	2.0	19	--
B5	2-11-84	5.18	8.2	7.00	203	19.4	80	11.5	2.2	27	--
B6	2-11-84	6.68	8.7	6.88	261	16.0	101	15.0	17.0	21	0
B7	2-11-84	8.18	9.0	7.94	519	40.0	224	26.0	57.6	16	0
B8	2-11-84	9.68	9.2	7.93	524	44.4	230	23.2	62.0	19	0
B9	2-11-84	11.18	9.7	8.07	427	64.2	194	18.6	33.7	25	9
C1	2-11-84	4.44	6.5	8.02	430	42.0	184	35.0	15.2	6	0
C2	2-11-84	6.44	7.1	7.90	468	41.6	200	35.8	17.4	16	0
C3	2-11-84	8.44	7.9	7.86	460	48.2	202	22.5	47.8	17	1
C4	2-11-84	10.44	8.2	7.78	434	70.6	198	19.5	25.0	26	7
C5	2-11-84	12.44	8.8	7.94	423	52.6	188	25.0	26.6	20	4
C6	2-11-84	14.44	8.9	8.15	476	41.2	209	30.5	33.7	15	3
C7	2-11-84	16.44	9.0	8.19	476	39.0	212	30.0	44.6	12	0
C8	2-11-84	18.44	9.1	8.21	456	36.2	200	29.0	37.0	10	--
C9	2-11-84	20.44	9.2	8.21	436	33.2	192	29.0	35.3	6	--
D1	2-11-84	4.60	6.6	8.06	627	37.0	270	42.0	54.9	<.4	--
D2	2-11-84	6.60	7.3	8.23	307	36.6	128	14.0	21.5	17	--
D3	2-11-84	8.60	8.0	7.79	249	48.0	110	6.8	12.8	22	--
D4	2-11-84	10.60	8.4	7.66	329	81.8	154	12.5	8.1	18	0
D5	2-11-84	12.60	8.9	7.82	385	52.2	167	20.5	19.3	14	4
D6	2-11-84	14.60	9.3	7.93	469	56.0	208	27.5	26.1	10	3
D7	2-11-84	16.60	9.6	8.17	476	38.0	208	30.5	33.7	<.4	0
D8	2-11-84	18.60	9.7	8.18	458	38.2	200	28.5	35.9	<.4	0
D9	2-11-84	20.60	9.7	8.17	457	34.6	199	29.5	35.9	<.4	0
D10	2-11-84	22.60	9.7	8.14	367	35.4	160	25.0	19.3	<.4	--
9c	2-11-84	7.80	--	6.90	398	17.8	163	27.0	29.6	29	1
14c	2-11-84	11.20	8.7	8.03	365	44.4	165	24.5	22.6	18	1
15c	2-11-84	11.27	8.8	8.04	435	34.0	198	32.0	28.8	16	0
16c	2-11-84	12.16	8.7	8.04	453	44.2	201	25.6	46.7	18	0
17c	2-11-84	13.57	9.0	8.18	439	26.2	188	33.0	33.7	16	0

Groundwater chemistry data for wells sampled April 28, 1984.

Well	Date	Depth	Temp	pH	Cond	Alk	THard	NO3,2	Cl	SO4	Ald
No.		ft	C		umhos	-----------ppm-----------					ppb
8b	4-18-84	3.89	4.9	5.72	116	9.0	47	9.2	--	6	0
8c	4-18-84	11.10	6.0	6.55	184	10.2	74	9.8	--	17	0
8d	4-18-84	28.61	9.3	8.33	303	46.0	137	19.0	--	13	0
9c	4-18-84	9.13	5.7	6.72	356	15.8	147	24.0	--	34	1
10b	4-18-84	5.15	4.7	5.64	341	4.0	138	30.4	--	14	0
10c	4-18-84	8.88	5.7	6.75	354	13.2	145	22.0	--	28	0
14b	4-18-84	7.86	6.1	7.32	338	26.0	149	20.0	--	24	0
14c	4-18-84	12.61	7.2	8.07	459	46.4	208	32.5	--	19	1
15b	4-18-84	8.33	6.2	7.82	356	19.8	147	20.2	--	32	0
15c	4-18-84	12.67	7.5	8.16	452	34.6	200	33.0	--	16	0
16b1	4-18-84	5.64	5.5	7.05	436	18.0	185	30.0	--	23	0
16b2	4-18-84	9.64	6.2	8.15	446	27.8	195	31.5	--	23	0
16c	4-18-84	13.55	7.4	8.25	470	44.4	208	26.5	--	16	0
17b	4-18-84	10.40	6.7	8.42	368	28.2	151	22.5	--	32	0
17c	4-18-84	14.66	7.8	8.36	420	27.8	175	32.4	--	15	0

APPENDIX F

Quality control information for aldicarb samples.

Well No.'s	Date sampled	Date Extracted	Spike Concentration ppm	Spike Recovery %	Duplicate Difference %
B3-B8	11-14-81	12 -81	--	--	--
I1-I10	11-14-81	1-7-81	1.55	--	--
J3-J8,J10	11-14-81	1 -81	--	--	--
B2-B9	11-19-81	11-17-82	0.70	83%	1%
J2-J8,J10	1-31-82	4-4-82	0.12	94%	--
I1-I10	2-1-82	4-7-82	0.18	119%	--
B2-B9, I4,4c,4d	2-20-82	4-5-82	1.33	79%	--
H9,3c	2-20-82				
9c	3-27-82	6-30-82	0.88	84%	--
B3-B9	3-27-82	10-3-84	0.88	90%	0%
Soil 1	3-27-82	6-16-82		--	--
A2-A6	5-25-82	6-10-82	0.96	83%	--
A7-A9,E3 E5-E6,13b	5-25-82	6-10-82	0.96	121%	--
B2-B9, 4d,13b	5-25-82	6-4-82	0.17	98%	--
I1-I10, J3-J10	5-25-82	6-11-82	0.96	122%	--
B2-B9	6-18-82	6-29-82	0.96	98%	--
A2-A4, 7a-7c	6-23-82	8-12-82	0.70	55%	--
A5-A9	6-23-82	9-16-82	0.70	83%	--
A2-A9	7-29-82	8-5-82	0.70	87%	5%
B2-B9	7-29-82	8-4-82	0.70	73%	2%
2b-2c,4d, 7a-7c	7-29-82	8-4-82	0.70	68%	5%
Soil 2	9-3-82	9-10-82	0.70	100%	--
A2-A9	9-3-82	9-20-82	0.70	79%	3%
B2-B7	9-3-82	10-6-82	0.70	79%	1%
B8-B9,3b G6-G7,H8-H9	9-3-82	10-11-82	0.70	69%	--
H2-H7	9-3-82	10-7-82	0.70	72%	--
I1-I10, 4c,4d	9-3-82	9-16-82	0.70	62%	--
2a-2c, 7a-7c	9-3-82	9-21-82	0.70	41%	--
A2-A9	10-15-82	11-11-82	0.70	68%	5%
B2-B9	10-15-82	11-3-82	0.70	66%	5%
I1-I10	10-12-82	10-13-82	0.70	62%	--
2b-2c,3c, 4d,7a-7c	10-15-82	11-11-82	0.70	80%	4%
B1-B9	11-23-82	3-1-82	0.70	68%	3%
I1-I10,4d	11-23-82	12-1-82	0.70	76%	--
A2-A8	3-13-83	5-6-83	0.88	106%	12%
B4-B9	3-13-83	5-9-83	0.88	92%	18%

Quality control information for aldicarb samples.

Well No.'s	Date sampled	Date Extracted	Spike Concentration ppm	Spike Recovery %	Duplicate Difference %
G1-G9	3-13-83	5-10-83	0.88	103%	13%
H7-H9,3c,4d	3-13-83	4-21-83	0.70	86%	13%
I4-I10	3-13-83	4-20-83	0.70	--	--
2a-2c,7a-7c	3-13-83	4-21-83	0.70	70%	5%
I4-I10	4-12-83	4-20-83	0.70	--	--
I5-I10,4a-4d	6-2-83	6-16-83	0.88	103%	--
I6,I10,4d, 11c-11d,12d	7-6-83	7-7-83	0.88	111%	--
B4-B9	8-11-83	8-16-83	0.88	101%	7%
C2-C8	8-11-83	8-17-83	0.88	89%	7%
C1,C9,D8-D11, 4c,4d	8-11-83	10-14-83	0.88	106%	--
D1-D7	8-11-83	8-19-83	0.88	89%	--
E5-E6,F1-F4	8-25-83	9-30-83	0.88	--	--
F5-F10	8-25-83	8-29-83	0.88	--	--
8a-8d,9b-9c, 10a-10b	8-25-83	9-29-83	0.88	--	--
A2-A9	10-17-83	10-28-83	0.88	88%	--
B4-B9	10-18-83	10-31-83	0.88	76%	1%
C1-C7	10-18-83	10-27-83	0.88	78%	--
D1-D7	10-18-83	11-3-83	0.88	77%	3%
2a-2c,4c-4d, 7a-7c	10-17-83	11-8-83	0.88	61%	--
9b,9c,14c-17c	1-6-84	1-25-84	0.73	35%	--
A4-A9	2-11-84	10-19-84	0.88	69%	3%
B6-B9	2-11-84	9-25-84	0.88	73%(B6) 80%(B8)	0% --
C1-C7	2-11-84	9-27-84	0.88	78%	20%
D4-D9	2-11-84	10-18-84	0.88 0.88	78%(D6) 80%(D9)	-- --
9c,14c-17c	2-11-84	4-9-84	1.28 0.74	65% --	-- --
8b-8d,9c, 10b,10c, 14b,14c	4-18-84	10-23-84	0.88	82%	--
15b,15c,16a-16c,17b,17c	4-18-84		0.88 0.83	81%(15c) 72%(16c)	-- --

APPENDIX G

Depth of water table below ground level in each well (depths in Wells A,I and J were extapolated from known depths in other wells until 9/3/82, in Wells B,G and H until 7/6/83, and in Wells E,F and J always.

Well	1981		1982												1983									1984			
No.	11/14	11/19	2/1	2/20	3/27	5/25	6/18	6/23	7/29	9/3	10/12	10/15	11/23	12/3	1/10	3/13	4/12	6/8	7/6	8/11	8/25	10/10	10/18	1/6	2/11	4/18	6/28
A						5.68		6.28	6.0	6.19	6.73	6.74	4.94	5.07	5.23	4.28		3.75					4.34		5.98		
B		8.07		9.2	8.20	7.10	7.35		7.41	7.63		8.12	6.28	6.36	6.36	5.65	5.56	5.36	6.69	7.93			5.70		7.32		4.14
C																				7.26			5.21		6.66		
D																				7.41			5.29		7.06		
E						7.13		7.64																			
F						5.05		5.53																			
G																										5.29	4.43
H																										5.44	4.54
I	5.96		6.65		6.04	4.68		5.43	5.20	5.3			4.18	4.35	4.55	3.55	3.49	3.05									
J	10.37		11.21		10.57	9.37		9.87																			
1b																						3.97					3.53
1c																						3.96					3.53
2b									5.26	5.41				4.08	4.40	3.29		3.58					3.57				3.31
2b2						4.8			5.17	5.37				4.22		3.3		3.47					3.45				3.17
2c					5.15				5.2	5.34		5.76				3.34		3.53					3.45				3.25
3c				7.35	6.15					5.81		6.32				4.85		3.78							5.6	4.26	3.58
4a																		5.79	7.24			6.44	6.09				5.56
4c			9.34	9.49	8.69	7.49	7.74	8.0		8.06			6.76					5.79	7.21	8.32		6.43	6.09		7.78		5.55
4d		8.5		9.60	8.7				7.8	8.02	8.48	8.51		6.85	6.85	6.05	5.96	5.76	7.13	8.4	7.91	6.4	6.07	7.15	7.75	6.35	5.53
5a												9.6						7.54	8.79			8.38					7.39
5b				11.88	8.20														8.88			8.44	8.52				7.39
6a																			-			7.11					6.03
6b																						7.13					6.03
6d																						6.98					5.99
7b									9.6	9.3				7.97	7.93	7.03		6.71					7.13				
7b2				10.4	9.7			9.3	8.85	9.28						6.98		6.7					7.11				
7c				10.14					8.84	9.36						6.99		6.72					7.13				6.13
8b																					4.19	2.87	2.56	3.49	4.02	2.78	2.50
8c					4.73																4.18	2.87				2.77	2.49
8d																					4.21	2.87				2.78	2.49
9b		6.4			6.7				5.7			6.35	4.55	4.57	4.78		4.90	3.96	4.92	6.2	5.65	4.32	4.01	5.06		4.28	3.77
9c					6.58			5.83		5.68									4.87		5.63	4.30		5.06	5.61	4.28	3.76
10b																					5.79	4.52		5.16		4.40	4.06
10c																					5.80	4.56	4.29			4.42	4.08
12c																			6.88							6.13	5.46
12d																			6.76							6.05	5.4
13d																			5.84							4.83	
14																								7.34	7.93	6.52	
15																								7.57	8.15	6.75	
16																								6.01	6.58	5.19	
17																								5.95	6.53	5.00	

APPENDIX H

Elevation of water table in each well for each sampling date (relative to ground level at Well 4) (same extrapolations as in Appendix G).

Well	1981		1982												1983									1984			
No.	11/14	11/19	2/1	2/20	3/27	5/25	6/18	6/23	7/29	9/3	10/12	10/15	11/23	12/3	1/10	3/13	4/12	6/8	7/6	8/11	8/25	10/10	10/18	1/6	2/11	4/18	6/28
A						7.00		7.60	7.32	7.51	8.05	8.06	6.26	6.39	6.55	5.60		5.07					5.70		7.30		
B		8.45		9.58	8.58	7.48	7.73		7.39	8.01		8.50	6.66		6.84	6.03	5.94	5.74	7.07	8.31			6.08		7.73	6.32	5.53
C																				8.42			6.37		7.82		
D																				8.54			6.42		8.09		
E						8.64		9.15													8.99						
F						8.69															8.96						
G																						4.98					5.84
H																						5.69					6.59
I	8.2		9.89		9.18	8.02		8.57	8.34	8.44	9.34		7.32	7.49	7.69	6.69	6.63	6.19									
J	9.7		10.54		9.9	8.7		8.7																			
1b																						4.12					3.68
1c																						4.11					3.68
2b									6.21	6.36				5.07	5.39	4.24		4.53					4.52				4.26
2b2						5.57			6.12	6.32				4.99		4.25		4.42					4.40				4.12
2c					6.1				6.15	6.29		6.71				4.29		4.48					4.40				4.20
3c				6.88	5.68					8.37		8.88				7.41		8.34							8.16	6.82	6.14
4a																		5.79	7.24			6.44	6.09				5.36
4c			9.34	9.49	8.69	7.49	7.74	7.84		8.06			6.76					5.79	7.21	8.32		6.43	6.04		7.78		5.55
4d		8.5		9.6	8.7				7.8	8.02	8.48	8.51		6.85	6.85	6.05	5.96	5.76	7.13	8.4	7.91	6.40	6.07	7.15	7.75	6.35	5.53
5a																		5.11	6.36			5.95					4.87
5b				9.38															6.38			5.94	5.70				4.89
6a																						1.98					1.00
6b																						1.98					1.00
6d																						1.95					0.96
7b									6.31	6.01		6.31		4.68	4.64	3.74		3.42					3.84				
7b2				6.93	6.41				5.56	5.99						3.69		3.41					3.82				
7c				6.85					5.55	6.07						3.70		3.43					3.84				2.84
8b																					12.54	11.22	10.91	11.84	12.37	11.13	10.85
8c					13.05																12.53	11.22				11.12	10.84
8d																					12.56	11.22				11.13	10.84
9b		11.05			11.35				10.35			11.00	9.20	9.22	9.43		8.55	8.61	9.57	10.85	10.30	8.97	8.66	9.71		8.93	8.42
9c					11.23	10.03				10.33									9.52		10.28	8.95		9.71	10.26	8.93	8.41
10b																					10.73	9.46		10.10		9.34	9.00
10c																					10.74	9.50	9.23			9.36	9.02
12c																			8.11							7.36	6.69
12d																			8.06							7.35	6.71
13d																											
14c																								7.85	8.44	7.03	
15c																								8.22	8.80	7.40	
16c																								8.71	9.28	7.94	
17c																								9.51	10.09	9.00	

APPENDIX I

Chronological relationships between wells and aldicarb plume given a groundwater flow rate of **1 ft/day** and 60 days for aldicarb to reach groundwater after application.

Well No.	Time for Aldicarb Plume to Reach Well After Temik Appl. (Days)		Date Aldicarb Plume Reaches Well		Length of Time Aldicarb is Present in Well (Days)	Period of Aldicarb Contamination
	1979	1980	1979	1980		
A	1297	61	Nov 82	Jul 80	2490	Jul 80-May 87
B	1515	261	Jul 83	Jan 81	2515	Jan 81-Dec 87
C	1614	360	Oct 83	May 81	2515	May 81-Apr 88
D	1711	457	Jan 84	Aug 81	2515	Aug 81-Jun 88
E	2265	980	Oct 85	Jan 83	2540	Jan 83-Jan 90
F	2867	1565	Apr 87	Aug 84	2540	Aug 84-Aug 91
G	949	197	Dec 81	Nov 80	2120	Nov 80-Oct 86
H	1515	566	Jul 83	Nov 81	2318	Nov 81-Apr 88
I	1801	687	Apr 84	Mar 82	2416	Mar 82-Nov 88
J	2132	1109	Mar 85	May 83	2342	May 83-Oct 89
1	-	-	-	-	0	-
2	131	131	Sep 79	Sep 80	962	Sep 83-May 83
3	1515	492	Jul 83	Sep 81	2367	Sep 81-Mar 88
4	1524	271	Jul 83	Jan 81	2564	Jan 81-Feb 88
5	1541	1343	Aug 83	Jan 84	1479	Jul 83-Feb 88
6	-	-	-	-	0	-
7	71	81	Jul 79	Jul 80	1257	Jul 79-Dec 83
8	4228	2946	Dec 90	Jun 88	2293	Jun 88-Sep 94
9	3227	1896	Mar 88	Jul 85	2589	Jul 85-Aug 92
10	4080	2773	Jul 90	Jan 88	1972	Jan 88-May 93
11	3562	2255	Feb 89	Jul 86	1751	Jul 86-May 91
12	1515	566	Jul 83	Nov 81	2318	Nov 81-Apr 88
13	1610	661	Sep 83	Feb 82	2318	Feb 82-Jul 88
14	1898	654	Jul 84	Feb 82	2540	Feb 82-Feb 89
15	2141	897	Mar 85	Oct 82	2540	Oct 82-Oct 89
16	2441	1197	Jan 86	Aug 83	2564	Aug 83-Sep 90
17	2932	1688	Jun 87	Dec 84	2589	Dec 84-Feb 92

Chronological relationships between wells and aldicarb plume given a groundwater flow rate of **1.5 ft/day** and 60 days for aldicarb to reach groundwater after application.

Well No.	Time for Aldicarb Plume to Reach Well After Temik Appl. (Days)		Date Aldicarb Plume Reaches Well		Length of Time Aldicarb is Present in Well (Days)	Period of Aldicarb Contamination
	1979	1980	1979	1980		
A	885	61	Oct 81	Jul 80	1660	Jul 80-Jan 85
B	1030	194	Feb 82	Nov 80	1677	Nov 80-Jun 85
C	1096	260	May 82	Jan 81	1677	Jan 81-Aug 85
D	1161	325	Jul 82	Mar 81	1677	Mar 81-Oct 85
E	1530	674	Jul 83	Mar 82	1693	Mar 82-Oct 86
F	1932	1063	Aug 84	Apr 83	1693	Apr 83-Nov 87
G	653	151	Feb 81	Oct 80	1413	Oct 80-Aug 84
H	1030	397	Feb 82	Jun 81	1545	Jun 81-Sep 85
I	1221	478	Sep 82	Aug 81	1611	Aug 81-Jan 86
J	1442	760	Apr 83	Jun 82	1561	Jun 82-Sep 86
1	-	-	-	-	0	-
2	108	107	Aug 79	Aug 80	641	Aug 79-May 82
3	1030	348	Feb 82	Apr 81	1578	Apr 81-Aug 85
4	1036	201	Mar 82	Nov 80	1709	Nov 80-Aug 85
5	1048	916	Mar 82	Nov 82	986	Nov 82-Jul 85
6	-	-	-	-	0	-
7	68	74	Jul 79	Jul 80	838	Jul 79-Oct 82
8	2839	1984	Feb 87	Oct 85	1529	Oct 85-Dec 89
9	2172	1284	Apr 85	Sep 84	1726	Sep 84-Aug 88
10	2740	1869	Nov 86	Jun 85	1315	Jun 85-Feb 89
11	2395	1524	Nov 85	Jul 84	1167	Jul 84-Sep 87
12	1030	398	Feb 82	Jun 81	1545	Jun 81-Sep 85
13	1094	461	May 82	Aug 81	1545	Aug 81-Nov 85
14	1286	456	Nov 82	Aug 81	1693	Aug 81-Mar 86
15	1448	618	Apr 83	Jan 82	1693	Jan 82-Sep 86
16	1648	818	Nov 83	Sep 82	1709	Sep 82-Apr 87
17	1975	1146	Oct 84	Jun 83	1726	Jun 83-Mar 88

APPENDIX I, continued

Chronological relationships between wells and aldicarb plume given a groundwater flow rate of **2 ft/day** and 60 days for aldicarb to reach groundwater after application.

Well No.	Time for Aldicarb Plume to Reach Well After Temik Appl. (Days)		Date Aldicarb Plume Reaches Well		Length of Time Aldicarb is Present in Well (Days)	Period of Aldicarb Contamination
	1979	1980	1979	1980		
A	679	61	Mar 81	Jul 80	1245	Jul 80-Dec 83
B	788	161	Jun 81	Oct 80	1258	Oct 80-Mar 84
C	838	210	Aug 81	Nov 80	1258	Nov 80-May 84
D	886	259	Oct 81	Jan 81	1258	Jan 81-Mau 84
E	1163	520	Jul 82	Oct 81	1270	Oct 81-Apr 85
F	1464	813	May 83	Jul 82	1270	Jul 82-Jan 86
G	505	129	Sep 80	Sep 80	1060	Sep 80-Aug 83
H	787	313	Jun 81	Mar 81	1159	Mar 81-May 84
I	931	374	Nov 81	May 81	1208	May 81-Sep 84
J	1096	585	May 82	Dec 81	1171	Dec 81-Feb 85
1	-	-	-	-	0	-
2	96	96	Aug 79	Aug 80	481	Aug 79-Dec 81
3	788	276	Jun 81	Feb 81	1184	Feb 81-Apr 84
4	792	166	Jul 81	Oct 80	1282	Oct 80-Apr 84
5	801	702	Jul 81	Apr 82	740	Jul 81-Apr 84
6	-	-	-	-	0	-
7	66	71	Jul 79	Jul 80	628	Jun 79-Mar 82
8	2144	1504	May 85	Jun 84	1146	Jun 84-Aug 87
9	1644	978	Nov 83	Jan 83	1294	Jan 83-Jul 86
10	2070	1417	Jan 85	Mar 84	986	Mar 84-Dec 86
11	1812	1158	Apr 84	Jul 83	875	Jul 83-Dec 85
12	788	313	Jun 81	Mar 81	1159	Mar 81-May 84
13	835	361	Aug 81	Apr 81	1159	Apr 81-Jul 84
14	979	357	Jan 82	Apr 81	1270	Apr 81-Oct 84
15	1101	479	May 82	Aug 81	1270	Aug 81-Feb 85
16	1251	629	Oct 82	Jan 82	1282	Jan 82-Aug 85
17	1469	874	Jun 83	Sep 82	1294	Sep 82-Apr 86

Chronological relationships between wells and aldicarb plume given a groundwater flow rate of **3 ft/day** and 60 days for aldicarb to reach groundwater after application.

Well No.	Time for Aldicarb Plume to Reach Well After Temik Appl. (Days)		Date Aldicarb Plume Reaches Well		Length of Time Aldicarb is Present in Well (Days)	Period of Aldicarb Contamination
	1979	1980	1979	1980		
A	473	61	Aug 80	Jul 80	830	Jul 80-Oct 82
B	545	128	Oct 80	Sep 80	838	Sep 80-Dec 82
C	579	161	Dec 80	Oct 80	838	Oct 80-Jan 83
D	611	193	Jan 81	Nov 80	838	Nov 80-Mar 83
E	796	367	Jul 81	May 81	847	May 81-Sep 83
F	996	562	Jan 82	Nov 81	847	Nov 81-Mar 84
G	357	106	Apr 80	Aug 80	706	Apr 80-Jul 82
H	546	229	Oct 80	Dec 80	772	Oct 80-Feb 83
I	641	270	Feb 81	Jan 81	805	Jan 81-Apr 83
J	751	410	May 81	Jun 81	781	Jun 81-Aug 83
1	-	-	-	-	0	-
2	84	84	Jul 79	Jul 80	321	Jul 79-Jun 81
3	546	205	Oct 80	Nov 80	789	Oct 80-Jan 83
4	549	131	Nov 80	Sep 80	855	Nov 80-Jan 83
5	554	18	Nov 80	Sep 81	493	Nov 80-Jan 83
6	-	-	-	-	0	-
7	64	64	Jul 79	Jul 80	419	Jul 79-Sep 81
8	1450	1023	Apr 83	Feb 83	764	Feb 83-Mar 85
9	1116	673	May 82	Mar 82	863	Mar 82-Jul 84
10	1401	965	Mar 83	Dec 82	657	Dec 82-Oct 84
11	1228	792	Sep 82	Jul 82	584	Jul 82-Feb 84
12	546	229	Oct 80	Dec 80	773	Oct 80-Feb 84
13	577	261	Dec 80	Jan 81	773	Dec 80-Mar 84
14	673	259	Mar 81	Jan 81	847	Mar 81-May 83
15	754	340	May 81	Apr 81	847	Apr 81-Aug 83
16	854	440	Sep 81	Jul 81	855	Jul 81-Nov 83
17	1018	603	Feb 82	Dec 81	863	Dec 81-May 84

APPENDIX J

Results of laboratory study on aldicarb degradation.

Well No.	Date sampled	Date Extracted	Aldicarb Conc. ppb	Aldicarb Duplicate ppb	Aldicarb Conc. Corrected ppb	Aldicarb Duplicate Corrected ppb
B6	3-27-82	3-30-82	54	52	0	0
B6	3-27-82	6-15-82	57	55	44	42
B6	3-27-82	8-3-82	51	52	0	0
B6	3-27-82	10-14-82	40	40	37	37
B6	3-27-82	2-1-83	48	43	112	100
B6	3-27-82	5-13-83	45	39	38	33
B6	3-27-82	7-13-83	49	51	42	44
B6	3-27-82	11-21-83	46	43	0	0
B6	3-27-82	9-28-84	40	39	40	39
B7	3-27-82	3-30-82	90	84	0	0
B7	3-27-82	8-3-82	75	-	-	-
B7	3-27-82	10-14-82	74	79	172	184
B7	3-27-82	2-1-83	63	64	83	84
B7	3-27-82	5-13-83	74	69	54	51
B7	3-27-82	7-13-83	81	82	62	63
B7	3-27-82	11-21-83	76	74	0	0
B7	3-27-82	9-28-84	64	66	79	81
B8	3-13-83	3-16-83	12	12	16	16
B8	3-13-83	5-13-83	15	24	0	0
B8	3-13-83	7-13-83	12	13	15	16
B8	3-13-83	11-21-83	9	10	19	21
B8	3-13-83	9-28-84	4	5	7	8

APPENDIX K

Quality control information for laboratory study on aldicarb degradation.

Well No.	Date sampled	Date Extracted	Spike Concentration ppm	Spike Recovery %	Duplicate Difference %
B6	3-27-82	3-30-82	0.05	0%	4%
B6	3-27-82	6-15-82	0.96	130%	4%
B6	3-27-82	8-3-82	0.70	0%	2%
B6	3-27-82	10-14-82	0.70	107%	0%
B6	3-27-82	2-1-83	0.70	43%	10%
B6	3-27-82	5-13-83	0.88	117%	13%
B6	3-27-82	7-13-83	0.88	117%	4%
B6	3-27-82	11-21-83	0.73	0%	7%
B6	3-27-82	9-28-84	0.88	101%	3%
B7	3-27-82	3-30-82	0.05	0%	7%
B7	3-27-82	8-3-82	0.70	-	-
B7	3-27-82	10-14-82	0.70	43%	6%
B7	3-27-82	2-1-83	0.70	76%	2%
B7	3-27-82	5-13-83	0.88	136%	7%
B7	3-27-82	7-13-83	0.88	131%	1%
B7	3-27-82	11-21-83	0.73	0%	3%
B7	3-27-82	9-28-84	0.88	81%	3%
B8	3-13-83	3-16-83	0.87	75%	0%
B8	3-13-83	5-13-83	0.88	0%	38%
B8	3-13-83	7-13-83	0.88	82%	8%
B8	3-13-83	11-21-83	0.73	48%	10%
B8	3-13-83	9-28-84	0.88	59%	12%