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# The Composition of Soils, Plants, and Waters in the TJ Drain Catchment Area, Newlands Irrigation Project, Churchill County, Nevada

by

R.R. Tidball[1], S.A. Wilson[1], and Tony Cappalucci[2]

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[1]U.S. Geological Survey, Denver Federal Center, Box 25046, MS973, Denver, CO 80225

[2]U.S. Bureau of Reclamation, Denver Federal Center, Denver, CO 80225

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# The composition of soils, plants, and waters in the TJ Drain catchment area, Newlands Irrigation Project, Churchill County, Nevada

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## ABSTRACT

Samples of soils, vegetation, and shallow groundwater were collected within the catchment area of the TJ Drain on the Fallon Indian Reservation, Churchill County, Nevada. All samples were analyzed for about 40 elements. Soils were analyzed both for total and water-extractable element content, the distributions of data are plotted on maps. In general, the concentrations of several elements, particularly those in more readily soluble forms (As, Li, Mo), tend to occur in higher concentrations on lands not previously irrigated. Specific conductivity of soil-water extracts indicates that only tolerant crops could produce satisfactory yields on some of these nonirrigated soils. The composition of soils in the study area is not unusual compared to other soils within the closed Lahontan basin, but they do contain higher amounts of several elements compared to other western soils outside of the closed basin. Two environmentally sensitive elements, Se and Hg, are anomalous. Se is low in concentration (geometric mean in surface soils, 0.1 ppm). The maximum Hg value was 32 ppm compared to a typical background value for soils of about 50 ppb.

The composition of some groundwaters in terms of As, B, and Mo exceeds State or Federal water quality criteria for crops, livestock, aquatic life, or municipal use. The shallow groundwaters probably represent a mixture of old groundwater and new irrigation water that percolates through the soil profile. Alfalfa, the principal cultivated crop, has moderately elevated amounts of As, but Se and Mo are within the normal range for this plant. The Cu/Mo ratio of alfalfa is well above the threshold where white muscle disease in livestock would become a problem. Big greasewood has only about one tenth of the amount of Mo and Se compared to that growing in a similar setting in Mason valley, Lyon County, Nevada.

## INTRODUCTION

In 1989 the U.S.Geological Survey and the Bureau of Reclamation investigated the distribution of elements on lands within and adjacent to the Fallon Indian Reservation, Churchill County, Nevada (Figure 1). The investigation focused on lands serviced by the TJ Drain and a short tributary, TJ Stub, a local irrigation return flow system within the Newlands Irrigation Project that removes drainage water from agricultural fields and deposits it into the Stillwater Wildlife Management Area (SWMA). The irrigated area is shown in Figure 2. Following a consideration of the various components of the local irrigation system, the objective was to determine what elements are mobilized, and to estimate their impact on TJ-Drain and SWMA water quality. This was accomplished by examining soils, drain sediments, groundwaters, native

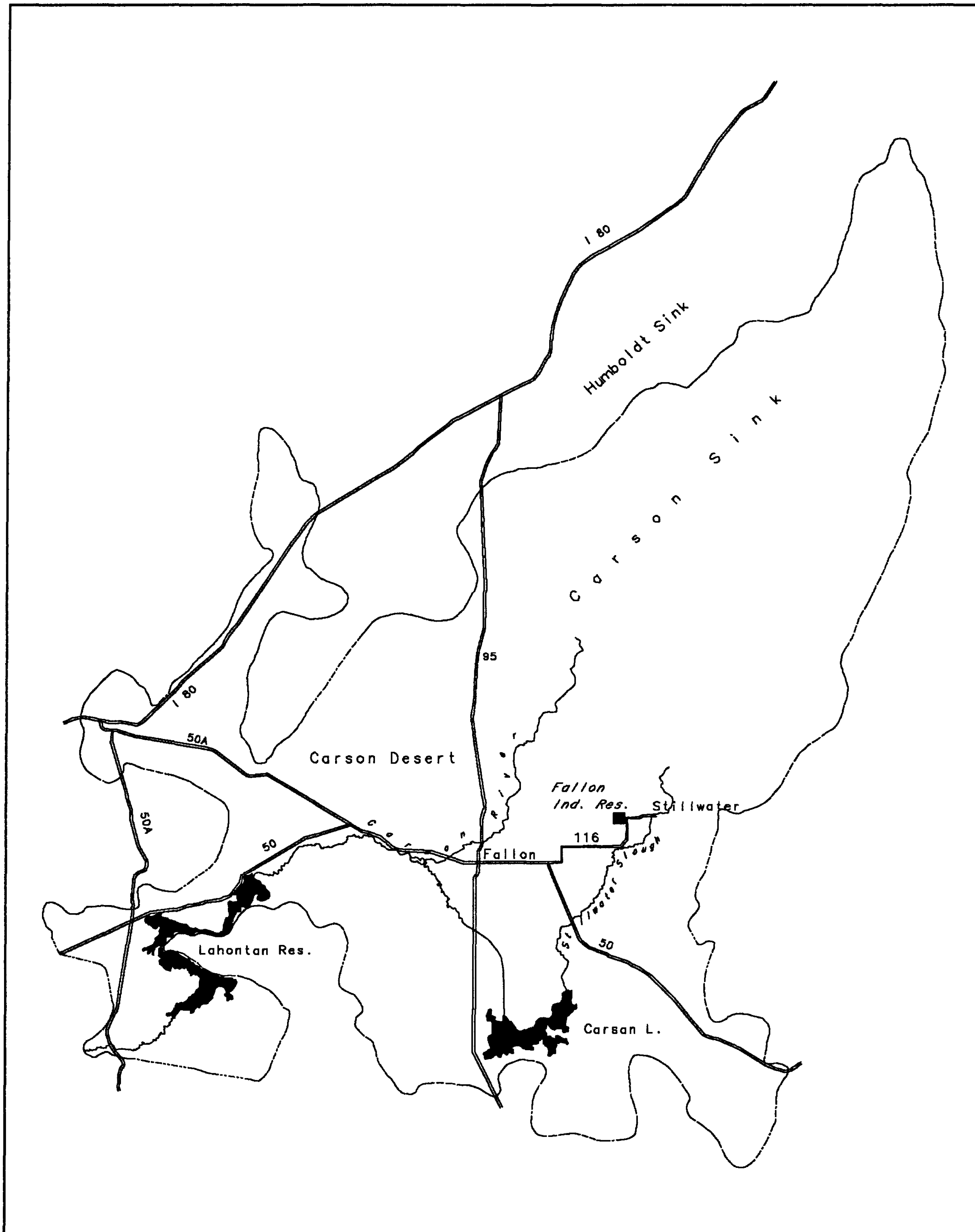


**Figure 1.**--Outline map of the Lahontan Basin in Churchill and Lyon Counties, Nevada. TJ Drain is located partially on the Fallon Indian Reservation.

vegetation, alfalfa, and return flow waters. Data on drain sediments and return-flow waters were reported by Wilson and others (in press). The data for soils, vegetation, and groundwater are the subject of this report.

Sampling occurred in April, 1989, and required approximately two weeks to complete. Whereas this time period is classified as the early irrigation season in the study area (Hoffman and others, 1989), in fact, no irrigation was observed during the sampling period. The composition of the groundwater is therefore assumed to be in equilibrium with the solid materials to the extent that several months had elapsed since the previous irrigation season. Because of the seasonality of the water management, the results from this study may show elevated element concentrations not typical of the entire irrigation season. If element concentrations are atypical, the study will still be relevant because during the period of irrigation any precipitated elements will be redissolved and eventually relocated into the groundwater and/or through the TJ Drain to the SWMA.

## Background

Previous investigations by the Department of Interior's Selenium Irrigation Task Force (SEITF) (Hoffman and others, 1989) and the Fish and Wildlife Service (FWS) (Finger and others, 1988) have indicated that waters derived from the study area may contain constituents which adversely affect certain wildlife species. Experiments done by the FWS over a ten day period indicated that waters from the region were toxic to bluegill, larval fathead minnow and daphnids. Studies performed by the SEITF found that areas affected by irrigation drainage contained constituents which exceeded Federal and State criteria for aquatic life or the propagation of wildlife (Hoffman, 1989). Concerns were expressed over potential adverse environmental impact from As, Hg, Mo, and Se. Based on these investigations, this study employed a more comprehensive sample design to evaluate the entire drainage/irrigation systems in order to develop a more complete understanding of the local ecosystem.

## Geology

The study area lies within the Lahontan basin, the largest intermontane basin in northern Nevada, a part of the Basin and Range physiographic province. The Carson Sink lies in the lowest part of the basin. The Lahontan basin and the Carson Sink comprise the main bed of Pleistocene Lake Lahontan (see Figure 1). The parent materials from which the soils of the study area developed are Holocene lacustrine sediments, mostly fine grained, modified in places by an overprint of coarser-grained fluvial sediments and aeolian sands. The sediments, which are about 300 m thick, predominantly reflect a variety of local lithologic sources that surround the Lahontan basin including andesites and associated breccia, silicic and rhyolitic intrusives, ash-flow tuffs, basalts, sedimentary rocks of the Stillwater and West Humboldt Ranges, and granites from the Sierra Nevada.

The soils in the Lahontan basin in general are developed on fine-grained lacustrine sediments. The character of the parent material changes, however, as it grades into sandy beach deposits along the shore. Locally the beaches are covered by a veneer of detritus that originates from nearby source-rock material. The parent material in some local areas within the lake bed are modified by aeolian sand that have accumulated into dunes.

### Structure

High-angle, northwest- to northeast-trending faults that occur in the vicinity of the community of Stillwater are described by Morgan (1982). The northwest faults are older, probably pre-Miocene. Younger faults of Pliocene age changed the direction toward north to northeast. More recent faulting commenced during the Pleistocene; the most recent was in 1954. Traces of the younger faults as adapted from Morgan (1982) are shown in Figure 2.

There are several geothermal resource areas in Churchill County (Olmstead and others, 1984), one of which underlies the area surrounding Stillwater and the TJ Drain (Morgan, 1982). Fracture zones along faults increase the permeability and provide conduits for the movement of hot waters from deep reservoirs. The major fault just east of Stillwater is judged to be the conduit for geothermal waters that make up this local geothermal resource area which extends from Stillwater northwest toward the TJ Drain.

The composition of the shallow groundwater in the study area probably represents some mixture of regional nonthermal groundwater, which has a lateral movement northward and northeastward toward the Carson Sink, and deeper confined thermal waters that move upward along fault controlled channels (Morgan, 1982). Since the advent of irrigation, recharge from canal leakage and percolating irrigation water have become the most significant component of the mixture.

## METHODS

### Field samples

Soil and groundwater samples

Soil samples were collected from 37 sites in the vicinity of TJ Drain and the Fallon Indian Reservation (see Figure 2). Thirty one of the sites (A1...G7) were arranged in a grid pattern with approximately one mile spacing across the study area. At the grid sites, soil samples were collected from the surface horizons, 0-1 foot (0-30 cm) depth, and at the depth of the shallow water table; the samples represent a vertical composite over a depth interval of 6-12 inches (15-30 cm). In addition, 6 sites designated as "complete profiles" (CP1...CP6) were selected where composite soil samples were collected at one-foot (30 cm) intervals throughout the soil profile down to the water table (level ranged in depth 5-13 feet (150-400 cm)). Samples from the surface horizons were obtained with a hand shovel. Samples at depth were obtained by use of a stainless steel soil auger. The soil samples were air dried, disaggregated, and the less-than-2-mm fraction was ground to -100 mesh. The -100 mesh material was used for all analyses.

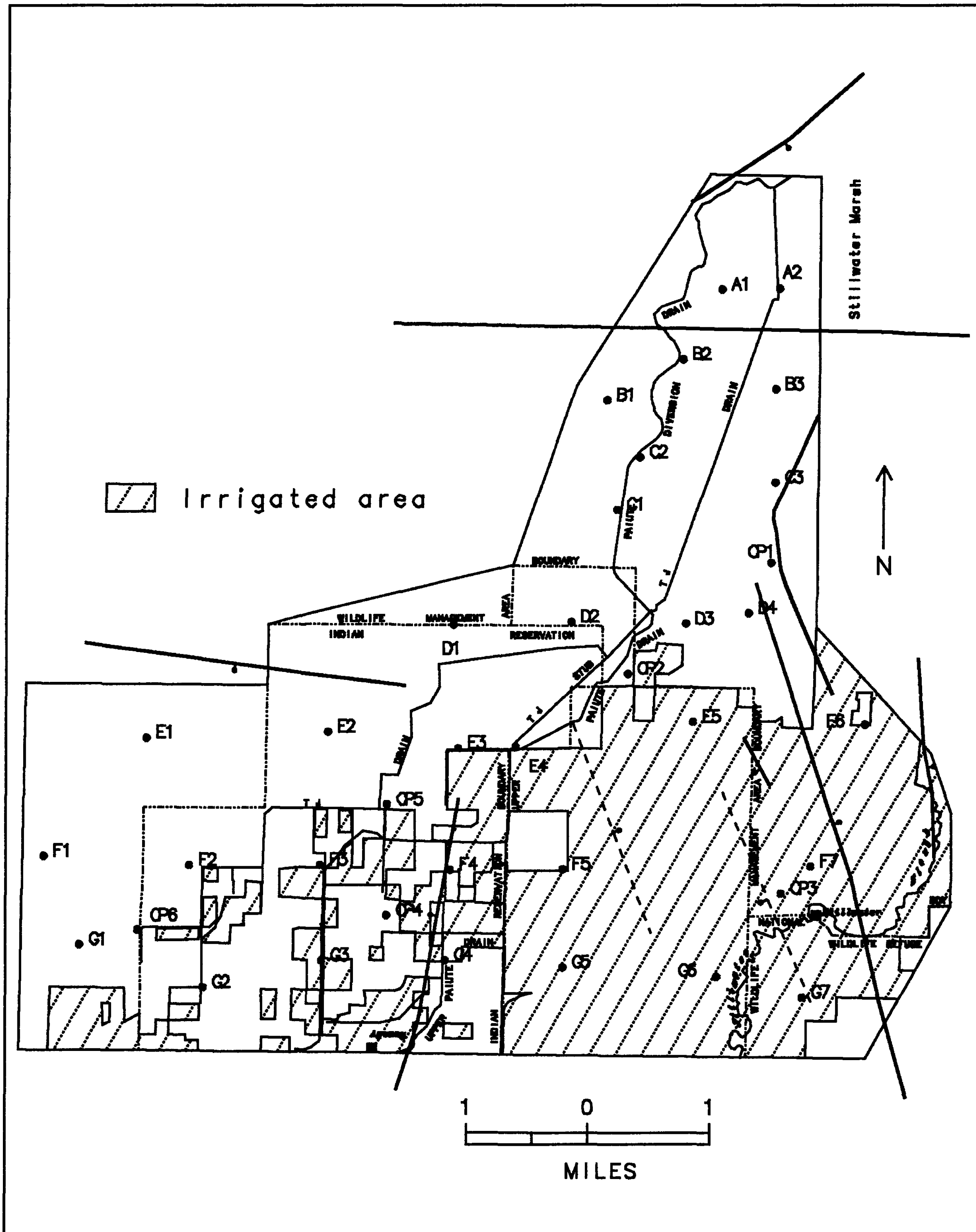


**Figure 2.**--TJ Drain study area, Fallon Indian Reservation, and Stillwater Wildlife Management Area. Traces of local faults (solid-known, dashed-uncertain, ball on down-thrown side) (Morgan, 1982). Sampling sites, A1... and CP1...

Water samples (100 ml each) were collected by use of suction pump and hose at each of the 37 soil sites from a depth at which water accumulated in the auger hole. This water, hereafter referred to as "groundwater", is taken to be representative of that water which is in equilibrium with the solid, mineral, soil material. Water samples were filtered through a 0.45 micron filter, and acidified to pH 1.

Vegetation samples

Samples of alfalfa (Medicago sativa L.) vegetation were collected at each of the soil sites where it was available. A composite of stems, leaves, and flowers were selected from several alfalfa plants within a radius of 5 meters. Alfalfa is the most common cultivated plant in the irrigated part of the study area, and it was found at 12 sites. Alternatively, the native plant, big greasewood (Sarcobatus vermiculatus [Hook.] Torr.) was usually collected if available where alfalfa did not occur. A composite of leaves and recent twigs were selected from several sides of 2 or 3 adjacent plants. Generally greasewood occupied noncultivated sites, but both plants were collected at six sites, F3, F4, F5, G2, G3, and G4. No plants were available at E3 and G7.

## Chemical methods

Samples of soil were analyzed for total amounts of 40 elements by inductively coupled argon plasma atomic emission spectroscopy (ICAP). In addition As and Se were determined by hydride generation atomic absorption spectroscopy (HG-AAS), and Hg was determined by cold vapor generation atomic absorption spectroscopy (CV-AAS). Boron is not reported because it is volatilized in the acid digestion, and W and Zr are not completely soluble.

Water extracts (1:5 soil to water) were analyzed for 28 elements using ICAP, As and Se by HG-AAS, $Cl^-$ and $SO_4^{2-}$ by anion chromatography (IC), pH by pH meter in solution, and specific conductivity by conductivity meter in solution. Specific conductivity is reported as mmhos/cm in the extract solution. Groundwaters were analyzed for 28 elements by ICAP and As and Se were determined by HG-AAS. Dissolved elements in water are present in some ionic form. With the exception of $Cl^-$ and $SO_4^{2-}$, the ionic form is not determined; all analyses are therefore reported as total concentrations in solution.

The ash content of plant samples was determined, and ash was then analyzed for 40 elements by ICAP. The results are recomputed and reported on a plant dry-weight basis. Analyses for As and Se were done by HG-AAS on dry plant material to avoid volatilizing the elements by the ashing process. The original analytical data were reported by Wilson and others (in press). A detailed discussion of analytical procedures was reported by Baedeker (1987).

The lower limits of detection for the several elements according to the method used is shown in Table 1. The limits shown for a given element differ according to the media. The reason is that limit reflects the original media analyzed: for example, if the media is a solid (or a plant ash) that is put into solution for analysis then the limit is computed back to the solid (or plant ash). The limit for a water sample is computed back to the original sample according to any dilutions or preconcentrations that may have been applied.

**Table 1.**--Lower limits of determination for chemical methods and sample media. [CV-AAS, cold vapor generation atomic absorption spectroscopy. HG-AAS, hydride generation atomic absorption spectrocopy. IC, ion chromatography. ICAP, inductively coupled plasma atomic emission spectroscopy. All values in parts per million except as noted in parts per billion or percent. --, not determined.]

| Elements | Methods | Lower limits of determination | | | |
|---|---|---|---|---|---|
| | | Soils | Water extracts | Groundwater | Plant ash |
| Ag | ICAP | 2 | 0.2 | .04 | 4 |
| Al | ICAP | 0.005% | 10 | 2 | .01% |
| As | HG-AAS | .1 | 2 | 2 | .01 |
| Au | ICAP | 8 | -- | -- | 20 |
| Ba | ICAP | 1 | .2 | .04 | 2 |
| Be | ICAP | 1 | .1 | .02 | 2 |
| Bi | ICAP | 10 | 1 | .2 | 20 |
| Ca | ICAP | .005% | 2 | 2 | .01% |
| Cd | ICAP | 2 | .05 | .02 | 4 |
| Ce | ICAP | 4 | -- | -- | 8 |
| $Cl^-$ | IC | -- | .1 | -- | -- |
| Co | ICAP | 1 | .1 | .06 | 2 |
| Cr | ICAP | 1 | .1 | .02 | 2 |
| Cu | ICAP | 1 | .08 | .2 | 2 |
| Eu | ICAP | 2 | -- | -- | 4 |
| Fe | ICAP | .005% | 5 | 1 | .01% |
| Ga | ICAP | 4 | .5 | .1 | 8 |
| Hg | CV-AAS | 20ppb | .7ppb | -- | -- |
| Ho | ICAP | 4 | -- | -- | 8 |
| K | ICAP | .05% | 20 | 20 | .1% |
| La | ICAP | 2 | -- | -- | 4 |
| Li | ICAP | 2 | .01 | .08 | 4 |
| Mg | ICAP | .005% | 1 | 1 | .01% |

| Elements | Methods | Lower limits of determination | | | |
|---|---|---|---|---|---|
| | | Soils | Water extracts | Groundwater | Plant ash |
| Mn | ICAP | 4 | .1 | .02 | 8 |
| Mo | ICAP | 2 | .1 | .2 | 4 |
| Na | ICAP | .005% | 20 | 20 | .01% |
| Nb | ICAP | 4 | -- | -- | 8 |
| Nd | ICAP | 4 | -- | -- | 8 |
| Ni | ICAP | 2 | .1 | .1 | 4 |
| P | ICAP | .005% | -- | -- | -- |
| Pb | ICAP | 4 | .5 | .2 | 8 |
| $SO^{4-}$ | IC | -- | 2 | -- | -- |
| Sc | ICAP | 2 | -- | -- | 4 |
| Se | HG-AAS | .2 | 5ppb | 1ppb | .01 |
| Sn | ICAP | 10 | .6 | .1 | 20 |
| Sr | ICAP | 2 | .05 | .05 | 4 |
| Ta | ICAP | 40 | -- | -- | 80 |
| Th | ICAP | 4 | -- | -- | 8 |
| Ti | ICAP | .005% | .1 | .02 | .01% |
| U | ICAP | 100 | -- | -- | 200 |
| V | ICAP | 2 | .3 | .1 | 4 |
| Y | ICAP | 2 | -- | -- | 4 |
| Yb | ICAP | 1 | -- | -- | 2 |
| Zn | ICAP | 2 | .1 | .06 | 4 |
| Zr | ICAP | -- | .1 | -- | -- |

## Computation methods

Means and deviations are expressed either as arithmetic or geometric depending on whether the frequency distributions were more nearly normal or log normal, respectively. The means and deviations of censored distributions are estimated by Cohen's technique (Cohen, 1959). The degree of censoring one should accept before reporting a mean is arbitrarily set at 70 percent. Not every reader may agree with that threshold, but it should be recognized that the larger the amount of censoring, the more uncertain is the estimate. The detection ratio should be your guide to confidence in the values.

# RESULTS

The spatial distributions of soil constituents are shown in a series of figures located in the appendix. Each figure shows a plot of the soil sampling sites and the location of the major return-flow drains, TJ Drain, and TJ Stub. The concentrations of each constituent are shown by symbols and posting of larger values.

## Soil samples--total chemical analyses

The distributions of the total concentrations of 33 elements in the surface horizon (0-1 foot depth, 0-30 cm) are shown in Figures A1-A33 located in the Appendix. The figures include the surface horizons from both the grid sites and the complete-profile sites. Some elements are excluded from the illustrations because all of the values were found to be below the lower limit of determination shown in parentheses as follows: Au (8 ppm), Bi (10 ppm), Cd (2 ppm), Eu (2 ppm), Ho (4 ppm), Sn (10 ppm), Ta (40 ppm), and U (100 ppm).

The average compositions of surface horizons of soils in the TJ Drain study area are compared to the average compositions of surface soils from throughout the Lahontan basin area in Table 2. The mean for the Lahontan basin is computed from 283 samples collected in a previous unpublished study by the author. Means and deviations are expressed either as arithmetic or geometric depending on whether the frequency distributions were more nearly normal or log normal, respectively. The means and deviations of censored distributions were estimated by Cohen's technique (Cohen, 1959).

The average composition of soils in the TJ Drain study area is similar to that of the broader Lahontan basin. Soils in the TJ Drain study area tend to have higher minimum values and narrower ranges. Several elements have higher maximum observed values in the Lahontan basin, but this is because of certain local source-rock influences or depositional concentrations. The TJ Drain area does not have these extremes.

**Table 2.**--Comparison of summary statistics for total chemical analyses of soil surface horizons. Data are from the Lahontan basin (first line) and the TJ-Drain study area (**, second line). Means and deviations of censored data estimated by Cohen's technique (Cohen, 1959). Data transformed to logarithms except where reported as arithmetic statistics. [Leaders (--), no data or not calculated. #, arithmetic mean and standard deviation given.]

| Element | Detection Ratio | Geometric Mean | Geometric Deviation | Observed range |
|---|---|---|---|---|
| Ag, ppm | 3:283 | -- | -- | <2-17 |
| ** | 2:36 | -- | -- | <2-4 |
| Al, pct. | 283:283 | 7.55# | 0.92# | 1.0-9.8 |
| ** | 36:36 | 8.23 | 1.06 | 7.13-10.2 |
| As, ppm | 283:283 | 12 | 1.9 | 3.2-66 |
| ** | 36:36 | 11 | 1.9 | 3.6-40 |
| B, ppm | 266:283 | 15 | 6.7 | <.4-590 |
| ** | -- | -- | -- | -- |
| Ba, ppm | 283:283 | 834# | 173# | 89-1300 |
| ** | 36:36 | 840# | 190# | 310-1020 |
| Be, ppm | 282:283 | 1.5 | 1.4 | <1-2 |
| ** | 36:36 | -- | -- | 2-2 |
| C, pct. | 275:283 | .58 | 3.8 | <.01-4.65 |
| ** | -- | -- | -- | -- |
| Ca, pct. | 283:283 | 3.8 | 1.6 | .7-17 |
| ** | 36:36 | 2.67 | 1.19 | 2.01-4.46 |
| Ce, ppm | 283:283 | 43# | 9.6# | 8-98 |
| ** | 36:36 | 46 | 1.2 | 34-68 |
| Co, ppm | 283:283 | 12 | 1.4 | 3-49 |
| ** | 36:36 | 11 | 1.3 | 7-21 |
| Cr, ppm | 283:283 | 30 | 1.7 | 2-320 |
| ** | 36:36 | 28# | 5.7# | 18-42 |
| Cu, ppm | 283:283 | 24 | 1.8 | 4-170 |

| Element | Detection Ratio | Geometric Mean | Geometric Deviation | Observed range |
|---|---|---|---|---|
| ** | 36:36 | 22 | 1.8 | 8-63 |
| Fe, pct. | 283:283 | 2.83 | 1.38 | .53-6.8 |
| ** | 36:36 | 2.79 | 1.34 | 1.67-5.01 |
| Ga, ppm | 282:283 | 17[#] | 2.2[#] | <4-24 |
| ** | 36:36 | 18 | 1.1 | 16-26 |
| Hg, ppm | 172:283 | .025 | 9.0 | <.02-140 |
| ** | 18:36 | .017 | -- | <.02-32 |
| K, pct. | 283:283 | 2.26[#] | .38[#] | .57-3.7 |
| ** | 36:36 | 2.24[#] | 1.52[#] | 1.87-2.56 |
| La, ppm | 283:283 | 25[#] | 5.1[#] | 5-41 |
| ** | 36:36 | 27 | 1.2 | 21-39 |
| Li, ppm | 283:283 | 51 | 2.1 | 12-530 |
| ** | 36:36 | 38 | 1.5 | 19-134 |
| Mg, pct. | 283:283 | 1.34 | 1.68 | .3-5.5 |
| ** | 36:36 | 1.06 | 1.37 | .61-2.33 |
| Mn, ppm | 283:283 | 600 | 1.4 | 110-1200 |
| ** | 36:36 | 500 | 1.4 | 278-863 |
| Mo, ppm | 84:283 | 1.2 | -- | <2-20 |
| ** | 6:36 | -- | -- | <2-13 |
| Na, pct. | 283:283 | 3.08 | 1.50 | .57-28 |
| ** | 36:36 | 2.72[#] | .43[#] | 1.77-3.8 |
| Nb, ppm | 268:283 | 6.8 | 1.4 | <4-23 |
| ** | 27:36 | 5[#] | 1.7[#] | <4-9 |
| Nd, ppm | 282:283 | 21[#] | 4.5[#] | <4-34 |
| ** | 36:36 | 22 | 1.2 | 15-32 |
| Ni, ppm | 282:283 | 16 | 1.8 | <2-280 |
| ** | 36:36 | 15 | 1.3 | 8-25 |

| Element | Detection Ratio | Geometric Mean | Geometric Deviation | Observed range |
|---|---|---|---|---|
| P, pct. | 283:283 | .095# | .026# | .02-.19 |
| ** | 36:36 | .087# | .014# | .06-.11 |
| Pb, ppm | 281:283 | 16 | 1.3 | <4-150 |
| ** | 36:36 | 18 | 1.2 | 14-41 |
| S, pct. | 268:283 | .06 | 3.73 | <.01-1.70 |
| ** | -- | -- | -- | -- |
| Sb, ppm | 283:283 | 1.0 | 1.6 | .3-7.4 |
| ** | -- | -- | -- | -- |
| Sc, ppm | 282:283 | 9 | 1.4 | <2-28 |
| ** | 36:36 | 8 | 1.3 | 5-15 |
| Se, ppm | 222:283 | .2 | 2.4 | <.1-1.4 |
| ** | 11:25 | -- | -- | <.2-1.2 |
| Sr, ppm | 283:283 | 590 | 1.3 | 150-1700 |
| ** | 36:36 | 550# | 59# | 424-649 |
| Th, ppm | 264:283 | 10.7 | 1.38 | <2.80-20.1 |
| ** | 36:36 | 10.2 | 1.32 | 6-16 |
| Ti, pct. | 283:283 | .30 | 1.34 | .05-.87 |
| ** | 36:36 | .32# | .065# | .21-.48 |
| U, ppm | 269:283 | 3.7 | 1.87 | <.88-49.2 |
| ** | -- | -- | -- | -- |
| V, ppm | 283:283 | 84 | 1.4 | 21-230 |
| ** | 36:36 | 86# | 25# | 46-139 |
| Y, ppm | 283:283 | 13# | 3.2# | 2-23 |
| ** | 36:36 | 12 | 1.2 | 9-19 |
| Yb, ppm | 268:283 | 1.5 | 1.5 | <1-3 |
| ** | 33:36 | 1.2 | 1.4 | <1-2 |
| Zn, ppm | 283:283 | 61 | 1.5 | 15-170 |

| Element | Detection Ratio | Geometric Mean | Geometric Deviation | Observed range |
|---|---|---|---|---|
| ** | 36:36 | 59 | 1.5 | 29-122 |

Soil samples--water-extractable analyses

Summary statistics for 27 elements, specific conductivity, and Ph in 1:5 water-to-soil extracts from both surface horizon (0-1 foot) samples and horizons at water-table depth are shown in Table 3. The distributions of these constituents are shown in Figures A34-A59 and A60-A86, respectively. Some elements are excluded from the table and illustrations because most of the values were reported as less than the lower limit of determination as shown in parentheses: Ag (200 ppb), Be (100 ppb), Bi (1 ppm), Cd (50 ppb), Co (100 ppb), Ga (500 ppb), Pb (500 ppb), Sn (600 ppb), and Zr (100 ppb). Some elements are reported in the extracts that cannot be reported as totals because of volatilization by the acid digestion.

On the average, a number of elements show slightly higher concentrations at water-table depth than in the surface horizon (Table 3). This would suggest either leaching from the soil profile or upward recharge by poor quality groundwater. Some elements have higher concentrations at the surface: $Ca^{2+}$ and $Sr^{2+}$ probably accumulate at the surface by evaporation, and Hg accumulates by deposition. Copper tends to occur with the high Hg.

The distributions in surface horizons indicate that higher concentrations of the major cations, Ca, Mg, K, and Na, the major anions, $Cl^-$, and $SO_4^{--}$, and the trace elements, As, B, Li, Mo, Se, Sr, and Ti tend to occur in the northeast part of the study area. This distribution is balanced by higher concentrations of Al and Si in the southwest part of the area. High Hg is found on the floodplain of Stillwater Slough which historically carried the overflow of floodwaters from Carson Lake. It undoubtedly represents redistribution of Hg from the gold-ore processing mills that operated near Carson City in the latter half of the 19th century.

The distributions in deep horizons are much more varied geographically. A high concentration in a deep horizon is not necessarily reflected in the surface horizon at the same site as might be expected.

Variation of the concentrations of water-extractable As, B, Ca, $Cl^-$, Li, Mg, Mo, K, Se, Na, Sr, $SO_4^-$, and specific conductivity in the six complete soil profiles are shown in Figures A87-A99. All of the CP sites except CP3 represent noncultivated soil profiles. Specific conductivity, which reflects total dissolved electrolytes, shows little change with depth at the two sites along the upper part of the TJ Drain, CP5 and CP6 (Figure A101). Both of these sites are noncultivated, and CP5 borders an intermittent marsh area where dissolved ions have not accumulated. By contrast, site CP1, which is in a locale that has prominent surface accumulations of evaporites, has the highest specific conductivity at the surface (14 mmho) and also has a steep gradient with depth. Sites CP2, CP3, and CP4 exhibit more variable patterns with depth, but in all cases show an increase at 3 to 4 feet (90-120 cm) which could indicate a leaching effect. CP3 is the only cultivated profile and presumably the leaching would reflect the use of irrigation. The conductivity probably reflects primarily the distribution of $Na^+$ ion, with minor contribution from the other major ions, $Ca^{2+}$, $Mg^{2+}$, $K^+$, and $Cl^-$. The contribution of the several trace ions to the conductivity is probably insignificant.

**Table 3.**--Summary statistics of 1:5 soil-water extracts in TJ Drain area. First line is soil horizon, 0-1 foot depth; second line is horizon, depth of water table. Means and deviations of censored data estimated by Cohen's technique (Cohen, 1959). All data except pH transformed to logarithms.
[Leaders (--), no data or no calulation.]

| Element | Detection ratio | Geometric mean | Geometric deviation | Observed range |
|---|---|---|---|---|
| Al, ppm | 11:37 | 3.94 | 6.8 | <10-100 |
| | 15:37 | 6.35 | 12.5 | <10-750 |
| As, ppb | 37:37 | 450 | 3.1 | 20-280 |
| | 37:37 | 740 | 3.3 | 85-5500 |
| B, ppb | 36:37 | 7900 | 3.3 | <1000-75600 |
| | 37:37 | 9900 | 2.6 | 1600-58100 |
| Ba, ppb | 23:37 | 230 | 1.9 | <200-900 |
| | 19:37 | 200 | 2.6 | <200-2000 |
| Ca, ppm | 37:37 | 168 | 5.3 | 18-3170 |
| | 37:37 | 80 | 4.2 | 11-2330 |
| Cd, ppb | -- | -- | -- | -- |
| | 2:37 | -- | -- | <50-80 |
| $Cl^-$, ppm | 37:37 | 570 | 9.1 | 20-15200 |
| | 37:37 | 585 | 5.9 | 36-9250 |
| Co, ppb | 2:37 | -- | -- | <100-200 |
| | -- | -- | -- | -- |
| Cr, ppb | 31:37 | 110 | 1.4 | <100-200 |
| | 30:37 | 110 | 1.6 | <100-600 |
| Cu, ppb | 26:37 | 120 | 1.9 | <80-350 |
| | 14:37 | 53 | 3.4 | <80-590 |
| Fe, ppm | 15:37 | 3.3 | 9.2 | <5-130 |
| | 17:37 | 4.64 | 2.0 | <5-850 |
| Hg, ppb | 36:37 | 1 | 2.1 | <.03-32 |

| Element | Detection ratio | Geometric mean | Geometric deviation | Observed range |
|---|---|---|---|---|
| | 29:37 | .82 | 1.8 | <.55-4.9 |
| K, ppm | 35:37 | 89 | 2.6 | <20-560 |
| | 36:37 | 72 | 2.2 | 20-340 |
| Li, ppb | 36:37 | 320 | 2.1 | <100-1600 |
| | 37:37 | 400 | 2.0 | 100-1900 |
| Mg, ppm | 37:37 | 47 | 4.4 | 6-1130 |
| | 37:37 | 50 | 3.0 | 10-500 |
| Mn, ppb | 24:37 | 165 | 4.3 | <100-2400 |
| | 22:37 | 160 | 4.7 | <100-3400 |
| Mo, ppb | 20:37 | 120 | 5.7 | <100-7200 |
| | 32:37 | 400 | 3.2 | <100-2200 |
| Na, ppm | 37:37 | 960 | 4.4 | 60-14400 |
| | 37:37 | 1210 | 3.1 | 130-6900 |
| Ni, ppb | 22:37 | 110 | 1.8 | <100-400 |
| | 20:37 | 100 | 1.9 | <100-500 |
| pH, std. unit[1] | 37:37 | 8.1 | 3.4 | 7.0-8.7 |
| | 37:37 | 8.2 | .43 | 7.1-8.9 |
| Se, ppb | 28:37 | 17 | 7.7 | <5-1000 |
| | 28:37 | 11 | 3.6 | <5-200 |
| Si, ppm | 37:37 | 84 | 1.9 | 38-406 |
| | 37:37 | 116 | 2.9 | 30-2200 |
| $SO_4^{-2}$, ppm | 37:37 | 550 | 7.2 | 20-15000 |
| | 37:37 | 1450 | 3.3 | 90-14500 |
| Sr, ppb | 37:37 | 2000 | 5.0 | 210-41500 |
| | 37:37 | 1270 | 3.8 | 210-22000 |
| Ti, ppb | 24:37 | 210 | 4.2 | <200-3100 |
| | 33:37 | 590 | 4.7 | <100-19400 |

| Element | Detection ratio | Geometric mean | Geometric deviation | Observed range |
| --- | --- | --- | --- | --- |
| V, ppb | 28:37 | 730 | 4.1 | <300-10000 |
| | 30:37 | 730 | 3.3 | <300-7000 |
| Zn, ppb | 11:37 | 55 | 3.1 | <200-500 |
| | 10:37 | 34 | 5.4 | <100-1400 |
| Zr, ppb | 1:37 | -- | -- | <100-200 |
| | 10:37 | 36 | 4.5 | <100-1300 |
| Sp.Cond. mmho/cm | 37:37 | 1.62 | 4.0 | .220-17 |
| | 37:37 | 1.45 | 3.3 | .190-9.5 |

[1] Arithmetic mean and standard deviation of nontransformed data.

## Groundwater analyses

Summary statistics for groundwater samples collected at each soil sampling site are given in Table 4. The distributions of elements in groundwater samples are shown in Figures A100-A114. Several elements exceed the Nevada State standards for toxic constituents in fresh water. The average for As is about 4 times higher than the aquatic-life criterion of 40 ppb and is nearly twice the irrigation criterion of 100 ppb. A total of 33 samples out of 36 analyzed exceeded the criteria for aquatic life. The high As samples (Figure A101) are located in the northeastern end of the study area on noncultivated land. Site C1 (2000 ppb) and C2 (1200 ppb) are located outside of the irrigation project but beside Paiute Diversion Drain. Aerial photos show a difference in vegetation along a part of the drain suggesting that the drain has been leaking water. Thus these sites may have elevated As either from natural geologic causes or from the drain water. Site B3 (1400 ppb), also outside the irrigation project, is not next to the drain but is close enough to the Stillwater marsh area to reflect groundwater close to the surface. Other sites with As in the range of 200-800 ppb are located along the upper reaches of TJ Drain and surely contribute to the As load downstream.

Samples with high B are widely distributed throughout the catchment area of both TJ Drain and Paiute Drain. The average for B is over 12 times higher than the criterion of 1000 ppb for agricultural crops. A total of 35 out of 36 samples exceeded the irrigation standard. Site B1 with 102,000 ppb B probably represents evaporative concentration because the site is located in the vicinity of ephemeral lakes and playas that collect runoff from the surrounding area.

The mean concentrations in groundwater for As, B, Mn, and Mo all exceed the standards, respectively. Numerous samples contained excessive amounts of several elements. Out of 36 samples analyzed, the numbers of samples that exceeded the respective standards are as follows: As, 33 samples out of 36 analyzed exceeded the criteria of 40 ppb for aquatic life. B, 35 out of 36 exceeded 1000 ppb for agricultural crops; Mn, 19 out 36 exceeded 50 ppb for municipal supply; Mo, 20 out of 36 exceeded 10 ppb for agricultural crops; Se, 3 out 36 exceeded 50 ppb for aquatic life and livestock; a mean for V was not computed because there are only 5 analyses above the limit of detection, but all 5 values exceed the standard of 100 ppb for agricultural crops. Other A common distribution pattern for several elements is for higher values to be found centrally in the catchment area and low values to occur in the southeastern part of the study area. There does appear to be a slight bias in favor of higher elemental content of groundwater at sites that are not under irrigation, but the case is not well proven because exceptions do occur.

## Vegetation samples--alfalfa, total analyses of plant ash

All analyses were done on plant ash except for As and Se which were done on the original dry plant material. Concentrations are reported on a plant-dry-weight basis after conversion from the ash-weight basis because the interest here is on animal nutrition. Wilson, and others (in press) also converted the original ash-weight data to a dry-weight basis and reported median values. Summary statistics for alfalfa samples collected at those soil

**Table 4.**--Summary statistics for groundwaters at each soil sampling site. Geometric means and deviations of censored data estimated from log transformed data by Cohen's technique (Cohen, 1959). Beneficial use refers to Nevada water-quality standards for toxic constituents in fresh water for use by aquatic life, livestock, agriculutural crops, or municipal water supply (Unpubl., Irene L. Murphy, 1987, Legal standards and recommended criteria, Office of Policy Analysis, Dept. of Interior).
[Leaders (--), no data or no calculation. Asterisk (**), mean exceeds water-quality standard or recommended criterion for beneficial use.]

| Element | Detection ratio | Geometric mean | Geometric deviation | Observed range | Beneficial use |
|---|---|---|---|---|---|
| Al, ppm | 6:40 | -- | -- | <2-8 | -- |
| As, ppb | 40:40 | 180** | 3.4 | 16-2000 | 40[1] |
| B, ppb | 40:40 | 12300** | 4.0 | 800-102000 | 1000[2] |
| Ba, ppb | 18:22 | 35 | 2.2 | <40-130 | 1000[1,3] |
| Ca, ppm | 40:40 | 194 | 4.6 | 14.4-2470 | -- |
| K, ppm | 25:40 | 40 | 5.0 | <20-470 | -- |
| Li, ppb | 39:40 | 610 | 3.3 | 100-6910 | -- |
| Mg, ppm | 40:40 | 153 | 6.1 | 6.8-2250 | -- |
| Mn, ppb | 24:40 | 60** | 16 | <20-11900 | 50[4] |
| Mo, ppb | 21:40 | 290** | 5.2 | <200-4600 | 10[2] |
| Na, ppm | 38:40 | 2060 | 4.1 | 127->10000 | -- |
| Se, ppb | 21:40 | 1 | 22 | <1-1600 | 50[1,3] |
| Si, ppm | 40:40 | 29 | 1.3 | 16.6-48 | -- |
| Sr, ppb | 40:40 | 4100 | 5.3 | 270-70400 | -- |
| V, ppb | 5:40 | -- | -- | <100-300 | 100[5] |

[1] Nevada water-quality standard, fresh water, use: aquatic life
[2] " " " " " " use: agricultural crops
[3] " " " " " " use: livestock
[4] " " " " " " use: municipal supply
[5] National Academy Science, " " use: agricultural crops

sampling sites where it was available are shown in Table 5. The distributions of elements in alfalfa are shown in Figures A115-A140. Two elements are excluded from the illustrations because most of the values are below the limit of detection noted in parentheses: Sc (0.64 ppm), Y (0.64 ppm).

### Vegetation samples-big greasewood, total analyses of plant ash

All analyses were done on plant ash except for As and Se, which were done on the original dry material. Concentrations are reported on a plant-dry-weight basis to remain consistent with the alfalfa samples. The summary statistics are shown in Table 6. The distributions of elements in greasewood are shown in Figures A141-A164. The presence of greasewood at a sampling site tends to imply that the site was not under irrigation. For the few exceptions in the southwest part of the study area where both alfalfa and greasewood were sampled at the same site; the greasewood was selected from a nearby fence row or field margin.

## DISCUSSION

### Soil samples

The soils exhibit chemical characteristics that are common to salt-affected soils in arid terrains of the west where evapotranspiration greatly exceeds precipitation. Elements that are more or less easily dissolved and transported in surface and groundwater tend to accumulate as evaporites around ephemeral lakes in closed basins. Less soluble elements may also be deposited in the basins as lacustrine sediments.

The total chemical composition of soils from the TJ Drain area were compared with similar soils developed on lacustrine sediments from throughout the Lahontan basin including part of the Carson Sink. Only small differences are found in the means of most elements which indicates that generally the TJ Drain area is similar to most of the Lahontan basin. The study area, however, is not similar to all alkali playas scattered throughout Lahontan basin and Carson Sink. Such departures can be seen in the maximum values for the basin which exceed the TJ Drain area. The sum of the means of major alkali and alkaline earth elements, Ca, K, Li, Mg, Na, and Sr, which could be taken as a measure of total evaporites, is 8.75 percent in TJ Drain area and 10.54 percent in Lahontan basin. This compares with 5.33 percent for all of the western U.S. (Shacklette and Boerngen, 1984).

The 1:5 soil-water extract is an attempt to portray that fraction of the total concentration of an element that is available for plant uptake or transport through the soil profile and groundwater system and reflects its solubility. Several representative elements illustrate this: soluble Ba, Cr, Cu, Ti, and Zn are 0.01-0.1 percent of the total; Ca, K, Mg, and Sr, 0.4-0.6 percent; As and Na, 3-7 percent; Se and Mo, 17 and 24 percent, respectively.

The specific conductivity of water extracts is a measure of the electrical conductance of the soil solution which reflects the dissolved salts. A plot of the specific conductivity versus the sum of dissolved ions in Figures 3 and 4 for surface and deep soil horizons shows

**Table 5.**--Summary statistics for alfalfa ash recomputed to a dry-weight basis. Geometric means and deviations of censored data estimated from log transformed data (except where noted as nontransformed) by Cohen's technique (Cohen, 1959).
[Leaders (--), no calculations. astrisk (*), nontransformed, arithmetic mean and standard deviation.]

| Element | Detection ratio | Geometric mean | Geometric deviation | Observed range |
|---|---|---|---|---|
| Ash, percent | 12:12 | 12.1 | 1.15 | 10.1-16 |
| Al, percent | 12:12 | 0.10 | 3.15 | .02-0.45 |
| As, ppm | 12:12 | .77 | 1.66 | .37-1.9 |
| Ba, ppm | 12:12 | 32.6 | 1.92 | 10.2-73.1 |
| Ca, percent | 12:12 | 2.27 | 1.20 | 1.50-2.98 |
| Ce, ppm | 3:12 | -- | -- | <1.1-3.0 |
| Co, ppm | 12:12 | .7 | 1.5 | .3-1.2 |
| Cr, ppm | 12:12 | 2.7 | 2.3 | .9-12.4 |
| Cu, ppm | 12:12 | 12.9 | 1.2 | 10.4-16.8 |
| Fe, percent | 12:12 | .06 | 2.5 | .02-.22 |
| K, percent | 12:12 | 1.74 | 1.28 | 1.17-2.52 |
| La, ppm | 12:12 | 1.0 | 1.6 | .52-2.2 |
| Li, ppm | 12:12 | 6.6 | 1.3 | 4.3-9.5 |
| Mg, percent | 12:12 | .40 | 1.24 | .29-.64 |
| Mn, ppm | 12:12 | 52 | 1.3 | 33-85 |
| Mo, ppm | 12:12 | 3.4 | 1.4 | 1.6-5.0 |
| Nd, ppm | 9:12 | 1.3 | 1.5 | <1.0-2.2 |
| Na, percent | 12:12 | .26 | 1.63 | .08-.46 |
| Ni, ppm | 12:12 | 1.1 | 1.5 | .6-2.0 |
| P, percent | 12:12 | .39 | 1.3 | .26-.60 |
| Pb, ppm | 3:12 | -- | -- | <1.1-1.3 |
| Sc, ppm | 1:12 | -- | -- | <.6-.7 |
| Se, ppm | 12:12 | .10 | 2.25 | .02-.48 |
| Sr, ppm | 12:12 | 245 | 1.18 | 157-293 |
| Ti, percent | 10:12 | .004 | 3.23 | <.001-.019 |
| V, ppm | 9:12 | 1.2 | 3.4 | <.5-6.2 |

| | | | | |
|---|---|---|---|---|
| Zn, ppm | 12:12 | 30 | 1.4 | 18-50 |
| Cu/Mo | 12:12 | 3.95 | 1.14 | 2.5-6.5 |

**Table 6.**--Summary statistics for greasewood ash recomputed to a dry-weight basis. Geometric means and deviations of censored data estimated from log transformed data by Cohen's technique (Cohen, 1959).
[Leaders (--), no calculations.]

| Element | Detection ratio | Geometric mean | Geometric deviation | Observed range |
|---|---|---|---|---|
| Ash, percent | 29:29 | 9.53 | 1.56 | 3.64-19.5 |
| Al, percent | 29:29 | 0.55 | 1.89 | 0.16-1.46 |
| As, ppm | 29:29 | .14 | 1.5 | .07-.32 |
| Ba, ppm | 29:29 | 107 | 1.92 | 23-281 |
| Ca, percent | 29:29 | 7.68 | 1.44 | 4.32-17.6 |
| Co, ppm | 25:29 | .3 | 1.4 | <.1-.5 |
| Cr, ppm | 29:29 | 14 | 1.9 | 4-51 |
| Cu, ppm | 29:29 | 88 | 1.3 | 45-200 |
| Fe, percent | 29:29 | .32 | 1.77 | .1-.77 |
| K, percent | 29:29 | 12.8 | 1.35 | 7.8-27.7 |
| La, ppm | 2:29 | -- | -- | <.78-1 |
| Li, ppm | 29:29 | 27 | 1.6 | 12-64 |
| Mg, percent | 29:29 | 1.69 | 1.75 | 1.01-7.28 |
| Mn, ppm | 29:29 | 897 | 1.99 | 239-3770 |
| Mo, ppm | 23:29 | .9 | 2.0 | <.41-5 |
| Na, percent | 29;29 | 16.4 | 1.36 | 8.09-24.9 |
| Ni, ppm | 6:29 | -- | -- | <.66-1 |
| P, percent | 29:29 | 1.29 | 1.31 | .89-3.41 |
| Pb, ppm | 1:29 | -- | -- | <1.56-3 |
| Se, ppm | 28:29 | .01 | 3.6 | <.002-.02 |
| Sr, ppm | 29:29 | 828 | 1.72 | 342-2250 |
| Ti, percent | 28:29 | .003 | 1.65 | <.001-.007 |
| V, ppm | 16:29 | .8 | 1.5 | <.7-2 |
| Zn, ppm | 29:29 | 115 | 1.38 | 68-297 |

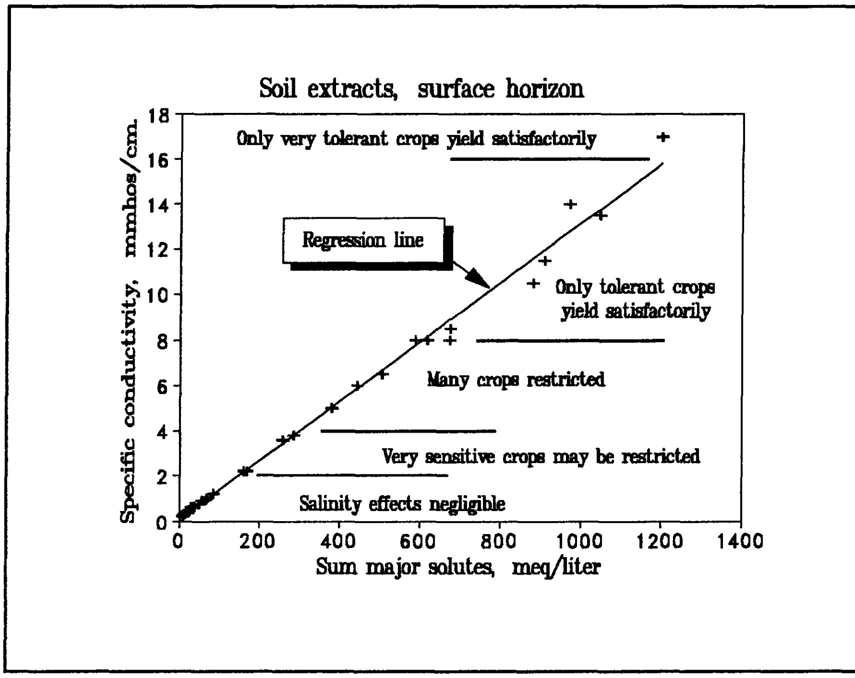


**Figure 3**.--Plot of specific conductivity versus sum of major solute ions--$Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, $Cl^{-}$, and $SO_4^{2-}$--in 1:5 water extracts from soil horizons, 0-1 foot depth.

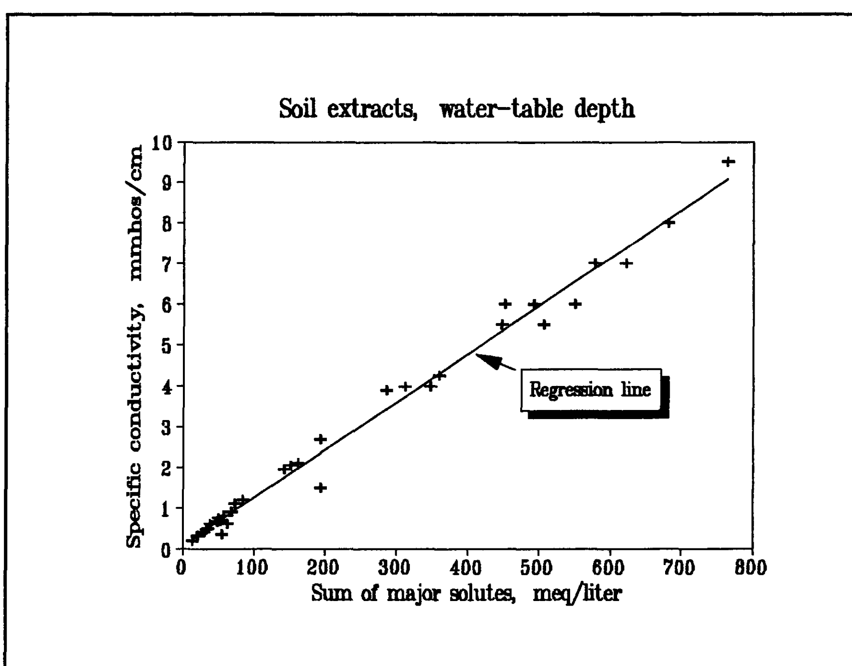


**Figure 4**.--Plot of specific conductivity versus sum of major solute ions--$Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, $Cl^{-}$, and $SO4^{2-}$--in 1:5 water extracts at water-table depth.

a linear relationship between the two. The sum of dissolved ions are taken to be the sum of the milliequivalents of the major ions, $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, $Cl^{-}$, and $SO_4^{2-}$.

The conductivities of both 1:5 extracts and saturation extracts are used to estimate soil salinity and its effect on crop yield, but the saturation extract is more consistent (Richards, 1954). The 1:5 extract is easier to obtain and is still reliable if the salts are predominantly chlorides. If appreciable amounts of less soluble sulfates and carbonates are present, then the saturation extract is preferred. A scale (Richards, 1954, p. 9) of the effect of salinity on crop yields based on saturation extracts is shown in Figure 3. Note that the conductivities being compared here are 1:5 extracts. The soils that are indicated as being able to support only tolerant or very tolerant crops are mostly located in the northeast part of the study area outside of the present irrigated zone.

The mean conductivity of surface horizons is only slightly higher than at water table depth, but the range is much larger in the surface indicating that evaporative concentration is occurring. Prolonged leaching of soils within the irrigation area has undoubtedly removed some soluble salts, but there are still occurrences of intermediate conductivities within the irrigated area and low values in nonirrigated areas. Elevated values that appear within irrigated areas are actually undeveloped, nonirrigated fields, and low values in nonirrigated areas are probably in soils modified by aeolian deposits.

## Groundwater

Morgan (1982) reported on the quality of groundwater in the shallow unconfined aquifer within a few meters depth as determined in a number of test wells in the Stillwater area, which includes the TJ-Drain area. The shallow groundwater is predominantly a NaCl water (Morgan, 1982). A comparison of the composition of the groundwater found in the present study with that of Morgan (1982) is shown in Table 7. The means of Morgan are presumed to be arithmetic so they would tend to be slightly larger than a corresponding geometric mean. The differences between the two data sets are not significant.

Sources of recharge to the groundwater include rainwater from surrounding mountains, upwelling thermal water, and percolating irrigation water. Irrigation water, which is likely the predominant source of recharge (Morgan, 1982), would tend to dilute the concentrations of constituents in the thermal waters. The concentrations of As, B, and Na reported by Morgan are considered to be elevated so even with dilution the concentrations we find exceed the State standards for beneficial use.

The high As values are located in the northeast part of the study area near the lower end of the watertable gradient. The form of the As was not determined, but the inorganic forms would likely occur as either arsenate (As V), $HAsO_4^{-2}$, or arsenite (As III), $H_3AsO_3$. Both forms are fairly water soluble in the pH range of 7-8. Groundwater pH was not determined, but the pH of the 1:5 extracts at the water-table depth ranges from 7.1 to 8.9 (Figure A86). Arsenate occurs in oxidizing environments and tends to be more strongly adsorbed on colloids. The arsenite form occurs in reducing conditions. It is less strongly adsorbed on colloids and is more toxic to aquatic organisms.

A couple of high B values are also located at the low end of the watertable gradient, but otherwise many of the elevated values are scattered throughout the study area.

**Table 7**.--Comparison of shallow groundwater composition from TJ-Drain study area with the data of Morgan (1982) for the Stillwater area.
[Values in parts per million or mg./L]

| Elements | TJ-Drain study | | Data of Morgan (1982) | |
|---|---|---|---|---|
| | Geometric Mean | Range | Mean | Range |
| As | 0.18 | 0.016-2 | 0.7 | 0.4-0.9 |
| B | 12.3 | .8-102 | 34 | 18-76 |
| Ca | 194 | 14-2470 | 450 | 86-960 |
| $Cl^-$ | -- | -- | 6400 | 4500-7500 |
| K | 40 | <20-470 | 150 | 59-210 |
| Li | .61 | .1-6.9 | 2.4 | 1.2-3.9 |
| Mg | 153 | 6.8-2250 | 490 | 85-1100 |
| Na | 2060 | 127->10,000 | 4580 | 2900-7300 |

The potential gradient of the groundwater within the area is toward the northeast with a potentiometric level at the northeastern end of the TJ Drain study area actually above the ground surface (Morgan, 1982).

There is little relationship between concentrations found in groundwaters and 1:5 soil extracts from the same horizon and same site. The groundwater is expected to be in equilibrium with the solid materials and it should be representative of the concentration of dissolved constituents. The mean concentrations of more than half of the elements are less in the groundwater than in the 1:5 extracts. The means for B, Ca, Mg, Na, and Sr are greater in groundwater than in the 1:5 extracts. In general, Se is not significant in the study area being less than 100 ppb; the single exception is at site F5 where 1600 ppb was found. This same sample also contained large amounts of Al, Ca, Mg, Na, and Sr. The reason for this anomalous Se is not clear. The site is in the vicinity of local faults that could be a source of migrating fluids, but this is not a convincing argument because groundwater from a geothermal well blowout in 1989 in NW1/4, S6, T19N, R31E contained 18,400 ppb B, 94 ppm Ca, 2700 ppm $Cl^-$, 3.9 ppm Mg , 1600 ppm Na, and 2200 ppb Sr but less than 1 ppb Se (M.S. Lico, private commun., 1990)

## Alfalfa

The composition of alfalfa in the study area is well within the normal range as reported elsewhere (Kabata-Pendias, Pendias, 1984; Chapman, 1966). Nearly all of the metals are about one order of magnitude less than values reported by Erdman and others (1991) for alfalfa grown over the Cody Shale in Wyoming. The Cody Shale is a seleniferous formation, and the alfalfa in that locality has a median Se concentration of 0.9 ppm (J.A. Erdman, private commun., 1991). The mean Se concentration in the TJ Drain area is 0.1 ppm with an observed range of 0.02-0.48. The range of the data as well as their distribution (Figure A135) suggests that Se uptake varies widely over rather short distances. The source of this variation could either be in the supply of Se or in the irrigation management of the fields. Erdman and others (1991) noted that temporal variation in the Se concentration of alfalfa in Wyoming seemed to result from the coincidence of sampling with irrigation events. The application of irrigation water diluted the selenate in the pore water and leached it beyond the root zone, whereas in more arid conditions a buildup of selenate in the pore water occurred within the root zone. The TJ Drain area is apparently free of white-muscle disease in livestock (Se deficiency from hay containing less than about 0.1 ppm) (Allaway and Hodgson, 1964, p. 274) and alkali disease (Se toxicity from hay containing 10-30 ppm) (Church, 1971).

Arsenic in alfalfa in the TJ Drain area appears to be moderately elevated with values ranging from 0.37 to 1.9 ppm. This compares with the Cody Shale described above where As is usually found at less than 0.05 ppm. Arsenic in alfalfa from various parts of the Northern Great Plains including coal mine reclamation sites (J.A. Erdman, private commun., 1991) ranged from 0.05 to 0.35 ppm.

Alfalfa can tolerate only about 10 mg/L (10 ppm) of B in water (Green and others, 1976). The mean of B in surface horizon extracts and groundwaters is 7.9 and 12.3 ppm, respectively, with numerous values that exceed the tolerance level. It is probable that the B concentration in the soil solution would be diluted below this threshold by irrigation.

The composition of alfalfa does not appear to be a precursor for molybdenosis, a Mo-induced Cu deficiency in foraging animals. The recommended Cu:Mo ratio in cattle forage is about 6:1 (Dollahite and others, 1972); molybdenosis develops at ratios below 2:1. A distribution of Cu:Mo ratios in alfalfa is shown in Figure 5; the ratios range from 2.5 to 6.5. The lower ratios are distributed across the southern part of the study area, and the higher ratios are closer to the Stillwater marsh area. Alfalfa is regarded as being moderately tolerant of saline soils. Aerial photos show that alfalfa fields in the study area have spotty coverage suggesting that some areas may be too saline for optimum alfalfa production. Any expansion of the irrigation system into the northeast part of the study area could expect detrimental salinity conditions.

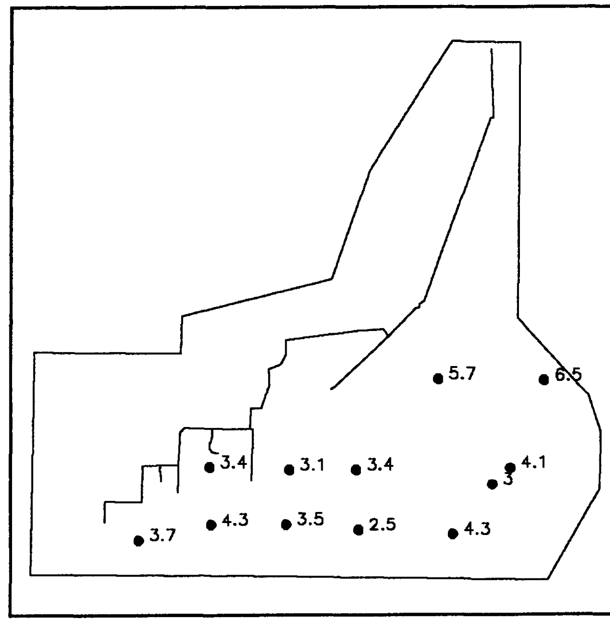


**Figure 5**.--Copper/molybdenum ratio in alfalfa ash.

Big greasewood

The composition of greasewood from within the irrigated area tends to be moderately higher in Ca, Cr, Cu, K, P and Zn than vegetation from within the nonirrigated area. The ash yield tends to be higher in locations where there is more abundant water available. A comparison with data for greasewood in the Mason valley, Lyon County, Nevada, (Erdman and others, in press B) indicates that the average ash content of greasewood in the TJ drain study area is about 2 percent lower and Ba, Ca, Cr, Cu, Li, Mn, P, Sr Ti, and Zn are 2 to 3 times higher than in Mason valley; Mo and Se are about 10 times lower.

Vegetation as an indicator

One of the objectives in sampling vegetation is to determine whether it serves an indicator of the chemical environment especially the dissolved forms of elements. Alfalfa is not only the most common cultivated plant in the area, but it is also a perennial with a deep root system. Greasewood is also a phreatophyte (taps the watertable with deep root system) so it might be expected to reflect the composition of the groundwater. The usefulness of these plants as indicators, however, is only partially successful. Correlations between plant composition expressed on a plant dry weight basis and "available" dissolved ions in 1:5 water extracts from the surface soil horizon and the groundwater, respectively, are shown in Table 8. Although a few elements, such as As and Se in alfalfa, exhibit a moderate correlation with both of the dissolved sources, most elements have very small correlations with either water extracts or groundwater. This is similar to previous field studies that show little or no correspondence between "available" measures and plant contents (Olson and others, 1942; Peterson and others, 1981, p. 288). One reason is that nutrient uptake is controlled in part by plant physiology.

**Table 8.**--Comparison of correlation coefficients between elements in plants and dissolved forms in 1:5 soil-water extracts of soil surface horizons and groundwater at the same sampling sites.
[Leader (--), not determined. Asterisk, (*) significant at 5 percent level; (**) significant at 1 percent level.]

| Element | Alfalfa [1] | | Big greasewood [2] | |
|---|---|---|---|---|
| | Surface-water extract | Ground-water | Surface-water extract | Ground-water |
| Al | 0.12 | -0.25 | 0.08 | -0.03 |
| As | .41 | .63* | .45* | .34 |
| Ba | .57 | .30 | -.05 | 0.10 |
| Ca | .09 | .09 | -.39* | .26 |
| Cr | .09 | -- | -.32 | -- |
| Cu | -.10 | -- | -.44* | -- |
| Fe | .13 | -- | .05 | -- |
| K | -.06 | -.11 | -.12 | -.11 |
| Li | .07 | .15 | -.11 | .47* |
| Mg | .17 | .20 | .40* | -.05 |
| Mn | .19 | -.08 | -.15 | .19 |
| Mo | .47 | .30 | .07 | .46* |
| Na | .22 | .13 | -.41* | .33 |
| Ni | .54 | -- | -.12 | -- |
| Se | .71** | .61* | .42* | .22 |
| Sr | .26 | .39 | -.08 | .22 |
| Ti | -.12 | -- | -.11 | -- |
| V | .28 | .34 | .43* | .08 |
| Zn | -.23 | -- | 0 | -- |

[1] Threshold of significance at 5 percent level, 0.58
" " " " 1 " " , .71

[2] Threshold of significance at 5 percent level, .37

# SUMMARY

Soil investigations show that undeveloped native soils tend to be higher in several elements (As, Mo, Li) than those already subjected to irrigation. This probably reflects the leaching of elements from the soils by irrigation. There are occasional exceptions to this generalization which may reflect local variability of unknown origin. Two elements which show anomalous values in soils studies are Se and Hg: Hg is high and Se is low. In the case of Hg, elevated values were observed which reflect historical contamination by gold-ore milling operations up stream. In the case of Se, concentrations below baseline values were observed for the study area, an indication that Se is unlikely to present a serious environmental problem. In general, the composition of solids in the TJ Drain area is not unusual in the context of other soils in the Lahontan basin, but compared to soils in arid, drained basins, they do exhibit elevated levels for several elements.

Groundwater data indicate that the concentrations of As, B, and Mo exceed State water quality criteria. Manganese and V just barely exceed the criteria.

Alfalfa, which is the principal cultivated crop on irrigated land, tends to have moderately elevated amounts of As, but Se and Mo are within the normal range for this plant. Big greasewood appears to have a larger ash yield in areas where there is more available water. Big greasewood in the TJ-Drain area has 10 times lower Mo and Se compared to big greasewood in Mason valley, Lyon County, Nevada.

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APPENDIX

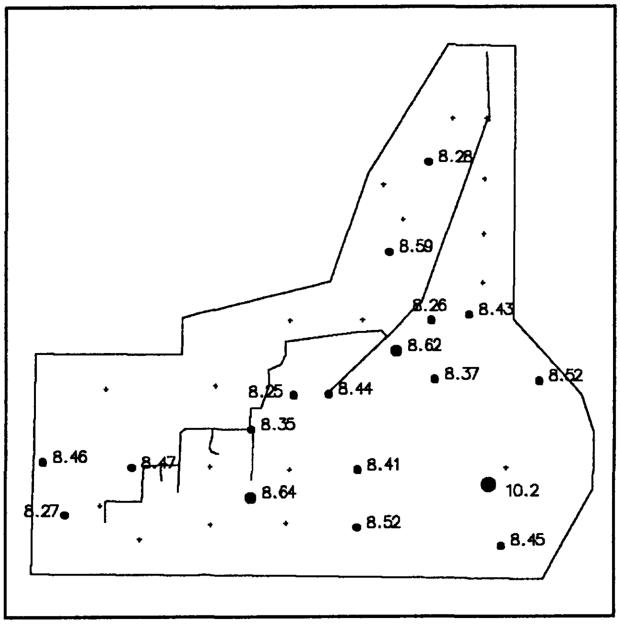



**Figure A1**.--Total aluminum (percent) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

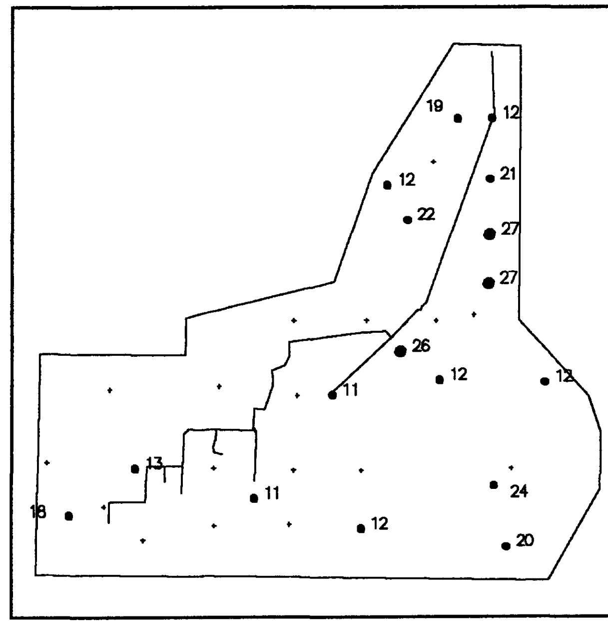



**Figure A2**.--Total arsenic (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

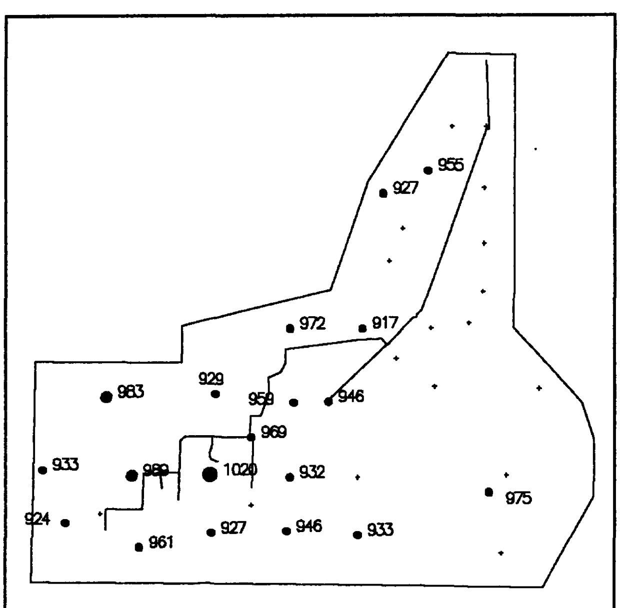



**Figure A3**.--Total barium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

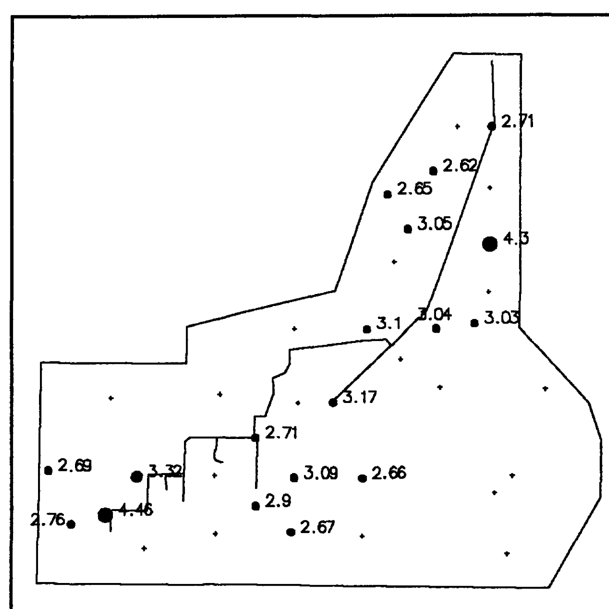
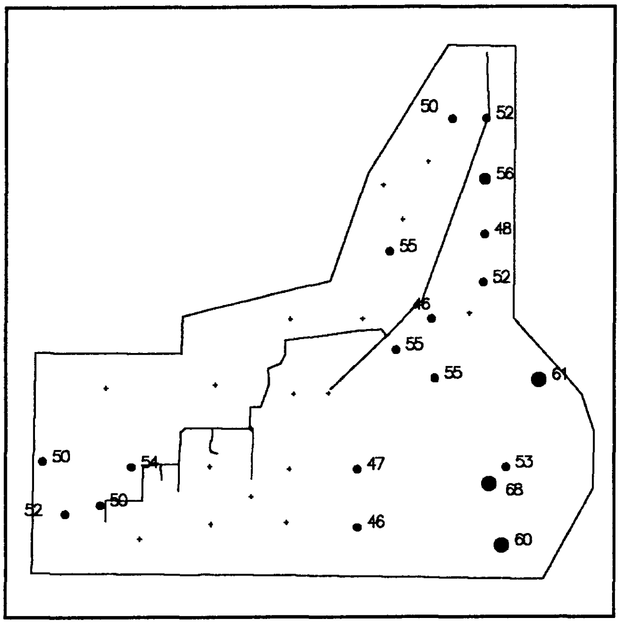



**Figure A4**.--Total calcium (percent) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.



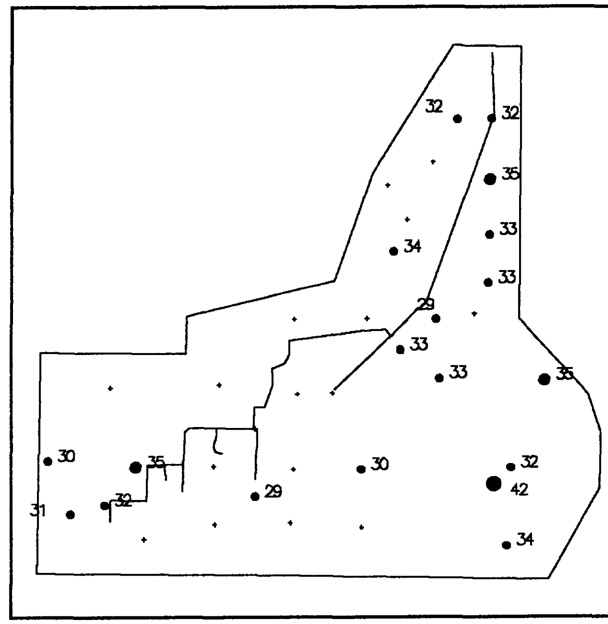
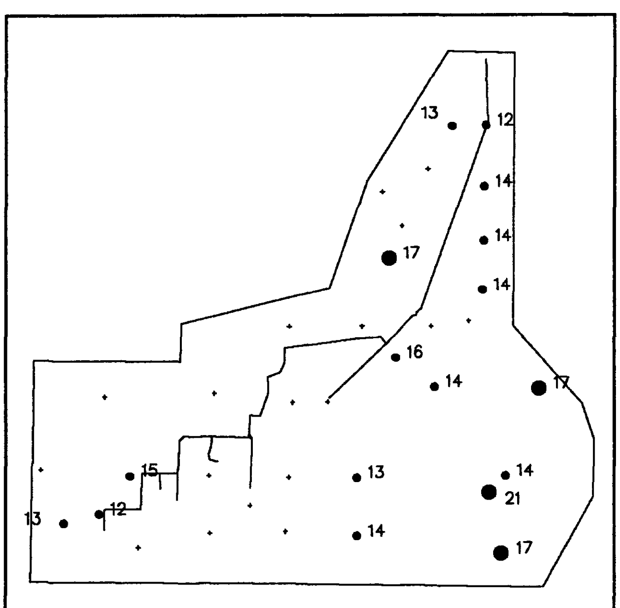




**Figure A5**.--Total cerium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

**Figure A6**.--Total chromium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.



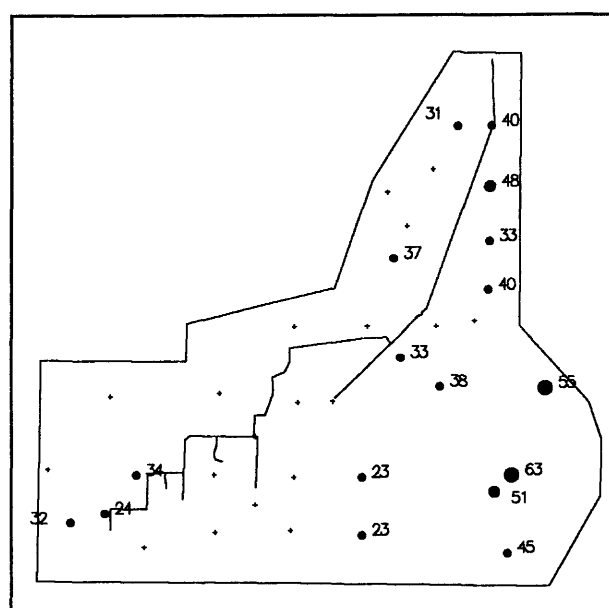




**Figure A7**.--Total cobalt (ppm) in surface horizon of soil, 0-1 foot depth. Values above 50th percentile are posted. Largest dots are above 95th percentile.

**Figure A8**.--Total copper (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

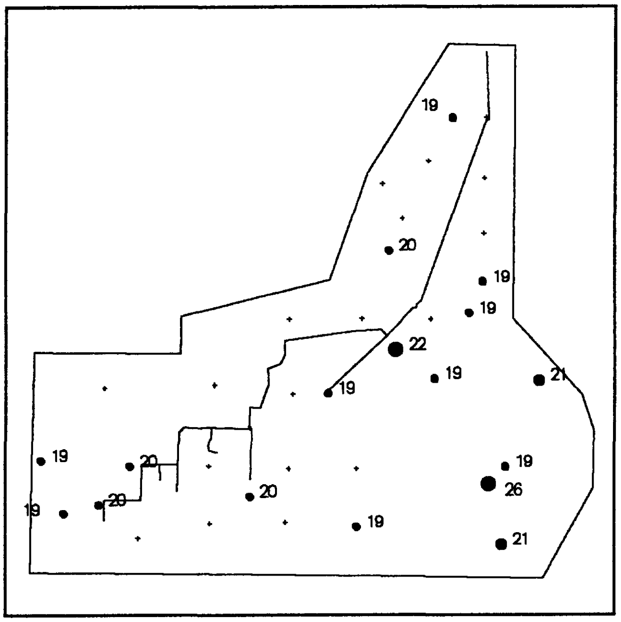



**Figure A9**.--Total gallium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

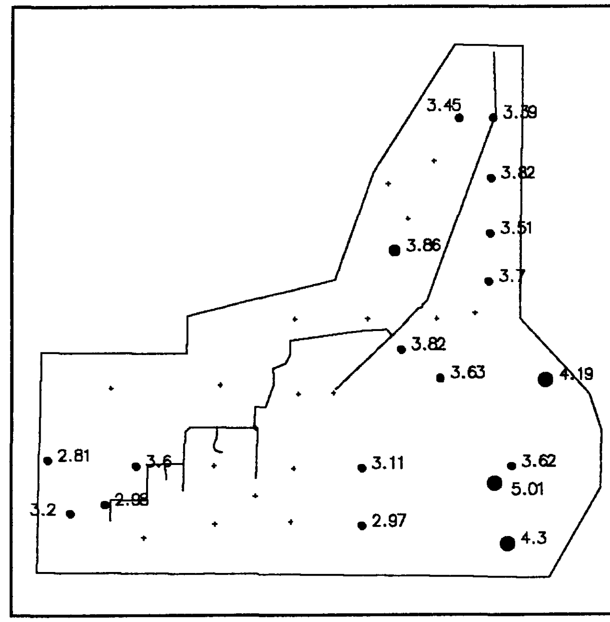



**Figure A10**.--Total iron (percent) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

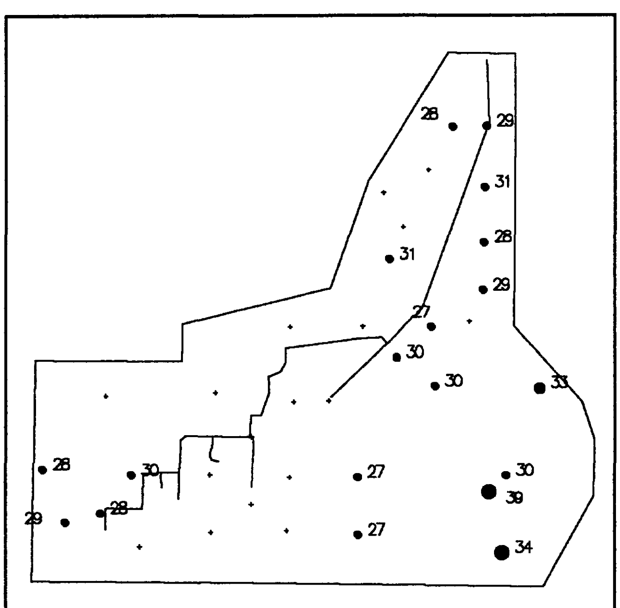



**Figure A11**.--Total lanthanum (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

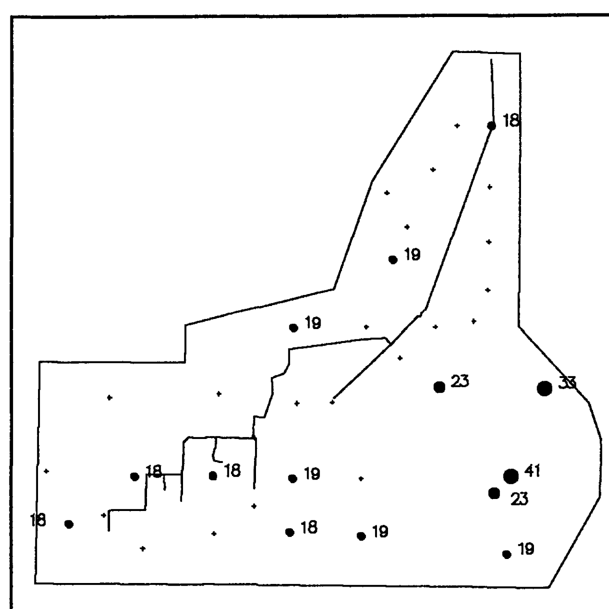



**Figure A12**.--Total lead (ppm) in surface soil horizon, 0-1 foot depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

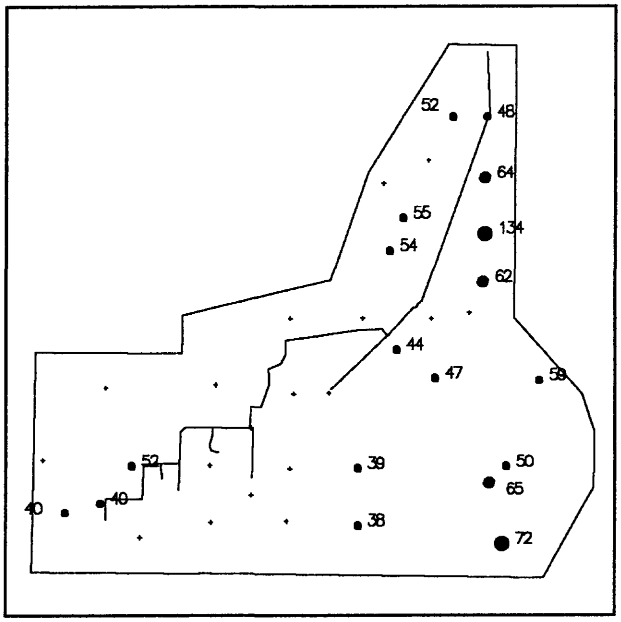



**Figure A13.**--Total lithium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

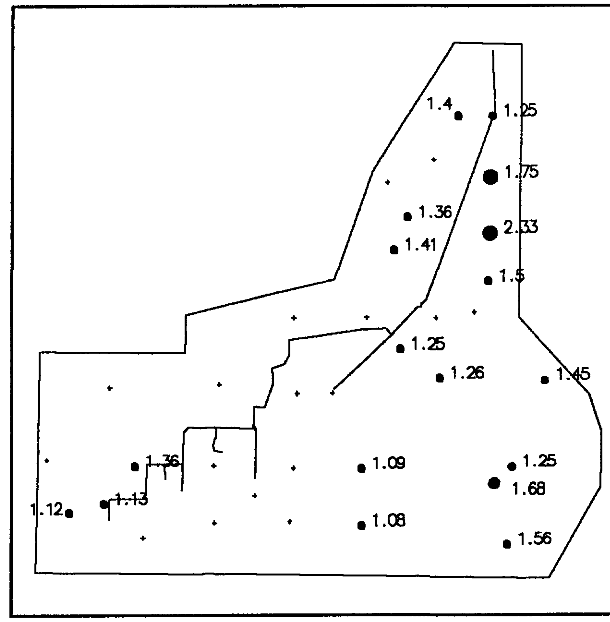



**Figure A14.**--Total magnesium (percent) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

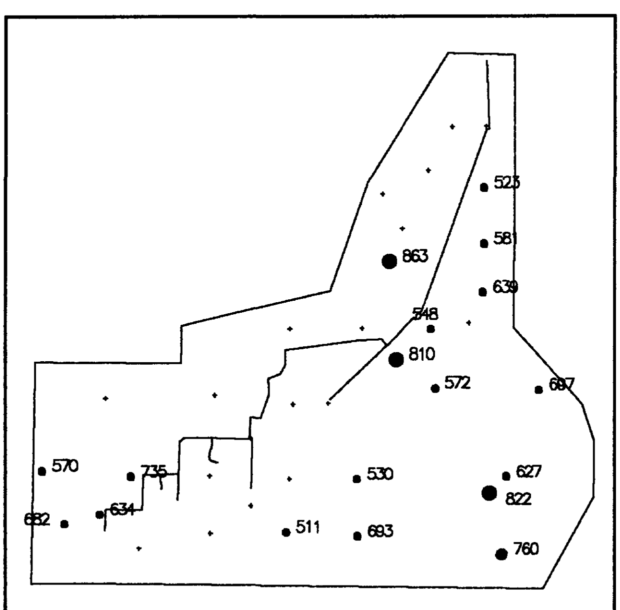



**Figure A15.**--Total manganese (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

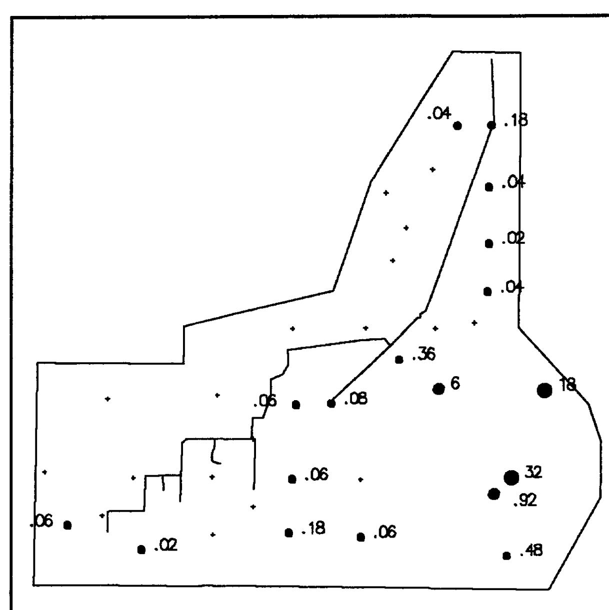



**Figure A16.**--Total mercury (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

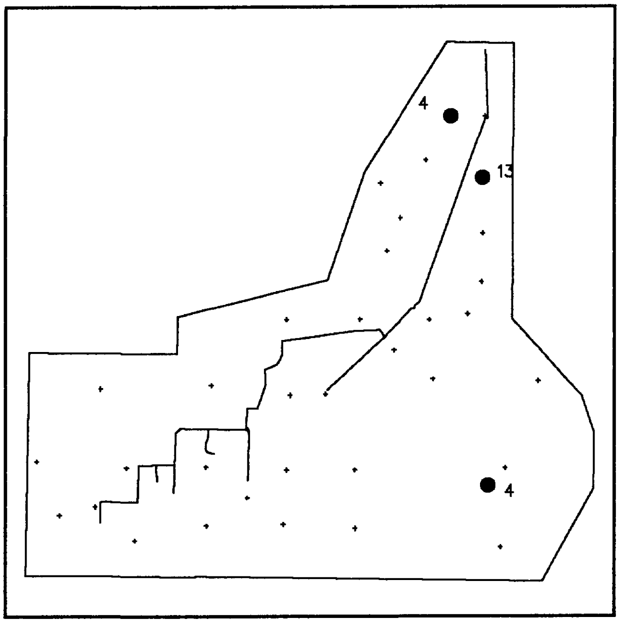



**Figure A17**.--Total molybdenum (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-95th percentile, not posted. Large dot, 95-100th percentile.

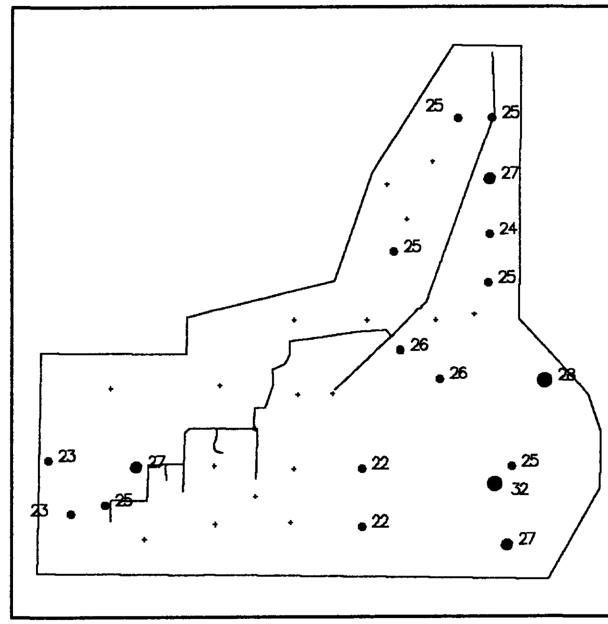



**Figure A18**.--Total neodymium (ppm) in surface soil horizon, 0-1 foot depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

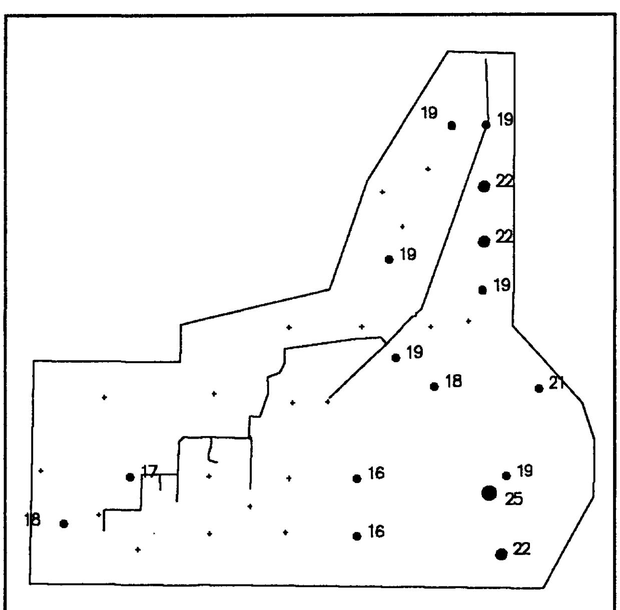



**Figure A19**.--Total nickel (ppm) in surface soil horizon, 0-1 foot depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

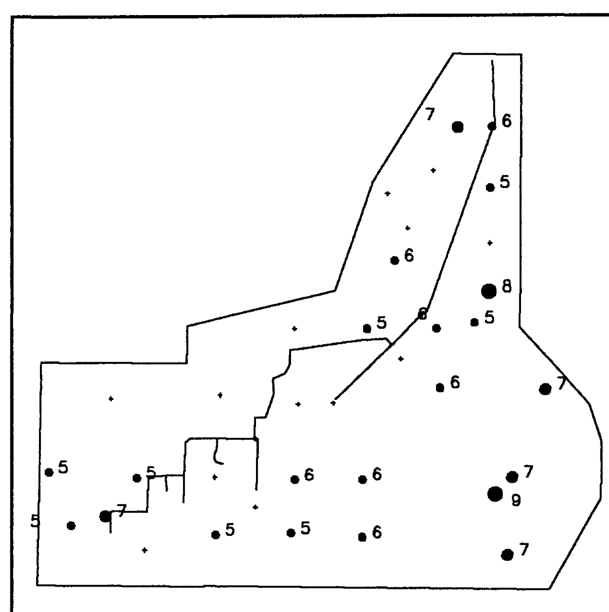



**Figure A20**.--Total niobium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

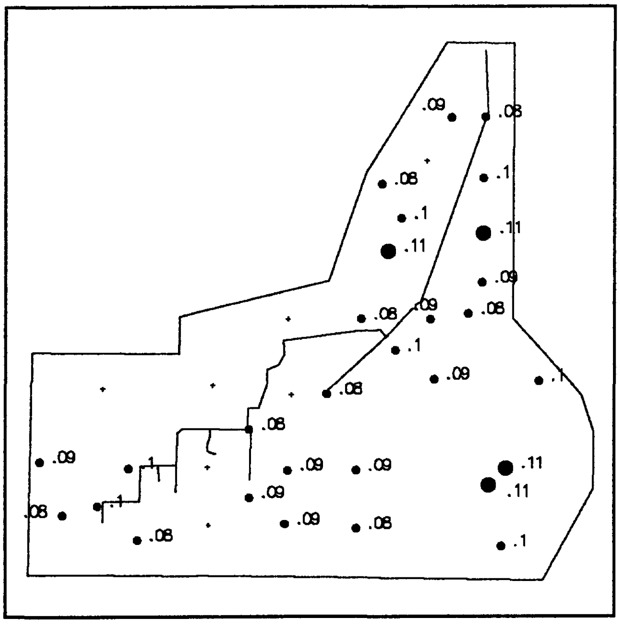



**Figure A21.**--Total phosphorus (ppm) in surface soil horizon, 0-1 foot depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

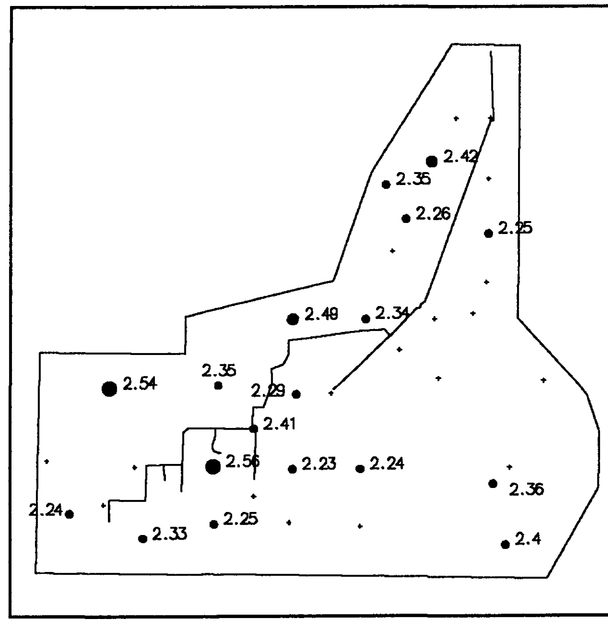



**Figure A22.**--Total potassium (percent) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

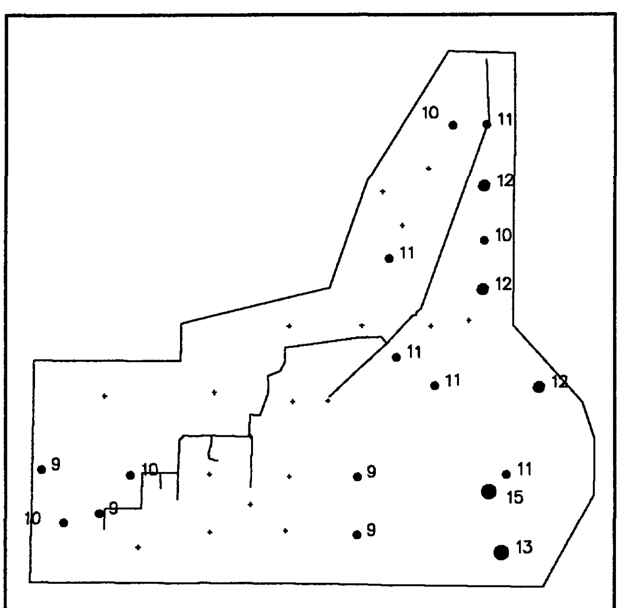



**Figure A23.**--Total scandium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

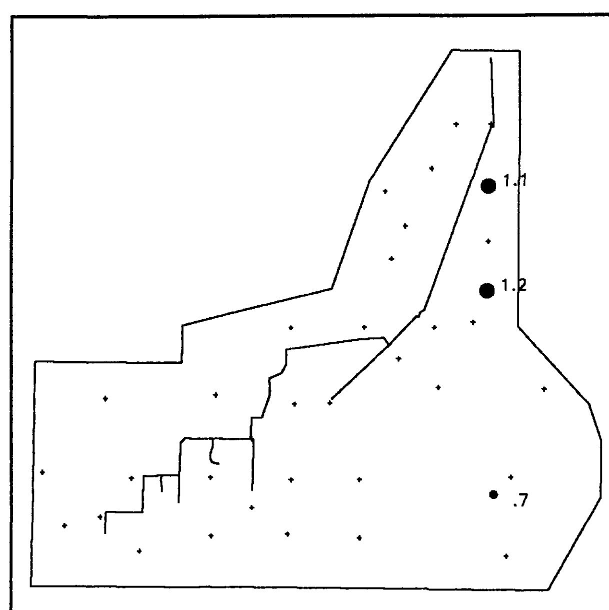



**Figure A24.**--Total selenium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

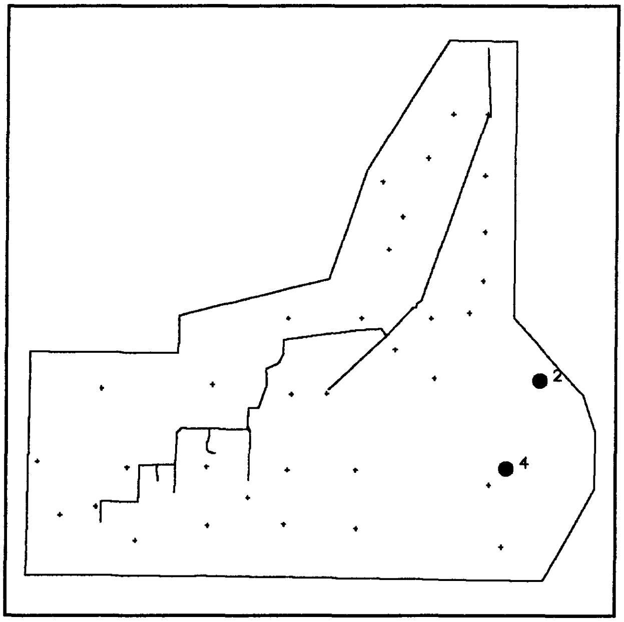



**Figure A25**.--Total silver (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-95th percentile, not posted. Large dot, 95-100th percentile.

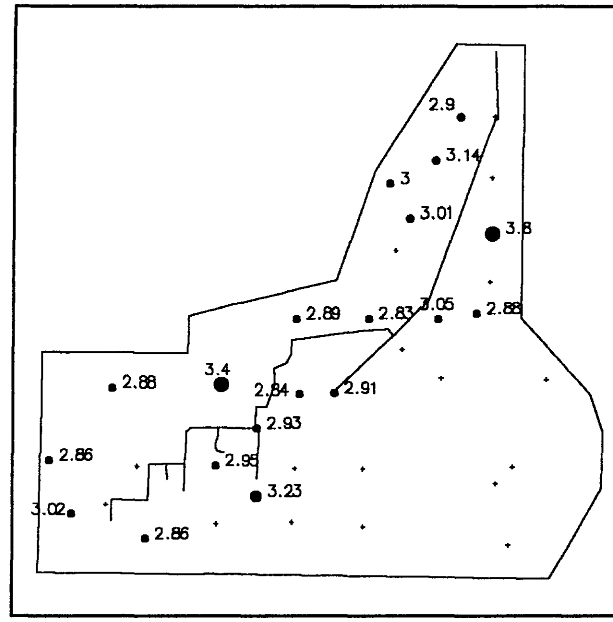



**Figure A26**.--Total sodium (percent) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

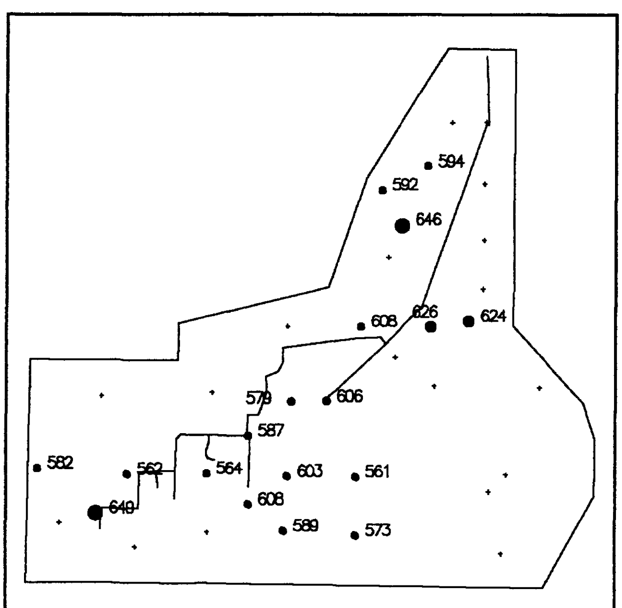



**Figure A27**.--Total strontium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

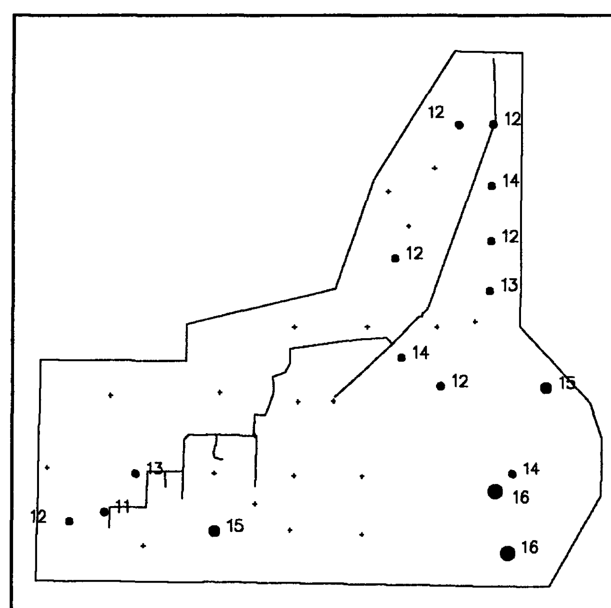



**Figure A28**.--Total thorium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

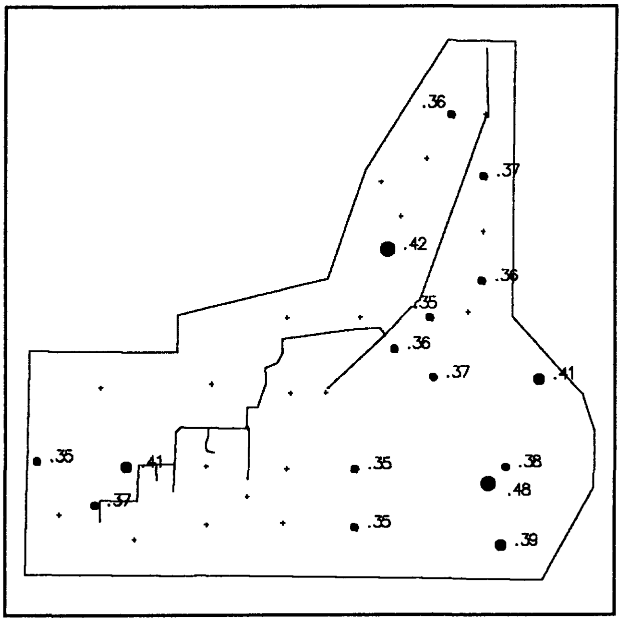



**Figure A29**.--Total titanium (percent) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

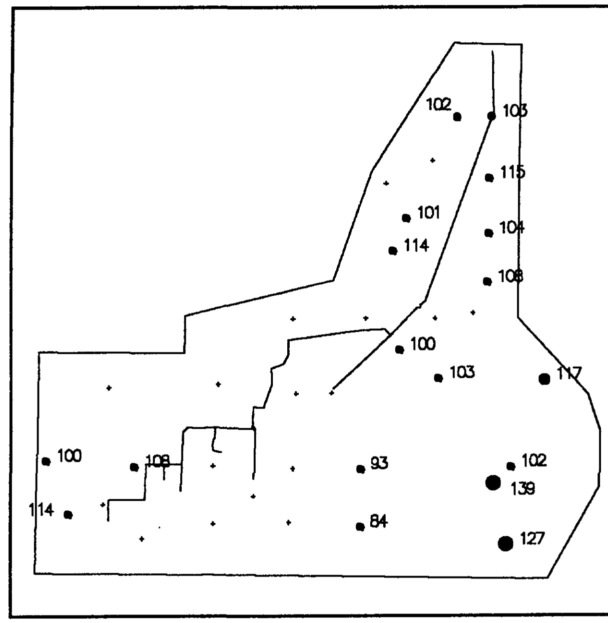



**Figure A30**.--Total vanadium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

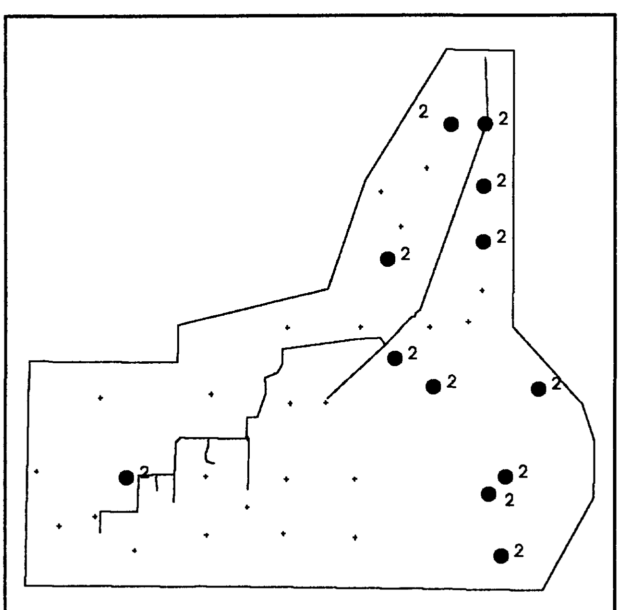



**Figure A31**.--Total ytterbium (ppm) in surface horizon of soil, 0-1 foot depth. Small dot, 0-95th percentile, not posted. Large dot, 95-100th percentile.

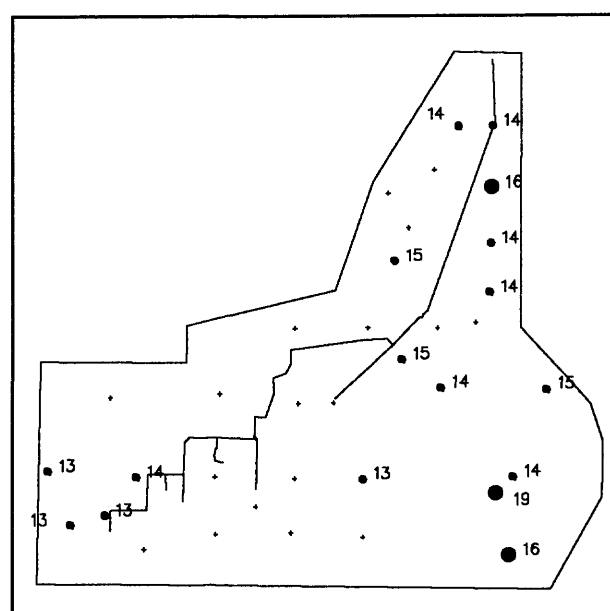



**Figure A32**.--Total yttrium (ppm) in surface horizon of soil, 0-1 depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

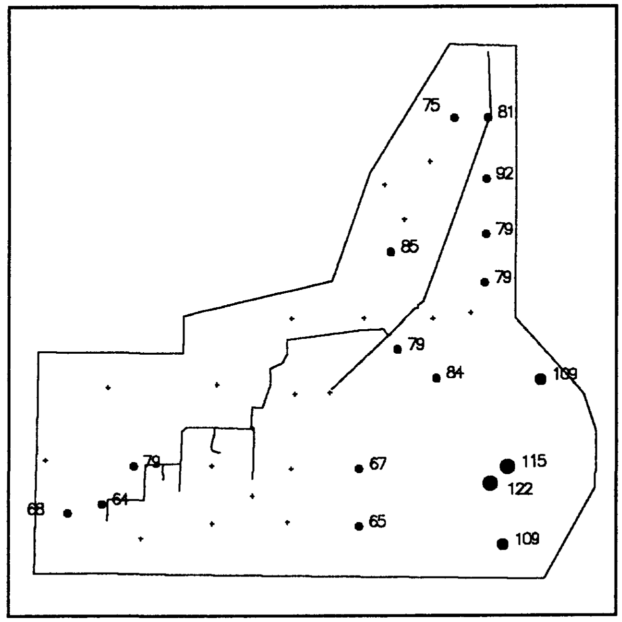



**Figure A33**.--Total zinc (ppm) in surface soil, 0-1 foot depth. Small dot, 0-50th percentile, not posted. Intermediate dot, posted 50-95th percentile. Large dot, 95-100th percentile.

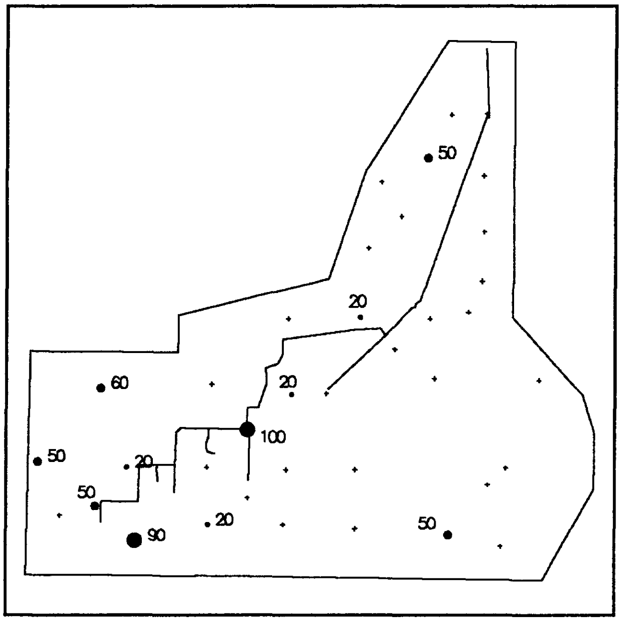



**Figure A34.**--Aluminum (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

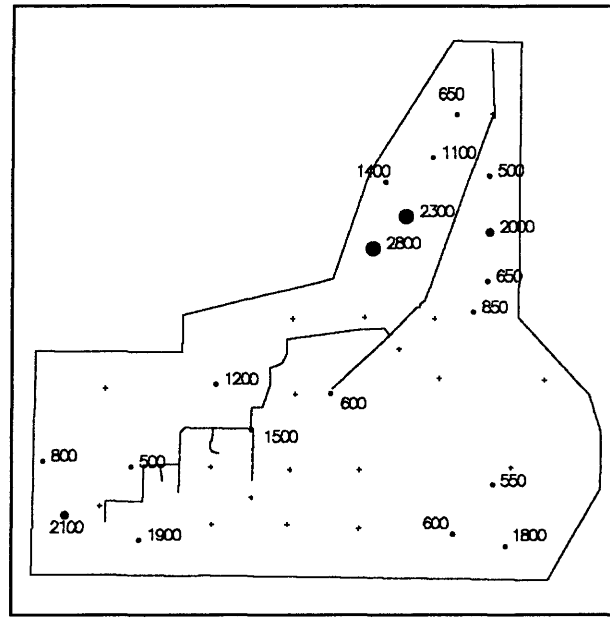



**Figure A35.**--Arsenic (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

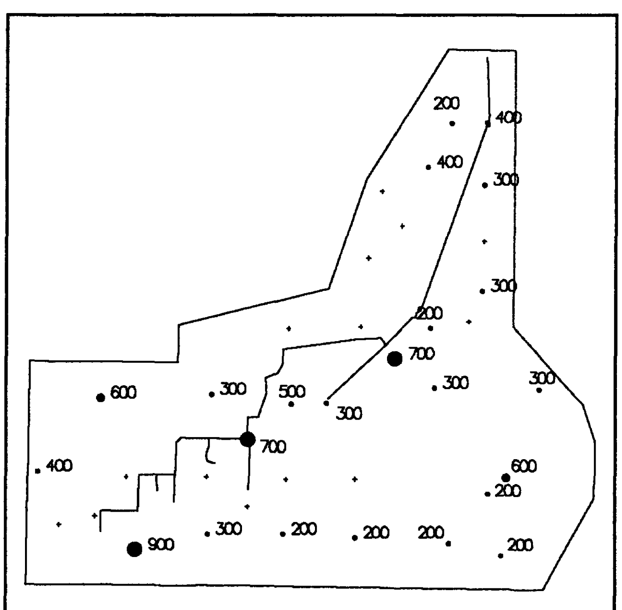



**Figure A36.**--Barium (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

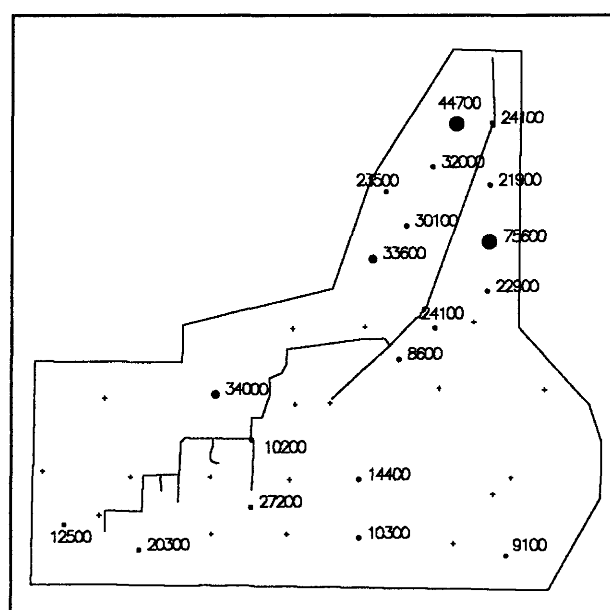



**Figure A37.**--Boron (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

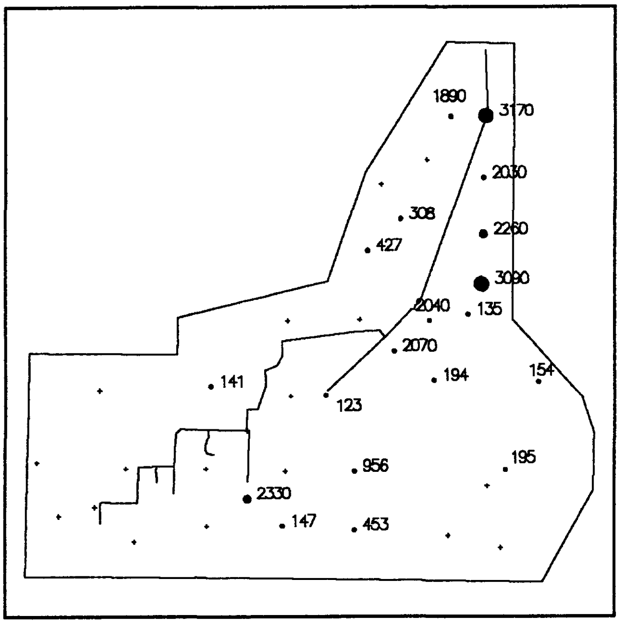



**Figure A38**.--Calcium (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

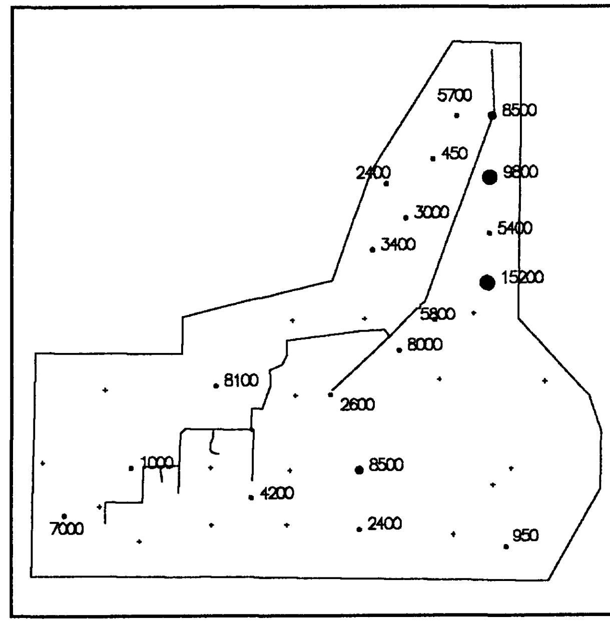



**Figure A39**.--Chloride (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

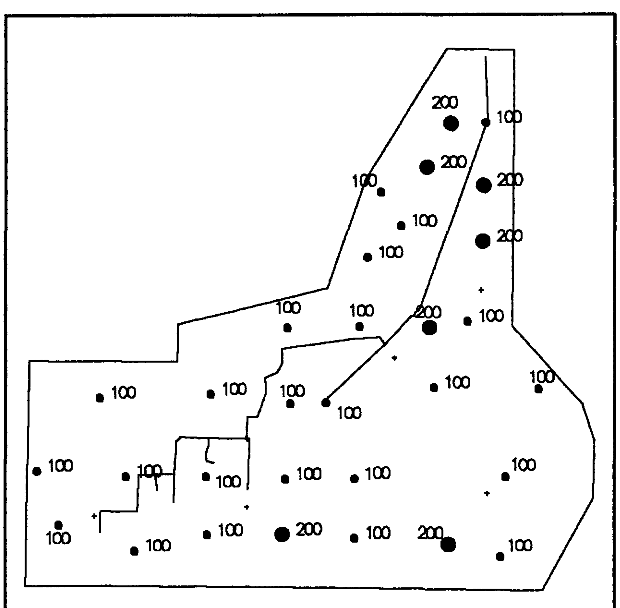



**Figure A40**.--Chromium (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

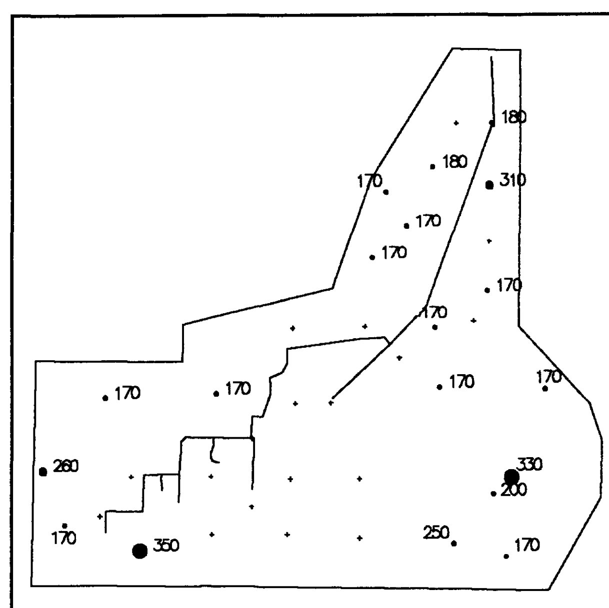



**Figure A41**.--Copper (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

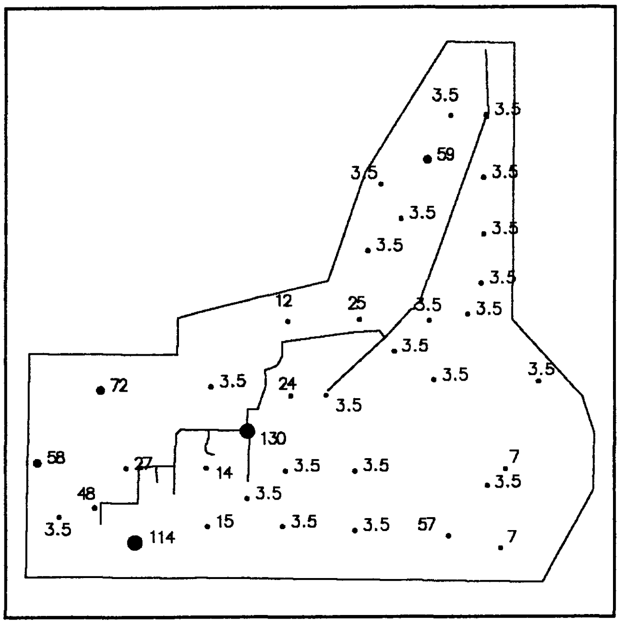



**Figure A42.**--Iron (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

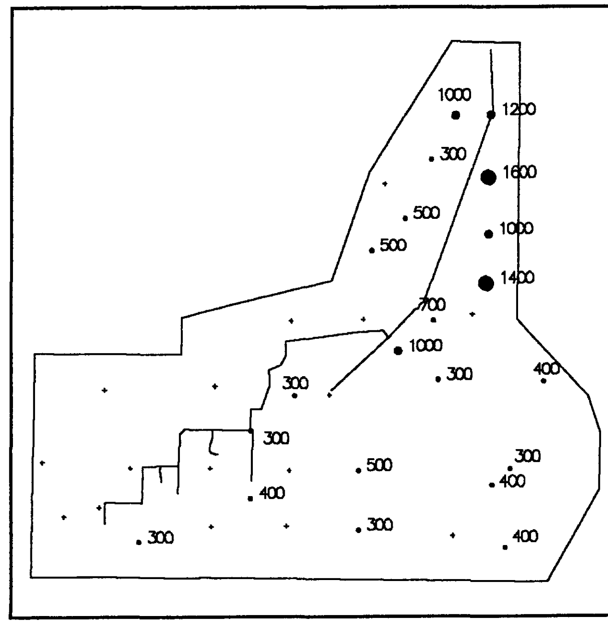



**Figure A43.**--Lithium (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

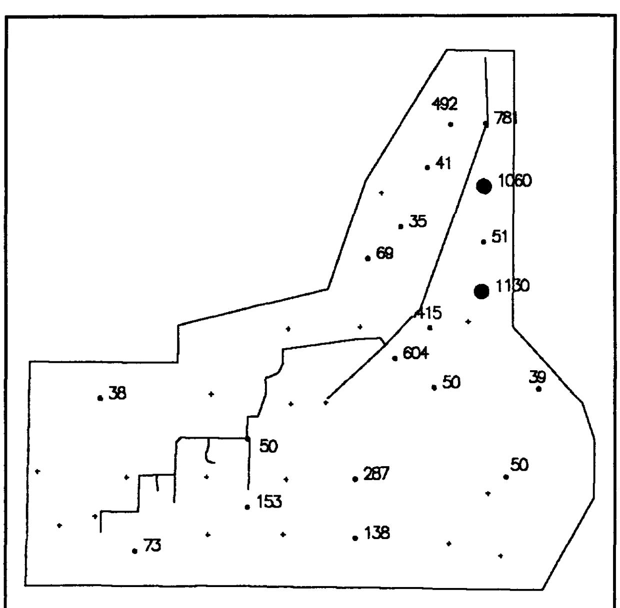



**Figure A44.**--Magnesium (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

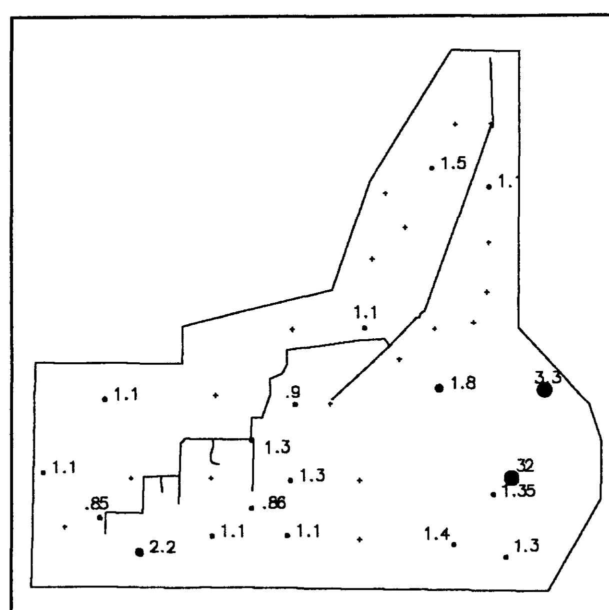



**Figure A45.**--Mercury (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

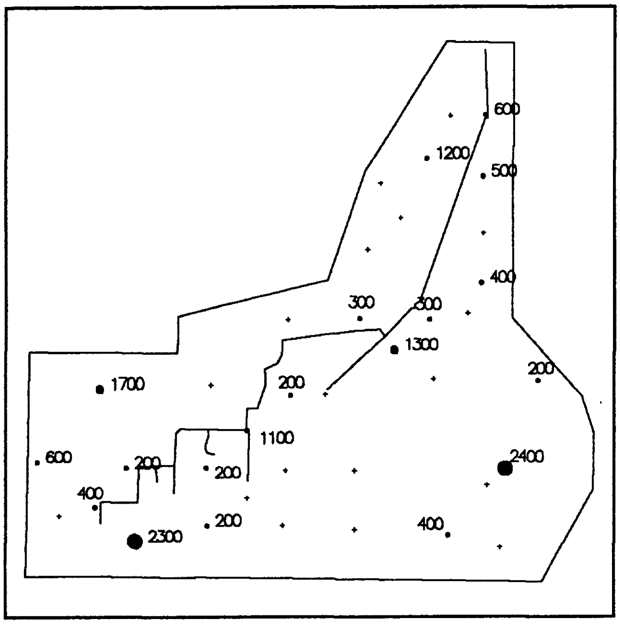



**Figure A46.**--Manganese (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

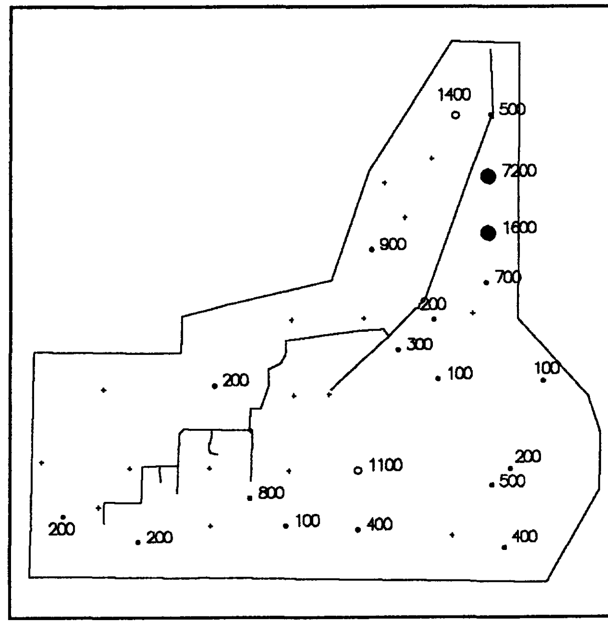



**Figure A47.**--Molybdenum (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

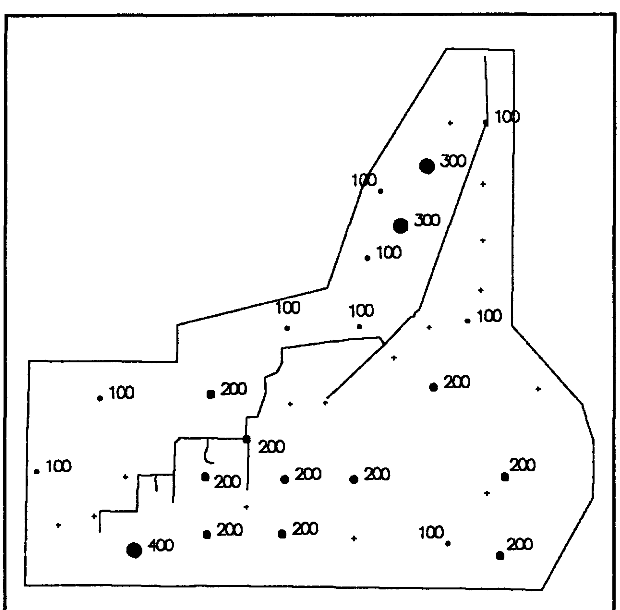



**Figure A48.**--Nickel (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

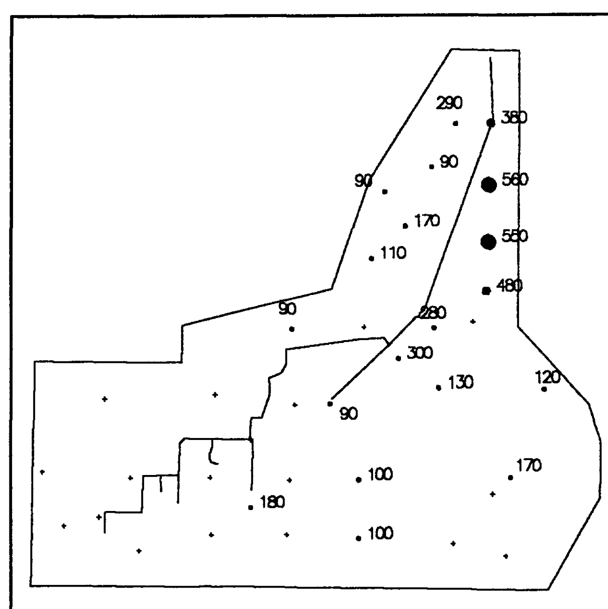



**Figure A49.**--Potassium (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

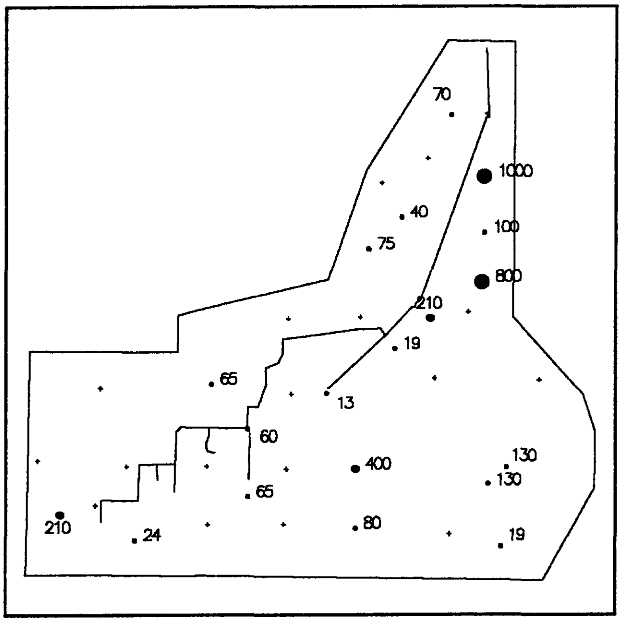



**Figure A50.**--Selenium (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

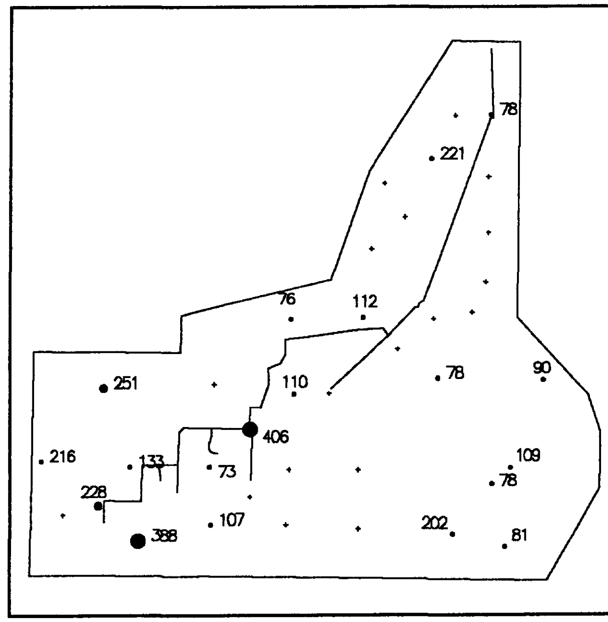



**Figure A51.**--Silicon (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

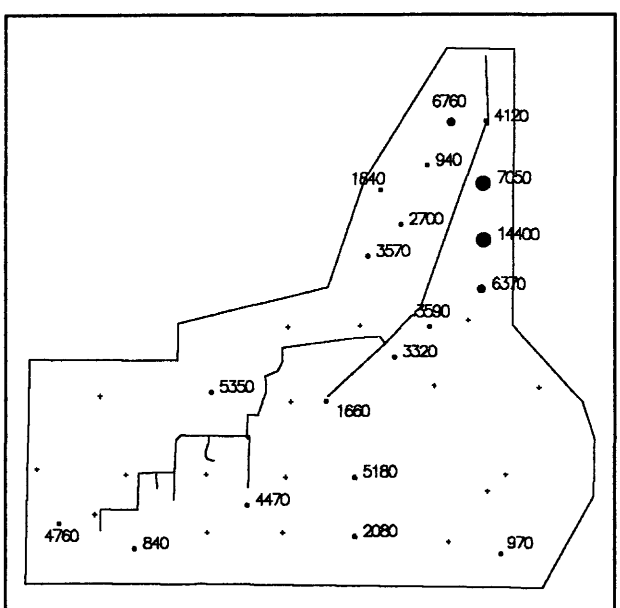



**Figure A52.**--Sodium (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

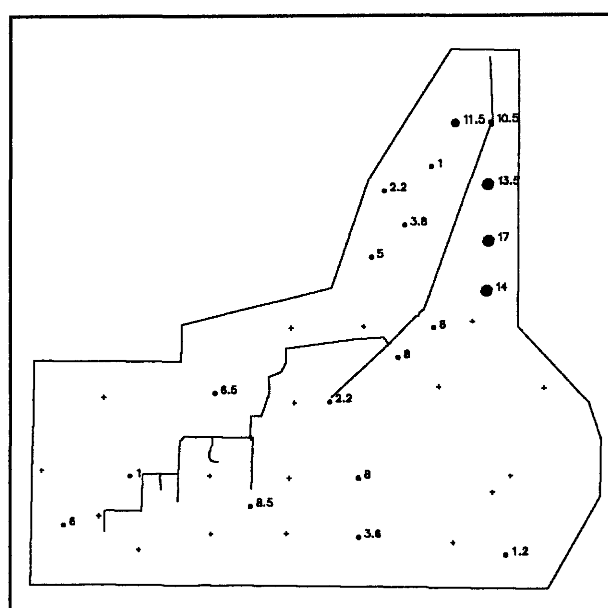


**Figure A53.**--Specific conductivity (mmho/cm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

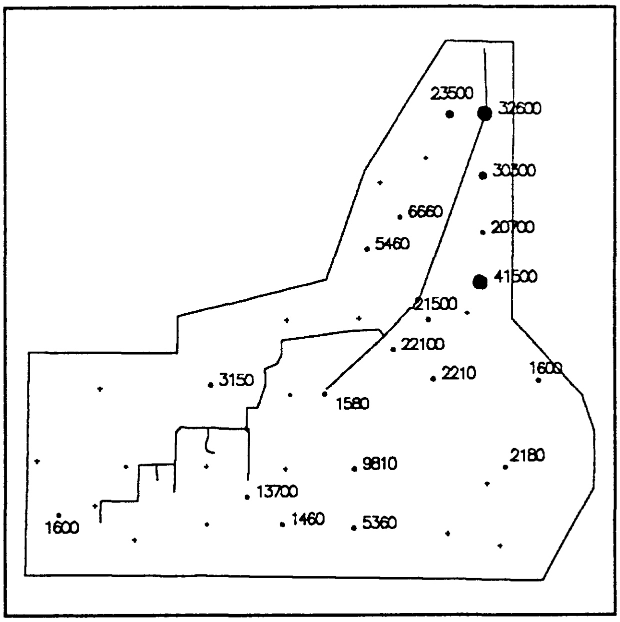



**Figure A54.**--Strontium (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

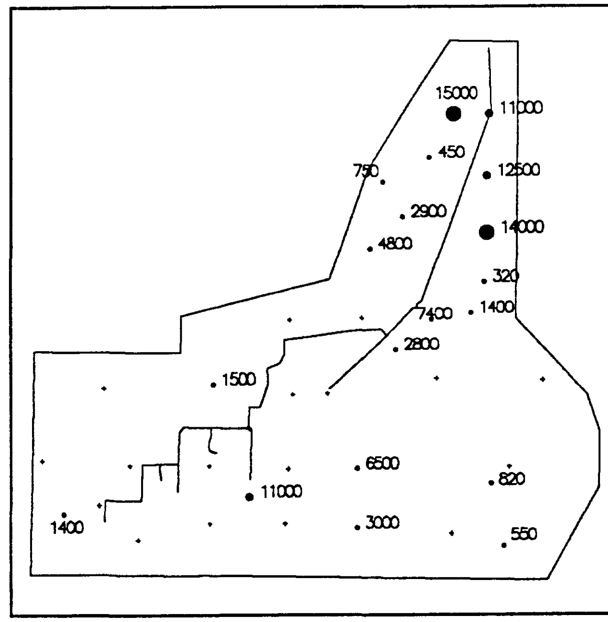



**Figure A55.**--Sulfate (ppm) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

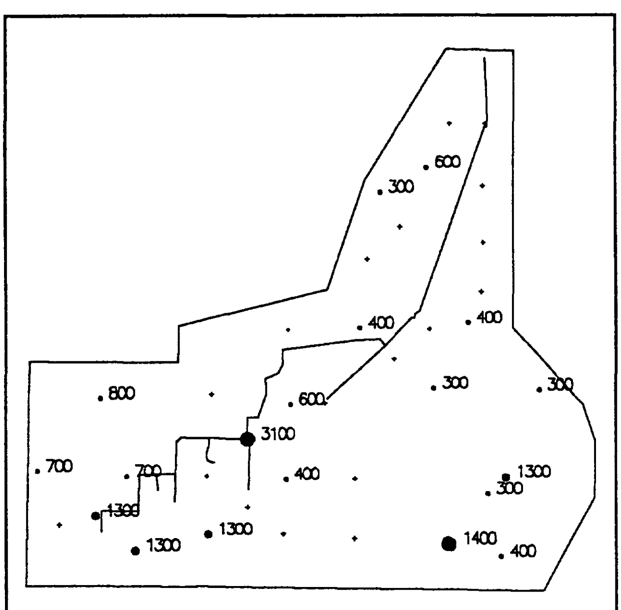



**Figure A56.**--Titanium (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

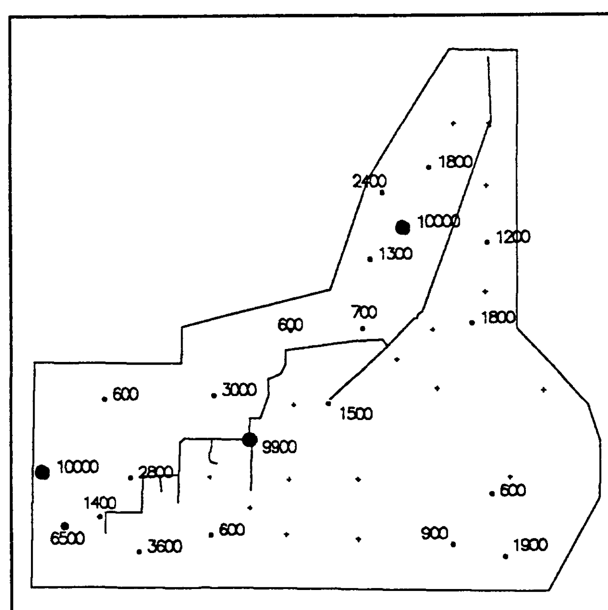



**Figure A57.**--Vanadium (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

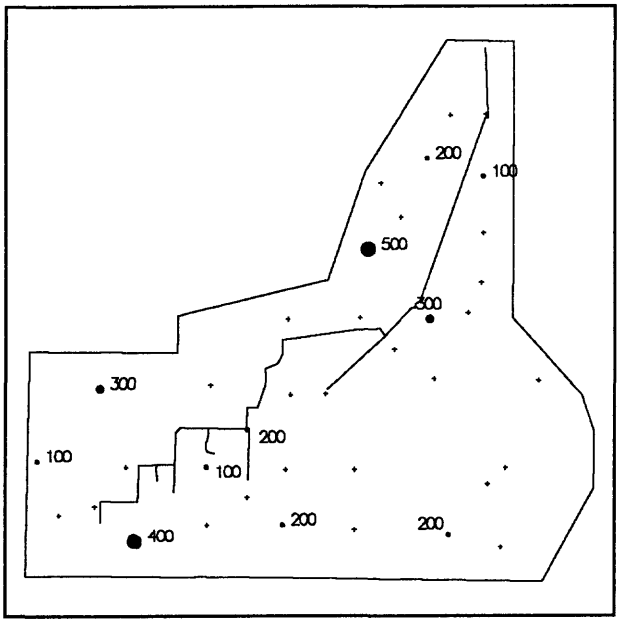



**Figure A58**.--Zinc (ppb) in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

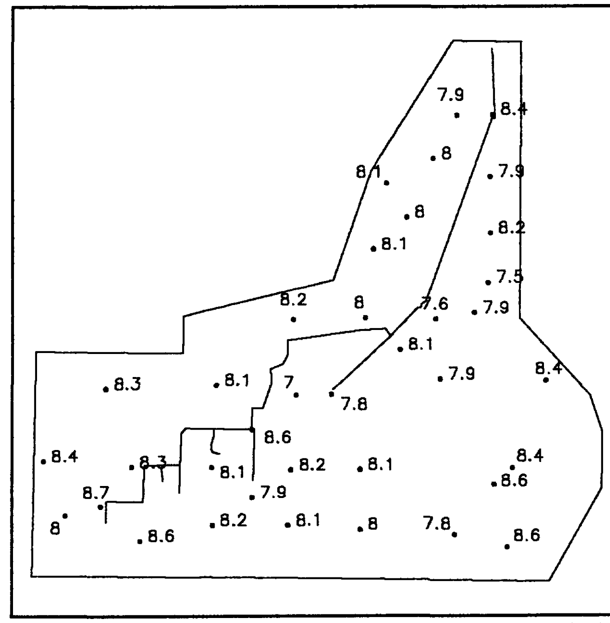


**Figure A59**.--pH in soil-water extracts in 0-1 foot horizon. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

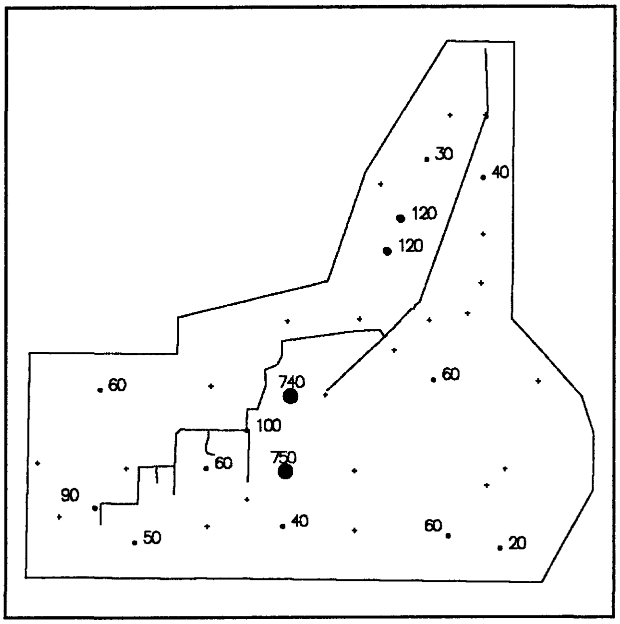



**Figure A60.**--Aluminum (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

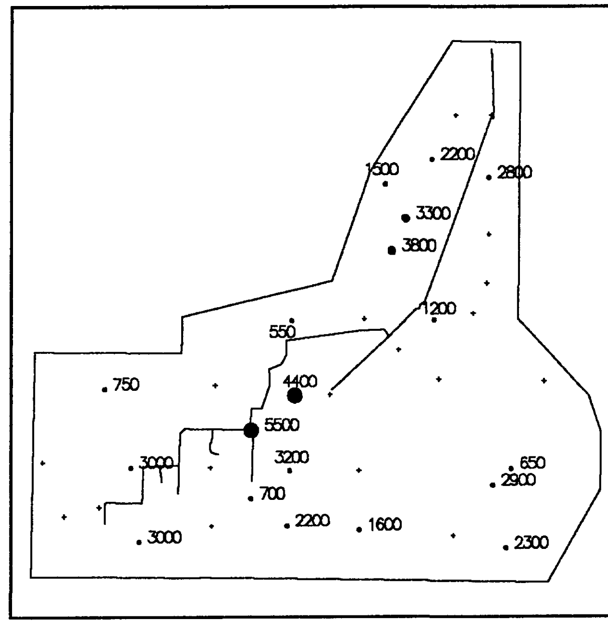



**Figure A61.**--Arsenic (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

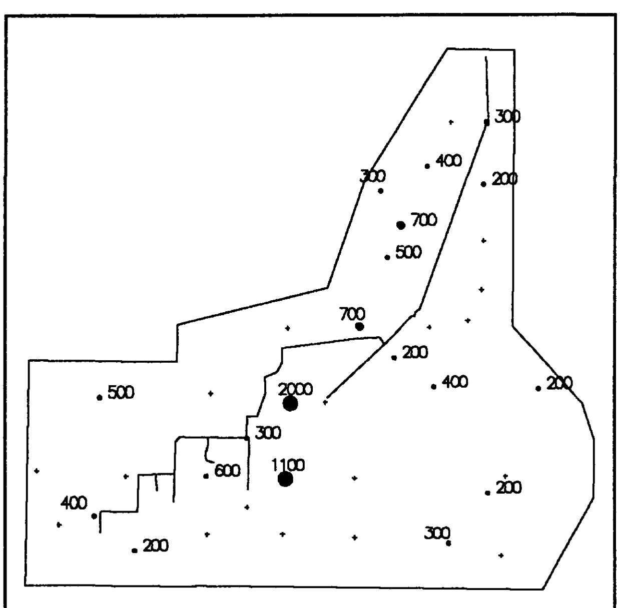



**Figure A62.**--Barium (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

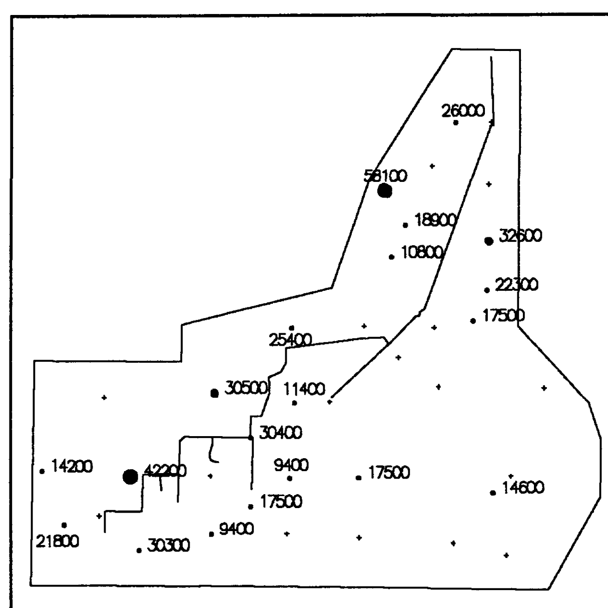



**Figure A63.**--Boron (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

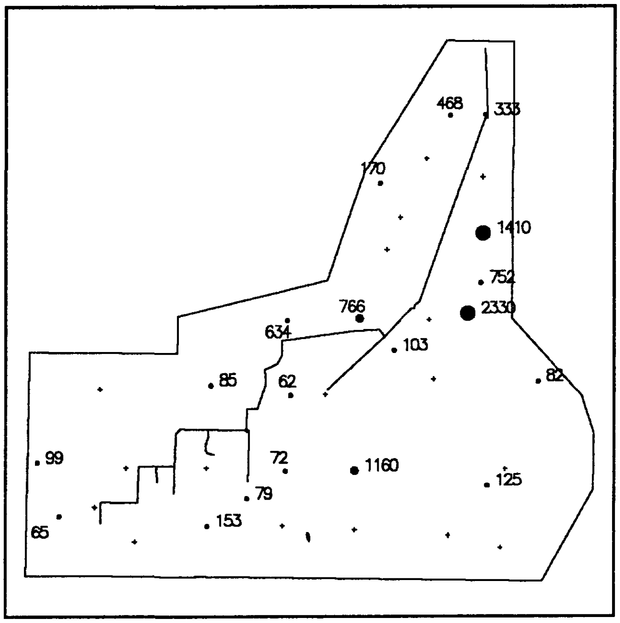



**Figure A64.**--Calcium (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

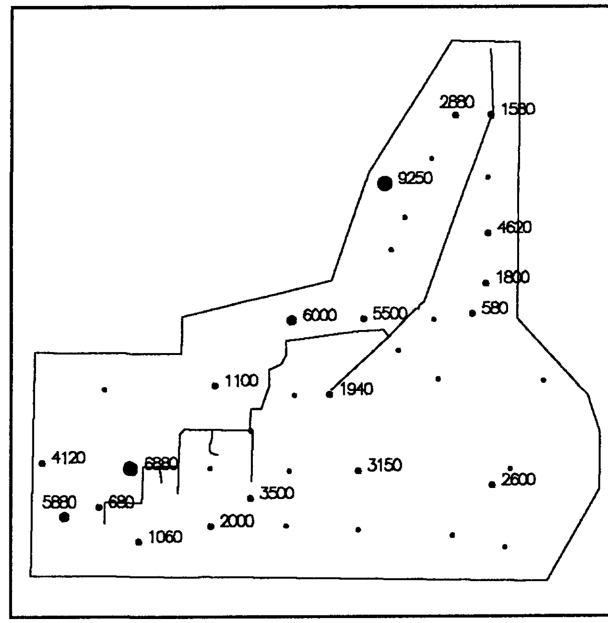



**Figure A65.**--Chloride (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

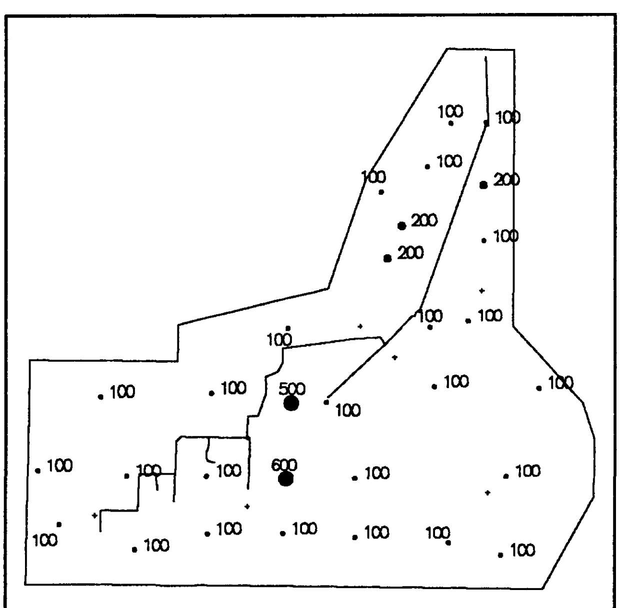



**Figure A66.**--Chromium (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

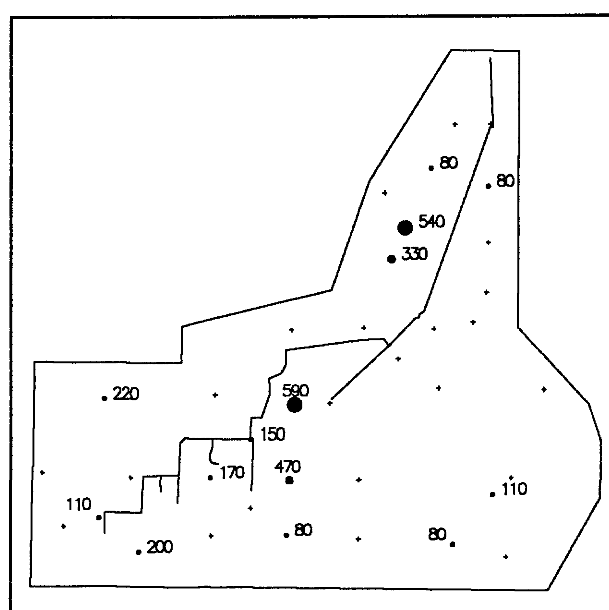



**Figure A67.**--Copper (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

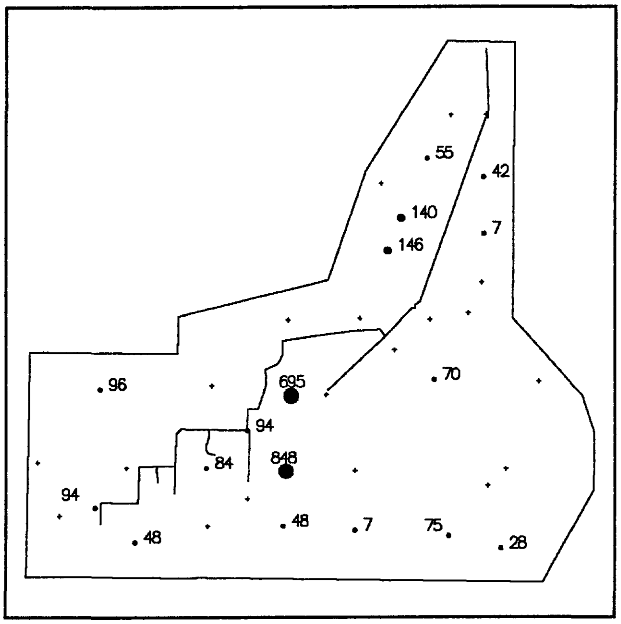



**Figure A68**.--Iron (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

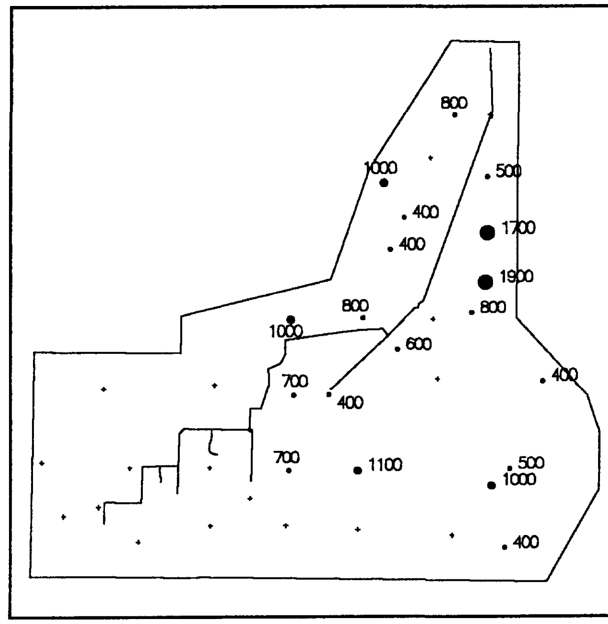



**Figure A69**.--Lithium (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

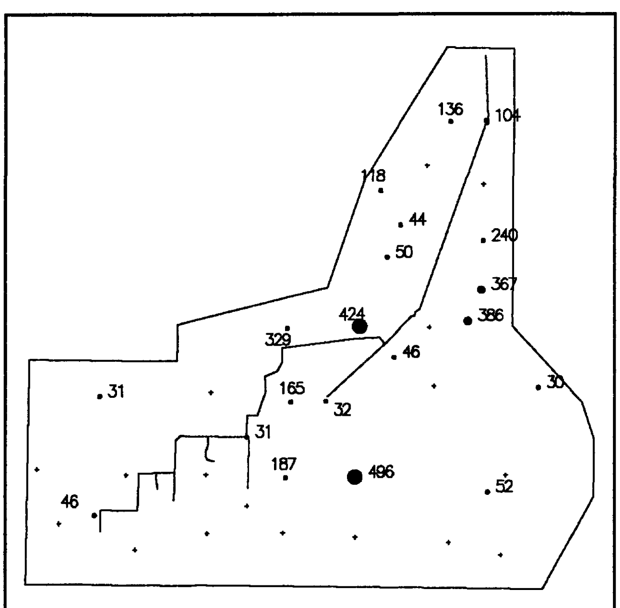



**Figure A70**.--Magnesium (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

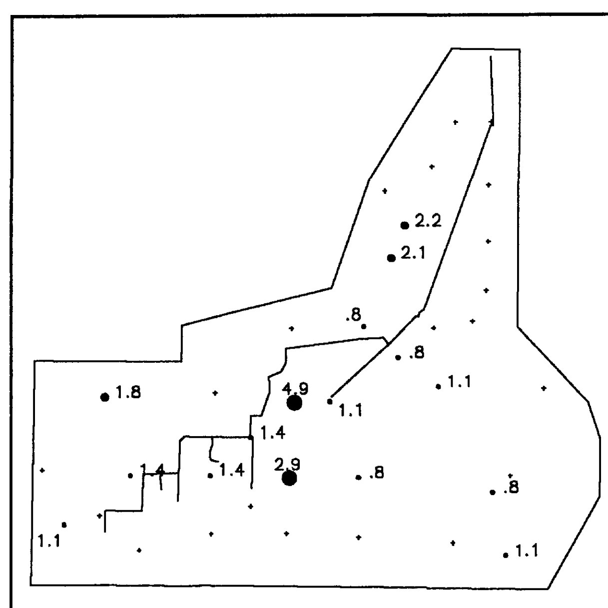



**Figure A71**.--Mercury (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

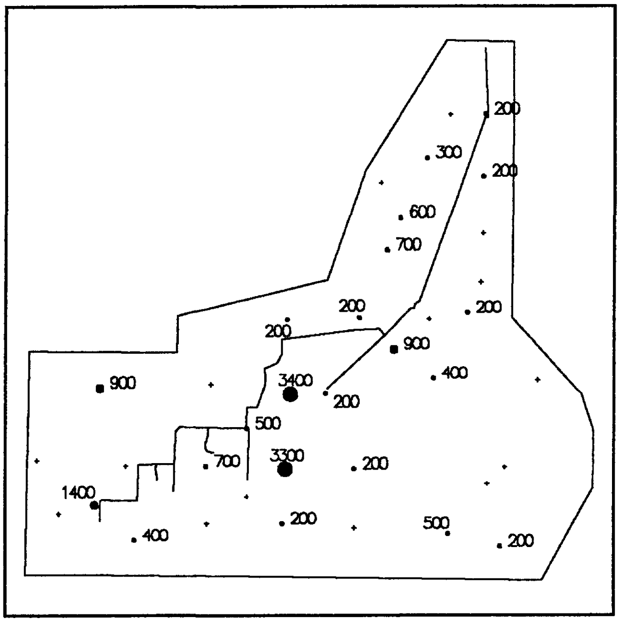



**Figure A72.**--Manganese (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

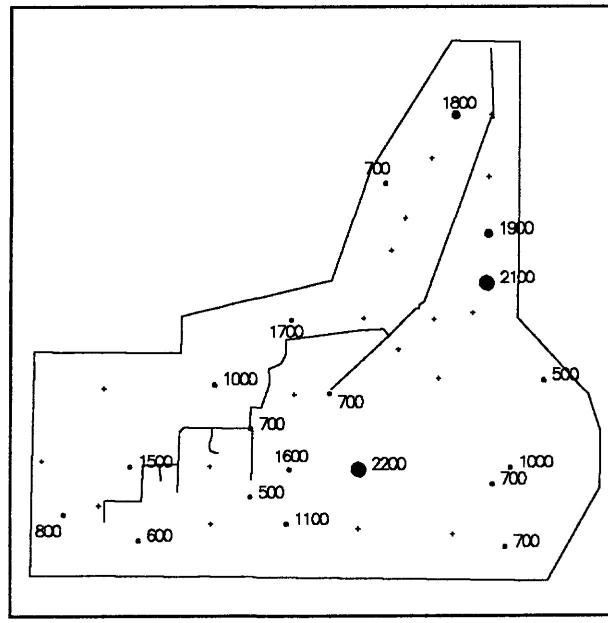



**Figure A73.**--Molybdenum (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

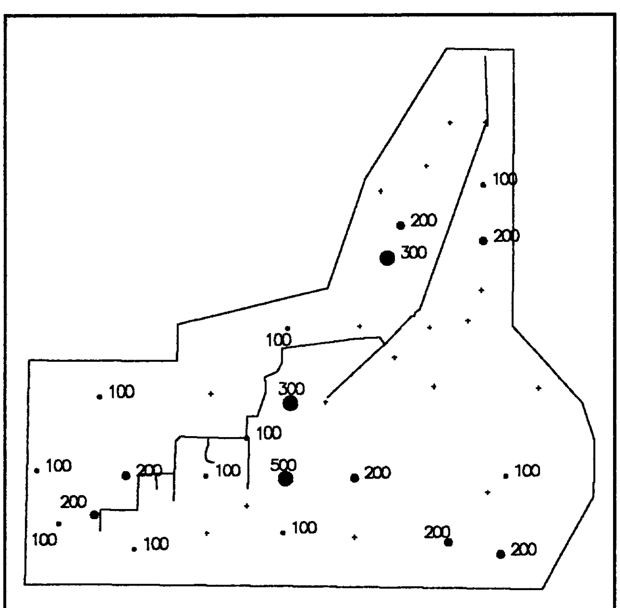



**Figure A74.**--Nickel (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

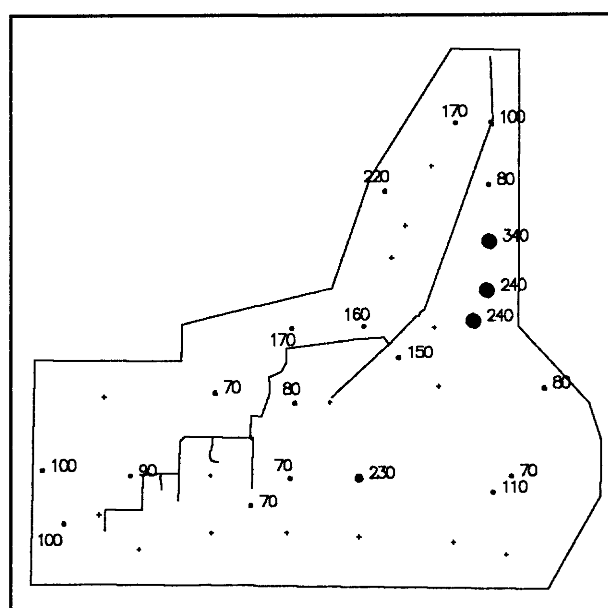



**Figure A75.**--Potassium (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

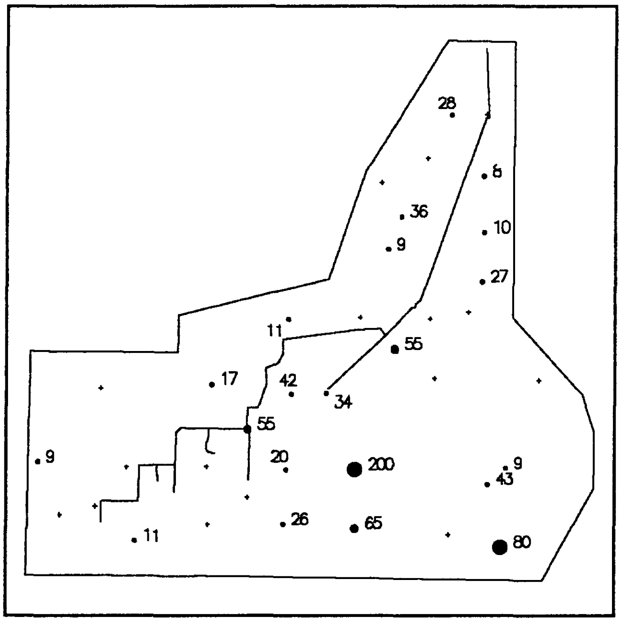



**Figure A76**.--Selenium (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

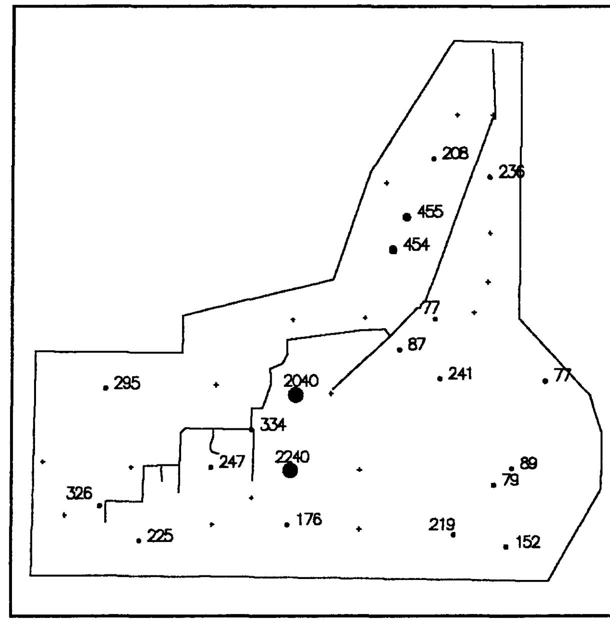



**Figure A77**.--Silicon (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

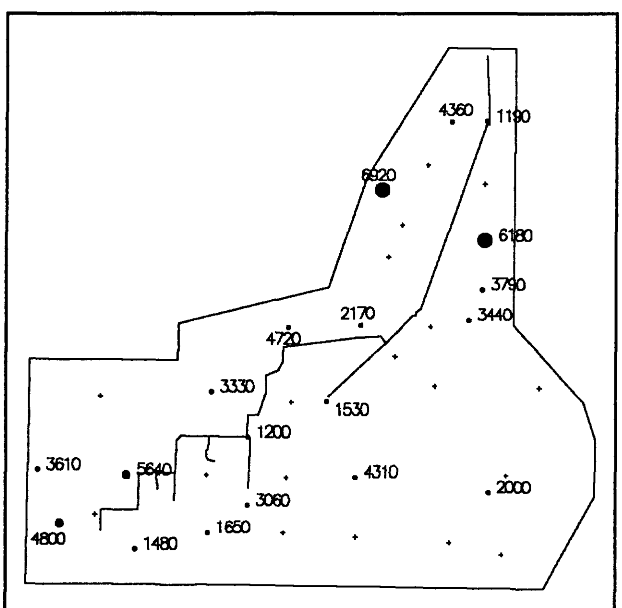



**Figure A78**.--Sodium (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

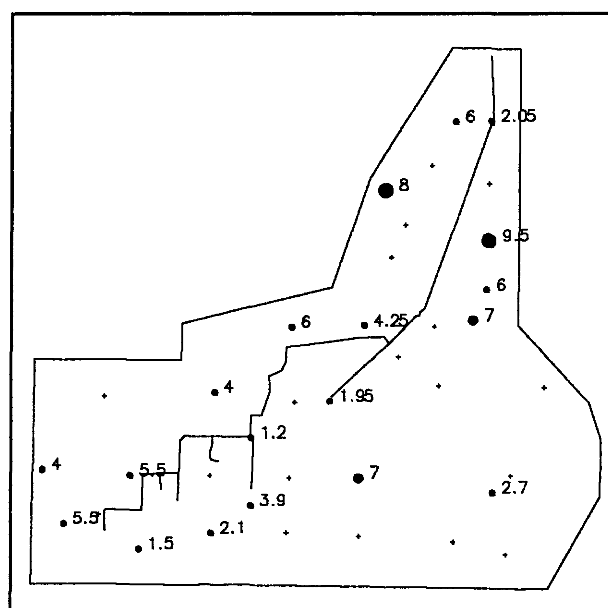



**Figure A79**.--Specific conductivity (mmho/cm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

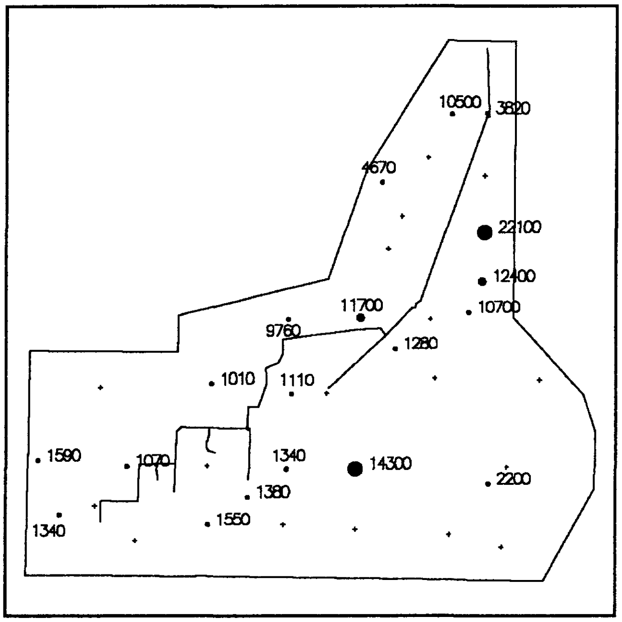



**Figure A80**.--Strontium (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

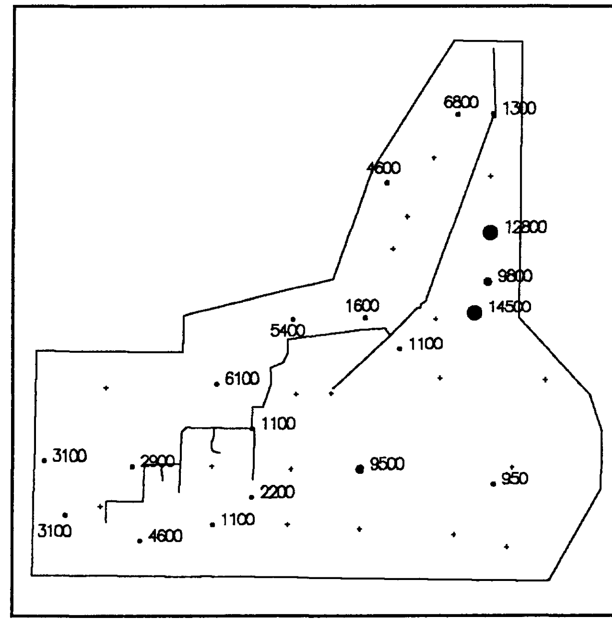



**Figure A81**.--Sulfate (ppm) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

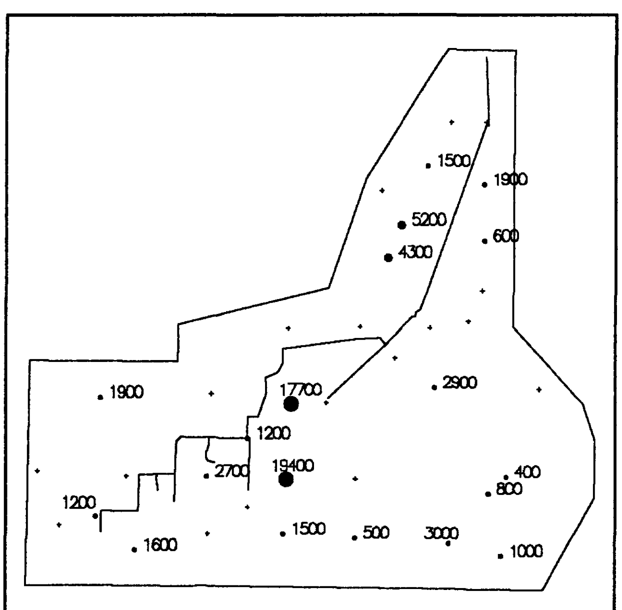



**Figure A82**.--Titanium (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

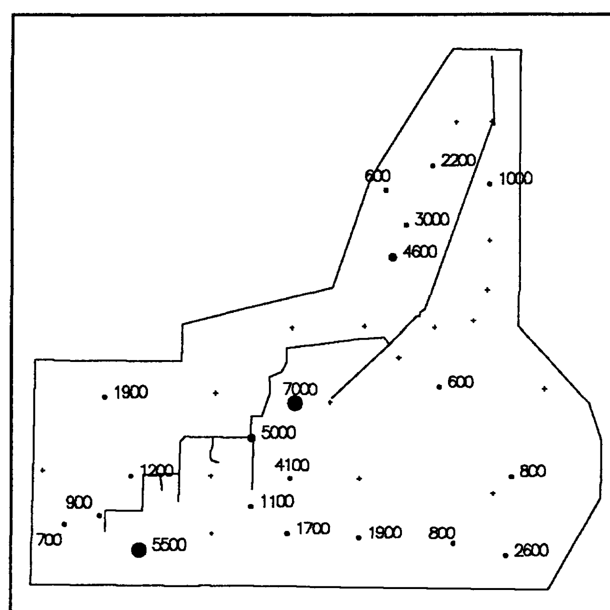



**Figure A83**.--Vanadium (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

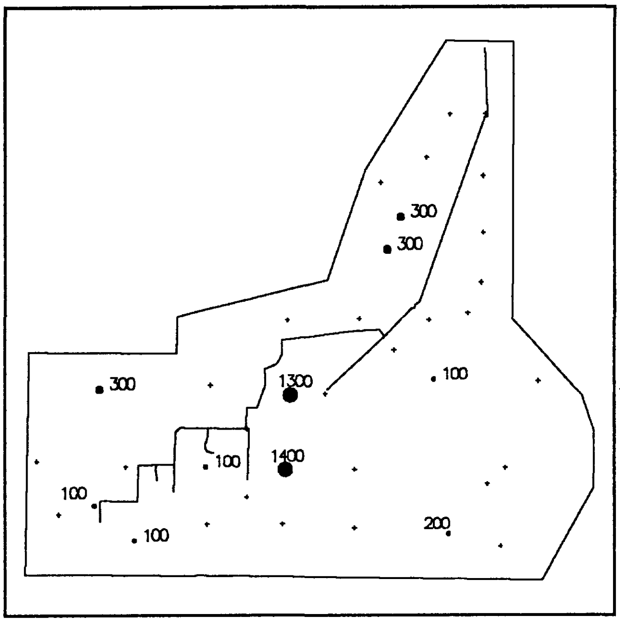




**Figure A84**.--Zinc (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

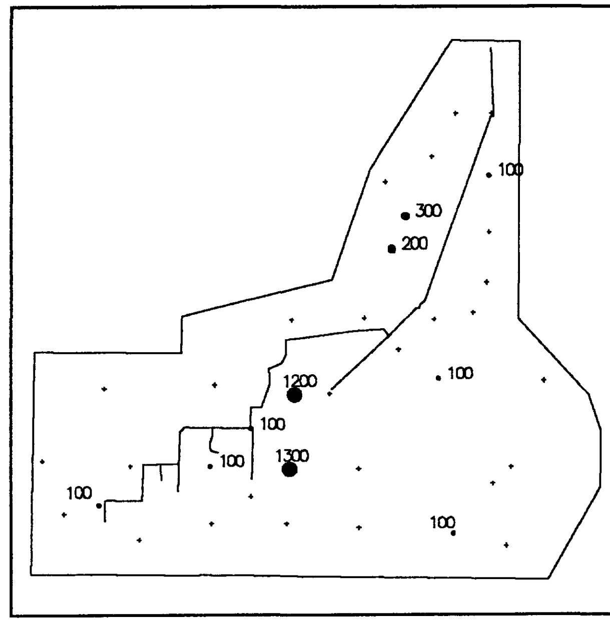




**Figure A85**.--Zircon (ppb) in soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

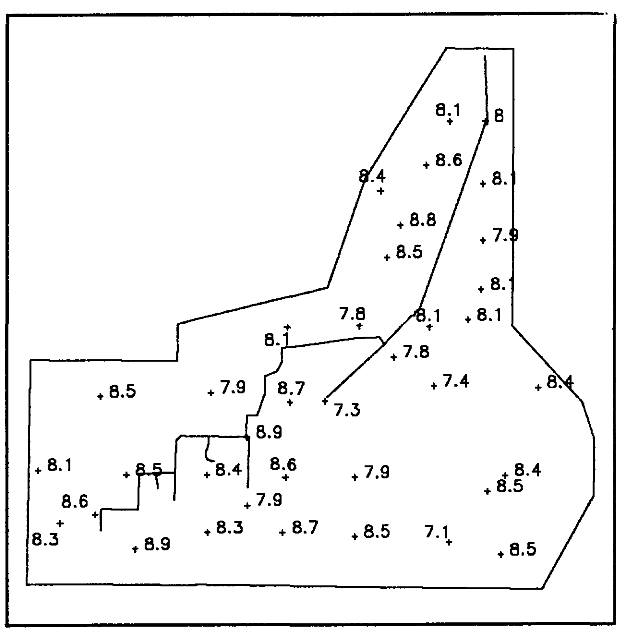




**Figure A86**.--pH of soil-water extracts at water-table depth. Small dot, posted 50-90th percentile. Intermediate dot, posted 90-95th percentile. Large dot, posted 95-100th percentile.

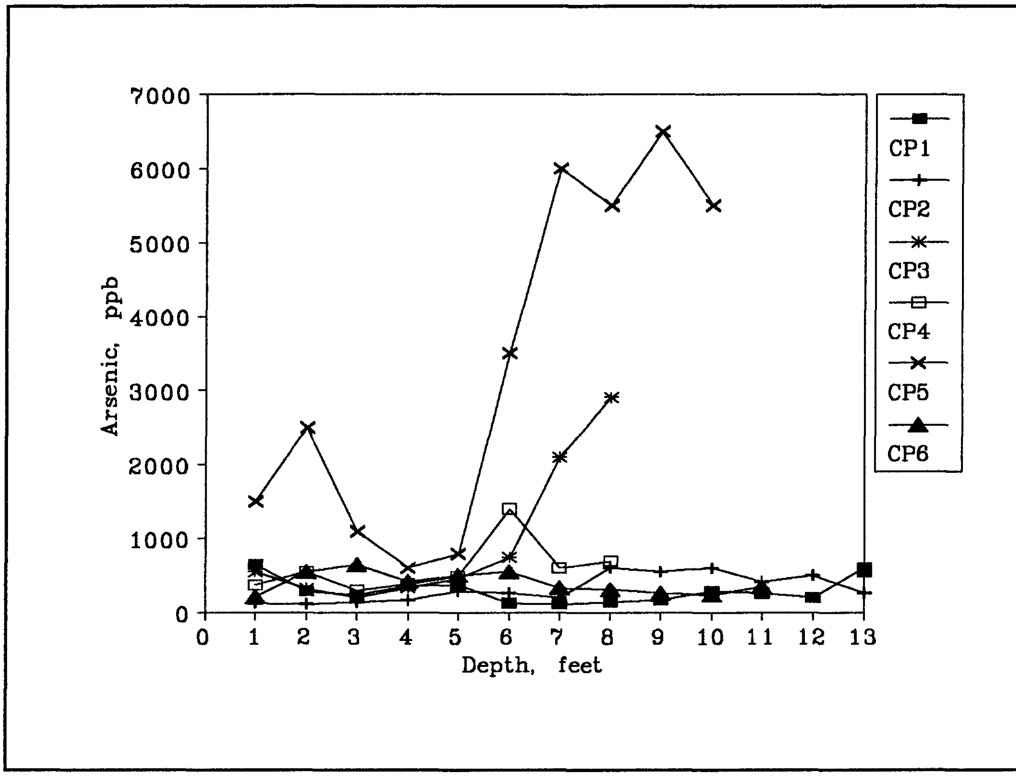



**Figure A87.**--Plot of water-extractable arsenic with depth in 6 soil profiles (CP1-CP6).

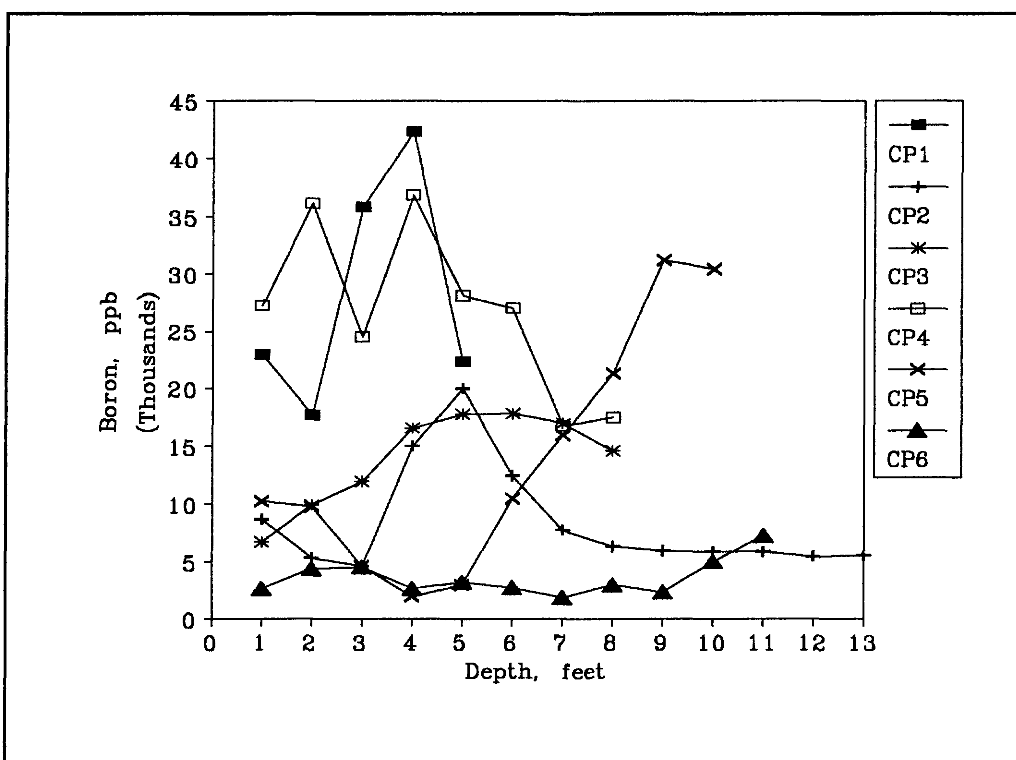



**Figure A88.**--Plot of water-extractable boron with depth in 6 soil profiles (CP1-CP6).

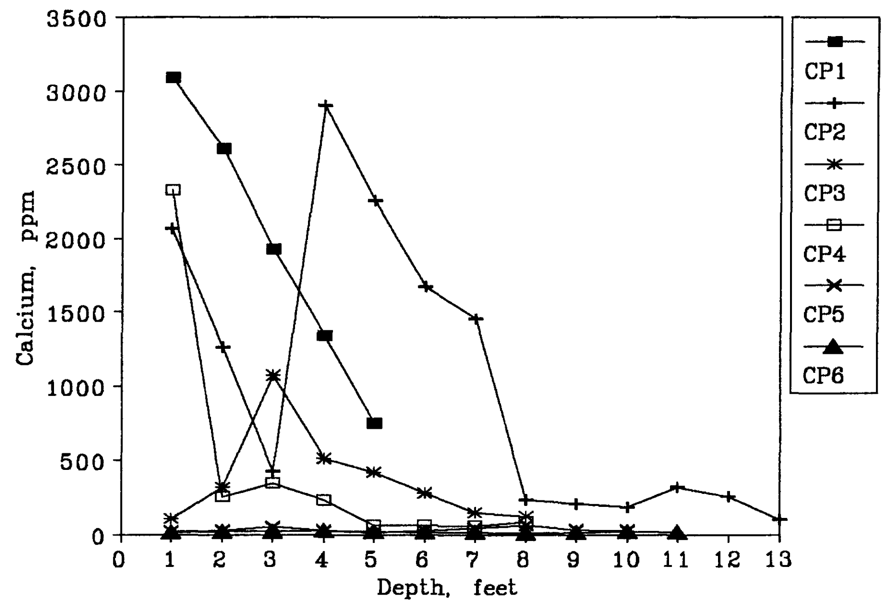



**Figure A89.**--Plot of water-extractable calcium with depth in 6 soil profiles (CP1-CP6).

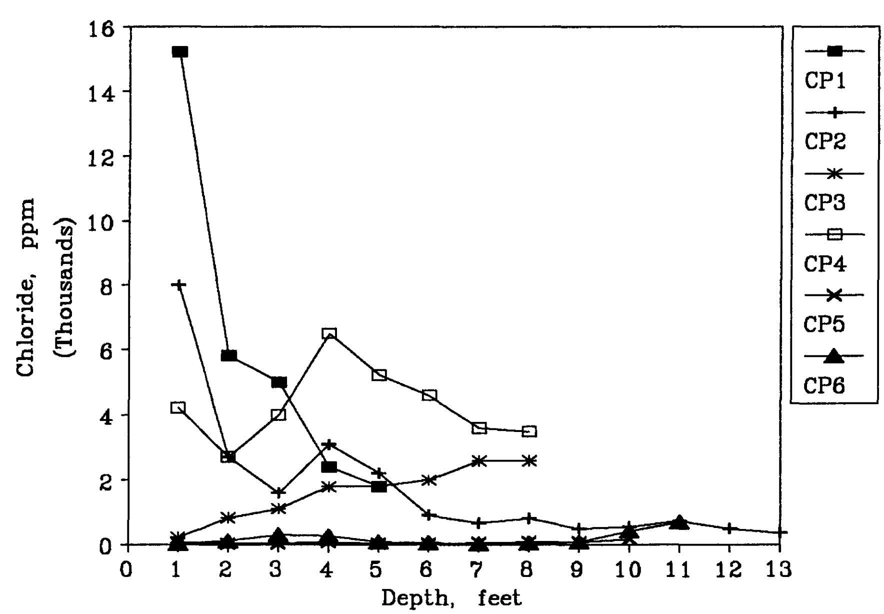



**Figure A90.**--Plot of water-extractable chloride with depth in 6 soil profiles (CP1-CP6).

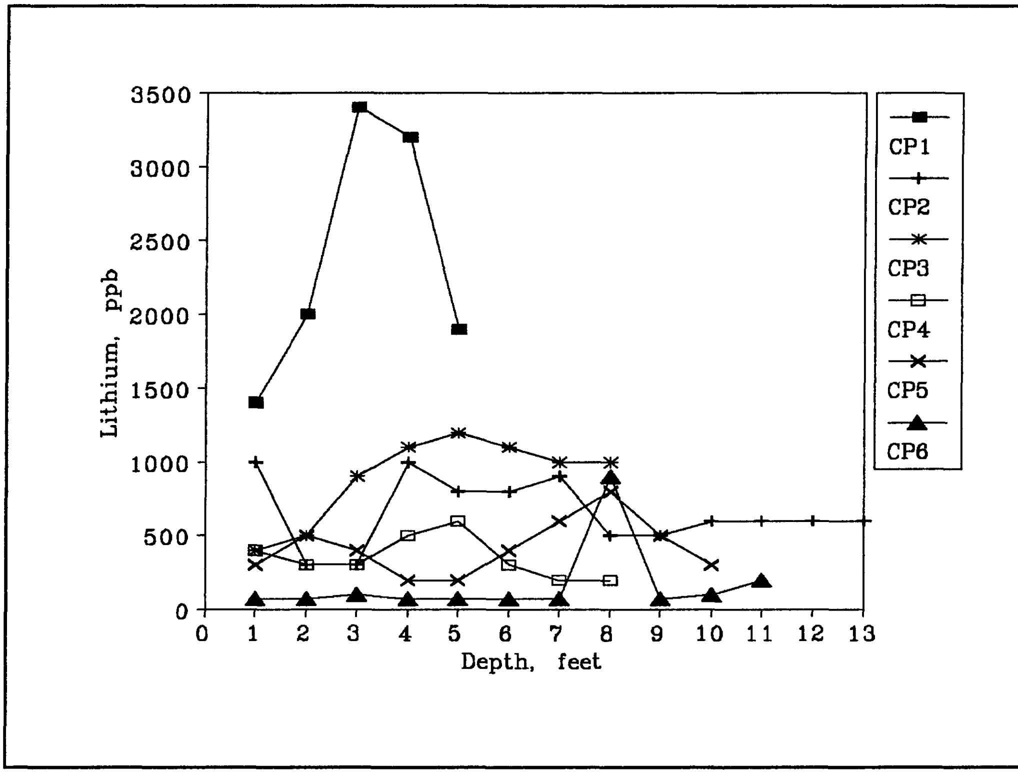


**Figure A91.**--Plot of water-extractable lithium with depth in 6 soil profiles (CP1-CP6).

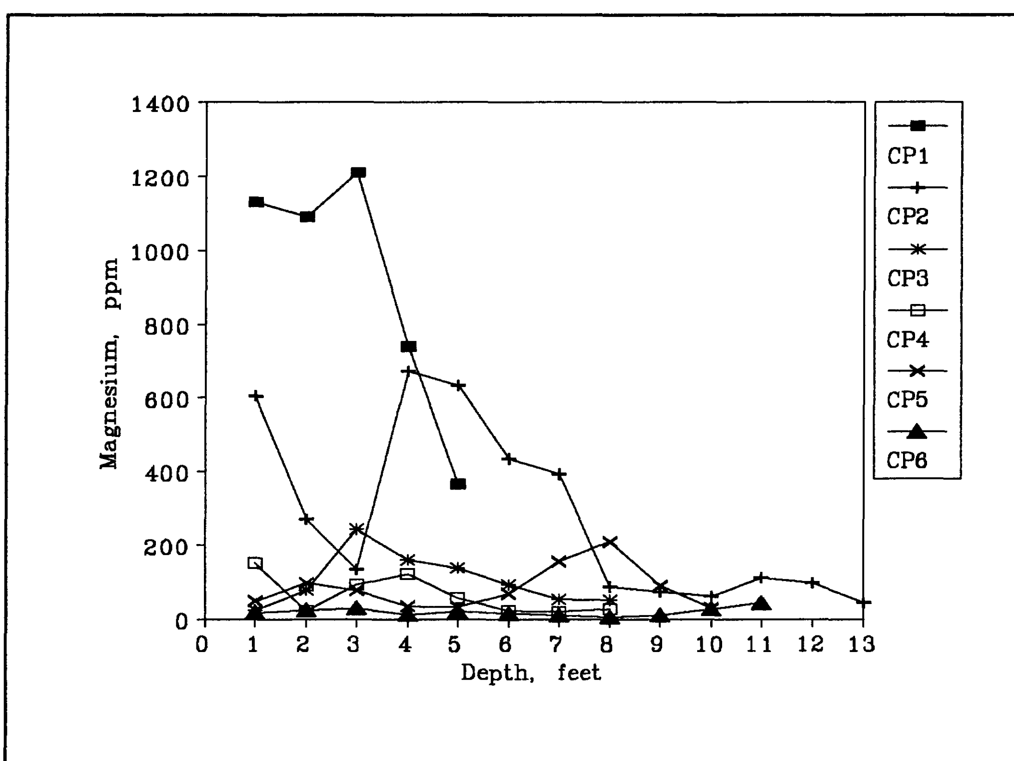


**Figure A92.**--Plot of water-extractable magnesium with depth in 6 soil profiles (CP1-CP6).

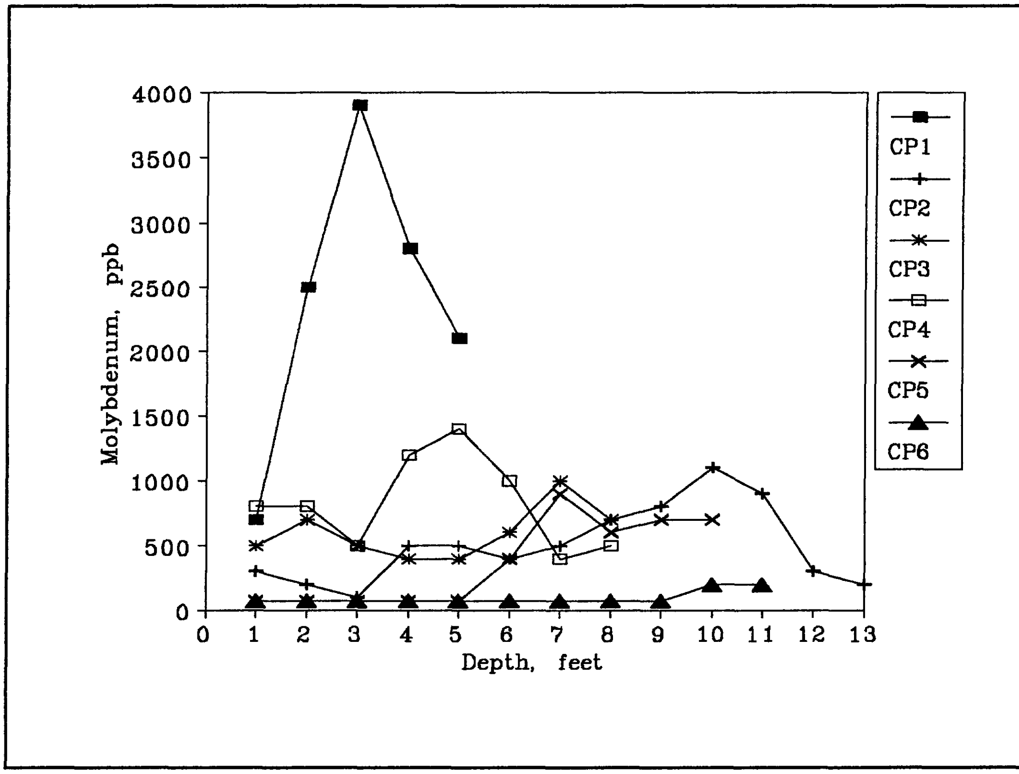



**Figure A93.**--Plot of water-extractable molybdenum with depth in 6 soil profiles (CP1-CP6).

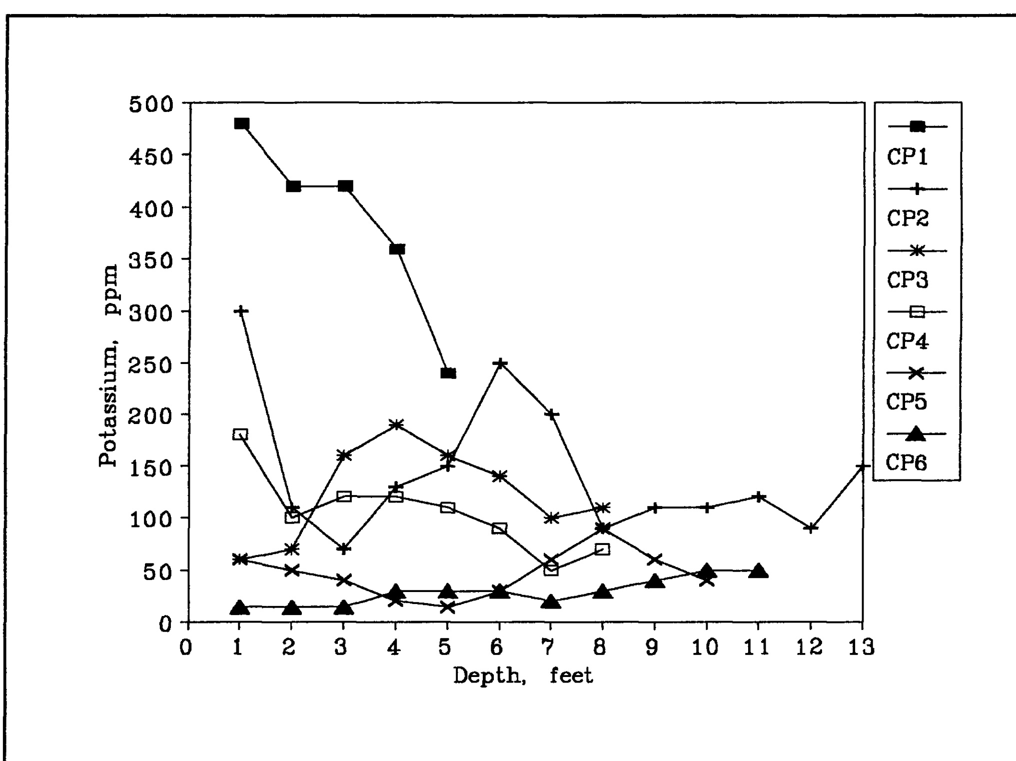



**Figure A94.**--Plot of water-extractable potassium with depth in 6 soil profiles (CP1-CP6).

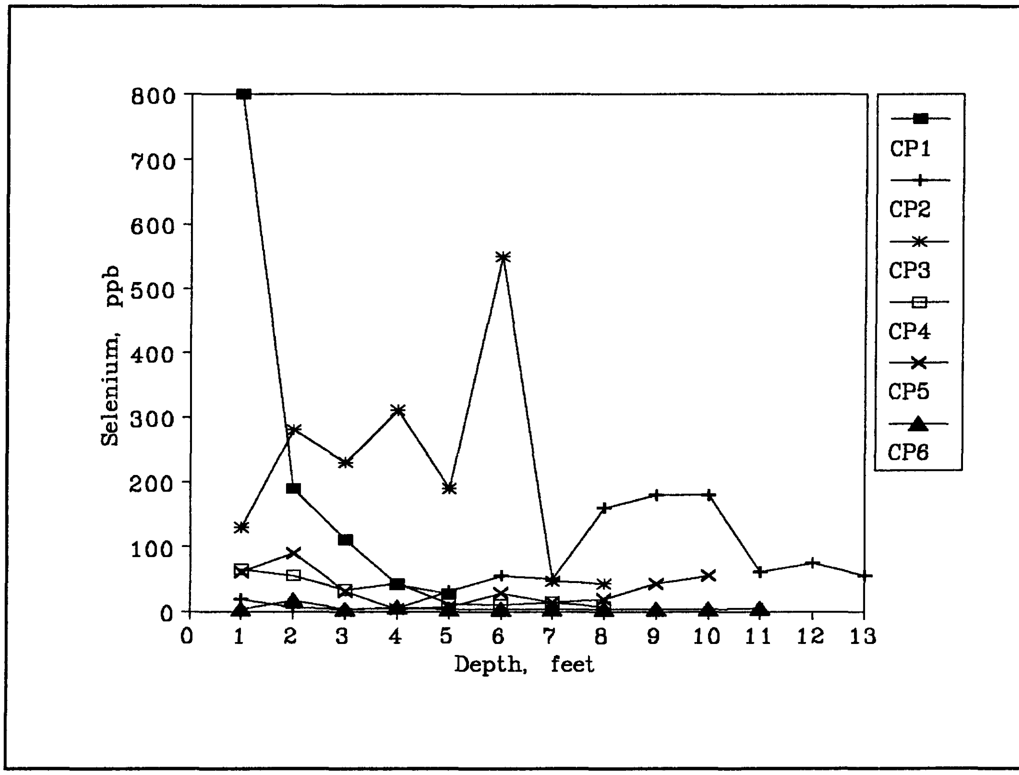



**Figure A95**.--Plot of water-extractable selenium with depth in 6 soil profiles (CP1-CP6).

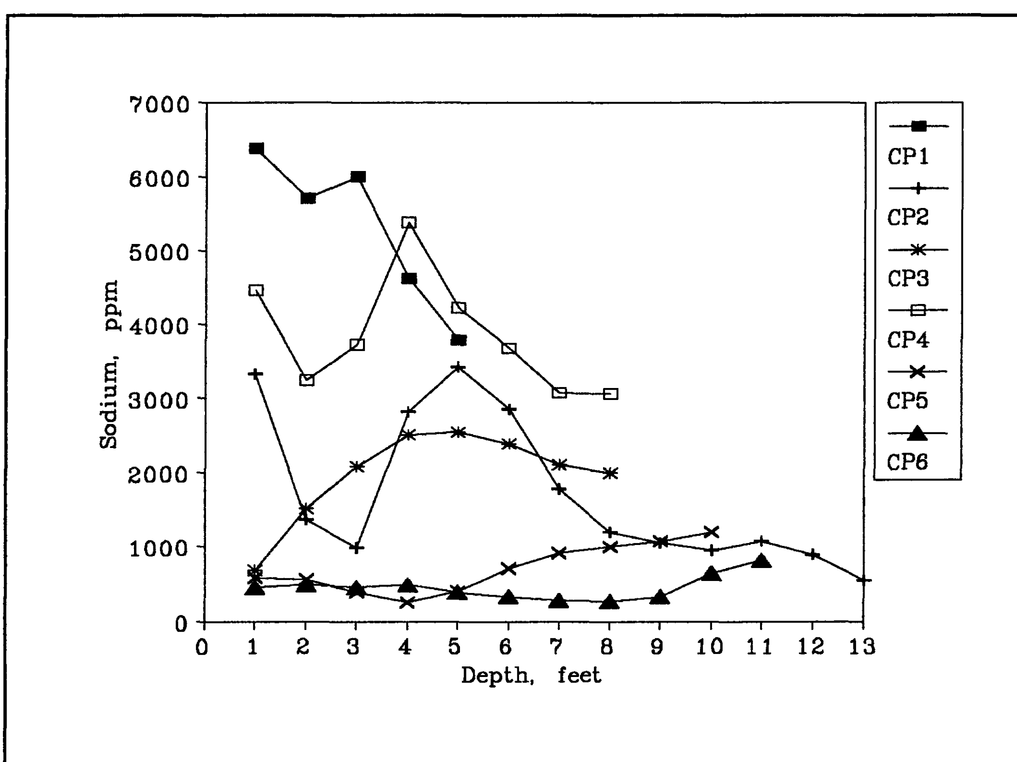



**Figure A96**.--Plot of water-extractable sodium with depth in 6 soil profiles (CP1-CP6).

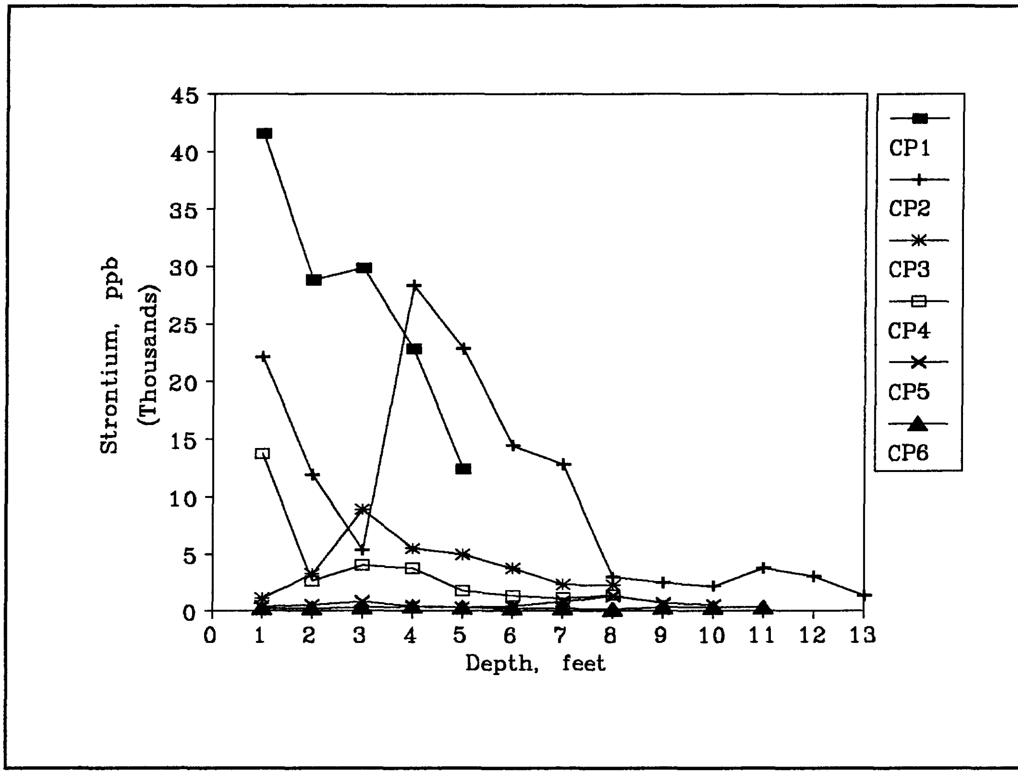



**Figure A97**.--Plot of water-extractable strontium with depth in 6 soil profiles (CP1-CP6).

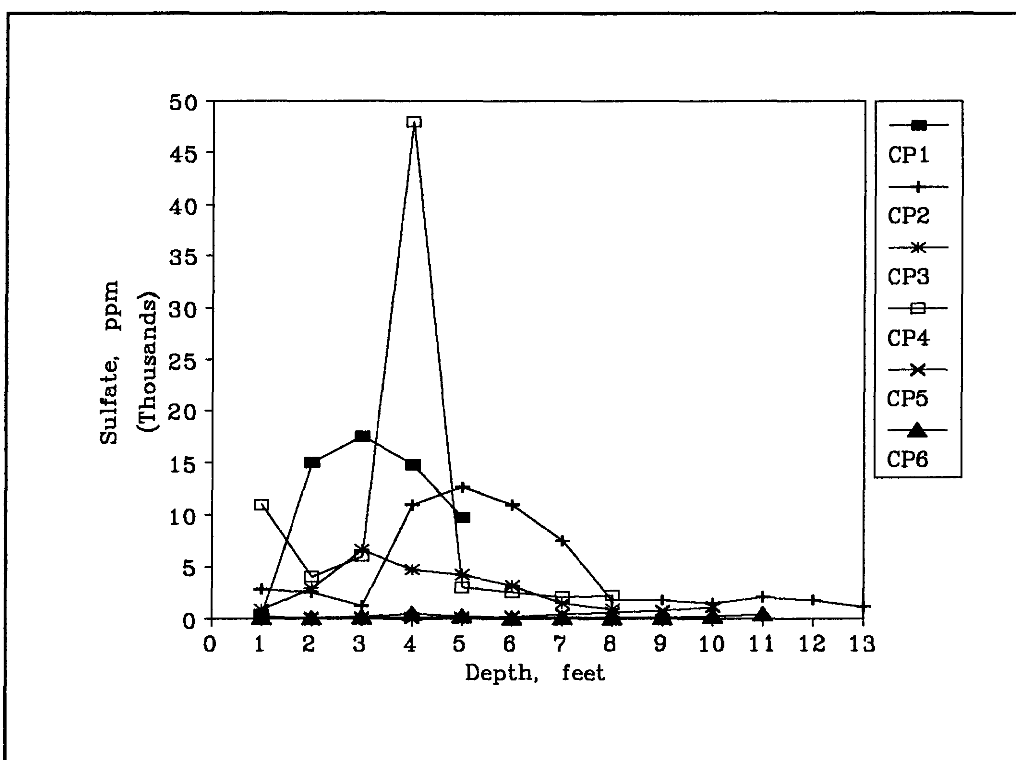



**Figure A98**.--Plot of water-extractable sulfate with depth in 6 soil profiles (CP1-CP6).

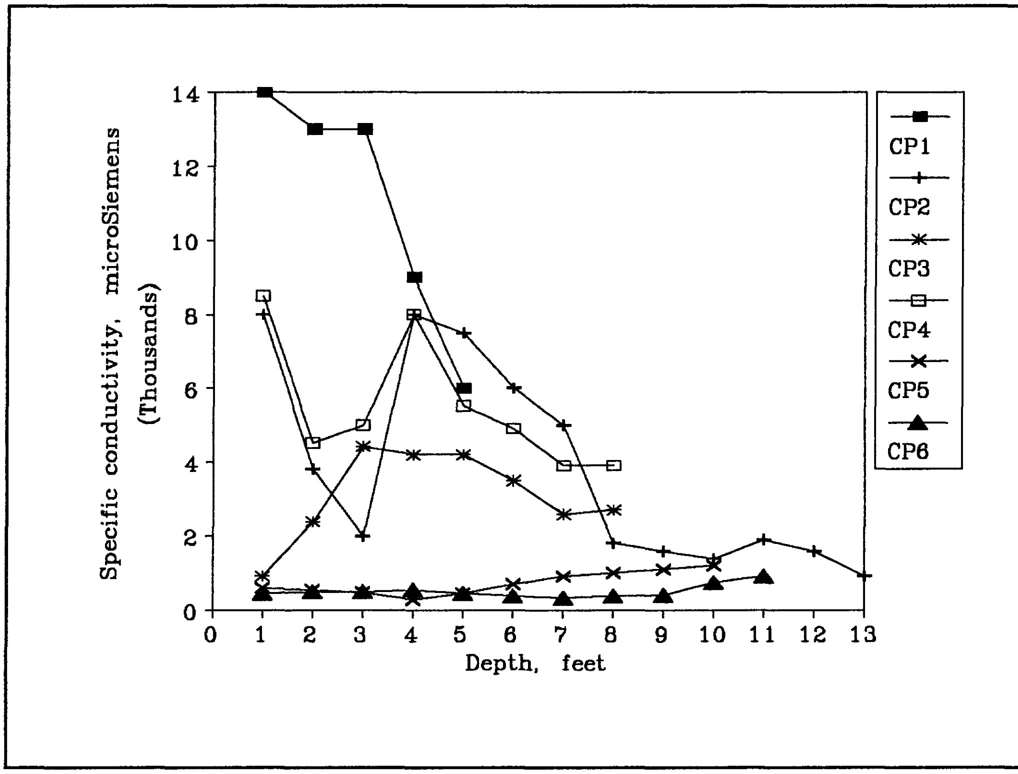


**Figure A99**.--Plot of water-extractable specific conductivity with depth in 6 soil profiles (CP1-CP6).

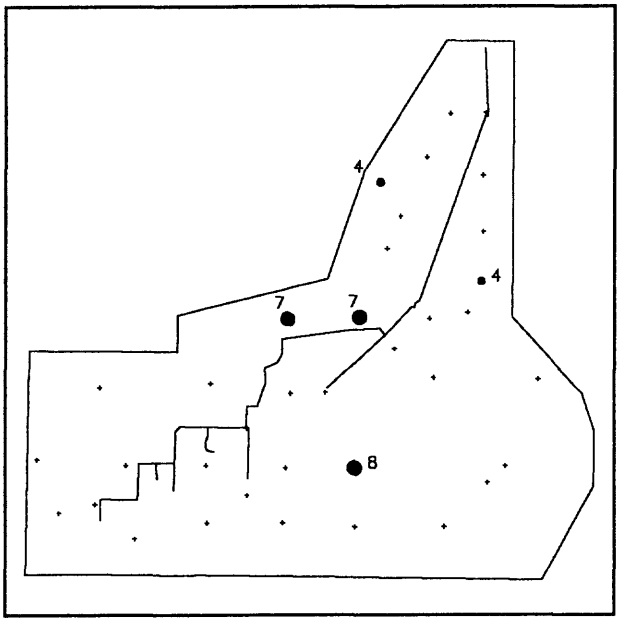



**Figure A100**.--Aluminum (ppm) in groundwater. Plus, less than 2 ppm-90th percentile. Small dot, 90-95th. Large dot, 95-100th.

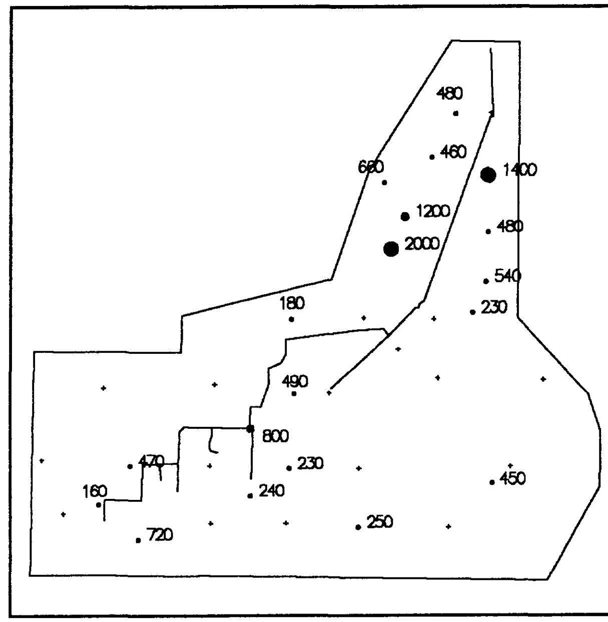



**Figure A101**.-- Arsenic (ppb) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

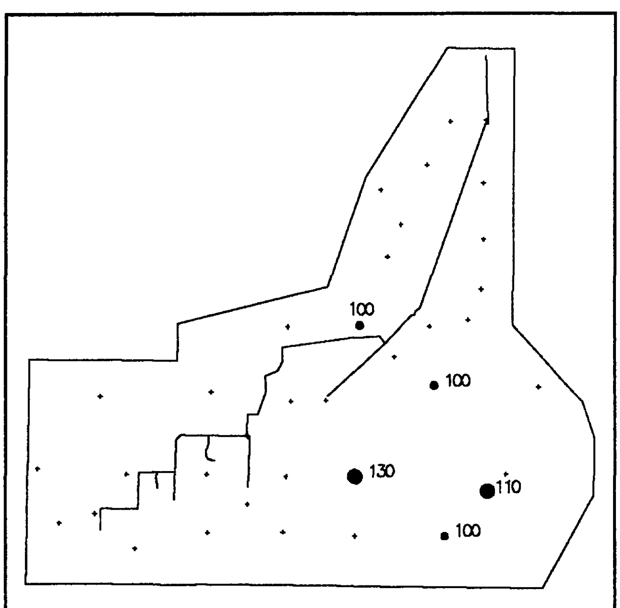



**Figure A102**.--Barium (ppb) in groundwater. Plus, less than 50 ppb-90th percentile. Small dot, 90-95th. Large dot, 95-100th.

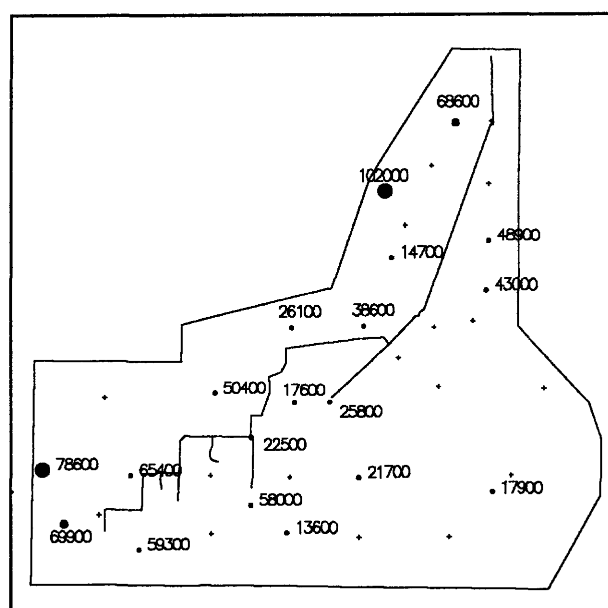



**Figure A103**.--Boron (ppb) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

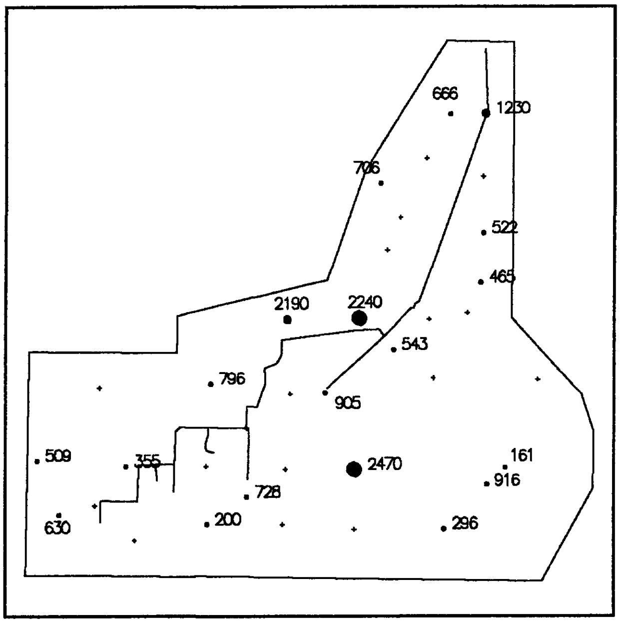



**Figure A104**.--Calcium (ppm) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

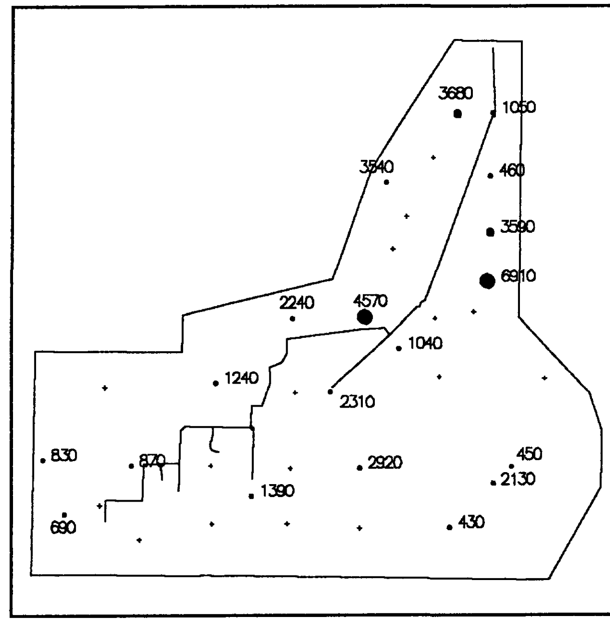



**Figure A105**.--Lithium (ppb) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

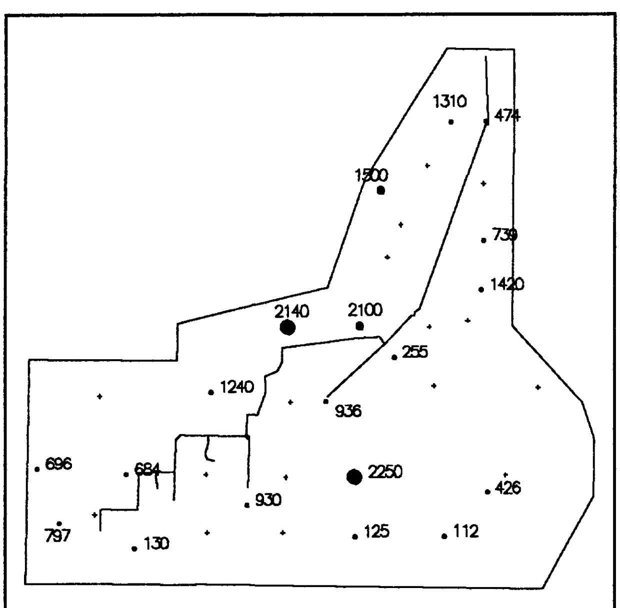



**Figure A106**.--Magnesium (ppm) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

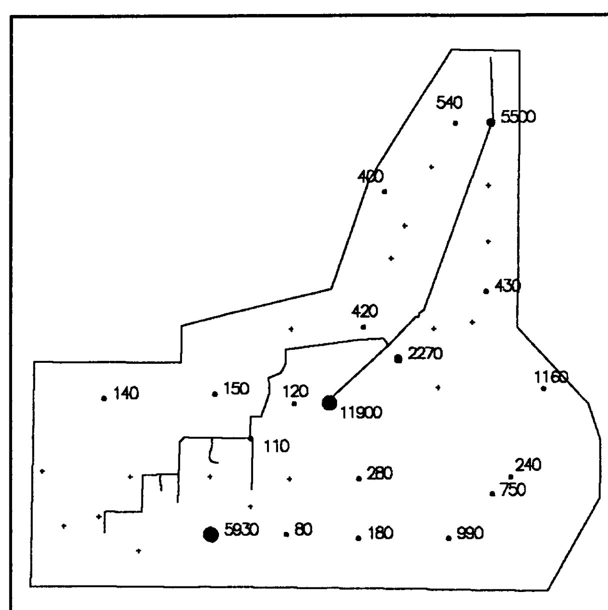



**Figure A107**.--Manganese (ppb) in groundwater. Plus, less than 20 ppb-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

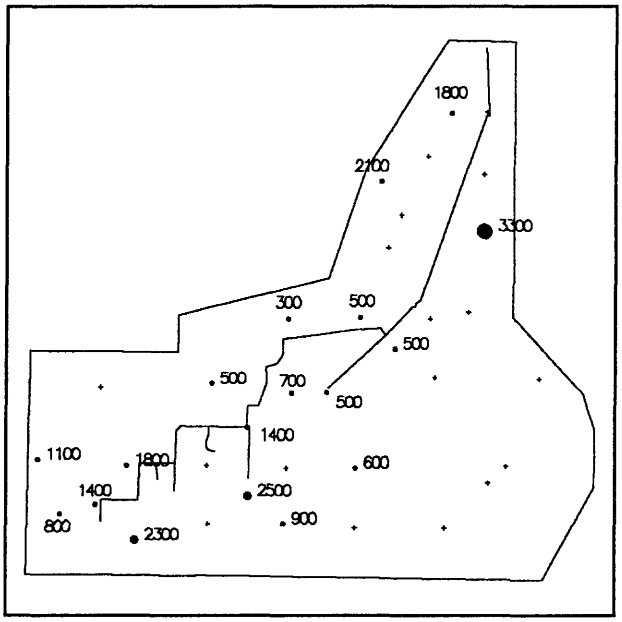



**Figure A108.**--Molybdenum (ppb) in groundwater. Plus, less than 200 ppb-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

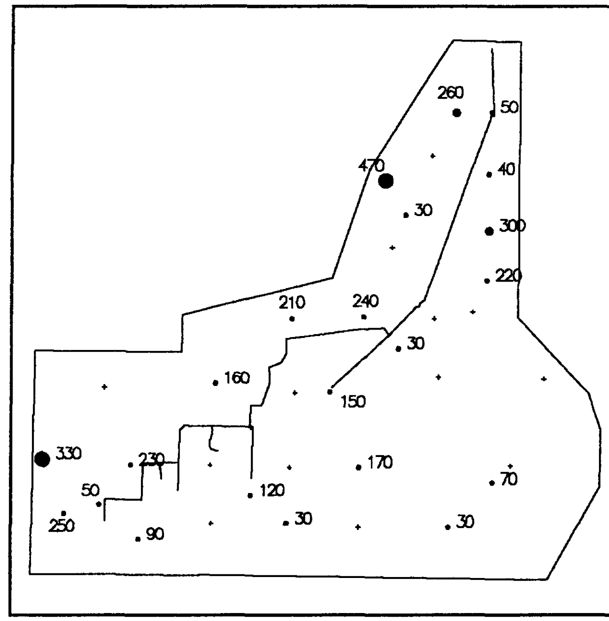



**Figure A109.**--Potassium (ppm) in groundwater. Plus, less than 20 ppm-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

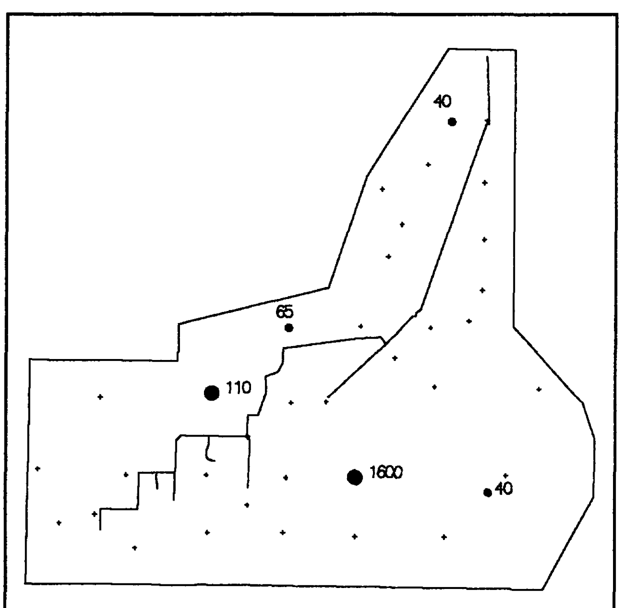



**Figure A110.**--Selenium (ppb) in groundwater. Plus, less than 1 ppb-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

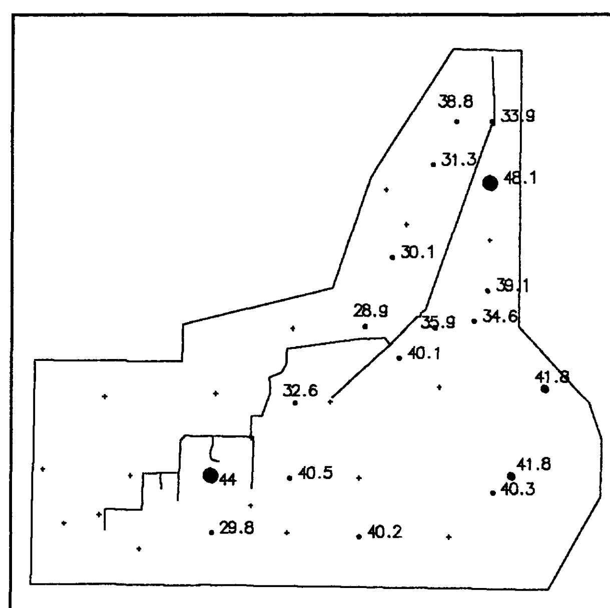



**Figure A111.**--Silicon (ppm) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

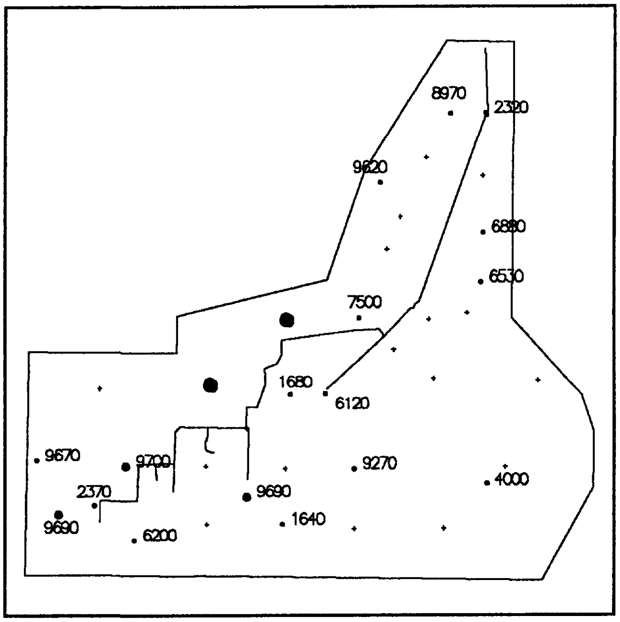



**Figure A112**.--Sodium (ppm) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95th-greater than 10,000 ppm.

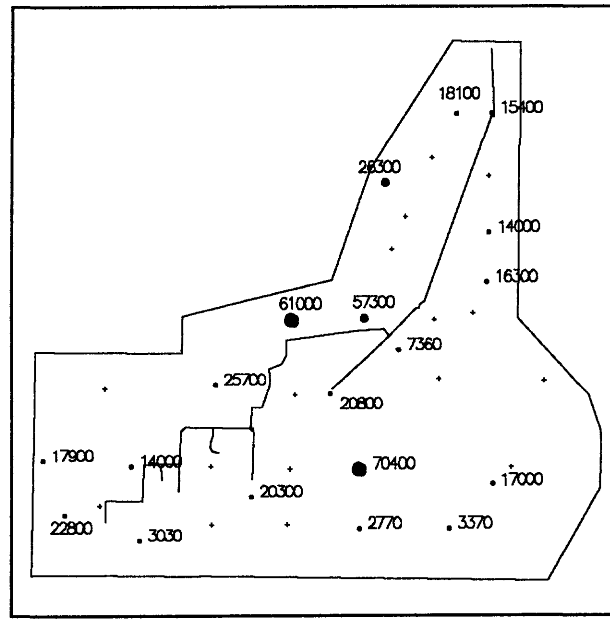



**Figure A113**.--Strontium (ppb) in groundwater. Plus, 0-50th percentile. Small dot, 50-90th. Intermediate dot, 90-95th. Large dot, 95-100th.

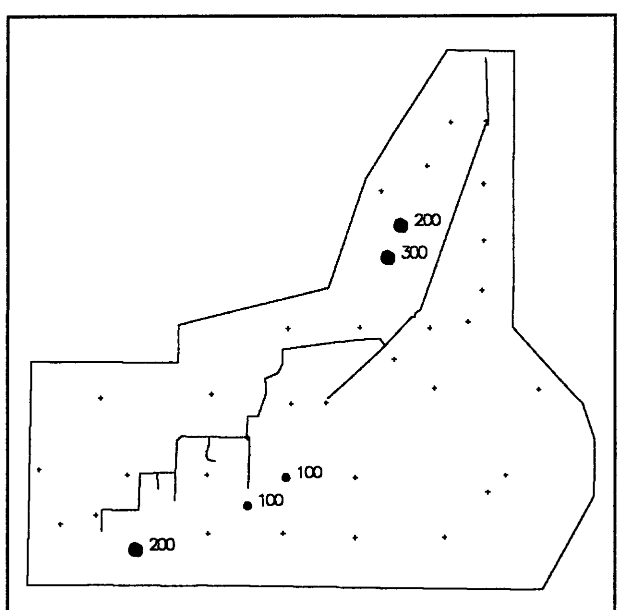



**Figure A114**.--Vanadium (ppb) in groundwater. Plus, less than 100 ppb-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

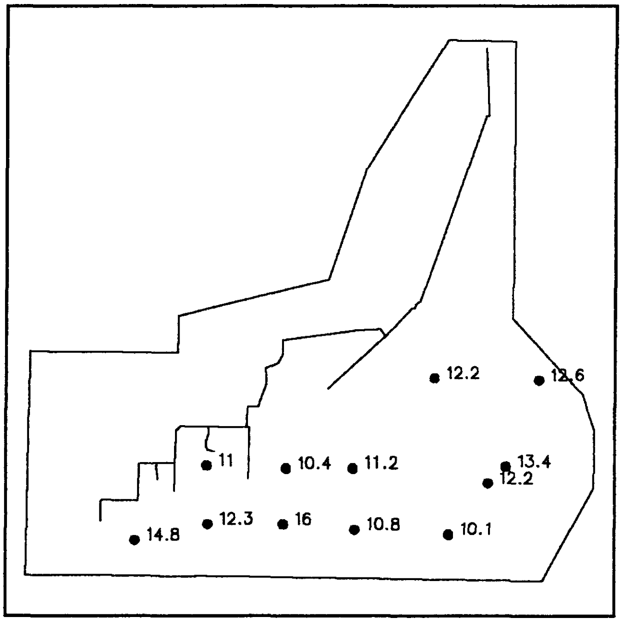



**Figure A115.**--Alfalfa ash, percent.

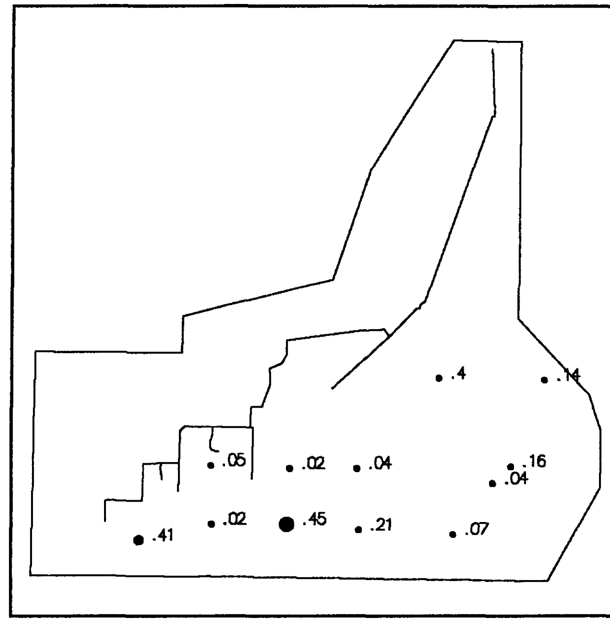



**Figure A116.**--Aluminum (percent) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile, intermediate dot, 90-95th percentile, large dot, 95-100th percentile.

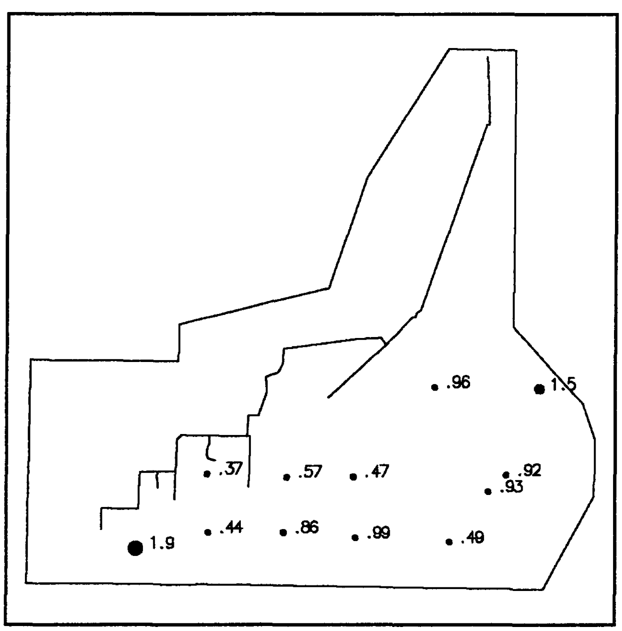



**Figure A117.**--Arsenic (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile, intermediate dot, 90-95th percentile, large dot, 95-100th percentile.

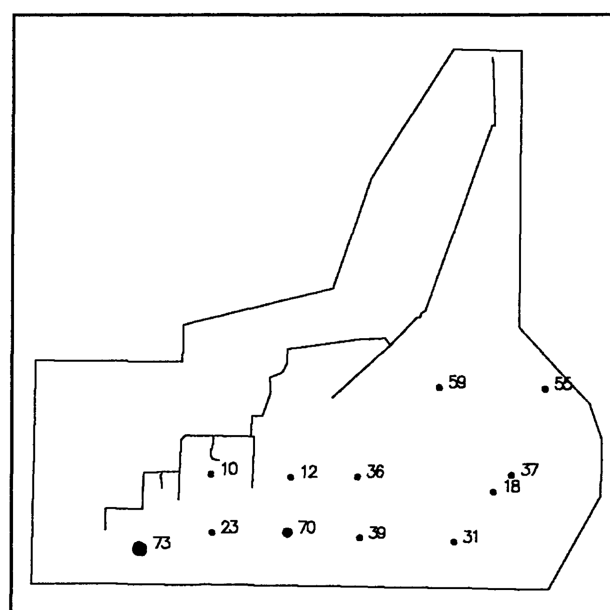



**Figure A118.**--Barium (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile, intermediate dot, 90-95th percentile, large dot, 95-100th percentile.

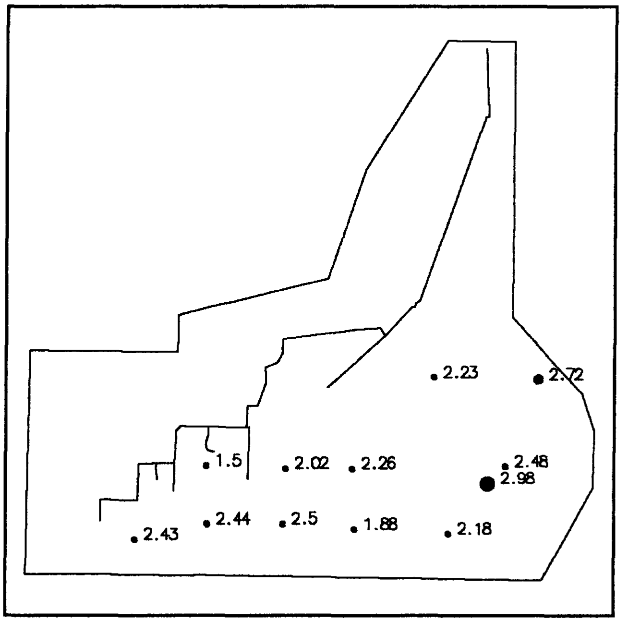



**Figure A119**.--Calcium (percent) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile, intermediate dot, 90-95th percentile, large dot, 95-100th percentile.

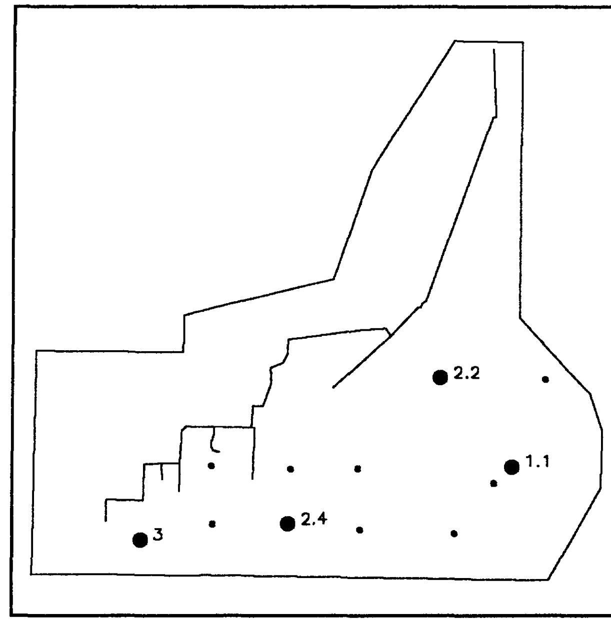



**Figure A120**.--Cerium (ppm) in alfalfa, values on plant dry-weight basis. Small dot, below limit of detection (1.08ppm), not posted. Large dot, censoring point-100th percentile.

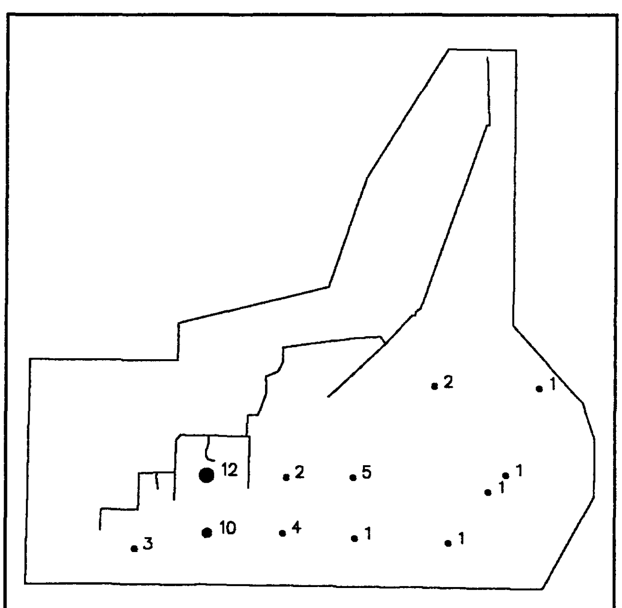



**Figure A121**.--Chromium (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

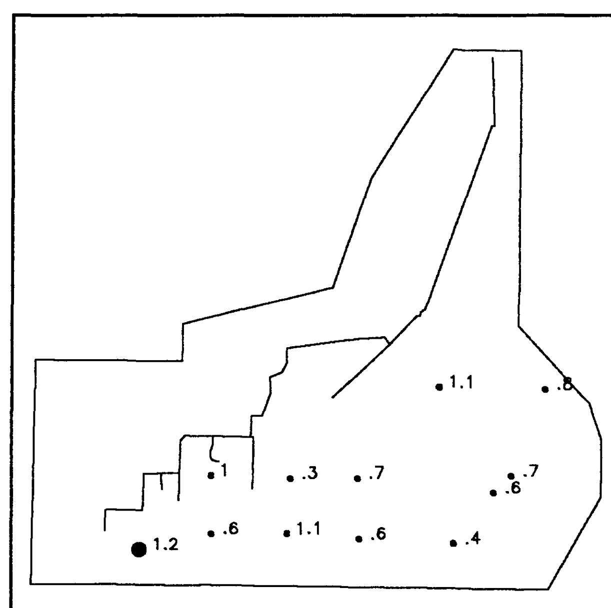



**Figure A122**.--Cobalt (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

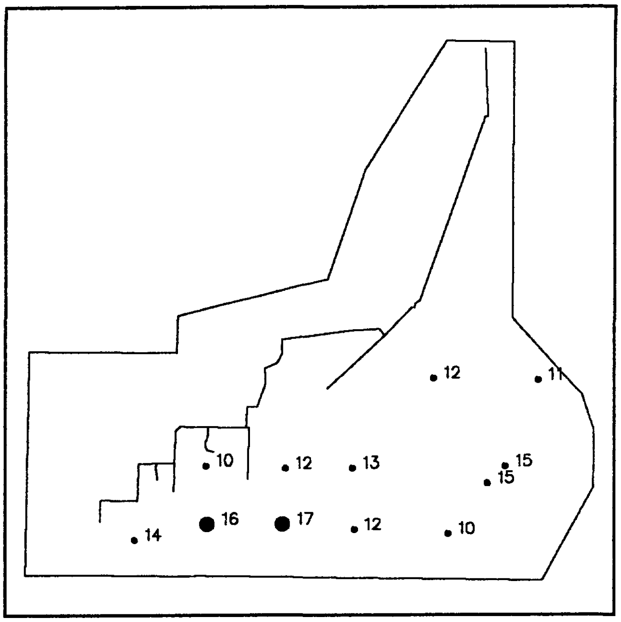



**Figure A123**.--Copper (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

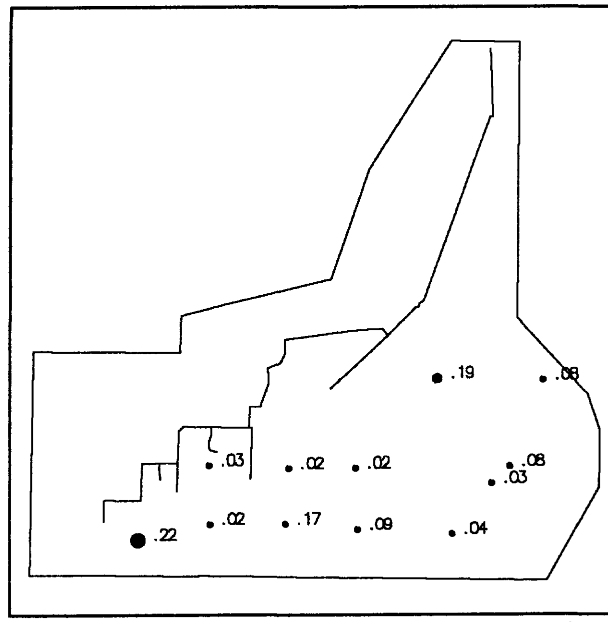



**Figure A124**.--Iron (percent) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

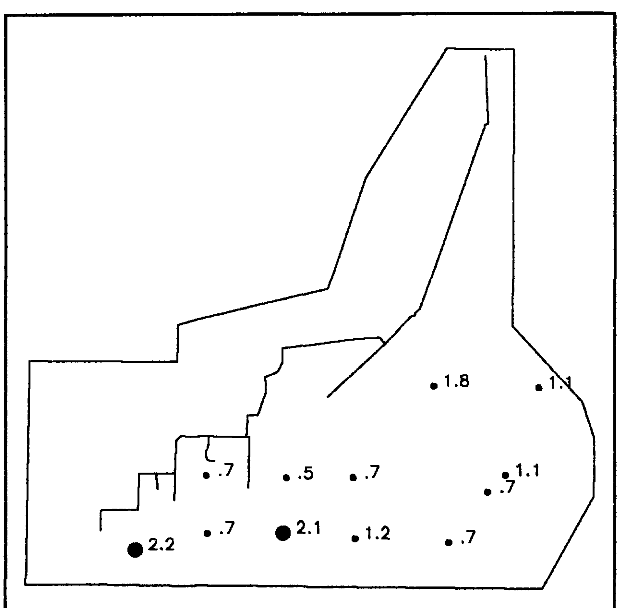



**Figure A125**.--Lanthanum (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Large dot, 90-100th percentile.

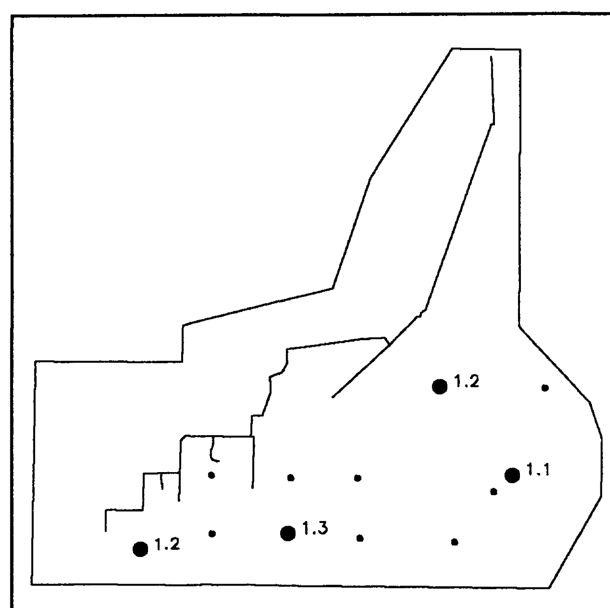



**Figure A126**.--Lead (ppm) in alfalfa, values on plant dry-weight basis. Censored data not posted. Posted above censoring point: large dot, censoring point-100th percentile.

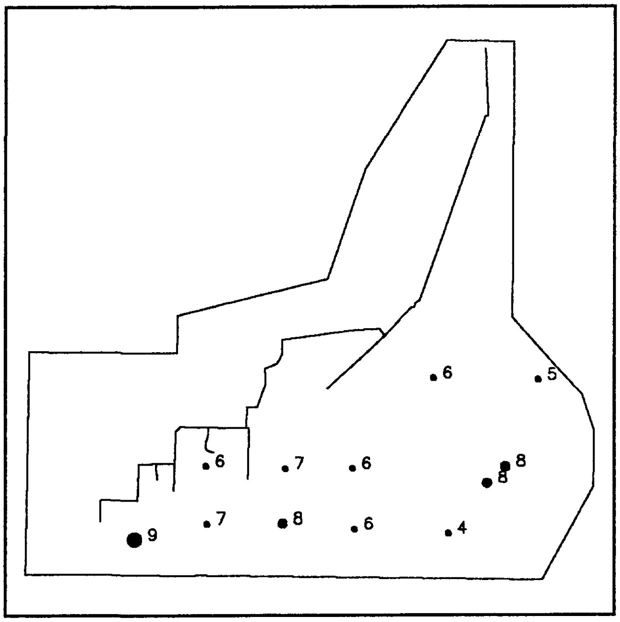



**Figure A127.**--Lithium (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

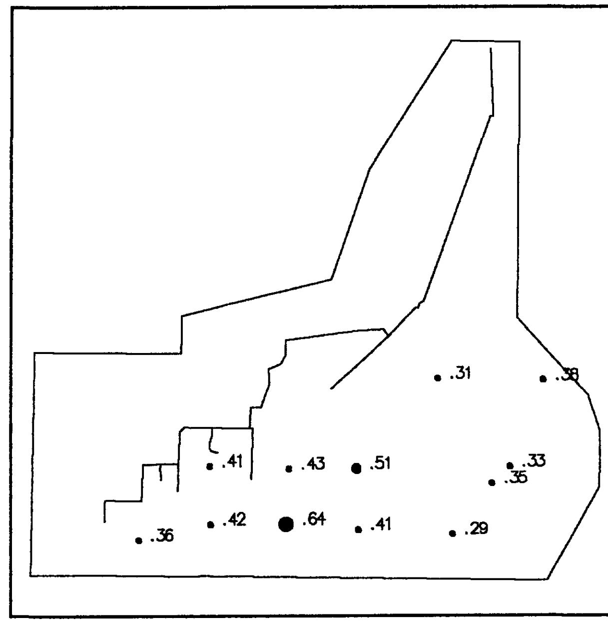



**Figure A128.**--Magnesium (percent) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

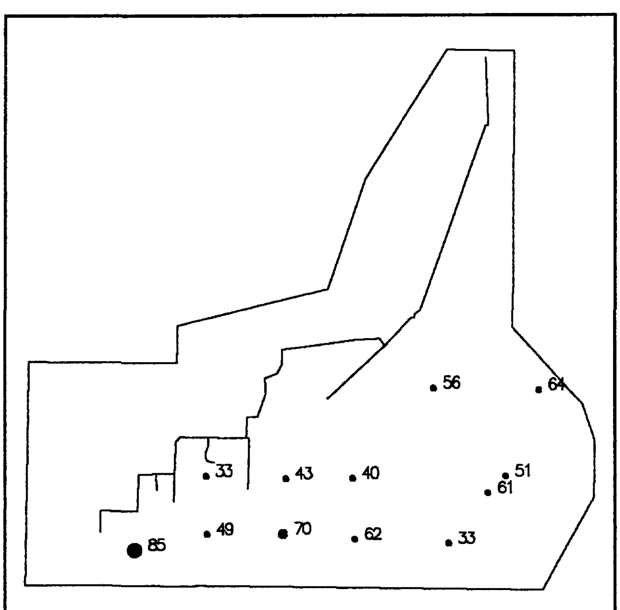



**Figure A129.**--Manganese (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

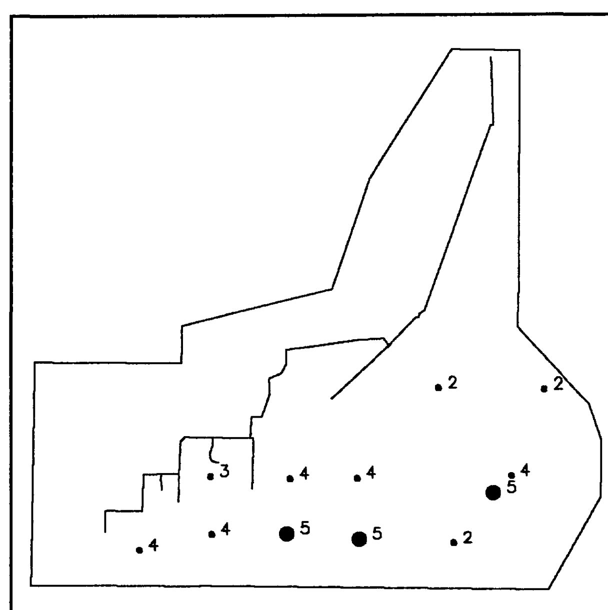



**Figure A130.**--Molybdenum (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.


**Figure A131**.--Neodymium (ppm) in alfalfa, values on plant dry-weight basis. Censored data not posted. Posted above censoring point: small dot, censoring point-90th percentile; large dot, 90-100th percentile.

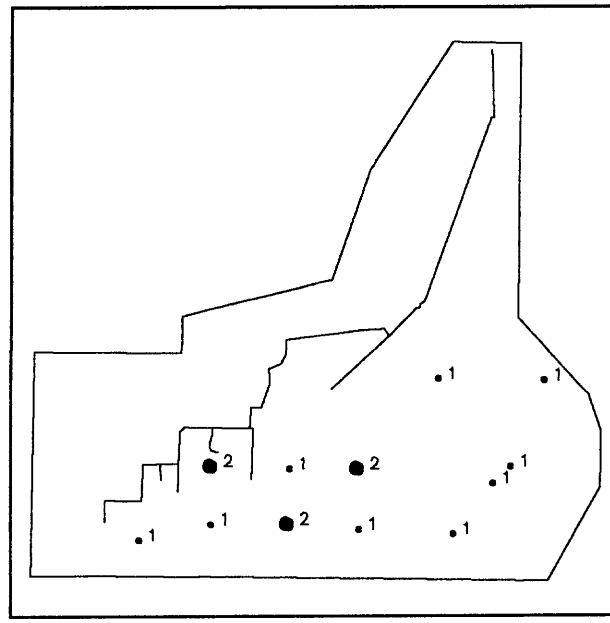



**Figure A132**.--Nickel (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

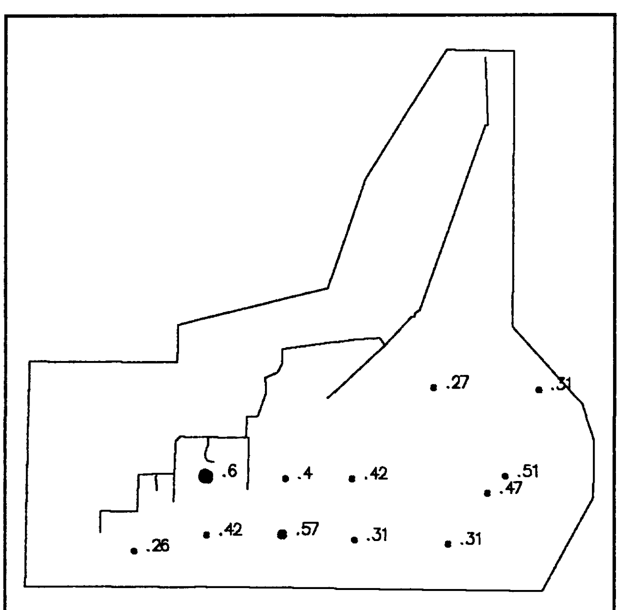



**Figure A133**.--Phosphorus (percent) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

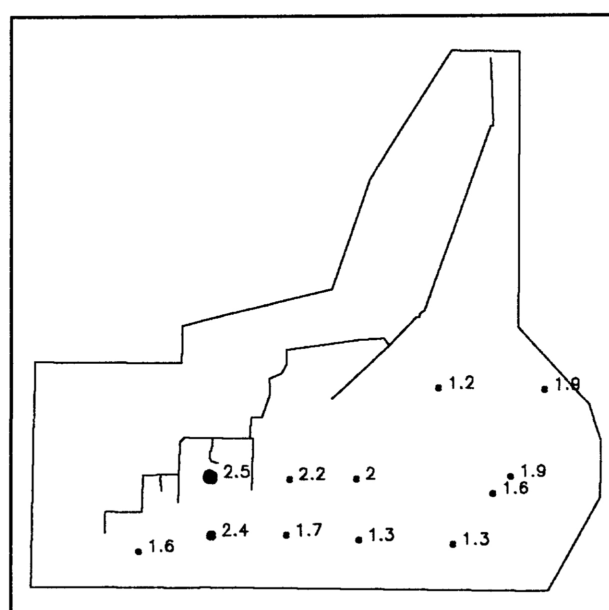



**Figure A134**.--Potassium (percent) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

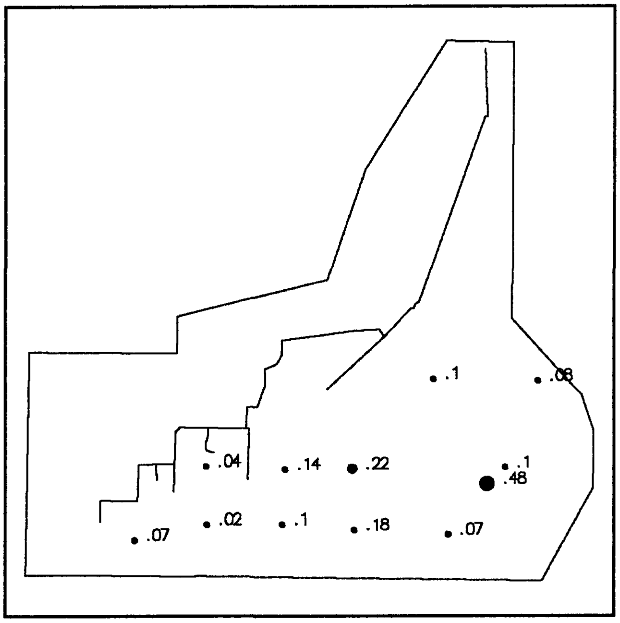



**Figure A135**.--Selenium (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile, intermediate dot, 90-95th percentile, large dot, 95-100th percentile.

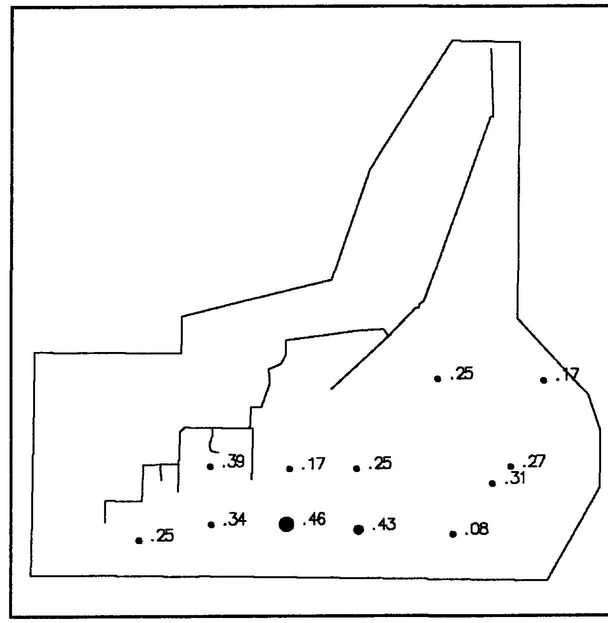



**Figure A136**.--Sodium (percent) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

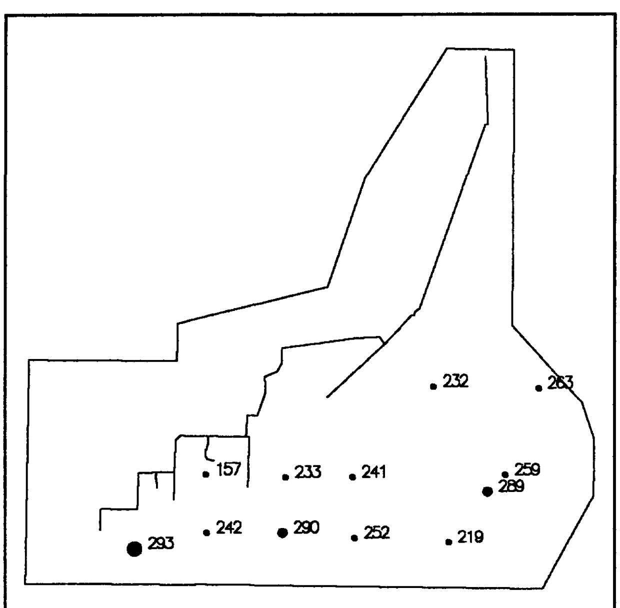



**Figure A137**.--Strontium (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

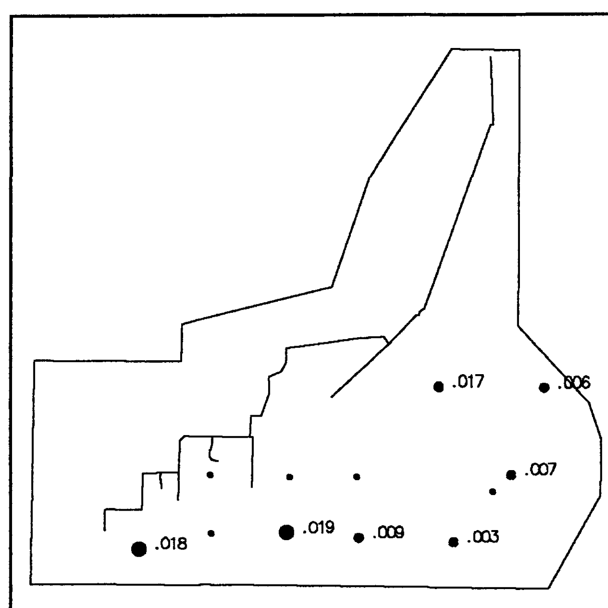



**Figure A138**.--Titanium (percent) in alfalfa, values on plant dry-weight basis. Censored data not posted. Posted above censoring point: small dot, censoring point-90th percentile; large dot, 90-100th percentile.

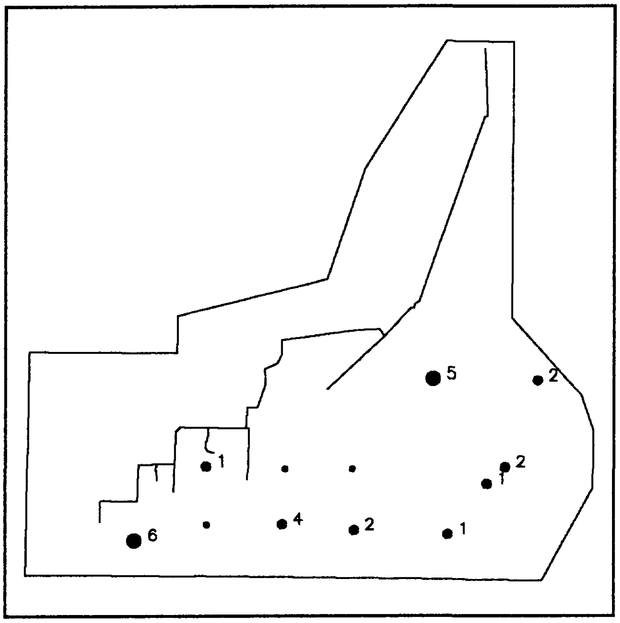



Figure A139.--Vanadium (ppm) in alfalfa, values on plant dry-weight basis. Censored data not posted. Posted above censoring point: intermediate dot, censoring point-90th percentile, large dot, 90-100th percentile.

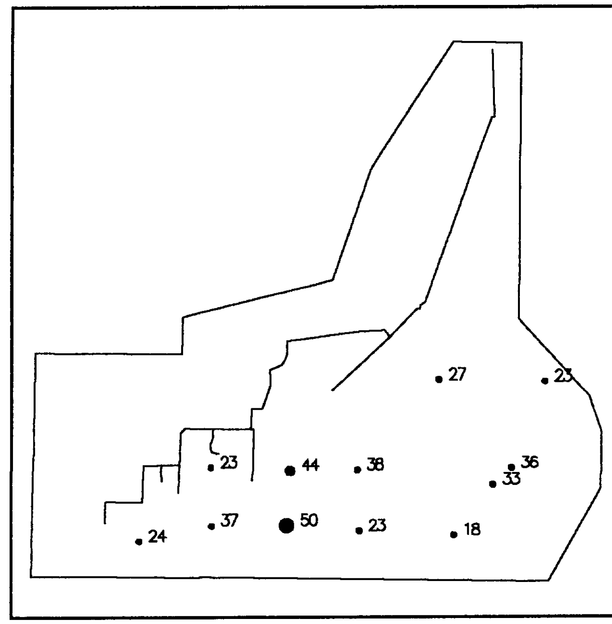



Figure A140.--Zinc (ppm) in alfalfa, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th percentile. Large dot, 95-100th percentile.

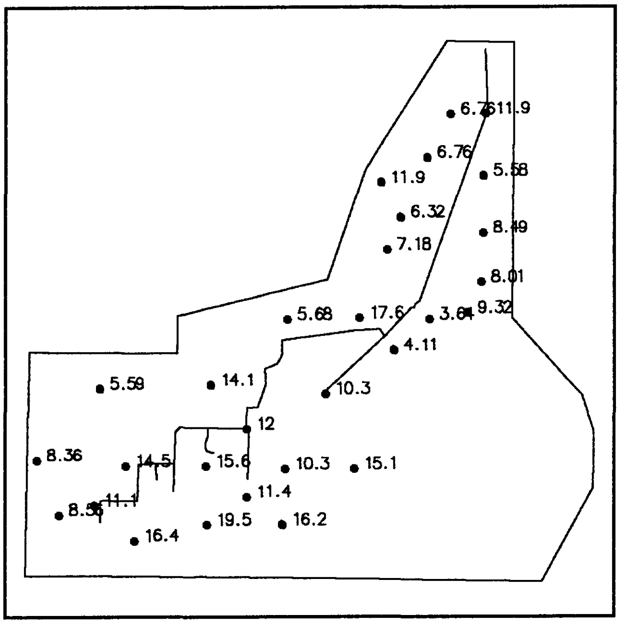



**Figure A141.**--Big Greasewood ash, percent.

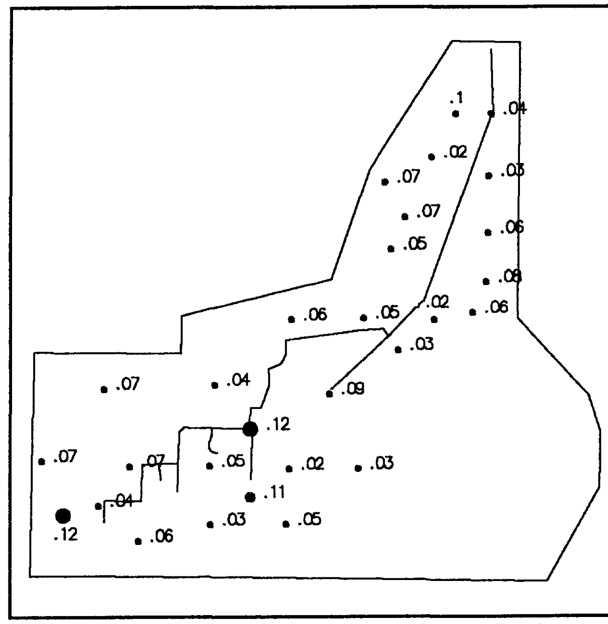



**Figure A142.**--Aluminum (percent) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

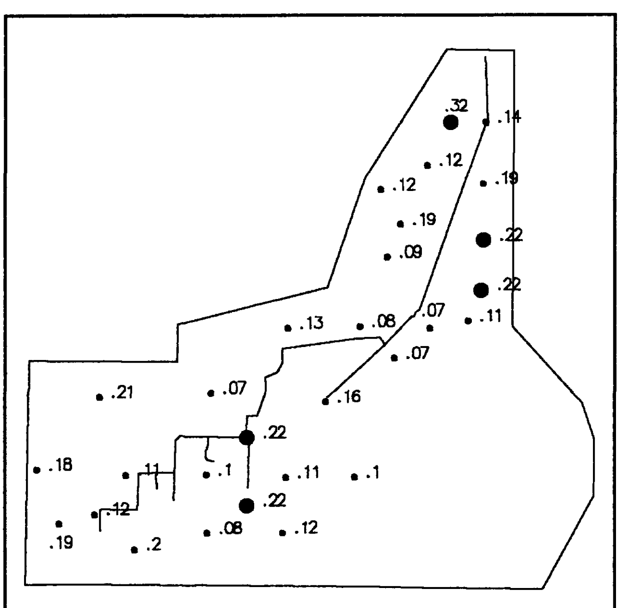



**Figure A143.**--Arsenic (ppm) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Large dot, 90-100th.

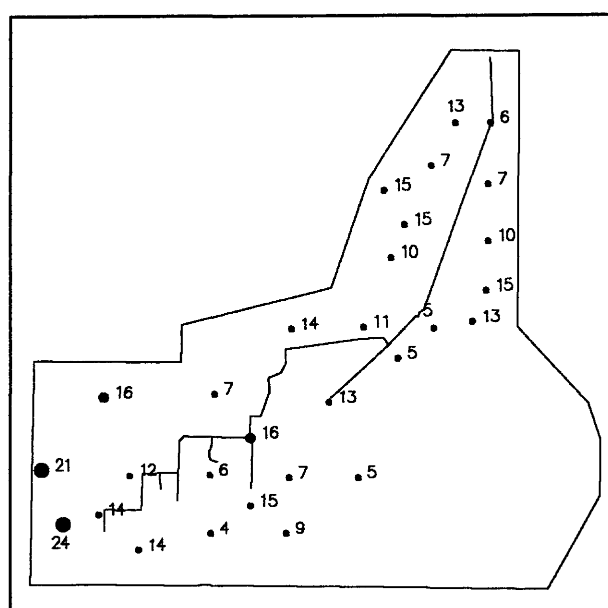



**Figure A144.**--Barium (ppm) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

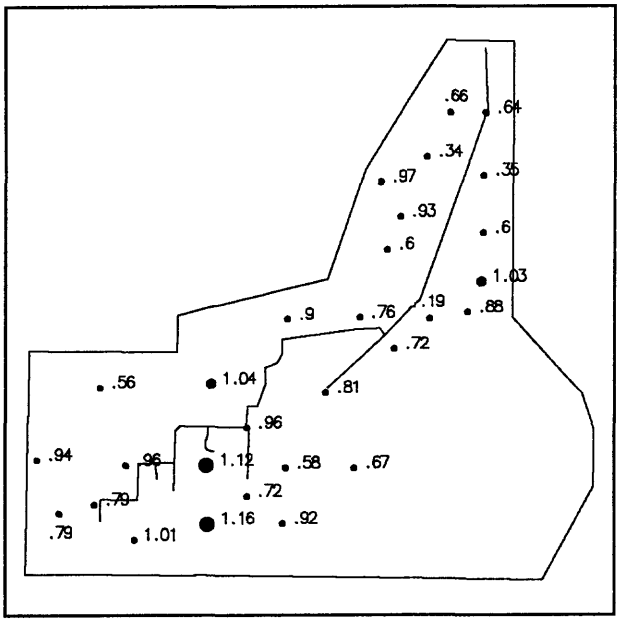


**Figure A145**.--Calcium (percent) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

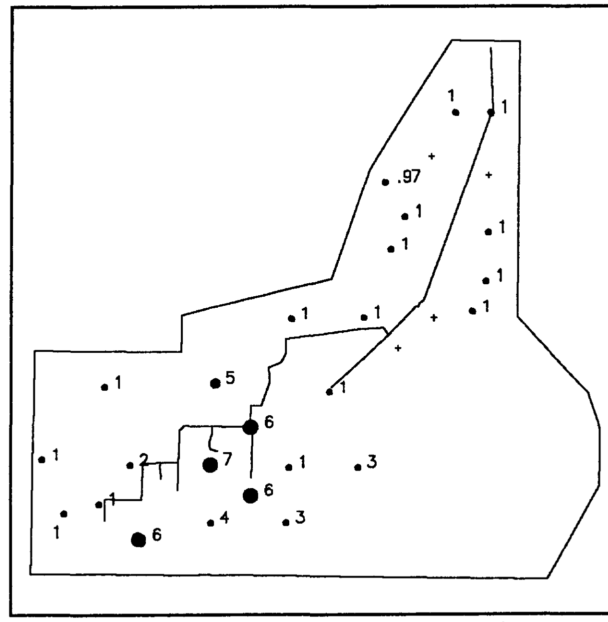


**Figure A146**.--Chromium (ppm) in big greasewood, values on plant dry-weight basis. Plus, below 1 ppm. Small dot, up to 90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

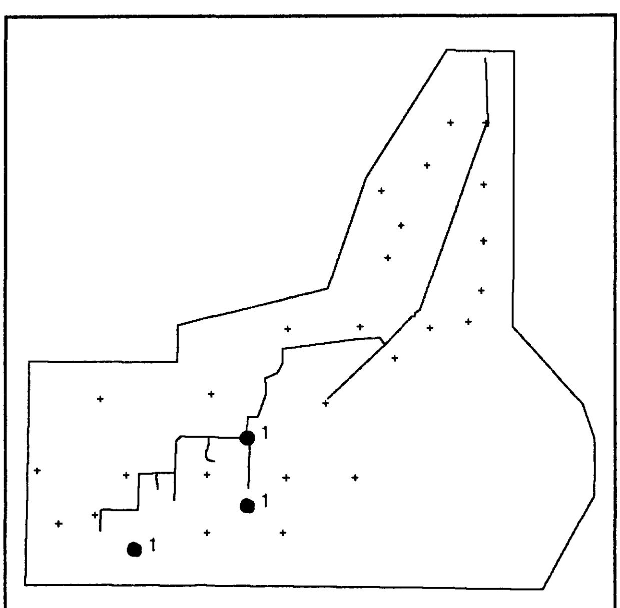


**Figure A147**.--Cobalt (ppm) in big greasewood, values on plant dry-weight basis. Plus, below limit of detection (0.11ppm). Small dot, up to 90th percentile. Intermediate dot, up to 90th. Large dot, 95-100th.

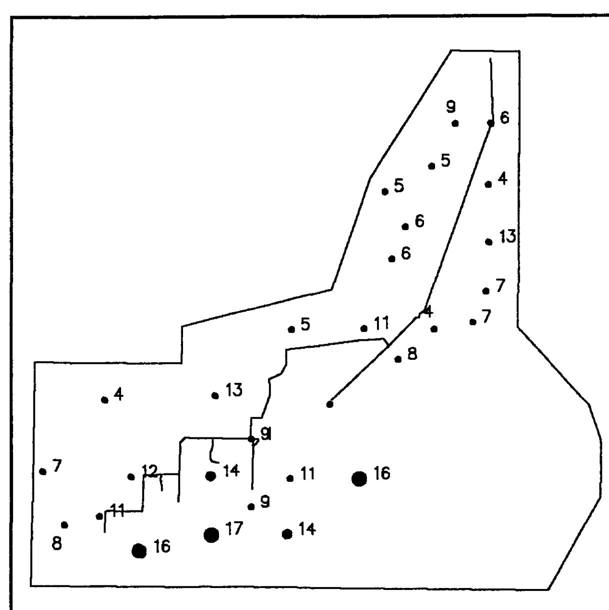


**Figure A148**.--Copper (ppm) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

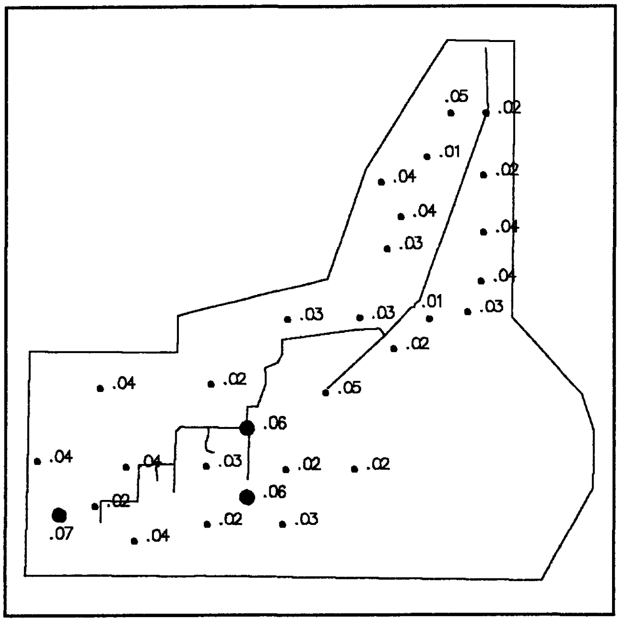



**Figure A149.**--Iron (percent) in big greasewood, values on plant dry-weight basis. Small dot, 0-95th percentile. Large dot, 95-100th.

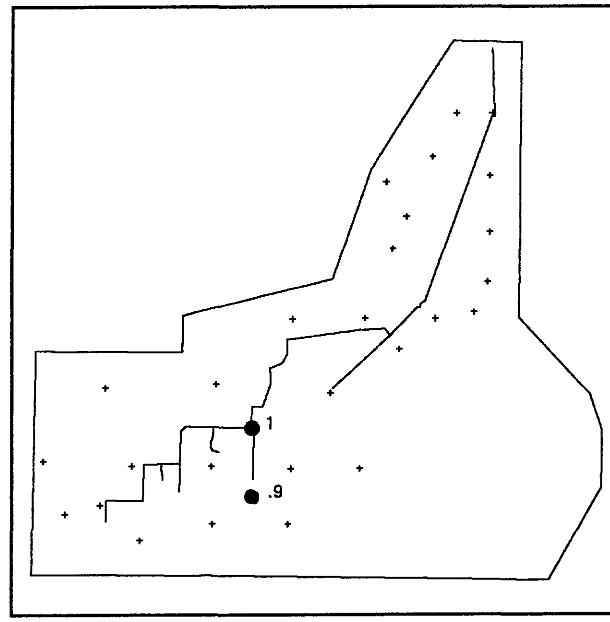



**Figure A150.**--Lanthanum (ppm) in big greasewood, values on plant dry-weight basis. Plus, below limit of detection (0.78 ppm). Large dot, above limit of detection.

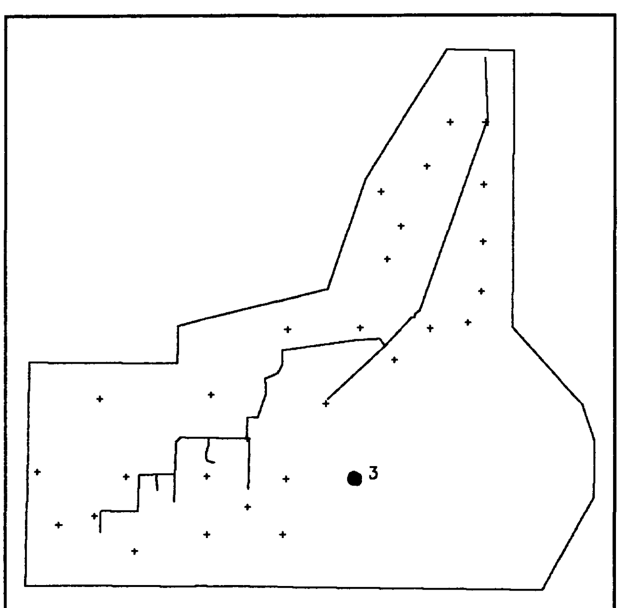



**Figure A151.**--Lead (ppm) in big greasewood, values on plant dry-weight basis. Plus, 0-95th percentile. Large dot, 95-100th.

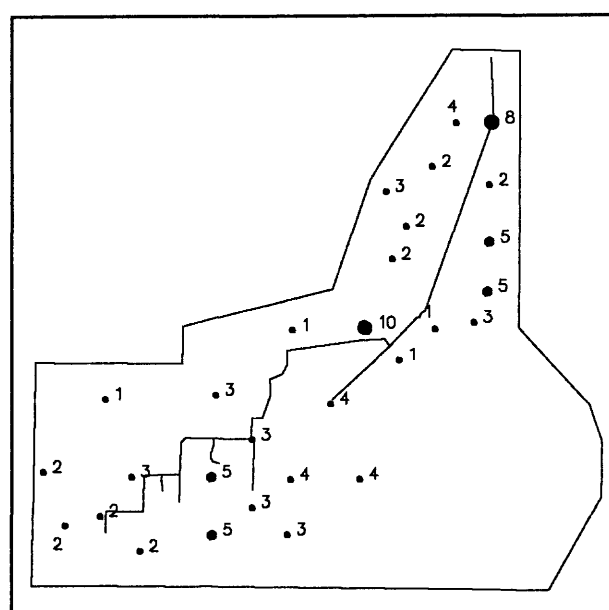



**Figure A152.**--Lithium (ppm) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

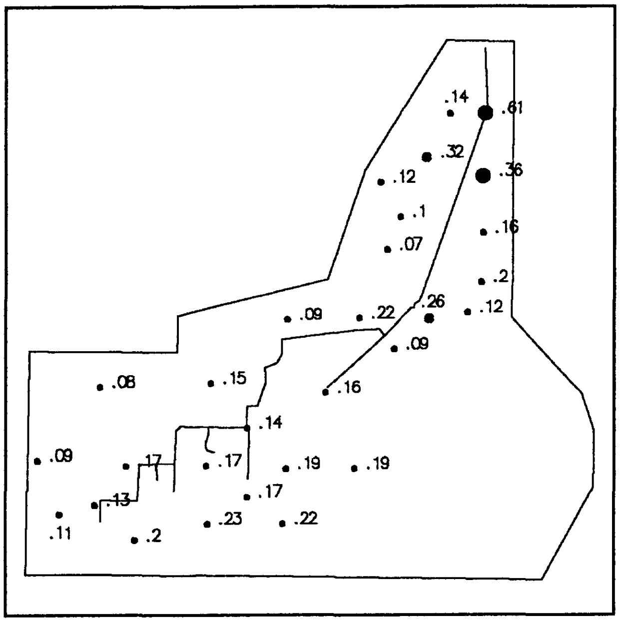



**Figure A153.**--Magnesium (percent) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

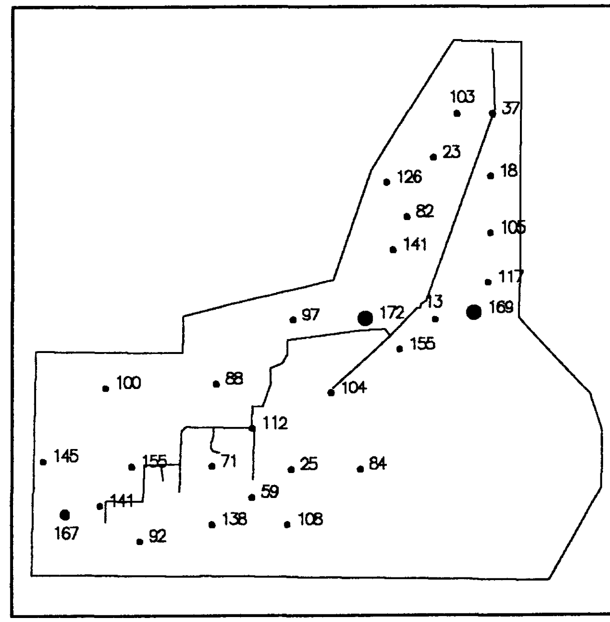



**Figure A154.**--Manganese (ppm) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

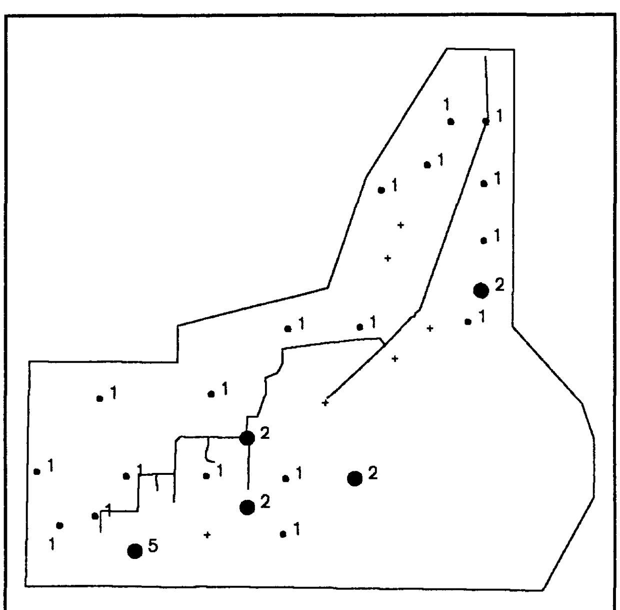


**Figure A155.**--Molybdenum (ppm) in big greasewood, values on plant dry-weight basis. Plus, below limit of detection (0.41ppm). Small dot, up to 90th percentile. Large dot, 90-100th.

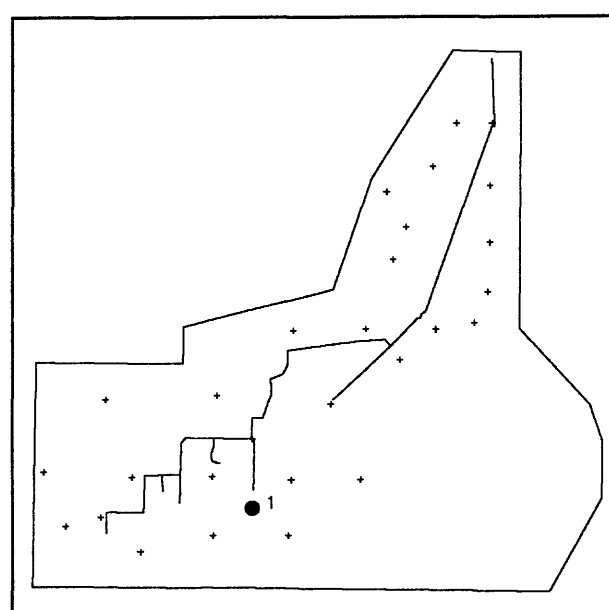


**Figure A156.**--Nickel (ppm) in big greasewood, values on plant dry-weight basis. Plus, below limit of detection (0.66ppm). Large dot, above limit of detection.

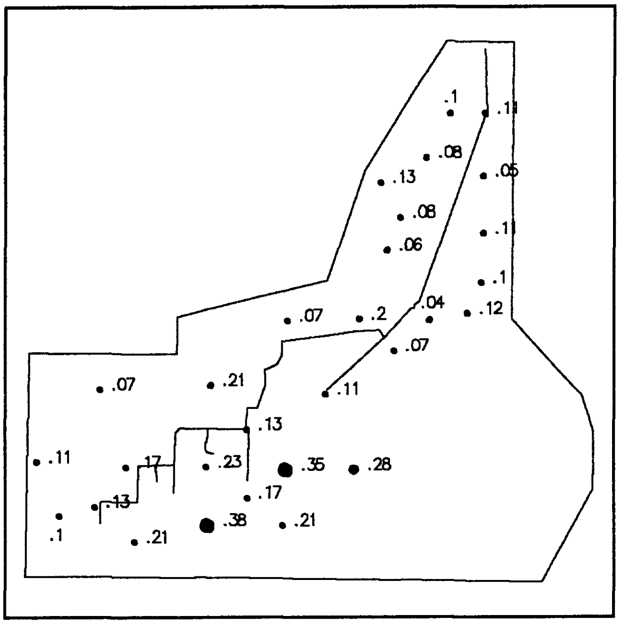



**Figure A157.**--Phosphorus (percent) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

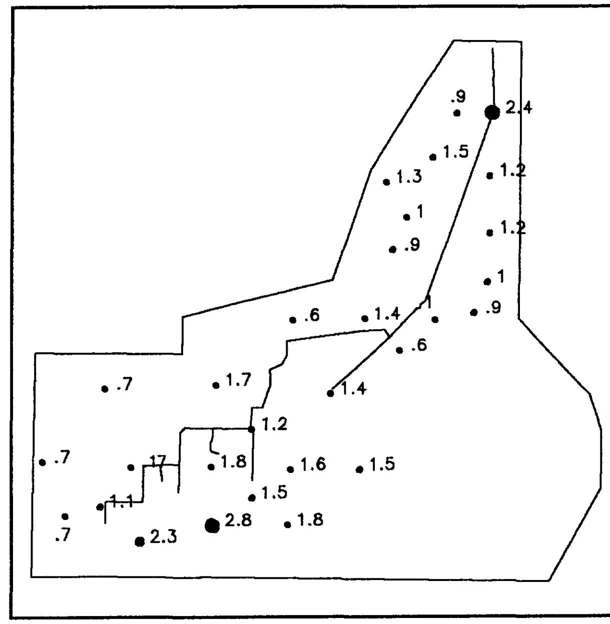



**Figure A158.**--Potassium (percent) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

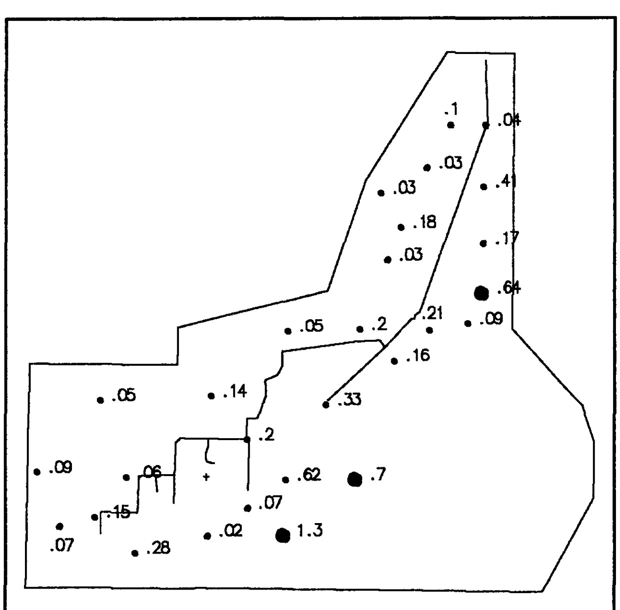



**Figure A159.**--Selenium (ppm) in big greasewood, values on plant dry-weight basis. Plus, below limit of detection (0.01ppm). Small dot, up to 90th percentile. Large dot, 90-100th.

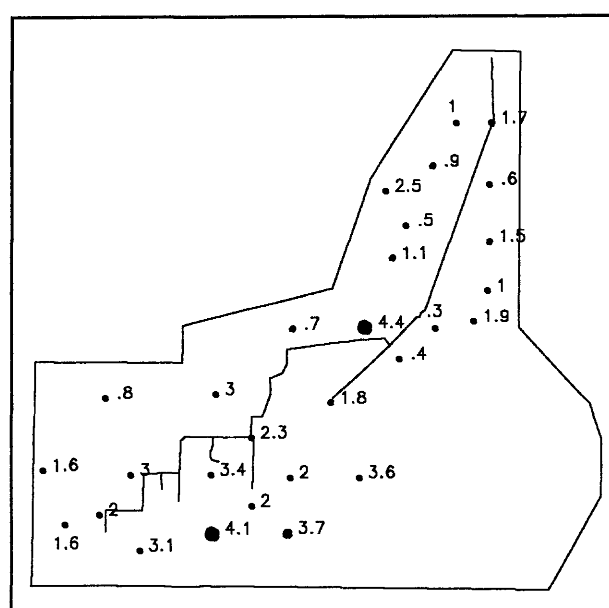



**Figure A160.**--Sodium (percent) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

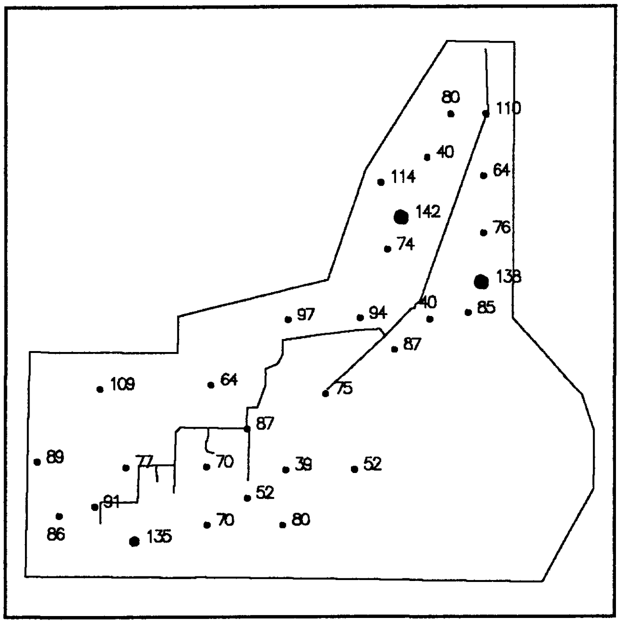



**Figure A161.**--Strontium (ppm) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.

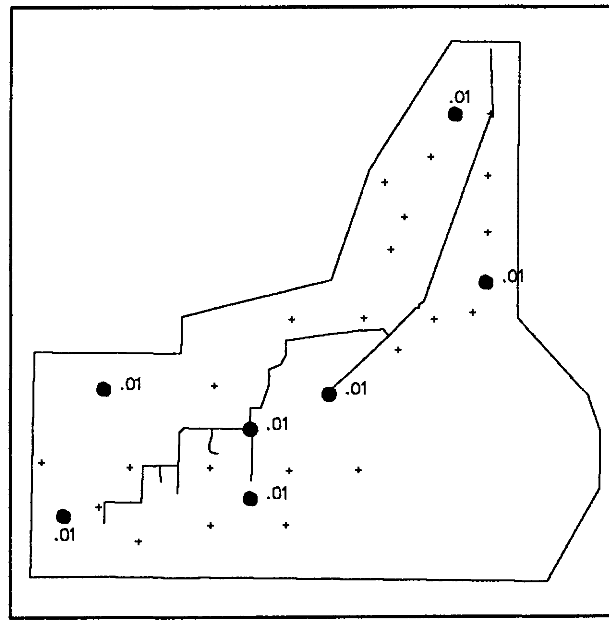



**Figure A162.**--Titanium (percent) in big greasewood, values on plant dry-weight basis. Plus, below limit of detection (0.001). Large dot, above limit of detection.

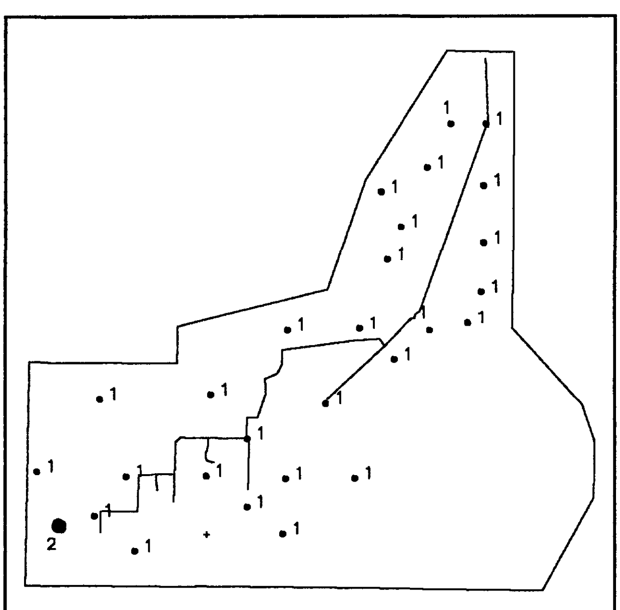



**Figure A163.**--Vanadium (ppm) in big greasewood, values on plant dry-weight basis. Plus, below limit of detection (0.71 ppm). Small dot, up to 90th percentile. Large dot, 90-100th.

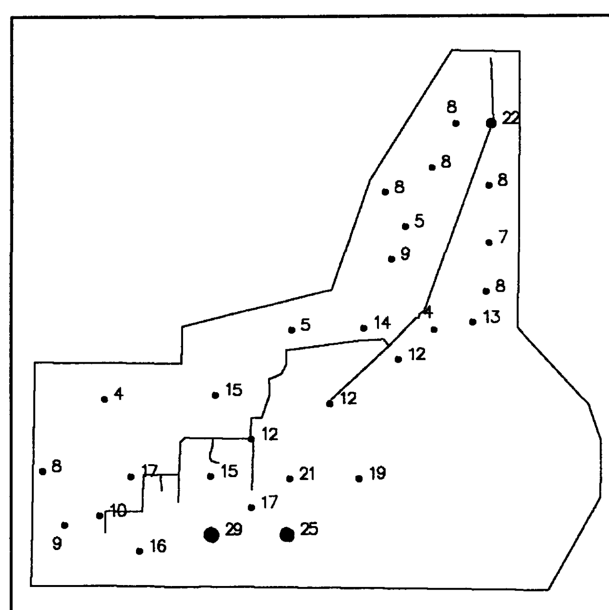



**Figure A164.**--Zinc (ppm) in big greasewood, values on plant dry-weight basis. Small dot, 0-90th percentile. Intermediate dot, 90-95th. Large dot, 95-100th.