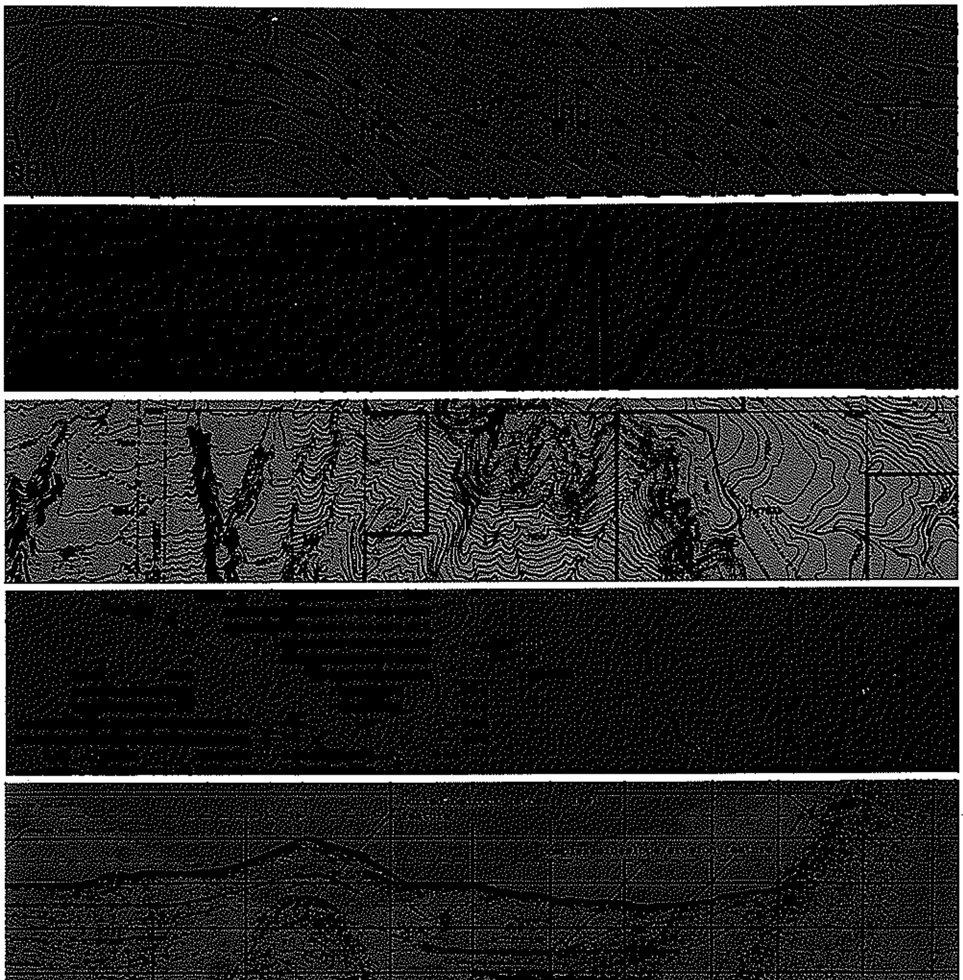

Technical Memorandum
Hydrologic and Soils Investigations
Chico Urban Area
for
County of Butte

DAMES & MOORE

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Technical Memorandum
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1.0 INTRODUCTION

This Technical Memorandum presents the results of current Hydrologic and Soils Investigations, and summarizes previous soil and groundwater studies conducted in the Chico Urban Area (CUA). This work was completed for the County of Butte, as part of CSA 114 which has funded previous investigations of groundwater in the CUA (Figure 1), in response to California Regional Water Quality Board (RWQCB) Order No. 90-126 (the Order). The Order was issued because previous studies of groundwater in the CUA indicated that individual septic waste systems were the primary contributor to nitrate impacts in groundwater in the CUA. The scope of the current work was developed by the Nitrate Study Team, including representatives from Butte County, citizens of Chico, the RWQCB, consultants, and other technical experts, in March 1995.

1.1 Goals and Objectives

The goal of this Technical Memorandum is to present an evaluation of current and historic sources of nitrate which may impact groundwater in the CUA. Specific objectives of this Technical Memorandum are to present current results of hydrologic and soils investigation supplemented by previous work. The evaluation of historic sources of nitrate will rely more heavily on modeling and results of previous investigations than on results from the recent work.

1.2 Previous Studies

As noted above, this Technical Memorandum will draw upon the results from previous investigations and studies. The results of these studies are presented in the sources listed below:

- The Study of Nitrates in the Ground Water of the Chico Area, Butte County (DWR, 1984);
- Determination of Nitrate Sources in Ground Water with Stable Nitrogen Isotopes, Greater Chico Area, Butte County (ARI, 1985);

- Review Committee Report on Evaluation of Sources of Nitrate in Ground Water of the Chico Urban Area, Butte County (Rolston, et al., 1989);

- RWQCB Board Order No. 90-126 (RWQCB, 1990);

- Nitrate Characterization Summary Report (Metcalf & Eddy, Inc., 1992);

- Historical Land Use Map (Heritage Partners, 1993, unpublished);

- Groundwater Nitrate Study, Chico Urban Area, Final Report (Dames & Moore, 1994); and

- Identification and Evaluation of Methods for Determining Sources of Nitrate Contamination in Groundwater: Guidance Manual (Rolston, et al., 1994).

1.3 Scope of Current Hydrologic and Soils Investigation

The purpose of the recent hydrologic and soils investigation activities was to provide information relating to existing conditions for infiltration and denitrification within the CUA for use in refining the parameters in the Hantzsche/Finnemore equation cited in the Order, and revised in the Implementation Plan. The scope of this recent work is presented below.

- Nitrate Source Evaluation which included:
  - Current and historic research on potential sources of nitrogen;
  - Collection and analysis of surface water, groundwater, animal waste, septic waste, inorganic fertilizers, for nitrate and delta-15 nitrogen isotope ($\delta^{15}N$) analysis; and
  - Geochemical modeling of nitrogen.

- Shallow Aquifer Characterization, which included:
  - Two rounds of all shallow aquifer monitoring wells;
  - Analysis of all samples for field parameters (temperature, conductivity, and pH), nitrate, and $\delta^{15}N$; and
  - Measurement of all wells for water levels.

- Vadose Zone Characterization, which included:
  - Modeling rainwater recharge in the CUA;
  - Collection and analysis of soil pore liquid samples from lysimeters for nitrate, ammonium and $\delta^{15}N$;
  - Five soil borings to groundwater adjacent to low-density septic systems, high-density septic systems, and an active almond orchard (see Figure 2B); and
  - Collection and analysis of soil samples for general chemical parameters, nitrate, ammonium, and total nitrogen.

The scope of work cited above was developed based on discussions with the County of Butte, The California Regional Water Quality Control Board (RWQCB), citizens of Chico and other members of the Nitrate Study Team.

1.4 Document Organization

This memorandum is organized in four sections following this introduction. Section 2.0 presents a discussion concerning the potential sources of nitrogen in the CUA. A discussion of the shallow aquifer characteristics is presented in Section 3.0, and soils and vadose zone conditions are described in Section 4.0. Section 5.0 presents a summary and the conclusions of this Technical Memorandum.

2.0 NITRATE SOURCE EVALUATION

This section presents the results of the nitrate source evaluation within the CUA. This evaluation includes the results of historical and current investigations. The potential sources of nitrate in the CUA include background soils, surface water, and groundwater, agricultural (animal wastes and fertilization), industrial (chemical manufacturing) sources, and domestic septic systems (single- and multiple-family dwellings). Nitrate migrating from these potential sources moves to groundwater in the shallow aquifer, or is denitrified to the atmosphere.

Section 2.1 presents a brief discussion of nitrogen geochemistry which is included to support later discussion of nitrogen occurrence in soils and groundwater. Section 2.2 present an evaluation of background soils, surface water and groundwater as possible sources of nitrate which may contribute to the observed occurrence of nitrate in groundwater. Section 2.3 discusses agricultural nitrogen sources derived from animal wastes, and from orchard fertilization. Section 2.4 presents the results of investigations of industrial sources of nitrogen. Section 2.5 presents an evaluation of domestic septic systems as a source of nitrogen.

2.1 Chemical Forms and Transformations of Nitrogen

This discussion will focus on the forms and movement of nitrogen in soils and in groundwater. Nitrogen is distributed throughout the shallow surface soils (0 to 5 feet below ground surface, bgs) adsorbed to solids, dissolved in pore liquids, and in gaseous form in voids throughout the vadose zone. Soil microbiological activity near the surface determines the chemical form and the mobility of nitrogen. However, when nitrogen reaches subsoils and the saturated aquifer materials (approximately 20 to 40 feet below ground surface (bgs) in the CUA), the predominant form of nitrogen is nitrate. At these depths, the level of biologic activity is low and any nitrate present in subsoils or groundwater remains unaffected by further microbial transformations.

Nitrogen is also present throughout the earth's atmosphere, which is composed of approximately 70% N_2, the most abundant form of nitrogen. Specialized soil microorganisms are capable of chemically reducing N_2 to form amino acids and protein. This process, nitrogen fixation, is the ultimate source of nitrogen in the earth's crust since few minerals contain nitrogen in any form.

Plants and animals require large quantities of nitrogen to produce amino acids and proteins. Nitrogen in the form of proteins and amino acids can be referred to as organic nitrogen, which is relatively immobile in soils because organic nitrogen compounds adsorb to soil surfaces. Once organic nitrogen enters soils or surface waters, a variety of microorganisms convert organic nitrogen to inorganic nitrogen in the form of ammonia (NH_3). Ammonia may be lost to the atmosphere or become dissolved in water forming ammonium (NH_4^+). Ammonium is strongly adsorbed to soils and is rarely detected below a depth of five feet bgs.

Ammonium is oxidized and converted into nitrate (NO_3^-) by a two-step process termed nitrification by a group of microorganisms occurring primarily in aerobic surface soils. Nitrate moves rapidly through soils and is accumulated by plant roots, which reduce nitrate into amino acid and proteins.

An additional microbial reaction in surface soils may convert nitrate into nitrogen gas (N_2) or nitrous oxide gases (NO, N_2O). This process, termed `denitrification,' is important from an environmental perspective since it may protect groundwater especially in soils where excess nitrate is present.

In summary, nitrogen exists in a variety of chemical forms (nitrate, ammonia, ammonium, and organic nitrogen) in solids, liquid, and gaseous forms. To account for these different nitrogen species with comparable chemical units, all total nitrogen, organic nitrogen, nitrate nitrogen, and ammonium nitrogen will be expressed as mgN/L (for water samples) or mgN/kg (for solid samples).

2.2 Background

The purpose of evaluating background sources of nitrogen (soil, surface water, groundwater) is to assess the contribution of nitrate from natural sources. For the purposes of this Technical Memorandum, background sources of nitrogen in soils are defined as that soil nitrogen present prior to human activity in the CUA. Background sources of nitrogen in groundwater and surface water are dissolved nitrate or nitrogen which flows onto or under the CUA from upgradient sources.

2.2.1 Background Nitrogen Contribution From Soils

The contribution of nitrate to groundwater from soils within the CUA was evaluated by the Technical Review Committee (Rolston, et al., 1989), which concluded that the contribution of soil nitrogen to groundwater is small, compared to other sources. The Technical Review Committee (Rolston, et al., 1989) conclusions are supported by several factors discussed previously in Section 2.1. Nitrogen is derived from surface biological activity, not from weathering of soil minerals; therefore, nitrate is likely to be present in surface soils, rather than in groundwater. Organic nitrogen produced by plants and animals is relatively immobile, and retained near the soil surface. In natural ecosystems, nitrogen is cycled between the atmosphere and soils, and little is lost below the root zone of plants and trees to groundwater.

2.2.2 Background Nitrogen Contribution From Surface Water and Groundwater

This section provides a brief summary of the shallow aquifer conditions within the CUA along with the estimated background contribution of nitrogen to the shallow zone aquifer.

Hydrogeologic Conditions in the CUA

The hydrogeology of the study area has been summarized in previous reports (Dames & Moore 1994). Figure 3 presents a schematic cross-section of the CUA. This cross-section provides some key points regarding surface water and groundwater flow. These points include:

- The surface topography slopes from the Sierra-Nevada mountains to the east of the CUA to the Sacramento River to west of the CUA.

- Several surface water bodes flow through the CUA from the mountains in the east to the Sacramento River west of the CUA.

- The shallow aquifer underlies approximately three-fourths of the CUA, but is not present in the northeastern CUA east of DMW-4.

Because the shallow aquifer is not present upgradient of the CUA, discussion of background water quality in the shallow aquifer is complicated. Surface water recharges both the shallow and intermediate aquifers in the eastern (upgradient) portion of the CUA. Therefore, surface water was sampled to evaluate the quality of the water recharging these aquifers.

In addition to surface water and groundwater and groundwater conditions within the CUA, the vadose zone soils in the CUA are sandy loam soils with rapid infiltration rates. Using the method cited in Rolston, et al. (1994), recharge of rainfall percolates into the shallow aquifer in 3 to 6 years.

Background Nitrogen Contributions from Surface Water

Surface water was sampled at nine separate locations as shown on Figure 2B. The data presented in Table 1 suggests that nitrate was not detected in three of four upstream surface samples (SW-1 to SW-4) collected from Big Chico Creek, Little Chico Creek and Butte Creek (Table 1). The one reported detection in surface water was 0.5 mgN/L.

Five additional surface water samples were collected from downstream locations in the CUA (SW-5 to SW-9), and results are presented in Table 1. The nitrate concentration reported in the sample from Lindo Channel was elevated compared to other samples, 10.8 mgN/L, whereas all other samples were below 1.5 mgN/L. No streamflow rates were measured during the time of sampling; therefore, it is difficult to interpret whether high nitrate concentration observed in Lindo Channel was due to algae growth resulting from low flow conditions, or because of urban runoff. The results of five of six downstream surface water samples suggest that urban runoff to surface water is not a source of nitrogen in the CUA.

Background Nitrogen Contributions from Groundwater

Evaluation of upgradient conditions for the shallow aquifer is not possible because the shallow aquifer begins in the CUA. The results for intermediate aquifer samples from DMW-4, EW-3, and EW-5, located upgradient of the CUA, are variable. Of these wells, only DMW-4 was constructed as a monitoring well. The remaining wells are supply wells, and the well construction details are not known. All three wells are in the upgradient portion of the CUA, but are not truly located outside of the CUA, and their locations may be impacted by golf-course and park fertilization (EW-3, EW-5), or by domestic septic systems (DMW-4). The installation of new monitoring wells upgradient of the CUA was not warranted because the well would need to be installed in the intermediate aquifer which is of less interest for the purposes of this study.

The results of the groundwater samples from upgradient intermediate aquifer wells (DMW-4, EW-3, and EW-5) in the northeastern CUA are inconsistent. Samples collected from DMW-4 and EW-03 on July 24, 1995 reported nitrate concentrations in excess of 10 mgN/L (19.9 and 17.1 mgN/L, respectively). Excluding these two samples, the remaining seven samples averaged 2.15 mgN/L, which is most likely indicative of background conditions in the intermediate aquifer. The $\delta^{15}N$ values were also inconsistent with values ranging from 2.27 to 12.27 within a average value of 7.3.

2.3 Agricultural Nitrogen Sources

This section is divided into two separate discussions of animal and inorganic fertilizers. Samples collected from the CUA were submitted for nitrate, total nitrogen, and $\delta^{15}N$ analysis.

2.3.1 Historic Animal Agricultural Operations

Animal agricultural operations in the Chico area from the early 1900s to the present, were the focus of a study which documents the size, location, type, and duration of animal agricultural operations throughout the Chico area (Heritage Partners, 1993, unpublished). Small-scale animal agriculture operations were commonplace in the 1940s until the 1960s. Prior to the urbanization of Chico, small farms (less than 20 acres) with dairy, poultry, hogs, and sheep were numerous, producing dairy products, meat, and eggs for local consumption with few large commercial operations. Today, the only ongoing animal agricultural operation is cattle and sheep grazing which occurs to the north and to the south of the CUA. Poultry operations in the CUA were numerous on family farms, and two or three turned into commercial-size ventures in the 1950s. These commercial poultry operations were located in the northwestern (downgradient) portion of the CUA. All but two of these businesses ceased operations by 1960, and these two operations closed in 1969 and 1974.

Animal operations in the CUA sold manure to crop and orchard farmers to enhance soil fertility and improve crop yields (Heritage Partners, 1993, unpublished). Most animal operations sold manure to crop and orchard farmers who applied manure to their land at agricultural rates, 100 to 300 pounds N/acre (Heritage Partners, 1993, unpublished).

Modeling of Nitrogen Transformations

To evaluate a worst-case scenario for nitrogen loading to soils from manure piles, several computer model simulations were performed in order to evaluate the nitrogen loading from the largest poultry, dairy, and cattle operations in the CUA (Heritage Partners, 1993, unpublished).

A model was developed from the Soil Science Society of America publication titled "Managing Nitrogen for Groundwater Quality and Farm Profitability" (Follett, et al., 1991) to predict the movement of nitrogen from various animal manures. The specific model parameters were developed by Eliot and Swanson, 1976; and Schepers and Mosier (Chapter 6 of Follett, et al., 1991). Table 2 presents a summary of model inputs used to estimate the effect of manure piles from the largest poultry, dairy and cattle operations documented in the CUA, which results in nitrate values that are likely on the high end of the possible range. The assumptions used for modeling were conservative to represent "worst-case" scenarios for each example model run.

The model output is provided in Tables 3a, 3b, 3c, and 3d. These simulations use estimated loading data from the CUA (Heritage Partners, 1993, unpublished) to evaluate residual nitrogen, 10 to 20 years following closure of these facilities. Tables 3a to 3d suggest the following:

- ❑ Despite initial high concentrations, the predicted residual nitrogen in soils from poultry manure pile simulations approaches background conditions after 10 years;
- ❑ Dairy operations in the CUA were so small that manure piles would probably not inhibit plant or crop growth, allowing these areas to recover to background levels in much less than 10 years; and
- ❑ Cattle grazing does not result in manure piles, and therefore, the residual nitrogen produced by cattle is not a source of nitrogen which could impact groundwater in the CUA.

Following conversion of organic nitrogen to nitrate, movement of nitrate from the surface to groundwater is rapid. Using a rough estimate of the percolation rate from the surface to groundwater based on recharge in the CUA (Rolston, et al., 1994), rainwater percolates into the shallow aquifer in 3 to 6 years. After nitrates reach the shallow aquifer, movement to the intermediate aquifer is also rapid. Pump test information obtained from the central CUA (URS, 1993) indicates that transport from the shallow to intermediate aquifers is rapid (less than one year), given the material types and downward vertical gradient.

Given the rapid nitrification (2 to 5 years), movement to shallow aquifer (3 to 6 years), and transport from shallow to intermediate aquifer, it is highly unlikely that past agricultural practices contribute significantly to the current shallow aquifer nitrate contamination.

2.3.2 Analysis of Animal Manure in the CUA

Manure samples from beef and dairy cattle, sheep, and swine from the CUA were obtained and analyzed for total Kjeldahl nitrogen (TKN) (total N), and the ^{15}N isotope ($\delta^{15}N$). The results of these analyses are presented in Table 1. Poultry manure was not sampled because no current poultry operations are present in or around the CUA.

The range of total nitrogen varied from 20 to 43 mg/kg. The $\delta^{15}N$ values varied from 3.82 to 7.71. As the manure degrades in soils, $\delta^{15}N$ values will continue to increase as volatilization and denitrification occur (Rolston, et al., 1994). Soil sample extracts from dairy manure impacted areas have $\delta^{15}N$ values ranging from 15 to 20 for $\delta^{15}N$.

2.3.3 Orchard and Crop Fertilization

Potential impacts on the shallow aquifer from fertilizers were evaluated by the Technical Review Committee (Rolston, et al., 1989). The conclusions reached by this study suggest that fertilizer from orchards surrounding the CUA could be a source of nitrogen observed in wells to the north, south and to the west, or downgradient of the CUA. The estimated nitrogen loading from fertilizers approached a maximum of 50 to 60 pounds N/acre-year. Section 4.0 discusses soil chemical data obtained from an almond orchard currently operating in the CUA.

Samples of granular agricultural fertilizers were collected from the CUA and analyzed for nitrate and $\delta^{15}N$. The results of these analyses are presented in Table 1. Nitrate concentrations ranged from approximately 500 to 1,000 mg/kg, and $\delta^{15}N$ values were 2.4 and 4.33. These values for $\delta^{15}N$ are consistent with other studies of δ^{5} N in fertilizer (Rolston, et al., 1994). The δ^{5} N values observed in three rounds of groundwater samples collected from the shallow aquifer (see Section 3.0) vary from 7 to 10, much higher than $\delta^{15}N$ values expected from fertilizer.

Granular fertilizer used in almond orchards were evaluated by the Technical Review Committee (Rolston, et al., 1989). Data from this study presented in Section 4.0 suggests that nitrogen loading from fertilizer may impact groundwater, but orchards are located to the north, south, and to the west of the CUA, locations which are crossgradient or downgradient of the CUA, and therefore not primary sources of nitrogen.

Granular inorganic fertilizers are converted to nitrate almost immediately after application to orchards. Once converted to nitrate, movement of nitrate to the shallow and intermediate aquifers is completed relatively quickly (approximately 3 to 6 years). Therefore, any nitrate from orchard fertilization will have no long-term residual impact on groundwater in the shallow aquifer.

2.4 Industrial Nitrogen Contribution

No industrial operations have been identified in the CUA. Historic aerial photographs were evaluated by Dames & Moore and personal interviews were conducted by Heritage Partners in an attempt to identify possible industrial or agricultural operations and facilities that may have been sources of nitrate-bearing materials.

Butte County Environmental Health Department (BCEHD) was contacted to determine if historical or current environmental investigations being conducted in the study area that may be a possible point source for nitrates. BCEHD reported there is no information available for sites under investigation within the study area. The DTSC is focusing on shallow groundwater contamination with chlorinated organic solvents in the greater downtown Chico area. These solvents have no connection with nitrate impacts in the CUA since nitrates were not used in the businesses which used solvents.

2.5 Septic Nitrogen Contribution

Domestic septic systems are located throughout the north, central, and western CUA. The RWQCB (1990) evaluated the septic system loading in the CUA and concluded that septic system densities greater than 1 family (2.33 people) per acre should be prohibited after July 1995 (RWQCB, 1990). This study (Section 4.0) identified soil and groundwater impacts from septic systems with densities of greater than 3 to 4 dwelling units (DU) per acre.

The groundwater quality in the shallow aquifer is discussed in Section 3.0. Section 3.0 presents results of recent sampling of the shallow aquifer, which showed that groundwater in the north, central, and western CUA is impacted with nitrate. The Technical Review Committee (Rolston, et al., 1989) suggested that septic system densities of 3 DU/acre may contribute up to approximately 54 lbs N/acre. Given the location of the high-density residential housing on septic systems and the areas of impacted groundwater, septic systems in the CUA are definitely the only recent source of N sufficient to cause the observed nitrate concentration in groundwater.

Septic tank systems in the CUA were sampled and analyzed for total nitrogen and $\delta^{15}N$. The results presented in Table 1 show that total nitrogen varied from approximately 44 mgN/L to 153 mgN/L. The $\delta^{15}N$ values varied from 3.95 to 14.28 with an average of 7.4.

3.0 SHALLOW AQUIFER CONDITIONS

The groundwater elevation in the shallow aquifer was initially measured in December 1993, using the shallow aquifer monitoring wells installed for this study (Figure 5). Subsequent groundwater elevation measurements were obtained in July and October 1995, prior to the collection of groundwater samples (Figures 7 and 8, respectively). Depth-to-water measurements and groundwater elevations are presented in Table 4.

3.1 Groundwater Flow

Groundwater measurement within the area covered by this investigation show that seasonal fluctuations in elevation correlate with the amount of annual precipitation. Groundwater elevations ranged from 126.6 to 161.13 feet above mean sea level (msl) in December 1993, from 132.48 to 173.25 feet above msl in July 1995, and from 129.37 to 208.70 feet above msl in October 1995. In general, water level elevations are highest in the north and east portions of the CUA, and lowest in the west and south. Depth to the water table from the ground surface ranged from approximately 16 to 45 feet below ground surface (bgs) in 1993, from 11 to 35 feet bgs in July 1995, and from 15 to 39 feet bgs in October 1995.

Groundwater elevations are higher immediately north of Lindo Channel and in the lower reach of Big Chico Creek, suggesting that these surface water features act as a source of recharge (see Section 4.0). Groundwater in the shallow aquifer is unconfined. The general flow direction is to the southwest: as shown on Figures 5, 7, and 8.

3.2 Groundwater Gradient

Groundwater gradients in the shallow aquifer is somewhat inconsistent, this is apparently due to the influence of surface water sources. From the limited data available, the gradient seems to increase toward the foothills to the east-northeast and around areas of groundwater recharge. In these areas, it ranges from 0.013 ft/ft to 0.003 ft/ft. On the western part of the CUA, the gradient flattens to about 0.0012 ft/ft. Groundwater velocities were not calculated due to the lack of information regarding the permeability of the aquifer material.

3.3 Shallow Aquifer Nitrate Chemistry

Groundwater samples were collected for nitrate analyses from the 18 shallow monitoring wells installed by Dames & Moore, as part of this investigation, and from 16 existing shallow-aquifer monitoring wells in December 1993, July 1995 and October 1995.

December 1993

In December 1993, nitrate values ranged from 66.67 mgN/L in well DMW-3 in the northwestern portion of the CUA, to 0.22 mgN/L in well MSMW-1 located in the eastern CUA. Average groundwater concentrations of nitrate in the 28 shallow aquifer wells in the CUA, tested in December 1993 was 10.11 mgN/L. Nitrate concentration contours for shallow aquifer values in December 1993 are presented in Figure 5.

July 1995

In July 1995, nitrate values ranged from 27.60 mgN/L from well ECMW-1 located in the central portion of the CUA, to non-detect in wells DMW-13 and DMW-15 located in the western CUA. Average groundwater concentrations of nitrate in the 28 shallow aquifer wells tested in July 1995 in the CUA was 4.09 mgN/L. Nitrate concentration contours for shallow aquifer values in July 1995 are presented in Figure 7.

October 1995

In October 1995, nitrate values ranged from 18.01 mgN/L from well DMW-11 in the north-central portion of the CUA, to 0.18 mgN/L in well NVMW-1 located in the south-central CUA. Average groundwater concentrations of nitrate in the 28 shallow aquifer wells tested in October 1995 in the CUA was 4.78 mgN/L. Nitrate concentration contours for shallow aquifer values in October 1995 are presented in Figure 8.

Overall, October 1995 results were higher than for July 1995, averaging 4.78 mgN/L. Nitrate concentrations in July and October 1995 were lower than average concentrations measured in 1993, probably the result of the unusually high rainfall conditions in 1994/1995, when the CUA received approximately 40 inches of rainfall as compared to 1992/1993 when the CUA only received 20 inches of rainfall.

3.4 Nitrogen Isotope Data

In addition to nitrate, groundwater samples collected from the shallow aquifer were analyzed for delta-15-N ($\delta^{15}N$). Samples were collected from 13 of the 18 shallow monitoring wells installed by Dames & Moore, and from 4 of the 16 existing shallow-aquifer monitoring wells previously sampled. Groundwater samples were collected for analysis of $\delta^{15}N$ in October 1994, July 1995, and October 1995.

Results of $\delta^{15}N$ analysis from the 17 wells sampled in October 1994, range from 3.26 to 10.02, with an average $\delta^{15}N$ value of 7.91. Each of these wells were re-sampled and analyzed for $\delta^{15}N$ in July and October 1995, with average $\delta^{15}N$ values of 6.98 and 9.42, respectively.

These average $\delta^{15}N$ concentrations were compared to published $\delta^{15}N$ analyses of various source materials, including agricultural fertilizer (2 to 5), and feedlot impacted groundwater (12 to 18). The observed values of $\delta^{15}N$ observed in the CUA (8 to 10) are more than those derived from agricultural fertilizer, and significantly less than those observed in feedlot-impacted groundwater. The groundwater $\delta^{15}N$ data from the unsewered areas of central CUA, are consistent with nitrate impacts from septic tank effluent which typically ranges from 6 to 12.

4.0 VADOSE ZONE CONDITIONS IN THE CUA

The primary objective of the vadose zone investigation was to obtain hydrogeologic information from soils underlying single- and multiple-family dwellings. This information was used in the re-evaluation of allowable septic system density, according to the Hantzsche/ Finnemore equation. To support this re-evaluation of allowable septic system density in the CUA, information supporting the estimated recharge rate and denitrification rate adjacent to septic systems in the CUA will be presented. Section 4.1 presents the evaluation of recharge. Section 4.2 summarizes soil-pore liquid data from the vadose zone. Sections 4.3 and 4.4 present the soil physical and soil chemical information, respectively, obtained from the recent soil boring investigation conducted in the CUA, which supports the estimate of denitrification adjacent to septic systems.

4.1 Recharge in the CUA

The Department of Water Resources (Bulletin 118-6, 1978) suggests that recharge in the CUA is comprised of two main components: applied water (30 percent of recharge), and precipitation and streams (70 percent of recharge). The principal sources of stream recharge in the CUA are the Big Chico, Little Chico, and Butte Creeks, with 6.5 percent of deep recharge attributable to Big Chico Creek alone (DWR, 1978). Recharge from Little Chico and Butte Creeks was not presented by the DWR; however, it can be assumed that the recharge would be slightly less than that of Big Chico Creek. Therefore, it is assumed that these sources of deep recharge account for 15 percent of the total recharge to the CUA. Recharge in the shallow aquifer from surface water is observed in groundwater contours shown in Figures 5, 6, and 7.

Recharge due to infiltration of precipitation and applied water in the CUA was estimated utilizing three separate methods: the Groundwater Fluctuation Method developed by the SWQCB (Rolston, et al., 1989), the HELP Model (U.S. EPA, 1995), and early estimates calculated by the Central Valley Regional Water Quality Control Board (RWQCB, 1989). These methods, along with an estimate of recharge to the CUA, are discussed below.

SWQCB Groundwater Fluctuation Method

The SWQCB groundwater fluctuation method utilizes measured seasonal fluctuations in the water table, along with an estimated value for the specific yield of the aquifer to calculate the amount of infiltration necessary to account for the seasonal change in the water table elevation. This method was used by the SWQCB (Rolston, et al., 1989) for estimating deep percolation in the CUA.

The SWQCB investigators obtained the change in the higher-versus-low depth to groundwater from water level data measured from State Well 22N/1E-9J2. This well was selected because it is not located near any obvious source of surface recharge; therefore, the deep percolation (and water table fluctuation) was considered to be derived from infiltration. In addition, based on the nature of the sandy silt soils present at the water table and in the zone affected by water table fluctuations in the CUA, a specific yield of 20 percent was assumed.

Using the SWQCB method for data obtained from State well 22N/1E-9J2 over an expanded period of time (1984 to 1995), the average high-versus-low water level was 8.7 feet. Based on observations of subsurface soils made during the drilling program, along with published values of average specific yields for various soil types (Fetter, 1990), previous estimates of a 20-percent specific yield appear valid. Utilizing an average annual rainfall total of 21.52 inches, a specific yield of 20 percent, and an average 8.7-foot fluctuation in the water table results in a predicted 20.97 inches per year of recharge or infiltration for the years 1984 through 1995.

HELP Model

The HELP model (U.S. EPA, 1995) was utilized to calculate deep percolation in the CUA using two different approaches. In the first approach, deep percolation was calculated for precipitation only. Actual daily precipitation and temperature data recorded for the years 1906 to 1994 at the Chico University Farm weather station (supplied by the National Climatic Data Center, or NCDC) were used in the calculation. Based on this information, the HELP model estimated 13.7 inches per year of deep percolation due to precipitation alone.

However, since precipitation is not the only source of deep percolation/recharge to the water table underlying the CUA, the HELP model was rerun utilizing several sources of information in addition to precipitation including: infiltration due to irrigation based on water usage data for the CUA supplied by the California Water Service (CWS), and infiltration from dry wells and percolation trenches simulated by the HELP model with the assistance of the City of Chico Public Works Department. Based on this information, the HELP model estimated 21.9

inches per year of deep percolation due to precipitation, irrigation, and other sources of infiltration.

Early Estimates of Recharge

Early estimates by the RWQCB of recharge in the CUA used monthly values for precipitation and evaporation for the CUA in which the months having excess of precipitation over evaporation were totaled, and equaled 12.31 inches per year. An assumption of 20 percent runoff was made, which reduced the value to 9.85 inches per year of deep percolation.

Recharge to the CUA

Early estimates by the RWQCB of recharge in the CUA appear to be too low when compared to those values calculated by the SWQCB method and the HELP model.

The estimate of deep percolation based on the SWQCB method (20.97 inches per year for the period 1984 through 1995) appears too high, given the corresponding average annual rainfall for the same period (21.52 inches per year). When averaged over time, this value suggests that almost all of the precipitation percolates to groundwater, and that there are no other sources of groundwater recharge. This value is especially high considering that a large portion of the CUA is occupied by impermeable surfaces such as pavement and structures.

Estimates for recharge calculated by the HELP model due to precipitation only (13.7 inches per year) do not account for other sources of recharge, and appear too low to account for the fluctuations observed in the water table elevations. A more accurate estimate of overall deep percolation appears to be that of the HELP model, which estimated 21.9 inches per year of deep percolation due to precipitation, irrigation, and other sources of infiltration. This estimate more than accounts for the fluctuations seen in the water table elevation; however, it does not account for upgradient recharge from streams and surface water bodies (underflow), suggesting that this estimate is also too high.

Therefore, the best estimates for recharge appears to be those which account for the water table fluctuations (SWQCB and HELP) with provisions made for recharge due to underflow.

Based on the information presented above, we can assume that approximately 15 percent of the total change in the water table is derived from underflow, and 85 percent of recharge is due to deep percolation. Applying the totals from the SWQCB and HELP models of approximately 21 inches per year, we can estimate a total infiltration of 18 inches per year.

4.2 Soil Pore Liquid Data

In order to evaluate the quality of water discharged from septic system leach lines as it moves downward to the shallow aquifer, soil pore liquid samplers (lysimeters) were installed in five locations in the CUA. The locations of these installations are shown in Figure 2B. Three of the locations are in leach fields of the single-family residences (LS-1, LS-4, and LS-5), and one location is in the leach fields of an apartment complex (LS-2). Another location (LS-3) is adjacent to a mobile-home park.

4.2.1 Lysimeter Installation Methods

Lysimeters were installed as near as possible to the septic system leach lines, 1 to 3 feet in all cases. The locations of the leach lines were obtained from existing maps provided by the owner and the County Health Department. The precise locations of the leach lines were determined by locating the drain rock using a soil probe.

Construction of septic systems in the CUA generally employs a single tank directing effluent to a "T" junction, which splits the flow of effluent into two leach lines constructed of slotted 4-inch-diameter PVC laid onto a sloped trench filled with crushed stone or drain rock. Groups or "nests" of lysimeters at multiple depths (5, 10, and 15 feet bgs) were installed on each leach line as close as possible to the "T" junction.

Lysimeters were constructed and installed consistent with ASTM methods listed in ASTM-#4696-92 (ASTM 1992). Installation utilized a four-inch boring to 4, 9, and 14 feet, with the last 1 foot augered to 1.5 inches utilizing a slurry composed of native soil cuttings and deionized water to seal the last 1 foot of each installation. A hydrated bentonite slurry was used to seal the lysimeter boreholes which were capped and sealed by a four-inch PVC casing installed flush with the soil surface to minimize interference with the existing landscape.

Lysimeter sampling employed standard practices of applying a vacuum of 500 millibars for 24 hours, and returning to sample the liquid into clean 50-milliliter capped glass containers The sampling dates and lysimeter analytical data are presented on Table 5 and Figure 9 and 10.

4.2.2 Lysimeter Results

The lysimeter data presented in Table 5 show the expected variability over time and location. The differences observed between the "A" and "B" location are considerable. Some of the potential reasons for the observed variability include:

- Slight differences in elevation between the leach lines. During low-flow conditions, one line may be dry, while the other line receives all of the influent.
- Differences in water use. This is expected to be more apparent in the single-family dwellings than in the apartment complexes.
- Differences in septic effluent quality. With greater water use, residence time of effluent within the septic tank will vary, which also varies the effectiveness of treatment.
- Differences in the soil conditions. Over small distances, this effect should be minimal, but could be a factor.
- Differences due to irregular flow paths in the subsurface.
- State of the lysimeter operation. With 26 lysimeter installations, some lysimeters will develop leaks or other mechanical problems, despite repairs employed to fix these problems.

Figure 9 presents the average nitrate concentration data collected from 1994 to 1995. These data show the expected variability with location. In general, nitrate concentration would be expected to decline with depth because of dilution/dispersion and denitrification in the vadose zone. This trend was observed in all but two locations (LS-5B and LS-3B) where average concentration of nitrate increased with depth.

4.2.3 Estimates of Denitrification

Rolston, et al. (1994) cited a study by Delwiche and Steyn (1970) which suggests that $\delta^{15}N$ values for nitrate could be quantitatively related to denitrification. As denitrification occurs in the soil column, the $\delta^{15}N$ value increases. For example, if the δ^{5} N value of septic effluent is approximately 5 in the septic tank, denitrification will increase the $\delta^{15}N$ value to perhaps 10 or 15, depending on the rate of denitrification. Delwiche and Steyn (1970) suggest an increase of 5 units of $\delta^{15}N$ is equivalent to approximately 25% denitrification.

The data for $\delta^{15}N$ from lysimeter data collected in the CUA is presented in Figure 10. This figure suggests that from the eight nests of lysimeters, two produced unreliable results, two suggested that little or no denitrification was observed, and four lysimeter nests suggested a significant denitrification rate ranging from approximately 40 to 60%.

4.3 Soil Physical Data

Four soil borings (B-1 through B-4) were drilled to groundwater within the north-central CUA (along the Lassen Avenue corridor) shown in Figure 2B. This area is characterized as containing a high density of apartments and multiple dwelling unit residences served by septic systems. Three of the four borings (B-1, B-2, and B-3) were drilled adjacent to septic systems from apartment houses (>8 DU/acre). The fourth soil boring (B-4) was in the same area, adjacent to a single-family residence (approximately 1 DU/acre). A fifth soil boring (B-5) was completed south of the CUA in an active almond orchard. This location was selected to obtain information regarding an agricultural setting outside the influence of septic systems.

The soils encountered in each of the four soil borings drilled within the CUA was fairly consistent. In general, the soils are coarse (consisting of silty sand, sand, and sandy gravels) and well drained (see boring logs, Appendix A). The depth to groundwater encountered in each location varied from approximately 25 to 41 feet bgs.

Perched water conditions were encountered at one location (soil boring B-2), located near one of the septic systems which serves an apartment complex/restaurant facility. An additional soil boring (B-2B), placed approximately 20 feet away from the first within the same leachfield, indicated that soils were only slightly moist. Perched water conditions under septic leachlines demonstrates septic system failure due to excessive loading or inappropriate soil infiltration rates in this and possibly other septic systems within the CUA.

4.4 Soil Chemical Data

In order to resolve some of the groundwater monitoring data in the north central portion of the CUA adjacent to Lassen Avenue, four soil borings were completed to groundwater, as described above. The fifth soil boring was placed in an active almond orchard in order to evaluate soil physical and chemical properties in a fertilized agricultural setting.

4.4.1 General Soil Chemical Parameters

During the completion of the five soil borings, soil samples were collected every five feet for chemical analysis. Table 6 presents the results of the general soil chemical analysis from the soil samples. Soil samples were analyzed for a variety of soil chemical parameters, including pH, organic matter (OM), phosphate (PO_4-P), potassium (K), magnesium (Mg), calcium (Ca), sodium (Na), cation exchange capacity (CEC), sulfur (S), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), boron (B), and chloride (Cl), in addition to total N, nitrate (NO_3), and ammonium (NH_4). Indicator parameters of septic system effluent included phosphate, iron, and acidity (pH).

pH

As organic nitrogen and other constituents are degraded, acidity is generated, and soil pH is reduced. This effect is observed from approximately 5 to 10 feet bgs in borings adjacent to multiple-family septic systems, borings B-1, B-2, B-2B, and B-3. No soil acidification was observed in the single-family residence (B-4) or in the almond orchard (B-5). The lack of soil acidification may be due to the lower loading rates of septic effluent in the case of B-4. In boring B-3, soil pH at the surface is reduced, but increases with depth consistent with surface application of fertilizers.

Phosphate

Household soaps contain phosphates (PO_4), which are discharged to septic systems. As a result, the soil PO_4 concentration is elevated to a depth of 10 to 15 feet bgs, where phosphate is adsorbed or attenuated by the soils. This affect was apparent for all soil borings except B-5, which was located in the almond orchard. In boring B-5, phosphate concentration was higher near the surface, declining with depth, suggesting that phosphate fertilizer was applied to the surface.

Iron

Similar to soil pH, soluble iron (Fe) is an indicator of microbial activity. As microorganisms degrade organic matter from septic system effluent electron acceptors such as oxygen (O_2) in the soil atmosphere become limited. Secondary electron acceptors including Fe^{+3} become reduced to Fe^{+2} as electrons are added. As a result, soluble Fe^{+2} concentrations increase. Nitrate is also a terminal electron acceptor through the process of denitrification.

Soluble iron concentrations in samples from boring B-1, B-2, B-2B and B-3 increase from approximately 5 to 10 feet bgs. This trend was not observed in the single-family residence boring B-4 or in almond orchard boring B-5 where Fe was elevated at the surface.

4.4.2 Soil Nitrogen

Soil samples were analyzed for total nitrogen, ammonium and nitrate. The data from borings B-1 through B-5 for total nitrogen, nitrate, and ammonium, are presented in Table 6 and Figures 11a through 11f.

Total Nitrogen

The concentrations of total nitrogen versus depth from 5 to 15 feet bgs for each soil boring are shown in Figures 11a through 11f. These results suggest that total nitrogen concentrations increase from 5 to approximately 15 feet bgs in soil borings located adjacent to the multiple-family apartment complex septic systems. In the single-family location boring B-4, total nitrogen decreased with depth with no apparent increase from 5 to 15 feet bgs. In the almond orchard, total nitrogen also decreased steadily with depth.

Ammonium-Nitrogen

Ammonium was measured in each soil sample as shown in Table 6 and Figures 11a through 11f. The concentrations of ammonium in the multiple-family apartment complex septic systems was well above those cited in the literature for fertilized soil or soil adjacent to single-family septic systems. Concentrations of ammonium in the range of 400 to 600 mgN/kg were reported for samples from borings B-1, B-2, and B-3 adjacent to multiple-family apartment complex septic systems at 5 to 10 feet bgs. The ammonium concentrations observed adjacent to the single-family septic system, boring B-4, and the agricultural location B-5, did not approach those observed near the multiple-family septic systems. Concentrations of ammonium did not exceed 20 mgN/kg in any sample from B-4 or B-5.

This finding was unexpected and presents some important implications to the CUA. The loading of septic system effluent in all three apartment complexes (B-1, B-2, and B-3) suggests that build-up of ammonium in soils is the most significant "pool" of nitrogen in soils. Soil ammonium is normally converted to nitrate in aerobic soils. Soil chemical results presented earlier suggest acidic, strongly reducing conditions which promote reduction of Fe^{+2}, may inhibit conversion of ammonium to nitrate. This buildup of soil ammonium in the range of 400 to 600 mgN/kg far exceeds concentrations in normal soils and if this loading continues, ammonium rather than NO_3-nitrogen will impact groundwater.

Nitrate

Concentrations of soil nitrate are presented in Figures 11a through 11f. These show variable trends of nitrate concentration with depth. Borings B-1 and B-3 show nitrate concentration increases from approximately 10 to 60 mgN/kg at depths of 5 to 10 feet bgs. In borings B-2 and B-2B, no increased nitrate was observed, perhaps due to the high loading, reduced environment. In boring B-4, from the single-family septic system, nitrate approached 40 mgN/kg at 20 feet bgs.

The soil chemical data collected from borings B-1 and B-3 suggest that denitrification is occurring beneath septic system leach lines from approximately 5 to 10 feet bgs. The data presented earlier showed distinct reduction in soil pH, and increases in soluble Fe in this same depth interval. The sharp reduction of nitrate concentration in borings B-1 and B-3 is consistent with the explanation that high organic loading from septic systems is creating a shortage of oxygen in the subsurface, resulting in reduction of alternate electron acceptors resulting in solubilization of Fe, and denitrification (the reduction of nitrate to N_2 and N_2O_X).

The lack of nitrate in the soil column in borings B-2 and B-2B suggests strongly anaerobic environments in which oxygen is so limiting that nitrate cannot be generated all. This location has a septic system and leach lines placed underneath an asphalt parking lot which effectively eliminates the movement of oxygen to the subsurface.

5.0 SUMMARY AND CONCLUSIONS

This hydrologic and soils investigation has reviewed previous information on nitrogen sources in the CUA and presented new data from recent investigation and monitoring studies. The results of new and existing information are summarized below.

5.1 Summary

Background Sources of Nitrogen

The background contribution of nitrogen in soils, surface water and groundwater were evaluated. The contribution of soil unaffected by CUA activities were estimated by Rolston, et al. (1989), to be on the order of 0 to 17 lbs/acre. The nitrogen contribution of surface water was measured in six upstream locations in the CUA. Nitrate could not be detected in four of six surface water samples, therefore, the nitrogen contribution from surface water is minimal. The nitrogen contribution to the shallow aquifer from upgradient sources can be neglected because the shallow aquifer does not exist upgradient of the CUA. The background nitrogen contribution from the intermediate aquifer is not relevant because the intermediate aquifer does not recharge the shallow aquifer due to a downward vertical gradient.

Agricultural Sources of Nitrogen

The results of a historical land-use study of animal agricultural operations within and outside the CUA was used to model worst-case loading of nitrogen to groundwater by animal manure degradation. These operations ceased in the 1960s and 1970s, and were located north, south, and west of the nitrate-impacted groundwater in the CUA.

The nitrification rates of animal waste were modeled and results of this modeling predict that most of the nitrogen in manure volatilizes rapidly, and remaining nitrogen mineralizes into nitrate within 2 to 5 years. Movement of nitrate from surface to groundwater is governed by infiltration rate of rainwater which carries nitrate to groundwater rapidly, within 3 to 6 years.

Pump test data from the central CUA (URS, 1993) indicates that movement from the shallow to the intermediate aquifer is rapid (one year or less) for non-adsorbing solutes such as nitrate. Based on this information, nitrate concentrations in the shallow aquifer, will approach background concentrations within 10 years following discharge of the animal waste at the surface. Animal agricultural operations with the potential to impact groundwater in the CUA ceased from 20 to 35 years ago.

Fertilization of orchard crops located to the north, west and south of the CUA was considered as a potential source of nitrate to groundwater. Granular inorganic fertilizer is converted to nitrate almost immediately (less than one year). Nitrate from granular fertilizer will not remain in the shallow aquifer more than approximately 8 years, the time required to convert all fertilizer nitrogen to nitrate (less than one year), for rainwater to move to groundwater (3 to 6 years), and transport from the shallow to intermediate aquifer (one year or less).

Industrial Sources of Nitrogen

No current or historic industrial operations which could be a significant nitrogen source were identified within the CUA. No reports of uncontrolled releases of nitrates could be identified within the CUA.

Domestic Septic Sources of Nitrogen

The large number of currently operating septic systems within the CUA indicate that domestic septic effluent is a major source of nitrogen which is still being generated in the north, central, and western portions of the CUA.

Shallow-Aquifer Conditions

The results of the recent groundwater monitoring well installation and sampling program of the shallow aquifer show that several high-density housing areas in the north, central and western portions of the CUA are impacted with nitrate. Analysis of monitoring well samples also show that portions of the shallow aquifer adjacent to unsewered and high-density residential housing have stable nitrogen isotope ratio ($\delta^{15}N$) values consistent with domestic septic system effluent.

Vadose Zone Conditions

Analysis of the infiltration rates through vadose zone soils in the CUA are consistent with previous estimates (Rolston, et al., 1989) which calculated infiltration rate in the range of 17 to 21 inches of water per year. Soil chemical data collected adjacent to septic leach lines in three multiple-family dwellings suggest very high loading rates resulting in unusual soil chemical conditions beneath the leach lines of these septic systems, which include:

- Oxygen-deficient anaerobic conditions from 5 to 15 feet bgs;
- Acidic soils from 5 to 15 feet bgs;
- Build-up of very high concentrations of ammonium up to 400 to 600 mgN/kg;
- Perched water conditions during the summer (3 to 15 feet bgs) in one location; and
- Inhibition of nitrification (the formation of nitrate) probably caused by extreme anaerobic conditions.

The soil conditions beneath the single-family dwelling were not consistent with multiple-family dwelling units, except that some oxygen deficiency did occur due to the build-up of soluble Fe from 5 to 15 feet bgs. These soils data, along with the results of soil pore liquid sampling, indicate that denitrification is occurring, although sporadically, beneath leach lines of both single- and multiple-family dwellings.

The estimate of denitrification was based on soils data and soil pore liquid samples analyzed for $\delta^{15}N$. An estimate of 30% denitrification was supported by the data using the method of Delwiche and Steyn (1970) cited by Rolston, et al. (1994).

5.2 Conclusions

This Technical Memorandum presents historical and current information which suggests that single- and multiple-family dwellings using septic systems for management of wastes are an important source of nitrogen which is impacting groundwater. Current agricultural fertilization of orchards to the north, south, and west of the CUA also appear to be a source of nitrogen downgradient or crossgradient to the CUA. The impact of single-family dwelling units (DU) at low to moderate densities (less than 3 to 4 DU per acre) may be attenuated by the relatively high recharge conditions within the CUA, and the denitrification which occurs in 5 to 15 feet bgs underneath septic leach lines. The impact of high density housing (greater than 3 to 4 DU per acre) presents a different, potentially larger problem for groundwater quality. Although evidence exists that denitrification occurs in these areas as well, the high loading rates of septic effluent has caused an unusually high build-up of ammonium in the soils below septic system of multiple-family dwellings. This build-up of ammonium in soils from 5 to 15 feet bgs is caused by excess loading of septic system effluent and needs to be addressed by some alternative wastewater treatment system for multiple-family dwellings.

6.0 REFERENCES

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Table 1
Source Samples, 1995
Chico Urban Area Nitrate Study

Sample ID	Sample Type	Sample Location	Date	Ammonium		Nitrate		Total Kjeldahl N	
				(ppm)	$\delta^{15}N$	(ppm)	$\delta^{15}N$	(ppm)	$\delta^{15}N$
FL-1	Fertilizer		11/15/95	-	-	497.00	4.33	-	-
FL-2	Fertilizer		11/15/95	-	-	989.00	2.24	-	-
MN-1	Manure	Beef Cattle	07/25/95	-	-	-	-	35.60	4.92
MN-2	Manure	Dairy Cattle	07/25/95	-	-	-	-	29.20	4.66
MN-3	Manure	Sheep	07/25/95	-	-	-	-	20.20	7.71
MN-3	Manure	Swine	07/25/95	-	-	-	-	43.60	3.82
ST-1	Septic Tank	Joshua Tree Apts-RTF	08/10/95	-	-	-	-	153.30	3.95
ST-2	Septic Tank	Casa de Flores Apts	08/10/95	-	-	-	-	108.50	6.86
ST-3	Septic Tank	Rice Bowl Apts	08/10/95	-	-	-	-	58.80	14.28
ST-4	Septic Tank	Rice Bowl Apts (dw)	08/10/95	-	-	-	-	43.80	5.59
ST-5	Septic Tank	Jones	08/10/95	-	-	-	-	47.80	8.83
ST-6	Septic Tank	Panecaldo	08/11/95	-	-	-	-	142.50	5.02
ST-7	Septic Tank	Andrews	08/11/95	-	-	-	-	101.25	7.26
SW-1	Surface Water	Butte Creek	08/11/95	-	-	0.00	-	-	-
SW-2	Surface Water	Little Chico Creek (u)	08/11/95	-	-	0.00	-	-	-
SW-3	Surface Water	Big Chico Creek (golf)	08/11/95	-	-	0.00	-	-	-
SW-4	Surface Water	Big Chico Creek (u)	08/11/95	-	-	0.50	24.45	-	-
SW-5	Surface Water	Sycamore Creek	08/11/95	-	-	1.40	10.87	-	-
SW-6	Surface Water	Lindo Channel	07/26/95	-	-	10.80	20.44	-	-
SW-7	Surface Water	Big Chico Creek (d)	07/26/95	-	-	1.40	7.33	-	-
SW-8	Surface Water	Little Chico Creek (d)	08/11/95	-	-	0.00	-	-	-
SW-9	Surface Water	Edgar Slough	07/26/95	-	-	0.00	-	-	-

- : Sample not analyzed for this parameter.

Table 2
Agricultural Animal Operations in the CUA – Shown on Figure 4
Chico Urban Area Nitrate Study

SITE	No. Animals/yr	lbs N/animal-yr	% Applied on Property	Last year of operation	Property Size (acres)	Annual Loading (Tons N/acre)
P-8	70,000	40	25	1974	10	35
P-9	104,000	30	75	1955	12	97.5
D-9	30	175	50	1965	5	0.2625
C-3	900	115	100	1955	4500	0.0175

Table 3a
Poultry Manure Degradation - Site P-8
Chico Urban Area Nitrate Study

YEAR	Manure Applied Tons N/Acre	Annual Volatilization & Denitrification Loss TonsN/Acre	Cumulative Gaseous N Loss Tons/Acre	Annual N Mineralization Tons N/Acre	Cumulative N Mineralization Tons/Acre	Residual N Remaining Tons N/Acre	Residual N Remaining Lbs N/Acre	% Remaining
1955	97.5	34.13	34.13	57.04	57.04	6.34	12675.00	7
1956		1.27	35.39	0.63	57.67	4.44	8872.50	5
1957		0.89	36.28	0.44	58.11	3.11	6210.75	3
1958		0.62	36.90	0.31	58.43	2.17	4347.53	2
1959		0.43	37.34	0.22	58.64	1.52	3043.27	2
1960		0.30	37.64	0.15	58.79	1.07	2130.29	1
1961		0.21	37.85	0.11	58.90	0.75	1491.20	1
1962		0.15	38.00	0.07	58.98	0.52	1043.84	1
1963		0.10	38.11	0.05	59.03	0.37	730.69	0
1964		0.07	38.18	0.04	59.06	0.26	511.48	0
1965		0.05	38.23	0.03	59.09	0.18	358.04	0
1966		0.04	38.27	0.02	59.11	0.13	250.63	0
1967		0.03	38.29	0.01	59.12	0.09	175.44	0
1968		0.02	38.31	0.01	59.13	0.06	122.81	0
1969		0.01	38.32	0.01	59.14	0.04	85.96	0
1970		0.01	38.33	0.00	59.14	0.03	60.18	0
1971		0.01	38.34	0.00	59.14	0.02	42.12	0
1972		0.00	38.34	0.00	59.15	0.01	29.49	0
1973		0.00	38.34	0.00	59.15	0.01	20.64	0
1974		0.00	38.35	0.00	59.15	0.01	14.45	0
1975		0.00	38.35	0.00	59.15	0.01	10.11	0
1976		0.00	38.35	0.00	59.15	0.00	7.08	0
1977		0.00	38.35	0.00	59.15	0.00	4.96	0
1978		0.00	38.35	0.00	59.15	0.00	3.47	0
1979		0.00	38.35	0.00	59.15	0.00	2.43	0
1980		0.00	38.35	0.00	59.15	0.00	1.70	0

Table 3b
Poultry Manure Degradation - Site P-9
Chico Urban Area Nitrate Study

YEAR	Manure Applied Tons N/Acre	Annual Volatilization & Denitrification Loss TonsN/Acre	Cumulative Gaseous N Loss Tons/Acre	Annual N Mineralization Tons N/Acre	Cumulative N Mineralization Tons/Acre	Residual N Remaining Tons N/Acre	Residual N Remaining Lbs N/Acre	% Remaining
1974	35	12.25	12.25	20.48	20.48	2.28	4550.00	7
1975		0.46	12.71	0.23	20.70	1.59	3185.00	5
1976		0.32	13.02	0.16	20.86	1.11	2229.50	3
1977		0.22	13.25	0.11	20.97	0.78	1560.65	2
1978		0.16	13.40	0.08	21.05	0.55	1092.46	2
1979		0.11	13.51	0.05	21.11	0.38	764.72	1
1980		0.08	13.59	0.04	21.14	0.27	535.30	1
1981		0.05	13.64	0.03	21.17	0.19	374.71	1
1982		0.04	13.68	0.02	21.19	0.13	262.30	0
1983		0.03	13.71	0.01	21.20	0.09	183.61	0
1984		0.02	13.72	0.01	21.21	0.06	128.53	0

Table 3c
Dairy Manure Degradation - Site D-9
Chico Urban Area Nitrate Study

YEAR	Manure Applied Tons N/Acre	Annual Volatilization & Denitrification Loss TonsN/Acre	Cumulative Gaseous N Loss Tons/Acre	Annual N Mineralization Tons N/Acre	Cumulative N Mineralization Tons/Acre	Residual N Remaining Tons N/Acre	Residual N Remaining Lbs N/Acre	% Remaining
1960	0	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1961		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1962		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1963		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1964		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1965		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1966		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1967		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1968		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1969		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1970		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1971		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1972		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1973		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1974		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1975		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1976		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1977		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1978		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1979		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!
1980		0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!

Table 3d
Cattle Manure Degradation - Site C-7
Chico Urban Area Nitrate Study

YEAR	Manure Applied Tons N/Acre	Annual Volatilization & Denitrification Loss TonsN/Acre	Cumulative Gaseous N Loss Tons/Acre	Annual N Mineralization Tons N/Acre	Cumulative N Mineralization Tons/Acre	Residual N Remaining Tons N/Acre	Residual N Remaining Lbs N/Acre	% Remaining
1960	0.0175	0.00	0.00	0.01	0.01	0.01	13.13	38
1961		0.00	0.01	0.00	0.01	0.00	9.19	26
1962		0.00	0.01	0.00	0.01	0.00	6.89	20
1963		0.00	0.01	0.00	0.01	0.00	5.17	15
1964		0.00	0.01	0.00	0.01	0.00	3.88	11
1965		0.00	0.01	0.00	0.01	0.00	2.91	8
1966		0.00	0.01	0.00	0.01	0.00	2.18	6
1967		0.00	0.01	0.00	0.01	0.00	1.64	5
1968		0.00	0.01	0.00	0.01	0.00	1.23	4
1969		0.00	0.01	0.00	0.01	0.00	0.92	3
1970		0.00	0.01	0.00	0.01	0.00	0.69	2
1971		0.00	0.01	0.00	0.01	0.00	0.52	1
1972		0.00	0.01	0.00	0.01	0.00	0.39	1
1973		0.00	0.01	0.00	0.01	0.00	0.29	1
1974		0.00	0.01	0.00	0.01	0.00	0.22	1
1975		0.00	0.01	0.00	0.01	0.00	0.16	0
1976		0.00	0.01	0.00	0.01	0.00	0.12	0
1977		0.00	0.01	0.00	0.01	0.00	0.09	0
1978		0.00	0.01	0.00	0.01	0.00	0.07	0
1979		0.00	0.01	0.00	0.01	0.00	0.05	0
1980		0.00	0.01	0.00	0.01	0.00	0.04	0

Table 4
Groundwater - Shallow Aquifer, 1993 - 1995
Chico Urban Area Nitrate Study

Sample Location	Date	Ammonium-N (ppm)	Ammonium-N d 15N	Nitrate-N (ppm)	Nitrate-N d 15N	Water Level feet, MSL	pH	EC mho/cm	TEMP. (F°)
102A	12/10/93	-	-	1.78	-	-*	7.25	333.0	65.1
2-51	12/10/93	-	-	2.22	-	-*	7.03	341.0	64.4
20D1	12/13/93	-	-	0.93	-	-*	8.41	178.0	59.2
20D1	10/28/94	-	-	-	7.38	-*	7.48	197.0	64.7
20D1	07/26/95	0.00	-	9.60	5.41	-*	7.23	270.0	68.9
20D1	10/16/95	0.00	-	1.68	8.23	-*	7.08	294.0	66.8
27Q1	12/15/93	-	-	0.44	-	-*	7.22	384.0	61.5
34A	11/18/93	-	-	7.11	-	-*	6.71	658.0	94.8
34A	07/25/95	0.00	-	2.70	4.50	-*	6.71	541.0	69.3
34A	10/16/95	0.00	-	3.14	6.49	-*	6.68	591.0	68.5
35M	11/17/93	-	-	2.22	-	-*	7.84	3.4	73.2
35M	10/28/94	-	-	-	6.47	-*	7.08	250.0	69.9
35M	07/25/95	0.20	-	2.50	6.06	-*	6.93	254.0	72.0
35M	10/16/95	0.10	-	0.98	8.16	-*	7.28	313.0	71.3
35M (Duplicate)	10/16/95	0.10	-	0.97	13.38	-*	7.28	313.0	71.3
46-S1	12/10/93	-	-	5.11	-	-*	7.53	427.0	67.5
46-S1	07/26/95	0.00	-	8.50	6.22	-*	6.75	483.0	68.7
46-S1 (Duplicate)	07/26/95	0.00	-	0.70		-*	6.75	483.0	68.7
46S1	10/16/95	0.08	-	3.62	9.94	-*	6.78	634.0	68.0
8AMW	11/21/93	-	-	0.27	-	-*	7.29	222.0	61.9
DMW-01	11/18/93	-	-	8.89	-	137.77	7.19	999.0	70.2
DMW-01	07/20/95	0.00	-	0.50	7.93	146.27	6.86	110.0	65.7
DMW-01	10/17/95	0.00	-	2.14	3.36	143.18	6.91	1041.0	65.7
DMW-02	11/21/93	-	-	3.33	-	160.93	7.77	562.0	57.4
DMW-02	10/28/94	-	-	-	8.52	156.89	7.95	584.0	62.8
DMW-02	07/20/95	0.00	-	5.80	7.36	168.25	7.05	94.0	66.9
DMW-02	10/17/95	0.00	-	6.44	6.50	163.59	7.00	738.0	66.1
DMW-03	11/17/93	-	-	66.67	-	139.29	7.09	1313.0	59.9

Sample Location	Date	Ammonium-N (ppm)	Ammonium-N d 15N	Nitrate-N (ppm)	Nitrate-N d 15N	Water Level feet, MSL	pH	EC mho/cm	TEMP. (F°)
DMW-03	10/28/94	-	-	-	9.84	128.91	6.77	1189.0	63.0
DMW-03 (Duplicate)	10/28/94	-	-	-	9.50	128.91	6.77	1189.0	63.0
DMW-03	07/19/95	0.10	-	1.70	7.97	147.17	7.00	874.0	67.0
DMW-03	10/17/95	0.00	-	1.26	7.19	142.77	7.20	790.0	64.5
DMW-04 (Duplicate)	10/17/95	0.10	-	2.58	4.99	132.61	6.80	176.0	66.3
DMW-05	11/21/93	-	-	18.20	-	154.59	7.69	559.0	57.0
DMW-05	10/28/94	-	-	-	9.96	149.28	8.28	651.0	62.4
DMW-05	07/20/95	0.00	-	4.20	8.32	166.28	7.49	91.0	68.8
DMW-05	10/17/95	0.00	-	7.82	6.44	159.08	7.40	639.0	66.1
DMW-06	11/22/93	-	-	2.84	-	154.80	7.41	588.0	63.7
DMW-06	10/28/94	-	-	-	8.57	148.39	7.36	536.0	69.1
DMW-06	07/20/95	0.00	-	0.90	8.26	168.37	6.86	78.0	69.8
DMW-06	10/17/95	0.00	-	5.08	7.73	162.04	6.90	599.0	57.0
DMW-06 (Duplicate)	07/20/95	0.00	-	4.70	7.79	168.37	6.86	78.0	69.8
DMW-07	11/21/93	-	-	12.67	-	146.46	7.16	614.0	62.8
DMW-07	07/20/95	0.00	-	2.40	7.76	158.78	6.91	66.0	71.6
DMW-07	10/17/95	0.10	-	3.12	8.00	150.10	7.00	546.0	69.1
DMW-08	11/15/93	-	-	2.44	-	134.13	7.15	370.0	590.0
DMW-08	10/28/94	-	-	-	3.26	124.53	7.31	284.0	68.2
DMW-08	07/20/95	0.00	-	8.70	3.64	142.66	6.90	131.0	62.8
DMW-08	10/17/95	0.10	-	17.68	-1.26	138.60	7.12	215.0	62.2
DMW-10	11/21/93	-	-	6.67	-	161.13	7.27	466.0	60.3
DMW-10	10/28/94	-	-	-	8.41	162.05	7.32	399.0	61.6
DMW-10	07/21/95	0.00	-	2.20	14.58	173.25	6.69	42.0	67.0
DMW-10	10/17/95	0.00	-	11.30	11.06	171.05	6.65	400.0	69.1
DMW-11	11/18/93	-	-	8.00	-	150.69	7.49	797.0	90.0
DMW-11	10/28/94	-	-	-	10.02	148.95	7.01	600.0	64.9
DMW-11	07/21/95	0.00	-	0.80	12.43	161.03	6.62	79.0	65.9
DMW-11	10/18/95	0.00	-	7.54	8.92	160.21	6.67	442.0	64.2
DMW-12	11/22/93	-	-	4.44	-	142.69	7.19	618.0	56.3
DMW-12	10/28/94	-	-	-	8.56	133.36	7.16	428.0	62.5
DMW-12	07/21/95	0.00	-	0.30		149.16	6.97	98.0	64.8
DMW-12	10/18/95	0.00	-	3.32	6.64	147.24	7.00	667.0	62.3
DMW-13	11/23/93	-	-	22.22	-	139.61	7.13	1278.0	57.0

Sample Location	Date	Ammonium-N (ppm)	Ammonium-N d 15N	Nitrate-N (ppm)	Nitrate-N d 15N	Water Level feet, MSL	pH	EC mho/cm	TEMP. (F0)
DMW-13	07/21/95	0.00	-	0.00		149.37	7.20	181.0	64.6
DMW-13	10/18/95	0.00	-	3.88	-6.40	144.49	7.15	1065.0	64.2
DMW-14	11/17/93	-	-	17.33	-	129.08	7.22	1108.0	63.70
DMW-14	10/28/94	-	-	-	6.40	118.66	6.97	70.0	-
DMW-14	07/21/95	0.00	-	0.30		137.91	6.96	160.0	64.6
DMW-14	10/18/95	0.00	-	2.68	-5.47	132.11	6.95	954.0	63.5
DMW-15	11/17/93	-	-	9.78	-	152.34	7.38	702.0	67.3
DMW-15	07/21/95	0.00	-	0.00		154.95	7.21	86.0	66.7
DMW-15	10/18/95	0.00	-	9.78	8.10	152.71	7.20	663.0	65.9
DMW-16	11/23/93	-	-	5.63	-	145.83	7.59	847.0	56.1
DMW-16	10/28/94	-	-	-	8.20	138.34	6.86	443.0	68.3
DMW-16	07/25/95	0.00	-	0.50	16.12	157.58	7.01	526.0	65.7
DMW-16	10/18/95	1.34	-	2.62	10.94	155.38	7.00	491.0	65.0
DMW-17	11/22/93	-	-	4.00	-	158.46	7.24	411.0	60.3
DMW-17	10/28/94	-	-	-	9.84	153.37	7.07	454.0	69.4
DMW-17	07/21/95	0.00	-	0.20		170.27	6.72	63.0	66.5
DMW-17	10/17/95	0.00	-	2.00	14.73	166.15	6.69	466.0	66.5
DMW-18	11/17/93	-	-	37.78	-	131.69	7.17	1339.0	61.0
DMW-18	10/28/94	-	-	-	7.99	121.82	7.19	1303.0	69.8
DMW-18	07/24/95	0.00	-	1.40	2.40	139.38	7.04	1043.0	67.6
DMW-18	10/16/95	0.00	-	18.01	6.23	136.00	7.00	1489.0	65.0
DMW-19	11/17/93	-	-	10.89	-	127.03	7.19	805.0	60.1
DMW-19	10/28/94	-	-	-	7.18	118.54	6.73	20.5	77.0
DMW-19	07/24/95	0.00	-	0.50	23.98	132.48	6.84	693.0	66.5
DMW-19	10/18/95	0.00	-	5.58	7.82	129.37	6.89	772.0	64.7
DMW-20	12/14/93	-	-	1.49	-	126.16	-	-	-
DMW-20	07/25/95	0.00	-	9.00	4.02	132.65	6.94	211.0	65.4
DMW-20	10/18/95	0.00	-	2.56	7.33	132.91	6.95	246.0	63.9
DMW-20 (Duplicate)	10/18/95	0.30	-	2.90	7.06	132.91	6.95	264.0	63.9
ECMW-1	12/11/93	-	-	1.82	-	-*	6.89	531.0	65.1
ECMW-1	07/26/95	0.00	-	27.60	8.09	-*	6.81	542.0	67.0
ECMW-1	10/16/95	0.00	-	3.32	6.21	-*	6.80	676.0	64.8
FAMW-2	12/11/93	-	-	11.56	-	-*	-	-	-
FAMW-2	07/26/95	0.00	10.91	1.90	5.63	-*	6.58	512.0	69.2

Sample Location	Date	Ammonium-N (ppm)	Ammonium-N d ^{15}N	Nitrate-N (ppm)	Nitrate-N d ^{15}N	Water Level feet, MSL	pH	EC mho/cm	TEMP. (F^{O})
FAMW-2	10/16/95	0.00	-	6.09	7.39	-*	6.65	641.0	66.3
MCMW	10/16/95	0.08	-	0.68	3.21	-*	7.20	291.0	67.6
MCMW-1	12/11/93	-	-	1.47	-	-*	6.75	335.0	64.9
MCMW-1	07/26/95	0.00	-	0.90	5.47	-*	7.10	221.0	68.8
MSMW-1	11/21/93	-	-	0.22	-	-*	7.04	293.0	63.9
MSMW-1	10/28/94	-	-	-	4.72	-*	6.79	293.0	72.2
MSMW-1	07/25/95	0.00	-	17.40	1.26	-*	6.80	346.0	68.5
MSMW-1	10/16/95	0.00	-	0.46	41.12	-*	6.74	402.0	68.9
NG-S1	12/14/93	-	-	13.11	-	-*	-	-	-
NVMW-1	12/15/93	-	-	0.73	-	-*	7.30	248.0	60.1
NVMW-1	07/26/95	0.00	-	0.80	6.78	-*	7.17	167.0	61.8
NVMW-1	10/16/95	0.00	-	0.18	-	-*	7.09	247.0	65.8
Spiked Blank	07/25/95	0.00	-	12.20	6.15	-*	6.94	211.0	65.4
Spiked Blank	10/18/95	0.18	-	18.48	1.38	-*	-	-	-
STMW-1	11/17/93	-	-	3.11	-	-*	8.44	472.0	80.4
STMW-1	10/28/94	-	-	-	9.23	-*	6.87	349.0	70.5
STMW-1	07/26/95	0.00	-	3.20	0.80	-*	6.60	375.0	70.0
STMW-1 (Duplicate)	07/26/95	0.00	-	1.80	1.64	-*	6.60	375.0	70.0

* : No water level information for all non-Dames & Moore wells due to either dedicated pump or no well head survey information.
- : Sample not analyzed for this parameter.

Table 5
Lysimeter Data, 1994-1995
Chico Urban Area Nitrate Study

Sample Location	Sample ID.	Depth feet, bgs	Date	Ammonium (ppm)	Ammonium d ^{15}N	Nitrate-N (ppm)	Nitrate-N d ^{15}N
Andrews A-05	LS-1A	5	12/07/94	-	-	3.20	-
Andrews A-05		5	12/14/94	-	-	3.70	-
Andrews A-05		5	12/27/94	-	-	1.60	-
Andrews A-05		5	01/06/95	-	-	4.60	-
Andrews A-05		5	05/01/95	4.90	22.75	0.00	-
Andrews A-05		5	07/21/95	17.90	10.44	-	-
Andrews A-10	LS-1A	10	12/07/94	-	-	-	-
Andrews A-10		10	12/14/94	-	-	36.10	-
Andrews A-10		10	12/27/94	-	-	0.60	-
Andrews A-10		10	01/06/95	-	-	1.40	-
Andrews A-10		10	05/01/95	0.90	-	9.00	1.14
Andrews A-10		10	07/21/95	-	-	3.20	-
Andrews A-10		10	10/20/95	20.18	-	-	-
Andrews A-15	LS-1A	15	12/07/94	-	-	12.60	-
Andrews A-15		15	12/14/94	-	-	19.90	-
Andrews A-15		15	12/27/94	-	-	0.60	-
Andrews A-15		15	01/06/95	-	-	5.00	-
Andrews A-15		15	05/01/95	-	-	8.70	24.49
Andrews A-15		15	07/21/95	-	-	1.30	30.65
Andrews B-05	LS-1B	5	12/07/94	-	-	33.90	-
Andrews B-05		5	12/14/94	-	-	51.90	-
Andrews B-05		5	12/27/94	-	-	161.40	-
Andrews B-05		5	01/06/95	-	-	104.00	-
Andrews B-05		5	05/01/95	-	-	8.80	1.69
Andrews B-05		5	07/21/95	-	-	2.20	-
Andrews B-10	LS-1B	10	12/07/94	-	-	-	-
Andrews B-10		10	12/14/94	-	-	-	-
Andrews B-10		10	12/27/94	-	-	-	-
Andrews B-10		10	01/06/95	-	-	-	-
Andrews B-10		10	05/01/95	-	-	5.40	8.46
Andrews B-10 (Duplicate)		10	05/01/95	-	-	5.30	7.43
Andrews B-10		10	07/21/95	-	-	2.20	9.09
Andrews B-10		10	10/20/95	0.00	-	1.64	5.47
Andrews B-15	LS-1B	15	12/07/94	-	-	16.50	-
Andrews B-15		15	12/14/94	-	-	24.80	-
Andrews B-15		15	12/27/94	-	-	32.50	-
Andrews B-15		15	01/06/95	-	-	24.40	-
Andrews B-15		15	05/01/95	-	-	7.90	9.76
Andrews B-15		15	07/21/95	-	-	10.00	-
Andrews B-15		15	10/20/95	0.00	-	5.00	1.83
Andrews C-20	LS-1C	20	7/21/95	1.60	28.20	19.10	2.51
Lab QA/QC	Spiked Blank	20	10/20/95	0.28	-	19.50	3.16
Beechwood Apts A-05	LS-2A	5	12/07/94	-	-	4.70	-

Sample Location	Sample ID.	Depth feet, bgs	Date	Ammonium (ppm)	Ammonium d 15N	Nitrate-N (ppm)	Nitrate-N d 15N
Beechwood Apts A-05		5	12/14/94	-	-	20.10	-
Beechwood Apts A-05		5	12/27/94	-	-	3.70	-
Beechwood Apts A-05		5	01/06/95	-	-	6.90	-
Beechwood Apts A-05		5	05/01/95	9.10	12.27	12.50	5.92
Beechwood Apts A-05		5	07/21/95	43.10	14.76	85.20	-28.52
Beechwood Apts A-05		5	10/20/95	20.36	-	2.42	13.98
Beechwood Apts A-10	LS-2A	10	12/07/94	-	-	7.50	-
Beechwood Apts A-10		10	12/14/94	-	-	9.00	-
Beechwood Apts A-10		10	12/27/94	-	-	175.40	-
Beechwood Apts A-10		10	01/06/95	-	-	87.80	
Beechwood Apts A-10		10	05/01/95	-	-	44.00	13.00
Beechwood Apts A-10		10	07/21/95	0.60	-	18.00	15.55
Beechwood Apts A-10		10	10/20/95	18.78	-	15.50	-39.37
Beechwood Apts A-15	LS-2A	15	12/07/94	-	-	19.90	-
Beechwood Apts A-15		15	12/14/94	-	-		-
Beechwood Apts A-15		15	12/27/94	-	-	0.00	-
Beechwood Apts A-15		15	01/06/95	-	-		-
Beechwood Apts A-15		15	05/01/95	2.70	15.54	24.50	14.01
Beechwood Apts A-15		15	07/21/95	-	17.79		-
Beechwood Apts B-05	LS-2B	5	12/07/94	-	-	3.80	-
Beechwood Apts B-05		5	12/14/94	-	-	4.70	-
Beechwood Apts B-05		5	12/27/94	-	-	0.80	-
Beechwood Apts B-05		5	01/06/95	-	-	5.00	-
Beechwood Apts B-05		5	05/01/95	41.40	11.19	19.00	8.39
Beechwood Apts B-05		5	07/21/95	23.80	-	3.00	17.20
Beechwood Apts B-05		5	10/20/95	13.02	-	24.70	18.45
Beechwood Apts B-10	LS-2B	10	12/07/94	-	-	-	-
Beechwood Apts B-10		10	12/14/94	-	-	9.30	-
Beechwood Apts B-10		10	12/27/94	-	-	-	-
Beechwood Apts B-10		10	01/06/95	-	-	-	-
Beechwood Apts B-10		10	05/01/95	1.20	-	48.30	3.88
Beechwood Apts B-10		10	07/21/95	-	-	-	-
Beechwood Apts B-15	LS-2B	15	12/07/94	-	-	-	-
Beechwood Apts B-15		15	12/14/94	-	-	11.50	-
Beechwood Apts B-15		15	12/27/94	-	-	-	-
Beechwood Apts B-15		15	01/06/95	-	-	-	-
Beechwood Apts B-15		15	05/01/95	0.30	-	48.50	4.70
Beechwood Apts B-15		15	07/21/95	3.70	-	191.00	
Beechwood Apts B-15		15	10/20/95	0.00	-	2.80	-1.75
Casa de Flores A-05	LS-3A	5	12/07/94	-	-	-	-
Casa de Flores A-05		5	12/14/94	-	-	-	-
Casa de Flores A-05		5	12/27/94	-	-	-	-
Casa de Flores A-05		5	01/06/95	-	-	-	-
Casa de Flores A-05		5	05/01/95	-	-	-	-
Casa de Flores A-05		5	07/21/95	-	-	-	-
Casa de Flores B-05	LS-3B	5	12/07/94	-	-	-	-
Casa de Flores B-05		5	12/14/94	-	-	240.00	
Casa de Flores B-05		5	12/27/94	-	-	-	-
Casa de Flores B-05		5	01/06/95	-	-	-	-

Sample Location	Sample ID.	Depth feet, bgs	Date	Ammonium (ppm)	Ammonium d ^{15}N	Nitrate-N (ppm)	Nitrate-N d ^{15}N
Casa de Flores B-05		5	05/01/95	-	-	-	-
Casa de Flores B-05		5	07/21/95	-	-	42.50	9.16
Casa de Flores B-05		5	10/20/95	0.00	-	2.84	13.64
Jones A-05	LS-4A	5	12/07/94	-	-	7.70	-
Jones A-05		5	12/14/94	-	-	10.20	-
Jones A-05		5	12/27/94	-	-	275.50	-
Jones A-05		5	01/06/95	-	-	4.70	-
Jones A-05		5	05/01/95	-	-	4.10	10.03
Jones A-05		5	07/21/95	-	-	-	-
Jones A-10	LS-4A	10	12/14/94	-	-	-	-
Jones A-10		10	12/27/94	-	-	-	-
Jones A-10		10	01/06/95	-	-	86.50	-
Jones A-10		10	05/01/95	-	-	10.50	8.44
Jones A-10		10	07/21/95	-	-	3.00	6.76
Jones A-15		15	12/07/94	-	-	-	-
Jones A-15	LS-4A	15	12/07/94	-	-	-	-
Jones A-15		15	12/14/94	-	-	76.50	-
Jones A-15		15	12/27/94	-	-	7.40	-
Jones A-15		15	01/06/95	-	-	108.00	-
Jones A-15		15	05/01/95	-	-	-	-
Jones A-15		15	07/21/95	2.40	-	73.60	
Jones A-15		15	10/20/95	0.00	-	61.86	-13.06
Jones B-05	LS-4B	5	12/07/94	-	-	12.60	-
Jones B-05		5	12/14/94	-	-	19.00	-
Jones B-05		5	12/27/94	-	-	27.50	-
Jones B-05		5	01/06/95	-	-	20.20	-
Jones B-05		5	05/01/95	-	-	5.20	10.21
Jones B-05		5	07/21/95	-	-	-	-
Jones B-10	LS-4B	10	12/07/94	-	-	-	-
Jones B-10		10	12/14/94	-	-	-	-
Jones B-10		10	12/27/94	-	-	-	-
Jones B-10		10	01/06/95	-	-	62.70	
Jones B-10		10	05/01/95	-	-	7.90	7.10
Jones B-10		10	07/21/95	12.00	-	27.00	14.24
Jones B-15	LS-4B	15	12/07/94	-	-	-	-
Jones B-15		15	12/14/94	-	-	-	-
Jones B-15		15	12/27/94	-	-	-	-
Jones B-15		15	01/06/95	-	-	156.00	-
Jones B-15		15	05/01/95	-	-	-	-
Jones B-15		15	07/21/95	-	-	-	-
Jones B-15		15	10/20/95	15.59	-	23.38	21.19
Panecaldo A-05	LS-5A	5	12/07/94	-	-	-	-
Panecaldo A-05		5	12/14/94	-	-	21.00	-
Panecaldo A-05		5	12/27/94	-	-	-	-
Panecaldo A-05		5	01/06/95	-	-	-	-
Panecaldo A-05		5	05/01/95	-	-	-	-
Panecaldo A-05		5	07/21/95	-	-	-	-
Panecaldo A-10	LS-5A	10	12/07/94	-	-	-	-
Panecaldo A-10		10	12/14/94	-	-	144.50	-

Sample Location	Sample ID.	Depth feet, bgs	Date	Ammonium (ppm)	Ammonium d 15N	Nitrate-N (ppm)	Nitrate-N d 15N
Panecaldo A-10		10	12/27/94	-	-	-	-
Panecaldo A-10		10	01/06/95	-	-	-	-
Panecaldo A-10		10	05/01/95	-	-	-	-
Panecaldo A-10		10	07/21/95	-	-	-	-
Panecaldo A-15	LS-5A	15	12/07/94	-	-	38.40	-
Panecaldo A-15		15	12/14/94	-	-	47.40	-
Panecaldo A-15		15	12/27/94	-	-	116.80	-
Panecaldo A-15		15	01/06/95	-	-	23.10	-
Panecaldo A-15		15	05/01/95	-	-	117.30	12.28
Panecaldo A-15		15	07/21/95	-	-	34.40	-
Panecaldo A-15		15	10/20/95	0.00	-	6.26	-24.32
Panecaldo Ad-15		15	05/01/95	-	-	118.20	12.80
Panecaldo B-05	LS-5B	5	12/07/94	-	-	76.80	-
Panecaldo B-05		5	12/14/94	-	-	85.80	-
Panecaldo B-05		5	12/27/94	-	-	255.50	-
Panecaldo B-05		5	01/06/95	-	-	110.20	-
Panecaldo B-05		5	05/01/95	-	-	16.60	7.93
Panecaldo B-05		5	07/21/95	-	-	17.20	6.73
Panecaldo B-05		5	10/20/95	0.00	-	0.66	9.57
Panecaldo B-10	LS-5B	10	12/07/94	-	-	-	-
Panecaldo B-10		10	12/14/94	-	-	7.90	-
Panecaldo B-10		10	12/27/94	-	-	10.50	-
Panecaldo B-10		10	01/06/95	-	-	10.40	-
Panecaldo B-10		10	05/01/95	-	-	13.60	6.93
Panecaldo B-10		10	07/21/95	-	-	-	-
Panecaldo B-10		10	10/20/95	0.00	-	5.90	9.02
Panecaldo B-15		15	12/07/94	-	-	3.40	-
Panecaldo B-15	LS-5B	15	12/14/94	-	-	-	-
Panecaldo B-15		15	12/27/94	-	-	-	-
Panecaldo B-15		15	01/06/95	-	-	-	-
Panecaldo B-15		15	05/01/95	-	-	10.40	20.33
Panecaldo B-15		15	07/21/95	-	-	8.20	-
Panecaldo B-15		15	10/20/95	0.00	-	2.80	29.50

- : Sample not analyzed for this parameter.

Table 6 Figures 11
Soil Boring Data
General Chemical Parameters, 1995
Chico Urban Area Nitrate Study

Sample Location	Date	Depth feet, bgs	Organic Matter	Phosphorus NaHCO3-P ppm-P	Potassium K ppm-K	Magnesium Mg ppm-Mg	Calcium Ca ppm-Ca	Sodium Na ppm-Na	pH	Cation Exchange Capacity	Sulfur S ppm-S	Zinc Zn ppm-Zn	Manganese Mn ppm-Mn	Iron Fe ppm-Fe	Copper Cu ppm-Cu	Boron B ppm-B	Chloride Cl ppm-Cl
B-1	9/25/95	0-1.5	0.6	40	255	787	1850	83	7.3	16.7	47	7.3	3	47	5.7	1.1	62
B-1	9/25/95	5-6.5	0.1	66	298	728	1480	67	5.3	20.9	2	16.9	9	88	14.6	0.6	35
B-1	9/25/95	7-8.5	0.1	63	309	647	1300	48	4.5	30.5	1	19.4	54	164	18.2	0.6	27
B-1	9/25/95	10-11	0.1	61	275	582	1150	94	6.7	12.2	2	10.2	77	107	10.8	0.5	27
B-1	9/25/95	15-16	0.1	1	140	683	1270	73	6.8	13	10	18.2	47	54	7.3	0.3	30
B-1	9/25/95	20-21	-*	-*	-*	-*	-*	-*	7.5	-*	-*	-*	-*	-*	-*	-*	200
B-1	9/25/95	25-26	0.1	1	39	981	1420	119	7.3	15.8	5	10	12	15	6.9	0.4	44
B-1	9/25/95	32-33	0.1	1	34	1710	2120	80	7.4	25.1	6	21.1	1	6	6.8	0.3	27
B-1	9/25/95	35-36	0.1	1	85	1920	2480	72	7.3	28.7	3	6.7	1	9	4.8	0.4	35
B-1	9/25/95	40-41	0.1	1	57	1329	2010	78	7.3	21.4	1	7.5	2	9	1.7	0.5	27
B-2	9/6/95	1.5-2	0.9	18	209	778	1440	41	7.3	14.3	5	5	160	67	5.9	0.5	-*
B-2	9/6/95	5-5.5	0.5	1	239	570	1070	82	7.4	11	2	5.3	20	280	2.9	0.6	16
B-2	9/6/95	7-7.5	0.2	34	267	597	1100	92	7.2	11.5	2	4.8	8	250	3.2	0.7	27
B-2	9/6/95	9.5	0.1	46	210	489	920	70	6.7	9.9	1	4.4	11	310	4.8	0.8	30
B-2	9/6/95	15	0.1	32	144	572	1030	72	6.7	11	1	7.7	740	2	5.5	0.5	12
B-2	9/6/95	21-22	0.1	10	52	1145	1500	164	7.2	17.7	1	5.1	9	11	2.5	0.6	20
B-2	9/6/95	25	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*
B-2	9/6/95	28	0.1	14	62	1160	1480	160	7	17.8	1	4.9	14	17	4	0.6	18
B-2	9/6/95	30	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*
B-2B	9/26/95	0-1.5	0.4	13	158	814	1700	43	7.4	15.8	2	8.7	210	31	6.1	5.2	27
B-2B	9/26/95	5-6.5	0.1	1	28	816	1610	103	8.1	15.3	1	3.1	250	31	5.4	1.2	21
B-2B	9/26/95	7-8.5	0.1	1	22	821	1450	145	7.6	14.7	1	4.2	490	26	5.3	0.7	18
B-2B	9/26/95	10-11	0.1	1	110	526	920	60	6.5	10.2	1	6.1	440	151	6.6	0.6	27
B-2B	9/6/95	15-16	0.1	1	144	674	970	60	6.6	11.7	1	0.9	410	145	6	0.9	18
B-2B	9/6/95	20-21	0.1	1	95	750	1060	85	7.5	12.1	1	21.2	360	35	12.6	0.6	23
B-2B	9/26/95	27-28	0.1	1	55	1132	1410	143	7.1	17.1	1	7.4	21	9	4.8	0.5	32
B-3	9/26/95	0.5-2	0.7	1	53	614	1550	45	7	13.1	2	6.6	5	19	11	0.9	18

Sample Location	Date	Depth feet, bgs	Organic Matter	Phosphorus NaHCO3-P ppm-P	Potassium K ppm-K	Magnesium Mg ppm-Mg	Calcium Ca ppm-Ca	Sodium Na ppm-Na	pH	Cation Exchange Capacity	Sulfur S ppm-S	Zinc Zn ppm-Zn	Manganese Mn ppm-Mn	Iron Fe ppm-Fe	Copper Cu ppm-Cu	Boron B ppm-B	Chloride Cl ppm-Cl
B-3	9/26/95	5-6.5	0.2	50	206	527	990	83	6.6	10.8	3	6.2	9	230	6.6	0.6	23
B-3	9/26/95	7-8.5	0.2	16	228	408	860	81	5.8	10.6	1	4.8	170	400	7.4	0.8	23
B-3	9/26/95	10-11	0.1	19	253	582	1100	72	7.1	11.2	1	4.6	27	19	3.5	0.6	23
B-3	9/26/95	16-16	0.1	1	38	876	930	66	7.1	12.2	1	6.5	6	19	4.9	0.3	27
B-3	9/26/95	20-21	0.1	1	52	1010	1330	108	6.5	16.8	1	5.7	6	15	3.6	0.5	21
B-3	9/26/95	25-26	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*
B-3	9/26/95	30-31	0.1	1	30	628	900	60	6.8	10.3	1	6.8	8	11	2.9	0.5	23
B-4	9/27/95	0-1.5	1.3	25	84	691	1550	56	7.5	13.9	6	4.7	13	17	4	1.5	35
B-4	9/27/95	5-6.5	0.3	27	120	815	1510	174	7	15.3	4	1.5	3	13	2.4	1.3	44
B-4	9/27/95	7-8.5	0.2	26	23	573	1640	147	7.1	13.6	1	0.4	2	12	1.9	0.6	27
B-4	9/27/95	10-11	0.1	2	23	688	1180	122	6.8	12.5	1	0.4	1	10	1.4	0.9	44
B-4	9/27/95	15-16	0.1	1	70	787	1260	131	6.8	13.9	1	2.5	3	15	2.4	1.1	112
B-4	9/27/95	20-21	0.1	1	62	854	1350	87	6.9	14.5	1	3.1	4	13	2.3	1.1	51
B-4	9/27/95	25-26	0.1	1	54	640	1030	55	7.3	10.8	1	6.2	4	19	6.2	0.7	62
B-4	9/27/95	30-31	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*
B-5	9/27/95	0-1.5	1.5	20	84	795	1730	32	4.9	27.7	4	8	23	144	17.1	0.8	21
B-5	9/27/95	5-6.5	0.1	1	43	1086	1750	46	6.8	18.5	1	5.3	3	19	4.5	1	14
B-5	9/27/95	7-8.5	0.1	1	19	904	1430	45	7.1	14.8	1	0.6	2	13	1.6	0.3	14
B-5	9/27/95	10-11	0.1	1	37	994	1570	55	7.5	16.3	4	12.5	1	12	6.7	0.3	23
B-5	9/27/95	15-16	0.1	1	50	1091	1720	115	7.2	18.2	21	1.7	4	12	2.8	1	20
B-5	9/27/95	20-21	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*
B-5	9/27/95	25-26	-*	-*	-*	-*	-*	-*	6.8	-*	-*	-*	-*	-*	-*	-*	18
B-5	9/27/95	30-31	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*
B-5	9/27/95	35-36	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*	-*

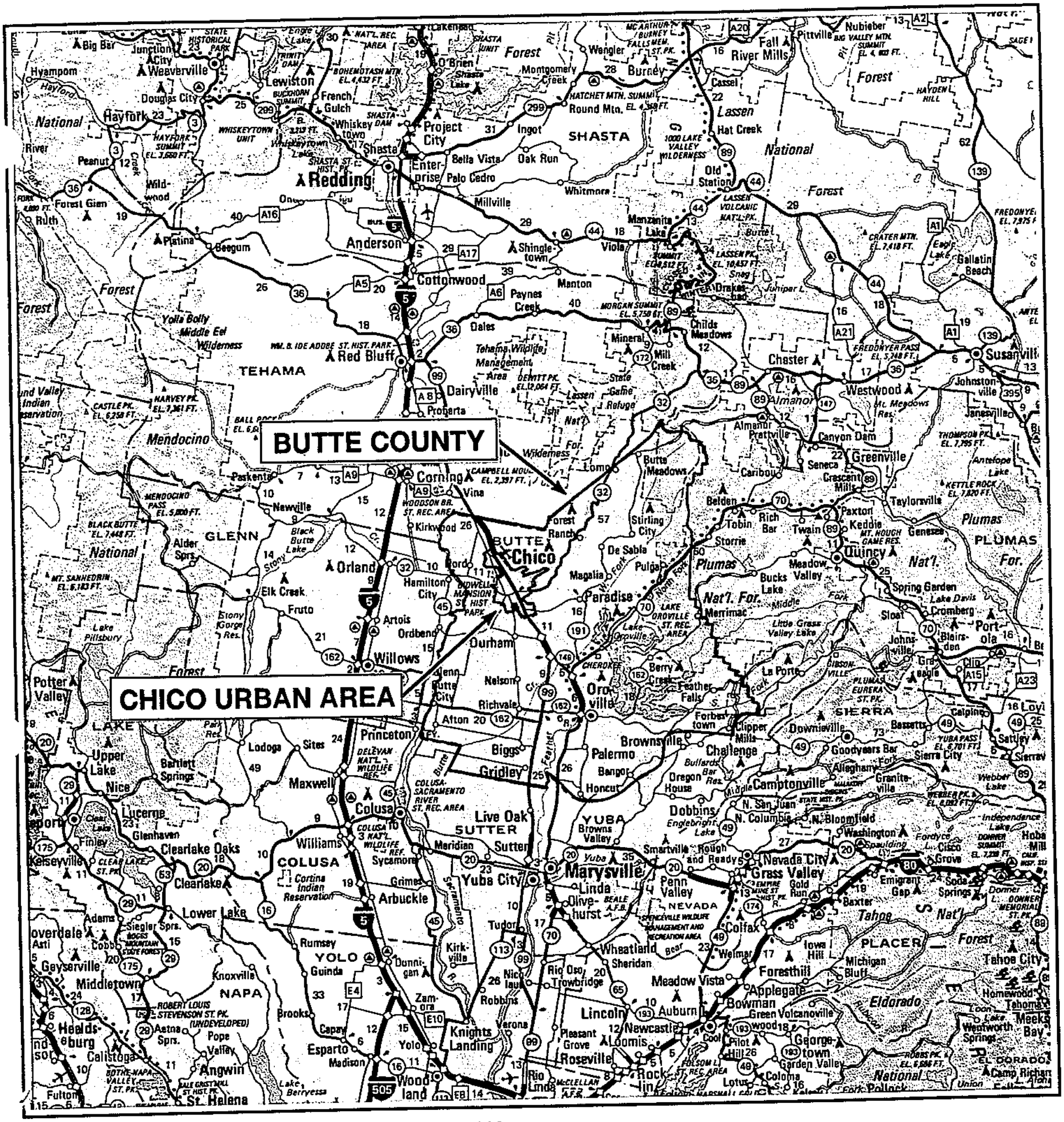
* : Insuffecient sample for chemical analysis.

Table 7
Soil Boring Data
Nitrogen Species, 1995
Chico Urban Area Nitrate Study

Sample Location	Date	Depth feet, bgs	Ammonium-N (ppm)	Nitrate-N (ppm)	Total Kjeldahl N (ppm)
B-1	9/25/95	1.5	1.8	12.0	1010.0
B-1	9/25/95	6.5	3.2	24.0	534.0
B-1	9/25/95	8.5	12.8	62.8	475.0
B-1	9/25/95	11.5	668.0	18.8	1012.0
B-1	9/25/95	16.5	115.0	16.0	19.0
B-1	9/25/95	21.5	5.2	13.6	60.0
B-1	9/25/95	26.5	2.2	9.8	5.0
B-1	9/25/95	33.5	1.6	9.6	311.0
B-1	9/25/95	36.5	1.2	15.0	274.0
B-1	9/25/95	41.5	1.6	18.4	278.0
B-2	9/6/95	2.5	94.0	1.0	773.0
B-2	9/6/95	5.5	578.0	2.8	1621.0
B-2	9/6/95	7.5	555.0	2.4	362.0
B-2	9/6/95	10	389.0	3.0	652.0
B-2	9/6/95	15.5	323.0	2.0	12.0
B-2	9/6/95	22	19.0	1.8	155.0
B-2	9/6/95	28.5	3.0	3.8	62.0
B-2	9/6/95	30.50	3.80	3.00	248.00
B-2B	9/26/95	1.5	23.4	2.2	803.0
B-2B	9/26/95	6.5	2.2	1.0	212.0
B-2B	9/26/95	8.5	9.2	2.2	232.0
B-2B	9/26/95	11.5	220.0	1.2	397.0
B-2B	9/26/95	16.5	259.0	3.4	528.0
B-2B	9/26/95	21.5	117.0	2.4	344.0
B-2B	9/26/95	28.5	3.2	1.0	86.0
B-3	9/26/95	2	4.8	5.8	726.0
B-3	9/26/95	6.5	2.8	70.0	231.0
B-3	9/26/95	8.5	467.0	6.8	779.0
B-3	9/26/95	11.5	342.0	2.8	619.0
B-3	9/26/95	16.5	4.0	5.0	146.0
B-3	9/26/95	21.5	2.6	4.8	151.0
B-3	9/26/95	26.5	2.0	2.8	79.0
B-3	9/26/95	31.5	1.0	6.8	103.0
B-4	9/27/95	1.5	16.6	4.2	1349.0
B-4	9/27/95	6.5	2.8	4.6	357.0
B-4	9/27/95	8.5	2.0	1.0	265.0
B-4	9/27/95	11.5	1.6	11.6	167.0
B-4	9/27/95	16.5	2.8	10.0	176.0
B-4	9/27/95	21.5	0.8	38.6	10.0
B-4	9/27/95	26.5	2.8	7.0	86.0
B-4	9/27/95	33.5	3.4	8.6	104.0
B-5	9/27/95	1.5	4.6	24.8	1250.0

Sample Location	Date	Depth feet, bgs	Ammonium-N (ppm)	Nitrate-N (ppm)	Total Kjeldahl N (ppm)
B-5	9/27/95	6.5	2.8	7.6	268.0
B-5	9/27/95	8.5	2.6	9.0	241.0
B-5	9/27/95	11.5	1.8	5.8	182.0
B-5	9/27/95	16.5	7.6	17.8	206.0
B-5	9/27/95	21.5	5.0	9.2	106.0
B-5	9/27/95	26.5	4.6	4.0	96.0
B-5	9/27/95	31.5	2.8	14.0	130.0
B-5	9/27/95	36.5	2.0	7.6	78.0

: Sample not analyzed for this parameter.



REFERENCE: California State Automobile Association, 1990

Scale in Miles 10 0 10 20 30 40

Scale in Kilometers 10 0 10 20 30 40

Scale = 1:324,000

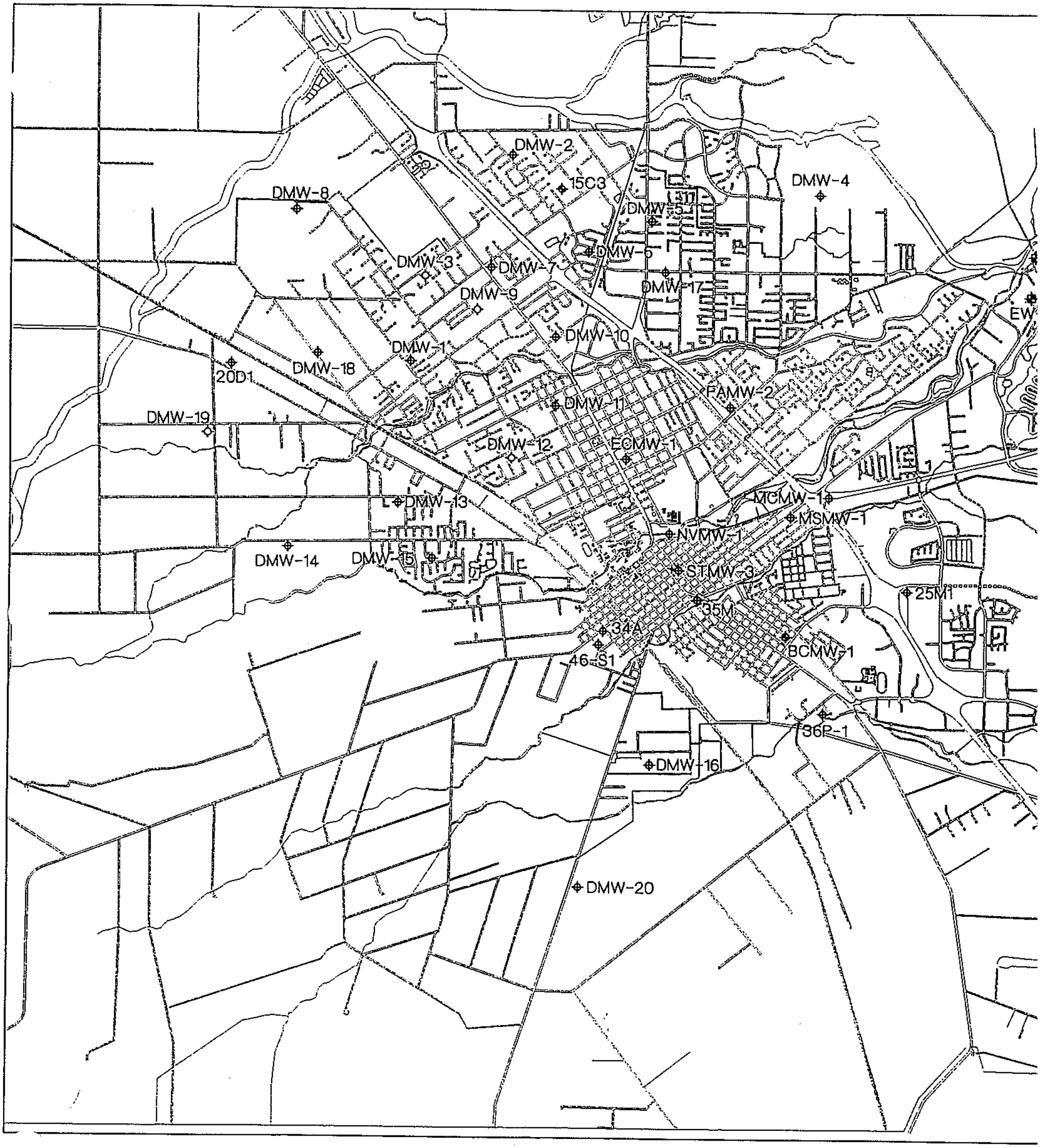
SITE LOCATION MAP

Butte County, California

DAMES & MOORE

FIGURE 1

27113-001-044.jdg.8/18/93.slm

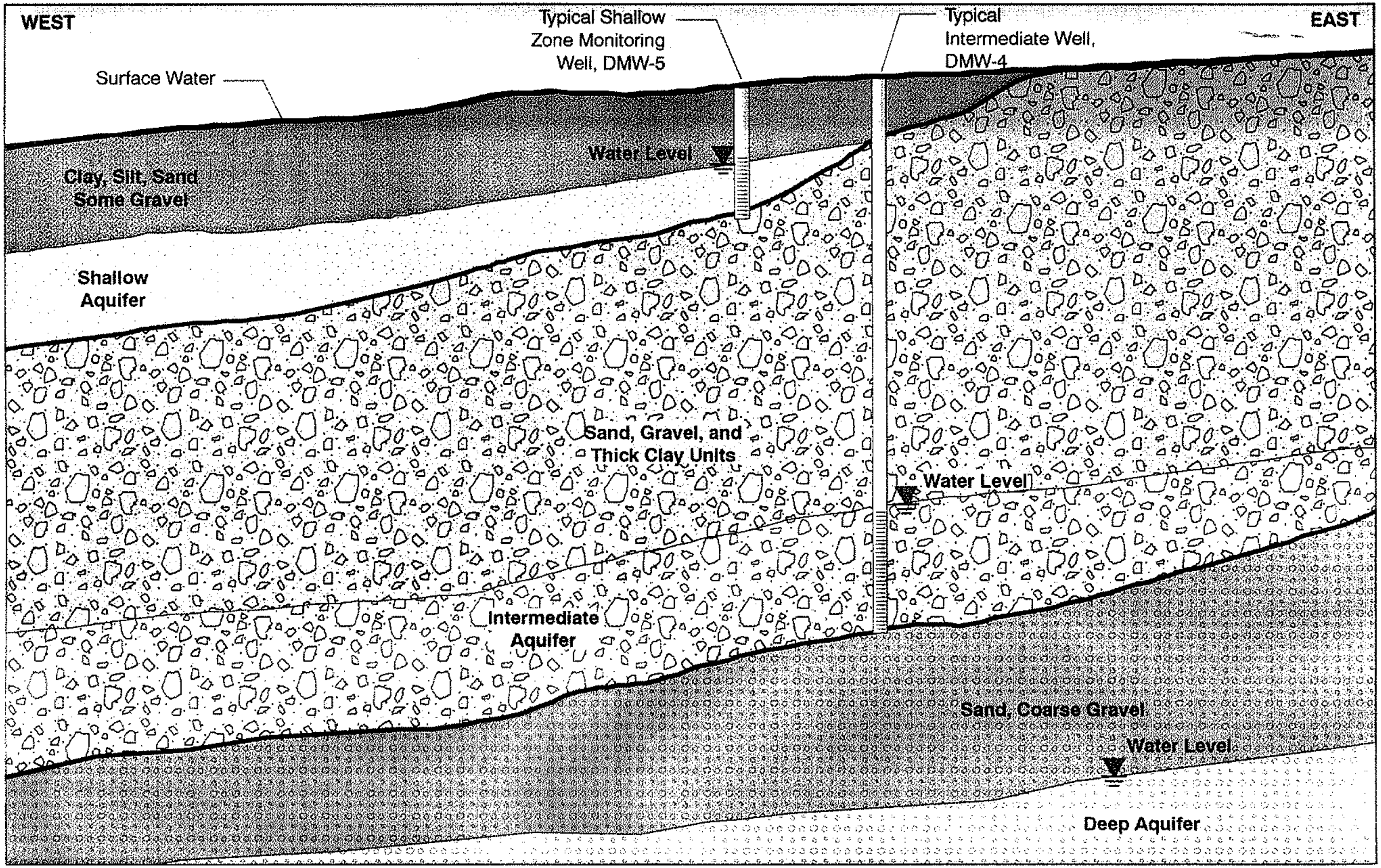


DAMES & MOORE

27113-001-044 BASE JBS

DAMES & MOORE

27113-001-044 BASE JBS



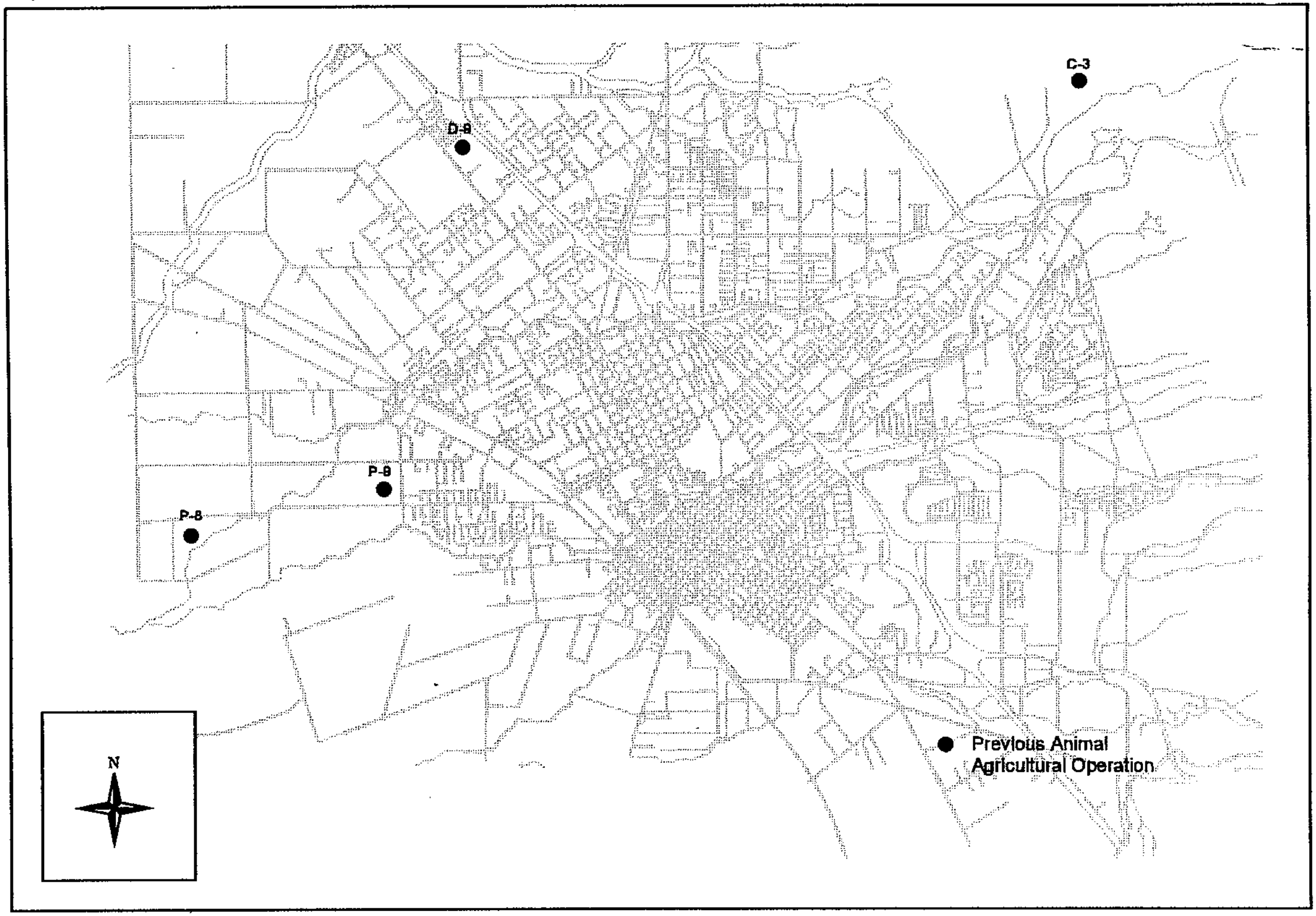
GENERALIZED HYDROGEOLOGIC CROSS SECTION OF THE CHICO URBAN AREA

Butte County, California

FIGURE 3

DAMES & MOORE

27113-004-9595-044 9595B.CDR 4/12/96

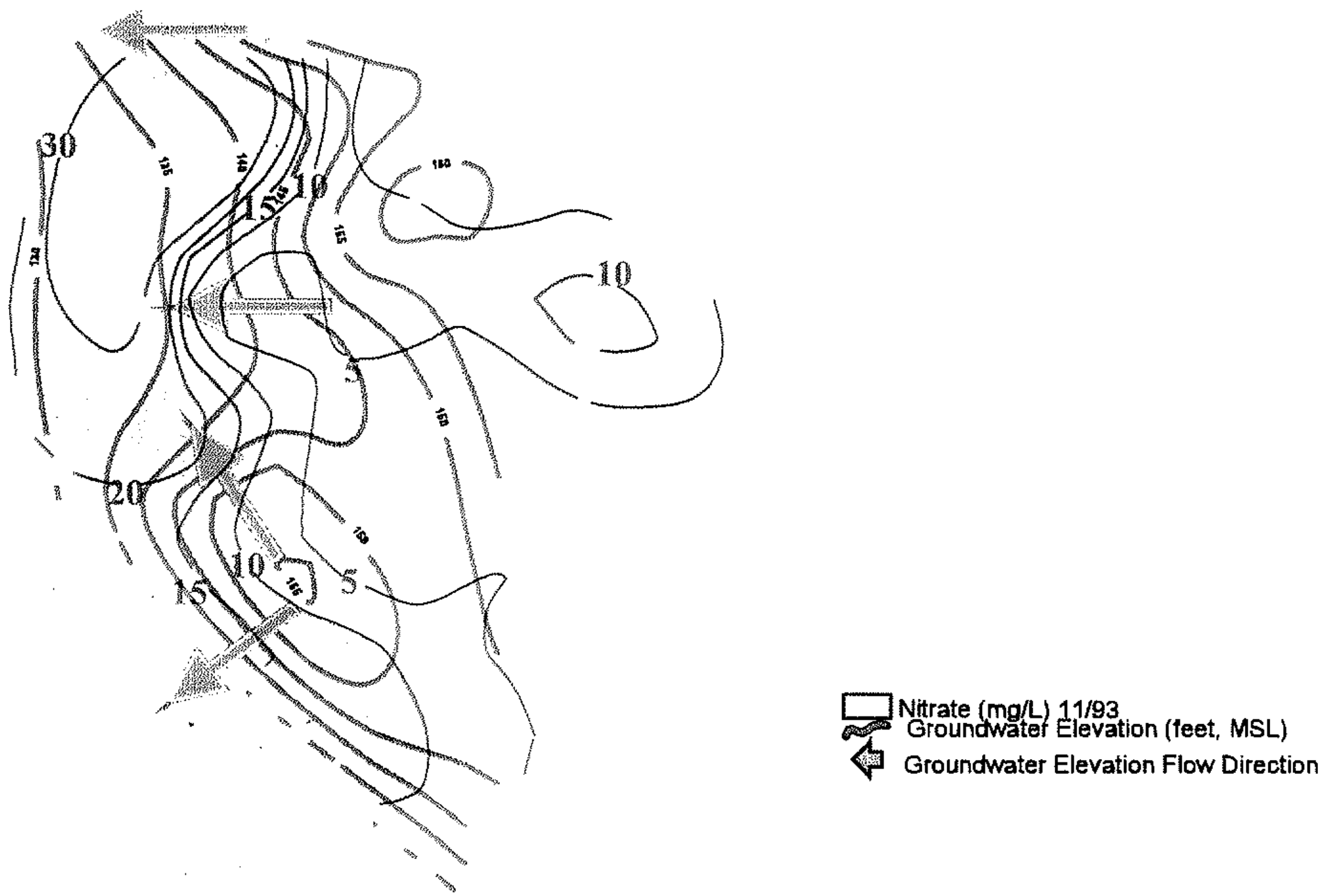


POTENTIAL NITROGEN SOURCES

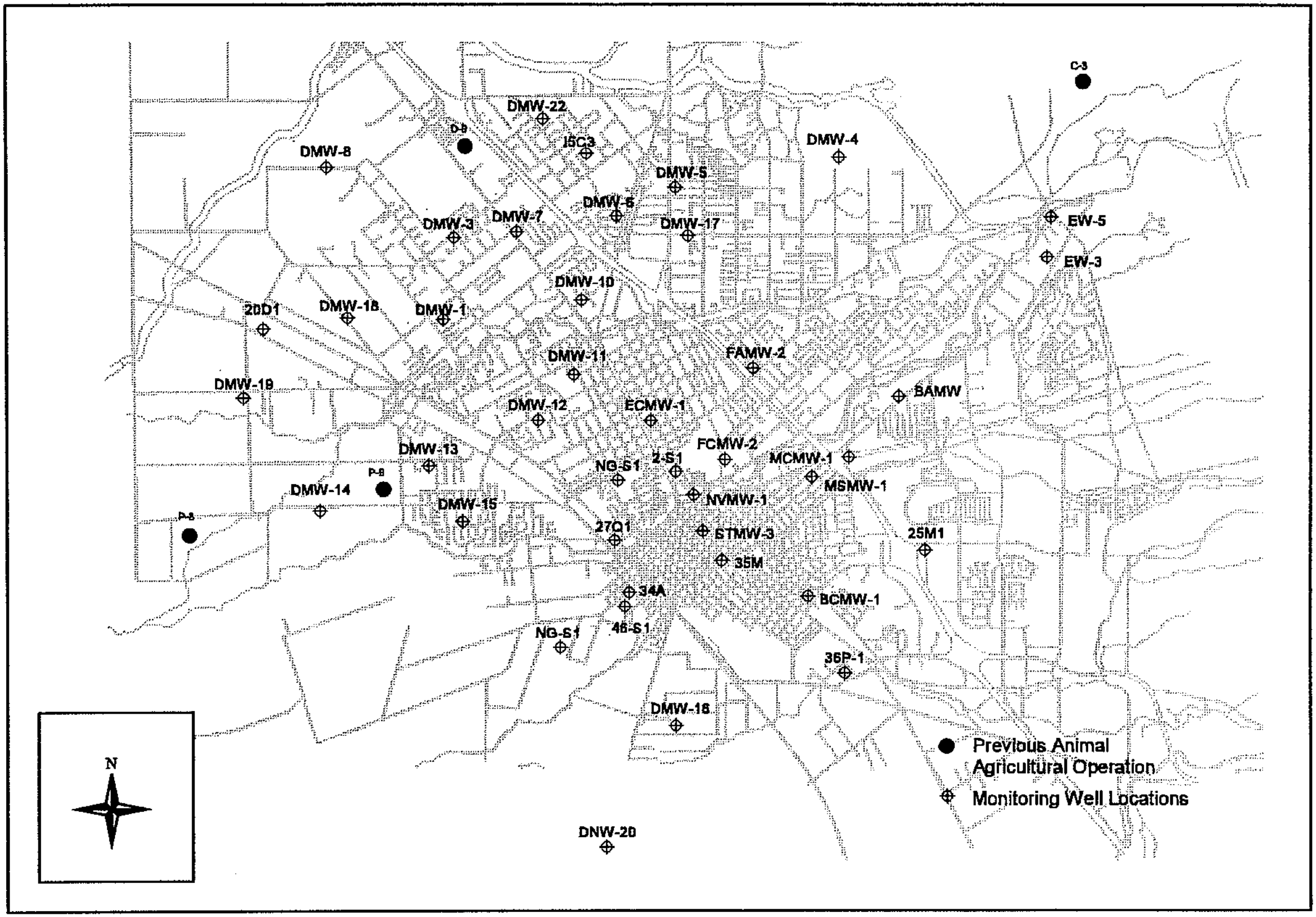
DAMES & MOORE

Job No. 27113-004-9595

Chico Urban Area
Butte County
Figure 4



30
10
15
10
20
10
15
5
Nitrate (mg/L) 11/93
Groundwater Elevation (feet, MSL)
Groundwater Elevation Flow Direction



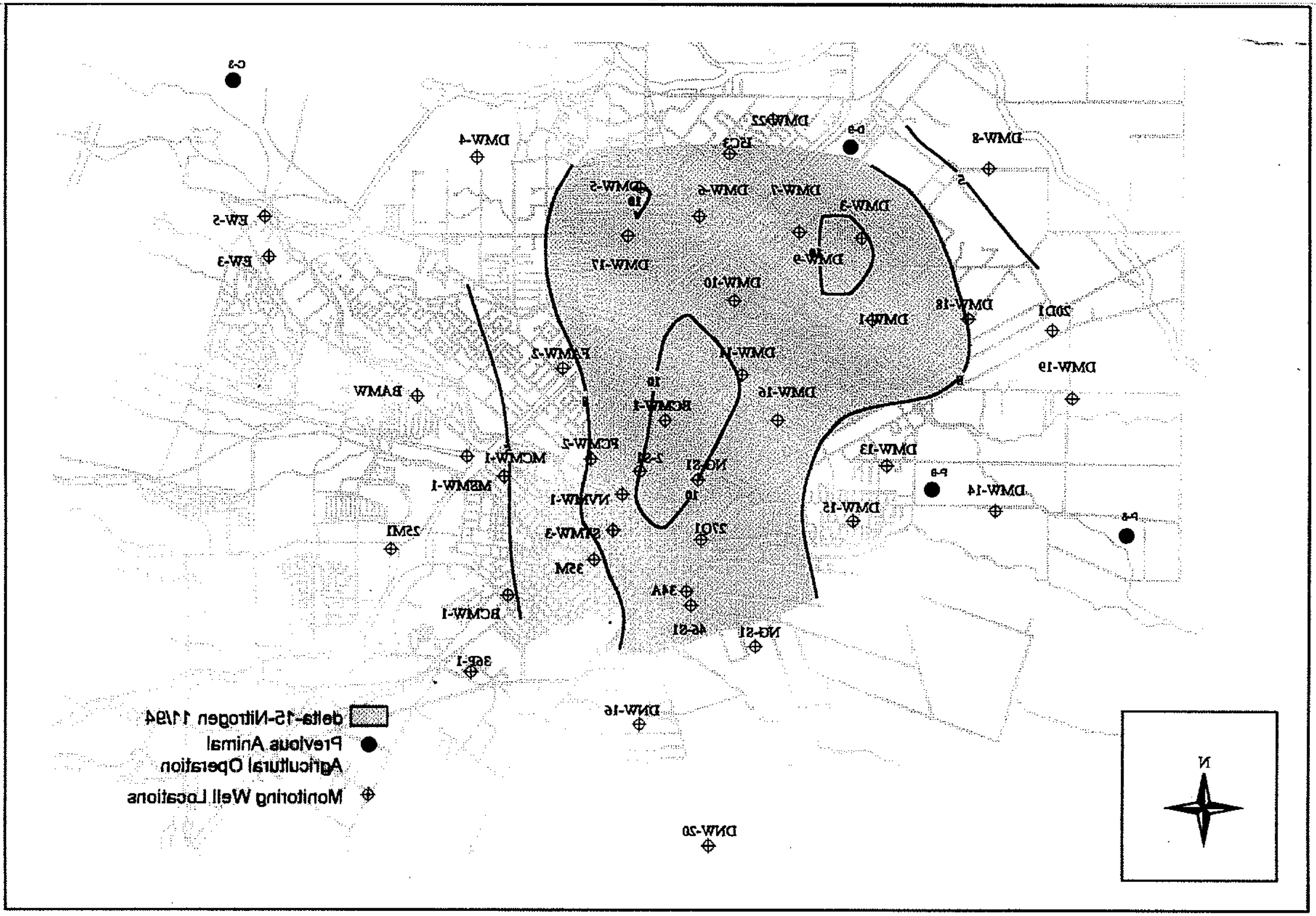
GROUNDWATER ELEVATION, NITRATE CONCENTRATION IN THE SHALLOW AQUIFER - NOVEMBER 1993

DAMES & MOORE

Chico Urban Area
Butte County

Job No. 27113-004-9595

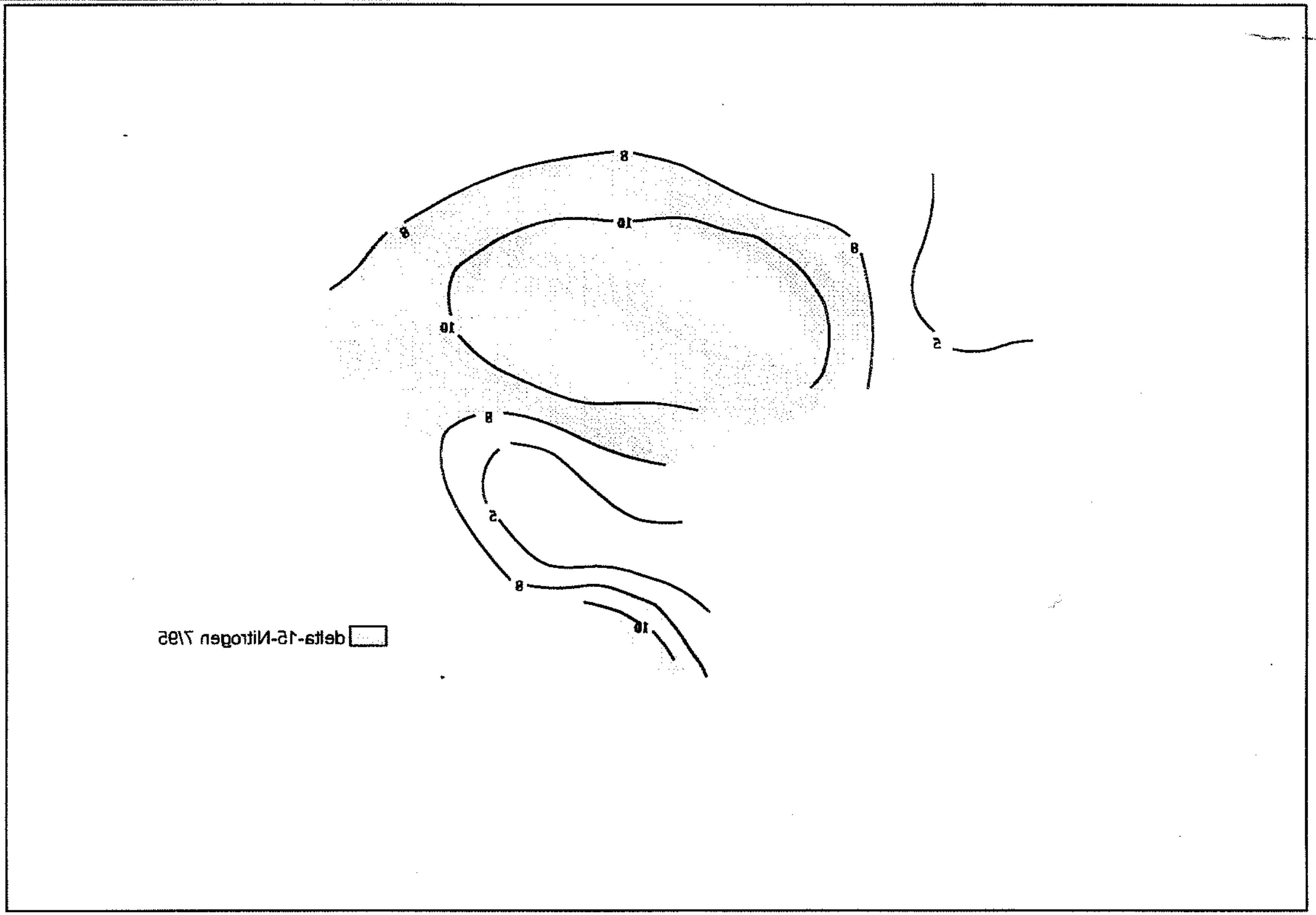
Figure 5

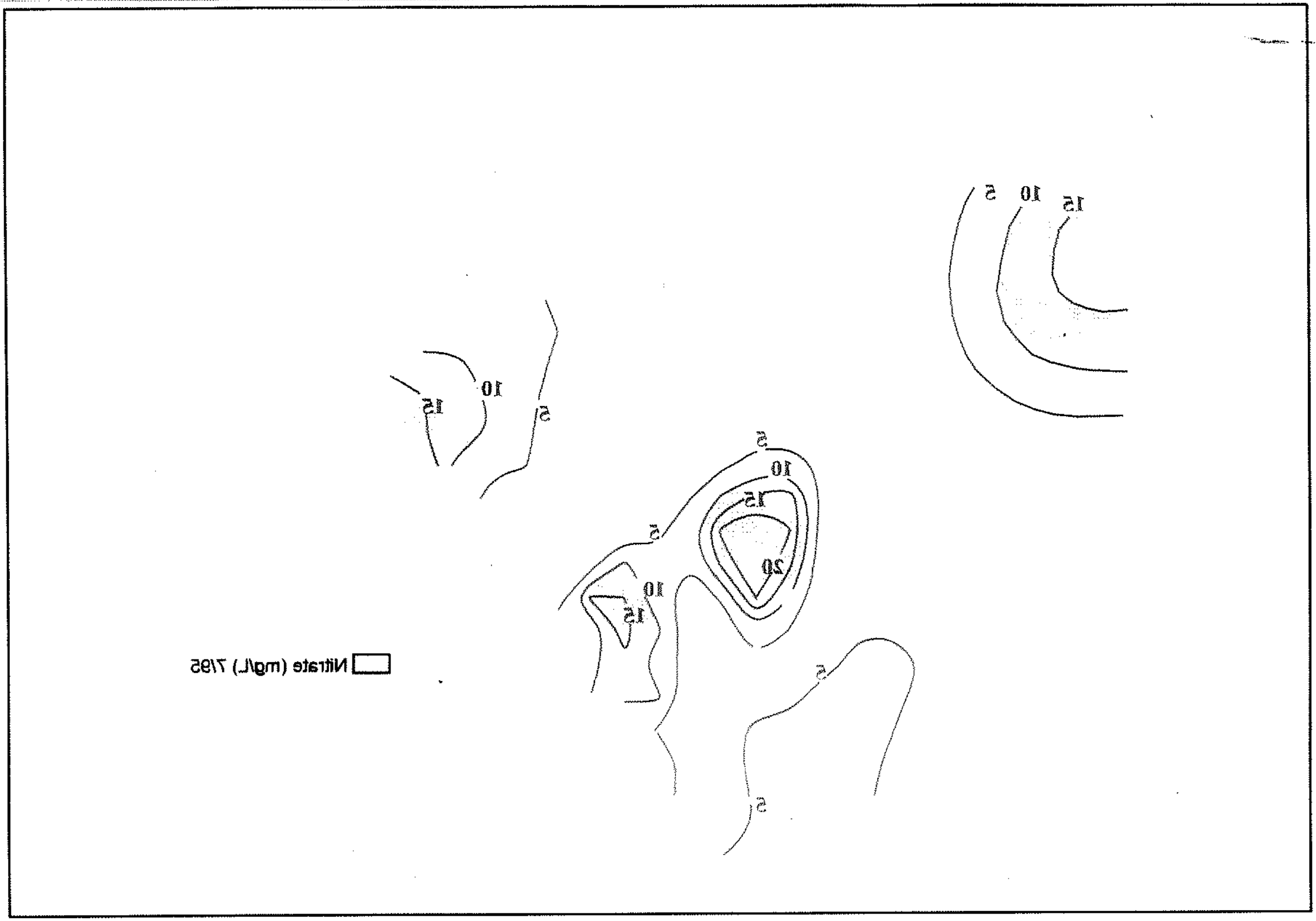


DELTA-15-N-VALUES IN THE SHALLOW AQUIFER - NOVEMBER 1994

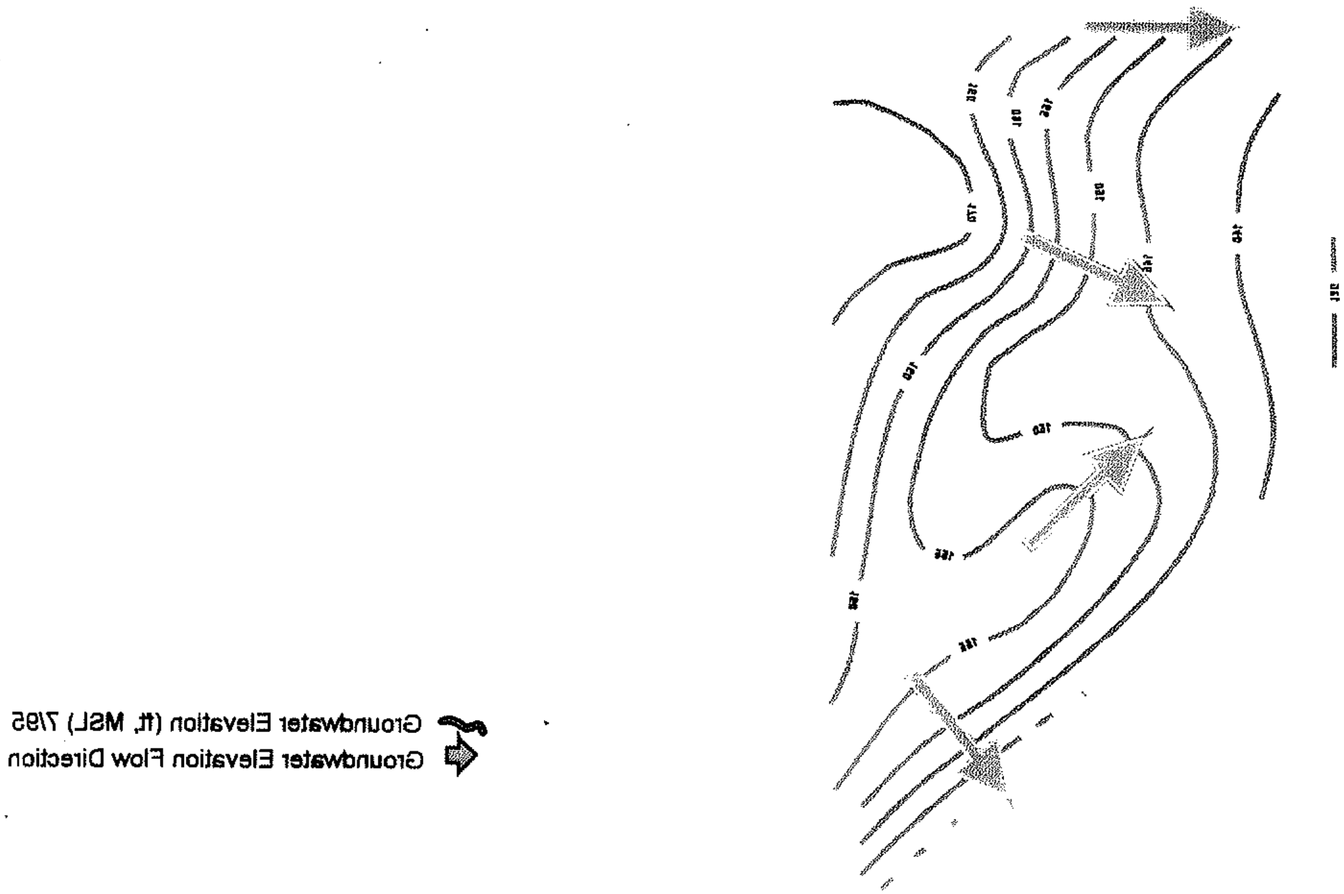
Chico Urban Area
Butte County
Figure 6

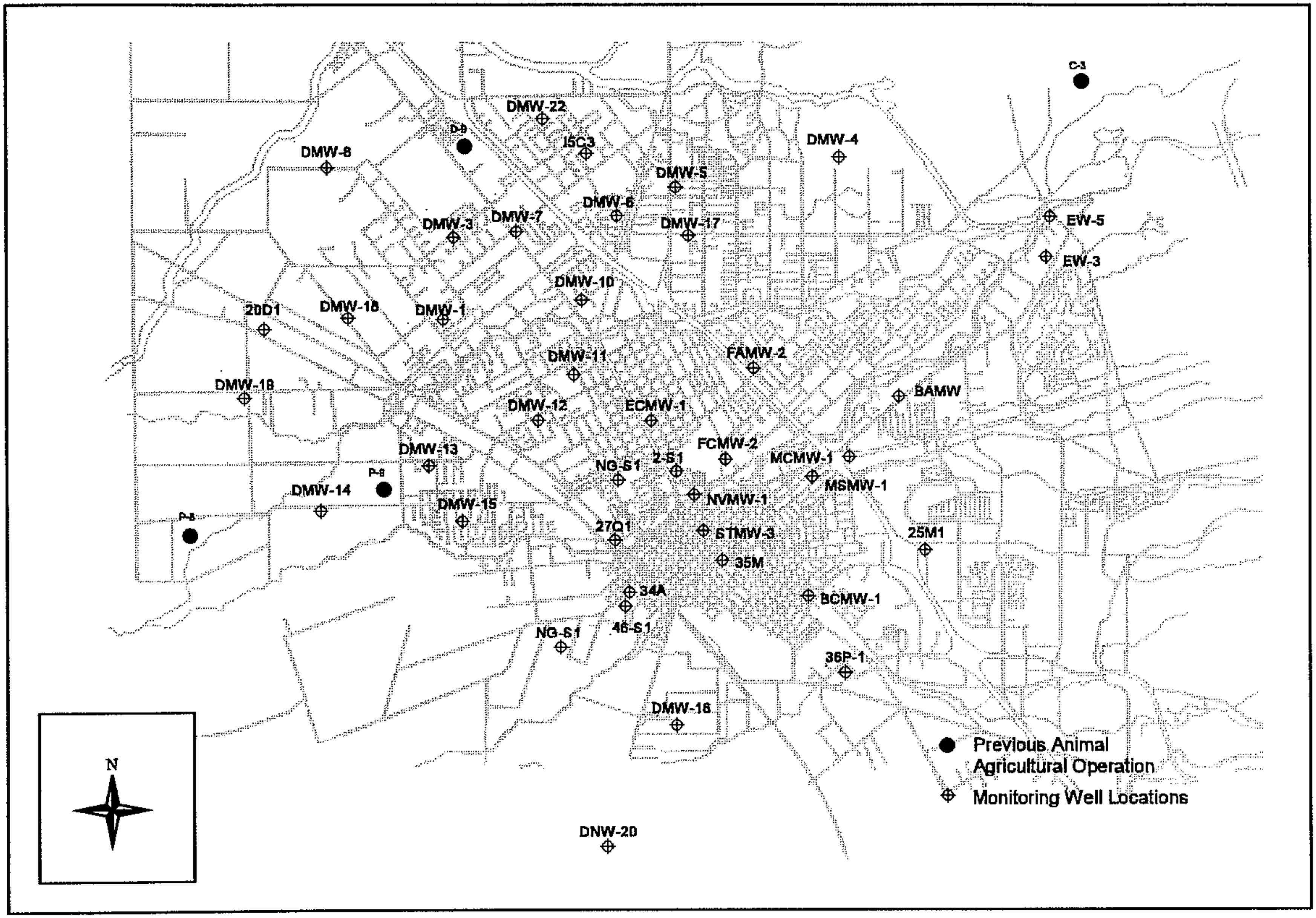
DAMES & MOORE
Job No. 27113-004-9595


8
10
5
delta-15-Nitrogen 7/95



Nitrate (mg/L) 7/95
5
10
15
20


Groundwater Elevation (ft, MSL) 7/95
Groundwater Elevation Flow Direction

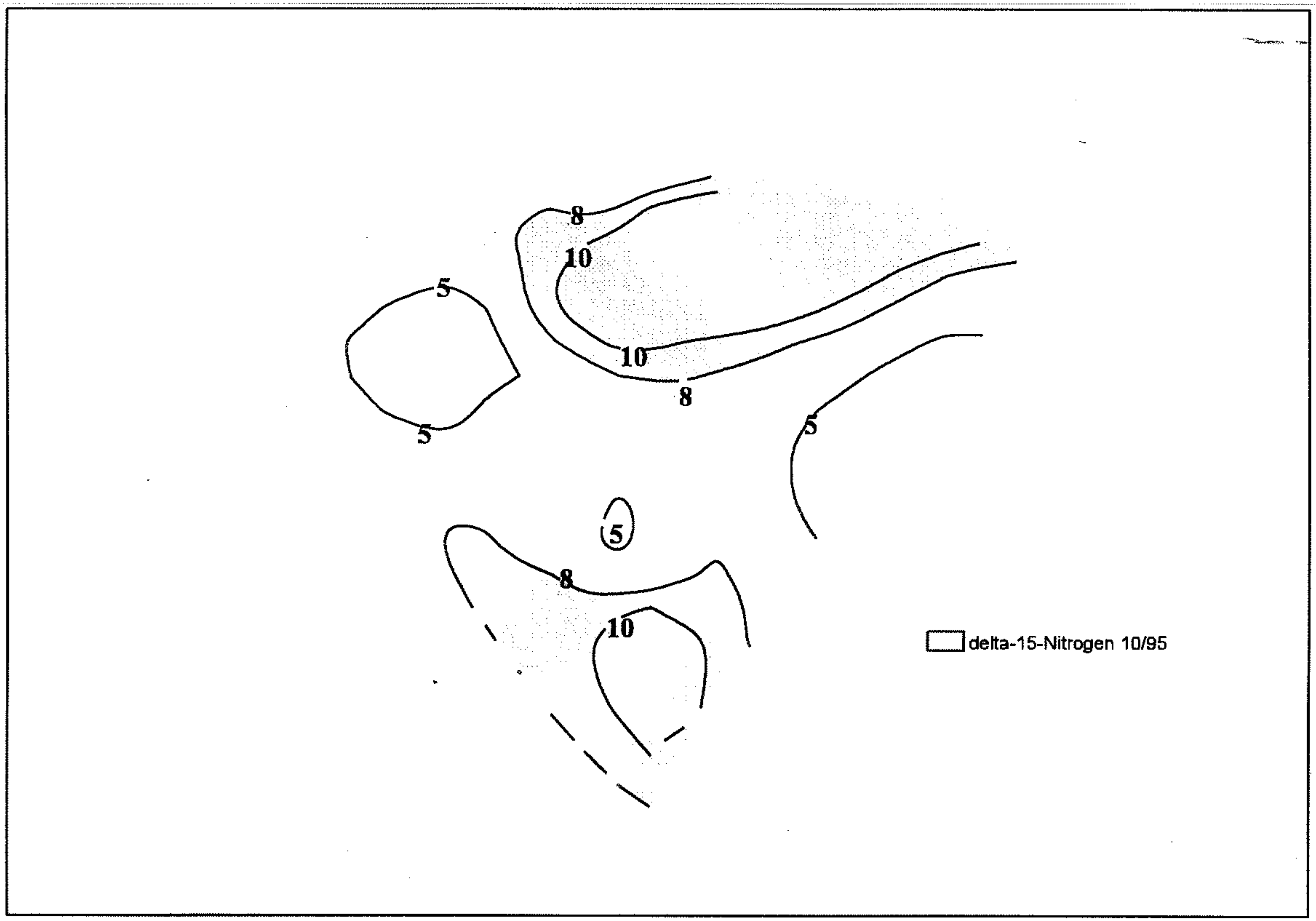


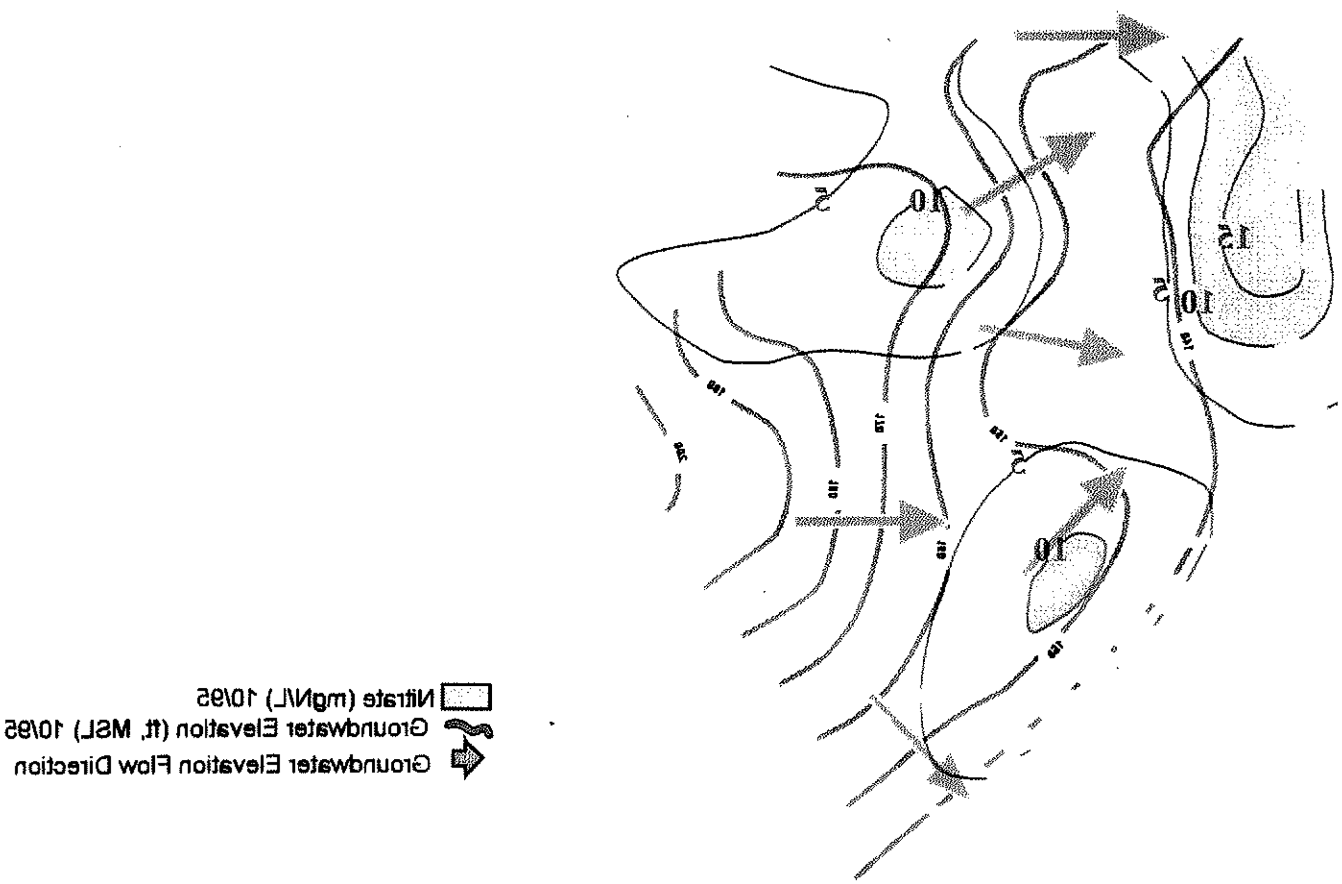
GROUNDWATER ELEVATION, NITRATE CONCENTRATION, DELTA-15-N-VALUES IN THE SHALLOW AQUIFER - JULY 1995

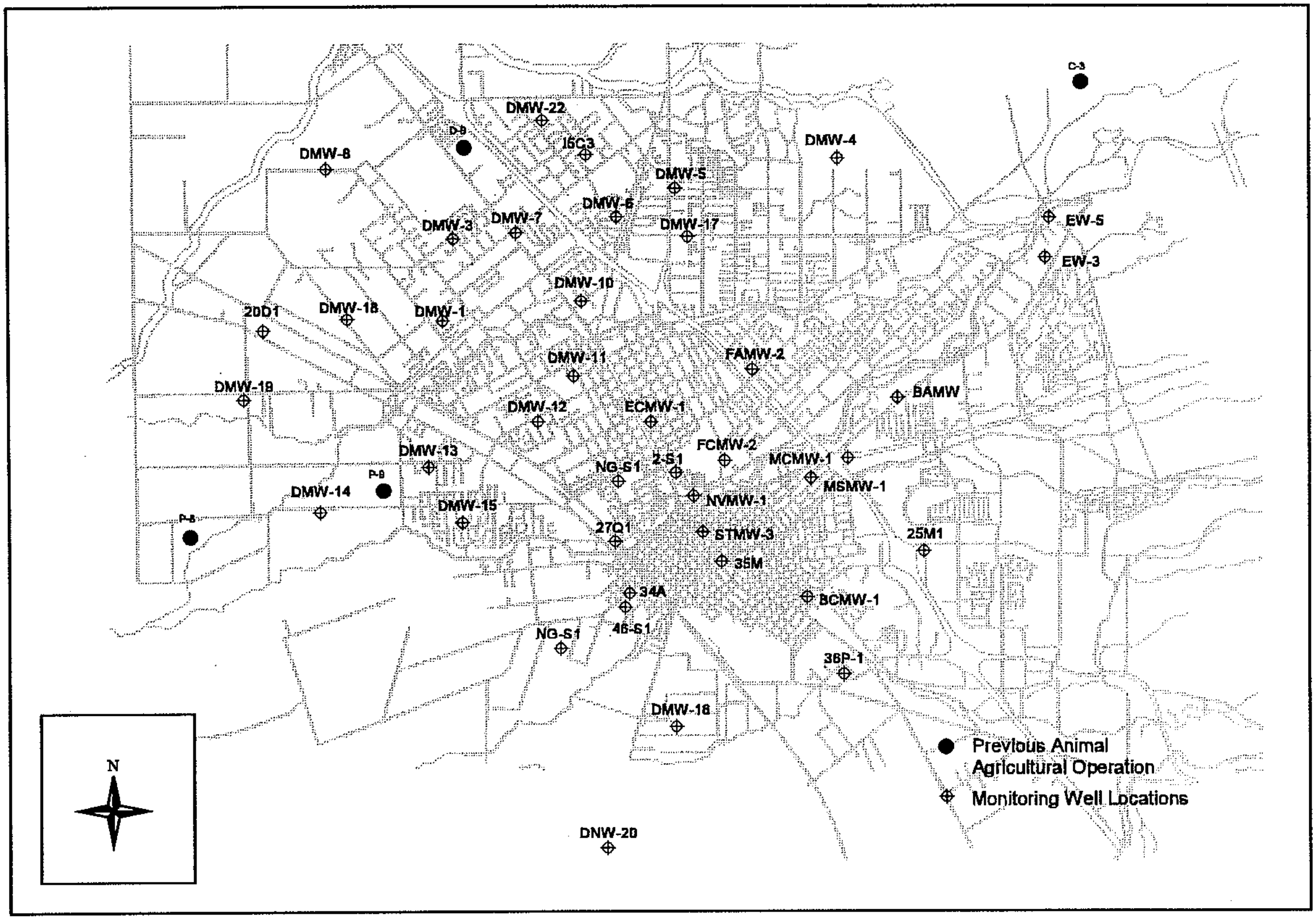
DAMES & MOORE

Job No. 27113-004-9595

Chico Urban Area
Butte County
Figure 7


8
10
5
10
8
5
5
5
8
10
delta-15-Nitrogen 10/95


Nitrate (mg/L) 10/95
Groundwater Elevation (ft, MSL) 10/95
Groundwater Elevation Flow Direction
5
10
15

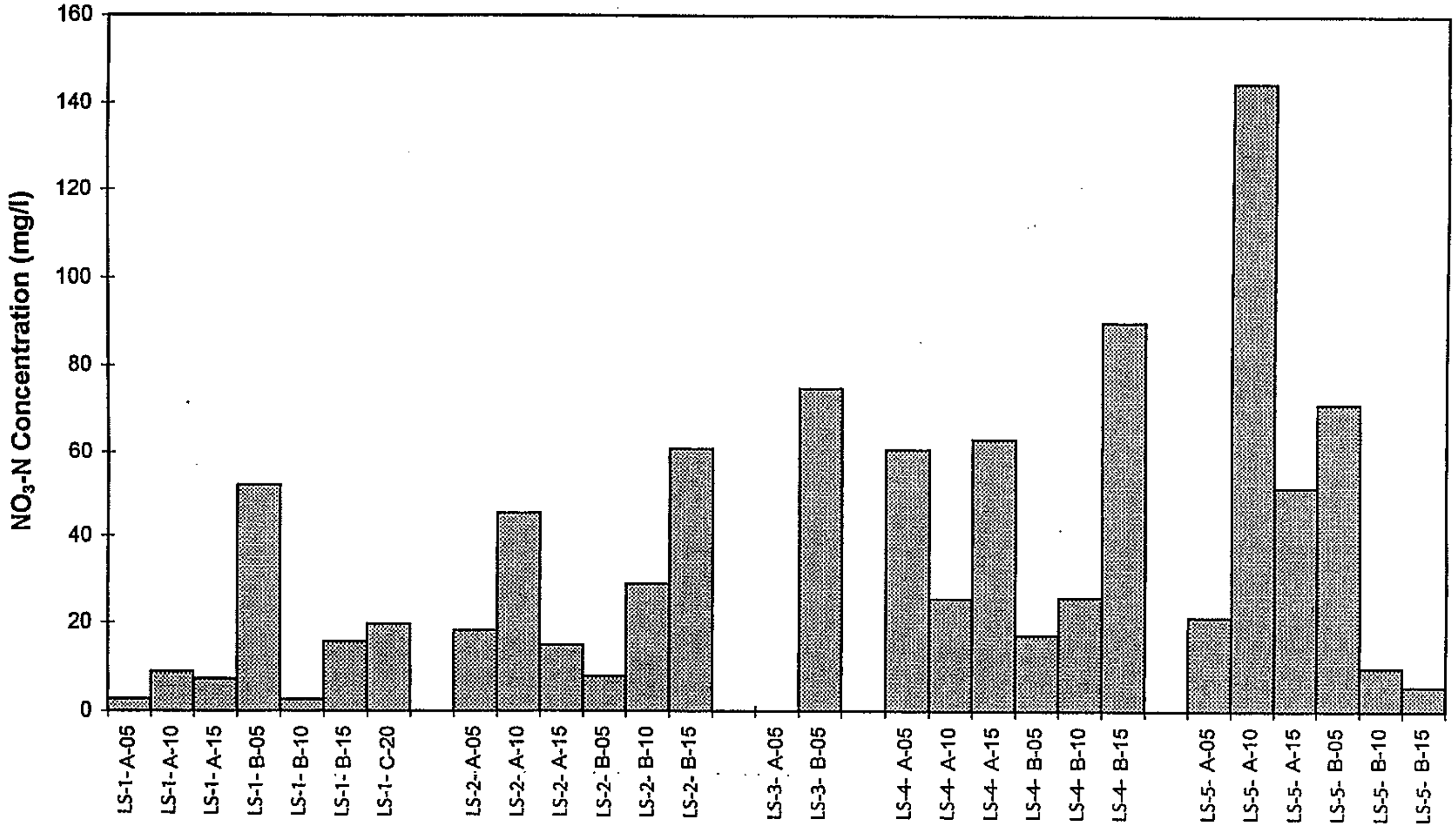


GROUNDWATER ELEVATION, NITRATE CONCENTRATION, DELTA-15-N-VALUES IN THE SHALLOW AQUIFER - OCTOBER 1995

DAMES & MOORE

Job No. 27113-004-9595

Chico Urban Area
Butte County
Figure 8

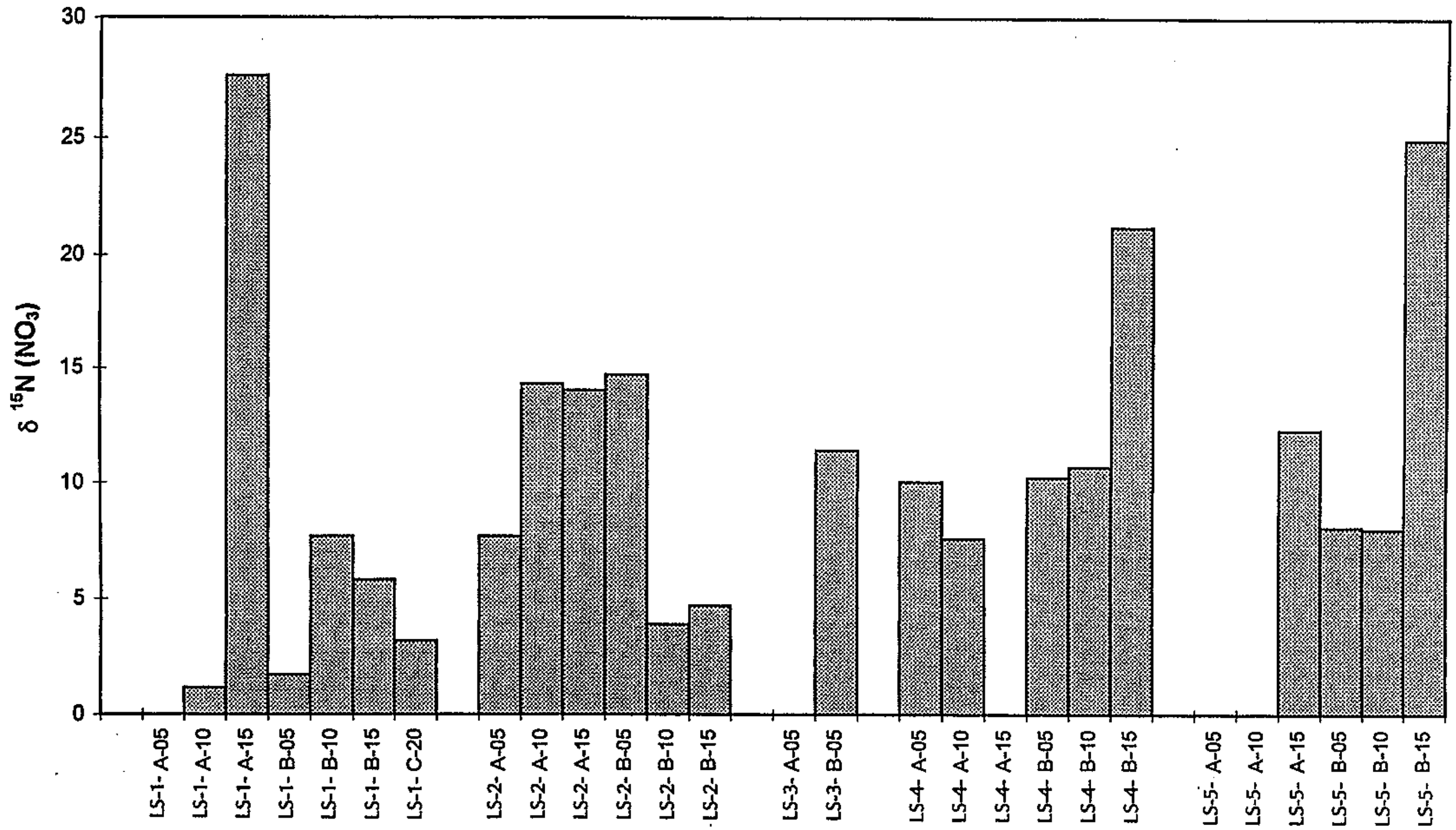


Average Nitrate Concentration in Soil Pore Liquid 1994-1995

DAMES & MOORE

Job No. 27113-004-9595

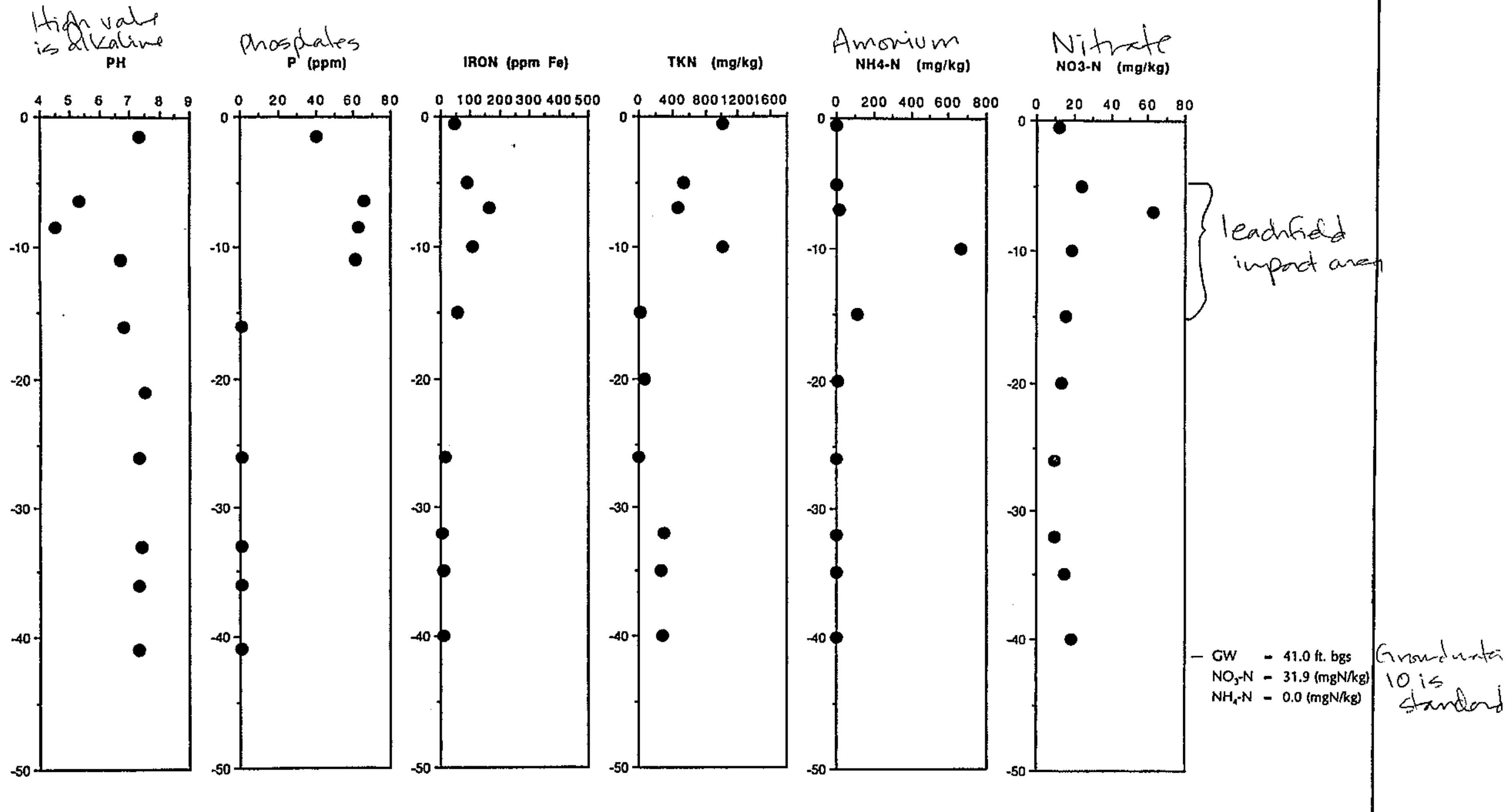
Chico Urban Area
Butte County
Figure 9



Average delta 15 N Values in Soil Pore Liquid 1994-1995

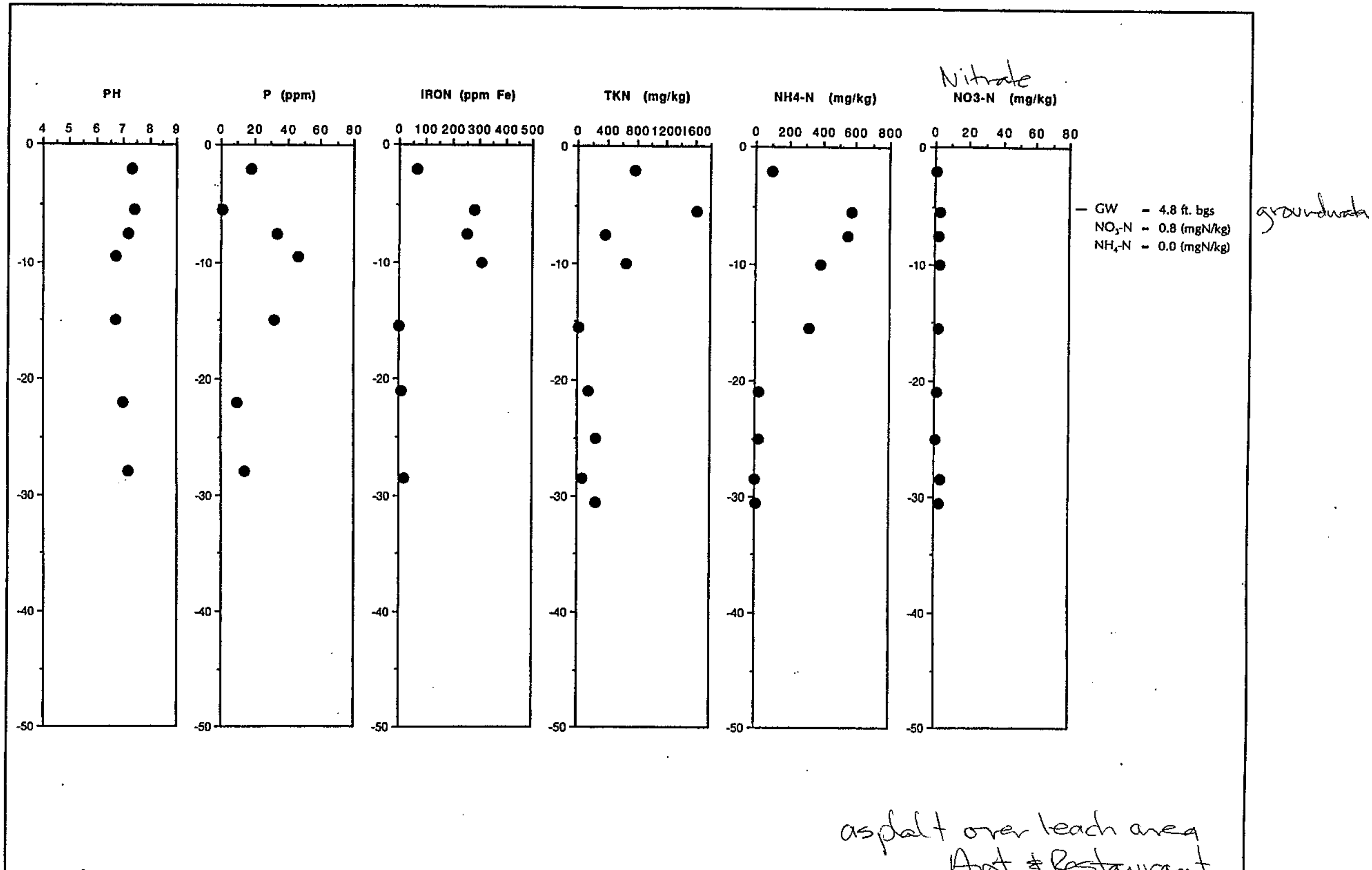
DAMES & MOORE
Job No. 27113-004-9595

Chico Urban Area
Butte County
Figure 10



Analytical Results - Soil Boring B-1
Concentration vs Depth
Chico Urban Area
Butte County
Figure 11a

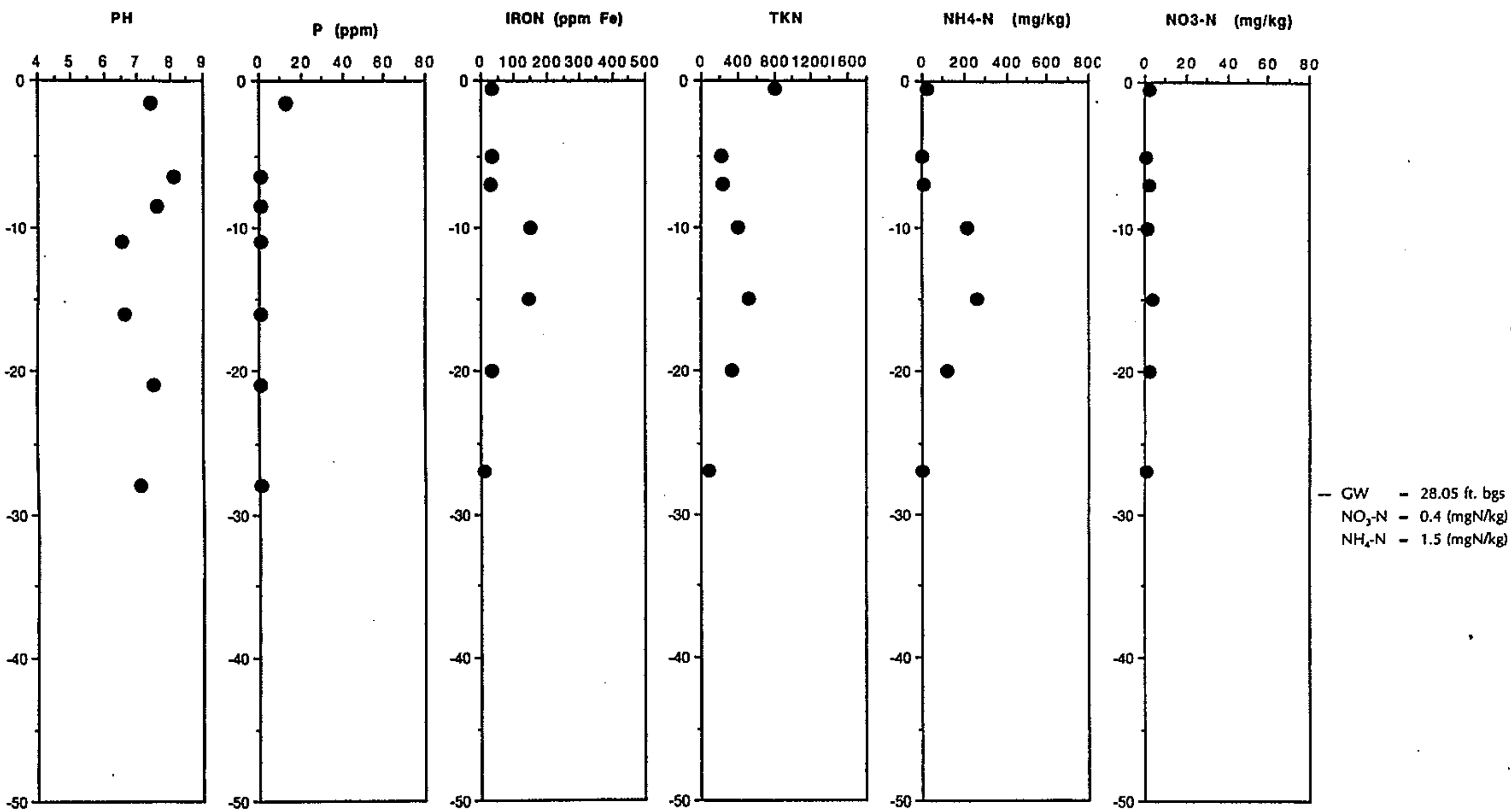
DAMES & MOORE
Job No. 27113-004-9595



Analytical Results - Soil Boring B-2
Concentration vs Depth

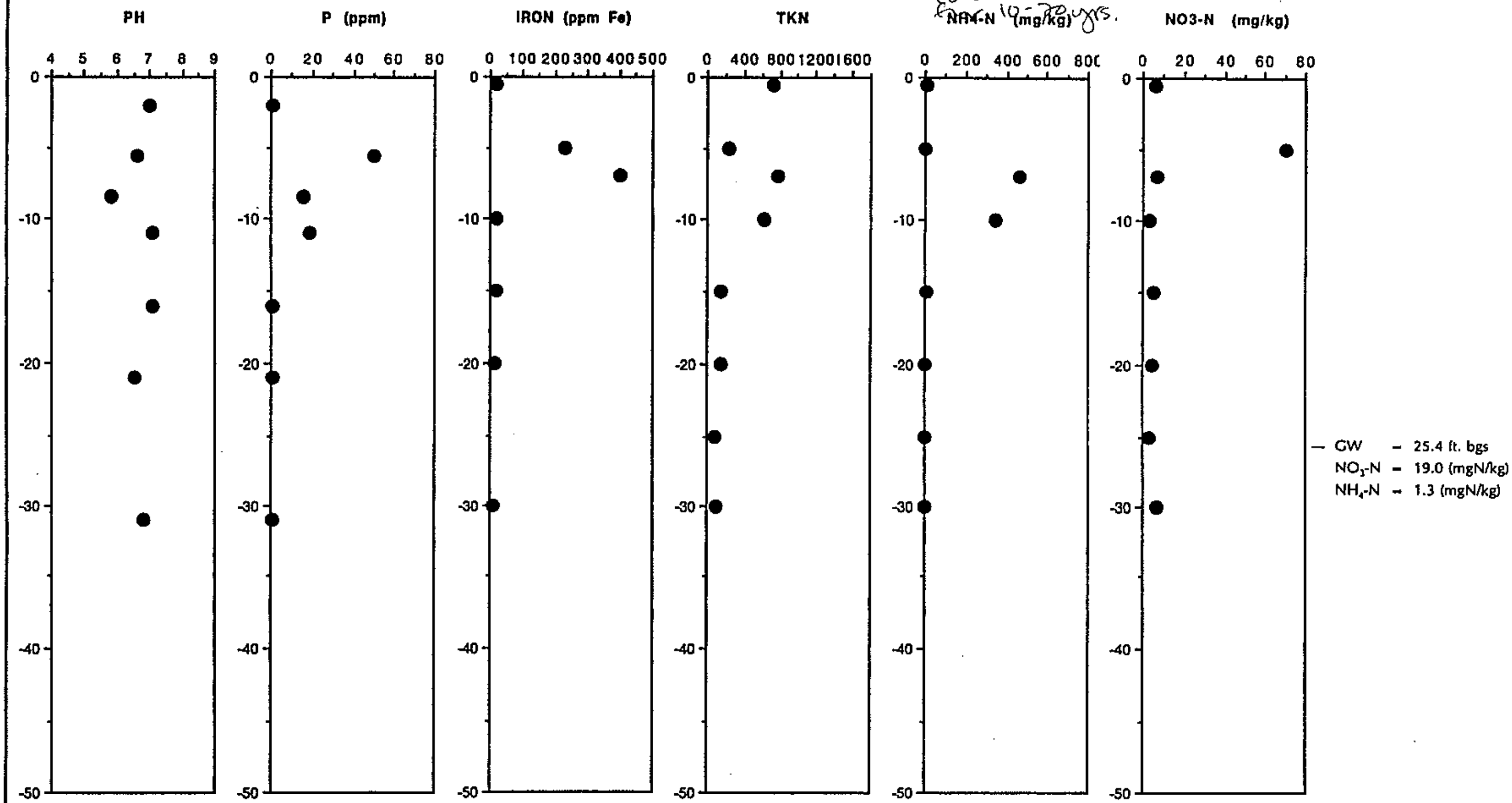
Chico Urban Area
Butte County
Figure 11b

DAMES & MOORE
Job No. 27113-004-9595



Analytical Results - Soil Boring B-2B
Concentration vs Depth
Chico Urban Area
Butte County
Figure 11c

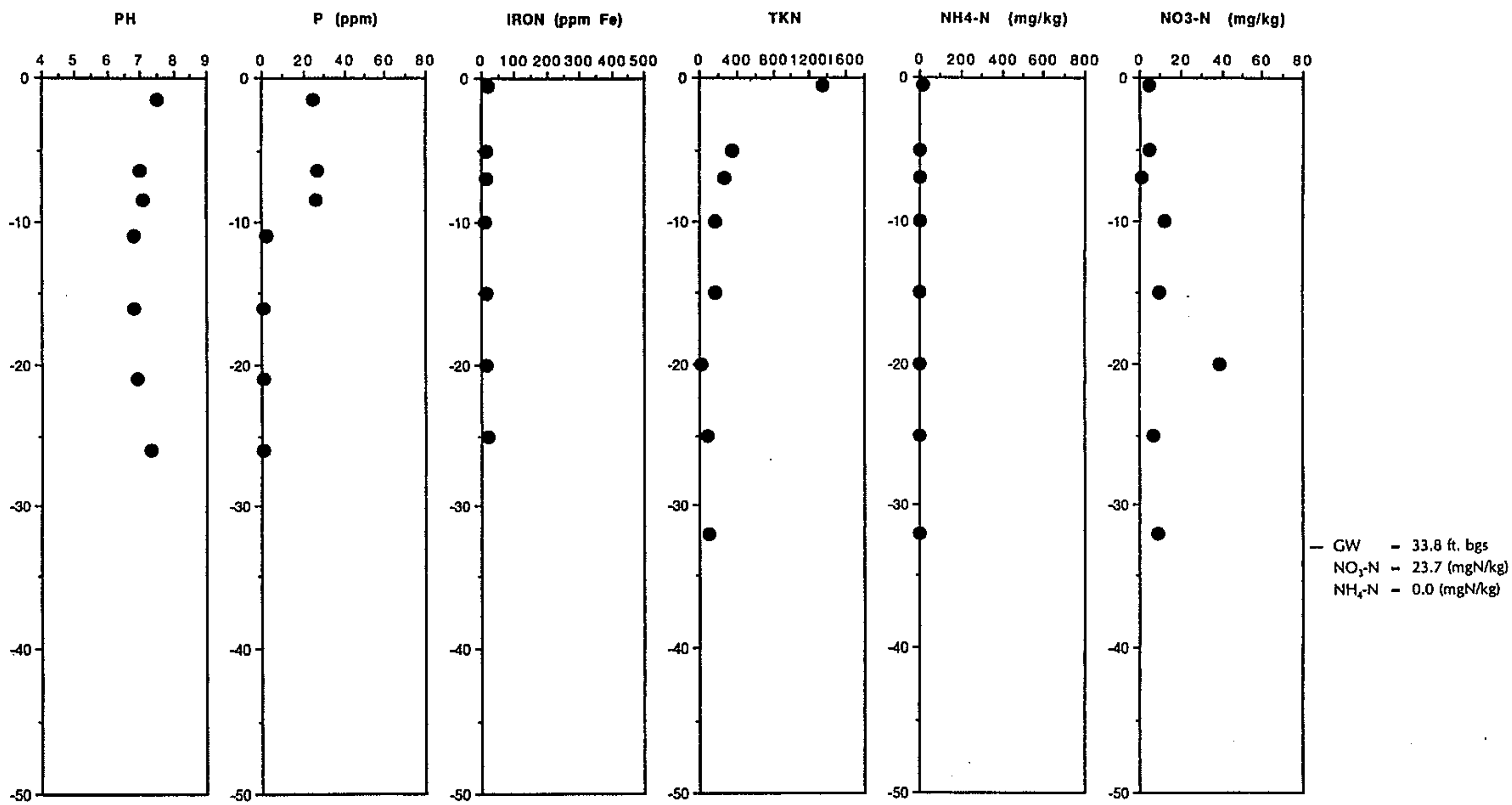
DAMES & MOORE
Job No. 27113-004-9595



apt

Analytical Results - Soil Boring B-3
Concentration vs Depth
Chico Urban Area
Butte County
Figure 11d

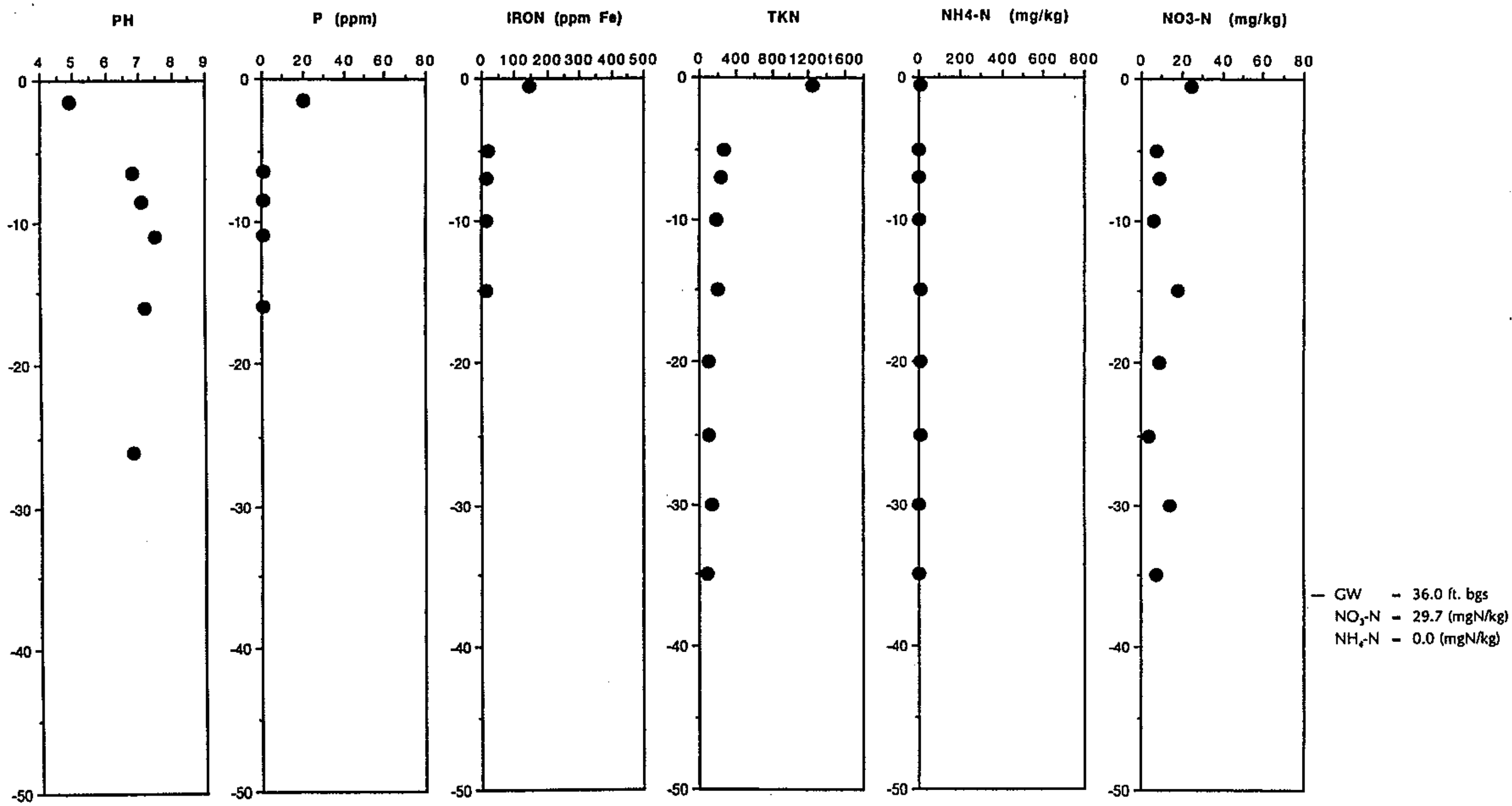
DAMES & MOORE
Job No. 27113-004-9595



SFR

Analytical Results - Soil Boring B-4
Concentration vs Depth
Chico Urban Area
Butte County
Figure 11e

DAMES & MOORE
Job No. 27113-004-9595



Analytical Results - Soil Boring B-5
Concentration vs Depth
Chico Urban Area
Butte County

DAMES & MOORE
Job No. 27113-004-9595

Figure 11f

SOIL BORING B-1

DRILLING METHOD	6" Hollow Stem Auger
SAMPLING METHOD	1.5" Cal. Modified Split Spoon Sampler
DATE COMPLETED	9/5/95
ELEVATION (TOP OF CASING)	

SAMPLING

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec
0	GP			24/18
	GP			24/12
5	GP			24/14
	GP			24/18
				24/20
10	GP			24/16
	GP			24/7
15	GP			24/10
	GP			24/12
	GP			12/6
	Drill			
20	Drill			
	Drill			
	DS			6/6
	Drill			
25	DS			6/6
	Drill			
	DS			6/6
	Drill			
30				
35				

SYMBOLS	DESCRIPTION
ML	DARK BROWN CLAYEY SILT, some sand, moist, soft, MC<PL, sand is very fine grained, rootlets. Decrease moisture.
SM	DARK BROWN SILTY SAND, trace clay, moist, loose to medium dense, sand is very fine to fine. Wet, decrease sand, increase silt. Decrease moisture to moist. Increase in sand (very fine to fine), decrease in clay.
SP	DARK BROWN MEDIUM SAND with fine gravel, moist, loose, (alluvial). Trace coarse gravel, (alluvial).
SM	DARK BROWN SILTY SAND, trace clay, wet, dense, sand is fine to medium.
SP	DARK BROWN MEDIUM SAND with fine gravel, wet, loose, (alluvial).
GM	BROWN SANDY GRAVEL with silt, moist, medium dense, gravel is 0.5 - >2" diameter angular to sub-rounded, sand is fine to medium angular to sub-rounded, poorly sorted. Increase cementation to weak to moderately cemented, decrease moisture to moist, volcanic clasts. Slough.
SM	RED-BROWN GRAVELLY SAND with silt, moist, medium dense to dense, sand is fine to coarse, predominantly medium angular to sub-rounded, gravel is 0.25 - >2" diameter, sub-rounded medium clasts.
GM	RED-BROWN SANDY GRAVEL with silt, moist, medium dense to dense, gravel is 0.25 - >2" diameter, sub-rounded to rounded, sand is fine to coarse, predominantly medium. Drilling refusal due to cobbles.

Total depth of boring = 29 ft bgs at 1810 hrs on 09/05/95.
Borehole grouted to 3 ft bgs on 09/05/95
Borehole filled to surface with native soil from 3 ft bgs and topped with grass 09/05/95.

Native Soil
Grout

SOIL BORING B-1

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-1B

DRILLING METHOD	8" HSA - Rhino Limited Access
SAMPLING METHOD	Continuous Core
DATE COMPLETED	9/26/95
ELEVATION (TOP OF CASING)	

SAMPLING

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec
0	CM	1	1A/	18/8
	DA			
5	CM	2	2A/2B	18/14
	CM	2	3A/3B	18/14
	DA			
10	CM	2	4A/4B	18/18
	DA			
20	CM	2	6A/6B	18/6
	DA			
25	CM	1	7A/	18/8
	CC			
	CC			
30	CC			
	CM	1	8A/8B	18/18
	CC			
35	CM	1	9A/	18/13

SYMBOLS / DESCRIPTION

Symbol	Description
ML	DARK BROWN CLAYEY SILT, some sand, moist, soft, MC<PL, sand is very fine grained, rootlets.
SM	DARK BROWN SILTY SAND, trace clay, moist, loose to medium dense, sand is very fine to fine. Increasing silt with depth, slight color change to gray brown. Variable amounts of silt and sand.
SP	OLIVE-BROWN GRAVELLY SAND with silt (10-15%), moist, loose, sand is fine to coarse, predominantly medium angular to sub-rounded, mostly mafic grains, gravel is .25 - .75" sub-angular to rounded.
GM	BROWN SANDY GRAVEL with silt, moist, medium dense, gravel is .5 - >2" diameter, angular to sub-rounded, sand is fine to medium, angular to sub-rounded, poorly sorted.
SM	Begin to continuous core. RED-BROWN GRAVELLY SAND with silt, moist, medium dense to dense, sand is fine to coarse, predominantly medium, angular to sub-rounded, gravel is .25 - >2" diameter, sub-rounded, MAFIC clasts.
GM	RED-BROWN SANDY GRAVEL with silt, moist, medium dense, gravel is predominantly .25 - >2" diameter, sub-rounded to rounded, sand is fine to coarse, predominantly medium, poorly sorted. Drilling very hard, large cobbles. Unable to sample at 30 feet, very hard, large cobbles suspected.
SM	RED-BROWN GRAVELLY SAND with silt, moist, medium dense.
ML	LIGHT BROWN CLAYEY SILT, trace fine sand, moist, MC<PL, small black fragments 1/16 - 1/8", small micropores. Increasing clay and moisture content with depth, mottled with red-brown.

Native Soil

Grout

Static Water Level

SOIL BORING B-1B

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-1B

DRILLING METHOD: 8" HSA - Rhino Limited Access
SAMPLING METHOD: Continuous Core
DATE COMPLETED: 9/26/95
ELEVATION (TOP OF CASING)

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec	Symbols	Description
35					ML	Variable amounts of silt and clay.
	CC					
	CC					
40	CM	2	10A/ 10B	18/18		
						Tag water at 41 ft bgs.
						Gradational contact.
					SM	OLIVE BROWN SILTY SAND, moist to wet, loose, sand is very fine to fine.
						Total depth of boring = 43.5 ft bgs at 11:15 on 9/26/95. Tag water at 41.0 ft bgs at 11:25 on 9/26/95. Hydropunch - only drive to 33 ft bgs, pull up and sample on 9/26/95. Borehole grouted to 3 ft bgs 9/26/95. Borehole filled to surface with native soil from 3 ft bgs and topped with topsoil and grass 9/26/95.
45						
50						
55						
60						
65						
70						

Grout

Static Water Level

SOIL BORING B-1B

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-2

DRILLING METHOD	6" Hollow Stem Auger
SAMPLING METHOD	2" Cal. Mod. Split Spoon Sampler
DATE COMPLETED	9/6/95
ELEVATION (TOP OF CASING)	

SAMPLING

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec
0	Drill			
	DS			24/17
				24/7
	DS			
5				24/18
	DS			
				24/16
	DS			
				24/19
10	DS			
				24/14
	DS			
	DS			24/16
15	DS			24/16
	DS			24/12
	DS			1/1
20	Drill			
	DS			12/12
	Drill			
	DS			3/3
	Drill			
25	DS			
	Drill			6/6
	DS			24/24
30	DS			24/24
	DS			24/18
35	HP			

DESCRIPTION

Symbols	Description
AC	Asphaltic concrete.
AB	Aggregate baserock.
ML	DARK BROWN SANDY SILT, some clay, moist, dense, sand is poorly graded fine to coarse.
	Decrease in clay to trace, sand predominantly fine, color change to gray-dark brown. Strong sewage odor, perched water at 4.77 ft bgs.
	DARK GRAY TO DARK BROWN SANDY SILT, wet, dense, sand is predominantly fine, decrease in clay to none.
SM	DARK GRAY SILTY SAND, wet, loose to medium dense, fine to medium sand, micaceous.
	Decrease in moisture to moist.
ML	YELLOWISH-RED TO DARK BROWN SANDY SILT, moist, dense.
ML	YELLOWISH-RED CLAYEY SILT with sand and gravel, moist, soft to medium stiff, fine to medium sand, gravel is fine.
GC	DARK BROWN SANDY GRAVEL with trace clay, wet, loose.
ML	YELLOWISH-RED RO DARK BROWN SANDY SILT, fine to medium sand, moist, dense.
SM	YELLOWISH-RED TO DARK BROWN SILTY SAND, moist, dense, sand is fine to medium grained, weakly to moderately cemented.
	Decrease in silt, increase is grain size to predominantly medium, decrease in cementation to weakly cemented.
ML	YELOWISH-RED CLAYEY SILT, moist, dense.

Note: Attempt Hydropunch from 33-38 ft bgs. Unable to drive Hydropunch.

Native Soil

Grout

Static Water Level

SOIL BORING B-2

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-2

DRILLING METHOD	6" Hollow Stem Auger
SAMPLING METHOD	2" Cal. Mod. Split Spoon Sampler
DATE COMPLETED	9/6/95
ELEVATION (TOP OF CASING)	

Depth in Feet	SAMPLING: Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec	SAMPLES	SYMBOLS	DESCRIPTION	Well (Grout)
35					(35–39)	ML		Grout (35–43.5)
39							Note: Attempt Hydropunch from 39-39.5 ft bgs. Unable to drive Hydropunch.	
43.5							Total depth of boring = 43.5 ft bgs at 18:33 on 9/6/95. Hydropunch - only drive to 33 ft bgs, pull up and sample. Borehole grouted to surface 9/6/96. Borehole topped with concrete.	

Depth scale: 35, 40, 45, 50, 55, 60, 65, 70

▼ *Static Water Level*

SOIL BORING B-2

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-2B

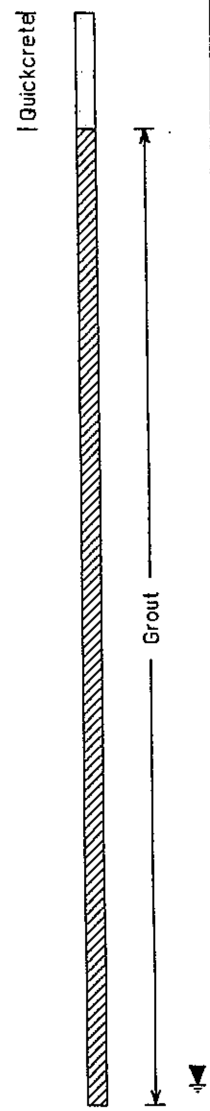
DRILLING METHOD	8" HSA - Rhino Limited Access
SAMPLING METHOD	Continuous Core
DATE COMPLETED	9/26/95
ELEVATION (TOP OF CASING)	

SAMPLING

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec
0	DA			
	CM	2	1A/1B	18/15
	CC			
	CC			
5	CM	2	2A/2AB	18/18
	CM	1	3A	18/8
	CC			
10	CM	2	4A/4B	18/14
	CC			
	CC			
15	CM	2	5A/5B	18/12
	CC			
	CC			
20	CM	1	6A	6/6
	CC			
	CC			
25	DA			
	CA	2	7A/7B	18/

SAMPLES

SYMBOLS	DESCRIPTION
AC	Asphaltic concrete.
AB	Aggregate baserock.
ML	DARK BROWN SANDY SILT, some clay, dry to moist, sand is very fine grained, MC≤PL.
	Color changes to brown, loss of clay, increase in very fine sand content, small micropores approximately 1/16" in diameter, variable sand content, dry to moist.
ML	OLIVE BROWN CLAYEY SILT with sand, moist, soft to medium, stiff, MC≤PL.
ML SM	RED-BROWN SANDY SILT/SILTY SAND, moist, soft, trace fine gravel, gravel approximately 1/4", sub-angular to sub-rounded.
SM	OLIVE BROWN SILTY SAND, moist, loose, sand is very fine to fine, well sorted, angular to sub-rounded.
ML	DARK BROWN SANDY SILT, moist, MC≤PL, soft, sand is very fine grained.
	Increase in clay content to sandy silt with clay, moist, sand is very fine, MC>PL.
	Increasing moisture content, moist to wet.
ML	RED-BROWN SANDY SILT, moist, well indurated, medium stiff to stiff, mottled, with black manganese oxide staining.
GM	OLIVE BROWN SILTY GRAVEL with sand, moist, gravel is 1/4 - >2" diameter, sub-angular to sub-rounded, sand is very fine to fine, gravels mostly mafic.
	Unable to sample due to large cobbles.
	Sample is saturated.
	Unable to sample due to large cobbles.
SM	BROWN SILTY SAND, trace clay, wet, medium dense, sand is very fine grained, increasing clay with depth, small micropores approximately 1/16" diameter, black organic material 1/8" fragments.
	Total depth of boring = 28.5 ft bgs at 17:40 on 9/26/95. Tag water at 28.05 ft bgs at 17:45 on 9/26/95. Grab groundwater sample on 9/26/95. Borehole grouted to 3 ft bgs 9/26/95. Borehole topped with Quickcrete on 9/26/95.



▼ *Static Water Level*

SOIL BORING B-2B

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-3

DRILLING METHOD: 8" HSA - Rhino Limited Access
SAMPLING METHOD: Continuous Core
DATE COMPLETED: 9/26/95
ELEVATION (TOP OF CASING)

SAMPLING

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec
0	CM	2	1A/1B	18/15
	CC			18/18
5	CM	2	2A/2B	18/18
	CM	2	3A/3B	18/18
	CC			
10	CM	2	4A/4B	18/12
	CC			
	CC			
15	CM	1	5A	18/8
	Begin	using	drive	hammer
	CC			
20	CM	1	6A	18/6
	CC			
	CC			
	CM	1	7A	18/6
25	CC			
	CC			
	CM	2	8A/8B	18/12

SYMBOLS	DESCRIPTION
ML	Lawn and roots to 6" bgs. RED-BROWN SANDY SILT, some clay, moist, rootlets to 5 ft bgs, sand is very fine to fine. Increasing moisture content with depth, MC>PL, decrease in clay content to none, increase in sand content to approximately 20 - 25%. Color change - gray, strong septic odor, set. Decrease in moisture content with depth. Gradational color change - brown, decrease in septic odor, decrease in moisture to moist.
SM	RED-BROWN SILTY SAND, moist, loose, sand is fine to medium grained, predominantly medium. Variable silt content, sand becoming predominantly fine, trace macropores, trace black organic material. Decrease in silt content to trace, increase in moisture content moist to wet, trace gravel, 1/2 - 3/4" rounded.
SM/SP	OLIVE BROWN GRAVELLY SAND, trace silt, trace gravel, wet, loose, sand is fine to coarse, predominantly medium sub-angular to sub-rounded, gravel is 1/4 - 3/4" sub-rounded.
CL	RED TO RED-BROWN SANDY CLAY with silt, dry to moist, medium stiff, manganese oxide staining, gravels 1/4 - 3/4" sub-rounded.
SM	RED TO RED-BROWN SILTY SAND with gravel, some clay, dry to moist, sand is fine to medium, gravel is 1/4 - 3/4" granite and mafic, variable clay content. Variable clay content in gravel matrix, MC<PL.
GM	RED-BROWN SILTY GRAVEL with sand, trace clay, wet, dense, sand is fine to medium, gravel is 1/4 - 3/4" rounded to sub-rounded, mafic.
SM	BROWN TO RED-BROWN SILTY SAND, trace clay, moist to wet, sand is fine to medium.
GM	RED-BROWN SILTY GRAVEL with sand, trace clay, wet, dense. Size of gravel increases to 2 - 3" diameter.
SM	GRAY-BROWN SILTY SAND, some gravel, wet, sand is fine to medium, predominantly medium angular to sub-rounded.

Total depth of boring = 31.5 ft bgs at 12:40 on 9/25/95.
Hydropunch from 31 - 35 ft bgs on 9/25/95.
Borehole grouted to 3 ft bgs 9/25/95.
Borehole filled from 3 ft bgs to surface with native soil and topped with grass 9/25/96.

Native Soil | Grout

▼ *Static Water Level*

SOIL BORING B-3

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-4

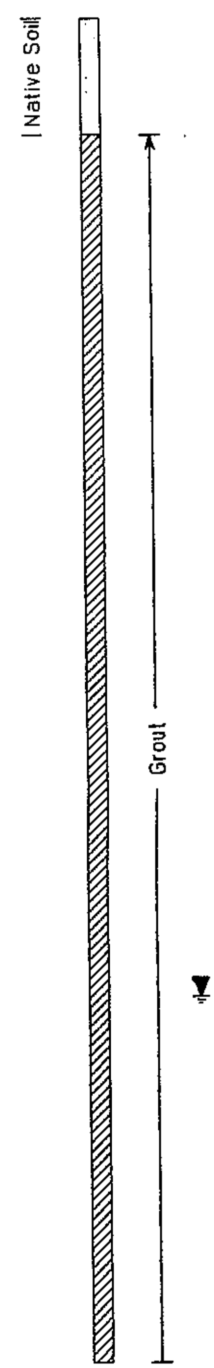
DRILLING METHOD	8" HSA - Rhino Limited Access
SAMPLING METHOD	Continuous Core
DATE COMPLETED	9/27/95
ELEVATION (TOP OF CASING)	

SAMPLING

Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec
CM	2	1A/1B	18/12
CC			
CC			
CM	2	2A/2B	18/12
CM	2	3A/3B	18/18
CC			
CM	2	4A/4B	18/13
CC			
CC			
CM			
CM	2	5A/5B	18/13
CC			
CC			
CM	2	6A/6B	18/13
CC			
CC			
CM	1	7A	18/7
CC			
CC			
CM	1	8A	18/7
CC			
CM	1	9A	6/6
CM			18/NR

Depth in Feet: 0, 5, 10, 15, 20, 25, 30, 35

SYMBOLS	DESCRIPTION
ML	DARK BROWN CLAYEY SILT, some sand, moist, MC<PL, abundant roots and rootlets, soft to very soft, sand is very grained.
ML	BROWN SILT, some sand, moist to dry, MC≤PL, sand is very fine, very soft to soft.
	Slight variation in fine sand content.
	Dry to slightly moist, very soft.
SM	BROWN SILTY SAND, dry to moist, loose to very loose, sand is very fine grained, well sorted, small micropores approximately 1/16" diameter.
ML	BROWN SANDY SILT, dry to moist, MC≤PL, very soft to soft, sand is very fine grained, small micropores up to 1/16" diameter.
	Increase in very fine sand content with depth.
SM	RED-BROWN SILTY SAND, moist, sand is very fine to fine (can no longer push sample, must hammer), poorly sorted mottled red-brown small micropores.
	Trace fine gravel, approximately 1/4" diameter, sub-angular to sub-rounded.
ML	OLIVE-BROWN SANDY GRAVEL with silt, moist, loose to medium dense, gravel is 1/2 to >2" diameter, sub-rounded, mostly mafic, sand is fine to coarse, predominantly medium, poorly sorted, angular to sub-rounded.
	Color change - red to red-brown, increase in clay in gravel matrix to some clay.
	Slight decrease in clay to trace clay.
	Decrease in gravel size to 1/4 to 1" clay, poorly sorted, increase in clay content to some clay, sand is fine to coarse.
	Large cobbles.



Static Water Level

SOIL BORING B-4

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-4

DRILLING METHOD	8" HSA – Rhino Limited Access
SAMPLING METHOD	Continuous Core
DATE COMPLETED	9/27/95
ELEVATION (TOP OF CASING)	

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec	SAMPLES	SYMBOLS	DESCRIPTION
35						ML	Total depth of boring = 35.5 ft bgs at 11:35 on 9/27/95. Tag water at 33.8 ft bgs at 11:32 on 9/27/95. Collect grab water sample at 11:40 on 9/27/95. Borehole grouted to 3 ft bgs 9/27/95. Borehole filled from 3 ft bgs to surface with native soil and topped with grass 9/27/96.
40							
45							
50							
55							
60							
65							
70							

Static Water Level

SOIL BORING B-5

DRILLING METHOD	8" HSA - Rhino Limited Access
SAMPLING METHOD	Continuous Core
DATE COMPLETED	9/27/95
ELEVATION (TOP OF CASING)	

SAMPLING

Depth in Feet	Sampler Type	No. of Rings	Sample #/Depth	Inches Driv/Rec
0	CM	1	1A/1B	18/7
	CC			
	CC			
5	CM	1	2A	18/8
	CM	2	3A/3B	18/12
	CC			
10	CM	1	4A	18/10
	CC			
	CC			
	CC			
15	CM	2	5A/5B	18/15
	CC			
	CC			
20	CM	1	6A	18/9
	CC			
	CC			
25	CM	1	7A	18/5
	DA			
	CC			
30	CM	1	8A	18/6
35	CM	1	9A	18/6

SYMBOLS	DESCRIPTION
ML	DARK BROWN CLAYEY SILT, trace sand, dry desication cracks at surface, MC≤PL, sand is very fine, moist at 6" bgs.
CL	DARK BROWN SILTY CLAY, trace sand, moist, MC<PL, soft, sand is very fine, brown organic material.
	Abundant micropores up to 1/8" diameter.
	Color change to brown, increase in silt content.
	Gradual increase in silt content with depth.
SM	BROWN CLAYEY SILT, trace fine sand, moist, MC<PL, sand is very fine, trace organic material - rootlets.
	Clay content decreasing with depth, fine sand content increasing with depth, abundant decaying organic material and micorpores up to 1/8" diameter.
	BROWN SANDY SILT, trace clay, moist, MC<PL, sand is very fine, decrease in amount of organic material.
	Color change to light brown with red-brown mottling, weak to moderately indurated, abundant macropores to 1/8" diameter.
CL	BROWN SILTY CLAY, trace fine sand, moist, MC<PL, soft.
ML	BROWN SANDY SILT, trace clay, moist, MC<PL, soft, mottled red-brown, increase in sand content and size with depth, trace gravels, 1/4" diameter rounded.
SM	Must use hammer to drive sampler. BROWN SILTY SAND, trace gravel, moist, loose to medium dense, sand is fine to medium, predominantly medium grained.
GM	SANDY GRAVEL with silt, moist, dense, gravel is 1/4 - 2" diameter, sub-rounded.
SC	CLAY SAND with silt, moist, loose to medium dense, sand is very fine, variable clay and silt content.
GM	SANDY GRAVEL with silt, moist, dense, gravel is 1/4 - <2" diameter, sub-angular to sub-rounded.
	Unable to drive sampler, drilling hard, large cobbles.
	Unable to drive sampler due to rock and large cobbles.

Native Soil

Grout

Static Water Level

SOIL BORING B-5

Butte County

Dames & Moore

27113-004-5305-044

SOIL BORING B-5

DRILLING METHOD	8" HSA - Rhino Limited Access
SAMPLING METHOD	Continuous Core
DATE COMPLETED	9/27/95
ELEVATION (TOP OF CASING)	

SAMPLING: Sampler Type | No. of Rings | Sample #/Depth | Inches Driv/Rec | SAMPLES

Depth in Feet	SYMBOLS		DESCRIPTION
35		GM	Sample saturated.
			Total depth of boring = 36.5 ft bgs at 16:35 on 9/27/95. Tag water at 36.0 ft bgs at 16:45 on 9/27/95. Collect grab water sample at 36 ft bgs at 17:00 on 9/27/95. Borehole grouted to 3 ft bgs 9/27/95. Borehole filled from 3 ft bgs to surface with native soil and topped with grass 9/27/96.
40			
45			
50			
55			
60			
65			
70			

Grout

▼ *Static Water Level*

Table B-1
Water Level Change in Well
22N/1E-9J2, 1984-1995
Chico Urban Area Nitrate Study

Date	R.P. to W.S[1] feet	W.T. Change[2] feet	Annual Precipitation year	Annual Precipitation inches
10/1/84	30.30		1984	20.92
3/4/85	24.50	5.80		
10/4/85	35.20		1985	16.29
3/4/86	24.00	11.20		
10/10/86	31.60		1986	25.73
5/26/87	27.20	4.40		
11/10/87	35.60		1987	25.76
3/17/88	32.70	2.90		
10/19/88	40.60		1988	16.50
3/10/89	33.40	7.20		
10/10/89	40.50		1989	21.89
3/5/90	34.10	6.40		
10/9/90	45.70		1990	15.32
3/6/91	40.00	5.70		
9/10/91	47.60		1991	22.48
3/4/92	39.10	8.50		
9/14/92	48.00		1992	24.23
4/16/93	32.40	15.60		
8/18/93	42.00		1993	24.08
3/15/94	34.00	8.00		
7/12/94	46.90		1994	23.50
4/20/95	26.50	20.40		
Average		8.74		21.52
Deep Percolation (in)		20.97		

[1] Reference Point to Water Surface
[2] Water Table Change

SUPPLEMENT NO. 1: RESPONSES TO QUESTIONS

BUTTE COUNTY
ADMINISTRATIVE OFFICE

MAY - 7 1996

OROVILLE, CALIFORNIA

TECHNICAL MEMORANDUM

HYDROLOGIC AND SOILS INVESTIGATIONS

CHICO URBAN AREA

The referenced technical memorandum was presented to members of the Citizen's Nitrate Advisory Committee (CNAC), by Dames & Moore soil scientist and principal author Jeff Bold, PhD., at the committee meeting of April 25, 1996. This supplement documents key questions and responses which arose in the discussion, and is offered for ongoing reference by committee members.

Question: Many aspects of the technical memorandum relate to material previously issued, can these previous documents be made available for convenient review by committee members and the general public?

Response: Key materials have been submitted to the Chico Branch of the Butte County Library and Meriam Library on the CSUC campus, and are available for review at those locations. This collection is listed on the attached sheet and may be augmented in the future as appropriate.

Question: Why was the isotope analysis (referred to as delta-N-15, or $\delta^{15}N$) conducted for groundwater samples, and what do the results mean?

Response: The isotope analysis of nitrate in groundwater samples is an additional tool used by hydrogeologists and groundwater chemists to characterize the source of nitrate in groundwater. As explained in more detail by Rolston, et al (1994), and summarized in the Technical Memorandum (p.13), $\delta^{15}N$ values found in background groundwater and groundwater samples impacted by fertilizers vary from approximately 0 to 5. Groundwater samples collected adjacent to dairies and other animal production operations results in $\delta^{15}N$ values from approximately 12 to 18.. Groundwater impacted by septic systems have $\delta^{15}N$ values from approximately 8 to 10, similar to the $\delta^{15}N$ values found in the unsewered areas of Chico. See Table 4 of the Technical Memorandum.

Question: Could leaking sewer pipes account for the observed nitrate impacts in groundwater?

Response: There is no information to support this contention, and substantial evidence and logic to refute it, as follows.

1. The location of nitrate impacts are adjacent to and downgradient from unsewered areas. The seven monitoring wells located in the sewered portions of central Chico show consistently low nitrate over the past three years. Out of the 19 groundwater samples collected from these seven wells, all 19 are less than 10 mgN/L, and 15 of 17 samples less than 5 mgN/L, well below the drinking water standard of 10 mgN/L.

2. Based upon known operations of the collection system, a worst-case assumption of the volume of sewer pipe leakage would be in the range of 5% of total wastewater volume in the system, during the 4-6 driest months of the year.. This assumed leakage would account for approximately 7.5 tons N/year, compared with the nitrogen discharged from septic systems of approximately 192 tons N/year. Thus, although sewer pipe leakage may be a minor source of nitrate in soils in the immediate vicinity of leaks, the volume is minor and cannot account for the widespread nitrate presence.

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BINDER-A

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BINDER-B

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SPIRAL BOUND

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3. Record data from the treatment plant indicate that flows are very consistent at about 100 gallons per person per day (gpcd) during dry weather. Because there are few signficant non-domestic dischargers, this is on the high side of average per capita wastewater flow, which averages 50-60 gpcd nationwide. Since the local flow is greater than the average, it seems highly unlikely that a substantial amount is leaking out of the pipe. Further, chemical analysis of the influent received at the treatment plant shows that the flow is not substantially diluted, as would be the case if fresh water were replacing sewage.

Question: Doesn't the contamination of some areas of Chico with trichloroethylene (TCE), which reached the soil from leaking sewer lines, indicate that nitrate contamination could also occur in this manner?

Response: The relative concentrations and risks must be understood. When solvents such as TCE or other hazardous substances are dumped into sewers, their concentrations exceed drinking water standards by a factor of 10,000 to 100,000. A small leak in the pipe could dangerously degrade the groundwater quality because the concentration is so much higher than the drinking water standard. Conversely, raw sewage is only 5 to 10 times the drinking water standard for nitrogen. Therefore, several complete breaks in the sewer lines would be necessary to contaminate groundwater above the drinking water standard in a significant area.

Question: Why did the recent Dames & Moore study not include a boring and soil sample analysis of a sewered portion of the Chico Urban Area.

Response: As indicated in the above response, there was virtually no reason to further investigate portions of Chico not impacted with nitrate, as is typical of those sewered areas that are outside of the influence of upgradient septic systems.

The soil boring program was undertaken to provide additional evidence that higher density residential dwellings on septic systems contribute substantially to the nitrate impacts on groundwater. The results of the analyses soil boring samples showed that high levels of ammonium-N in soils was the result of high septic wastewater loading associated with higher density dwellings. Soil borings completed in sewered areas would, at best, merely confirm or deny the presence of leaks at a specific location. This information is meaningless to our efforts, because we know that sewer leaks occur but their impact on groundwater is insignificant.

The above responses were prepared by Jeffrey Bold, PhD., Dames & Moore, Ronald Dykstra, P.E., RWQCB, and Stephen Honeycutt, Heritage Partners.

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GLOSSARY

A

acre-foot. A volume of water that covers one acre to a depth of one foot. Equivalent to 43,560 cubic feet or 325,829 gallons.

adsorption. The process by which chemicals are held on the surface of a mineral or soil particle.

alluvial. Describes unconsolidated material such as sand, gravel, and silt which has been deposited by flowing water.

aquifer. An underground formation of rock or sediment which is saturated and sufficiently permeable to transmit water to a well or spring.

B

best management practices. Techniques and practices that are accepted as the most effective and practical means to control pollutants or otherwise conserve water resources.

BMPs. See best management practices.

C

California Environmental Quality Act of 1970. An act that requires public agency decision makers to consider the environmental impacts of a proposed plan.

capital costs. Costs of financing construction and equipment. Capital costs are usually fixed, one-time expenses. Compare operating and maintenance costs.

carcinogen. A substance which produces cancer.

CEQA. See California Environmental Quality Act of 1970.

chlorination. The addition of chlorine to water, generally for the purpose of disinfection.

cone of depression. The depression or drop in water level near a well, resulting from the pumping of that well.

confined aquifer. An aquifer in which ground water is confined or overlain by an impermeable or semi-permeable formation. Compare unconfined aquifer, semi-confined aquifer.

contaminant. Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.

D

degradation. Chemical or biological breakdown of a complex compound into simpler compounds.

$\delta^{15}N$ (delta-15-N). The ratio of the two naturally occurring isotopes of nitrogen. This is expressed as a ratio of ^{15}N:^{14}N multiplied by 1000.

denitrification. The biochemical conversion of dissolved nitrate and nitrogen in soil or water to nitrogen gas.

diffusion. The movement of suspended or dissolved particles from an area of higher concentration to an area of lower concentration as the result of random movement of individual particles.

E

effluent. Water or other liquid flowing from a reservoir, basin, or treatment plant.

EPA. The U.S. Environmental Protection Agency.

F

filtration. The process of removing particulate matter from water by passing it through a porous medium.

fresh water. Water that contains less than 1,000 mg/l total dissolved solids.

G

geophysical log. A detailed description of all underground features discovered during the drilling of a well, including types of formations encountered and their physical characteristics.

gpd. Gallons per day.

grey water. Wastewater other than sewage, such as sink, shower, or washing machine drainage.

groundwater, ground water. Water occurring beneath the earth's surface.

groundwater basin. An interconnected permeable geologic formation capable of storing a significant groundwater supply.

H

hydraulic conductivity. A measure of the rate at which water can move through a permeable medium (soil).

hydraulic gradient. The slope of the water table at a particular point.

hydrologic cycle. The natural process by which water cycles from the atmosphere to the earth (via precipitation), and back to the atmosphere again (via evaporation and other processes).

hydrology. The study of the occurrence, distribution, circulation, and characteristics of natural waters of the earth.

I

impermeable. Describes material or soil that significantly restricts the movement or passage of water. Compare permeable.

infiltration. The flow of water downward from the land surface into and through soil layers.

influent. Water or other liquid flowing into a reservoir, basin, or treatment plant.

inorganic. Describes material that is of mineral origin. Specifically, describes chemical compounds that do not contain carbon and hydrogen. Compare organic.

isotopes. Forms of an element with differing atomic masses due to variable numbers of neutrons.

JKL

landfill. A facility in which solid waste from municipal or industrial sources is disposed.

leachate. The liquid waste that results from water passing through waste materials.

M

maximum contaminant level. The highest level of a contaminant permissible in water in a public water system.

MCL. See maximum contaminant level.

mg/l. See milligrams per liter.

mgd. Million gallons per day.

milligrams per liter. A measure of concentration of a dissolved substance. A concentration of 1 mg/l means that one milligram of a substance is dissolved in each liter of water. For practical purposes, this unit of measurement is equivalent to parts per million, or ppm.

modeling. Use of mathematical equations to simulate and predict real events and processes.

monitoring well. A well used either to collect water samples for purposes of water quality testing, or to measure groundwater levels.

MOU. Memorandum of Understanding.

municipal waste. Waste originating from a community. May be composed of domestic (sewage) and industrial wastewater.

N

non-point source. A source of pollution that does not have a single point of origin. Pollution from a farmer's field or from urban street runoff falls in this category. Compare point source.

non-potable. Describes water that may contain objectionable pollution, contamination, minerals, or infective agents and is considered unsafe or unsuitable for drinking. Compare potable.

NPDES. National Pollutant Discharge Elimination System. Established under the Clean Water Act of 1972, it provides for regulation and monitoring of municipal and industrial waste discharges through a permit system.

O

operation and maintenance costs. The costs of operating a system such as a treatment plant. "O & M" costs are ongoing expenses, such as for repair or for employee salaries. Compare capital costs.

organic. Describes material that originates from plant or animal sources. Specifically, describes chemical compounds containing carbon and hydrogen. Compare inorganic.

P

parts per million. A measure of concentration of a dissolved substance. Compare milligrams per liter.

pathogen. A microorganism capable of causing disease.

percolation. The slow seepage of water into and through the ground.

permeability. Describes the ability of rock or soil to transmit water.

permeable. Describes material or soil that allows the movement or passage of water through it. Compare impermeable.

plume. The area occupied by a groundwater contaminant after it has begun to spread, through diffusion or other forces, away from its point of origin.

point source. A stationary source or fixed facility from which pollutants are discharged. Compare non-point source.

pollutant. Any substance introduced into the environment may that adversely affect the usefulness of a resource.

pore space. The space between mineral grains in a porous medium.

potable. Describes water that is safe and satisfactory for drinking and cooking. Compare non-potable water.

potentiometric surface. The level to which water will rise in a well that penetrates an aquifer. In an unconfined aquifer, equivalent to the water table.

ppm. See parts per million.

precipitation. Atmospheric moisture, such as rain or snow, that falls to earth.

primary treatment. Initial stage of treatment of wastewater, primarily consisting of removal of settleable solids.

public water system. A system for the provision to the public of piped water intended for human consumption. Such system must have at least 15 service connections, or regularly serve an average of at least 25 individuals daily for at least 60 days out of the year.

QR

receiving waters. Bodies of water that receive runoff or wastewater discharges, such as streams, rivers, and lakes.

recharge. Process by which precipitation or applied water seeps or percolates into the groundwater system.

reclaimed water. Wastewater that has been treated and brought to a level of water quality that makes it suitable for further beneficial use, e.g. irrigation or drinking.

remedial action plan. A formal plan of action for cleanup of a contaminated site.

reservoir. A natural or man-made holding area used to store, regulate, or control water.

runoff. That part of precipitation, snow melt, or irrigation water that drains or flows off the land into streams or other surface waters.

S

Safe Drinking Water Act. An Act passed by Congress in 1976 that establishes a cooperative program among local, state, and federal agencies to insure safe drinking water for consumers. It authorizes EPA to set drinking water standards (including maximum contaminant levels), and provides special protection to sole source aquifers.

salinity. The relative concentration of dissolved salts in water.

saturated zone. The area below the water table where all open spaces are filled with water. Compare unsaturated zone.

secondary treatment. Stage of wastewater treatment wherein bacteria are used to break down organic materials and significantly reduce biochemical oxygen demand.

semi-confined aquifer. An aquifer that is partially confined or overlain by a formation of low permeability through which water can pass slowly. Compare confined aquifer, unconfined aquifer.

sole source aquifer. An aquifer that supplies 50 percent or more of the drinking water for an area.

spreading basin, spreading grounds. A man-made basin or series of basins designed to retain water for the purpose of recharging groundwater supplies.

static water level. The elevation or level of water in a well when the pump is not operating.

surface water. All water naturally open to the atmosphere, including rivers, streams, lakes, reservoirs, etc.

T

TDS. See total dissolved solids.

tertiary treatment. An advanced stage of wastewater treatment designed to remove nutrients or other constituents remaining after secondary treatment.

Title 22. That portion of the California Administrative Code which requires that producers of drinking water regularly monitor their wells and other sources of supply for various chemical constituents.

total dissolved solids. All of the dissolved solids in a sample of water, measured by evaporating the sample and weighing the residue.

transmissivity. The rate at which water is transmitted through an aquifer.

U

unconfined aquifer. An aquifer that does not have confining formations or layers. Compare confined aquifer, semi-confined aquifer.

unsaturated zone. The area between the land surface and water table in which pore spaces are not completely filled with water. Also known as the vadose zone. Compare saturated zone.

V

vadose zone. See unsaturated zone.

W

wastewater. The used water and dissolved and suspended solids that are the result of domestic or industrial uses of water Includes municipal waste or sewage.

water purveyor. An agency or person that supplies water.

water supply system. A facility designed for the distribution of potable water, typically including storage tanks and a network of pipes.

water table. The elevation or level of ground water. The upper surface of the saturated zone in an unconfined aquifer.

watershed. The land area that drains into a stream. An area that contributes runoff to a specific body of water. Same as drainage basin, hydrologic basin.

well. A bored, drilled, or driven shaft, or a dug hole, whose purpose is to reach underground water supplies.

XYZ