GROUND WATER QUALITY IN THE SOUTH GRASSLAND AREA OF THE WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

California Regional Water Quality Control Board
Central Valley Region
3443 Routier Road, Sacramento, California

May, 1989

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

The staff persons involved in the preparation of this report are:

Polly Lowry, Environmental Specialist
Rudy J. Schnagl, Senior Land and Water Use Analyst
Jeanne L. Gonzalez, Geologic Assistant

Special thanks go to the well owners in the South Grassland area, without whose cooperation this study would not have been possible.

TABLE OF CONTENTS

APPENDICES

FIGURES AND TABLES

FIGURES

TABLES

SUMMARY

To determine if the long-term use of irrigation return flows entering the Southern Division of the Grassland Water District (SDGWD) has impacted the quality of the local ground water, the Regional Board staff began a survey of well use in the South Grassland area in the summer of 1985 and sampled 44 wells for mineral and trace elements between August 1985 and July 1986. Wells were sampled in three different zones. Zone 1 is within the SDGWD and represents the area which has received agricultural drainage discharges prior to 1985 for spring and summer irrigation and as part of the fall and winter wetland floodwater. Zone 2 is upslope of Zone 1 and represents upgradient water quality. Zone 3, to the north and east of the SDGWD, is downslope of Zone 1 and was chosen to determine if the quality of ground water in this zone is similar to that in Zone 1. In determining the possible causes of the identified ground water quality problems a review was made of the history of land and water use, quality of the irrigation water, ground water geochemistry, and well construction methods common in the area.

Of the 136 active wells identified in the study area, over half are currently being used for domestic purposes, with irrigation being the second most common use. Ground water is also being used to a limited extent for stock watering, dairy operations, industrial purposes, and for recreation. Of the 44 wells which were sampled 34 are domestic wells, nine are irrigation wells, and one is used for both domestic and stock watering purposes. Except for one well completed in the lower water-bearing zone in Zone 3, all wells sampled are completed in the upper water-bearing zone.

Levels of TDS, EC, and chloride in Zones 1 and 3 are similar and significantly higher than in Zone 2. Median TDS, EC, and chloride concentrations were 920 mg/L, 1485 µmhos/cm, and 155 mg/L, respectively, in Zone 2. Median TDS and EC in Zones 1 and 3 were approximately three times those observed in Zone 2, while median chloride concentrations were approximately seven times those observed in Zone 2. Zone 1 had a median boron concentration of 4 mg/L, while Zones 2 and 3 had median boron concentrations of 1.6 and 1.4 mg/L, respectively.

With the exception of molybdenum in Zone 1, median trace element concentrations in Zones 1 and 3 were both low, typically near or below their detection limits. In Zone 1 the median molybdenum concentration was 12 µg/L. Except for selenium and chromium the median trace element concentrations were low in Zone 2 also. The median concentrations of selenium and chromium in this zone were 3 µg/L and 38 µg/L, respectively.

The quality of the ground water in each of the three study zones has an impact on the identified beneficial uses. The TDS in all 12 of the domestic wells sampled in Zone 1, nine of the 18 domestic wells sampled in Zone 2, and all five of the domestic wells sampled in Zone 3 was near or greater than the EPA's maximum recommended secondary drinking water criterion of 1000 mg/L. Selenium concentrations in two domestic wells in Zone 2 were at or slightly greater than the state's primary maximum contaminant level (MCL) of 10 µg/L. These two wells ranged from 10 to 14 µg/L selenium. One well in Zone 2 had a chromium level of 56 µg/L, exceeding the state's MCL of 50 µg/L.

In Zone 2 three irrigation wells, ranging from 2.1 to 4.6 mg/L boron, exceeded boron levels suggested for agricultural water quality. Two of these wells had 350 and 370 mg/L chloride, at or above the 10 meq/L level recommended to prevent severe problems in chloride sensitive plants. In addition, one of these two wells had a selenium concentration of 30 µg/L, which exceeds the agricultural water quality goal of 20 µg/L. The EC of 5600 µmhos/cm and 1600 mg/L chloride concentration of the one irrigation well in Zone 3 exceeded water quality goals for agriculture.

Prior to 1985 Zone 1 received agricultural drainage water from upslope areas for spring and summer irrigation. Both Delta Mendota Canal (DMC) water and agricultural drainage water was used for flooding wetlands in the fall and winter months. In 1985 the SDGWD stopped using agricultural drainage water and relied on surplus irrigation water from upslope areas for spring and summer irrigation. DMC water continued to be used for fall and winter flooding of the wetlands. Zone 2 is supplied with irrigation water from the DMC, the Mendota Pool, the California Aqueduct, some irrigation wells, and minor diversions from the Almond Drive Drain and the Charleston Drain. Zone 3 is supplied with irrigation water from the Mendota Pool and a few irrigation wells.

The quality of the irrigation supply water from the DMC and Mendota Pool is considerably better than that of the agricultural drainage water which was used in Zone 1 prior to 1985. From December 1985 to September 1986 water from the both the DMC and the Mendota Pool had median values of EC, boron, and chloride below 750 µmhos/cm, 0.75 mg/L, and 100 mg/L, respectively. All median trace element concentrations were well below any water quality criteria for either drinking water or agricultural purposes.

Median values of salinity, boron, and chloride in the agricultural drainage water discharged to Zone 1 prior to 1985 were commonly above levels recommended for agricultural purposes. In water year 1986 the range of median values of EC, boron, and chloride for six of the seven drains which discharged to the SDGWD were between 2950 and 4500 µmhos/cm, 3.9 and 8.1 mg/L, and 375 and 510 mg/L, respectively. Except for selenium and molybdenum, median trace element concentrations of these drains do not exceed either drinking or agricultural water quality criteria. The range of median values of selenium and molybdenum were 3 to 93 µg/L and less than 5 to 14 µg/L, respectively.

Although both the application of agricultural drainage water to the SDGWD and the natural features of the area have probably affected the quality of ground water in Zone 1, it is not possible to determine from this study which has had a stronger influence. It is known from early studies that the quality of the ground water in the SDGWD was of poor quality even before subsurface drainage was applied to the area. The arid climate, shallow water table, and fine-textured and poorly-drained soils present in the SDGWD have resulted in the evaporative concentration of salts in both soils and ground water. The application of agricultural drainage water high in salinity, boron, chloride and molybdenum results in further evapoconcentration of these parameters. Salinity, boron, and chloride may also be higher in this zone than in Zone 2 due to natural increases in the downslope direction, while higher molybdenum concentrations are probably related to the presence of Sierra Nevada deposits.

High selenium concentrations in the agricultural drainage water which was applied to the wetlands in Zone 1 does not appear to have impacted the quality of the ground water in this zone. However, it has resulted in the bioaccumulation of selenium by the aquatic food chain of waterfowl and waterbirds in the South Grassland area and probably the accumulation of selenium in the sediments in the wetlands.

The natural features of the area probably have the major influence on ground water quality in Zone 2. Concentrations of selenium and chromium in this zone appear to be related to Coast Range source material, while detectable levels of molybdenum are probably related to Sierra Nevada sediments. Elevated levels of TDS, boron, and chloride occur in both ground water derived from Coast Range sediments as well as in ground water derived from a combination of Sierra Nevada and Coast Range sediments, however the highest concentrations of these three parameters occur in ground water derived from both the Sierra Nevada and Coast Range sediments.

TDS, chloride, selenium, and chromium concentrations in Zone 3 were similar to those concentrations observed in Zone 1. While these concentrations may reflect movement downgradient from Zone 1, they may also reflect naturally elevated levels common in ground water derived from both Coast Range and Sierra Nevada sediments and/or they may be due to the evapoconcentration which occurs in an arid climate and shallow water table.

The available data indicates that it is not unusual for wells in the study area to be completed without a sanitary surface seal. Such wells allow surface water to move readily down the annular space of the well and into the water-bearing zone, carrying any pollutants with it. Due to the large number of wells in the area it is possible that agricultural drainage water has moved into the upper water-bearing zone in this manner.

INTRODUCTION

Purpose

The discovery of high levels of selenium and other trace elements in the irrigation return flows entering the Grassland Water District (GWD) raised the concern that the long term use of this water in the Grassland area may have impacted the qualilty of the local ground water. This study was conducted to determine to what extent the ground water in the Southern Division of the Grasssland Water District (SDGWD) is used, what the beneficial uses of the ground water are, and to identify and determine the causes of any water quality problems.

Scope of the Investigation

To determine the extent of ground water use in the study area , a search of well logs on file at the California Department of Water Resources (CDWR) was conducted and a field survey of all wells in the area was initiated in August 1985. To determine beneficial uses the Water Quality Control Plan for the San Joaquin River Basin (SWRCB, 1975) was reviewed and information from well logs and well owners was obtained. A sampling program was initiated in August 1985 and ended in July 1986 to determine the ground water quality in as many of the operating wells as possible. This water quality data was used to identify constituents which are of concern to the current beneficial uses.

In determining the causes of water quality problems the history of land and water use in the South Grassland area was reviewed and the quality of both the agricultural drainage water and surface water used for irrigation in the area was studied. In addition, the upgradient water quality was determined and a review of the natural geochemistry of the ground water was made in an effort to separate natural causes of water quality problems from those which may result from irrigation practices. Well construction methods were studied to determine the influences these practices may have on the ground water quality.

STUDY AREA

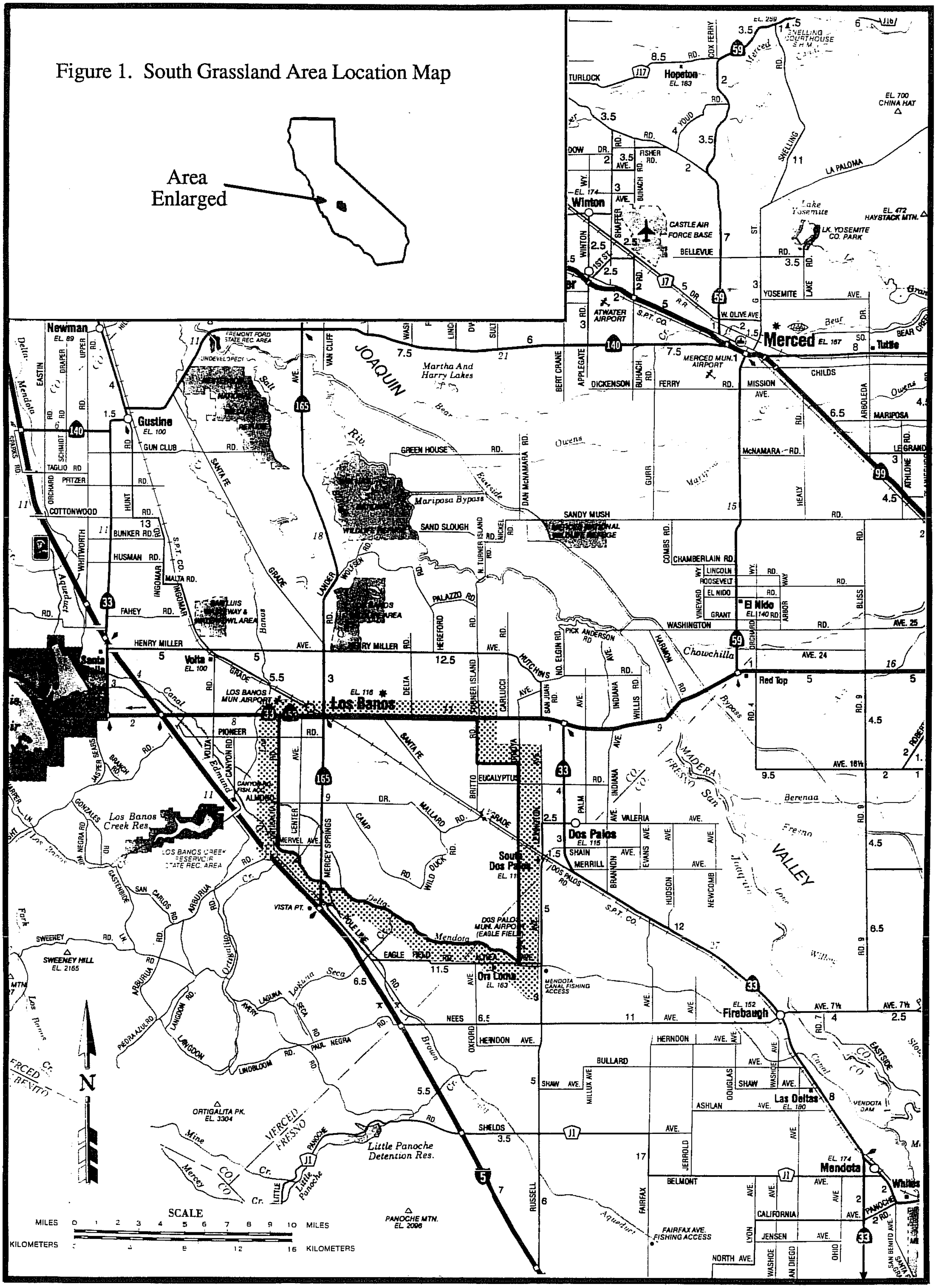
Area Description

The study area covers approximately 82 square miles in the western San Joaquin Valley between Los Banos and South Dos Palos (Figure 1). It includes almost all of the 20,642 acres within the SDGWD and some of the surrounding areas to the north, south, east and west.

The topography of the study area is gently sloping to flat. The highest elevation is 200 feet above sea level in the southwest. The land slopes gradually down toward the northeast to an elevation of 100 feet in the central portion of the study area. From this central area, the remaining land to the north and east is nearly flat.

Hot, dry summers and cool, damp winters characterize the study area. Summer temperatures often exceed 100° F, while winter temperatures are seldom below freezing. The average precipitation is 10 inches per year, with peak rainfalls occurring between November and February (Kauffeld and Loth, 1985).

Figure 1. South Grassland Area Location Map



Most of the land in the central portion of the study area is owned by hunting clubs and is flooded during the fall and winter to attract migratory waterfowl. During the spring and summer this seasonal wetland is drained to encourage the growth of food plants for waterfowl, while some sections are used for pasture. The land on the west and east sides of the study area is privately owned and used for irrigated agriculture. Two dairies are present on the west side of the study area.

Historical Land and Water Use

From 1860 to about 1935 water from the San Joaquin River and other natural streams and sloughs were diverted to the Grasslands area (the area covered by the northern and southern divisions of the current Grassland Water District) to irrigate cropland, pasture land, and the wetlands waterfowl habitat. The Delta Mendota Canal (DMC) was designed in 1935 to bring water from the Sacramento-San Joaquin Delta area to the Grasslands area. From 1944 to 1951 interim water from the Central Valley Project (CVP) was used to supply cattlemen and duck clubs. In 1954 the GWD was formed to assume responsibility for the distribution of water and maintenance of facilities in the 51,000 acre district, of which 20,642 acres is in the SDGWD. After 1954 the GWD serviced the 51,000 acres with 50,000 acre-feet of CVP contract water and drain water from upslope agricultural land. Drainage water in the 1950's was primarily surface drainage and operational spill with some subsurface drainage. In 1963 GWD received an additional 3,500 acre-feet per year of CVP water, increasing the total CVP water to 53,500 acre-feet per year.

Perched water levels in the croplands upslope of the SDGWD began to rise as a result of the importation of CVP water via the DMC and the subsequent increase in irrigated cropland. Tile drain systems were installed to control the rising water table. These systems discharged subsurface drainage from the upslope croplands into the historical drainage systems serving the GWD. The subsurface drainage, high in TDS, boron, and selenium, gradually changed the quality of water available to the GWD as more and more tile drain systems were installed. Prior to 1985 drain water alone was used to irrigate the GWD wetland habitat and grazing lands in the spring and summer. The drain water is discharged from several draining entities to the south of the SDGWD. Fresh water from the CVP was mixed with drain water for flooding the wetlands in the fall and winter.

In 1980 water quality standards of 2,500 parts per million (ppm) TDS and 6 ppm boron were set for drainage entering the district. In early 1985 elevated levels of selenium in the drain water was recognized as a potential threat to waterfowl and other wildlife and to downstream water quality. As a result, in 1985 water users in the GWD ceased using drain water for irrigation to prevent any further contamination of land, fish, or wildlife. An additional 23,779 acre-feet of fresh water from the CVP and the draining entities allowed the GWD duck clubs to provide fall and winter habitat and hunting in 1985. Additional surplus irrigation water from the areas to the south of the SDGWD was used for irrigation in the SDGWD during the spring and summer of 1985 and 1986.

Present Land and Water Use

Most of the 20,642 acres of the SDGWD is managed to provide habitat for wintering waterfowl. Portions of the study area surrounding the SGWD are used for agriculture. Crops grown include alfalfa, corn, cotton, melons, sugar beets, rice, and tomatoes in addition to permanent pasture and tree crops such as apricots, almonds, walnuts, and plums. These crops are irrigated with water from the DMC and the Mendota Pool.

The SDGWD currently receives about 22,500 acre feet per year (af/y) of CVP water which is used from mid-September to November 30 to flood the wetland habitat (Marciochi, 1987 personal communication).

Recreational activities in the SDGWD include waterfowl hunting, fishing, upland game hunting, birdwatching, and nature tours.

Study Zones

For the purposes of this report, the study area has been divided into three zones (Figure 2). Zone 1 includes the land which has received agricultural drainage water for spring and summer irrigation and fall and winter flooding prior to 1985 (Paveglio and Bunck, 1987). Almost all of this zone lies within the SDGWD. Zone 2 is to the west and south of Zone 1. It is upslope of Zone 1 and was sampled to represent upgradient water quality. Zone 3 covers the area to the north and east of Zone 1. This zone is downslope of Zone 1 and was included to determine if ground water in Zone 3 is similar to that in the SDGWD.

GEOLOGY

The San Joaquin Valley is a broad structural trough which forms the southern two-thirds of the Central Valley. Its border extends to the Sierra Nevada fault block on the east and to the folded and faulted Coast Ranges on the west. The valley has received marine and continental deposits from both of these mountain blocks. Deposits in the eastern and central parts of the valley are gently dipping to horizontal, unconformably overlying Sierra Nevada granitic rocks. Steeply dipping deposits lie unconformably over ultramafic intrusives and the Franciscan Formation at the valley's extreme western boundary. The sediments in the west-central part of the valley are greater than 12,000 feet.

The San Joaquin River and its tributaries drain the San Joaquin Valley between Mendota and the Sacramento-San Joaquin Delta. Intermittent streams drain both the Coast Ranges and the Sierra Nevada. In addition, four major rivers drain the Sierra Nevada in the northern San Joaquin Valley. The present location of the San Joaquin Valley's axis is a result of an eastward migration which started about 600,000 years ago. Thus, Sierra Nevada deposits extend far west of the modern day axis, and interfinger with Coast Range deposits in the subsurface.

Low alluvial plains and fans make up the majority of the valley floor. These plains and fans are underlain by undeformed to slightly deformed Quaternary alluvial sediments deposited by streams draining the mountains bordering the uplands. Sandy soils are typical on the upper parts of the fans while silty soils are more common at the lower ends. Overflow lands in the valley trough are bounded on both the east and west by the low plains and fans. The soils underlying these areas are impervious clays and clay adobe.

The geology of the ground water reservoirs underlying the South Grassland area consists of consolidated and unconsolidated deposits. The younger unconsolidated deposits are the most important water-bearing formations. While the older consolidated deposits underlying the study area are not an important source of ground water these same formations make up the hills of the Coast Ranges, and are thus the source material of the valley's sediments.

Consolidated Deposits

Consolidated deposits underlying the water-bearing deposits beneath the western San Joaquin Valley consist of a basement complex and overlying sedimentary rocks. The basement complex is composed of unknown thicknesses of granitic, ultramafic, and Franciscan rocks of Jurassic and Cretaceous age. The sedimentary rocks overlying the basement complex are mostly marine deposits of Late Cretaceous to Miocene age. These deposits are in fault contact with the Franciscan Formation and are at least 10,000 feet thick.

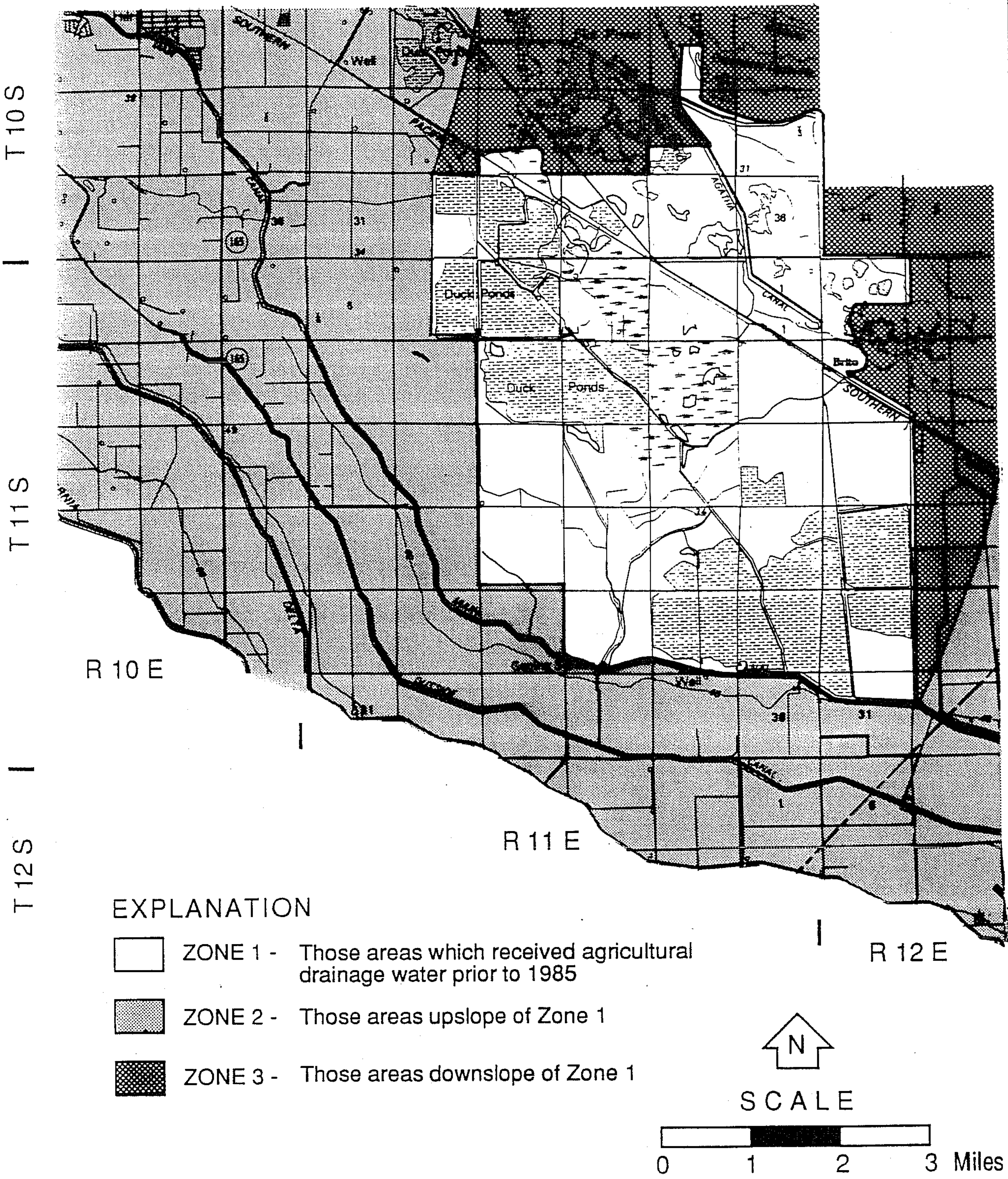


Figure 2. South Grassland Ground Water Study Area

Both the marine sedimentary rock and Franciscan rocks make up the hills of the Coast Ranges, dipping eastward beneath the younger water-bearing sediments in the western San Joaquin Valley. These consolidated rocks have very limited use as a ground water reservoir due to poor permeability and/or high salinity.

Unconsolidated Deposits

Unconsolidated deposits underlying the western San Joaquin Valley consist of continental deposits of the Pliocene to Pleistocene age Tulare Formation and Quaternary age terrace, alluvium, and flood-basin deposits. Figure 3 shows the geomorphology within the study area.

The Tulare Formation is the most important water-bearing formation in the western San Joaquin Valley, its base approximating the base of the usable ground water reservoir. This formation lies conformably over the consolidated marine sediments and is up to 1000 feet thick between Tracy and Dos Palos. Beds, lenses, and tongues of clay, sand, and gravel derived from the Coast Ranges to the west and the Sierra Nevada to the east make up the Tulare Formation. Coast Range deposits derived from the Franciscan Formation and younger sedimentary rocks are interbedded with micaceous, arkosic Sierran deposits (Figure 4). These sediments were deposited in alternating subaerial oxidizing and subaqueous reducing environments.

A continuous, greenish-blue to gray diatomaceous clay layer within the Tulare Formation underlies the entire west side of the San Joaquin Valley between Tracy and Dos Palos, cropping out along the foothills of the Coast Ranges. This clay, the Corcoran Clay, divides the Tulare Formation into an upper and lower section, having a maximum measured thickness and average thickness of 120 and 80 feet, respectively, between Tracy and Dos Palos. The upper section of the Tulare Formation is approximately 200 feet thick near Dos Palos, thinning to a featheredge along the valley margin to the west. Coast Range and Sierra Nevada source material in the upper section vary from oxidized to reduced deposits, oxidized deposits usually consisting of Coast Range sediments deposited on alluvial fans. Reduced sediments deposited in either the valley trough or in lakes can be Coast Range or Sierra Nevada deposits.

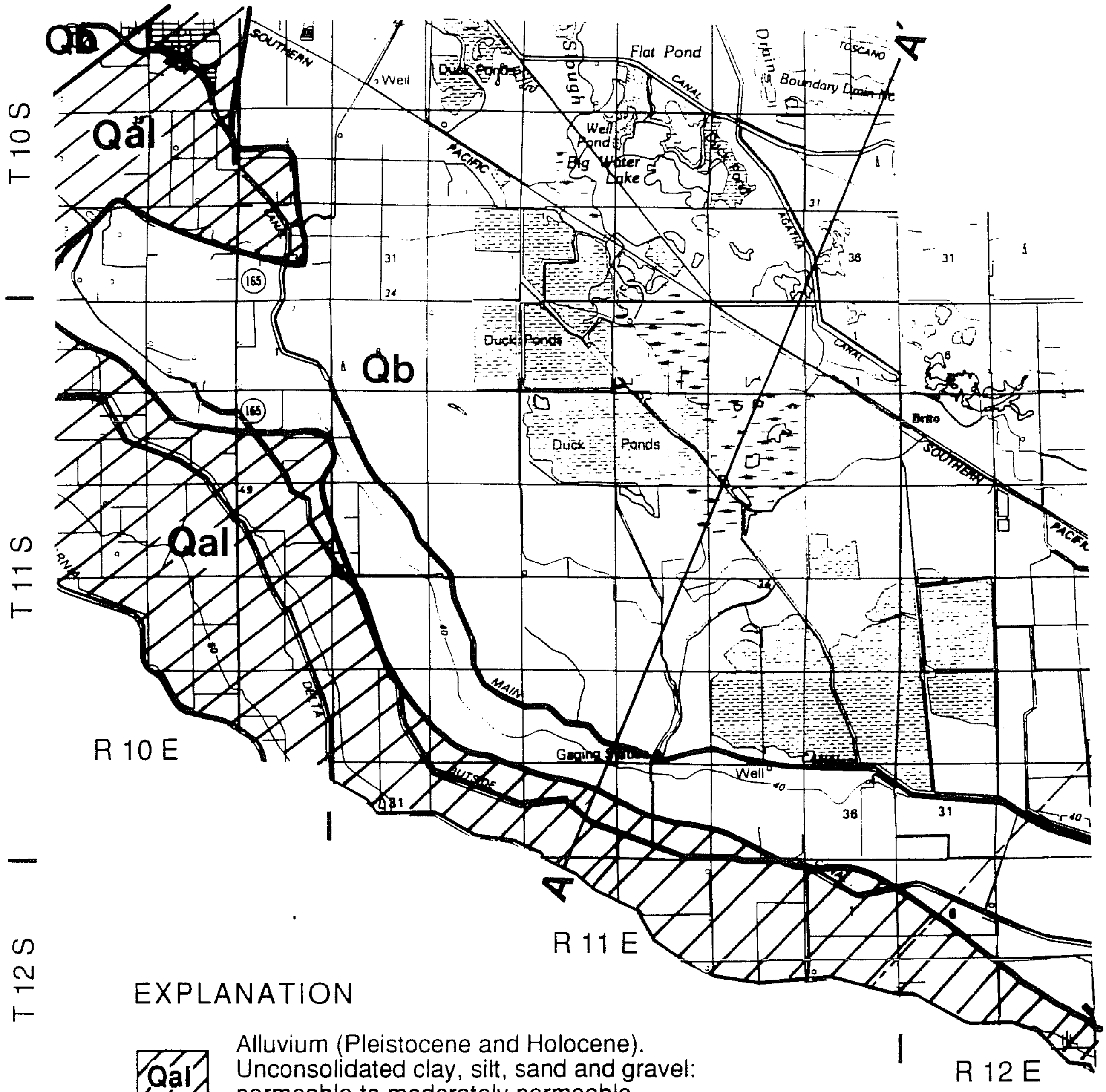
Below the Corcoran Clay, the lower section of the Tulare Formation thickens from a featheredge along the foothills of the Coast Range to about 650 feet in the valley trough near Dos Palos. In addition to being mostly reduced, the sediments in the lower section are mostly derived from the Coast Ranges.

Pleistocene Terrace deposits overlie the older Tulare Formation along the valley margin. These deposits consist of yellow, tan, and light- to dark-brown silt, sand, and gravel in a matrix of sand and/or clay. At Panoche and Cantua Creeks to the south of Dos Palos the terrace deposits range in thickness from 2 to 20 feet. Usually these deposits are flat-lying, but may dip up to 9 degrees to the northeast into the San Joaquin Valley.

Pleistocene and Holocene alluvium lies conformably over the Tulare Formation in the valley, while angular discordance characterizes the contact between these two formations along the Coast Range foothills. Where alluvium overlies terrace deposits the contact is conformable. Alluvium reaches an assumed maximum thickness of 100 feet in the Tracy-Dos Palos area, thinning to a featheredge along the western margin of the valley. These deposits are similar to the oxidized zones of the Tulare Formation, being composed of interbedded, poorly- to well-sorted clay, silt, sand, and gravel.

Flood-basin deposits of Pleistocene and Holocene age form a veneer of overbank, backwater, and channel deposits of reworked Coast Range and Sierra material, lying conformably over alluvium. On the surface these deposits appear as a flat-lying meander plain. In the study area these deposits reach a maximum thickness of 50 feet. Light- to dark-brown and gray clay, silt, sand, and organic materials make up the flood-basin deposits, with local high concentrations of salts and alkali.

Figure 3. Geomorphology of the South Grassland Area (adapted from Page, 1986)



EXPLANATION

Qal — Alluvium (Pleistocene and Holocene). Unconsolidated clay, silt, sand and gravel: permeable to moderately permeable.

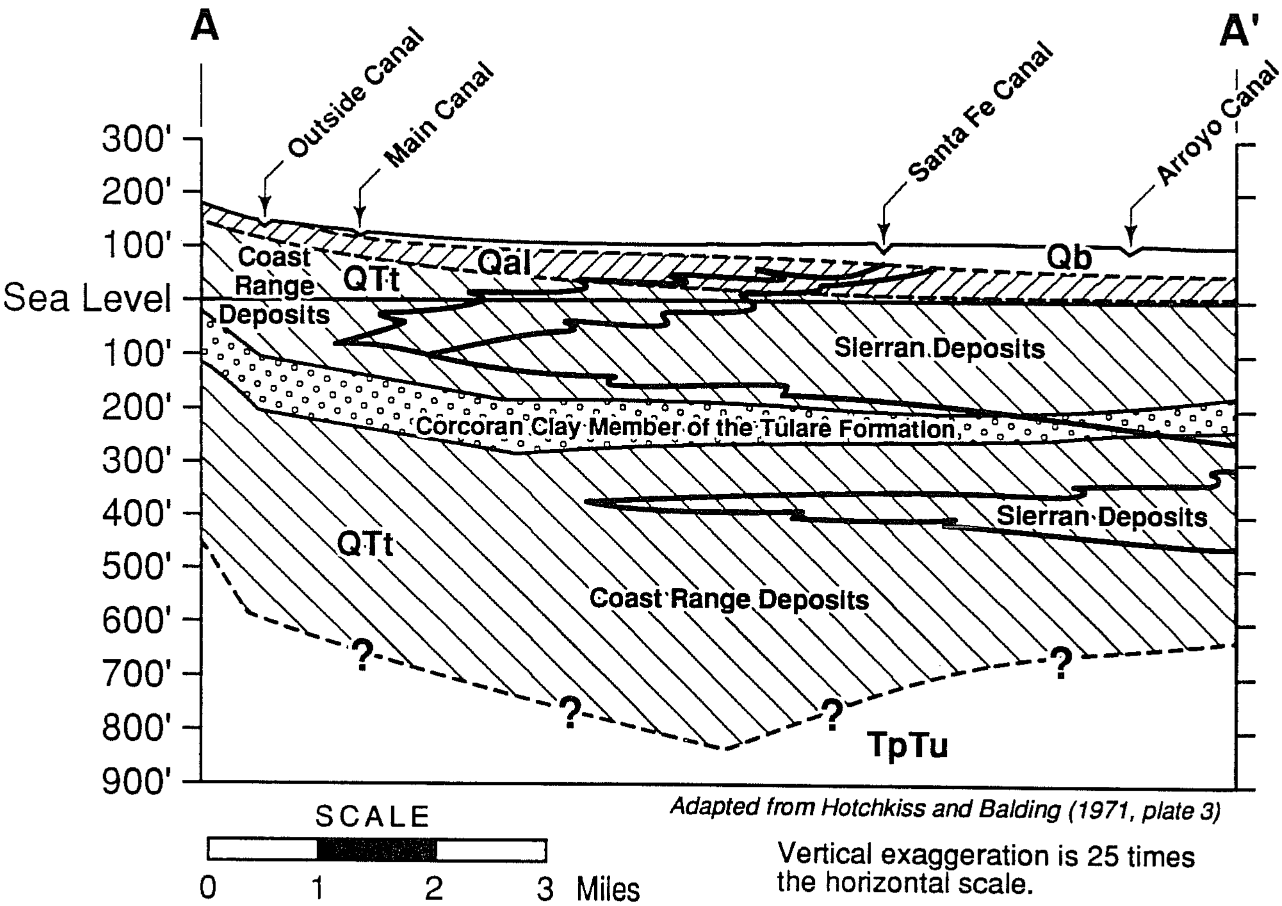
Qb — Flood-basin deposits (Pleistocene and Holocene). Unconsolidated surficial and near surface deposits of clay, silt, sand, and gravel: moderately to poorly permeable.

N

SCALE

0 1 2 3 Miles

Figure 4. Geologic Cross Section Through the South Grassland Study Area



Adapted from Hotchkiss and Balding (1971, plate 3)

Vertical exaggeration is 25 times the horizontal scale.

Datum is mean sea level.

EXPLANATION

Pleistocene and Holocene	Qal	Alluvium. Unconsolidated clay, silt, sand, and gravel: permeable to moderately permeable.
	Qb	Flood-basin deposits. Unconsolidated surficial and near surface deposits of clay, slit, sand, and gravel: moderately to poorly permeable.
Pliocene and Pleistocene	QTt	Tulare Formation. Unconsolidated and semiconsolidated continental deposits, poor to well-sorted fluvial deposits of clay, silt, and gravel interbedded with lacustrine sediments: highly to variably permeable.
Pre-Pliocene	TpTu	Sedimentary Rocks. Unconsolidated, semiconsolidated, and well indurated continental and marine clay, silt, sand, and gravel; sandstone, silicous shale; bentonite; clay stone; carbonaceous shale.

SYMBOLS

- Boundary between geologic source areas
- Corcoran Clay member of the Tulare Formation
- Stratigraphic unit contact: queried where evidence in inconclusive

HYDROLOGY

Upper Water-Bearing Zone

Ground water in the South Grassland area occurs in two water-bearing zones: and upper water-bearing zone and a lower water-bearing zone. The upper water-bearing zone occurs in the upper section of the Tulare Formation and the overlying alluvium, extending from the water table to the top of the Corcoran Clay. Due to local, discontinuous clay layers semiconfined and confined conditions are common, as well as unconfined conditions. The water table is from 1 to 10 feet below the ground surface in the central and eastern portions of the study area and up to 100 feet deep in the western and southernmost portions. The thickness of the upper zone in the study area is between approximately 250 and 350 feet. Ground water flows to the north and northeast at a gradient between about 26 feet per mile in the western part of the study area and about 3 feet per mile in the northern part of the study area. Appendix A shows ground water levels for fall and spring 1985. Recharge to the upper zone is by percolation of irrigation water and water ponded in duck ponds, seepage from canals and drainage ditches, and inflow of ground water from the south and southwest.

Lower Water-Bearing Zone

The lower water-bearing zone extends from the base of the Corcoran Clay to the base of fresh water, a thickness of up to 650 feet in the South Grassland area. Before the development of agriculture in the western San Joaquin Valley ground water in the lower zone flowed to the north and northeast. The potentiometric surface was typically 10 to 20 feet lower than the water table of the upper zone along the Coast Range and 0 to 10 feet higher along the valley trough. Very limited information exists on the current level of the potentiometric surface in the South Grassland area, but studies of the area to the immediate south show that increased irrigation with ground water in the early 1900's resulted in a lowering of the potentiometric surface of 100 to 200 feet, causing a reversal of flow direction from eastward to westward and downward flow from the upper water-bearing zone (Belitz, 1988). Although the potentiometric surface has recovered somewhat since the importation of surface water via the DMC and the resultant decrease in ground water pumpage, ground water in the lower zone still flows in a west to southwest direction. Similar conditions are likely to exist in the South Grassland area.

WELL SURVEY RESULTS

Beneficial Uses of Ground Water

The Water Quality Control Plan Report (SWRCB, 1975) lists municipal and domestic, irrigation, stock watering, industrial process supply, and industrial service supply as the beneficial uses of ground water in the South Grassland area. Of the wells within the study area which were identified as being active, 85 are used for domestic purposes, 43 for irrigation, seven for stock watering, five for dairy operations, three for industrial supply, and two for recreation purposes. Several of these wells are used for multiple purposes. All twelve of the wells which were sampled in Zone 1 are used for domestic purposes. Seventeen (17) domestic wells, eight irrigation wells, and one domestic well which is also used for stock watering were sampled in Zone 2. Five (5) domestic wells and one irrigation well were sampled in Zone 3.

Active, Abandoned, and Observation Wells

One hundred and thirty-six (136) active wells were identified and located within the study area. Forty-four (44) of these wells were sampled (Figure 5). Except for one well in Zone 3 which is completed in the lower water-bearing zone, all of the wells sampled are completed in the upper water-bearing zone. Well data for the wells sampled is given in Appendix B.

One hundred and sixteen (116) abandoned wells and 87 observation (inactive) wells were identified and located in the study area. The California Department of Water Resources (DWR) defines an abandoned well to be one which has not been used for a period of one year. For the purposes of this report a well is considered to be abandoned if the pump has been pulled out, the power has been disconnected, or the well has been destroyed. If the well owner demonstrates his intention to use the well after a year of non-use then it is considered to be "inactive" (DWR, 1981). Observation wells are commonly considered to be inactive and for the purposes of this report they will be considered as such, unless it is known that they have been destroyed, in which case they are listed as abandoned. Well data for active wells which were not sampled and for abandoned and observation wells is given in Appendix C. Many of the abandoned wells were used for irrigation. These wells were probably abandoned after the importation of irrigation water via the DMC.

It should be noted that since the DWR does not have records of all wells and since field investigations do not always locate every well, the list of active, abandoned and observation wells given above should not be considered complete, but merely an approximation, and probably an underestimation, of the actual numbers of these wells.

Well Construction Methods

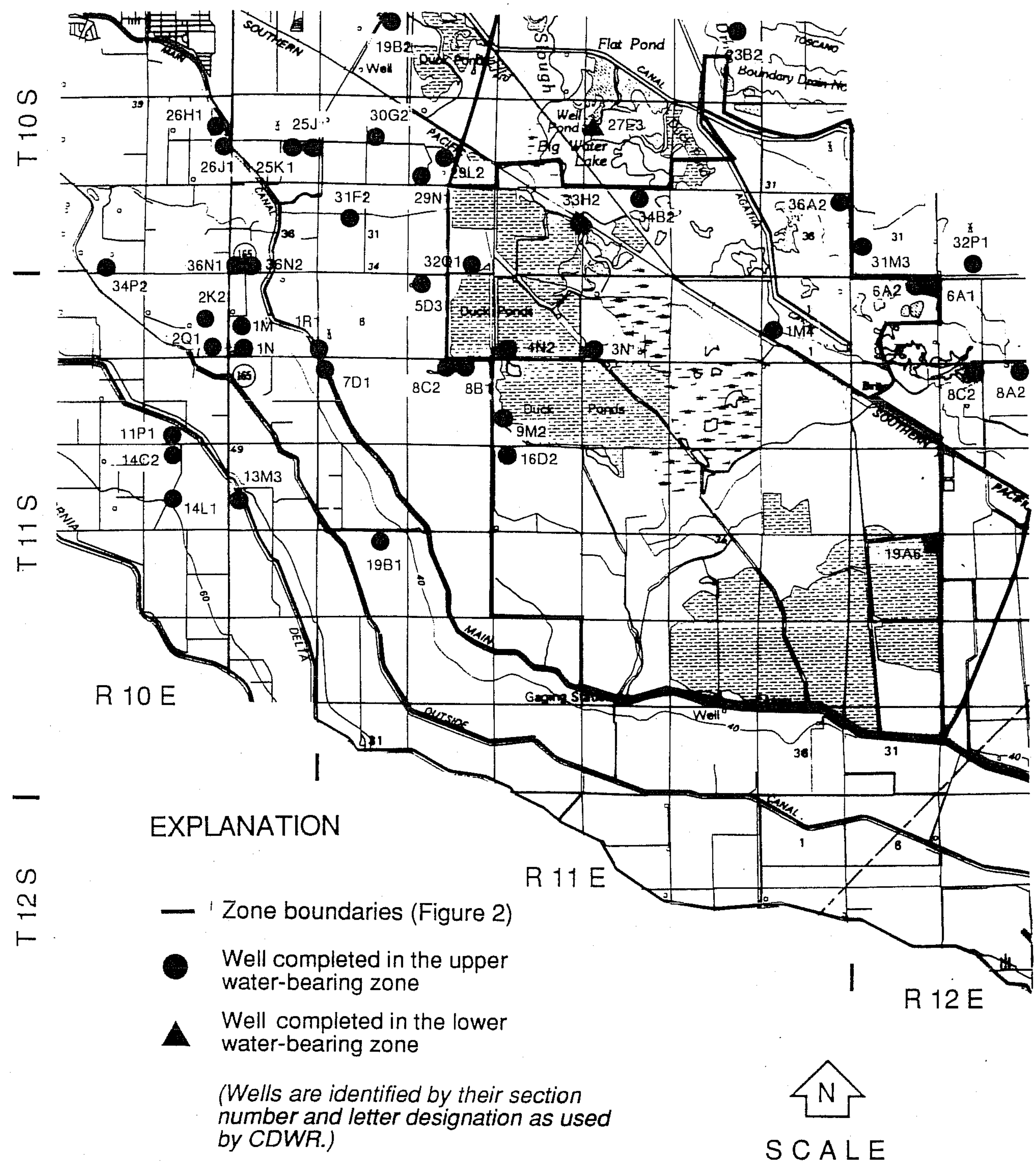
Some well construction methods can increase the likelihood of pollutants entering either the upper or the lower water-bearing zone. A well completed without a sanitary surface seal allows surface water to move readily down the annular space of the well and into the upper water-bearing zone, carrying any pollutants present with it.

Contamination of the lower water-bearing zone can occur when the perforation interval of the well covers both water-bearing zones or when the perforation interval covers only the lower zone and there is no seal between the two zones. Such contamination of the lower water-bearing zone is especially likely to occur when the head in the upper water-bearing zone is higher than the head in the lower, confined zone.

The location of the well also influences the likelihood of pollutants entering the ground water. The nearer a well is to the source of pollutant the the greater the chance that polluted surface waters can move down the well's annular space and into the ground water, especially if the well does not have a sanitary surface seal.

It is not unusual for wells in the study area to be completed without a sanitary surface seal. Of the 44 wells sampled, at least eight do not have surface seals, while 18 additional wells may not have seals. Two (2) of the 12 wells sampled in Zone 1 do not have a surface seal, while four others in this zone may not have such seals. The one well sampled in this study which is perforated in the confined zone is perforated only below the Corcoran Clay and has a cement plug sealing the lower zone from the upper zone. Well log data which is available indicates that at least a few of the abandoned and active wells not sampled were also completed without sanitary surface seals (Appendix C).

Figure 5. Well Sample Locations



Water quality data for the three zones is presented in Appendix D. Zones 1 and 2 include 12 and 26 wells, respectively, completed in the upper water-bearing zone. Zone 3 includes five wells completed in the upper zone and one well completed in the lower zone. Well sample locations are shown in Figure 5.

Upper Water-bearing Zone

Minerals

Of the 43 wells completed in the upper water-bearing zone 16 had water of mixed type, 3 had water of bicarbonate type, 15 had water of chloride type, 7 had water of sulfate type, and 2 had water of uncertain type. In each of the three zones, sodium was the predominant cation in over 50% of the wells, with the remaining wells having no dominant cation. The predominant anion in over 50% of the wells in Zone 1 and in all of the wells in Zone 3 was chloride. Over 50% of the wells in Zone 2 had no dominant anion. Table 1 presents a summary of the percent of cations and anions in the three zones and Figures 6, 7, and 8 show the chemical compostion of water from the Zones 1, 2, and 3, respectively.

Table 1. Percent of Cations and Anions in Ground Water of the Upper Water-Bearing Zone

LOCATION	NUMBER OF WELLS	CATIONS				ANIONS			
		% Ca Dominant	% Mg Dominant	% Na & K Dominant	% no Dominant	% HCO3 + CO3 Dominant	% Cl Dominant	% SO4 Dominant	% no Dominant
Zone 1	12	0	0	83	17	0	67	25	8
Zone 2	24	0	0	67	33	12	8	17	63
Zone 3	5	0	0	60	40	0	100	0	0

Table 2 presents a summary of the mineral quality of ground water in the upper water-bearing zone. Median levels of total dissolved solids (TDS), electrical conductivity (EC), and boron were highest in Zone 1. In this zone TDS ranged from 970 to 4600 mg/L with a median of 2900 mg/L, EC ranged from 1380 to 7200 µmhos/cm with a median of 4650 µmhos/cm, and boron ranged from 1.3 to 5.3 mg/L with a median of 4 mg/L. Chloride concentrations, similar to those in Zone 3 and significantly higher than in Zone 2, ranged from 270 to 1800 mg/L with a median of 1000 mg/L.

The lowest levels of TDS, EC, and chloride were observed in Zone 2. Here TDS ranged from 290 to 2900 mg/L with a median of 920 mg/L, EC ranged from 500 to 3900 µmhos/cm with a median of 1485 µmhos/cm, and chloride ranged from 37 to 400 mg/L with a median of 155 mg/L. Boron concentrations ranged from 0.42 to 5.8 mg/L with a median of 1.6 mg/L.

Concentrations of TDS, EC, and chloride in Zone 3 were most similar to those observed in Zone 1. In this zone TDS ranged from 607 to 3240 mg/L with a median of 2500 mg/L, EC ranged from 1050 to 5600 µmhos/cm with a median of 4400 µmhos/cm, and chloride ranged from 400 to 1600 mg/L with a median of 1100 mg/L. Boron ranged from 0.92 to 1.6 mg/L with a median of 1.4 mg/L.

The distributions of TDS, boron, and chloride in the South Grassland area are shown in Figures 9, 10, and 11, respectively. It should be noted that the distribution boundaries in these figures are only approximations. Vertical variations in ground water quality have not been considered and no wells were available for sampling to determine the current ground water quality in the southern portion of the study area. Figure 12 shows that there is a well defined relationship between EC and chloride in all three zones. Chloride concentrations increase with increasing EC.

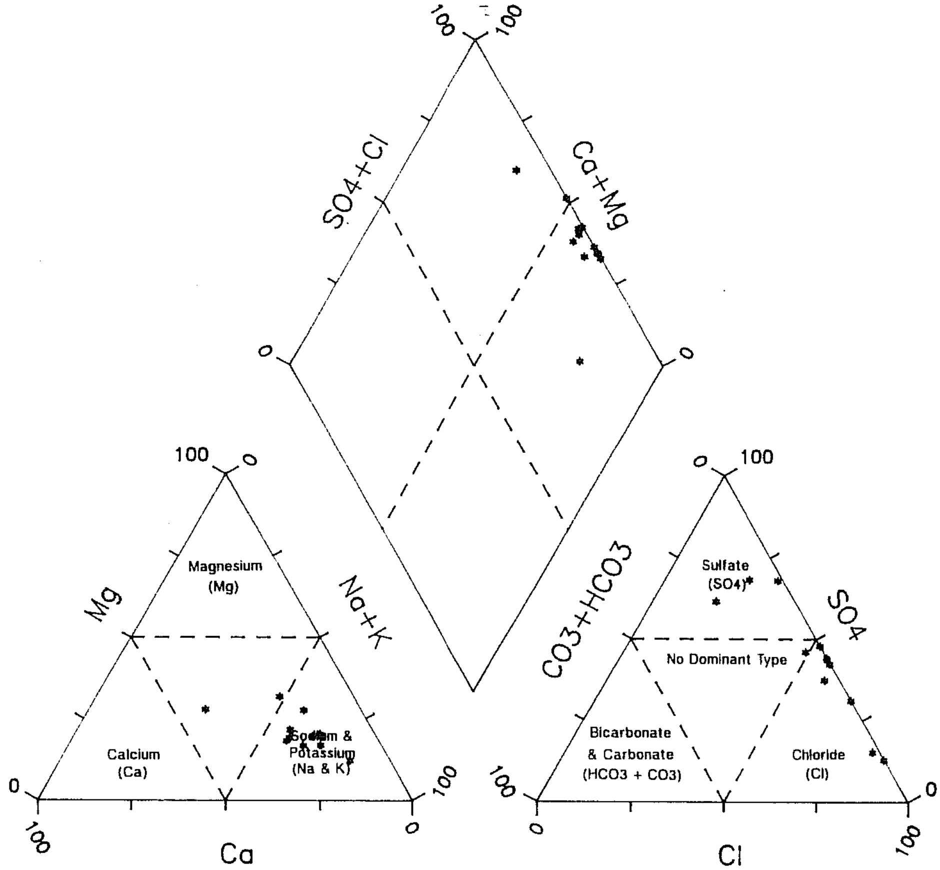


Figure 6. Chemical Compostion of Ground Water in Zone 1

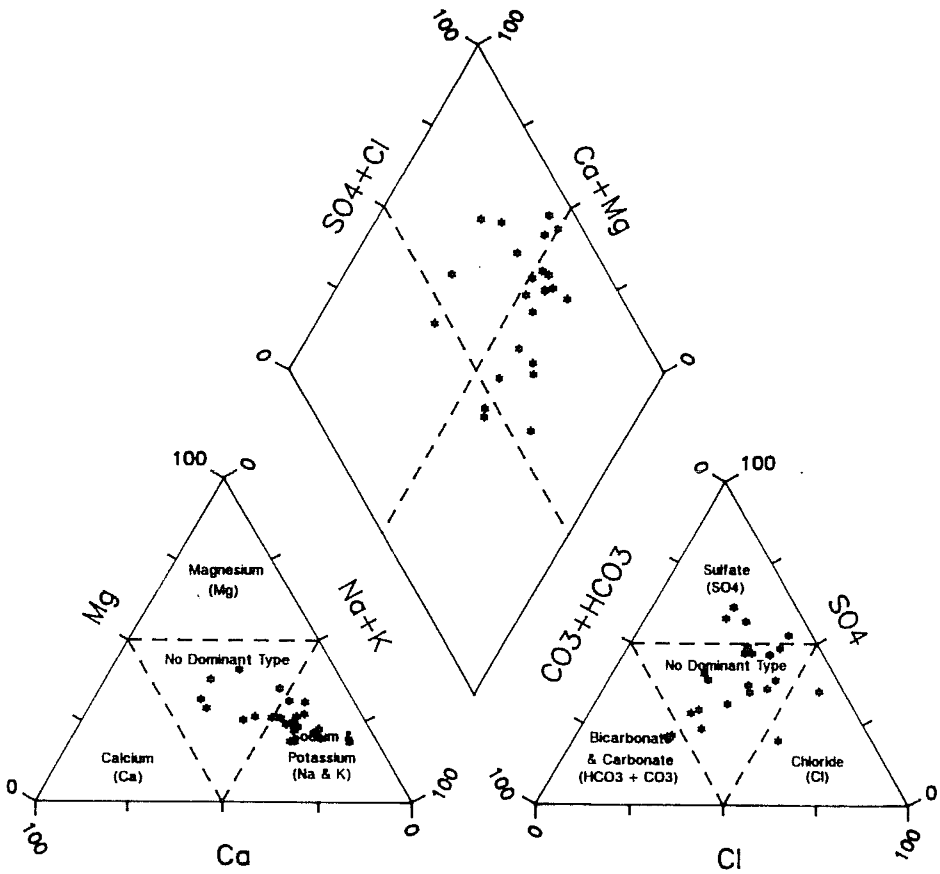


Figure 7. Chemical Composition of Ground Water in Zone 2

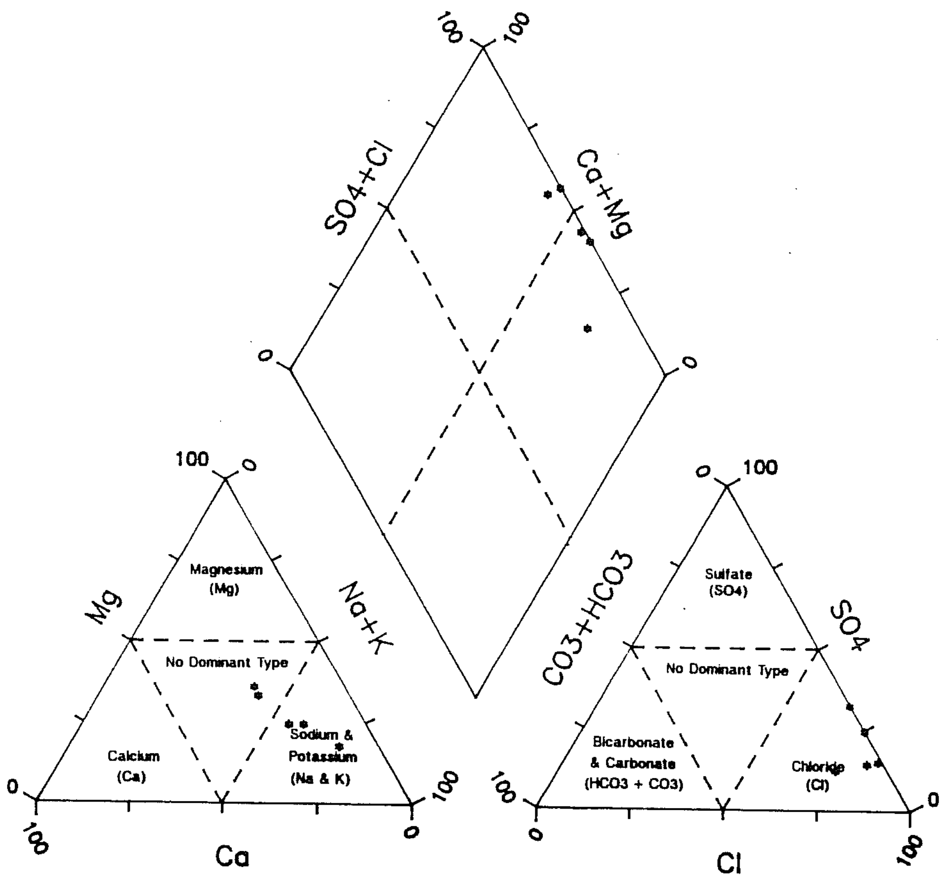


Figure 8. Chemical Composition of Ground Water in Zone 3.

Table 2. Mineral Quality of Ground Water in the Upper Water-Bearing Zone - Medians and Ranges

LOCATION	NUMBER OF WELLS	TDS (mg/L)	EC (µmhos/cm)	B (mg/L)	Cl (mg/L)
		(median/range)			
Zone 1	12	2900 970 - 4600	4650 1380 - 7200	4 1.3 - 5.3	1000 270 - 1800
Zone 2	26	920 290 - 2900	1485 500 - 3900	1.6 0.42 - 5.8	155 37 - 400
Zone 3	5	2500 607 - 3240	4400 1050 - 5600	1.4 0.92 - 1.6	1100 400 - 1600

Figure 9. Distribution of TDS in the South Grassland Area Ground Water

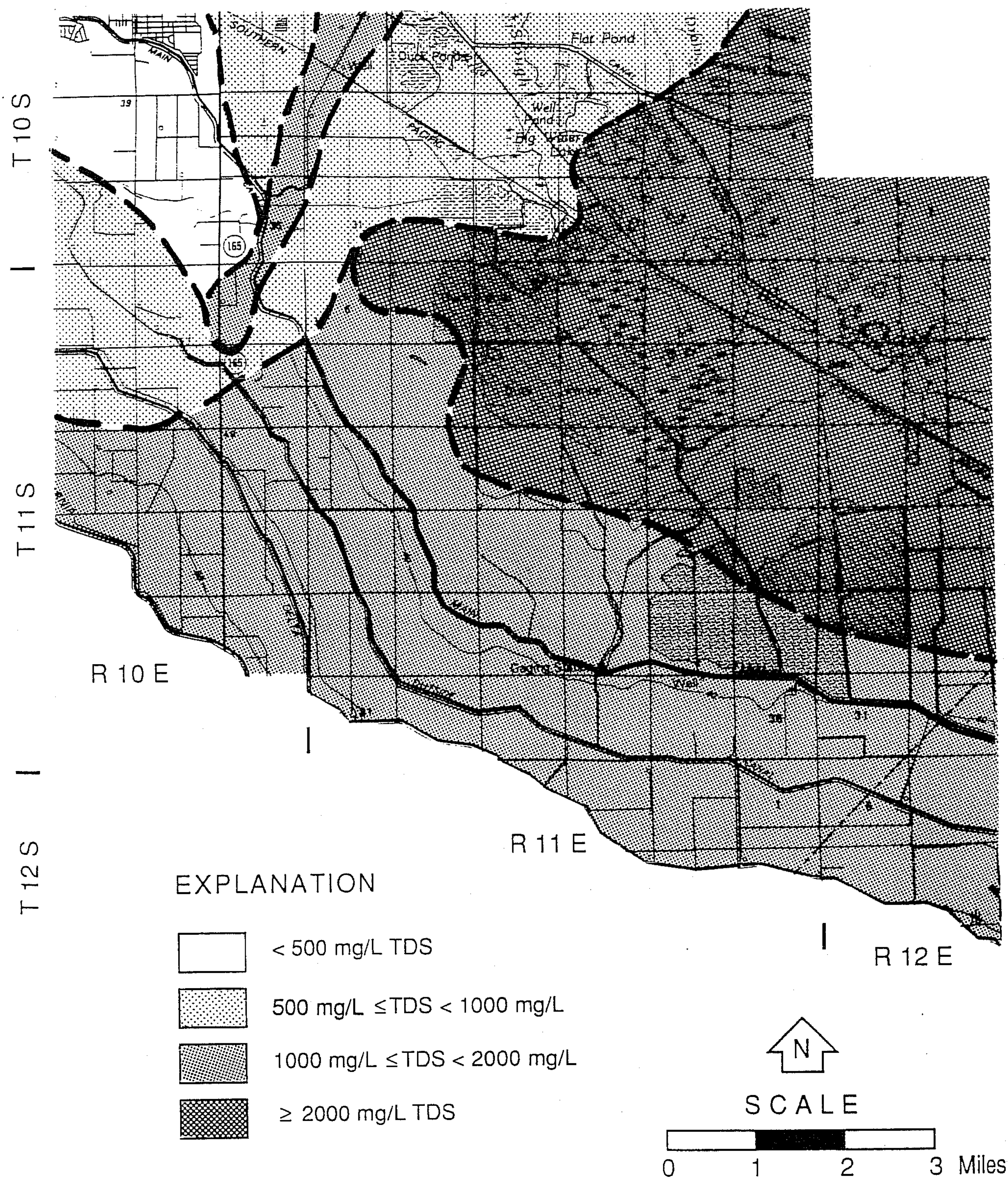


Figure 10. Distribution of Boron in the South Grassland Area Ground Water

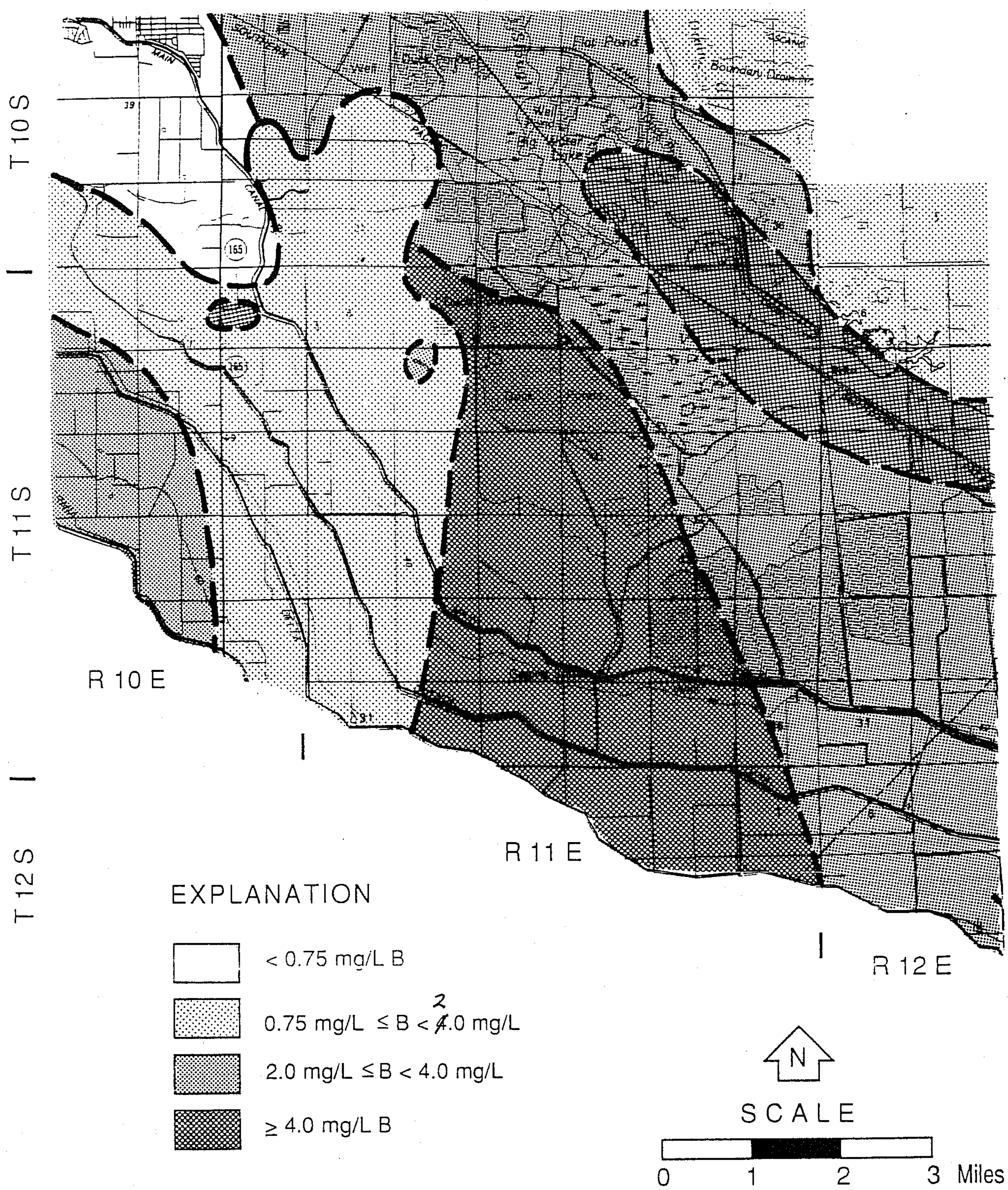
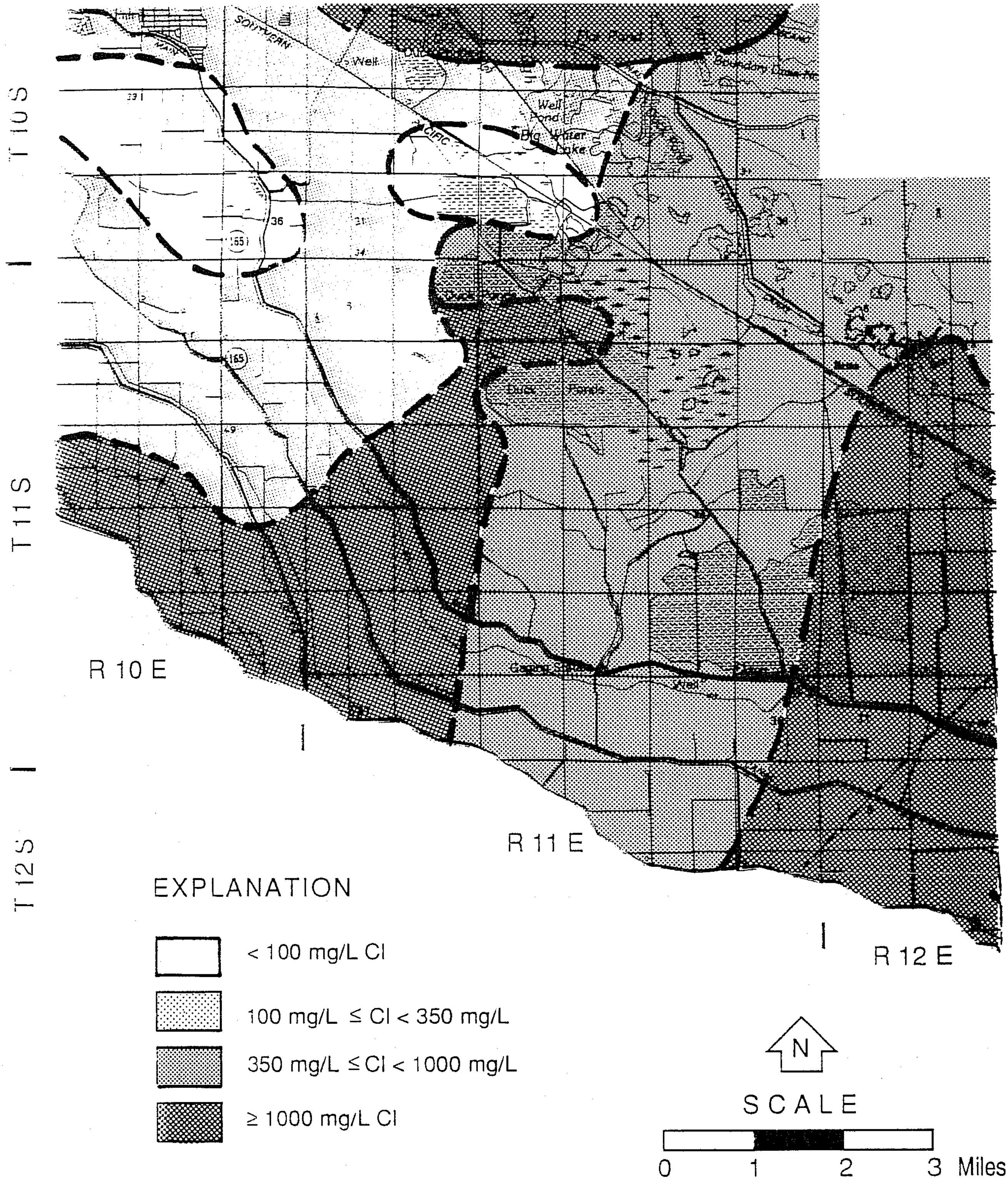


Figure 11. Distribution of Chloride in the South Grassland Area Ground Water



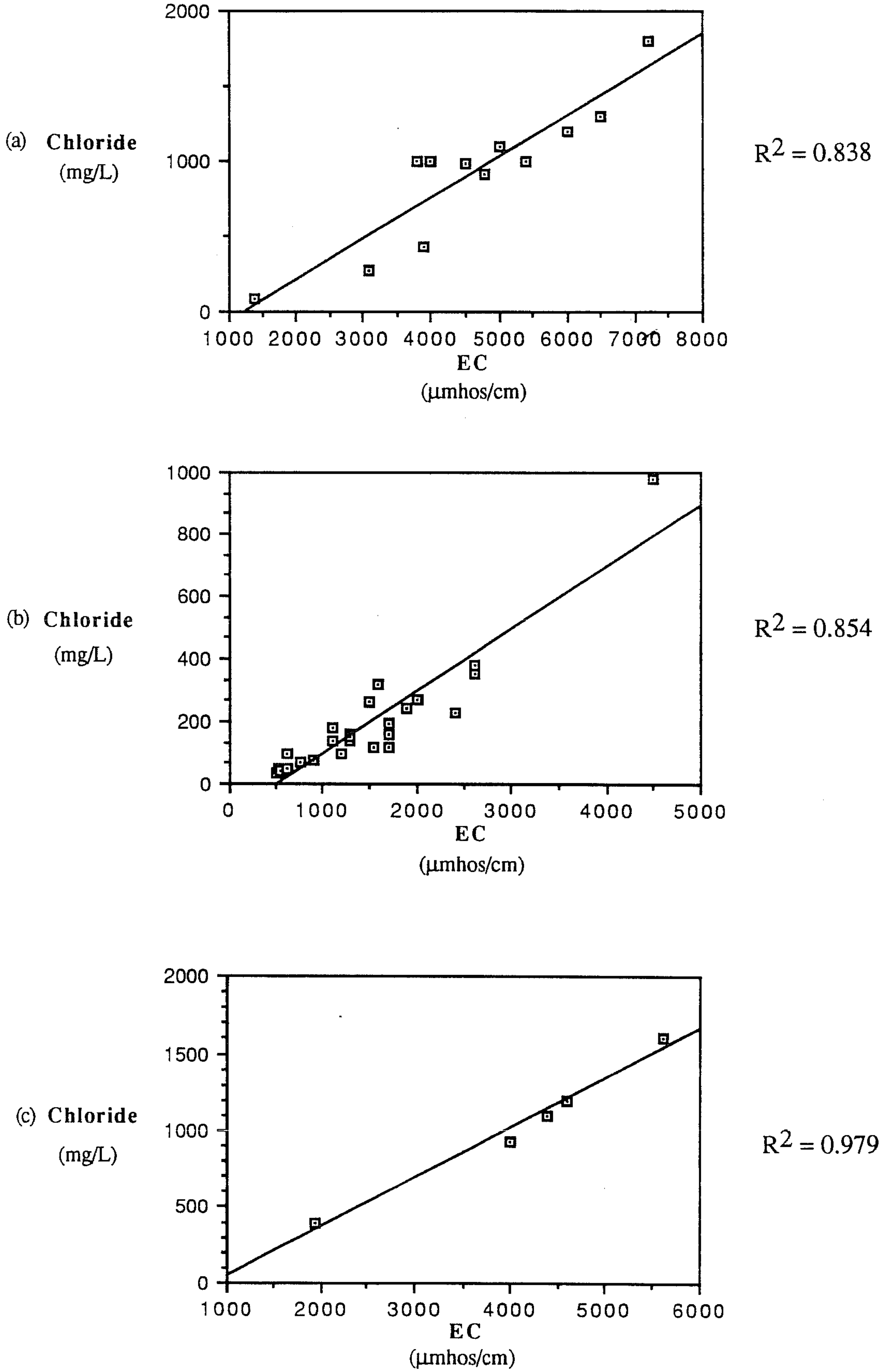


Figure 12. EC vs Chloride
(a) Zone 1, (b) Zone 2, and (c) Zone 3.

Trace Elements

A summary of trace element concentrations in the upper water-bearing zone is given in Table 3. Mercury and lead concentrations, not included in the summary, were below detection limits for all wells sampled. Except for levels of molybdenum* and zinc, Zone 1 had among the lowest median concentrations for all of the trace elements analyzed. In this zone median concentrations for selenium, chromium, copper, and nickel were <1 µg/L, 1 µg/L, 1 µg/L, and <5 µg/L, respectively. Median concentrations of molybdenum and zinc were 12 µg/L and 35 µg/L, respectively.

Median concentrations of selenium and chromium were highest in Zone 2, while median concentrations of zinc were the lowest in this zone. Median concentrations of selenium, chromium, and zinc were 3 µg/L, 38 µg/L, and 6 µg/L, respectively. Median concentrations of molybdenum and nickel were both below their detection limits. The median copper concentration in this zone was 2 µg/L, similar to the concentrations observed in both Zones 1 and 3.

The median concentrations of selenium, copper, molybdenum and nickel were all below detection limits in Zone 3. The median chromium and zinc concentration in this zone were 1 µg/L and 70 µg/L, respectively. The distributions of selenium and chromium in the South Grassland area are shown in Figures 13 and 14, respectively. The distribution boundaries in these figures are only approximations, as in Figures 9, 10, and 11.

Table 3. Trace Element Concentrations of Ground Water in the Upper Water-Bearing Zone -Medians and Ranges

LOCATION	NUMBER OF WELLS	Se (µg/L)	Cr (µg/L)	Cu (µg/L)	Mo (µg/L)	Ni (µg/L)	Zn (µg/L)
		(median/range)					
Zone 1	12	< 1	1	1	12	< 5	35
		<1 - 7	<1 - 11	<1 -110	<5 - 30	<1 - 18	10 - 620
Zone 2	26	3	38	2	< 5	< 5	6
		<1 - 30	<1 - 74	<1 - 54	<5 - 30	<5 - 7	<1 - 180
Zone 3	5	< 1	1	<1	< 10	< 5	70
		all <1	<1 - 3	<1 - 30	all <10	all <5	10 - 160

Lower Water-Bearing Zone

Minerals

The one well completed in the lower water-bearing zone has a sodium sulfate type water. The TDS , EC, boron, and chloride concentrations were 1100 mg/L, 1500 µmhos/cm, 2.6 mg/L, and 96 mg/L, respectively. Water quality data for this well is shown in Appendix D.

Trace Elements

Trace element concentrations in the lower water-bearing zone were low in this well. Selenium, chromium, molybdenum, nickel, mercury and lead concentrations were all below their detection limits. Copper and zinc concentrations were 1µg/L and 2 µg/L, respectively.

*Note: The EPA approved method which was used for molybdenum analysis has since been shown to under recover molybdenum at calcium to sulfate ratios of less than 0.5. Appendix D shows that the actual molybdenum concentrations for 24 of the 44 wells sampled may be higher than indicated.

Figure 13. Distribution of Total Selenium in the South Grassland Area Ground Water

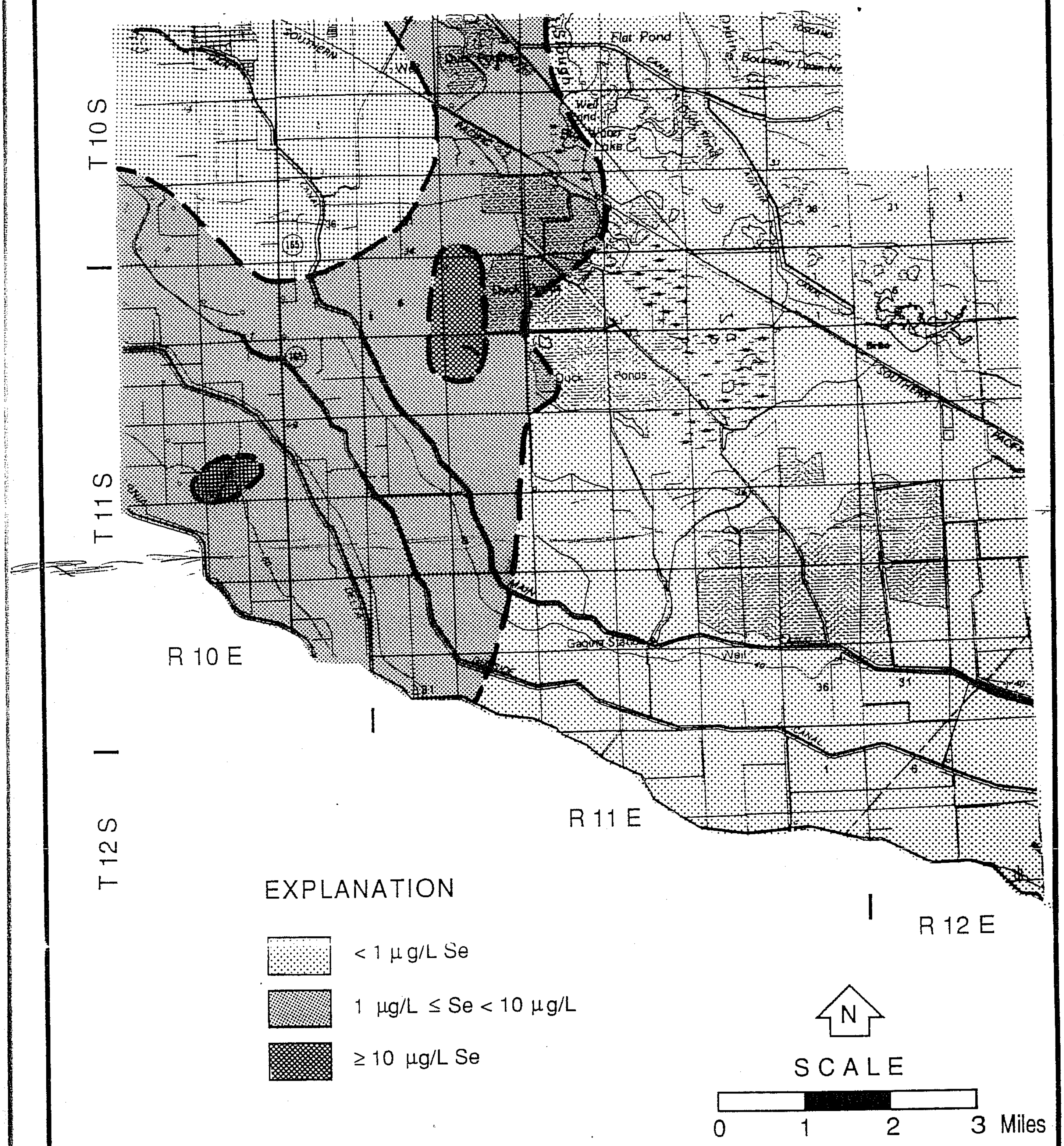
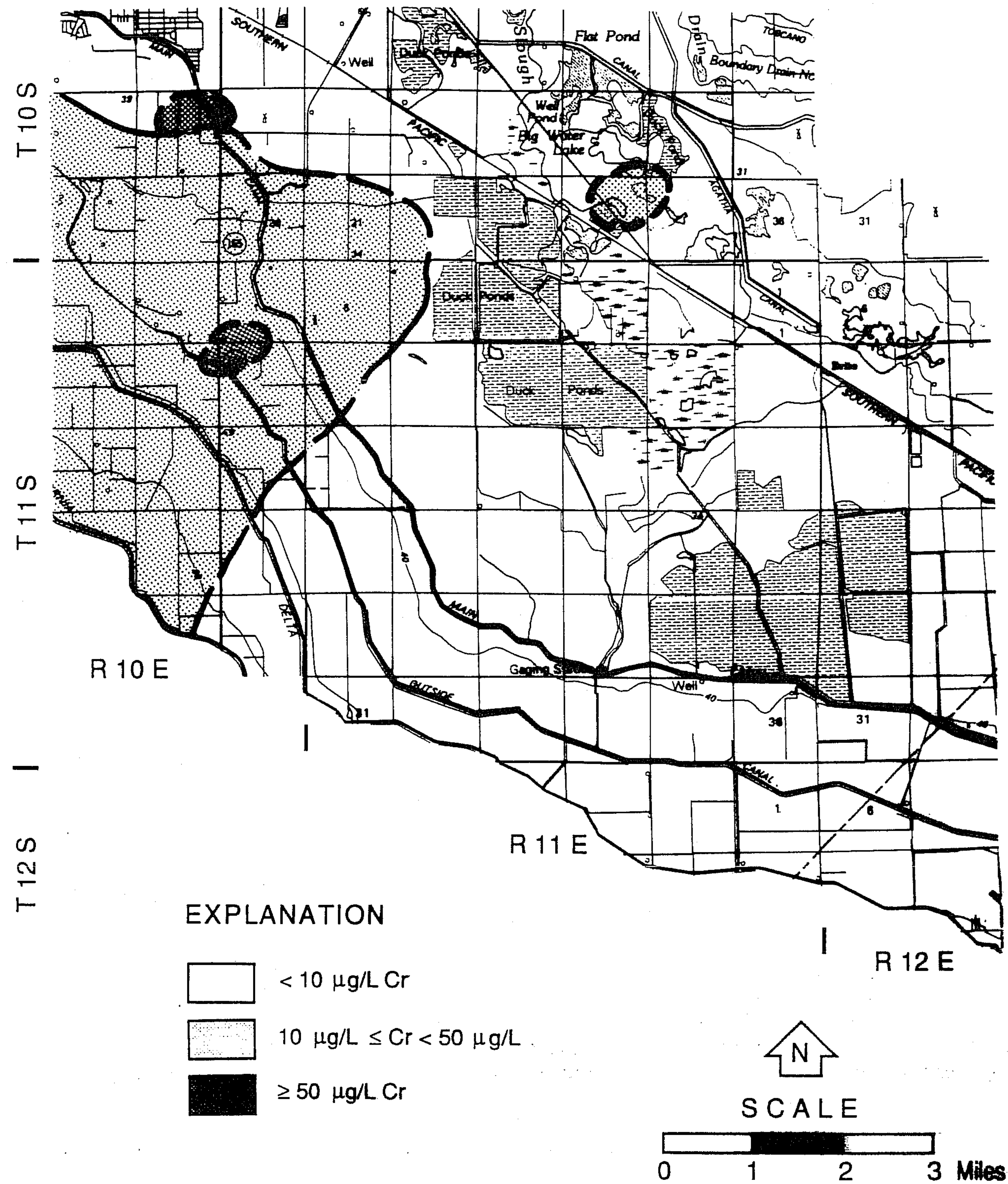


Figure 14. Distribution of Total Chromium in the South Grassland Area Ground Water



Ground Water Geochemistry

Ground water quality is influenced by the depositional environment, climate, depth of the water table, topography, texture and origin of the sediments, and the quality of applied irrigation water. The depositional environment is important in that oxidizing environments result in greater mobility for such elements as selenium and molybdenum, while reducing environments may result in the immobilization of these same elements. Both selenium and molybdenum are in their most mobile form under oxidizing conditions, selenium as selenate (+6 valence) and molybdenum as molybdate (+6 valence). Under reducing conditions selenate is readily reduced to selenite, which is much less mobile than selenate and which can readily form insoluble precipitates with ferric hydroxides or adsorb onto ferrous oxyhydroxides and clay minerals (Andrews and Shields, 1986). Selenite may also be further reduced to elemental selenium or selenide, both relatively insoluble forms of selenium. Molybdenum precipitates with common metals as metal molybdates or sulfides under reducing conditions (Deverel and Millard, 1986).

An arid climate and shallow ground water will result in the evaporative concentration of salts in both soils and ground water. In addition to an arid climate and shallow ground water, fine-textured, poorly-drained soils in the South Grassland area have also resulted in saline soils that limit the production of vegetation for cattle (Nazar, unpublished). A 1986 United States Geological Survey (USGS) study indicates that soils in the western San Joaquin Vallley change with topgraphy, changing in an eastward direction from low salinity in the alluvial fan zone to moderate to high salinity and then to low salinity in the basin trough zone (Deverel and Millard, 1986). Another USGS study has shown that shallow ground water salinity is significantly correlated to soil salinity in the area to the immediate south of the South Grassland study area (Deverel and Gallanthine, 1988).

In a study on shallow (≤ 10 meters) ground water in the western San Joaquin Valley Deverel and Millard, 1986 concluded that ground water derived from alluvial fan sediments originating from the Coast Ranges has higher concentrations of selenium and chromium than ground water derived from basin trough sediments originating from both the Sierra Nevada and Coast Ranges. Molybenum, salinity, boron, and chloride concentrations were found to be greatest in ground water derived from the basin trough sediments, molybdenum concentrations appearing to be related to the presence of Sierra Nevada sediments.

Surficially, the geology of the study area is composed of alluvial fan deposits derived from the Coast Ranges and the flood-basin deposits derived from both the Coast Ranges and the Sierra Nevada. The alluvial fan deposits are predominantly underlain by oxidized Coast Range sediments of the Tulare Formation, while flood-basin deposits are underlain by reduced and oxidized Coast Range and Sierra Nevada sediments of the Tulare Formation. The flood basin deposits of this study are approximately equivalent to the basin trough deposits of the USGS study mentioned in the preceding paragraph.

Only six wells sampled in this study are completed in sediments beneath the alluvial fan deposits. All of these six wells (wells 10S 10E 26H1, 10S 10E 26J1, 11S 10E 11P1, 11S 10E 13M3, 11S 10E 14C2, and 11S 10E 14L1), are located in Zone 2 and the quality of the ground water should only be influenced geologically by Coast Range deposits. Thirty-seven (37) wells sampled are completed beneath flood-basin deposits, and are located in Zones 1, 2, and 3. The ground water from these wells is influenced by varying, unknown proportions of Coast Range and Sierra Nevada deposits. Median values and ranges of EC, boron, chloride, selenium, chromium, and molybdenum for ground water derived from beneath each of the two geologic zones is presented in Table 4. In spite of the differences in sample size and the uncertainty of the origin of ground water in the wells which are located beneath the flood-basin deposits, the results of this study show there are some similarities to the USGS findings regarding the quality of shallow ground water in the western San Joaquin Valley.

Table 4. Water Quality of Wells Completed in the Upper Water-Bearing Zone and Underlying the Alluvial Fan and Flood-Basin Deposits-Medians and Ranges

GEOLOGIC ZONE	Number of Wells	EC (µmhos/cm)	Cl (mg/L)	B (mg/L)	Se (µg/L)	Cr (µg/L)	Mo (µg/L)
		(median / range)					
Alluvial Fan	6	1700 500 - 2600	175 37 - 380	2 0.42 - 2.3	4 <1 - 30	44 37 - 56	<5 all <5
Flood-Basin	37	2100 550 - 7200	275 38 - 1800	1.6 0.56 - 5.8	<1 <1 - 14	3 < 1 - 74	<10 <5 - 30

In the USGS study the median and maximum salinity were higher in the shallow ground water from the basin trough than the shallow ground water from the alluvial fan. In the South Grassland area both the median and maximum salinity were also greater in the ground water which is influenced by both Coast Range and Sierra Nevada deposits, although the difference in the median EC of ground water derived from beneath the two different geologic zones is not great.

Median and maximum boron concentrations were higher in the shallow ground water of the basin trough zone compared to the alluvial fan zone in the USGS study. The median boron concentrations in ground water from beneath the two geologic zones in the South Grassland area study were similar although the maximum boron concentrations were found in ground water beneath the flood-plain deposits.

The USGS study showed that the median and maximum chloride concentrations were greater in the shallow ground water of the basin trough zone than of the alluvial fan zone. The same is true of the results of this study of the South Grassland area. Median and maximum chloride concentrations were higher in ground water derived from the Coast Range and Sierra Nevada deposits underlying the flood-basin zone than in ground water derived from Coast Range deposits underlying the alluvial fan zone.

In both the USGS study and this study the median selenium and chromium concentrations were highest in ground water of the alluvial fan zone, indicating the Coast Range as the source material for both. In addition, from Figures 13 and 14 it appears that both selenium and chromium may be related to the Ortigalita Creek alluvial fan (Figure 1 shows the location of Ortigalita Creek). Between October 1985 and January 1988 selenium levels in Ortigalita Creek near Interstate 5 ranged from 4 to 10 µg/L, and between October 1985 and January 1987 chromium levels there ranged form <1 to 17 µg/L (CRWQCB files).

In the South Grassland area, maximum molybdenum concentrations were highest in ground water beneath the flood-basin zone as they were in the basin trough zone of the USGS study. In fact, no molybdenum was detected in ground water beneath the alluvial fan zone in this study. Due to differences in detection limits in this study, an accurate comparison of median values of molybdenum cannot be made between ground water derived from the two geologic zones.

Poor quality irrigation water applied in excess of crop requirements has the potential for leaching to the ground water and impacting its quality. Agricultural drainage water, which was used for spring and summer irrigation and fall and winter wetland flooding in the SDGWD, is typically high in EC, boron, chloride, and selenium. The levels of EC, boron, and chloride are correspondingly higher in the ground water in Zone 1 than in Zone 2. In addition to the influence of return irrigation and drainage waters on the ground water quality in Zone 1, the natural features of the area (arid climate, shallow ground water, fine-textured and poorly-drained soils, and the presence of Sierra Nevada and Coast Range sediments in the subsurface) have also increased these levels above normal. It is not possible to determine from the results of this study which factor has had the most important influence on the ground water quality in this area. A 1953 study (USBR, 1953) indicated that the quality of the ground water was poor in the GWD even before subsurface drainage water was applied to the area. This early study concluded that the distribution of suitable and unsuitable ground water in the Grassland area is almost completely controlled by the geology of the area, but that high chloride waters may represent return irrigation and drainage water.

The high selenium concentrations in the agricultural drain water which was applied to the wetlands in Zone 1 do not appear to have impacted the quality of ground water sampled in this study. The use of drain water, however, has resulted in the bioaccumulation of selenium by the aquatic food chain of waterfowl and waterbirds in the South Grassland area (Paveglio and Bunck, 1987). It is also likely that selenium has accumulated in the sediments in the South Grassland area, since studies at Kesterson Reservoir have shown that, at shallow depths soluble selenium is removed from water as it percolates through sediments rich in organic matter, and at greater depths sediments poor in organic carbon can remove soluble selenium from ground water (Lawrence Berkeley Laboratory, 1987).

WATER QUALITY AND BENEFICIAL USES

Ground Water

Zone 1

The twelve wells sampled in Zone 1 are all used for domestic purposes. The TDS for all of these wells, which ranged from 970 to 4600 mg/L, was near or greater than the Environmental Protection Agency (EPA)'s maximum recommended secondary drinking water criterion of 1000 mg/L TDS. Trace element concentrations did not exceed any drinking water standard in any of the wells in this zone.

Zone 2

Of the 26 wells sampled in Zone 2, 18 are used for domestic purposes and eight are used for irrigation. One of the domestic wells is also used for stock watering. Nine of the 18 domestic wells had TDS levels near or greater than 1000 mg/L. These nine wells ranged fom 980 to 2900 mg/L TDS. Two of the domestic wells exceeded the state's primary maximum contaminant level (MCL) of 10 µg/L for selenium. The selenium in these two wells ranged from 10 to 14 µg/L. One domestic well, with 56 µg/L chromium, exceeded the state's primary MCL of 50 µg/L chromium. All other trace element concentrations in these 18 domestic wells were below drinking water standards.

None of the eight irrigation wells sampled in Zone 2 had EC levels greater than 3000 µmhos/cm, the level suggested to prevent severe problems in crops, however a few wells had concentrations of boron, chloride, and selenium which exceeded water quality goals for agriculture. One well with 4.6 mg/L boron exceeded the 3.0 mg/L boron level suggested for agricultural water quality. Two wells had 350 and 380 mg/L chloride, which is equal to or greater than the 10 meq/L level recommended to prevent severe problems for chloride sensitive plants. One of these two wells also had a selenium concentration of 30 µg/L. This level exceeds the water quality goal of 20 µg/L selenium for agriculture (Ayers and Westcot, 1985).

Zone 3

Five of the wells sampled in Zone 3 are used for domestic purposes and one is used for irrigation. The TDS for all five domestic wells, which ranged from 982 to 2600 mg/L, was near or greater than 1000 mg/L. One of these wells is completed in the lower water-bearing zone. Trace element concentrations did not exceed any drinking water standard in any of these domestic wells.

The EC level of 5600 μmhos/cm and chloride level of 1600 mg/l in the one irrigation well sampled in this zone exceeded water quality goals for agriculture.

Irrigation Water

Zone 1

Prior to 1985 Zone 1 received agricultural drainage water from south of the study area for spring and summer irrigation and for mixing with CVP water for wetland flooding in the fall and winter. Seven main drains discharged into that part of the South Grassland study area represented by Zone 1. Six of these drains are the Panoche, Hamburg, Rice and Charleston drains and the Agatha Canal and Camp 13 Slough. RWQCB data (James et al., 1988) for water year 1986 (October 1, 1985 to September 30, 1986) indicates the median values of EC, boron, chloride, and selenium for these six drains as shown in Tables 5 and 6. The seventh drain which discharges to the area is the Almond Drive Drain. No data is available for this drain for water year 1986, however, data for water year 1987 (October 1, 1986 to September 30, 1987) shows this drain had median values for EC, boron, chloride, and selenium of 1925 μmhos/cm, 2.1 mg/L, 224 mg/L, and 4.8 μg/L, respectively.

Levels of salinity, boron, and chloride in these agricultural drainage waters are high in terms of water quality recommended for agricultural purposes, while selenium levels and TDS (based on a minimum of TDS = 0.6 X EC) are high in terms of both agriculture and drinking water purposes. In addition, selenium levels are high in terms of those levels recommended for wetland habitats. A water quality objective of 2 μg/L selenium has been recommended by the Regional Water Quality Board for waterfowl habitat in the GWD (RWQCB, 1988).

During the winter months the SDGWD receives water from the DMC to flood the duck ponds. Forty-five percent of the 50,000 acre-ft of water contracted to the GWD is distributed to SDGWD from mid-September to November 30. Water quality of the DMC water is shown in Tables 7 and 8 and is discussed in the next section. Before 1985 an additional 94,000 af/y of agricultural drainage water was used in the GWD. Approximately 30,000 af/y was used for fall and winter flooding, with the remaining drain water being used for maintenance of pond levels later in the season and spring and summer irrigation of waterfowl plant food.

Zone 2

Central California Irrigation District (CCID) manages most of the water in Zone 2, supplying water to this area from the Outside and Main Canals. Both of these canals are supplied with water from the DMC and the Mendota Pool. A small area between the west boundary of Zone 1 and the CCID Main Canal is not managed by any water district. Crops in this area are irrigated with drain water diverted from the Almond Drive Drain and Charleston Drain. San Luis Water District manages a small part of the southwest portion of the study area, supplying that area with water from the DMC and the California Aqueduct. Irrigation wells are also used to supply water to crops in Zone 2. The quality of water from the DMC and the Mendota Pool is shown in Tables 7 and 8. All median trace element concentrations were well below any water quality goals for agriculture, the median values for selenium, chromium, copper, molybdenum, and nickel being below their detection limits. Almond Drive Drain and Charleston Drain water quality is shown in Tables 5 and 6. Water from the California Aqueduct is similar in quality to water from the DMC.

Zone 3

The CCID (Poso Canal Company) and San Luis Canal Company manage the distribution of water in Zone 3. Water from the Mendota Pool is used to supply this area. Mendota Pool water quality is shown in Tables 7 and 8.

Table 5. Mineral Quality of Agricultural Drainage Discharges into Zone 1- Water Year 1986-Medians and Ranges (James et al., 1988)

SITE NAME	EC (µmhos/cm)	B (mg/L)	Cl (mg/L)
	(median/range)		
Panoche Drain @ O'Banion Gauge Stn	3400 2700 - 4310	5.8 4.1 - 9.4	390 300 - 580
Agatha Canal @ Helm Canal*	3300 360 - 5200	5.6 0.34 - 9.5	400 36 - 630
Hamburg Drain near Camp 13 Slough	3250 2000 - 4300	4 1.2 - 6.4	400 110 - 570
Camp 13 Slough @ Gauge Stn*	2950 1100 - 2300	3.9 1.7 - 6.9	375 120 - 580
Charleston Drain @ CCID Main Canal	4500 1700 - 6000	4.7 1.5 - 7.7	510 210 - 790
Rice Drain @ Mallard Rd	3300 1600 - 6900	8.1 3.8 - 19	350 15 - 740
Almond Drive Drain**	1925 1100 - 2590	2.1 0.83 - 2.9	224 110 - 290

* Medians and ranges of mineral concentrations in the Agatha Canal and Camp 13 Slough include fall deliveries of fresh water to the SDGWD.
** Data for the Almond Drive Drain is for Water Year 1987.

Table 6. Trace Element Concentrations of Agricultural Drainage Discharges into Zone 1- Water Year 1986 -Medians and Ranges (James et al., 1988)

SITE NAME	Se (µg/L)	Cr (µg/L)	Cu (µg/L)	Mo (µg/L)	Ni (µg/L)	Zn (µg/L)
	(median/range)					
Panoche Drain @ O'Banion Gauge Stn	56 43 - 69	25.5 9 - 45	5.5 <10 - 13	6.1 3.8 - 8	15 7 - 45	15 5 - 30
Agatha Canal @ Helm Canal*	44 .9 - 74	13 3 - 53	9 3 - 20	<5 <5 - 16	21 3 - 55	16 8 - 32
Hamburg Drain near Camp 13 Slough	51 4 - 84	13 <1 - 24	5 <1 - 14	4 1 - 8	10 <5 - 43	13 2 - 56
Camp 13 Slough @ Gauge Stn*	43 13 - 74	14 2 - 36	6.5 2 - 18	<5 2 - 11	19.5 11 - 38	16 9 - 34
Charleston Drain @ CCID Main Canal	93 23 - 129	9 5 - 15	10 <10 - 24	7.9 2 - 14	14 6 - 100	18 8 - 230
Rice Drain @ Mallard Rd	3 1.6 - 5	5 1 - 19	6 3 - 28	14 <5 - 37	23 9 - 78	13 4 - 15
Almond Drive Drain**	4.8 2.1 - 8.6	28 2 - 47	11 1 - 38	4.5 1 - 8	21 <5 - 41	25 3 - 78

* Medians and ranges of trace element concentrations in the Agatha Canal and Camp 13 Slough include fall deliveries of fresh water to the SDGWD.
** Data for the Almond Drive Drain is for Water Year 1987.

Table 7. Mineral Quality of Irrigation Supply Water Used in Zone 2- December 1985 to September 1986 -Medians and Ranges (Grassland Task Force, 1988)

SAMPLE LOCATION	EC (µmhos/cm)	B (mg/L)	Cl (mg/L)
	(median/range)		
DMC @ Check 13 (Hwy 207)	340 250 - 600	0.24 0.17 - 0.65	52 27 - 110
Mendota Pool @ Mowry Bridge	360 60 - 870	0.26 0.15 - 0.48	50 4 - 138

Table 8. Trace Element Concentrations of Irrigation Supply Water Used in Zone 2- December 1985 to September 1986 -Medians and Ranges (Grassland Task Force, 1988)

SAMPLE LOCATION	Se* (µg/L)	Cr (µg/L)	Cu (µg/L)	Mo (µg/L)	Ni (µg/L)	Zn (µg/L)
	(median/range)					
DMC @ Check 13 (Hwy 207)	< 1 <1 - 1	<10 all <10	< 10 all <10	< 10 <10 - 40	< 10 <10 -10	20 <10 -250
Mendota Pool @ Mowry Bridge	1 <1 - 1	< 10 <10 -60	< 10 <10 - 40	< 10 all <10	< 10 <10 - 50	40 20 - 120

* Selenium analyses are for March 1986 to September 1986

REFERENCES

Andrews, J., and Shields, W., 1986. Selenium speciation and hydrologic conditions affecting ground water contamination near Kesterson Reservoir. Proceedings of the Agricultural Impacts on Ground Water, August 11 - 13, 1986, Omaha Nebraska, National Water Well Association.

Ayers, R.S., and Westcot, D.W., 1985. Water quality for agriculture, FAO irrigation and drainage paper 29, revision 1. Food and Agriculture Organization of the United Nations, Rome, Italy.

Belitz, K., 1988. Character and evolution of the ground-water flow system in the central part of the western San Joaquin Valley, California. U.S. Geological Survey Open-File Report 87-573.

Birkeland, P.W., 1984. Soils and geomorphology. Oxford University Press.

California Department of Water Resources, 1981. Water well standards: State of California, Bulletin 74-81.

California Department of Water Resources, 1985. Lines of equal elevation of water in wells, unconfined aquifers, San Joaquin Valley, Fall and Spring 1985.

Davis, G.H., Green, J.H., Olmstead, F.H., and Brown, D.W., 1959. Ground-water conditions and storage capacity in the San Joaquin Valley California. U.S. Geological Survey Water-Supply Paper 1469.

Davis, G.H., 1961. Geologic control of mineral composition of stream waters of the eastern slope of the southern Coast Ranges, California. U.S. Geological Water-Supply Paper 1535-B.

Deverel, S.J. and Millard, S.P., 1986. Distribution and mobility of selenium and other trace elements in shallow ground water of the western San Joaquin Valley, California. USGS Open-File Report 86-538.

Deverel, S.J. and Gallanthine, S.K., 1988. Relation of salinity and selenium in shallow ground water to hydrologic and geochemical processes, western San Joaquin Valley, California. U.S. Geological Survey Open-File Report 88-336.

Grassland Water District, Grassland Water Task Force, 1986. Ecological and water management characterization of Grassland Water District.

Grassland Task Force, 1988. Grassland area monitoring report, April 20, 1988. Summers Engineering, Inc., Hanford, CA.

Hotchkiss, Wm. R., and Balding, G.O., 1971. Geology, hydrology, and water quality of the Tracy-Dos Palos area San Joaquin Valley, California. U.S. Geological Survey Open-File Report.

James, E.W., Westcot, D.W., Grewell, B.J., Belden, K.K., Boyd, T.F., Waters, I. R., Thomasson, R.R., 1988. Agricultural drainage contribution to water quality in the grassland area of western Merced County, California. California Regional Water Quality Control Board, Central Valley Region.

Kauffeld and Loth, 1985. Environmental assessment. Proposed acquition of East Grasslands National Wildlife Management area, Merced County. California Department of the Interior, U.S. Fish and Wildlife Service, Region 1, Portland, Oregon.

Lawrence Berkeley Laboratory, 1985. Geochemical, hydrological, and ecological characterization of Kesterson Reservoir, progress report (20 August - 30 November, 1985). Earth Sciences Division.

Lawrence Berkeley Laboratory, 1987. Hydrological, geochemical, and ecological characterization of Kesterson Reservoir, sixth progress report (April through June, 1987). Earth Sciences Division.

Miller, R.E., Green, J.H., and Davis, G.H., 1971. Geology of the compacting deposits in the Los Banos-Kettleman City subsidence area, California. U.S. Geological Survey Professional paper 497-E.

Nazar, P., 1989. Soil survey of Merced County, California, western part. U.S. Department of Agriculture, Soil Conservation Service, in progress.

Page, R.W., 1986. Geology of the fresh ground-water basin of the Central Valley, California (with texture maps and sections). U.S. Geological Survey Professional Paper 1401-C.

Paveglio, F.L. and Bunck, C.M., 1987. Preliminary summary, Grasslands contaminant study, selenium in algae and wintering and resident waterfowl and waterbirds. U.S. Fish and Wildlife Service in cooperation with San Joaquin Valley Drainage Program.

Regional Water Quality Control Board, Central Valley Region, 1988. Amendments to the water quality control plan for the San Joaquin Basin (5C) for the control of agricultural subsurface drainage discharges.

Schnagl, R.J. and Gonzalez, J.L., 1985. Ground water quality in the vicinity of the southern division of Grassland Water District, Merced County - a preliminary report. California Regional Water Quality Control Board, Central Valley Region.

State Water Resources Control Board, 1975. Water Quality Control Plan Report: San Joaquin Basin (5C).

Tanji, K., Lauchli, A., and Meyer, J., 1986. Selenium in the San Joaquin Valley. Environment, Vol. 28, No. 6.

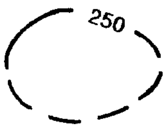
U.S. Bureau of Reclamation, 1953. Preliminary Report on ground water in the proposed Grassland Water District.

UC Salinity/Drainage Task Force, 1987. Sources of selenium and salinity in soils and sediments on the west side of the San Joaquin Valley. 1986-87 Technical Progress Report.

APPENDIX A

GROUND WATER ELEVATION CONTOURS FOR THE UPPER WATER-BEARING ZONE IN THE SOUTH GRASSLAND AREA, 1985

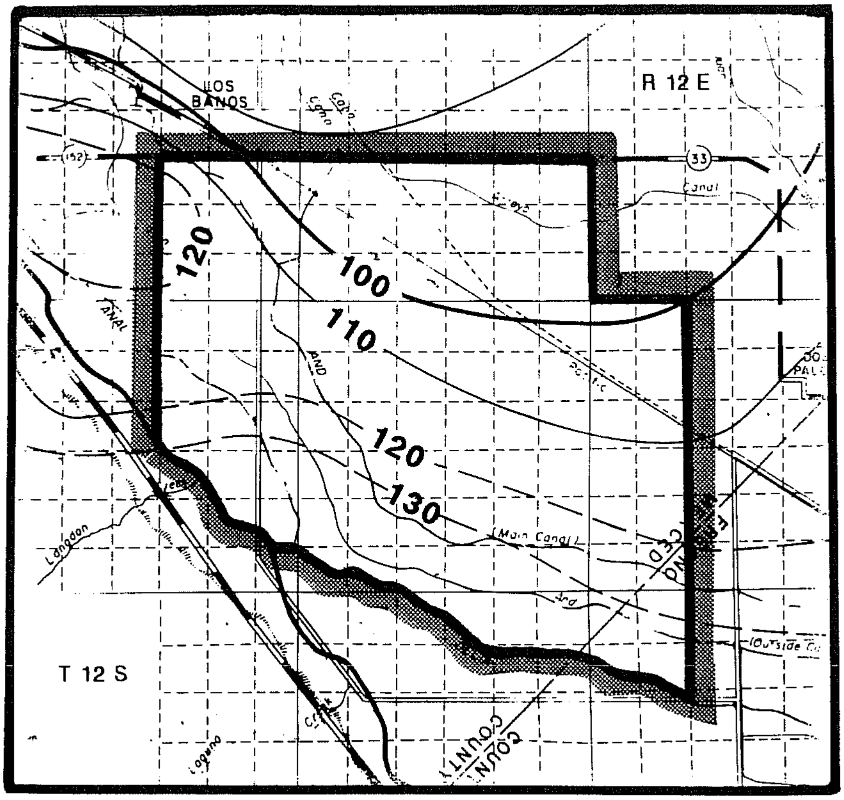
Explanation for symbols used in Appendix A:



Lines of equal elevation of water in the upper water-bearing zone, contours dashed where inferred, contour interval 10 feet.

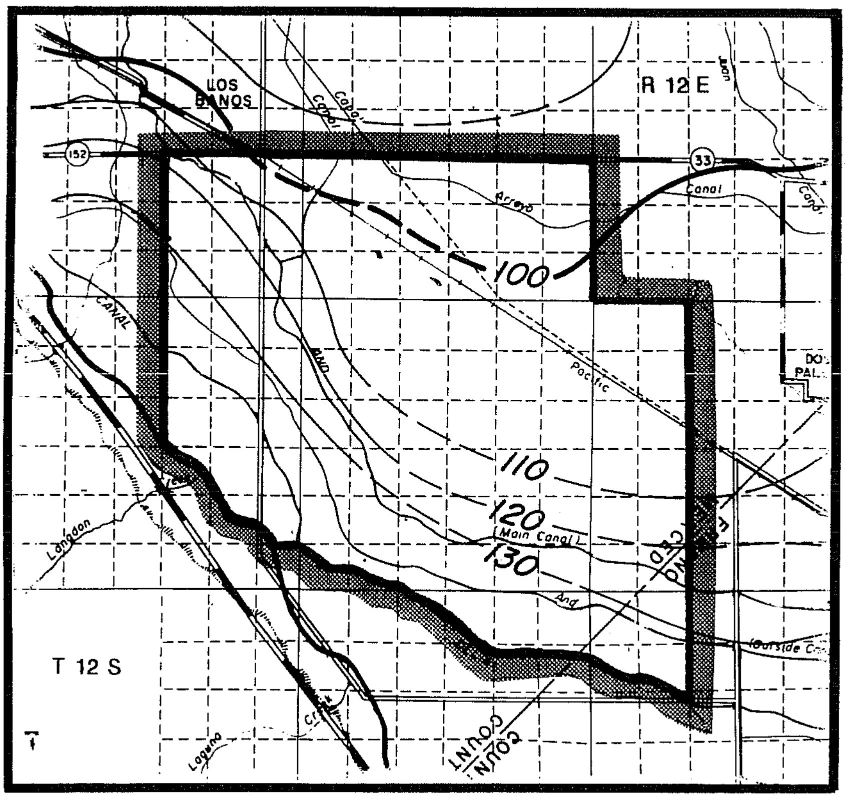
GROUND WATER ELEVATION CONTOURS FOR THE UPPER WATER-BEARING ZONE IN THE SOUTH GRASSLAND AREA, 1985

Spring 1985



N

Fall 1985



APPENDIX B

DATA FOR WELLS SAMPLED IN THE SOUTH GRASSLAND AREA

Explanation for symbols used in Appendix B:

Water-Bearing Zone

U = Upper Water-Bearing Zone
L = Lower Water-Bearing Zone

Well Use

D = Domestic
I = Irrigation
S = Stock

Well Depths

Well depths are represented by the bottom of the perforation interval or the depth of casing if the perforation interval is unknown. Where neither the perforation interval nor the casing depth is known the total well depth is reported, and followed by a ?.

Blank spaces indicate the data is unknown.

DATA FOR WELLS SAMPLED IN THE SOUTH GRASSLAND AREA

ZONE	WELL NUMBER	WELL DEPTH (FT)	DEPTH OF SURFACE SEAL (FT)	WATER-BEARING ZONE	WELL USE
1	10S 11E 32Q1	140	20	U	D
1	10S 11E 33H2	150		U	D
1	10S 11E 34B2	145	50	U	D
1	10S 11E 36A2	55		U	D
1	11S 11E 01M4	137	None	U	D
1	11S 11E 03N	240?		U	D
1	11S 11E 04N2	300?	None	U	D
1	11S 11E 09M2	85?		U	D
1	11S 11E 16D2	123	50	U	D
1	11S 12E 06A1	240	60	U	D
1	11S 12E 06A2	180	125	U	D
1	11S 12E 19A6	170	65	U	D
2	10S 10E 25J	90?		U	D
2	10S 10E 25K1	62	47	U	D
2	10S 10E 26H1	215	50	U	D
2	10S 10E 26J1	165	20	U	D
2	10S 10E 34P2	150		U	D
2	10S 10E 36N1	210	50	U	D
2	10S 10E 36N2	170	20	U	D
2	10S 11E 19B2	165	100	U	I
2	10S 11E 29L2	165		U	D
2	10S 11E 29N1	190	150	U	D
2	10S 11E 30G2	214	None	U	I
2	10S 11E 31F2	300	None	U	I
2	11S 10E 01M	252?		U	I
2	11S 10E 01N	270?		U	I
2	11S 10E 01R1	294		U	I
2	11S 10E 02K2	300	None	U	I
2	11S 10E 02Q1	175	20	U	D
2	11S 10E 11P1	180		U	D
2	11S 10E 13M3	156	50	U	D
2	11S 10E 14C2	169	None	U	D
2	11S 10E 14L1	240	None	U	I
2	11S 11E 05D3	135?		U	D
2	11S 11E 07D1	121	20	U	D, S
2	11S 11E 08B1	190?		U	D
2	11S 11E 08C2	190	80?	U	D
2	11S 11E 19B1	32?		U	D
3	10S 11E 23B2	140?	50	U	D
3	10S 11E 27E3	460		L	D
3	10S 12E 31M3	130		U	D
3	10S 12E 32P1	100		U	D
3	11S 12E 08A2	108	None	U	I
3	11S 12E 08C2	110?		U	D

APPENDIX C

DATA FOR WELLS NOT SAMPLED IN THE SOUTH GRASSLAND AREA
(Active, Abandoned, and Observation Wells)

Explanation for symbols used in Appendix C:

Well Use

C - Dairy

D - Domestic

E - Exploratory

I - Irrigation

In - Industrial

M - Municipal

O - Observation

R - Recreation

S - Stock Watering

Blank spaces under Well Depth, Use, and Depth of Surface Seal indicate unknown data.

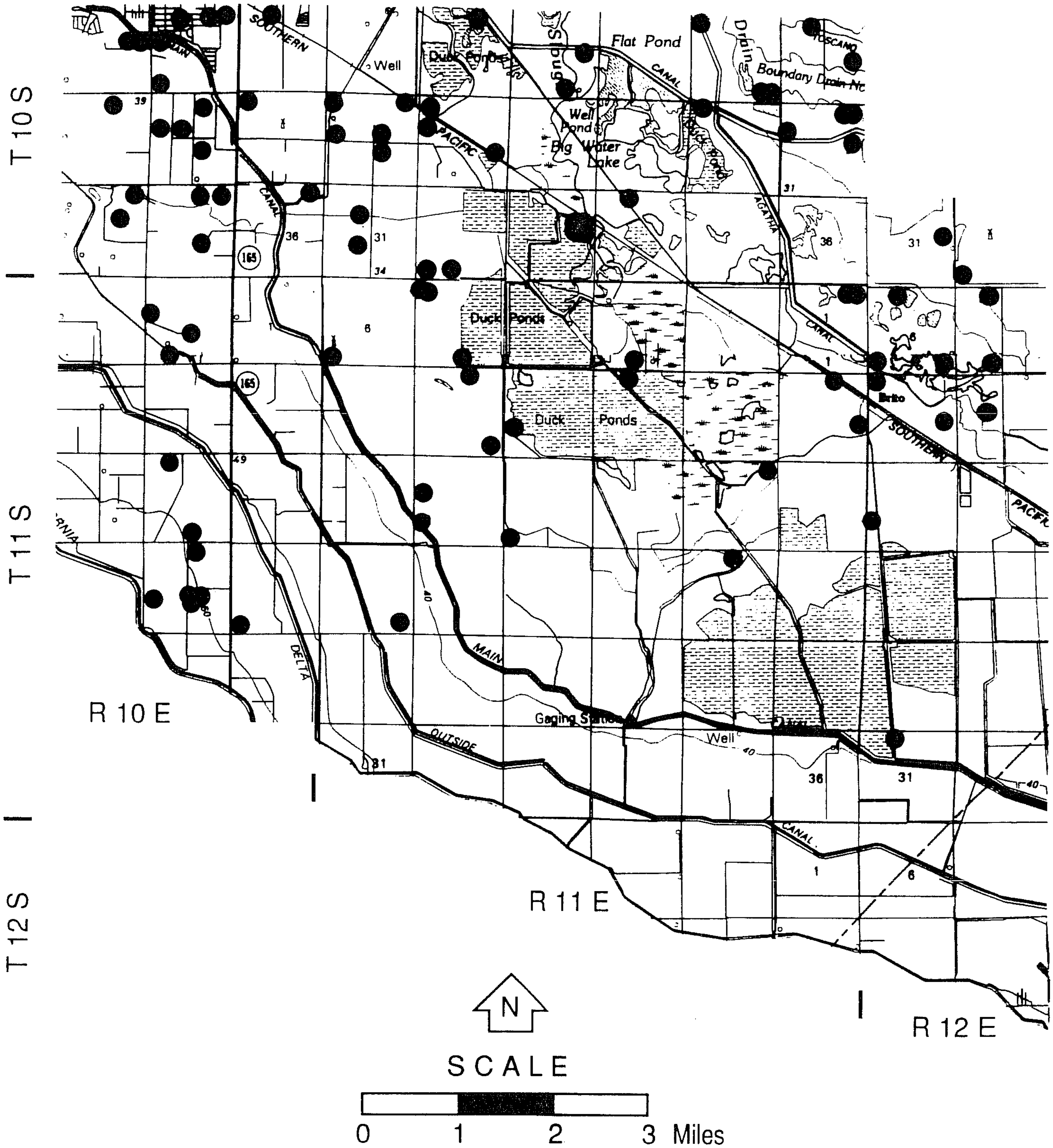
ACTIVE WELLS

WELL NUMBER	WELL DEPTH (FT)	USE	DEPTH OF SURFACE SEAL (FT)
10S 10E 22H3	90	D	
10S 10E 22H4	100	D	
10S 10E 23A1	210	In	
10S 10E 23B1	320	I	67
10S 10E 23C1	204	I	
10S 10E 23E2	310	I,M	
10S 10E 23N1	100	D	50
10S 10E 24C	52	D	
10S 10E 25D2	231	D	
10S 10E 26B1	215	D	50
10S 10E 26E1	103	D	50
10S 10E 26F1	267	I,S	
10S 10E 26K1	180	I	140
10S 10E 27B2	240	D	
10S 10E 34A1	218	C	
10S 10E 34G1	250	C	
10S 10E 35A1	160	D	50
10S 10E 35B1	70	D	30
10S 10E 35K1	160	D	20
10S 10E 36A1	130	C	50
10S 11E 20B1	130	D	50
10S 11E 21J1	65	I	
10S 11E 21Q2	35	D	
10S 11E 23D3		D	
10S 11E 23R1	75	D	
10S 11E 23R2		I	
10S 11E 24C1		D	
10S 11E 24H1		I	
10S 11E 25A1		D	
10S 11E 25A2		C	
10S 11E 25E2		D	
10S 11E 25H2		D	
10S 11E 26D2	80	D	50
10S 11E 29D1		I	
10S 11E 29E1	35	D	
10S 11E 29J1	205	I	
10S 11E 30A1		I	
10S 11E 30D1	205	I	
10S 11E 30E1		I	
10S 11E 30G1	200	I	
10S 11E 30K1		D	
10S 11E 31F1	34	S	
10S 11E 31L1		D	
10S 11E 32N2		S	
10S 11E 32P1		I,D	
10S 11E 33H4		D	

ACTIVE WELLS

WELL NUMBER	WELL DEPTH (FT)	USE	DEPTH OF SURFACE SEAL (FT)
10S 11E 33H5		D	
10S 11E 33H6		D	
10S 11E 33H7		D	
10S 11E 34C1	160	D	
10S 12E 31J1		I	
10S 12E 32N3	110	D	
11S 10E 02E2	240	I	
11S 10E 02K1	224	I	
11S 10E 02P1	238	I	
11S 10E 14C1	240	C	50
11S 10E 14Q	138	D	20
11S 10E 23B3	216	I	none
11S 10E 23K1		I	
11S 10E 23K2	370	I	
11S 10E 23K3	210	I	none
11S 10E 23M1		I	
11S 10E 24N1	127	In	
11S 11E 01A1		D,I	
11S 11E 01A2		D	
11S 11E 03P1		D,I	
11S 11E 05D2	140	D	
11S 11E 05D3	231	I	
11S 11E 05Q1	280	D,I,R	
11S 11E 06N1	294	I	
11S 11E 08B2		D	
11S 11E 08R1	80	D	
11S 11E 09M1	263	R,I	
11S 11E 10C2		D	
11S 11E 12B1		I	
11S 11E 12J1		D	
11S 11E 14A2	100	D	
11S 11E 16N1		I	
11S 11E 17E1		S	
11S 11E 17M1	27	S	
11S 11E 19R1		D	
11S 11E 23B2		D	
11S 12E 05C1	45	D,S	
11S 12E 05P2	130	D	
11S 12E 06C1		D	
11S 12E 06N2		D	
11S 12E 06R1		I	
11S 12E 07D1		D	
11S 12E 07J2		D	
11S 12E 08F1	57	In	12
11S 12E 18M2	185	D	150
11S 12E 31C2		I	

Active Well Locations



ABANDONED WELLS

WELL NUMBER	WELL DEPTH (FT)	PREVIOUS USE	DEPTH OF SURFACE SEAL (FT)
10S 11E 20G	295	I	25
10S 11E 21Q1	450	D	
10S 11E 22D1	10	O	
10S 11E 23B1			
10S 11E 23D1	10	O	
10S 11E 23D2			
10S 11E 23R3			
10S 11E 24C2			
10S 11E 24L1			
10S 11E 24N1		O	
10S 11E 25E1	20	D	
10S 11E 25H1	72		
10S 11E 25R		D	
10S 11E 26D1	30	D	
10S 11E 27E2	475	I	
10S 11E 29L1	114		
10S 11E 29P1	152	I	
10S 11E 32N1	34	S	
10S 11E 32R2	20	D	
10S 11E 33D1			
10S 11E 33H1		I	
10S 11E 33H3			
10S 11E 34N1		I	
10S 11E 36A1			
10S 11E 36H1		I	
10S 12E 31M1	38	S	
10S 12E 31M2	50	D	
10S 12E 31P1	255	I	none
10S 12E 32N1	172	D	50
10S 12E 32N2		D	
10S 12E 32R1	12.5	0	
11S 10E 13N1	240	I	none
11S 10E 22H1	250	I	
11S 10E 23B1	200	I	
11S 10E 23E1	180	D	20
11S 10E 25Q1			
11S 10E 26G1			
11S 11E 01M1	58		
11S 11E 01M2		I	
11S 11E 01M3		D	
11S 11E 01N		S	
11S 11E 03D			
11S 11E 03Q1	277		
11S 11E 04C1		I	
11S 11E 04G1		I	
11S 11E 04N1		I	

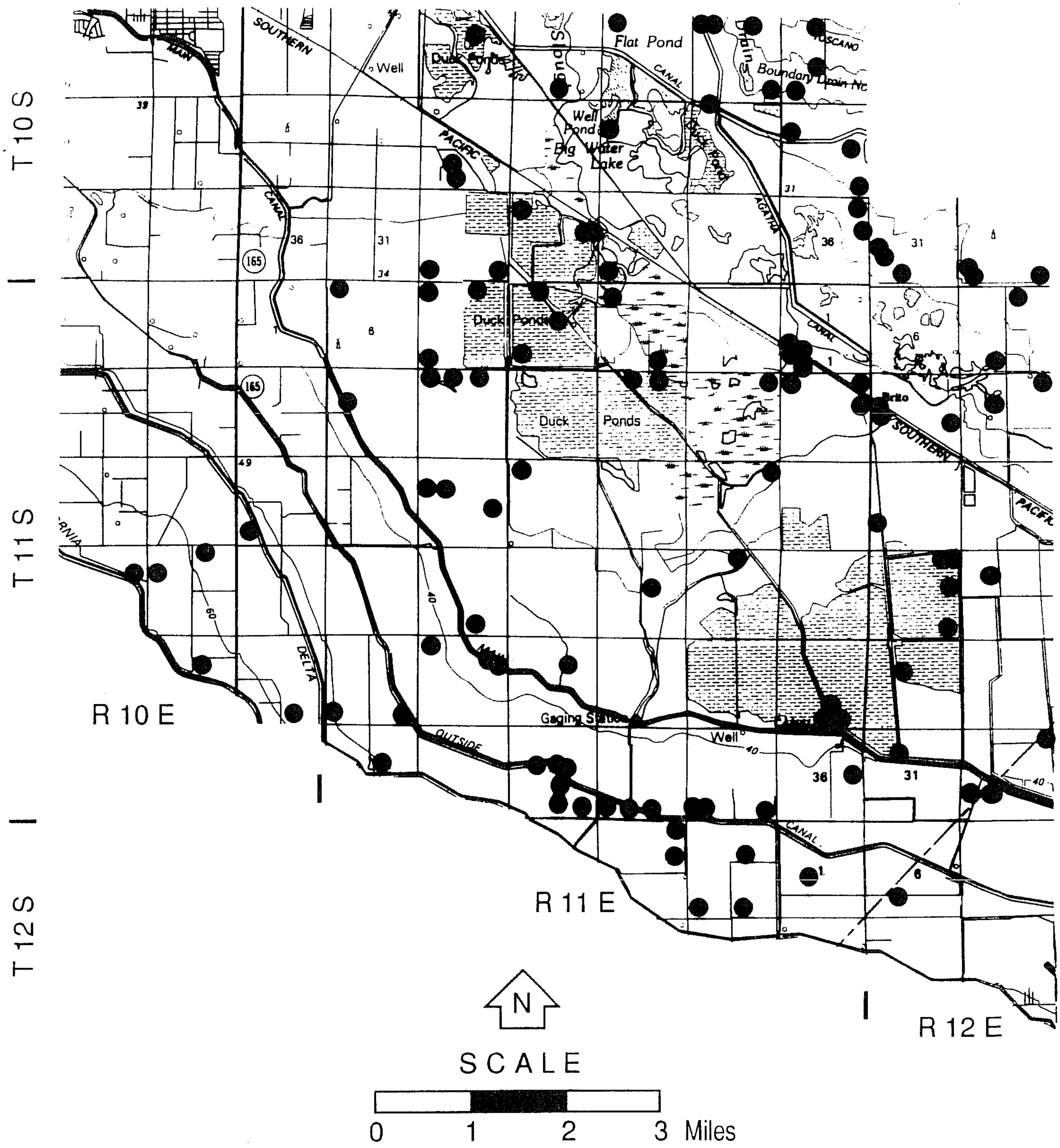
ABANDONED WELLS

WELL NUMBER	WELL DEPTH (FT)	PREVIOUS USE	DEPTH OF SURFACE SEAL (FT)
11S 11E 05B1		D	
11S 11E 05D1			
11S 11E 05N1	10	O	
11S 11E 06D1			
11S 11E 07E1	16		
11S 11E 08B1			
11S 11E 08C1	90		
11S 11E 08D1	120	S	
11S 11E 10B1		I	
11S 11E 10C1		I	
11S 11E 11A			
11S 11E 12A1		I	
11S 11E 12D1	75		
11S 11E 12H		I	
11S 11E 14A1	48		
11S 11E 16D1	140	D	
11S 11E 17E2	240	I	
11S 11E 17F0	332	I	
11S 11E 17J1			
11S 11E 20Q1		I	
11S 11E 22K1	12	O	
11S 11E 23B3		D	
11S 11E 25Q1		I	
11S 11E 25Q10	12	O	
11S 11E 25Q4		I	
11S 11E 28G1	38.5		
11S 11E 29D1		I	
11S 11E 29H1	7	S	
11S 11E 29H2	154		
11S 11E 30N1	450	I	
11S 11E 30R	390	I	none
11S 11E 31G1	350	I	
11S 11E 33F1		S	
11S 11E 33G1		I	
11S 11E 33G2		S	
11S 11E 33K1		I	
11S 11E 33Q1		I	
11S 11E 33R1	613	I	
11S 11E 34N1	615	I	
11S 11E 34P1	699	I	
11S 11E 34Q1	648	I	
11S 11E 35N1	434		
11S 11E 35N2	660	I	24
11S 11E 35R1		I	
11S 11E 36H1		I	
11S 12E 05B1	5	O	

ABANDONED WELLS

WELL NUMBER	WELL DEPTH (FT)	PREVIOUS USE	DEPTH OF SURFACE SEAL (FT)
11S 12E 05P1			
11S 12E 07E1	410	D	
11S 12E 07E2	488	In	
11S 12E 07J1		I	
11S 12E 08A1	108	I	none
11S 12E 08F2		I	
11S 12E 18M1			
11S 12E 19A1	255	D	
11S 12E 19A5		D,I	
11S 12E 19H1	235		
11S 12E 19R1	275		
11S 12E 20F1	255		
11S 12E 30F1			
11S 12E 31C1		I	
11S 12E 32A1			
11S 12E 32L1			
11S 12E 32M1	488	I	
12S 11E 01L1	1646	E	
12S 11E 02G1	416	E	
12S 11E 02N1	1667	E	
12S 11E 02Q1	1689	E	
12S 11E 03A1	599	I	
12S 11E 03H1		I	
12S 12E 06P1	10	O	

Abandoned Well Locations



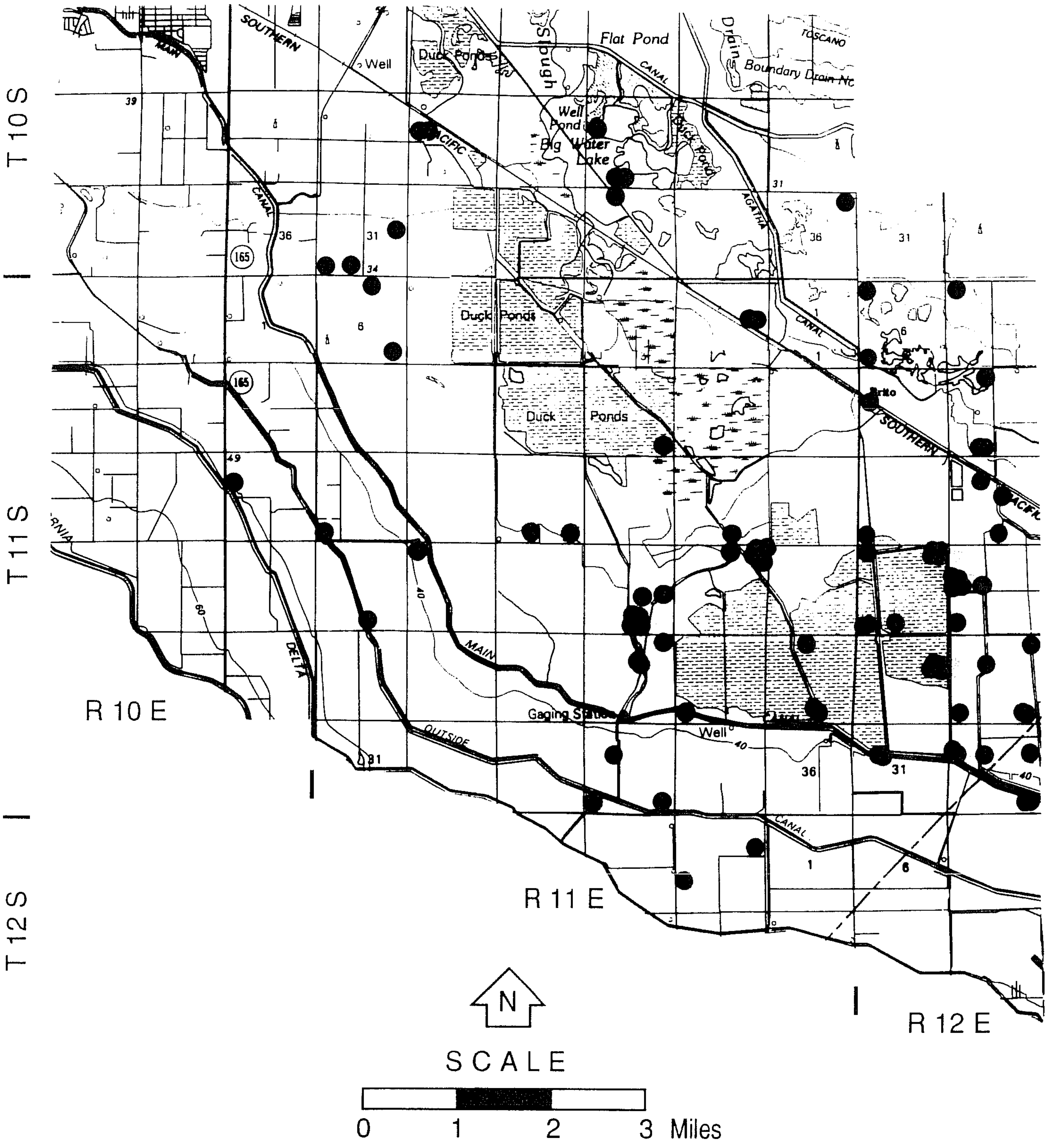
OBSERVATION WELLS

WELL NUMBER	WELL DEPTH (FT)	DEPTH OF SURFACE SEAL (FT)
10S 11E 27E1	385	
10S 11E 27P1	12.5	
10S 11E 27P2	14	
10S 11E 29E2	6	
10S 11E 29E3		
10S 11E 31K1		
10S 11E 31N1		
10S 11E 31P1	6.4	
10S 11E 34C1	5	
10S 11E 36A1		
11S 10E 24E1	11.6	
11S 11E 02J1	600	
11S 11E 02J2	300	
11S 11E 06B1		
11S 11E 06R1		
11S 11E 10R1	7	
11S 11E 14Q0	10	
11S 11E 16P1	10	
11S 11E 16R1	20	
11S 11E 18N0	101.5	
11S 11E 19Q1	7.2	
11S 11E 20D1		
11S 11E 22J0	45	
11S 11E 22K0	43.5	
11S 11E 22Q0	500	
11S 11E 22Q1	597	
11S 11E 22Q2	480	
11S 11E 22Q3	330	
11S 11E 23A0	100	
11S 11E 23A1	68	
11S 11E 23A2	99	
11S 11E 23A3	93	
11S 11E 23B1	21	
11S 11E 25C1	20	
11S 11E 25Q0	46	9
11S 11E 25Q3	46	
11S 11E 26N1	16	
11S 11E 27A0	59.8	
11S 11E 27G0	36	
11S 11E 27G1	12	
11S 11E 34F1	12	
11S 11E 34N2		
11S 11E 34R1	21	
11S 12E 05D1		
11S 12E 06D1		
11S 12E 06N1		

OBSERVATION WELLS

WELL NUMBER	WELL DEPTH (FT)	DEPTH OF SURFACE SEAL (FT)
11S 12E 07E3	12	
11S 12E 08C1		
11S 12E 08P1	9	
11S 12E 08P2		
11S 12E 17F1	12	
11S 12E 17K1	19.2	
11S 12E 17Q1	17	
11S 12E 18N0	100	
11S 12E 19A0	9	
11S 12E 19A2	42	
11S 12E 19A3	98	
11S 12E 19A4	100	
11S 12E 19D1	13.5	
11S 12E 19N1	101	
11S 12E 19N2	11	
11S 12E 19P0	101	
11S 12E 20E0	100	
11S 12E 20E1	40	
11S 12E 20E2	12	
11S 12E 20E3	97	
11S 12E 20F2	19.3	
11S 12E 20N0	50	
11S 12E 29A0	40.8	
11S 12E 29F1	11.5	
11S 12E 29N0	31.5	
11S 12E 29R0	97.5	
11S 12E 29R1	12	
11S 12E 30H0	101	
11S 12E 30H1	101	
11S 12E 30H2	21.5	
11S 12E 30H3	48	
11S 12E 31F0	38	
11S 12E 31F1	39	
11S 12E 32E0	35	
11S 12E 32E1		
11S 12E 32F1	18.9	
11S 12E 32H0	30.2	
11S 12E 32R0	49	
11S 12E 32R1	125	
12S 11E 02H1	14.5	
12S 11E 02M1	13.5	

Observation Well Locations



APPENDIX D

SOUTH GRASSLAND AREA GROUND WATER QUALITY

Explanation for symbols used in Appendix D:

Constituents:

EC = electrical conductivity in micromhos/cm

TDS = total dissolved solids

Ca = calcium

Mg = magnesium

Na = sodium

K = potassium

Cl = chloride

SO_4 = sulfate

Carb Alk = carbonate alkalinity

Bicar Alk = bicarbonate alkalinity

B = boron

Cr = chromium (total)

Cu = copper (total)

Hg = mercury (total)

Mo = molybdenum (total)

N = nickel (total)

Pb = lead (total)

Se = selenium (total)

Zn = zinc (total)

Blank spaces indicate the lab did not analyze for that constituent.

* Sample taken before three casing volumes of water were purged from the well.

** Completed in the lower water-bearing zone

\# Ca/SO_4, on an equivalent basis, is less than 0.50, indicating that molybdenum may be under recovered

\+ Due to a laboratory error, the field EC is given for well number 11S 12E 08A2, with a corresponding calculated TDS.

SOUTH GRASSLAND AREA GROUND WATER QUALITY

ZONE	WELL NUMBER	SAMPLE DATE	EC	TDS mg/L	pH	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	SO4 mg/L	Carb Alk mg/L	Bi-carb Alk mg/L	Total Hardness mg/L	B mg/L	Cr ug/L	Cu ug/L	Hg ug/L	Mo ug/L	Ni ug/L	Pb ug/L	Se ug/L	Zn ug/L
1	10S 11E 32Q1	20 JAN 86	5000	3700	8.4	179	194	781	4.5	1100	1400	8	180	1200	3.7	<1	1	<0.5	<5#	<1	<5	7	40
1	10S 11E 33H2	28*AUG 85	1550	944		5	24	240	3.4	83	400				3.2	40	70	<1	10#	90	12	<1	2160
		20*JAN 86	1490	1100	8.4	40	24	266	2.9	97	460	16	180	200	3.2	<1	5	<0.5	5#	<1	<5	<1	220
		20*JAN 86	1380	970	8.4	30	21	257	2.7	84	410	16	180	220	3.0	<1	2	<0.5	12#	1	<5	<1	80
1	10S 11E 34B2	7 AUG 85	6000	4000		170	139	904	5.8	1200	1500				4.2	11	95	<1	10#	<5	<10	<1	620
1	10S 11E 36A2	7 AUG 85	7200	4600		279	273	808	6.4	1800	1100				2.2	3	2	<1	<10	<5	<10	<1	30
1	11S 11E 01M4	7 AUG 85	6500	4400		211	151	944	5.8	1300	1400				4.5	4	110	<1	20#	5	<10	<1	70
1	11S 11E 03N	27 AUG 85	3900	2800		173	103	524	4.2	430	1300				5.3	3	2	<1	30#	18	<10	<1	10
1	11S 11E 04N2	27 AUG 85	4800	3000		132	110	692	3.6	920	970				4.7	1	4	<1	20#	<5	<10	<1	20
1	11S 11E 09M2	27 AUG 85	5400	3300		156	98	760	3.6	1000	1000				5.2	1	<1	<1	20#	<5	<10	1	90
1	11S 11E 16D2	7 AUG 85	4800	3000		180	86	684	3.4	1000	940				5.0	2	2	<1	20#	<5	<10	<1	50
		20 JAN 86	4500	2100	8.3	199	96	702	3.3	980	850	0	120	910	5.0	<1	<1	<0.5	13	<1	<5	<1	90
1	11S 12E 06A1	7 AUG 85	3800	2190		159	71	432	5.3	1000	200				1.3	3	<1	<1	<10	<5	<10	<1	10
1	11S 12E 06A2	7 AUG 85	4000	2200		157	79	456	5.8	1000	250				1.4	2	1	<1	<10	<5	<10	<1	10
1	11S 12E 19A6	8 AUG 85	3100	2380		280	115	246	4.9	270	1100				2.6	1	<1	<1	20	<5	<10	<1	20
2	10S 10E 25J	31 JULY 86	1900	1200	7.9	33	46	190	1.5	240	130			300	2.1	3	2	<0.5	10	<5	<5	<1	39
2	10S 10E 25K1	31 JULY 86	1300	840	7.9	54	54	85	2.6	160	180			320	0.93	3	<1	<0.5	<5	<5	<5	<1	2
		duplicate	1300	810	8.1	52	53	85	2.6	160	180			340	0.87	3	<1	<0.5	<5	<5	<5	<1	2
2	10S 10E 26H1	12 JUNE 86	500	290	8.4	38	17	34	2.0	37	42	8	130	170	0.46	56	<1	<0.5	<5	<5	<5	<1	2
2	10S 10E 26J1	13 JUNE 86	540	300	8.3	43	21	35	1.9	51	72	0	130	180	0.42	38	<1	<0.5	<5	<5	<5	<1	3
2	10S 10E 34P2	13 JUNE 86	1500	780	8.0	87	59	81	4.2	260	130	0	210	540	0.83	13	2	<0.5	<5	7	<5	1	10
2	10S 10E 36N1	12 JUNE 86	550	310	8.4	21	11	67	1.4	38	45	8	140	94	0.56	40	1	<0.5	<5	<5	<5	<1	2
2	10S 10E 36N2	12 JUNE 86	620	360	8.4	26	13	78	1.2	49	57	8	170	120	0.69	46	1	<0.5	<5	<5	<5	<1	28
2	10S 11E 19B2	7 AUG 85	2600	1630		116	77	284	3.3	350	610				2.1	6	<1	<1	<10#	<5	<10	2	10
2	10S 11E 29L2	28 AUG 85	920	571		17	20	130	1.7	79	150				1.2	3	<1	<1	<10#	<5	<10	6	10
		20 JAN 86	900	620	8.5	26	21	138	1.6	79	180	16	180	170	1.1	3	<1	<0.5	<5#	<1	<5	6	4
2	10S 11E 29N1	31 JULY 86	750	480	7.9	31	21	104	1.5	68	98			160	0.97	1	<1	<0.5	5	<5	<5	4	4
2	10S 11E 30G2	31 JULY 86	1300	790	7.9	39	44	140	2.3	150	200			250	1.3	<1	<1	<0.5	<5#	<5	<5	<1	<1
2	10S 11E 31F2	31 JULY 86	1100	690	8.0	38	38	150	1.7	140	150			200	1.5	15	2	<0.5	<5	<5	<5	<1	<1
2	11S 10E 01M	13 JUNE 86	2400	1700	8.2	96	66	290	2.8	230	650	0	230	520	4.6	49	5	<0.5	<5#	<5	<5	4	9
2	11S 10E 01N	13 JUNE 86	1700	1100	8.2	72	51	190	2.3	120	440	0	200	420	1.8	74	6	<0.5	<5#	<5	<5	5	2
2	11S 10E 01R1	28 AUG 85	1100	628		24	35	120	2.7	100	210				1.2	40	2	<1	<10#	<5	<10	3	4
2	11S 10E 02K2	13 JUNE 86	1300	860	8.4	82	40	130	2.3	140	280	8	150	370	1.1	42	1	<0.5	<5	<5	<5	4	2
2	11S 10E 02Q1	13 JUNE 86	1200	740	8.4	41	31	150	1.4	100	200	8	220	240	1.7	48	1	<0.5	6#	<5	<5	2	5

SOUTH GRASSLAND AREA GROUND WATER QUALITY

ZONE	WELL NUMBER	SAMPLE DATE	EC	TDS mg/L	pH	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Cl mg/L	SO4 mg/L	Carb Alk mg/L	Bi-carb Alk mg/L	Total Hardness mg/L	B mg/L	Cr ug/L	Cu ug/L	Hg ug/L	Mo ug/L	Ni ug/L	Pb ug/L	Se ug/L	Zn ug/L
2	11S 10E 11P1	13 JUNE 86	1700	980	8.2	20	31	240	1.2	160	160	0	380	160	2.1	37	6	<0.5	<5#	<5	<5	3	58
2	11S 10E 13M3	13 JUNE 86	1900	1100	8.1	55	51	210	1.8	240	290	0	270	410	1.9	46	7	<0.5	<5#	<5	<5	9	2
2	11S 10E 14C2	13 JUNE 86	1700	1000	8.2	39	40	220	2.0	190	230	0	310	300	2.3	49	2	<0.5	<5#	<5	<5	4	15
2	11S 10E 14L1	13 JUNE 86	2600	1700	8.1	100	78	290	2.5	360	450	0	340	480	2.2	43	2	<0.5	<5	<5	<5	29	2
		duplicate	2600	1700	8.1	102	74	290	2.5	380	450	0	250	560	2.3	43	3	<0.5	<5	<5	<5	30	6
2	11S 11E 05D3	28 AUG 85	3900	2900		75	118	632	2.0	160	450				5.8	12	1	<1	30#	<5	<10	14	10
		20 JAN 86	1550	1100	8.5	50	56	229	1.7	120	460	24	160	390	2.0	17	2	<0.5	<5#	<1	<5	10	9
2	11S 11E 07D1	20 JAN 86	1470	1100	8.4	59	46	203	1.8	180	340	16	160	380	1.6	47	2	<0.5	5#	<1	<5	8	7
2	11S 11E 08B1	7 AUG 85	2300	1400		86	89	248	2.9	360	580				1.6	27	54	<1	<10#	<5	<10	7	40
		20 JAN 86	2100	1600	8.4	84	103	268	2.7	320	520	8	140	700	1.7	21	28	<0.5	<5#	1	<5	7	40
2	11S 11E 08C2	7 AUG 85	2300	1390		67	47	316	2.2	280	450				2.1	3	1	<1	20#	<5	<10	12	40
		20 JAN 86	2000	1400	8.5	64	54	310	2.0	270	440	16	160	500	2.1	1	4	<0.5	<5#	<1	<5	11	180
2	11S 11E 19B1	5 AUG 86	2200	1300	7.9	110	63	210	1.6	400	330			580	1.5	4	<1	<0.5	<5	<5	<5	1.1	9
3	10S 11E 23B2	27 AUG 85	1950	982		32	33	262	2.4	400	92				0.92	<1	1	<1	<10	<5	<10	<1	70
3	10S 11E 27E3**	7* AUG 85	1650	1100		29	13	294	3.1	110	510				2.7	1	1	<1	20#	<5	<10	<1	20
		20 JAN 86	1500	1100	8.4	44	14	278	2.8	96	500	16	140	170	2.6	<1	1	<0.5	<5#	<1	<5	<1	2
3	10S 12E 31M3	27 AUG 85	4400	2600		148	109	476	5.4	1100	270				1.6	1	<1	<1	<10	<5	<10	<1	10
3	10S 12E 32P1	7 AUG 85	4600	2500		197	183	396	5.8	1200	290				1.4	<1	<1	<1	<10	<5	<10	<1	160
3	11S 12E 08A2	7 AUG 85	5600+	3240		274	233	576	9.9	1600	710				1.1	3	<1	<1	<10	<5	<10	<1	10
3	11S 12E 08C2	27 AUG 85	4000	2300		114	104	484	4.9	930	610				1.4	1	30	<1	<10#	<5	<10	<1	70