DOE/NV/10845-16
UC-703

GROUNDWATER CHEMISTRY AT THE NEVADA TEST SITE:
Data and Preliminary Interpretations

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Prepared by

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Submitted to

DOE Nevada Operations Office
U.S. Department of Energy

March 1993

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Publication No. 45100

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GROUNDWATER CHEMISTRY AT THE NEVADA TEST SITE:
Data and Preliminary Interpretations

by

Water Resources Center
Desert Research Institute
University and Community College System of Nevada

prepared for
DOE Nevada Operations Office
U.S. Department of Energy
Las Vegas, Nevada

Publication No. 45100

March 1993

The work upon which this report is based was supported by the U.S. Department of Energy under Contract #DE-AC08-90NV10845.

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ABSTRACT

The interpretation of chemical analyses of groundwater collected at and near the Nevada Test Site (NTS) has been vital in developing conceptual models of groundwater flow in the area. These conceptual models are tested using recent chemical data generated by the Desert Research Institute, as well as historic analyses from the U.S. Geological Survey. A total of 81 wells are represented by analyses from 1957 to 1990, with generally excellent agreement between repeat samples from the same location. As identified by previous workers, three hydrochemical facies are represented by the samples: Ca–Mg–HCO_3 water in carbonate rocks or alluvium derived from carbonates, Na–K–HCO_3 water in volcanic rocks and alluvium derived from volcanic rocks, and a mixed facies found in many carbonate and alluvium water samples, and some volcanic waters. There is a general lack of lateral continuity in chemical characteristics along presumed flowpaths within each hydrologic unit (alluvium, carbonate, and volcanic). Though a lack of continuity between basins on the east side of the NTS was expected for water in alluvial and volcanic units due to the absence of interbasin flow, chemical differences observed within individual basins suggest a dominance of vertical over lateral flow. Groundwater in volcanic materials on the east side of Yucca and Frenchman Flats and on the west side of Pahute Mesa and Yucca Mountain has a nearly pure Na–K–HCO_3 signature that reflects contact with primarily volcanic material. Groundwater in volcanic units in the middle of the NTS and on the east side of Pahute Mesa contains a higher proportion of Ca, Mg, Cl, and SO_4 than the other volcanic waters and indicates the contribution of water from the upper carbonate aquifer and/or hydrothermally altered regions. The lack of lateral chemical continuity in volcanic water on Pahute Mesa is attributed to stratigraphic and structural complexities in the volcanic units of the caldera complex. Areal variations in conservative ions in the carbonate aquifer indicate that though the lower carbonate aquifer may be considered a single hydraulic unit in gross flow terms, it may be considerably more complex when evaluating solute transport. Striking differences between groundwater in carbonate units at the south end of Yucca Flat and groundwater upgradient indicate the contribution of water from volcanic units, either by downward leakage or by lateral flow from structurally juxtaposed formations. A similar contribution of groundwater from volcanic formations is indicated by sodium and chloride concentrations in the carbonate aquifer near Fortymile Wash. The reduction in dissolved solutes in the carbonate aquifer at the southeast end of the NTS, as compared to water sampled at the south end of Yucca Flat, suggests a major contribution of groundwater flow coming from east of the NTS.

INTRODUCTION

The dissolved ionic constituents of groundwater are a record of the minerals the water has contacted (either dissolving or precipitating) as it moves through soil and rock. As such, the chemistry of the water can be used to trace groundwater movement. The chemistry of groundwater in the Nevada Test Site (NTS) area has been instrumental in the development of the most basic flow hypotheses for the region. For example, the movement of water from volcanic aquifers into the regional carbonate aquifer in the vicinity of the NTS was deduced in large part by an increase in sodium concentration in the carbonate groundwater sampled at and downgradient from the NTS (Schoff and Moore, 1964). Low sodium concentrations in groundwater from the carbonate aquifer in the vicinity of Indian Springs were used as evidence that a groundwater divide directs flow from the NTS toward Ash Meadows rather than Las Vegas. Recognizing the importance of groundwater chemistry to hydrogeologic interpretations, the U.S. Geological Survey (USGS) performed extensive sampling in the NTS region that culminated with publications by Blankennagel and Weir in 1973 and Winograd and Thordarson in 1975. Three hydrochemical facies in and near the NTS were recognized: a Ca–Mg–HCO_3 facies from groundwater in carbonate rocks east and south of the NTS, a Na–K–HCO_3 facies from groundwater in volcanic rocks, and a Ca–Mg–Na–HCO_3 (mixed facies) in carbonate rocks beneath the NTS and in the east–central Amargosa Desert and Ash Meadows areas (Schoff and Moore, 1964).

The chemical data from which so many important conclusions were drawn are scattered through a number of USGS publications, and a few are referenced as personal communications or data on file in Denver USGS offices. Most of these data were obtained from samples collected in the late 1950s and early 1960s, though a few new wells were drilled and sampled in the late 1970s. The late 1980s and early 1990s have seen a resurgence of water sampling on the NTS, with samples collected from pre–existing wells and 28 new wells. These samples have been collected and analyzed by the Desert Research Institute (DRI).

This document compiles the USGS and DRI analyses in an effort to present a reasonably complete dataset for groundwater chemistry at the NTS. No exhaustive effort was made to identify all historic data; rather, the focus was on compiling the bulk of the analyses used to formulate important ideas about groundwater flow at the NTS. Some data, particularly recent samples from the Yucca Mountain area, have no doubt been overlooked. In cases where both old (1957–1977) and new (1983–1990) samples were available for the same well, the analyses have been compared using trilinear diagrams of ion percentages. In most cases, analyses compared well, so the datasets were combined and mean values for the constituents and pH for a given well were calculated. By dividing the wells into three groups based on the reported lithology of the sampling horizon (alluvium, volcanic, carbonate), the areal distribution of ions was mapped and compared to general groundwater flow directions.

Data Sources

Chemical data for the period 1957 to 1977 were gathered from the following USGS reports: Schoff and Moore (1964), Blankennagel and Weir (1973), Young (1965), Thordarson *et al.* (1962), Robinson and Beetem (1965), and Dinwiddie and Weir (1979). These data are presented in Appendix A. Well names used in the appendices and throughout the text of this report are consistent with the names used in the 1991 edition of the Raytheon Services Nevada "NTS Drilling and Mining Summary." Wells are reported in the appendices in order of increasing Nevada state north coordinate.

All analyses but one reported from the period 1983 to 1990 were performed by the Water Analysis Laboratory of the Desert Research Institute. The one exception is the analysis from UE–25p #1, performed by the USGS and reported by Benson and McKinley (1985). Some of these DRI analyses have appeared previously in specific project reports prepared by DRI for the Department of Energy. These data are presented in Appendix B. Together, the USGS and DRI analyses represent 81 wells at and near the NTS (Figure 1). Average ion and pH values computed by combining the 1957–1977 and 1983–1990 datasets are given in Appendix C.

The chemical analyses reported in the appendices were performed on samples collected in several different ways. Samples were either collected during drilling and well development, with permanent pumps installed in supply wells, with temporary pumps used for aquifer testing and sampling, or with bailers. The degree to which a sample is representative of formation water varies with each method, but also varies with how a method was applied (*e.g.*, number of pumping volumes before sampling) and sample collection and preservation procedures (*e.g.*, filtering and acidifying cation samples). No attempt was made to assign quality ratings to the analyses assembled for this report because detailed sampling information was rarely available. However, it may aid the reader to keep in mind the following generalizations. Many of the analyses reported in Appendix A and the 1988 analyses from Pahute Mesa #3 in Appendix B were collected during drilling and well development and the resulting analyses could be influenced by residual drilling fluids. In some cases, this means that the producing horizon is actually different from sample to sample (*e.g.*, samples were collected from multiple formations in UE–16d Eleana, USGS HTH #1, and U–19d #2). In Appendix B, samples from NTS supply wells were collected by pumping, and due to the lengthy pumping history of these wells, these samples are the most likely to be representative of formation water. These supply wells are those with "Water Well" in the name, plus UE–16d Eleana. Wells located around Yucca Mountain (wells with a "WT" for water table in the name) were sampled with a low volume piston pump and collected after pH, temperature, and electrical conductivity had stabilized (Matuska, 1989). The other samples in Appendix B were collected with a discrete bailer. The bailer was evacuated at the surface, lowered to a depth corresponding to a screened or open interval, then a valve was opened for sample collection. Because the water collected was present in the well bore, not the formation, there is the possibility that degassing of CO_2 could have occurred and altered the pH and ion concentrations, and that reactions with casing materials could have occurred.

COMPARISON BETWEEN 1957–1977 DATA AND 1984–1990 DATA

Eighteen wells have chemical analyses available from both the earlier and later sampling periods. Of these 18, 12 have no major change in salinity and relative ion percentages between the

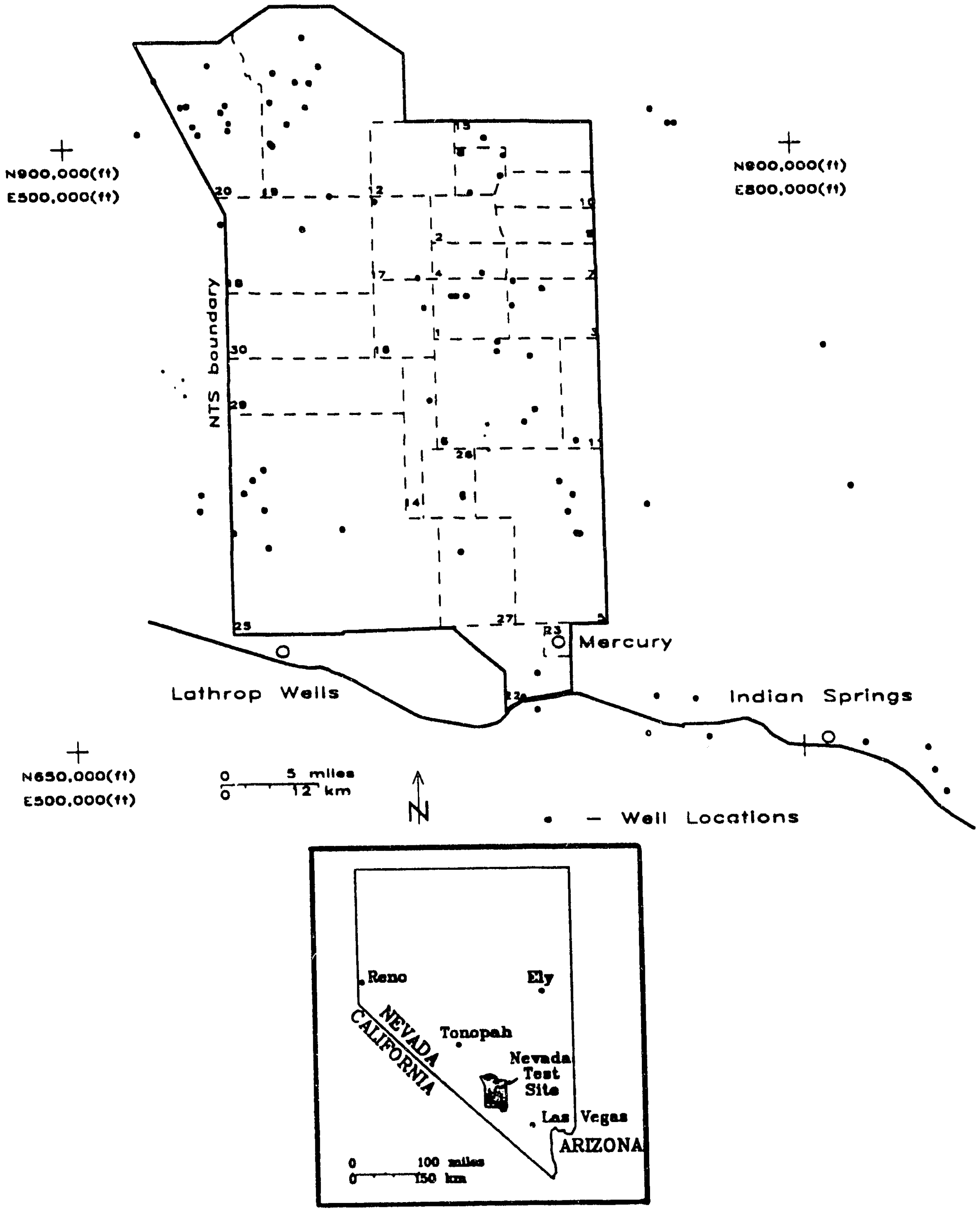


Figure 1. Location of the Nevada Test Site and wells with chemical analyses reported in this study. Well names can be found on detailed maps later in the report.

two groups. In a few cases (*e.g.*, Water Well 2), there is no obvious break between the 1957–1977 and 1984–1990 data groups but there is a relatively large spread in the ion ratios of the earlier analyses. This may be caused by continuing well development with pumping, resulting in more representative formation water with time. The six wells with significant differences between the old and new analyses are discussed below in the following order: UE–15d Water Well, UE–16f Eleana, UE–16d Eleana, Army 6A, USGS Test Well D, and USGS HTH #1. Because there is little change in overall salinity of samples from a given well, trilinear plots are used to discuss temporal changes in measured chemical composition. On the plots,the water composition is represented as percentages of the total milliequivalents per liter of cations (left triangle), percentages of the total milliequivalents per liter of anions (right triangle), and a combined representation of the anions and cations by projecting these points onto a central diamond.

A sample collected from UE–15d Water Well in 1989 is within 10% of the ion ratios of samples collected in 1961 and 1962 (Figure 2). However, two samples collected in 1990 have shifted to approximately 15 to 20% more calcium relative to other cations, as compared to the earlier samples. Total salinity is essentially unchanged. It seems unlikely that preservation or analytical errors could be the source of the difference because there are two independent samples defining each group, and anion percentages remain stable. Rather, the difference may be related to a reduction in pumping at the well that began in 1990 and culminated with the pump becoming inoperative in 1991. This well is completed in fractured quartzite with a dolomite unit at the bottom of the hole. The 1960's and 1989 samples probably reflect water produced primarily from the quartzite. The change in chemistry in 1990 could reflect mixing of water from the dolomite in the well bore in the long periods between pumping in 1990. The shift in chemical composition is important because there has been an increase in the tritium concentration in this well over the last 15 years (Lyles, 1990 and 1992). Identifying the formations contributing water to the well would aid in determining the source of the tritium. To this end, the inoperative pump in UE–15d Water Well should be pulled and hydrologic logging performed.

Analyses are available from UE–16f Eleana from samples collected at the time of drilling and testing (1977) and in 1988. The three samples show a progressive increase in the amount of HCO_3 relative to the other anions, with the 1988 sample having greater than 95% HCO_3, less than 5% Cl, and essentially no SO_4 (Figure 3). This trend could be the result of well development, meaning that the most recent sample is the most representative of formation water.

The three 1977 samples from UE–16d Eleana were collected during drilling and show up to 10% shifts in ion percentages from one sample to another (Figure 4). Presumably, these variations are related to different contributing horizons at the time of sampling. The 1977 sample most different from the 1990 sample was collected on 6–19–77 and is recorded as being from the Eleana Formation (quartzite). The well was recompleted in 1981 with the Eleana Formation cemented off and perforations installed across the Tippipah Limestone, so it is not surprising that there are differences between the 6–19–77 sample and the one in 1990. The greatest similarity in cations exists between the 1990 sample and the one collected on 6–14–77. The 6–14 sample was the only earlier sample

	Date (m/d/y)	Depth (m)	TDS (mg/l)
A	11/12/61	591	438
B	03/27/62	1829	436
C	09/11/89	495	435
D	04/16/90	495	493
E	08/01/90	495	408

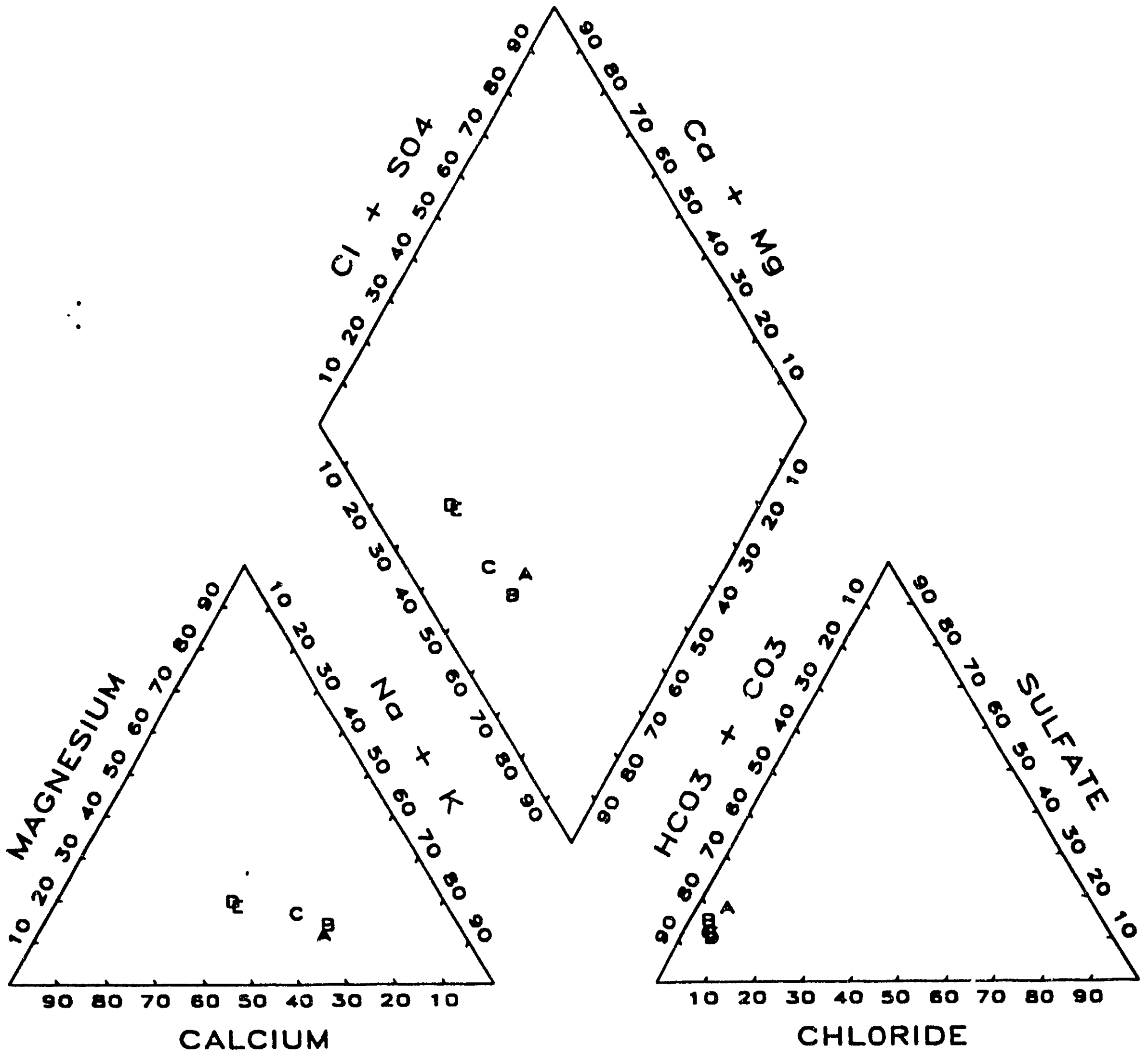


Figure 2. Trilinear diagram showing relative ion percentages for samples collected from UE–15d Water Well. The depth of the 1989 and 1990 samples is the location of the pump. The well was open to 1829 m.

	Date (m/d/y)	Depth (m)	TDS (mg/l)
A	08/20/77	207--256	1040
B	09/25/77	394--436	1080
C	09/20/88	378	975

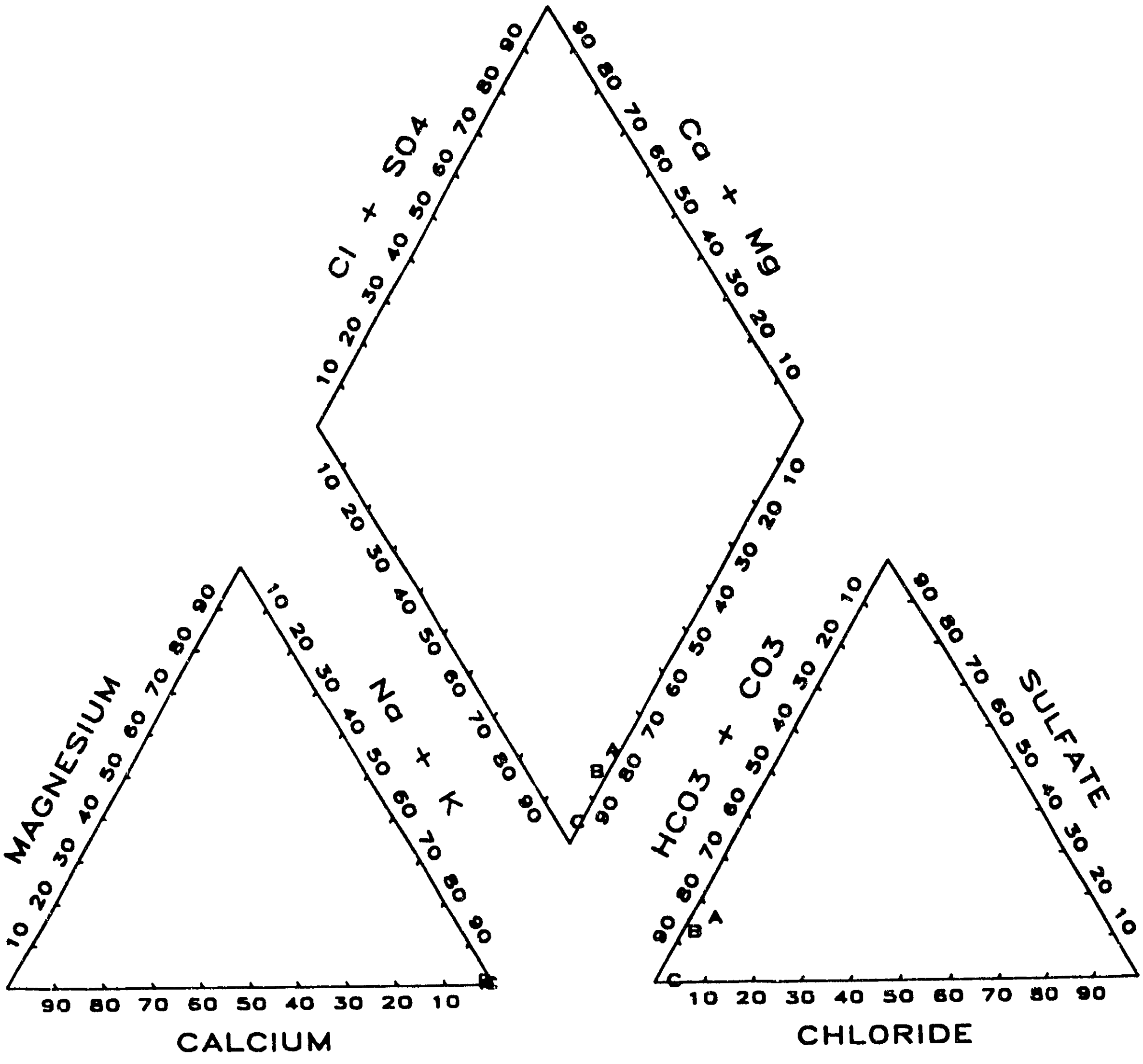


Figure 3. Trilinear diagram showing relative ion percentages for samples collected from well UE–16f Eleana.

	Date (m/d/y)	Depth (m)	TDS (mg/l)
A	05/23/77	25–253	309
B	06/14/77	25–646	386
C	06/19/77	468–527	359
D	06/15/90	335	418

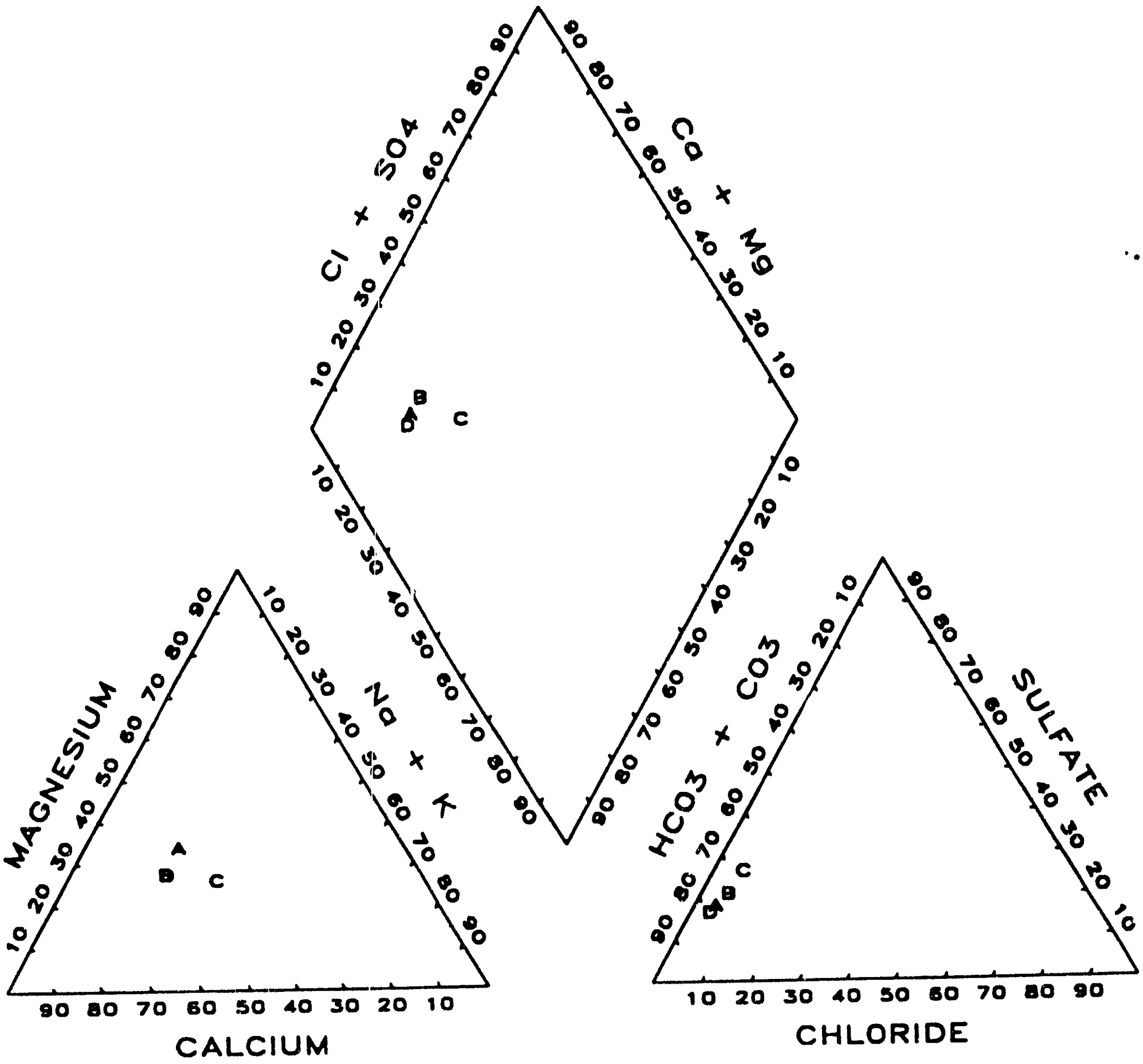


Figure 4. Trilinear diagram showing relative ion percentages for samples collected from well UE–16d Eleana.

that was collected by pumping, and the similarity in chemistries suggests that the Tippipah Limestone was probably the major contributing zone to the borehole during pumping in 1977.

The 1958 analysis of water from well Army 6A differs drastically from two analyses of samples collected in 1986 (Figure 5). The total dissolved solids (TDS) concentration in the more recent samples is about 7% lower than the earlier one, but the major difference is a large increase in the amount of magnesium at the expense of sodium, and an increase in SO_4 at the expense of HCO_3. Schoff and Moore (1964) were suspicious of the 1958 analysis because it yielded a Na–K water in an area where other water was a Ca–Mg type. The later analyses do not resolve the problem, but instead make it one of a Mg–SO_4 type water in a Ca–Mg–HCO_3 area. Schoff and Moore concluded that the earlier analysis did not represent formation water and suggested that it could have been contaminated by cement used in the well during completion. However, the measured pH (8.0) was much lower than what would be expected from a cement–contaminated water (greater than 11). The later analyses also have reasonable pH values (around 8.6), and cation/anion charge balances are very good for both the 1958 and later analyses.

Though cement contamination seems unlikely, water introduced during drilling could have altered the *in situ* chemistry. Given that the well has a low production rate (1 to 2 gpm) and was abandoned immediately, water introduced during drilling in 1955 may not have been purged by the time the sample was collected in 1958. The difference between the 1958 and 1986 analyses may indicate that diffusive and/or advective flow have equilibrated the well with its surroundings. The log of well Army 6A includes quartzite and limestone, but only quartzite and siltstone are intersected by the perforated interval (Moore, 1962). Both the old and new analyses indicate equilibrium with dolomite, and some source of sulfate is needed, neither of which are consistent with a quartzite aquifer. Though anomalous, there are other wells with unusual chemistries in the area (USGS HTH "F" and Army 6) that have been attributed to hydrothermal activity and/or as yet undetected evaporite deposits in the subsurface. Pumping the well at a low flow rate, monitoring field parameters, then sampling after purging many well volumes could reduce the uncertainty about the chemistry of this well.

Samples collected in 1986 from USGS Test Well D are substantially lower in TDS than the one collected in 1961. This difference in TDS is not reflected in any change in cation ratios (Figure 6), but a shift to a higher proportion of HCO_3 in the 1986 samples is due to lower Cl and sulfate concentrations in those samples as compared to the 1961 sample. The 1960 sample was collected from a bailer after three hours of nearly continuous bailing had removed 12,000 liters (3100 gallons) from the well (Thordarson *et al.*, 1962). Though care was taken to minimize contamination of groundwater by using a cable–tool rig and not introducing bentonite or chemical additives in the zone of saturation, the aquifer was penetrated by at least 16 meters (53 ft) and water was injected in the hole for cuttings removal, before groundwater was recognized. The hole also experienced serious caving problems both from the overlying tuff units when the hole penetrated the carbonates (with blocks of tuff falling into the bailer), and from interbedded siltstone and argillite formations. Fine material from these horizons may have dissolved into the well water and added to the TDS concentration. Though no extensive well development or pumping is known to have occurred at

	Date (m/d/y)	Depth (m)	TDS (mg/l)
A	04/27/58	382	718
B	06/25/86	320	686
C	06/25/86	324	673

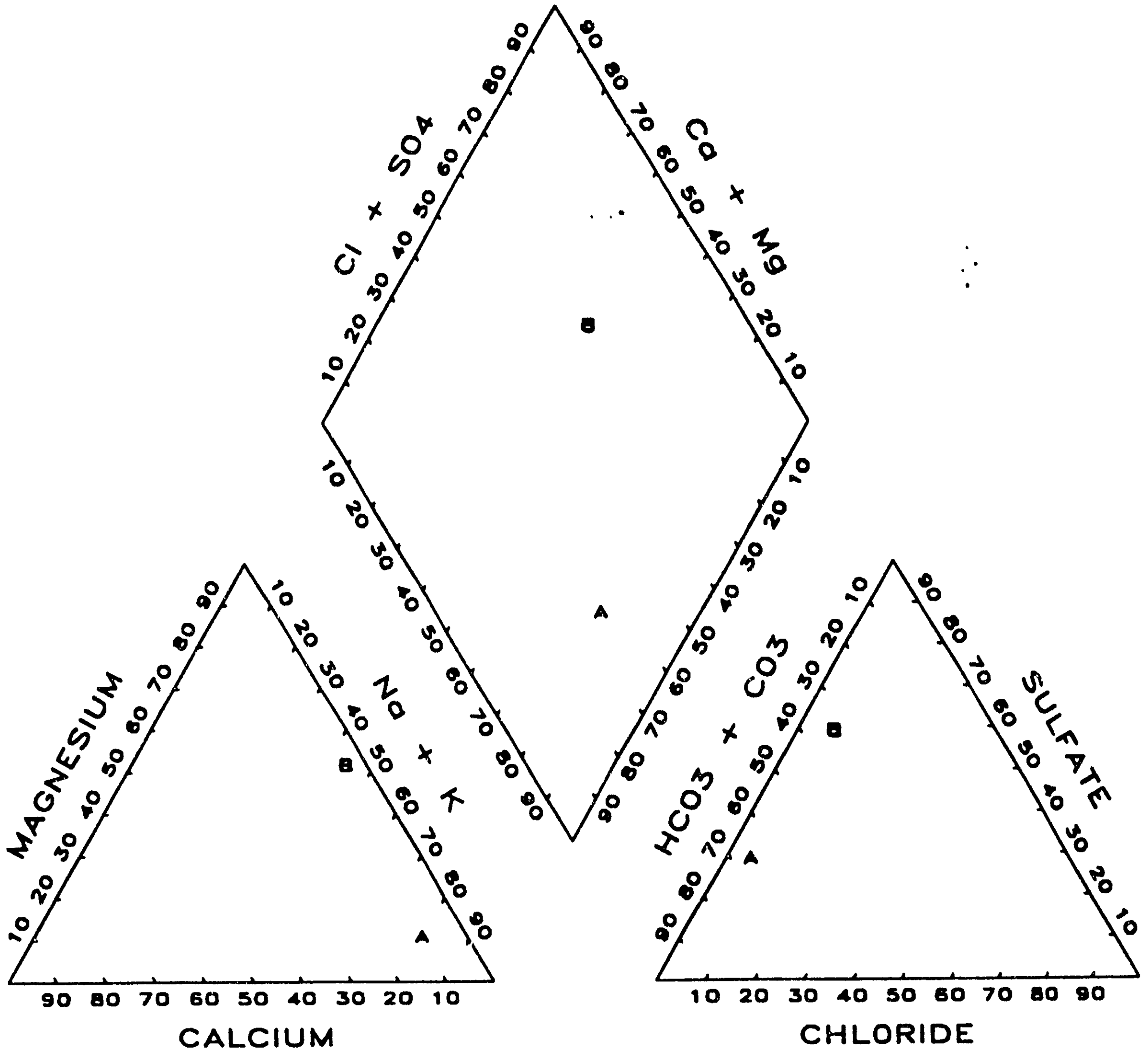


Figure 5. Trilinear diagram showing relative ion percentages for samples collected from well Army 6A.

	Date (m/d/y)	Depth (m)	TDS (mg/l)
A	01/09/60	594	398
B	06/23/86	531	321
C	06/23/86	561	321

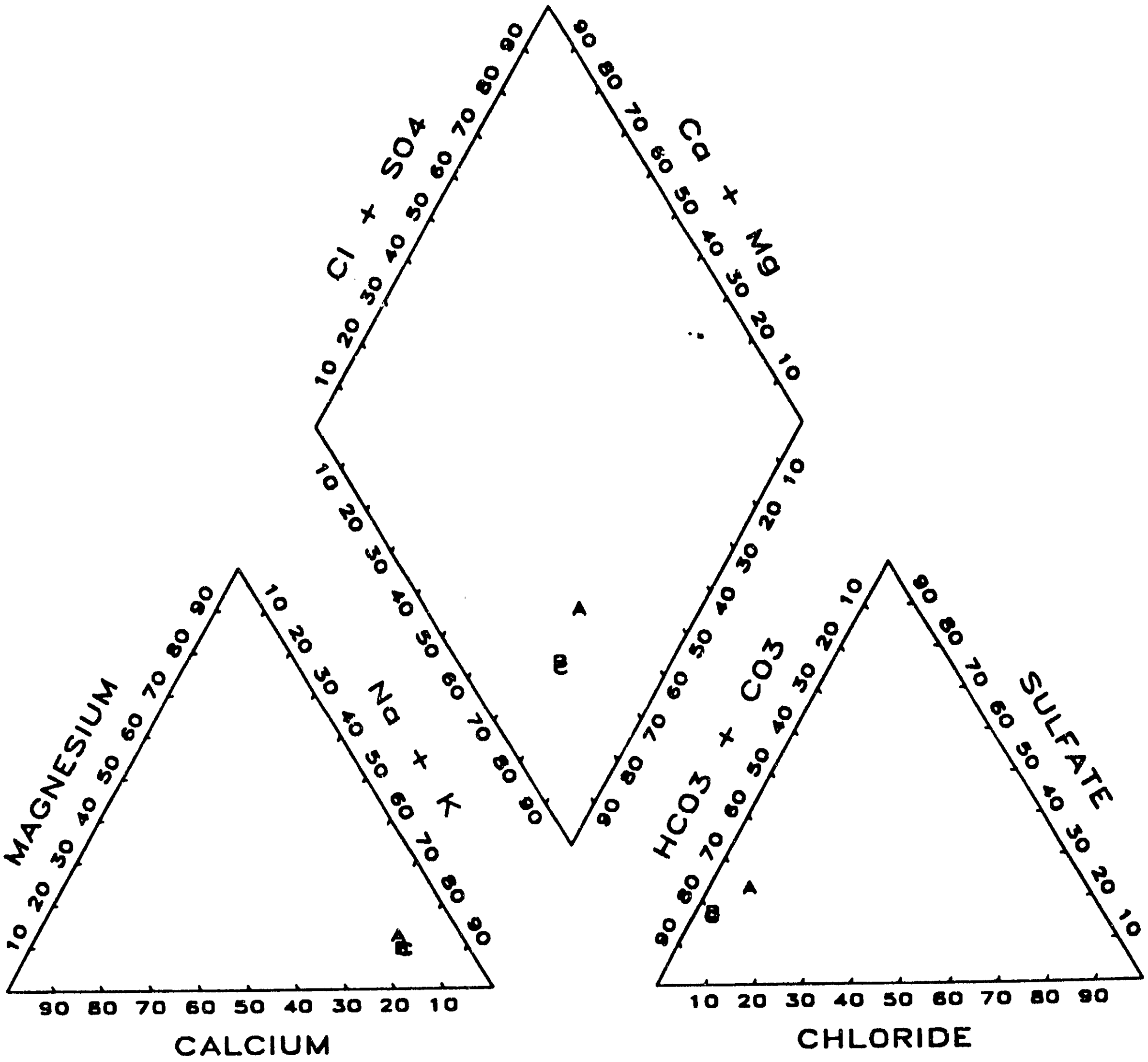


Figure 6. Trilinear diagram showing relative ion percentages for samples collected from USGS Test Well D.

USGS Test Well D between 1961 and 1986, equilibration of well water with the carbonate aquifer by advective or diffusive flow is reasonable over this time scale. Though the ionic composition of the 1986 samples may be more representative of formation water, the lower pH of the 1961 sample may be closer to *in situ* conditions. The 1986 samples were collected with a discrete bailer without previous purging of wellbore water, so some degassing of CO_2 and elevation of pH could have occurred. As with Army 6A, new samples from this well should be collected after pumping and monitoring field parameters.

Some of the variation observed at well USGS HTH #1 (Figure 7) comes from sampling from two discrete aquifers. Samples from the underlying carbonate aquifer were only collected in 1961 and 1962. These are the samples with the highest calcium percentages. The other samples collected in 1960 and from 1986–1990 were collected from volcanic zones and show higher proportions of sodium and bicarbonate, with the 1986–1990 set clustering more in the Na and HCO_3 apexes. All of the samples together appear to form a mixing line between a higher salinity, carbonate–influenced water and a lower salinity, volcanic–influenced water. This suggests that differences between individual samples relate to their collection position in the borehole rather than any hydrochemical changes with time. Flow relationships between the five perforated intervals in USGS HTH #1 and how they relate to the 1986–1990 samples are discussed by Lyles *et al.* (1991).

AREAL DISTRIBUTION OF DISSOLVED IONS IN GROUNDWATER

The three hydrochemical facies identified by previous workers are also represented in the averaged dataset created by combining the 1957–1977 data with the 1984–1990 data. Groundwater ranges from a Ca–Mg–HCO_3 water to a Na–K–HCO_3 water, with a rough mixing line between the two on the cation triangle (Figure 8). Water from volcanic rocks predominates in the Na–K area, while water from the carbonate rocks has generally higher percentages of calcium and magnesium. Most waters from carbonate rocks have a mixed chemical character, as do some volcanic aquifer waters. Water from alluvial deposits spans the chemical spectrum, depending on the source rock for the alluvial material. With the exception of a few outliers, there is less variation in anion percentages, with most waters dominated by bicarbonate.

The chemistry of the combined dataset continues to strongly support the hypothesis of Schoff and Moore (1964) and others that two distinct types of water develop depending on whether groundwater moves through a volcanic or carbonate aquifer. Significantly, the mixed nature of many samples from the NTS area indicates a water that has moved through both types of material.

Given the importance of aquifer material on groundwater chemistry, the combined 1957–1990 dataset was subdivided into three groups: wells completed in alluvium (14 wells), wells completed in carbonate rocks (17 wells), and wells completed in volcanic rocks (50 wells). This simplistic designation, while easy to make in many cases, was more problematic in others. An example is UE–16f Eleana, which is completed in the Eleana Formation, comprised of siltstone, sandstone, and quartzite with minor limestone. This well was grouped with the carbonates because the lithology seemed to have more in common with that group than with the volcanics or alluvium. However, it

	Date (m/d/y)	Depth (m)	TDS (mg/l)
A	10/01/60	171	151
B	10/20/60	337	150
C	06/09/61c	1137	278
D	08/11/62c	1282	208
E	07/24/86	461	141
F	07/28/87	725	129
G	07/28/87	1119	115
H	04/25/89	588	125
I	04/25/89	622	128

	Date (m/d/y)	Depth (m)	TDS (mg/l)
J	04/26/89	651	124
K	04/26/89	686	126
L	09/24/90	472	153
M	09/24/90	588	127
N	09/24/90	622	126
O	09/25/90	649	124
P	09/25/90	686	128
Q	09/25/90	732	124
R	09/26/90	1122	107

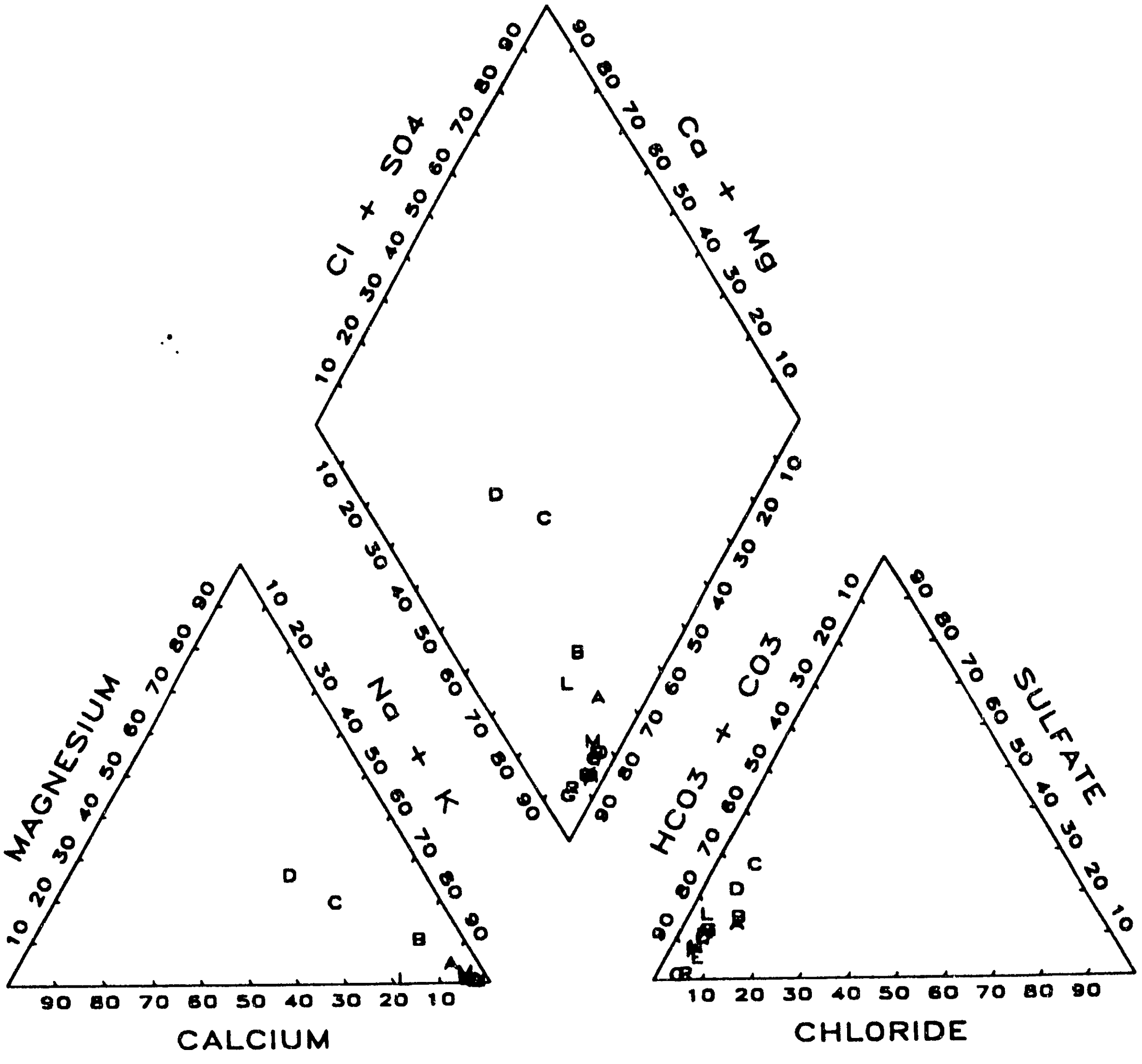


Figure 7. Trilinear diagram showing relative ion percentages for samples collected from well USGS HTH #1. Samples C and D (with a "c" after the date) were collected from carbonate rocks, while all of the others were from volcanic units.

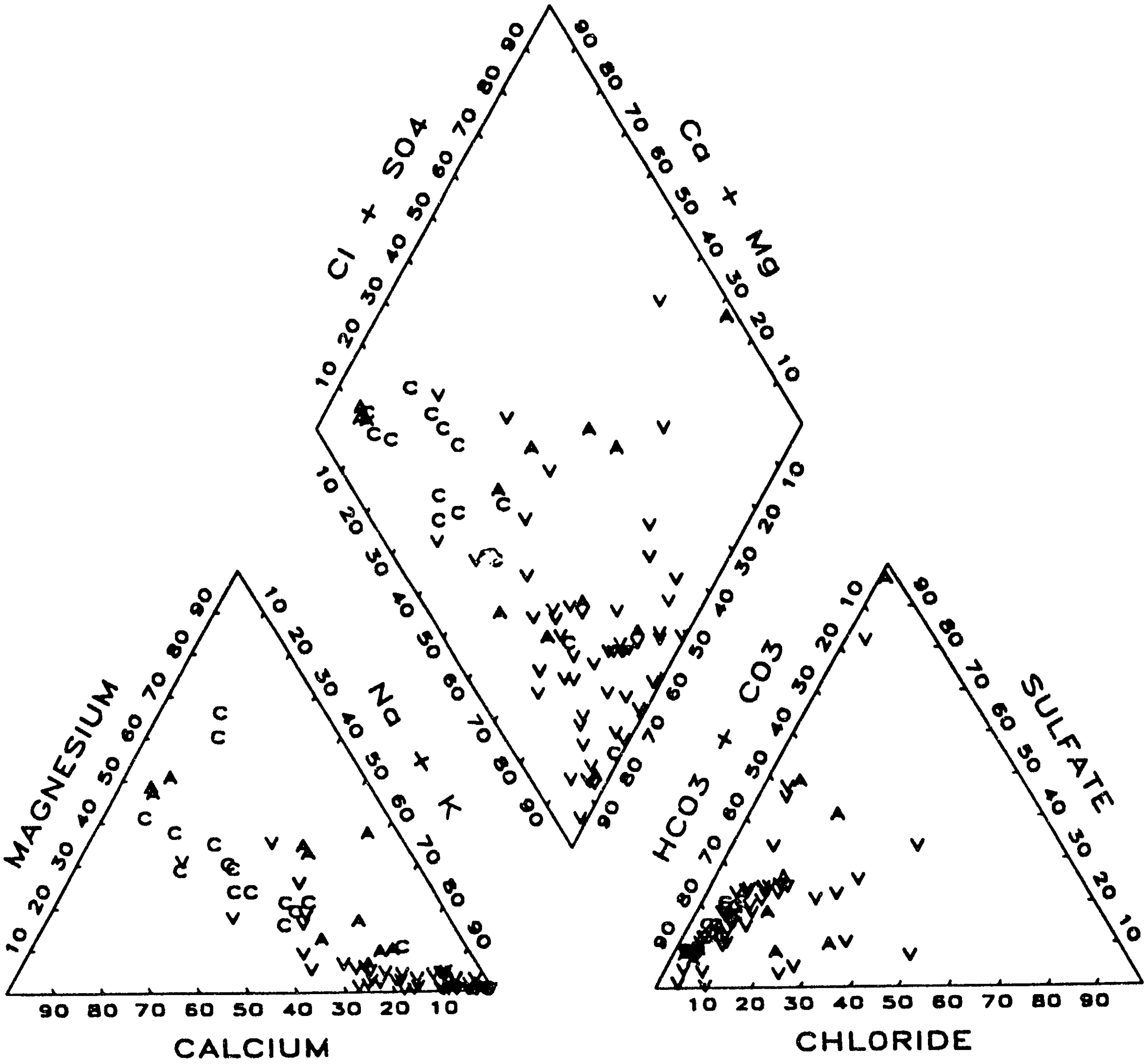


Figure 8. Trilinear diagram showing relative ion percentages for samples collected from all wells reported in this study, differentiated based on aquifer rock type. Aquifer designations are as follows: A=alluvium, C=carbonate, and V=volcanic. Averaged values used to construct this diagram are reported in Appendix C.

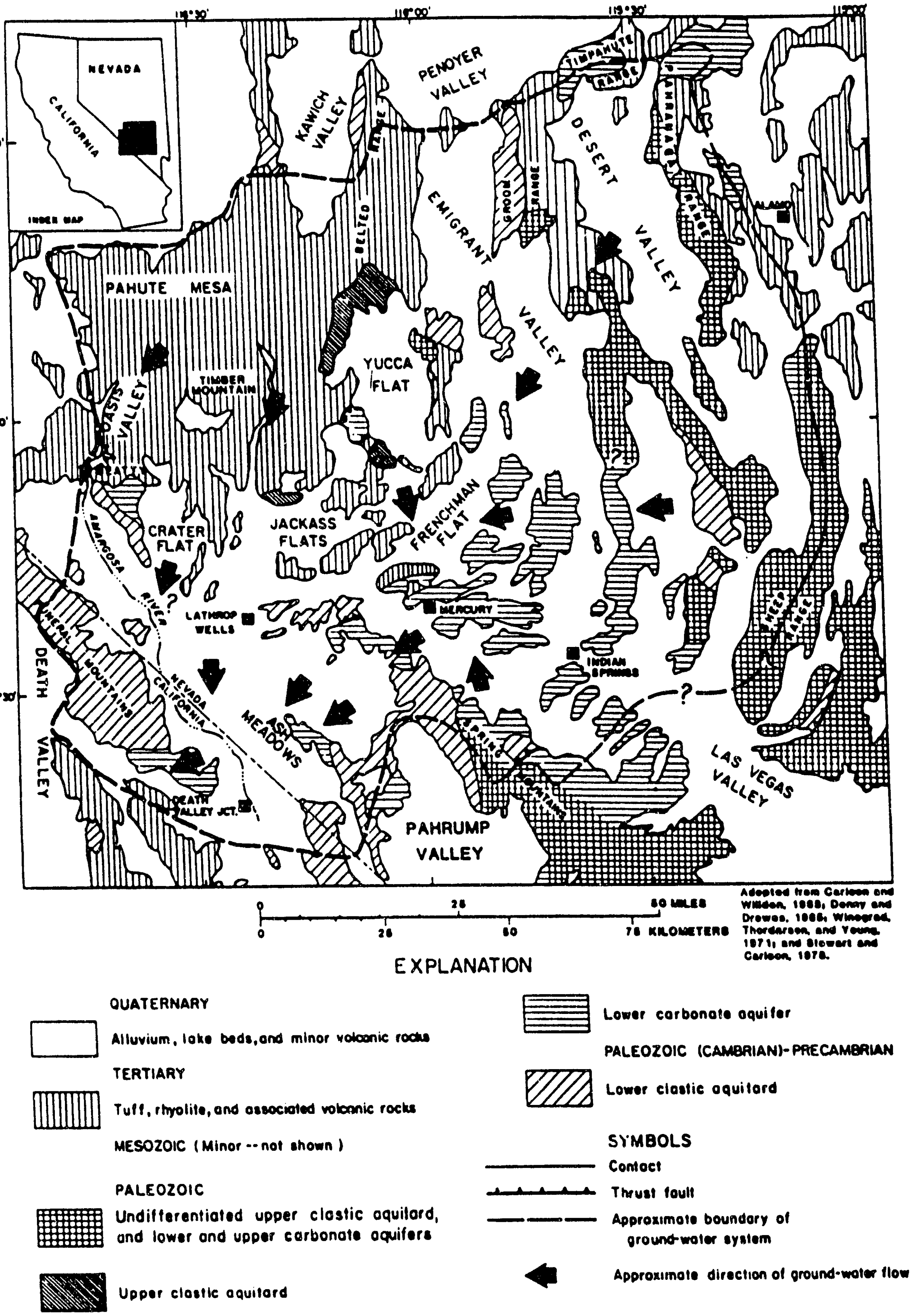
has essentially 100% Na+K in terms of cations, making it chemically unlike the other carbonate wells and more similar to the volcanics. Despite such problems, aquifer designations were made based on rock type rather than by second guessing the chemical interpretations to follow.

The chemical data were examined in the context of our present knowledge of the physical flow system. Groundwater flow directions in the NTS area have been suggested based on geologic and geophysical information, water–level data, precipitation data, spring discharge measurements, aquifer test data, as well as water chemistry. Though considerable uncertainty in flow boundaries and inter–unit flow exists, workers have generally agreed on the gross regional groundwater flow directions at the NTS. Flow is believed to move primarily in a north–to–south direction across the NTS with an additional component of northeast to southwest flow (Figure 9). Flow southward through Yucca Flat into Frenchman Flat is joined by a component of westerly flow from Emigrant Valley and other areas east of the NTS. After passing through Mercury Valley, there is a southwestward turn as groundwater moves toward the discharge area in Ash Meadows. Components of groundwater flow beneath Pahute Mesa move southward into the Fortymile Wash structural feature and on to discharge at Alkali Flat and in Death Valley. There is also southwestward flow from Pahute Mesa to Oasis Valley. Flow relationships between the east and west sides of the NTS are less certain, with postulated flow from Pahute/Rainier Mesas into Yucca Flat in the north and possibly from western Yucca and Frenchman Flats to Jackass Flats in the south.

The following sections compare the chemical data for each type of aquifer material with the postulated flow directions discussed above. Well water chemistry is represented on maps using Stiff diagrams. The Stiff diagrams show the geochemical similarities and differences among wells; the cation concentrations are plotted on the left side of each Stiff figure in units of milliequivalents per liter, while the anions are similarly plotted on the right side. The graphical similarities/differences between Stiff diagrams represent the geochemical similarities/differences of the water samples collected from each well (Hem, 1985).

Alluvium Wells

All wells providing water samples from alluvial material in this study are located either in the eastern part of the NTS or east of the NTS (Figure 10). Regional (interbasin) groundwater flow beneath the eastern part of the NTS is believed to occur only through carbonate rocks (Winograd and Thordarson, 1975). Groundwater in alluvial deposits is isolated in each basin, so regional trends in ion concentrations would not be expected in wells completed in alluvium. For example, USGS Water Well A and UE–6d are in Yucca Flat, while Water Well 5B and Water Well 5C are in Frenchman Flat. Alluvial materials are absent in some locations and unsaturated in others between Yucca and Frenchman Flats so that water cannot flow from UE–6d to Water Well 5B without entering volcanic and carbonate units. This segmentation of alluvial water is reflected in the areal distribution of ions shown on Figure 11. The difference in ion concentrations within an individual basin (*e.g.*, sodium at Water Well 5B is 97 mg/L, while at Water Well 5C it is 129 mg/L) is also marked and suggests a lack of well–developed lateral flow systems that would homogenize chemical character within each basin. The logical extension of this observation is that vertical flow dominates



Adopted from Carlson and Willden, 1968; Denny and Drewes, 1965; Winograd, Thordarson, and Young, 1971; and Stewart and Carlson, 1978.

Figure 9. General groundwater flow directions in the NTS area. From Waddell (1982).

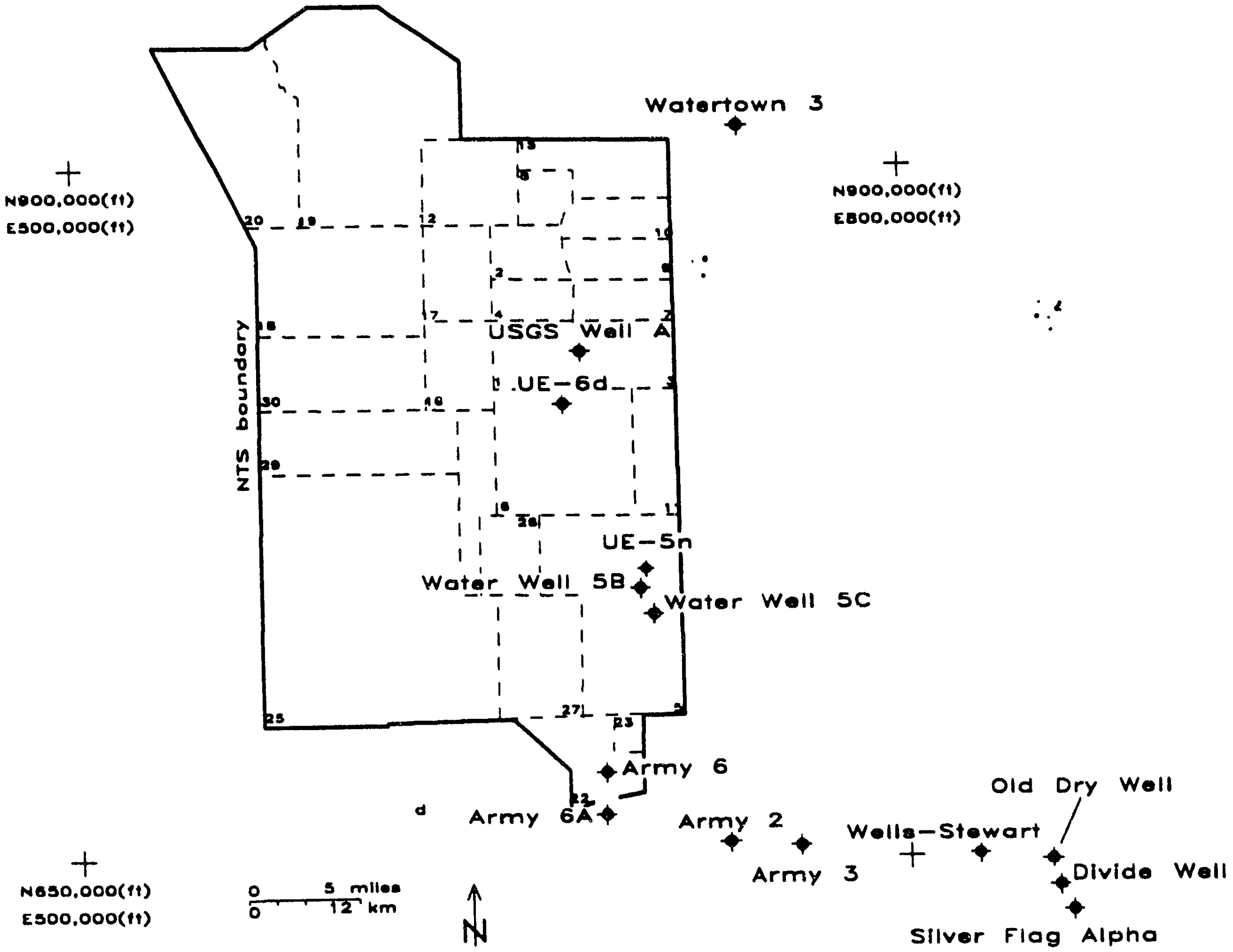


Figure 10. Wells completed in alluvial materials at and near the NTS for which water chemistry data are available. Nevada state coordinates are shown for reference.

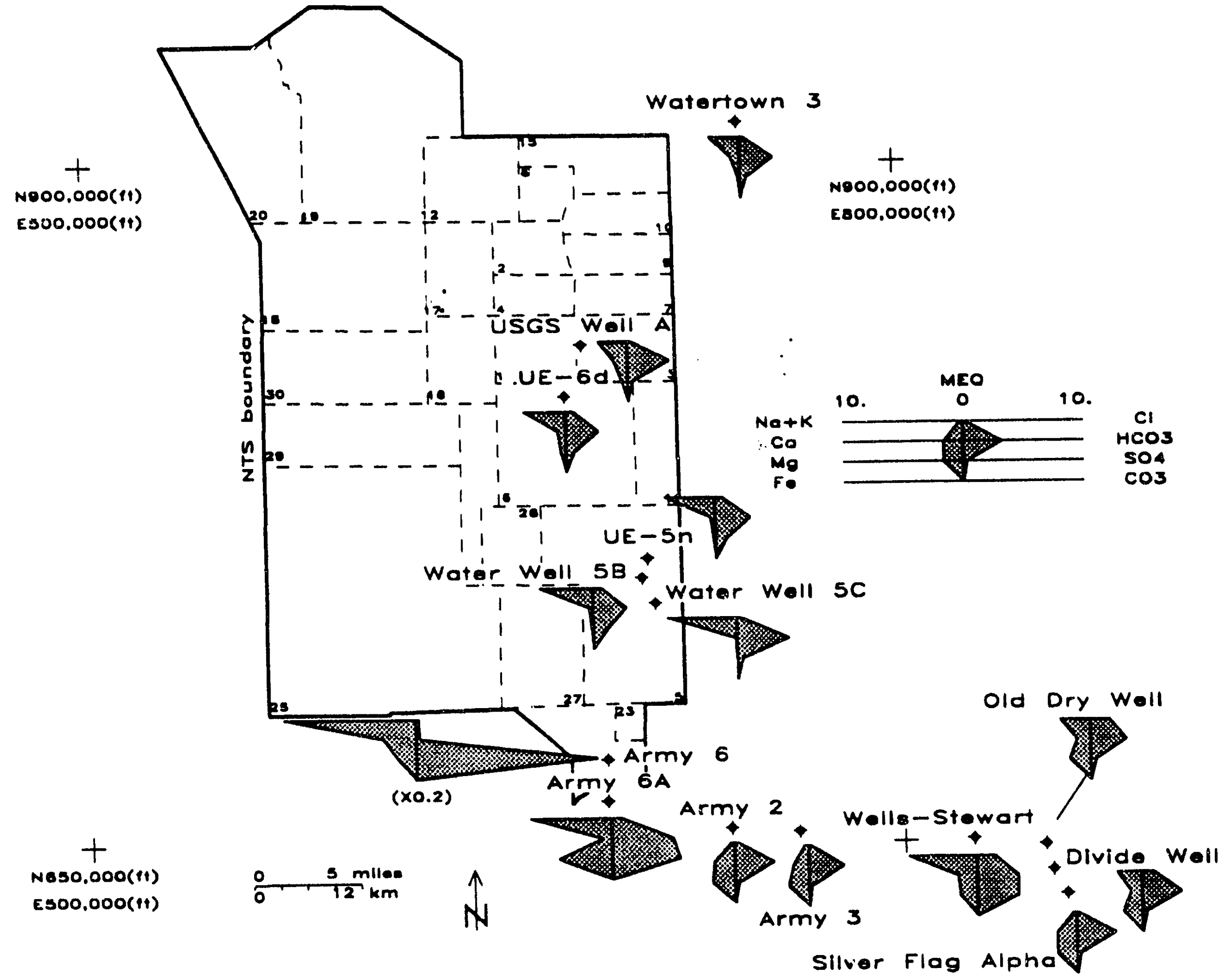


Figure 11. Areal variation in water chemistry for wells completed in alluvial materials, as represented by Stiff diagrams.

in the alluvium. The one exception appears to be the saturated alluvium in the vicinity of wells Army #2 and Army #3, where there is good consistency in ion concentrations.

Carbonate Wells

As with the alluvium wells, all but one of the carbonate wells for which chemistry data were available are located on the eastern part of the NTS, or east of the NTS (Figure 12). Flow is believed to move through carbonate rocks from the north end of Yucca Flat, through Frenchman Flat and Mercury Valley. A westward flowing component joins this southerly component from the area sampled by USGS HTH #10 and USGS HTH #4, and points east, and this combined system moves in a southwestwardly direction toward Ash Meadows. Quartz and Sand Springs, also east of the NTS, occur in the Pintwater Range and represent perched water that does not contribute to the regional flow system. The one western carbonate well, UE–25p #1, is located in the Fortymile Wash drainage, where flow is believed to be more directly southward to Ash Meadows.

Though the carbonate aquifer is considered a regional aquifer system, the groundwater chemistry reveals that the units intersected by the carbonate wells are not chemically homogeneous. Though some of the variation in ion composition seen on the carbonate map (Figure 13) can be attributed to the lumping of all pre–Tertiary units for mapping purposes (in particular, UE–15d Water Well, UE–16d Eleana, and UE–16f Eleana are not sampling the lower carbonate aquifer), unaccounted shifts in ion concentrations occur. For example, USGS Test Well D and UE–1c sample carbonate units about 3000 m (10,000 ft) apart in mid–Yucca Flat. Dissolved chloride is over 1.5 times higher at USGS Test Well D and dissolved sodium is almost three times greater than at UE–1c. UE–1c is located farther to the south (downgradient) and thus would be expected to either have similar or higher dissolved ion concentrations than USGS Test Well D. Moving farther southward along the presumed flow direction, chloride and sodium values increase markedly at USGS Water Well C and Water Well C–1, indicating a contribution of water from volcanic units. Water could be moving into the carbonates by enhanced downward leakage through volcanics and alluvium beneath Yucca Lake or laterally where volcanic units are juxtaposed with carbonates along faults. USGS Water Well C and Water Well C–1 are located in the upper plate of a low–angle thrust fault (Winograd and Thordarson, 1975), which probably abuts volcanic units to the north of the wells. The very old radiocarbon age of water in Water Well C–1 (greater than 30,000 years before present; Boughton, 1986) indicates that the water has had a long residence time, whether derived from lateral or vertical flow. Relatively high chloride and sodium concentrations at UE–25p #1 similarly indicate a contribution of volcanic water to the carbonate aquifer in the Fortymile Wash area. Saturation calculations show that all of the carbonate waters are saturated with respect to calcite and quartz, whether they have mixed with volcanic water or not.

The wide concentration variations in conservative ions such as chloride and sodium suggest a complex carbonate system possibly containing isolated flow units such as the fault block containing the C wells. Transmissivity in the lower carbonate aquifer is structurally controlled and known to have a wide range in values. However, hydraulic testing indicates that water–bearing fractures are reasonably well connected, creating a grossly homogeneous aquifer (Winograd and Thordarson, 1975). In addition, Winograd and Thordarson report nearly identical chemical analyses

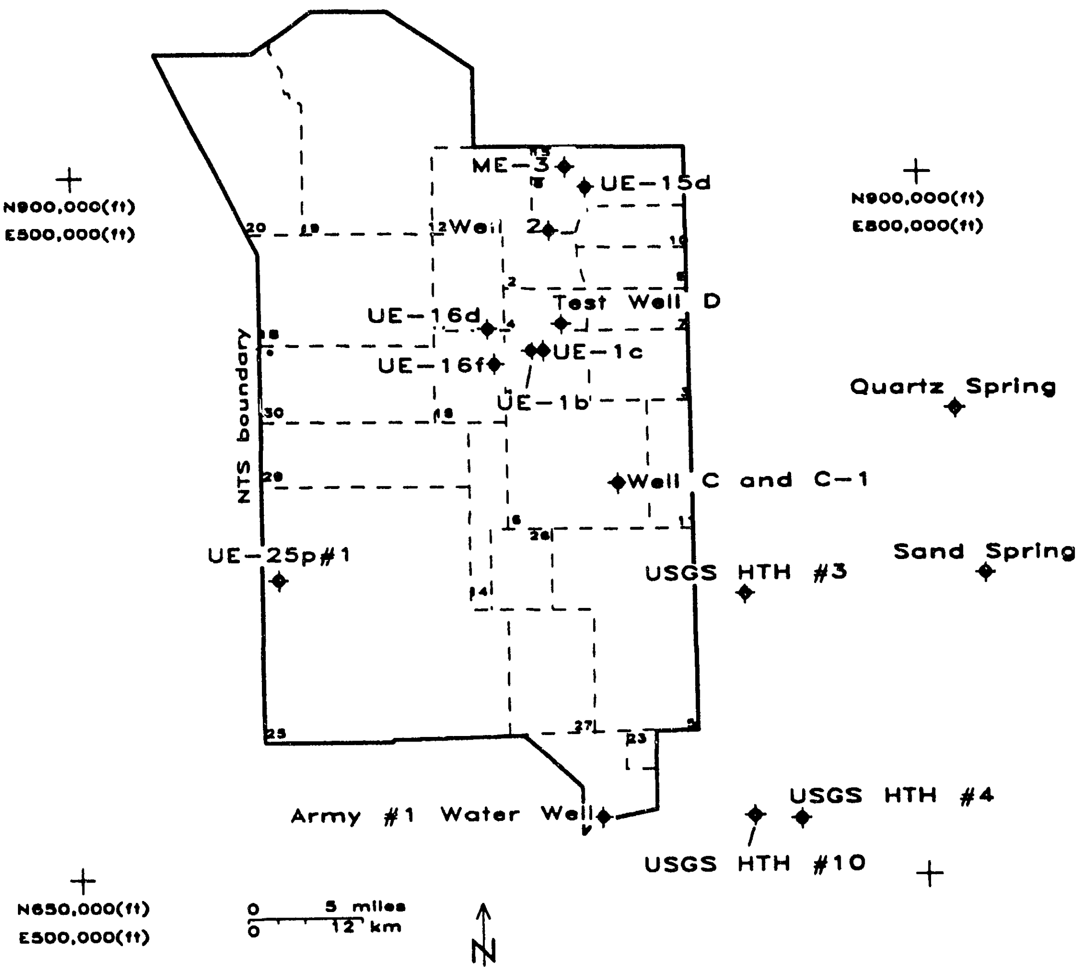


Figure 12. Wells and springs completed in carbonate rocks (or similar formations) at and near the NTS for which water chemistry data are available. Nevada state coordinates are shown for reference.

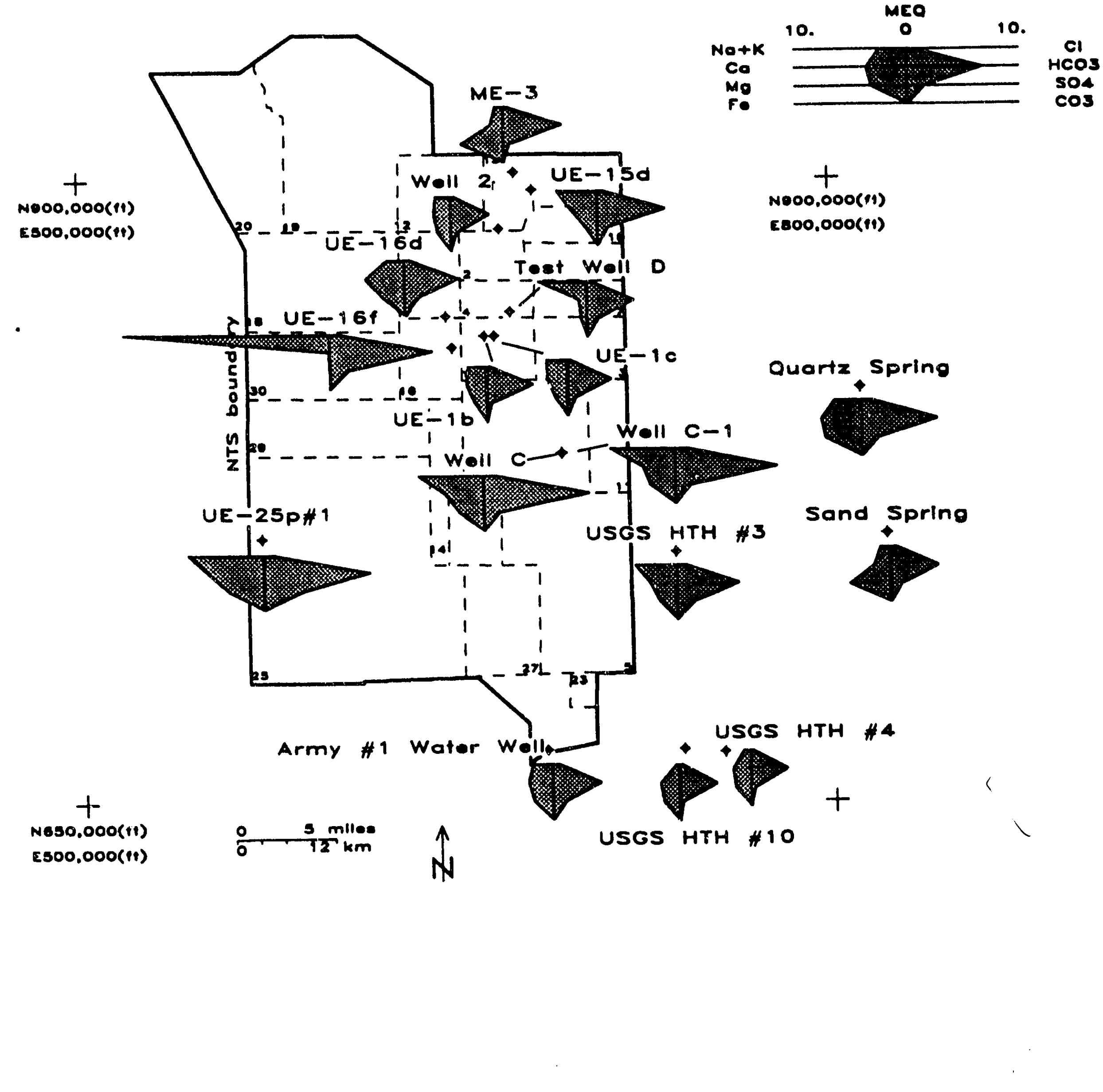


Figure 13. Areal variation in water chemistry for wells and springs completed in carbonate rocks (or similar formations), as represented by Stiff diagrams.

for water from different formations comprising the lower carbonate aquifer, sampled within a single well. Despite this earlier work, the range in groundwater chemistry in the carbonate aquifer across the eastern portion of the NTS indicates that though the lower carbonate aquifer may be considered a single hydraulic unit in gross flow terms, it may be considerably more complex when considering solute transport.

One feature of the carbonate hydrochemical map that can be explained is the significant decrease in dissolved ion concentrations that occurs between the south end of Yucca Flat and Mercury Valley, as typified by the halving of chloride and reduction by two–thirds in sodium concentrations from USGS Water Well C to Army #1 Water Well. Such a reduction in conservative ions could only occur with the addition of a lower salinity water to the system. Leakage from the alluvium and volcanic aquifers in Frenchman Flat cannot be a source of dilution because sodium concentrations are much higher in those units than those at Army #1 Water Well. A more likely source of dilution, suggested by most flow models, is the movement of water from points east and south in the carbonate units. Groundwater in the USGS HTH #4 and #10 area probably originates as recharge in the northern Spring Mountains (Byer, 1991; and Sadler *et al.*, 1991). The low salinity and relatively low calcite saturation index at these wells supports the relatively young ages (approximately 5000 years) calculated for groundwater in the area using a discrete–state compartment model (Sadler *et al.*, 1991). Using ion concentrations averaged between those of USGS HTH #10 and USGS HTH #4 to represent underflow from the east, the relative contributions from Yucca Flat (as represented by USGS Water Well C and Water Well C–1) and the eastern area required to produce the water sampled from Army #1 Water Well are approximately 30% water from Yucca Flat and 70% water from the east. These approximate percentages are upheld by all of the major ion concentrations with the exception of sulfate (Table 1). Several other wells in the vicinity of Army #1 Water Well have high sulfate concentrations (Army 6 and Army 6A), suggesting a local source for dissolved sulfate, either from hydrothermally altered rocks or gypsum deposits.

Table 1. Dissolved ion concentrations in mg/L for wells in three areas of the carbonate aquifer and calculated mass percentages needed to create water at Army #1 Water Well from the other two types.

Ion	Concentration in Well C	Concentration in HTH 4 & 10	Concentration in Army #1	Percent from Yucca Flat	Percent from east of NTS
Ca	65	36	44	35	65
Mg	28	18	21	30	70
Na	125	10	38	25	75
K	14	2	5	30	70
Cl	32	6	16	40	60
SO_4	65	16	53	75	25
HCO_3	555	197	257	15	85

Another possible explanation for the difference between the "C" wells and Army #1 Water Well is that water from USGS Water Well C and Water Well C–1 is not representative of the carbonate water composition leaving Yucca Flat. This would assume that the well C structural block is isolated from the rest of the flow system and that flow from Yucca Flat is typified by the composition of water from Water Well 2, UE–1b, and UE–1c. This scenario would allow little or no contribution of water from the east, and is not compatible with the conceptual groundwater flow models.

Volcanic Wells

Wells that penetrate volcanic units are found throughout the NTS (Figures 14 and 15). In the eastern area, coincident with the areas where there are alluvium and carbonate wells, the volcanic aquifers are not believed to form continuous interbasin flow units. As with groundwater in the alluvium, it is believed that water in the volcanics must discharge to the carbonate aquifer to flow from Yucca Flat to Frenchman Flat and then to Mercury Valley. Spatial variations in ion concentrations from these wells suggest the absence of a well–integrated lateral groundwater flow system (Figure 16). One general pattern is suggested by the data, however. Wells on the west side of Yucca and Frenchman Flats tend to have higher calcium and magnesium concentrations and lower pH values than wells to the east. This is balanced by lower sodium concentrations and/or higher chloride and sulfate concentrations. The wells showing the higher calcium and magnesium values are USGS HTH "F", Pluto 1, Pluto 5, UE–1a, and to a lesser extent Well 3 and Water Well #4. An exception to this trend is well UE–14b, located in Mid Valley, which does not have notably high calcium and magnesium concentrations, but does have higher sulfate than the eastern wells. The higher calcium and magnesium concentrations in the western Yucca and Frenchman wells (UE–1a, Well 3, Water Well #4) may reflect the movement of groundwater into volcanic units from the upper carbonate aquifer in the structurally complex area along the Eleana Formation subcrop bounding western Yucca Flat. The impact of hydrothermally altered rocks is believed to account for the higher sulfate concentration in J–11, USGS HTH "F" and possibly UE–14b. The Pluto wells sample perched water that probably receives calcium via surface recharge processes.

A lack of intrabasin chemical continuity is particularly noteworthy in Frenchman Flat where both sodium and bicarbonate are twice as high in Water Well 5A than in UE–5c Water Well, less than 10 km (six miles) to the north. In this case, and perhaps others, structural features may have isolated the volcanic units. Water Well 5A is on the opposite side of the Rock Valley Fault System from UE–5c Water Well and a 4 m (13 ft) difference in head values attests to some hydraulic discontinuity between the two areas.

Though chemical variations in water from volcanic wells on Pahute Mesa are generally less than variations found elsewhere on the NTS, ion concentrations in well water on the Mesa do not vary in any pattern consistent with postulated flow directions (Figure 17). This may indicate that the complex sequence of volcanic units beneath Pahute Mesa does not constitute a single, unified flow system. Within the saturated zone, the vertical and horizontal distribution of permeable ash–fall and ash–flow tuffs and lava flows that comprise the aquifers of Pahute Mesa is highly variable, even over short distances. This stratigraphic variability, coupled with structural control of groundwater flow through fractures in a complex caldera environment, results in a hydrologic system that does

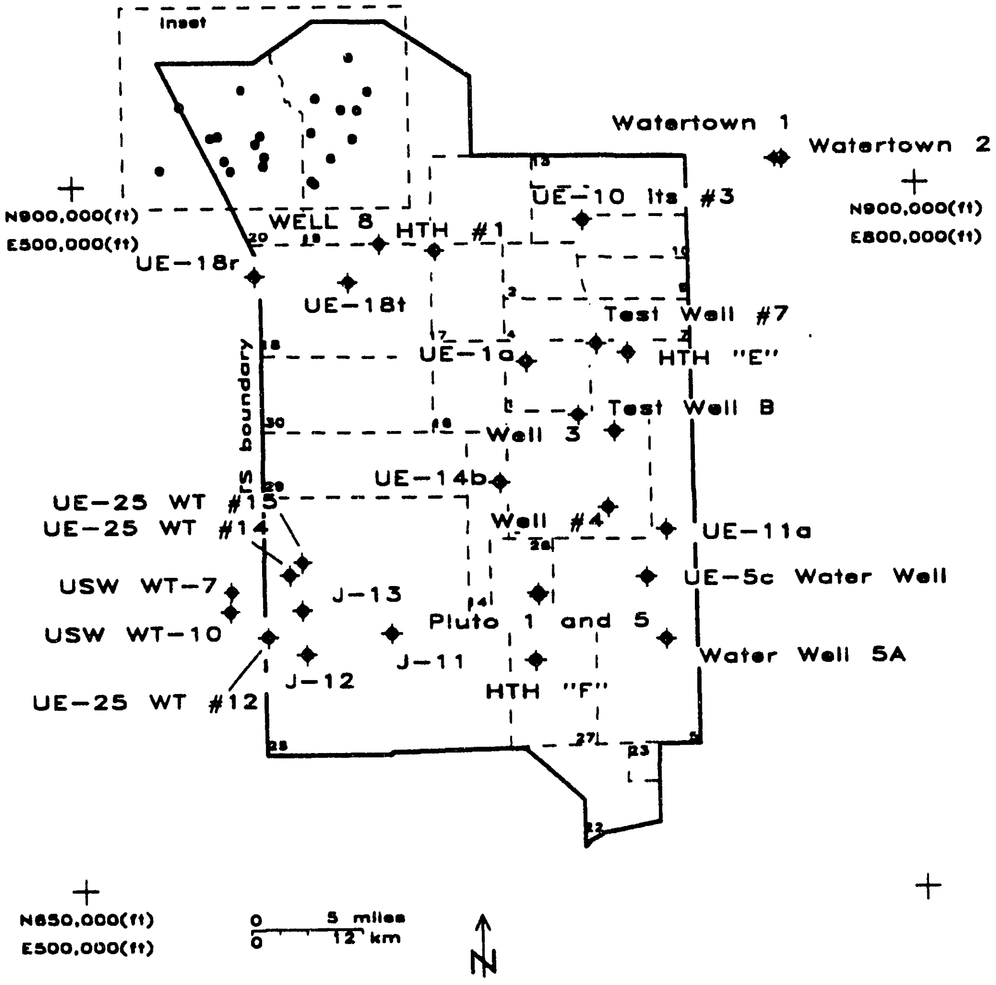


Figure 14. Wells completed in volcanic rocks at and near the NTS for which water chemistry data are available. Well names for the Pahute Mesa area can be found on Figure 15. Nevada state coordinates are shown for reference.

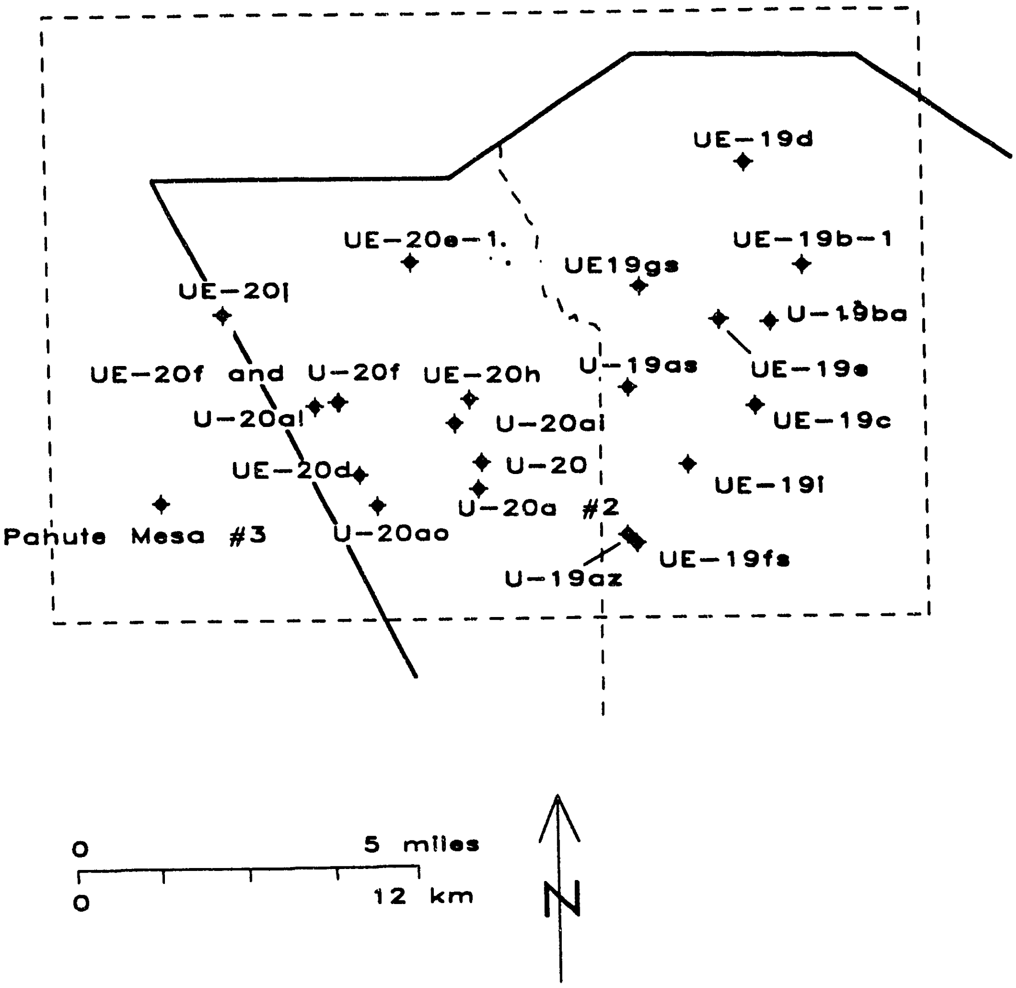


Figure 15. Wells completed in volcanic rocks on Pahute Mesa for which water chemistry data are available. For location relative to the NTS, see Figure 14.

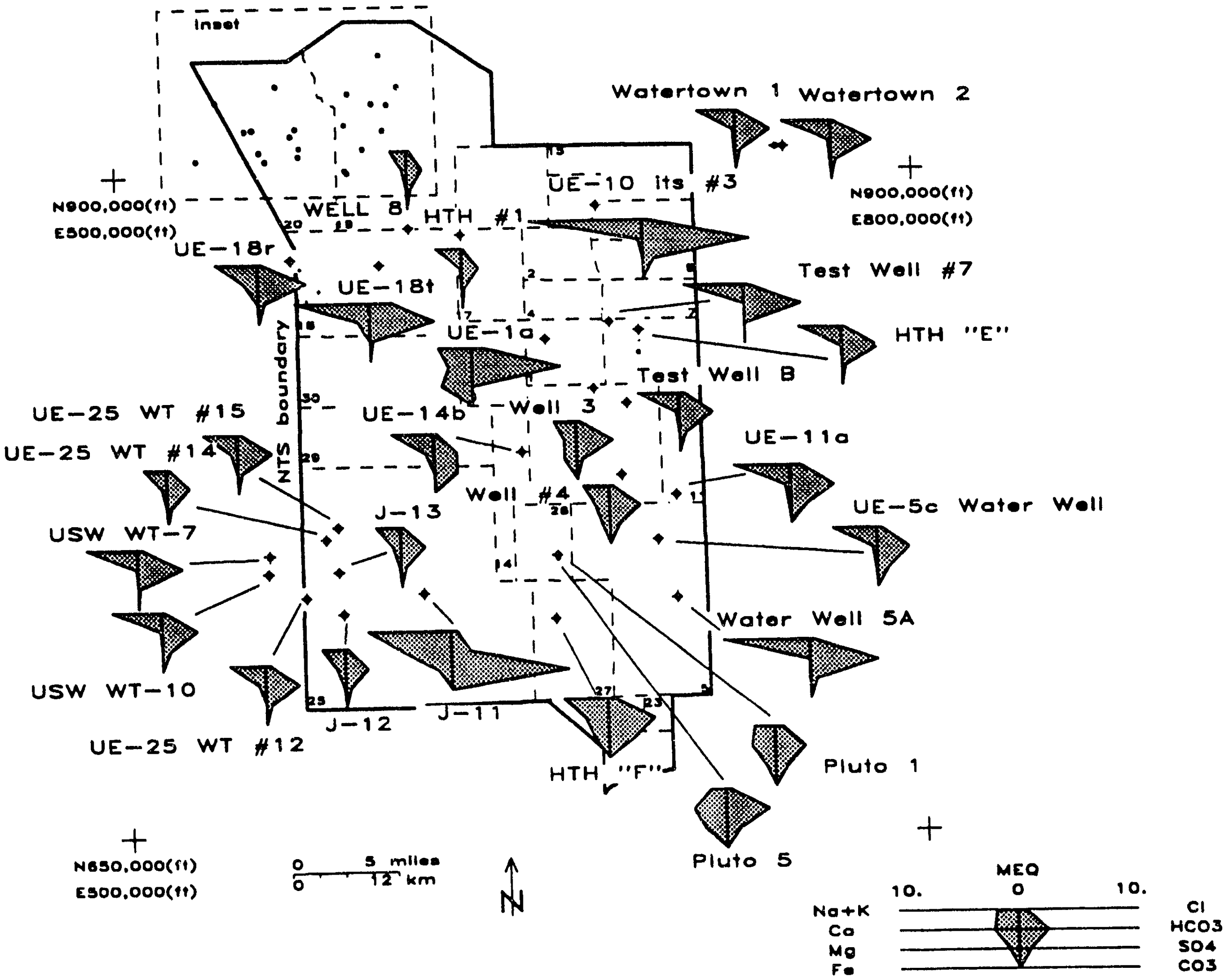


Figure 16. Areal variation in water chemistry for wells completed in volcanic rocks, as represented by Stiff diagrams. The Pahute Mesa area is shown separately on Figure 17 for clarity.

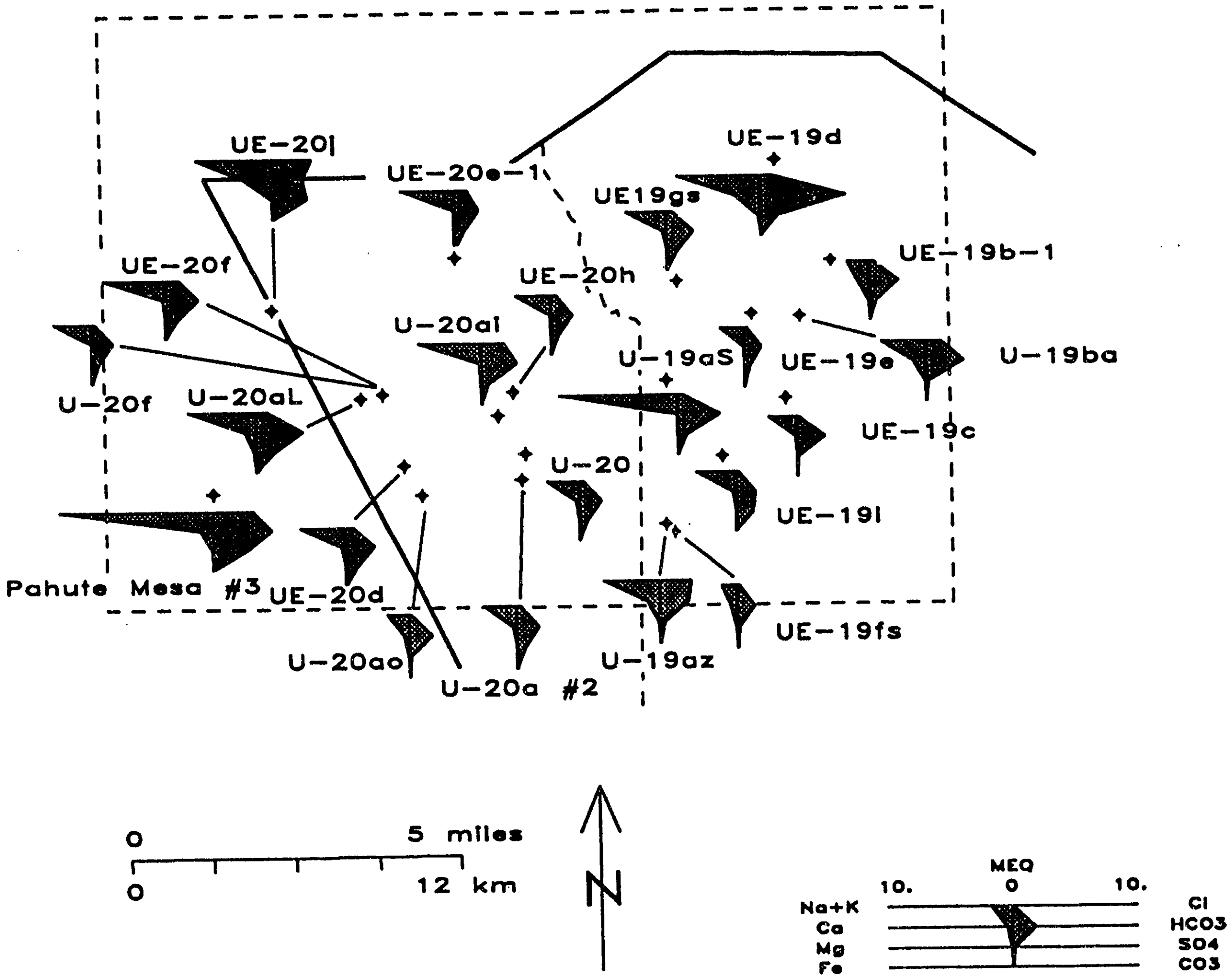


Figure 17. Areal variation in water chemistry for wells completed in volcanic rocks on Pahute Mesa, as represented by Stiff diagrams.

not have predictable continuity in lateral directions. The apparent lack of consistent chemical changes in downgradient directions may actually result from an incomplete understanding of flow path directions. In addition, some variability results from sampling perched horizons that may have been contaminated by drilling fluid (at U–19ba and U–19az).

Blankennagel and Weir (1973) observed that hydraulic heads decreased with depth beneath the eastern part of Pahute Mesa (indicating a potential for downward flow) and that heads increased with depth beneath western Pahute Mesa. In addition, they also observed that while sodium and bicarbonate were the dominant ions in all Pahute Mesa groundwater, there was proportionally more calcium in the area of downward flow and more sulfate and chloride in the zone of upward flow. The new data blur the distinction for cations, but the difference in anions is similar (Figure 18). Sulfate is often associated with hydrothermal alteration and is consistent with an area where deeper, older water is moving upward in the groundwater system.

Another cluster of volcanic aquifer samples is located in the southwest corner of the NTS (Figure 16). A major hydrologic feature in this area is Fortymile Wash, which is believed to mark a zone of higher hydraulic conductivity and greater recharge (Byer, 1991; Sadler *et al.*, 1991). With the newer samples, the chemical similarity between J–12 Water Well and J–13 Water Well can now be extended further north along the wash to UE–25 WT #14, which has an ionic composition very similar to the downgradient wells. Even farther to the north, UE–25 WT #15 is also similar to the other Fortymile Wash samples but has a higher percentage of sodium and bicarbonate. Well UE–18t is located much farther north, near the head of the wash and has a greater dissolved ion content than the southern Fortymile Wash wells. The lower salinity of the downgradient wells may reflect the diluting effect of infiltrating recharge along the length of the wash.

The southern Fortymile Wash wells have about five times the amount of calcium and over 10 times the amount of magnesium as the two wells (USW WT–7 and USW WT–10) in the drainage basin west of Yucca Mountain. The western wells have a dominantly Na–HCO_3 signature characteristic of water from volcanic aquifers. The higher concentration of calcium and magnesium in the Fortymile Wash area may indicate a contribution of water from underlying carbonate rocks, infiltration of rainfall that dissolves near–surface calcium deposits, or mixing with water from areas east of Fortymile Wash, where higher dissolved ion concentrations are attributed to interaction with hydrothermally altered rocks. Groundwater from J–11 represents this higher Ca–SO_4 water, which is also found at USGS HTH "F." The chemistry of the carbonate water in Fortymile Wash, as sampled by UE–25p#1, indicates mixing of volcanic water into the carbonate unit rather than movement of water from the carbonates to volcanics. Either this mixing occurs outside the area sampled by the volcanic wells (e.g., where the carbonates abut the nearby caldera complexes), or the calcium and magnesium in the volcanic wells must be from one of the sources other than the underlying carbonate. Based on geochemical and isotopic data, Matuska (1989) concluded that flow from the carbonates into the volcanics in the Fortymile area was unlikely.

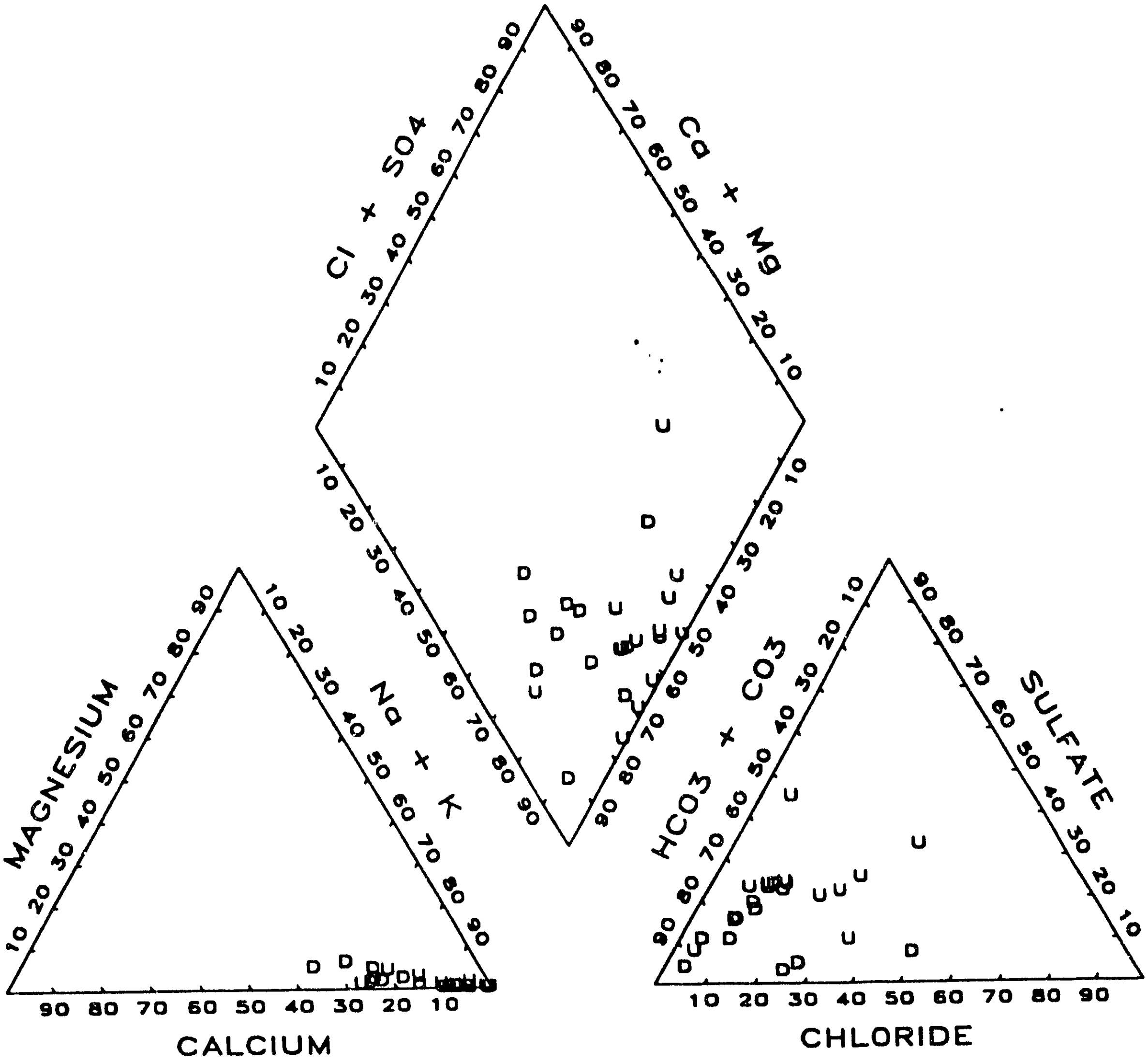


Figure 18. Trilinear diagram showing relative ion percentages for samples collected from volcanic aquifers on Pahute Mesa, differentiated based on their location relative to the areas of downward ("D") and upward ("U") flow defined by Blankennagel and Weir (1973).

CONCLUSIONS

Groundwater samples from 81 locations at and around the NTS have been analyzed for major dissolved constituents. Twenty–seven of these locations are new additions sampled by DRI after publication of major interpretive reports by the USGS. Eighteen locations were sampled by both DRI and the USGS with generally excellent agreement between results. Most cases with discrepancies can be explained by continued well development or changes in well completion over the years.

The new data support the occurrence of three hydrochemical facies in the NTS area, identified by previous workers. The distribution of these facies, in particular the presence of mixed cation water in the carbonates, has led to significant conclusions regarding gross groundwater flow by suggesting the movement of water from volcanic aquifers into the carbonate aquifer. However, when examined in detail, the hydrochemistry of the samples in this study is not fully compatible with concepts of regional lateral flow in the carbonate aquifer. There are wide variations in concentrations in generally conservative ions that suggest that though the carbonate aquifer may be considered a single hydrologic unit in gross flow terms, it may be considerably more complex when considering solute transport. The chemistry in wells at the south end of Yucca Flat and near Fortymile Wash indicates a greater contribution of water from volcanic units to the carbonate aquifer in these areas than found elsewhere at the NTS. Ionic concentrations indicate that at the southern end of the NTS, the majority of water in the carbonate system originated from areas east and south of the NTS, with only about 30% of the water coming from southern Yucca Flat.

While differences in chemistry in alluvium and volcanic wells between basins in the eastern NTS were expected because of a lack of interbasin flow, the absence of homogeneous chemical character within single basins suggests a lack of well–developed lateral flow systems and dominance of vertical groundwater flow in these units within each basin. Relatively higher calcium and magnesium in volcanic wells in the south–central part of the NTS (west side of Yucca and Frenchman Flats and east side of Jackass Flats) may reflect movement of water from the upper carbonate aquifer into the volcanics and contributions from hydrothermally altered areas. The low–calcium water found in eastern Yucca and Frenchman Flats and west of Yucca Mountain is typical of water that has encountered primarily volcanic material along its flowpath. Consistent chemical patterns could not be identified in the volcanic aquifers of Pahute Mesa, presumably because of complex stratigraphic and structural controls. In the southwestern part of the NTS, chemical homogeneity supports groundwater flow in volcanic units along Fortymile Wash, while the calcium and magnesium concentrations suggest a contribution of water from hydrothermally altered rocks in the area east of Fortymile Wash or from infiltration of rainfall that dissolved near-surface calcium deposits.

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APPENDIX A

Water chemistry data from samples collected between 1957 and 1977 from wells at and near the NTS. Data are from the USGS, with data sources listed in the text. Well names are consistent with those used in the 1991 edition of the Raytheon Services Nevada "NTS Drilling and Mining Summary." Wells are in order of increasing Nevada state north coordinate.

Appendix A. Chemical analysis for wells at and near the NTS, from USGS reports cited in the text. All concentrations are in mg/L.

Well Name	northing	easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Wells–Stewart	651000	825000	05/01/64	7.6	33.0	18.0	123.0	12.0	55.0	164	210	19.0
Army #3	654163	760615	01/28/59	7.9	27.0	21.0	6.8	1.4	6.0	11	186	6.6
Army #2	655582	735166	05/03/61	7.8	35.0	23.0	5.6	1.2	5.0	15	204	14.0
Army 6A	665641	690214	04/27/58	8.0	24.0	16.0	222.0	11.0	23.0	169	486	9.3
USGS HTH #4	669876	755215	09/13/62	7.5	34.0	17.0	13.0	2.5	6.10	17	197	20.0
Army #1 Water Well	670902	684772	07/10/62	7.1	47.0	21.0	37.0	5.2	16.0	53	256	21.0
Army #1 Water Well	670902	684772	07/15/62	7.5	46.0	21.0	38.0	4.9	17.0	58	254	20.0
Army #1 Water Well	670902	684772	10/20/64	7.3	45.0	21.0	38.0	5.2	16.0	52	256	19.0
USGS HTH #10	671051	739075	02/26/63	7.7	37.0	18.0	7.1	2.7	6.7	15	194	14.0
USGS HTH #10	671051	739075	02/04/64	7.6	37.0	19.0	6.9	0.0	5.0	14	201	15.0
Army 6	680800	690500	unknown	8.1	281.0	90.0	1291.0	0.0	35.0	3599	98	22.6
USGS HTH "F"	731053	661153	05/30/61	7.3	13.0	1.0	99.0	6.4	32.0	34	199	32.0
USGS HTH "F"	731053	661153	06/17/62	7.3	68.0	30.0	63.0	9.6	11.0	181	278	31.0
J–12 Water Well	733508	581012	04/25/58	8.2	9.6	1.9	46.0	5.2	7.0	24	121	26.0
J–12 Water Well	733508	581012	02/19/59	7.4	14.0	1.5	42.0	4.4	8.0	24	118	49.0
J–12 Water Well	733508	581012	03/31/62	8.0	14.0	2.5	39.0	6.0	8.8	19	119	60.0
J–12 Water Well	733508	581012	05/26/64	7.4	17.0	0.9	40.0	4.6	7.4	21	120	56.0
Water Well 5A	738361	707514	04/04/57	8.6	3.2	0.0	160.0	6.2	12.0	25	346	58.0
Water Well 5A	738361	707514	09/18/57	8.8	1.8	0.5	158.0	5.8	9.0	25	341	57.0
Water Well 5A	738361	707514	04/24/58	8.9	1.6	1.0	165.0	6.6	9.0	30	336	67.0
Water Well 5A	738361	707514	02/04/59	8.6	2.4	0.0	158.0	6.0	9.0	24	344	58.0
Water Well 5A	738361	707514	04/25/62	8.7	1.8	0.9	163.0	5.6	11.0	27	345	49.0
Water Well 5A	738361	707514	06/04/64	8.9	2.7	0.4	163.0	6.4	11.0	27	384	50.0
J–11	740890	611821	09/18/57	7.8	85.0	14.0	157.0	16.0	20.0	484	102	67.0
J–11	740890	611821	04/24/58	8.0	84.0	13.0	154.0	16.0	18.0	479	104	67.0
J–11	740890	611821	12/16/58	7.6	82.0	13.0	143.0	15.0	18.0	449	102	68.0
Water Well 5C	742860	705888	04/01/57	8.7	3.2	0.1	126.0	5.4	10.0	25	266	56.0
Water Well 5C	742860	705888	09/18/57	8.8	1.8	0.7	128.0	5.6	9.0	24	263	55.0
Water Well 5C	742860	705888	03/24/58	8.8	2.4	0.5	130.0	6.8	8.0	26	262	58.0
Water Well 5C	742860	705888	12/09/58	8.5	1.6	1.0	126.0	5.8	10.0	24	265	59.0
Water Well 5C	742860	705888	04/25/62	8.7	3.1	0.5	128.0	5.6	8.9	25	258	53.0
Water Well 5C	742860	705888	06/14/64	8.8	2.0	0.6	130.0	5.6	8.5	24	309	50.0

Appendix A. **Chemical analysis for wells at and near the NTS, from USGS reports cited in the text. All concentrations are in mg/L (continued).**

Well Name	northing	easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Water Well 5B	747359	704263	04/04/57	8.4	8.0	1.5	96.0	11.0	25.0	55	168	64.0
Water Well 5B	747359	704263	09/18/57	9.0	5.6	1.0	102.0	10.0	24.0	59	155	16.0
Water Well 5B	747359	704263	03/24/58	8.4	8.0	1.9	96.0	11.0	23.0	60	166	61.0
Water Well 5B	747359	704263	04/25/62	8.3	9.0	2.2	95.0	10.0	22.0	57	163	62.0
Water Well 5B	747359	704263	06/13/64	8.4	7.8	1.8	94.0	11.0	22.0	57	178	54.0
J–13 Water Well	749209	579651	01/01/63	7.0	14.0	2.4	46.0	6.6	8.4	25	124	57.0
J–13 Water Well	749209	579651	05/25/64	7.1	14.0	1.8	48.0	5.0	7.4	23	136	58.0
USGS HTH #3	750189	736937	05/10/62	7.3	51.0	21.0	83.0	7.6	23.0	84	328	24.0
Water Well C–1	790011	692132	10/10/62	8.3	17.0	28.0	126.0	15.0	35.0	61	386	27.0
Water Well C–1	790011	692132	06/14/64	6.9	74.0	29.0	123.0	14.0	34.0	66	576	29.0
USGS Water Well C	790082	692061	09/01/61	7.0	74.0	27.0	142.0	15.0	34.0	71	577	30.0
USGS Water Well C	790082	692061	01/19/62	7.2	70.0	19.0	130.0	12.0	23.0	75	560	30.0
USGS Water Well C	790082	692061	04/25/62	7.2	80.0	27.0	128.0	13.0	34.0	63	576	33.0
USGS Water Well C	790082	692061	10/16/64	6.7	47.0	26.0	119.0	14.0	35.0	64	472	30.0
Well 3	817795	677762	04/04/57	7.8	22.0	12.0	40.0	7.4	8.0	22	192	74.0
Well 3	817795	677762	09/18/57	8.0	19.0	13.0	39.0	7.4	6.0	21	194	74.0
Well 3	817795	677762	03/24/58	8.1	21.0	12.0	40.0	7.4	5.0	22	196	66.0
Well 3	817795	677762	12/02/58	7.8	19.0	14.0	37.0	7.4	5.0	21	190	72.0
Well 3	817795	677762	12/19/61	7.5	20.0	11.0	39.0	7.6	6.5	23	189	76.0
Well 3	817795	677762	04/25/62	7.8	20.0	12.0	38.0	7.2	6.4	22	195	26.0
Well 3	817795	677762	05/27/64	7.9	22.0	11.0	38.0	8.0	5.6	19	196	64.0
UE–16f Eleana	832355	648843	08/20/77	8.6	4.2	0.6	420.0	1.4	33.0	130	860	2.2
UE–16f Eleana	832355	648843	09/25/77	8.2	5.2	2.0	430.0	3.0	18.0	110	1000	7.2
USGS Water Well A	833000	684000	09/21/60	7.6	28.0	4.6	51.0	8.7	6.0	18	212	62.0
USGS Water Well A	833000	684000	04/25/61	8.0	22.0	7.4	53.0	8.8	6.5	21	206	81.0
USGS Water Well A	833000	684000	12/19/61	7.6	22.0	6.5	50.0	8.4	6.0	23	207	82.0
USGS Water Well A	833000	684000	06/13/64	7.8	23.0	6.6	50.0	8.4	5.6	18	212	72.0
HTH "E"	839989	696001	07/31/60	9.0	1.6	0.0	81.0	2.6	6.0	16	187	61.0
Test Well #7	843192	684654	02/04/58	7.3	1.0	0.2	113.0	4.6	8.0	2	286	1.4
UE–16d Eleana	844878	646567	05/23/77	7.8	68.0	30.0	28.0	7.8	9.2	49	270	18.0
UE–16d Eleana	844878	646567	06/14/77	7.2	79.0	25.0	30.0	6.6	13.0	62	280	31.0
UE–16d Eleana	844878	646567	06/19/77	7.4	58.0	21.0	44.0	5.7	14.0	79	260	29.0

Appendix A. **Chemical analysis for wells at and near the NTS, from USGS reports cited in the text. All concentrations are in mg/L (continued).**

Well Name	northing easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
USGS Test Well D	846600 672600	01/09/61	7.8	17.0	10.0	107.0	14.0	20.0	71	274	18.0
UE–18r	868100 564700	01/29/68	8.0	26.0	1.0	81.0	3.1	7.8	24	252	45.0
USGS HTH #1	876855 629310	10/01/60	7.6	2.0	0.0	36.0	1.0	7.0	11	82	39.0
USGS HTH #1	876855 629310	10/20/60	7.5	4.0	0.0	36.0	6.5	6.5	12	78	38.0
USGS HTH #1	876855 629310	06/09/61	7.7	21.0	11.0	62.0	1.7	13.0	59	180	20.0
USGS HTH #1	876855 629310	08/11/62	7.2	20.0	11.0	35.0	3.2	8.7	35	150	19.0
Water Well 8	879468 609999	10/15/64	6.8*	8.8	0.9	30.0	3.3	7.8	16	78	45.0
Water Well 2	880000 668720	04/25/62	7.7	22.0	19.0	24.0	5.6	7.7	23	186	53.0
Water Well 2	880000 6687[illegible]	05/28/64	7.6	30.0	10.0	28.0	6.6	5.6	21	190	46.0
UE–15d Water Well	895709 682084	11/12/61	7.7	45.0	11.0	98.0	16.0	17.0	65	357	8.5
UE–15d Water Well	895709 682084	03/27/62	7.8	41.0	13.0	96.0	15.0	11.0	54	384	17.0
UE–19fS	900900 587084	08/18/65	8.1	11.0	1.6	29.0	3.0	6.3	9	86	56.0
Marble #3	903096 674866	07/11/59	7.9	25.0	47.0	15.0	3.8	5.0	24	310	24.0
U–20a #2 Water Well	907448 568671	10/14/64	6.9	5.9	0.1	58.0	1.9	11.0	28	108	41.0
U–20a #2 Water Well	907448 568671	03/10/66	7.7	6.1	0.1	55.0	0.2	11.0	27	106	48.0
Watertown 1	909046 749549	09/18/57	8.0	5.6	1.5	67.0	8.6	6.0	18	175	84.0
Watertown 1	909046 749549	04/25/58	8.2	4.8	2.4	68.0	8.8	6.0	22	177	86.0
Watertown 2	909062 752226	08/18/57	8.3	5.6	1.2	86.0	9.2	6.0	19	215	90.0
Watertown 2	909062 752226	04/25/58	8.5	4.8	1.9	86.0	9.0	7.0	22	204	81.0
UE–20d	909200 554300	03/08/66	8.2	1.4	0.1	81.0	0.2	23.0	40	122	37.0
UE–20d	909200 554300	03/08/66	8.3	1.4	0.1	83.0	0.1	24.0	42	120	46.0
UE–20d	909200 554300	07/27/66	7.8	4.3	0.1	88.0	1.7	23.0	44	137	47.0
UE–20d	909200 554300	07/28/66	8.4	21.0	0.1	68.0	0.5	8.8	53	143	52.0
UE–20d	909200 554300	08/12/66	8.5	8.5	0.1	107.0	2.6	24.0	40	192	45.0
UE–19i	910098 593107	09/02/65	7.7	5.0	0.1	75.0	0.5	7.0	70	98	39.0
Watertown 3	914990 742272	11/25/59	7.8	16.0	2.9	56.0	5.6	8.0	25	170	78.0
UE–19c Water Well	917050 601027	05/07/64	7.6	1.0	0.1	29.0	0.1	2.6	5	66	41.0
UE–19c Water Well	917050 601027	09/03/66	7.9	13.0	0.1	141.0	0.2	7.7	0	400	30.0
U–20f	917825 551857	03/28/66	8.9	0.8	0.1	69.0	0.6	6.6	30	103	36.0
U–20f	917825 551857	05/27/66	9.1	0.4	0.1	69.0	0.8	7.0	23	98	39.0
UE–20f	917825 552007	08/11/64	7.2	4.8	0.1	113.0	2.0	40.0	48	164	47.0
UE–20h	918015 567747	08/26/65	8.1	0.6	0.1	64.0	1.8	15.0	30	107	49.0

Appendix A. **Chemical analysis for wells at and near the NTS, from USGS reports cited in the text. All concentrations are in mg/L (continued).**

Well Name	northing easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
U–19aS	919248 586326	06/07/65	9.3	2.0	0.1	200.0	5.5	19.0	26	174	66.0
U–19aS	919248 586326	06/07/65	8.4	1.2	0.1	189.0	5.8	11.0	27	205	66.0
U–19aS	919248 586326	06/07/65	9.3	1.6	0.1	263.0	7.1	12.0	51	261	84.0
UE–19e	927300 596999	04/22/65	7.4	0.5	0.1	50.0	1.2	11.0	20	86	50.0
UE–19e	927300 596999	08/01/66	8.2	3.7	0.1	43.0	0.8	3.7	16	80	56.0
UE–20j	928306 538537	10/21/64	7.0	46.0	1.2	138.0	6.4	115.0	135	150	44.0
UE–19gS	931338 587843	03/27/65	8.2	12.0	0.1	68.0	0.6	9.0	36	146	46.0
UE–19gS	931338 587843	02/08/66	8.2	2.8	0.1	84.0	1.5	22.0	43	123	50.0
UE–19b #1	933700 606835	06/21/64	6.7	20.0	1.7	43.0	2.9	13.0	24	130	47.0
UE–19b #1	933700 606835	10/13/64	7.4	24.0	2.4	42.0	3.0	6.8	21	150	41.0
UE–20e #1	934466 560958	06/05/64	7.7	0.4	0.1	112.0	3.8	57.0	43	130	44.0
UE–20e #1	934466 560958	03/08/66	8.5	0.2	0.1	83.0	2.0	20.0	42	119	36.0
U–19d #2	945991 600202	03/24/64	7.5	29.0	2.9	173.0	3.6	39.0	63	424	28.0
U–19d #2	945991 600202	06/27/64	7.9	44.0	5.0	150.0	3.7	33.0	80	380	58.0
U–19d #2	945991 600202	06/27/64	7.6	29.0	1.4	148.0	4.0	30.0	66	320	49.0
U–19d #2	945991 600202	03/09/66	7.9	58.0	2.8	153.0	3.7	19.0	60	481	55.0
U–19d #2	945991 600202	03/09/66	7.9	57.0	2.8	153.0	4.3	20.0	57	489	55.0

*value from Blankennagel and Weir (1973), reported as 7.1 by Robinson and Beetem (1965).

APPENDIX B

Water chemistry data from samples collected between 1983 and 1990 from wells at and near the NTS. Samples were collected and analyzed by DRI. Well names are consistent with those used in the 1991 edition of the Raytheon Services Nevada "NTS Drilling and Mining Summary." Wells are in order of increasing Nevada state north coordinate.

Appendix B. **Chemical analysis for wells and springs sampled at and near the NTS by DRI between 1983 and 1990. All concentrations are in mg/L.**

Well Name	northing	easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Silver Flag Alpha	630524	858934	12/18/87	7.99	32.40	20.50	5.8	1.50	3.3	13.4	197.0	15.0
Divide Well	643689	852236	07/26/87	8.37	17.10	18.70	71.3	9.20	65.9	25.4	193.0	21.0
Divide Well	643689	852236	12/19/87	8.10	22.20	20.60	17.7	3.42	3.4	11.3	202.0	26.0
Old Dry Well	648737	851520	07/27/87	8.67	22.50	20.50	93.0	8.96	107.0	36.1	168.0	22.0
Old Dry Well	648737	851520	12/19/87	8.10	22.00	22.00	15.0	2.19	5.3	13.0	195.0	26.0
Army 6A	665641	690214	06/25/86	8.64	10.30	72.60	114.0	6.32	30.6	319.0	224.0	3.0
Army 6A	665641	690214	06/25/86	8.60	10.50	73.60	116.0	6.54	31.8	319.0	228.0	3.0
Army #1 Water Well	670902	684772	04/17/90	8.03	37.60	21.60	39.4	5.68	16.0	51.1	259.0	20.3
Army #1 Water Well	670902	684772	07/30/90	7.88	44.10	20.40	37.9	5.70	15.7	52.5	258.0	20.0
Army #1 Water Well	670902	684772	09/10/90	8.03	44.10	20.50	38.3	5.82	15.6	52.3	260.0	20.3
J-12 Water Well	733508	581012	09/10/90	8.00	15.50	2.23	39.1	5.20	6.8	21.6	118.0	60.3
UE-25 WT #12	739726	567011	04/25/88	8.08	11.70	0.25	67.2	2.15	14.7	14.1	168.0	33.0
UE-25 WT #12	739726	567011	04/28/88	8.02	14.10	0.04	65.7	2.33	7.3	26.1	163.0	47.0
Water Well 5C	742860	705888	09/10/90	8.81	2.53	0.79	135.0	7.13	9.2	32.7	272.0	54.8
USW WT-10	748771	553302	05/16/88	8.42	2.72	0.07	93.8	1.14	7.8	33.6	183.0	47.0
J-13 Water Well	749209	579651	09/10/90	8.02	13.50	1.91	42.2	5.07	6.6	17.8	121.0	62.3
USGS HTH #3	750189	736937	06/16/90	8.27	48.80	19.70	79.6	9.18	23.2	66.8	343.0	17.4
Pluto 5	753602	662558	09/26/88	7.94	55.00	21.60	26.4	4.28	11.5	54.2	218.0	58.0
UE-5n	754460	706415	06/10/86	8.77	8.14	2.39	88.4	8.27	18.7	42.1	173.0	48.0
Pluto 1	754789	662481	11/02/84	7.97	40.50	9.83	36.2	7.68	23.7	46.9	150.0	54.0
USW WT-7	755570	553891	06/04/88	8.12	2.63	0.18	96.6	2.07	12.5	7.2	228.0	20.0
UE-25p #1*	756171	571485	05/12/83	6.60	100.00	39.00	150.00	12.00	28.0	160.0	569.0	41.0
Sand Spring	757105	821545	05/09/87	7.81	41.00	44.80	18.4	3.66	13.6	63.7	287.0	16.0
Sand Spring	757105	821545	01/03/88	8.73	18.80	43.50	18.8	4.57	16.2	24.1	220.0	14.0
UE-5c Water Well	760133	700997	09/10/90	8.51	9.08	2.08	83.5	6.26	12.1	44.0	163.0	60.2
UE-25 WT #14	761651	575210	03/26/88	7.31	9.23	0.79	42.4	5.54	7.5	18.6	116.0	58.0
UE-25 WT #15	766117	579806	04/23/88	7.62	11.60	1.71	61.8	4.60	11.5	16.1	168.0	53.0
UE-11a	777130	708280	08/26/88	8.08	9.05	2.72	106.0	4.66	24.6	59.9	217.0	58.0
Water Well #4	784999	687900	07/31/90	8.12	26.40	8.21	48.9	5.26	11.8	40.9	159.0	60.2
Water Well #4	784999	687900	09/11/90	8.13	24.70	8.18	48.1	5.34	11.4	41.2	158.0	61.1

Appendix B. **Chemical analysis for wells and springs sampled at and near the NTS by DRI between 1983 and 1990. All concentrations are in mg/L (continued).**

Well Name	northing easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Water Well C-1	790011 692132	09/11/89	7.85	66.50	28.20	123.0	14.70	34.2	64.8	589.0	30.0
Water Well C-1	790011 692132	04/16/90	7.69	76.20	29.50	123.0	13.80	33.8	63.8	587.0	30.1
Water Well C-1	790011 692132	07/31/90	7.78	46.50	28.30	124.0	12.90	33.3	66.9	576.0	29.5
Water Well C-1	790011 692132	09/11/90	7.85	74.50	28.20	126.0	13.20	33.2	65.0	584.0	30.6
USGS Water Well C	790082 692061	09/11/89	7.91	74.10	30.00	124.0	15.00	34.0	65.6	585.0	30.0
USGS Water Well C	790082 692061	04/16/90	7.65	75.70	29.80	123.0	13.90	34.0	64.5	589.0	29.7
USGS Water Well C	790082 692061	06/15/90	7.64	74.30	29.20	124.0	15.70	33.8	65.9	589.0	31.5
USGS Water Well C	790082 692061	09/11/90	7.79	73.90	28.20	127.0	13.20	33.2	65.0	581.0	29.8
UE-14b	794100 650111	09/01/88	8.37	13.40	0.26	80.4	1.12	7.4	92.5	119.0	44.0
USGS Test Well B	812044 690713	08/29/88	8.28	6.73	0.57	75.5	3.64	14.2	29.0	172.0	18.0
USGS Test Well B	812044 690713	04/16/90	8.32	6.00	0.58	77.1	3.37	18.6	23.4	167.0	18.3
UE-6d	814000 677500	06/12/86	8.30	21.20	9.65	58.2	11.60	8.2	18.5	245.0	53.0
UE-6d	814000 677500	06/12/86	9.73	7.09	1.59	87.4	11.20	34.7	50.8	85.3	2.1
Quartz Spring	815654 811539	05/09/87	0.00	76.20	39.10	53.8	3.66	25.1	66.6	425.0	52.0
Quartz Spring	815654 811539	01/02/88	8.21	66.90	38.80	54.5	2.17	30.6	79.8	383.0	43.0
UE-16f Eleana	832355 648843	09/20/88	9.41	1.52	0.40	412.0	1.41	19.7	1.7	799.0	6.0
UE-1a	837000 660000	08/24/88	8.01	41.10	32.40	59.1	12.30	30.7	1.0	448.0	19.0
UE-1b	837000 662000	08/31/88	8.08	37.90	13.50	31.6	11.50	7.7	20.3	248.0	85.0
UE-1c	837000 666000	08/31/88	7.98	34.10	13.20	33.7	12.70	6.7	34.1	238.0	98.0
UE-16d Eleana	844878 646567	06/15/90	7.95	78.00	24.60	30.2	6.98	11.0	58.2	363.0	31.3
USGS Test Well D	846600 672600	06/23/86	8.38	13.80	5.76	84.8	8.02	6.6	40.1	239.0	45.0
USGS Test Well D	846600 672600	06/23/86	8.36	13.20	5.53	84.4	9.26	7.0	37.9	242.0	45.0
UE-18t	865800 598400	09/23/88	8.63	22.20	1.00	141.0	8.16	64.4	10.8	331.0	7.0
UE-18r	868100 564700	09/23/88	8.15	20.60	0.95	75.0	3.32	6.9	23.4	225.0	52.0
USGS HTH #1	876855 629310	07/24/86	8.29	1.51	0.16	52.0	1.29	5.8	5.7	127.0	13.0
USGS HTH #1	876855 629310	07/28/87	9.00	1.46	0.20	48.2	0.30	3.2	5.6	96.1	23.0
USGS HTH #1	876855 629310	07/28/87	8.68	2.03	0.20	48.0	0.50	3.2	1.0	117.0	3.0
USGS HTH #1	876855 629310	04/25/89	9.18	1.02	0.07	49.4	0.25	3.1	6.2	91.4	19.6
USGS HTH #1	876855 629310	04/25/89	9.14	1.02	0.07	49.3	0.25	3.1	6.2	96.9	19.7
USGS HTH #1	876855 629310	04/26/89	9.28	1.37	0.07	50.3	0.22	3.1	6.0	87.9	21.6

Appendix B. Chemical analysis for wells and springs sampled at and near the NTS by DRI between 1983 and 1990. All concentrations are in mg/L (continued).

Well Name	northing	easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
USGS HTH #1	876855	629310	04/26/89	9.27	1.02	0.07	50.6	0.25	3.1	6.2	88.1	19.8
USGS HTH #1	876855	629310	09/24/90	8.76	9.83	0.32	53.1	1.13	3.4	17.4	116.0	10.7
USGS HTH #1	876855	629310	09/24/90	9.15	1.59	0.24	51.6	0.38	3.3	8.5	82.7	20.1
USGS HTH #1	876855	629310	09/24/90	9.15	1.91	0.78	52.1	0.79	3.3	8.8	80.7	19.8
USGS HTH #1	876855	629310	09/25/90	9.24	1.49	0.16	51.8	0.38	3.2	8.4	85.9	21.5
USGS HTH #1	876855	629310	09/25/90	9.21	1.38	0.16	51.4	0.41	3.3	8.6	78.5	20.0
USGS HTH #1	876855	629310	09/25/90	9.25	1.70	0.18	51.6	0.34	3.2	7.6	83.7	22.0
USGS HTH #1	876855	629310	09/26/90	9.18	2.12	0.22	51.4	0.77	3.6	0.9	93.5	2.5
Water Well 8	879468	609999	04/16/90	7.38	8.74	1.22	29.9	3.48	7.7	15.2	81.3	47.6
Water Well 8	879468	609999	06/15/90	7.60	8.05	1.21	30.4	3.71	7.6	15.0	76.6	49.0
Water Well 8	879468	609999	08/03/90	7.80	8.44	1.23	28.8	3.36	7.5	15.0	75.8	46.7
Water Well 8	879468	609999	09/11/90	7.81	8.44	1.25	28.5	3.42	7.2	14.7	76.0	47.4
Water Well 2	880000	668720	09/11/89	8.09	36.90	16.00	30.1	7.18	7.6	25.2	226.0	52.0
Water Well 2	880000	668720	04/16/90	7.88	36.20	15.40	30.0	6.80	7.7	23.7	226.0	51.1
Water Well 2	880000	668720	08/01/90	8.02	35.80	14.40	28.7	7.27	7.5	24.3	225.0	51.8
UE–10 ITS #3	887201	680700	08/25/88	8.32	7.79	0.38	209.0	21.50	10.2	42.8	543.0	62.0
UE–15d Water Well	895709	682084	09/11/89	8.04	47.80	15.10	78.8	14.60	15.0	43.0	394.0	27.0
UE–15d Water Well	895709	682084	04/16/90	7.83	58.40	15.70	45.1	16.80	14.7	32.5	327.0	74.8
UE–15d Water Well	895709	682084	08/01/90	7.91	56.70	14.60	47.9	15.10	14.6	36.2	332.0	60.3
U–19az	901894	586010	10/08/90	7.97	19.90	1.80	102.0	5.78	94.4	18.7	145.0	49.4
U–20ao	905600	556450	12/10/84	8.14	8.82	1.24	38.0	1.90	3.2	8.1	114.0	47.0
Pahute Mesa #3	906022	530998	09/12/88	8.31	19.60	0.72	190.0	15.90	114.0	131.0	209.0	55.0
Pahute Mesa #3	906022	530998	09/12/88	9.90	1.14	1.53	1200.0	10.80	318.0	222.0	1005.0	13.0
Pahute Mesa #3	906022	530998	09/12/88	8.34	19.20	0.74	190.0	15.60	114.0	137.0	209.0	55.0
Pahute Mesa #3	906022	530998	09/19/88	8.29	22.70	0.60	148.0	10.40	95.7	126.0	157.0	46.0
Pahute Mesa #3	906022	530998	09/22/88	9.83	1.43	1.55	1150.0	8.51	313.0	283.0	1086.0	15.0
Pahute Mesa #3	906022	530998	09/26/88	7.99	33.20	1.46	135.0	10.50	98.1	129.0	152.0	61.0
Pahute Mesa #3	906022	530998	09/27/88	8.05	34.00	1.51	134.0	10.90	98.9	130.0	149.0	61.0
Pahute Mesa #3	906022	530998	09/27/88	8.12	34.40	1.45	134.0	10.90	99.3	131.0	149.0	61.0
Pahute Mesa #3	906022	530998	10/04/88	9.09	3.48	1.03	78.6	3.84	24.8	23.7	132.0	42.0

Appendix B. **Chemical analysis for wells and springs sampled at and near the NTS by DRI between 1983 and 1990. All concentrations are in mg/L (continued).**

Well Name	northing	easting	date (m/d/y)	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Pahute Mesa #3	906022	530998	10/05/88	9.18	3.55	1.03	77.3	2.85	23.9	24.5	123.0	42.0
Pahute Mesa #3	906022	530998	10/05/88	8.78	15.80	1.36	138.0	10.20	88.4	127.0	102.0	4.0
Pahute Mesa #3	906022	530998	10/05/88	8.31	12.20	0.57	110.0	6.13	63.6	88.9	128.0	5.0
Pahute Mesa #3	906022	530998	10/20/88	9.17	3.30	0.30	43.2	0.80	4.3	10.3	65.5	38.2
Pahute Mesa #3	906022	530998	10/20/88	9.57	3.20	5.69	994.0	10.80	232.0	273.0	1220.0	5.8
Pahute Mesa #3	906022	530998	10/27/88	8.04	34.20	1.39	138.0	11.40	97.0	123.0	155.0	61.5
Pahute Mesa #3	906022	530998	10/27/88	8.14	34.90	1.42	141.0	11.60	95.0	122.0	165.0	60.2
Pahute Mesa #3	906022	530998	10/28/88	8.17	34.00	1.39	137.0	11.40	97.5	124.0	153.0	60.8
Pahute Mesa #3	906022	530998	05/17/89	7.94	30.20	0.82	141.0	10.90	94.0	130.0	159.0	61.2
Pahute Mesa #3	906022	530998	05/17/89	7.95	28.40	0.79	140.0	12.60	93.5	129.0	159.0	61.1
Pahute Mesa #3	906022	530998	05/17/89	7.98	30.10	0.60	137.0	16.60	92.9	125.0	164.0	60.0
U–20a #2 Water Well	907448	568671	04/01/88	8.03	6.18	0.23	59.4	1.73	11.8	32.6	111.0	51.0
U–20a #2 Water Well	907448	568671	04/10/88	8.27	6.34	0.24	62.6	2.27	11.2	38.4	112.0	52.0
U–20 Water Well	910582	569090	05/23/87	8.12	6.38	0.28	57.3	1.67	12.0	31.4	111.0	48.0
U–20 Water Well	910582	569090	04/16/90	8.06	5.65	0.22	58.4	1.83	11.9	28.9	113.0	48.9
U–20 Water Well	910582	569090	08/02/90	8.25	5.40	0.67	58.3	1.78	11.4	30.7	111.0	48.2
U–20 Water Well	910582	569090	09/11/90	8.33	6.15	0.44	57.0	1.74	11.4	30.7	107.0	49.2
U–20ai	915200	565901	03/12/85	8.43	4.29	1.05	115.0	7.17	63.5	26.0	175.0	58.0
UE–19c Water Well	917000	601027	04/16/90	8.52	1.29	0.10	35.0	0.38	2.6	6.6	70.2	45.2
UE–19c Water Well	917000	601027	08/02/90	8.51	1.42	0.22	30.2	0.79	2.4	5.8	67.1	44.2
UE–19c Water Well	917000	601027	09/11/90	8.59	1.54	0.25	32.9	0.76	2.4	6.1	64.9	45.4
U–20aL	917335	549200	11/08/84	8.30	23.70	2.68	122.0	11.10	32.8	77.6	250.0	58.0
U–20aL	917335	549200	11/08/84	8.43	13.10	2.05	117.0	11.00	30.5	68.0	213.0	59.0
U–19ba	926950	602900	11/06/90	7.81	20.70	1.13	78.3	6.06	39.0	9.7	181.0	49.4
U–19ba	926950	602900	11/06/90	8.06	20.50	1.09	77.8	6.08	43.9	9.7	181.0	49.1
U–19ba	926950	602900	11/27/90	8.07	20.80	1.16	79.0	5.47	40.9	10.2	189.0	47.2

*analysis reported by Benson and McKinley (1985)

APPENDIX C

Combined chemical dataset of samples collected from 1957 to 1990, with averages calculated for locations where multiple samples have been collected. The data in this table were used to construct the maps in Figures 11, 13, 16, and 17. Well names are consistent with those used in the 1991 edition of the Raytheon Services Nevada "NTS Drilling and Mining Summary." Wells are grouped according to producing formation and ordered within each group according to increasing north coordinate.

Appendix C. Combined data set of 1957 to 1990 data, with averages calculated for wells with multiple samples.

Well Name	# of Samples	northing	easting	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Formation: Alluvium												
Silver Flag Alpha	1	630524	858934	8.0	32.4	20.5	5.8	1.5	3.3	13	197	15.0
Divide Well	2	643689	852236	8.2	19.7	19.7	44.5	6.3	34.7	18	198	23.5
Old Dry Well	2	648737	851520	8.4	22.3	21.3	54.0	5.6	56.2	25	182	24.0
Wells–Stewart	1	651000	825000	7.6	33.0	18.0	123.0	12.0	55.0	164	210	19.0
Army #3	1	654163	760615	7.9	27.0	21.0	6.8	1.4	6.0	11	186	6.6
Army #2	1	655582	735166	7.8	35.0	23.0	5.6	1.2	5.0	15	204	14.0
Army 6A	3	665641	690214	8.4	15.0	54.1	150.7	8.0	28.8	269	313	5.1
Army 6	1	680800	690500	8.1	281.0	90.0	1291.0	0.0	35.0	3599	98	22.6
Water Well 5C	7	742860	705888	8.7	2.4	0.6	129.0	6.0	9.1	26	271	55.1
Water Well 5B	5	747359	704263	8.5	7.7	1.7	96.6	10.6	23.2	58	166	51.4
UE–5n	1	754460	706415	8.8	8.1	2.4	88.4	8.3	18.7	42	173	48.0
USGS Water Well A	4	833000	684000	7.8	23.8	6.3	51.0	8.6	6.0	20	209	74.3
UE–6d	2	814000	677500	9.0	14.1	5.6	72.8	11.4	21.5	35	165	27.6
Watertown 3	1	914990	742272	7.8	16.0	2.9	56.0	5.6	8.0	25	170	78.0
Formation: Carbonate												
USGS HTH #4	1	669876	755217	7.5	34.0	17.0	13.0	2.5	6.1	17	197	20.0
Army #1 Water Well	6	670902	684772	7.6	44.0	20.9	38.1	5.4	16.1	53	257	20.1
USGS HTH #10	1	671051	739075	7.7	37.0	18.5	7.0	1.4	5.9	15	198	14.5
USGS HTH #3	2	750189	736937	7.8	49.9	20.4	81.3	8.4	23.1	75	336	20.7
UE–25p #1	1	756171	571485	6.6	100.0	39.0	150.0	12.0	28.0	160	569	41.0
Sand Spring	2	757105	821545	8.3	29.9	44.2	18.6	4.1	14.9	44	254	15.0
Water Well C–1	6	790011	692132	7.7	59.1	28.5	124.2	13.9	33.9	65	550	29.4
USGS Water Well C	8	790082	692061	7.4	71.1	27.0	127.1	14.0	32.6	67	566	30.5
Quartz Spring	2	815654	811539	8.2	71.6	39.0	54.2	2.9	27.9	73	404	47.5
UE–16f Eleana	3	832355	648843	8.7	3.6	1.0	420.7	1.9	23.6	81	553	5.1
UE–1b	1	837000	662000	8.1	37.9	13.5	31.6	11.5	7.7	20	248	85.0
UE–1c	1	837000	666000	8.0	34.1	13.2	33.7	12.7	6.7	34	238	98.0
UE–16d Eleana	4	844878	646567	7.6	70.8	25.2	33.1	6.8	11.8	62	293	27.3
USGS Test Well D	3	846600	672600	8.2	14.7	7.1	92.1	10.4	11.2	50	251	36.0
Water Well 2	5	880000	668720	7.9	32.2	15.0	28.2	6.7	7.2	23	210	50.8
UE–15d Water Well	3	895709	682084	7.9	49.8	13.9	73.2	15.5	14.5	46	359	37.5
Marble #3	1	903096	674866	7.9	25.0	47.0	15.0	3.8	5.0	24	310	24.0

Appendix C. **Combined data set of 1957 to 1990 data, with averages calculated for wells with multiple samples (continued).**

Well Name	# of Samples	northing	easting	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Formation: Volcanic												
USGS HTH "F"	2	731053	661153	7.3	40.5	15.5	81.0	8.0	21.5	108	239	31.5
J–12 Water Well	5	733508	581012	7.8	14.0	1.8	41.2	5.1	7.6	22	119	50.3
Water Well 5A	6	738361	707514	8.8	2.3	0.5	161.2	6.1	10.2	26	349	56.5
UE–25 WT #12	2	739726	567011	8.1	12.9	0.1	66.5	2.2	11.0	20	166	40.0
J–11	1	740890	611821	7.8	83.7	13.3	151.3	15.7	18.7	471	103	67.3
USW WT–10	1	748771	553302	8.4	2.7	0.1	93.8	1.1	7.8	34	183	47.0
J–13 Water Well	4	749209	579651	7.3	13.9	2.1	45.6	5.8	7.7	23	126	58.6
Pluto 5	1	753602	662558	7.9	55.0	21.6	26.4	4.3	11.5	54	218	58.0
Pluto 1	1	754789	662481	8.0	40.5	9.8	36.2	7.7	23.7	47	150	54.0
USW WT–7	1	755570	553891	8.1	2.6	0.2	96.6	2.1	12.5	7	228	20.0
UE–5c Water Well		760133	700997	8.5	9.1	2.1	83.5	6.3	12.1	44	163	0
UE–25 WT #14	1	761651	575210	7.3	9.2	0.8	42.4	5.5	7.5	19	116	58.0
UE–25 WT #15	1	766117	579806	7.6	11.6	1.7	61.8	4.6	11.5	16	168	53.0
UE–11a	1	777130	708280	8.1	9.1	2.7	106.0	4.7	24.6	60	217	58.0
Water Well #4	4	784999	687900	8.1	25.6	8.2	48.5	5.3	11.6	41	159	0
UE–14b	1	794100	650111	8.4	13.4	0.3	80.4	1.1	7.4	93	119	44.0
USGS Test Well B	2	812044	690713	8.3	6.4	0.6	76.3	3.5	16.4	26	170	0
Well 3	7	817795	677762	7.8	20.4	12.1	38.7	7.5	6.1	21	193	64.6
UE–1a	1	837000	660000	8.0	41.1	32.4	59.1	12.3	30.7	1	448	19.0
HTH "E"	1	839989	696001	9.0	1.6	0.0	1.0	2.6	6.0	16	187	61.0
Test Well #7	1	843192	684654	7.3	1.0	0.2	113.0	4.6	8.0	2	286	1.4
UE–18t	1	865800	598400	8.6	22.2	1.0	141.0	8.2	64.4	11	331	7.0
UE–18r	2	868100	564700	8.1	23.3	1.0	78.0	3.2	7.4	24	239	48.5
USGS HTH #1	21	876855	629310	9.1	4.9	1.5	60.0	1.3	4.8	12	105	20.4
Water Well 8	6	879468	609999	7.4	8.5	1.1	29.6	3.4	7.6	15	78	46.8
UE–10 ITS #3	1	887201	680700	8.3	7.8	0.4	209.0	21.5	10.2	43	543	62.0
UE–19fS	1	900900	587084	8.1	11.0	1.6	29.0	3.0	6.3	9	86	56.0
U–19az	2	901894	586010	8.0	19.9	1.8	102.0	5.8	94.4	19	145	49.4
U–20ao	1	905600	556450	8.1	8.8	1.2	38.0	1.9	3.2	8.	114	47.0
Pahute Mesa #3	20	906022	530998	8.6	20.0	1.3	277.8	10.	112.9	129	292	43.4
U–20a #2 Water Well	2	907448	568671	7.7	6.1	0.2	58.8	1.5	11.3	32	109	48.0
Watertown 1	2	909046	749549	8.1	5.2	2.0	67.5	8.7	6.0	20	176	85.0

Appendix C. **Combined data set of 1957 to 1990 data, with averages calculated for wells with multiple samples (continued).**

Well Name	# of Samples	northing	easting	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	SiO_2
Formation: Volcanic (continued)												
Watertown 2	2	909062	752226	8.4	5.2	1.6	86.0	9.1	6.5	21	210	85.5
UE-20d	5	909200	554300	8.2	7.3	0.1	85.4	1.0	20.6	44	143	45.4
UE-19i	1	910098	593107	7.7	5.0	0.1	75.0	0.5	7.0	70	98	39.0
U-20 Water Well	1	910582	569090	8.2	5.9	0.4	57.8	1.8	11.7	30	111	0
U-20ai	1	915200	565901	8.4	4.3	1.1	115.0	7.2	63.5	26	175	58.0
UE-19c Water Well	2	917000	601027	8.2	3.7	0.2	53.6	0.5	3.5	5	134	41.2
U-20aL	2	917335	549200	8.4	18.4	2.4	119.5	11.1	31.7	73	232	58.5
U-20f	1	917825	551857	9.0	0.6	0.1	69.0	0.7	6.8	27	101	37.5
UE-20f	1	917825	552007	7.2	4.8	0.1	113.0	2.0	40.0	48	164	47.0
UE-20h	1	918015	567747	8.1	0.6	0.1	64.0	1.8	15.0	30	107	49.0
U-19aS	3	919248	586326	9.0	1.6	0.1	217.3	6.1	14.0	35	213	72.0
U-19ba	2	926950	602900	8.0	20.7	1.1	78.4	5.9	41.3	10	184	48.6
UE-19e	2	927300	596999	7.8	2.1	0.1	46.5	1.0	7.4	18	83	53.0
UE-20j	1	928306	538537	7.0	46.0	1.2	138.0	6.4	115.0	135	150	44.0
UE-19gS	2	931338	587843	8.2	7.4	0.1	76.0	1.1	15.5	40	135	48.0
UE-19b #1	2	933700	606835	7.1	22.0	2.1	42.5	3.0	9.9	23	140	44.0
UE-20e #1	2	934466	560958	8.1	0.3	0.1	97.5	2.9	38.5	43	125	40.0
U-19d #2	5	945991	600202	7.8	43.4	3.0	155.4	3.9	28.2	65	419	49.0

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8 / 11 / 93