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Groundwater Evaporation Estimates Using Stable Isotope and Chloride Data, Yelland Playa, Spring Valley, Nevada

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INTRODUCTION AND BACKGROUND

Bare soil evaporation from the shallow water table beneath playas can be an important discharge component of the groundwater budget for topographically closed basins and other hydrographic areas in Nevada. Effective groundwater management in Nevada relies on accurate estimates of the groundwater budget. Water budgets are generally determined by estimating groundwater discharge using physical measurements and extrapolating the estimates throughout the discharge area of a valley. While evaporation from bare soil can represent a significant component of groundwater discharge, it is difficult to measure in the field because of spatial and temporal variations in climate, water potential and soil hydraulic properties. Moreover, playa evaporation represents a special case because of salinity effects; salinity decreases the evaporation rate (Salhotra *et al.*, 1987) relative to fresh water due to a reduction in the vapor pressure gradient. Also, salts on playa surfaces can increase albedo and reduce the evaporation rate relative to a salt free surface and soil salts can reduce hydraulic conductivity. These factors inhibit the ability of traditional climatological and soil physics methods for estimating bare soil evaporation. The objective of the research described in this report was to assess the potential for using the distribution of soilwater stable isotope and chloride concentrations to estimate groundwater evaporation from Nevada playas.

Evaporation from a shallow water table is driven by the vapor pressure gradient between the soilwater and atmosphere and is generally proportional to groundwater depth. Several authors have measured and/or estimated groundwater evaporation for varying conditions. For steady-state conditions, Gardner (1958), Willis (1960), and Hadas and Hillel (1972) developed analytical solutions for the Buckingham-Darcy flux law:

$$E = -k(\Psi) \left(\frac{\partial \Psi}{\partial z} + 1 \right) \quad [1]$$

where, E is the evaporation rate, $k(\psi)$ is the hydraulic conductivity as a function of soil matric potential ψ and z is depth in the unsaturated zone soil profile. The solution to this equation, and experimental data developed by Gardner and Fireman (1958) and Willis (1960), showed that the evaporation rate decreases substantially at some depth below land surface. The depth-evaporation relationship depends on soil texture.

Stable Isotopes for Estimating Bare Soil Evaporation

In hydrogeological stable isotope studies, there are generally four isotopes of interest. Hydrogen is present in two isotopic forms, the common ^1H , and the relatively rare ^2H (deuterium, or D). Oxygen is also present in two forms, the common ^{16}O , and the relatively rare ^{18}O . The isotopes ^2H and ^{18}O have a larger atomic mass than their isotopic counterparts. As a consequence of this mass difference, the process of evaporation causes a preferential fractionation of the lighter isotopes to water vapor, and the heavier isotopes to liquid water. The degree of this fractionation is an indication of the evaporative 'history' of the water in lakes, soils, and groundwater. Stable isotopes of oxygen (^{18}O) and hydrogen (deuterium or D) have been used to estimate groundwater evaporation from vegetation free surfaces and playas. Zimmerman *et al.* (1967) conducted a series of laboratory experiments with variably saturated soil columns to study the processes controlling isotopic enrichment. Allison, Barnes

and colleagues developed theory and applications for using the depth distribution of stable isotopes in soilwater to estimate evaporation rates (e.g. Allison, 1982; Allison and Barnes, 1985; Barnes and Allison, 1983; Barnes and Allison, 1984). There have been few field applications of the method which are directly comparable to estimating evaporative flux from the Yelland playa. Allison and Barnes (1983, 1985) used the soilwater deuterium distribution to estimate groundwater evaporation flux rates from dry Lake Frome in south Australia. Taupin (1995) also applied the Allison *et al.* approach to estimate shallow groundwater evaporation flux rates in Niger.

Barnes and Allison (1983) developed the theory for the use of soilwater stable isotopes for estimating evaporation. They state that the method appears applicable to coarse-grained soils, but may not be applicable to fine-grained or clay soils. However, Allison *et al.* (1983) reported the results of laboratory column experiments in which measured evaporation rates were compared with isotope-derived estimates derived using the Barnes and Allison (1983) method for columns packed with attapulgite clay and clay loam. The isotope-derived evaporation estimates for these fine-grained soils agreed very well with measured rates, thus validating the application for the fine-textured soils. The clay and clay-loam soils examined by Allison *et al.* (1983) are assumed to be analogous to the Yelland playa for the purposes of this study.

The soilwater isotope profile that develops in a soil where there is groundwater evaporation from a shallow water table is the result of a balance between the upward evaporative flux and downward diffusive flux of water vapor. To estimate groundwater evaporation rates, the depth distribution of deuterium (δD) in the soil can be expressed as a function of depth and water content such that:

$$E = \frac{\Theta \tau D_{liq}}{z'} \quad [2]$$

where, E is the evaporation rate, z' is the penetration depth of deuterium enrichment resulting from evaporation (Zimmerman *et al.*, 1967), Θ is the average soil moisture content, τ is the soil tortuosity and D_{liq} is the diffusion coefficient of HDO in liquid water. The value for z' is determined by fitting the soil depth distribution of δD to the relationship developed by Zimmerman *et al.* (1967) where, δD is related exponentially to a depth moisture function:

$$\delta D_i - \delta D_{res} = (\delta D_{ef} - \delta D_{res}) \cdot e^{-\frac{f(z_i)}{z'}} \quad [3]$$

where, δD_i is the isotope value measured in the soilwater at the i^{th} depth interval, δD_{res} is the isotope value of the groundwater, and δD_{ef} is the isotope value of the soilwater at the evaporating front. The parameter $f(z_i)$ is a depth function that accounts for water content variations with depth. The penetration depth (z') is the depth in the soil profile where there is an abrupt decrease in the deuterium enrichment and represents the liquid-vapor phase interface. Allison and Barnes (1983) used this method, and that of Zimmerman *et al.* (1967), to estimate rates of 46 and 35 mm per year of evaporation from an Australian playa that receives an average 100 to 125 mm of precipitation annually, and has a groundwater depth of 30 cm. Their estimate was substantially lower than the pan evaporation rate of 2,200 mm per year. Gardner's (1958) method for estimating evaporation yields a value of greater than

1,100 mm per year for this site. Allison and Barnes (1983) reasoned that their reduced rate was the result of a reduced vapor pressure gradient due to saline water (saturated with NaCl) and the albedo of the salt-covered surface. This stable isotope method estimates long-term average evaporation and assumes that a steady state isotope profile has developed.

Soil Chloride Concentration Distribution for Estimating Bare Soil Evaporation

Allison and Barnes (1985) and Taupin (1995) used the soilwater chloride depth distribution to estimate shallow groundwater evaporation under the assumption that the chloride profile is at equilibrium such that the chloride concentration measured in the soilwater at the i^{th} depth interval, Cl_i , can be approximated by

$$Cl_i = (Cl_{ef} - Cl_{res}) \cdot e^{-\left(\frac{f(z_i)}{z_{Cl}} + Cl_{res}\right)} \quad [4]$$

where $f(z_i)$ is approximated by

$$f(z_i) = \Theta_{avg} \cdot \frac{(z_i - z_{ef})}{\Theta_i} \quad [5]$$

and

$$z'_{Cl} = \frac{\Theta_{avg} \tau D_{liq}}{E} \quad [6]$$

where, E is the evaporation rate and z'_{Cl} is the penetration depth of evaporation. The parameters Θ_{avg} is the average volumetric water content and Θ_i is the volumetric water content for the i^{th} depth interval, z_i , and z_{ef} is the depth of the evaporating front. The parameter D_{liq} is the diffusivity of chloride in water, Cl_{res} and Cl_{ef} are the chloride concentrations of the groundwater and of the soilwater at the evaporating front, respectively.

To assess the potential for using soilwater stable isotope values and chloride concentrations to estimate groundwater evaporation from playas in the Great Basin, soil samples were collected from two sites on the Yelland Playa in Spring Valley in eastern Nevada (Figure 1). The soil moisture content, the isotope content, and chloride concentration of the soilwater as a function of depth were determined. These data were used with the previously described methodologies to estimate groundwater evaporation from the Yelland Playa.

METHODS

Sample Collection

Using a Giddings® auger rig, a series of continuous soil cores were collected to a depth of approximately 3 m at two locations on the Yelland playa in October 2004 (Figure 1). Soil cores were collected in plastic liners placed inside 5-cm diameter stainless steel sampling tubes. Soil cores were sealed on site with plastic endcaps and tape, and stored in a cooler with dry ice for transport. Samples of the shallow groundwater were collected from the two core holes by bailing through the inside of the drill auger. These groundwater samples were analyzed for chloride and stable isotopes. The average measured soil temperature was 15 °C.

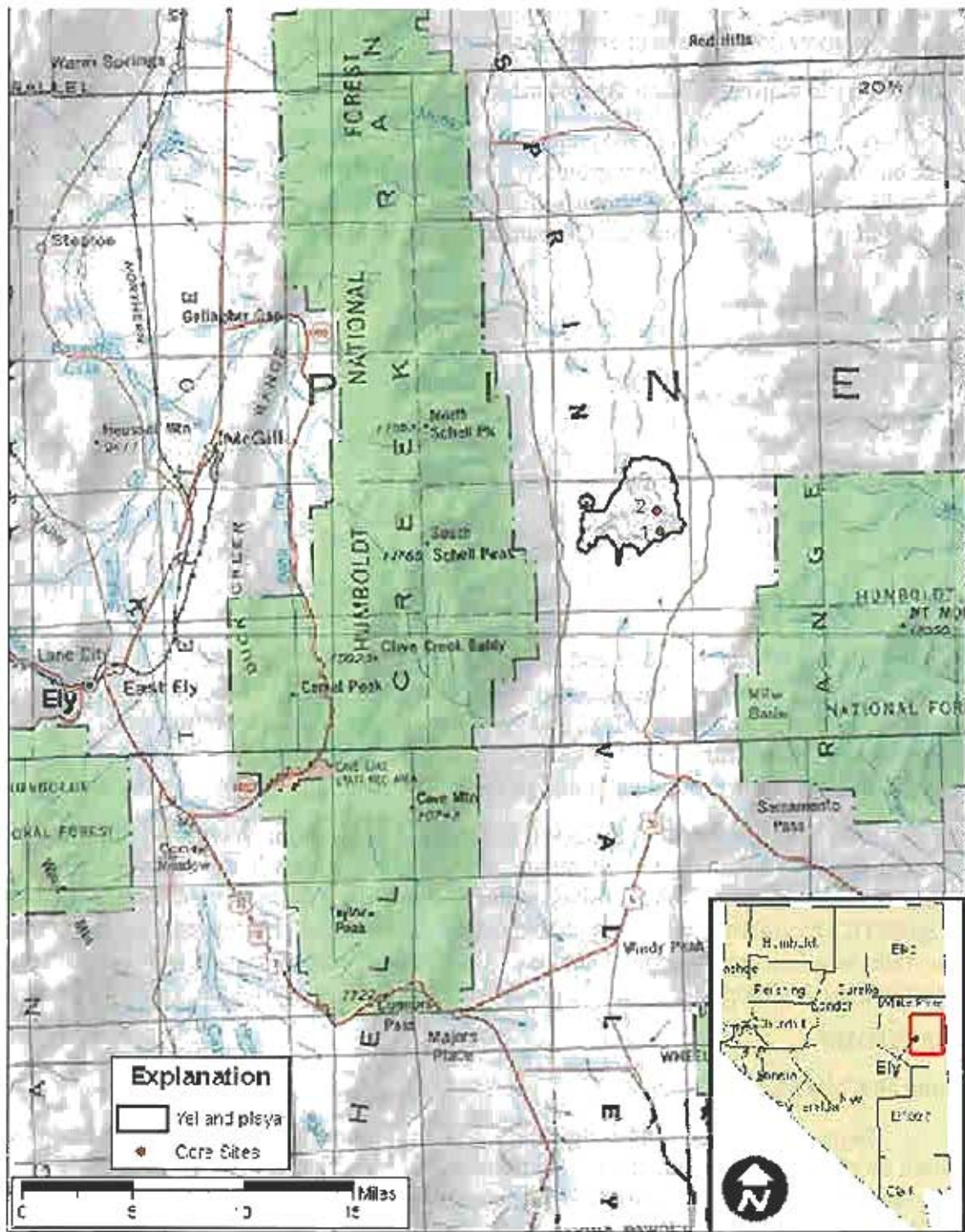


Figure 1. Map showing location of Yelland Playa (solid black line) in Spring Valley, Nevada and core Sites 1 and 2.

Sample Analysis

Soil cores were archived in a -15 °C freezer at the Desert Research Institute, Reno, Nevada. Sub-samples of each core were analyzed for gravimetric moisture content. A second set of sub-samples was used to form a 1:1 solution by weight with distilled water (Bill Albright, oral comm., DRI), the extract of which was analyzed for chloride concentration. A third set of sub-samples was subjected to cryogenic distillation to extract all the soilwater for stable isotopic analyses (Prudic *et al.*, 1997), which was done via mass spectrometry (Epstein and Mayeda, 1953; Kendall and Coplen, 1985).

RESULTS

At both sites, a clay-type soil was observed. The depth to groundwater was approximately 213 and 275 cm at Sites 1 and 2, respectively. The electrical conductivity of the groundwater at both sites was approximately 70,000 $\mu\text{S}/\text{cm}$.

Tables 1 and 2 show the results of the laboratory moisture content and isotopic analyses for Sites 1 and 2. Figure 2 shows the depth distribution of δD at the two sites. Both sites show substantial near-surface isotopic enrichment corresponding with decreasing soil moisture (Figure 3) and increasing chloride concentrations (Figure 4). Figure 5 shows the $\delta\text{D}/\delta^{18}\text{O}$ relationship for all samples. The slope of the linear best-fit line through these data (2.35) indicate a pattern of long-term evaporation from a dry soil (Allison, 1982).

Table 1. Stable isotopic composition of water extracted from soil cores at Sites 1 and 2 and groundwater from the core sites at Yelland Playa, Nevada.

Depth (cm)	$\delta^{18}\text{O}$ (‰)	δD (‰)
Site 1		
23	-1.97	-68.6
29	-2.32	-66.8
36	-2.55	-66.8
42	-4.73	-74.3
48	-5.45	-75.7
78	-6.33	-79.0
84	-6.83	-78.5
90	-7.04	-79.8
99	-6.48	-78.0
105	-6.70	-79.4
112	-6.47	-78.3
Groundwater (213 cm)	-5.4	-74.2
Site 2		
9.5	-6.37	-75.3
22	-2.82	-71.4
34	-4.83	-75.8
47	-5.43	-76.9
Groundwater (275 cm)	-5.52	-72.1

Table 2. Soil moisture and chloride concentrations from discrete zones from soil cores collected at Sites 1 and 2 at the Yelland Playa, Nevada.

	Depth (cm)	Chloride (mg/kg)	percent moisture (by weight)
Site 1			
	20	5,594	13.98
	26	5,096	23.82
	32	4,284	25.04
	39	3,417	25.15
	45	2,846	24.37
	74	2,459	24.80
	81	2,475	25.32
	88	2,495	25.49
	102	4,304	26.89
	109	2,952	27.43
Site 2			
	12	7,108	11.59
	18	5,971	14.82
	25	4,404	14.92
	31	4,049	18.76
	38	3,745	20.14
	44	3,484	22.17

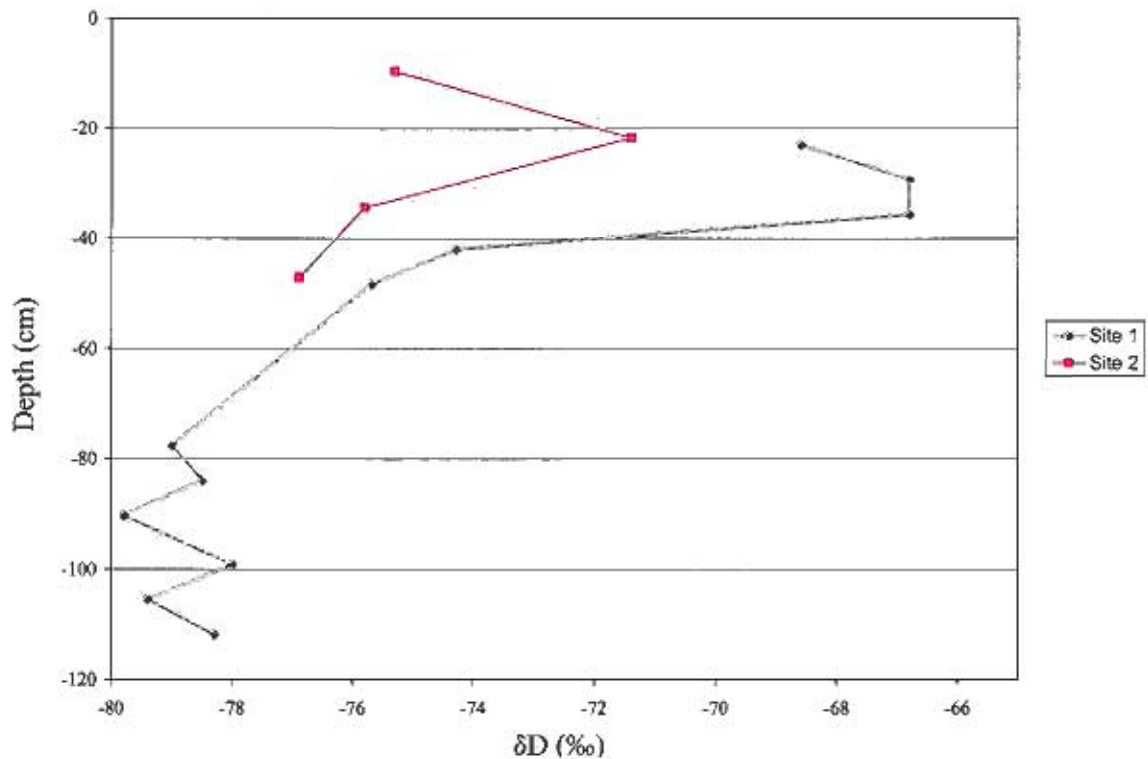


Figure 2. Depth distribution of δD in soilwater extracted from cores at Sites 1 and 2 in the Yelland Playa, Nevada.

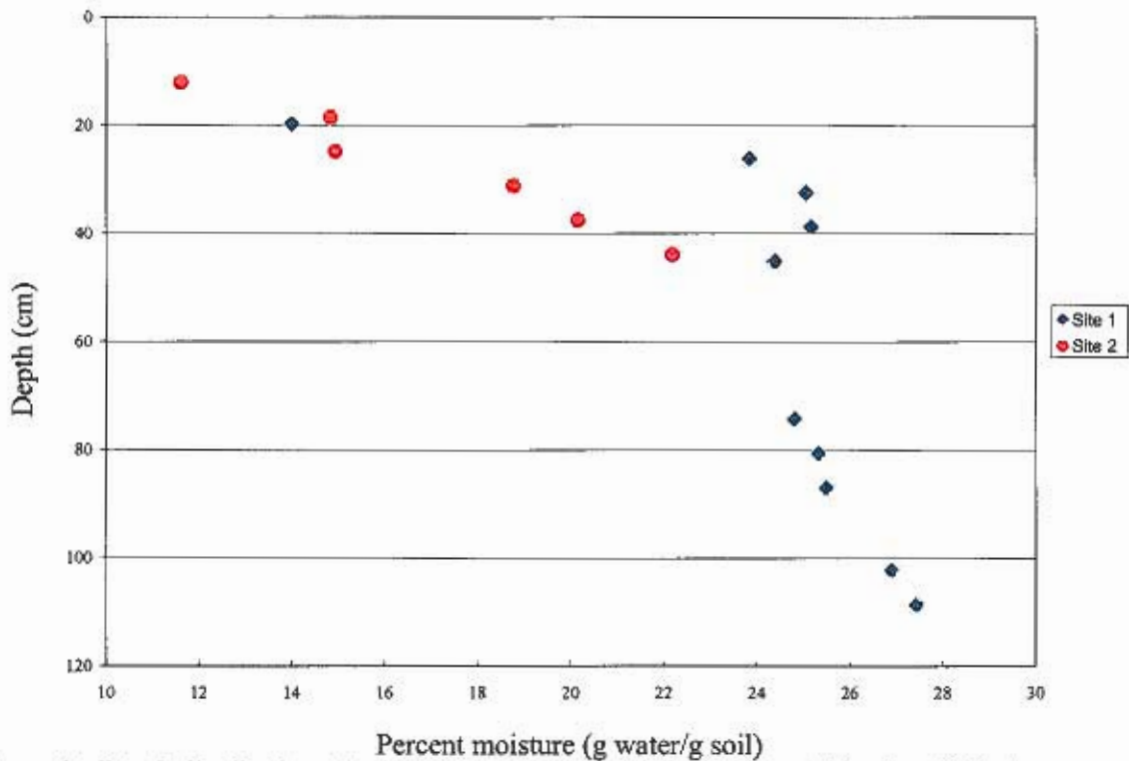


Figure 3. Depth distribution of soil moisture determined from cores at Sites 1 and 2 in the Yelland Playa, Nevada.

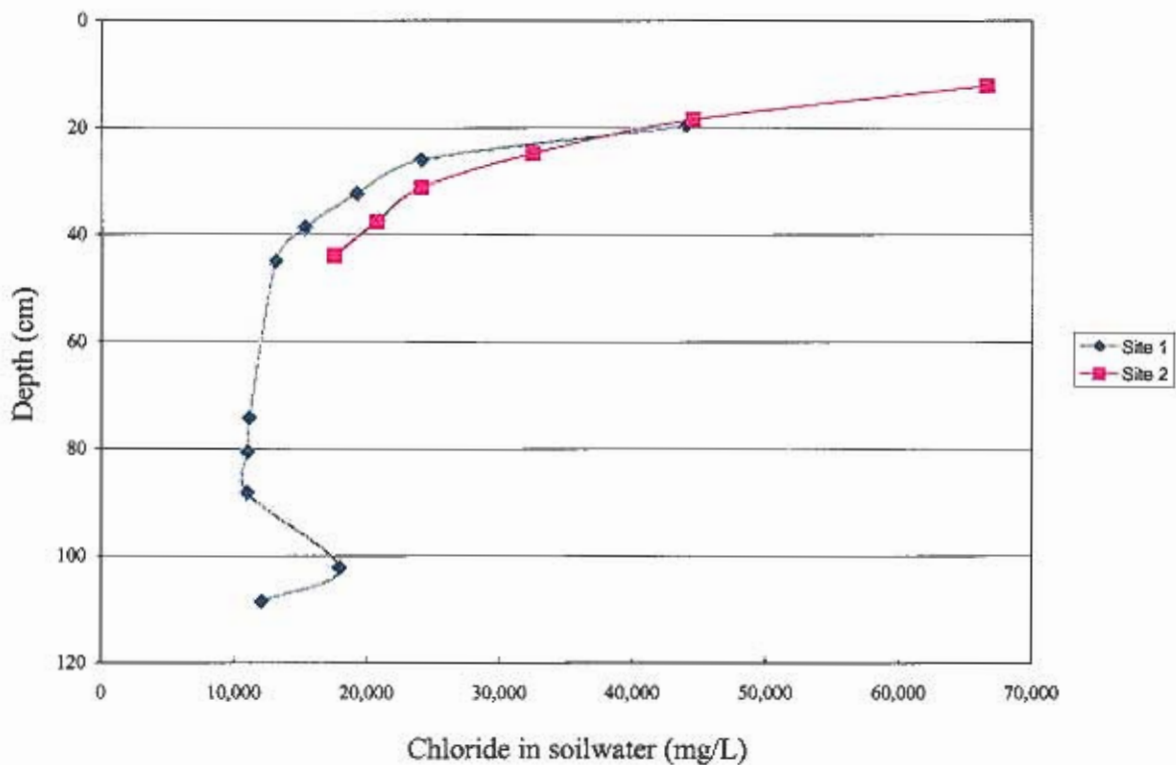


Figure 4. Soilwater chloride depth profile from cores collected at Sites 1 and 2 in the Yelland Playa, Nevada.

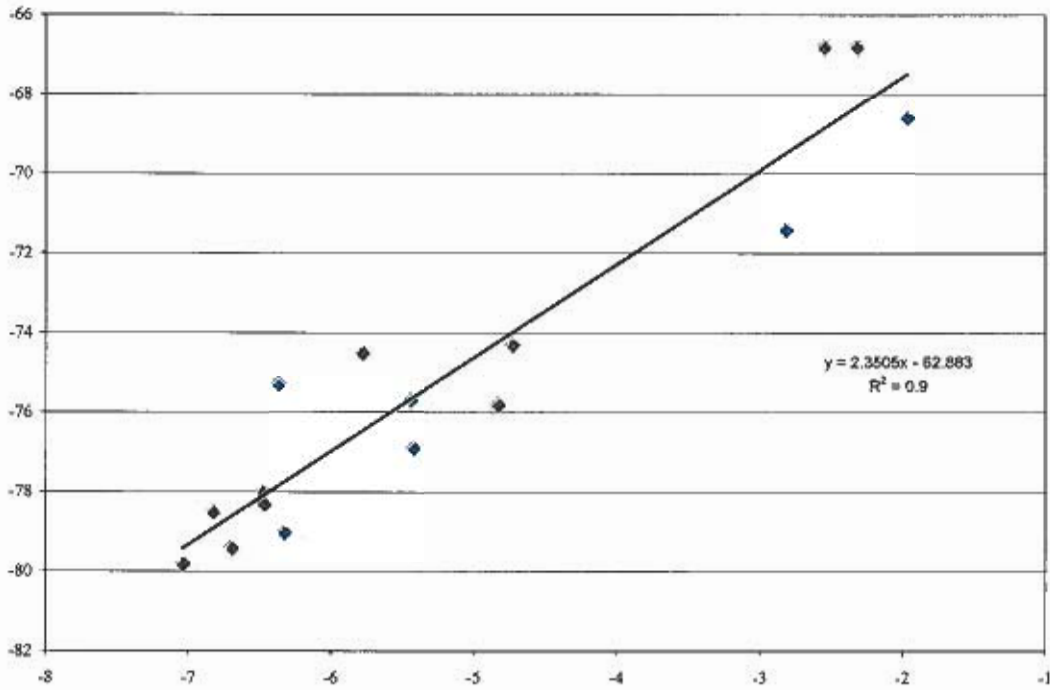


Figure 5. Plot of stable isotopes from sub-sampled cores at Sites 1 and 2 in the Yelland Playa.

Estimated Evaporation from Shallow Groundwater using Deuterium Data

Following the isotopic modeling methodology in Barnes and Allison (1983; 1984) and Allison *et al.* (1983), the evaporation rate from the shallow groundwater was estimated using the soilwater deuterium data. First, Equation 3 was applied to δD data for both sites. The variable $f(z)$ was estimated following the methodology provided in Taupin (1995)

$$f(z_i) = \Theta_{avg} \cdot \frac{(z_i - z_{ef})}{\Theta_i + N_{sat} \cdot D_{atm} \cdot \frac{n - \Theta_i}{\rho \cdot D_{liq}}} \quad [7]$$

In Equation 7, Θ_{avg} is the average volumetric water content; Θ_i is the volumetric water content for depth i ; z_i and z_{ef} are the depth at interval i and at the evaporating front, respectively; N_{sat} is the temperature-dependent saturated water vapor concentration of the soil atmosphere ($13.2 \times 10^{-3} \text{ kg/m}^3$ at 15°C) from Weast (1982); D_{atm} and D_{liq} are the diffusivities of deuterium in air and water, respectively; n is the soil porosity (estimated as 0.5); and ρ is the density of water. The values for D_{atm} and D_{liq} are $0.264 \times 10^{-4} \text{ m}^2/\text{s}$ (Taupin, 1995) and $1.777 \times 10^{-9} \text{ m}^2/\text{s}$ (Mills, 1973), respectively. The volumetric water content was estimated from the gravimetric soil moisture content by assuming a soil bulk density of 1.5 g/cm^3 .

In addition, the penetration depth z' in Equation 3 was estimated by plotting $\ln(\delta D - \delta D_{res})/(\delta D_{ef} - \delta D_{res})$ versus $-f(z)$. The slope of this relation is $1/z'$. The values of δD_{ef} and δD_{res} were adjusted to optimize the predicted fit for δD . Figure 6 shows the plot of \ln

$(\delta D - \delta D_{res})/(\delta D_{ef} - \delta D_{res})$ versus $-f(z)$ for δD for Site 1. There is a reasonable fit as indicated by the r^2 value of 0.75. Values for δD_{ef} and δD_{res} were -66.8 and -90 per mil, respectively.

The analysis of the δD data resulted in an estimated z' of 65 cm and generally good agreement between measured and predicted values (Figure 7). The root mean square error for estimated values was 5 percent. The evaporation rate was estimated using Equation (2). We estimated Θ_{avg} to be 0.38 (assuming a bulk density of 1.5 g/cm^3), τ was assumed to be 0.3 (per Allison and Barnes (1983) reported value for a clay), and D_{liq} is $1.777 \times 10^{-9} \text{ m}^2/\text{s}$ (Mills, 1973). This results in an annual evaporation estimate of 11 mm/yr plus or minus 0.6 mm/yr.

The data for Site 2 (Figure 2) indicate a shallower z' . The same calculations were applied to three points (at the 21.6, 34.3 and 47 cm depths) for Site 2. These calculations resulted in an r^2 value of 0.74 for $\ln (\delta D - \delta D_{res})/(\delta D_{ef} - \delta D_{res})$ versus $-f(z_i)$. Values for δD_{res} , δD_{ef} and z' were -83.5 per mil, -64 per mil and 14 cm, respectively. This resulted in an estimated evaporation rate of 42 mm/yr plus or minus 5.5 mm/yr based on the existing three data points. Figure 7 shows a reasonable fit for modeled estimates and measured values for δD values. However, due to the limited number of data points for analysis, the error in this evaporation rate is probably higher than the 5.5 mm/yr estimated from the root mean square error for the estimated values.

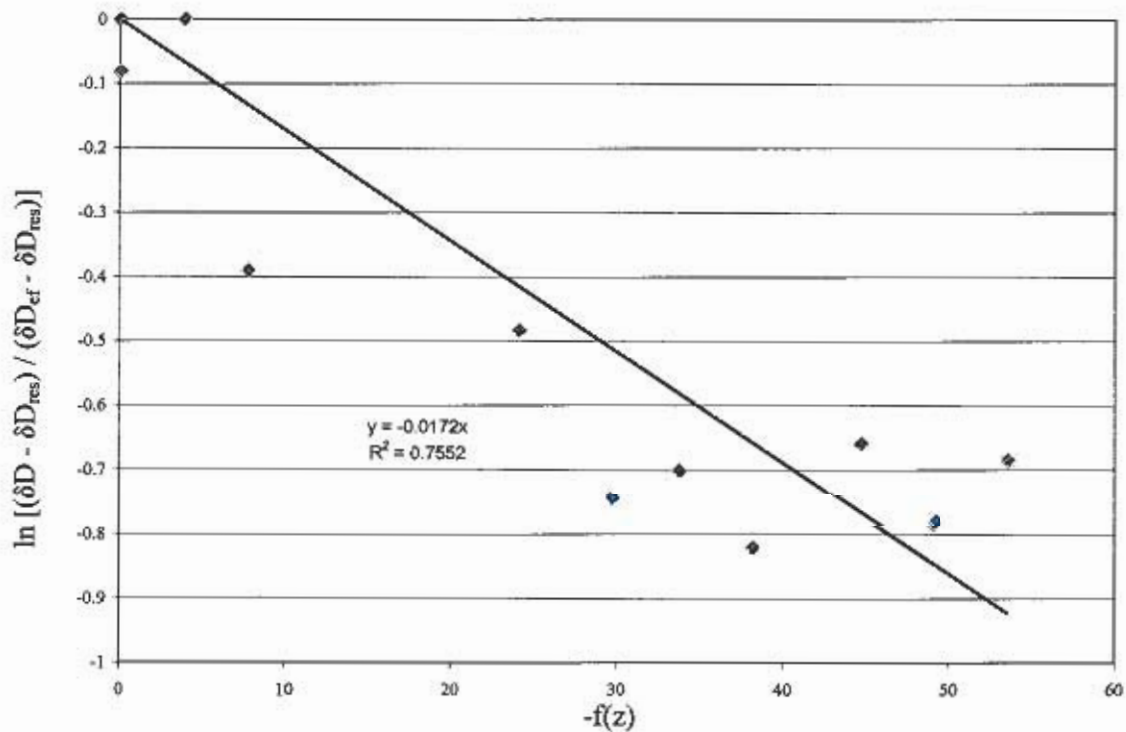


Figure 6. Graph showing relation of $\ln [(\delta D - \delta D_{res})/(\delta D_{ef} - \delta D_{res})]$ versus $-f(z_i)$ for deuterium for Site 1.

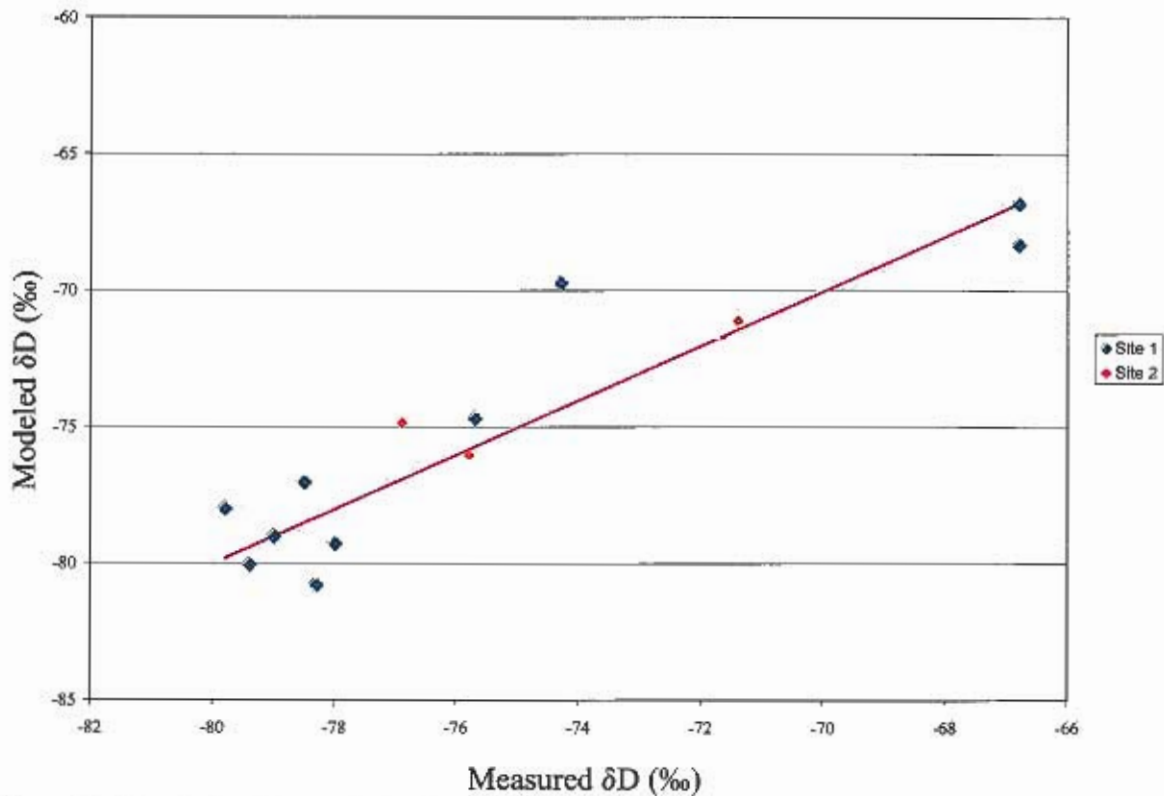


Figure 7. Graph showing model estimates versus measured values for δD for Sites 1 and 2.

Estimated Evaporation from Shallow Groundwater using Chloride Data

Following the method of Allison and Barnes (1985) the evaporation rate was estimated from shallow groundwater using the chloride data. First, Equation (4) was used to model the chloride profile. Using Equation (5), $f(z_i)$ was estimated and plotted as $\ln(Cl_i - Cl_{res}) / (Cl_{ef} - Cl_{res})$ versus $-f(z_i)$ for Site 1 (Figure 8). The results of these calculations are that the chloride method is of a limited applicability for Site 1 as compared to the deuterium approach, a conclusion which is justified by a smaller value of the correlation coefficient ($r^2 = 0.54$) than for deuterium ($r^2 = 0.75$). However, at Site 2, these calculations result in a high correlation coefficient ($r^2 = 0.98$) (Figure 9), indicating a greater applicability for evaporation estimation using chloride data. To estimate z' using Equation 6, a value for D_{liq} of $1.58 \times 10^{-9} \text{ m}^2/\text{s}$ (Mills and Lobo, 1989) was used. The slopes of the lines representing the $\ln(Cl_i - Cl_{res}) / (Cl_{ef} - Cl_{res})$ versus $-f(z)$ relation indicate z' values of 56 and 14 cm for Sites 1 and 2, respectively. Values of 4,000 and 7,000 mg/L were used for Sites 1 and 2 for Cl_{res} and 28,000 and 67,000 mg/L for Sites 1 and 2 for Cl_{ef} . This results in an annual evaporation estimate of 11 mm/yr plus or minus 4 mm/yr and 43 mm/yr plus or minus 2 mm/yr for Sites 1 and 2, respectively.

For Site 1, the chloride evaporation estimate is less certain than the deuterium estimate, as indicated by less predictive values using Equation (6) (see Figures 8 and 10). The model (equation) estimated chloride values agree with measured values within about 36 percent (percent root mean square error). The predictive value is much better for Site 2; the percent root mean square error is 4 percent. Table 3 summarizes the evaporation estimates.

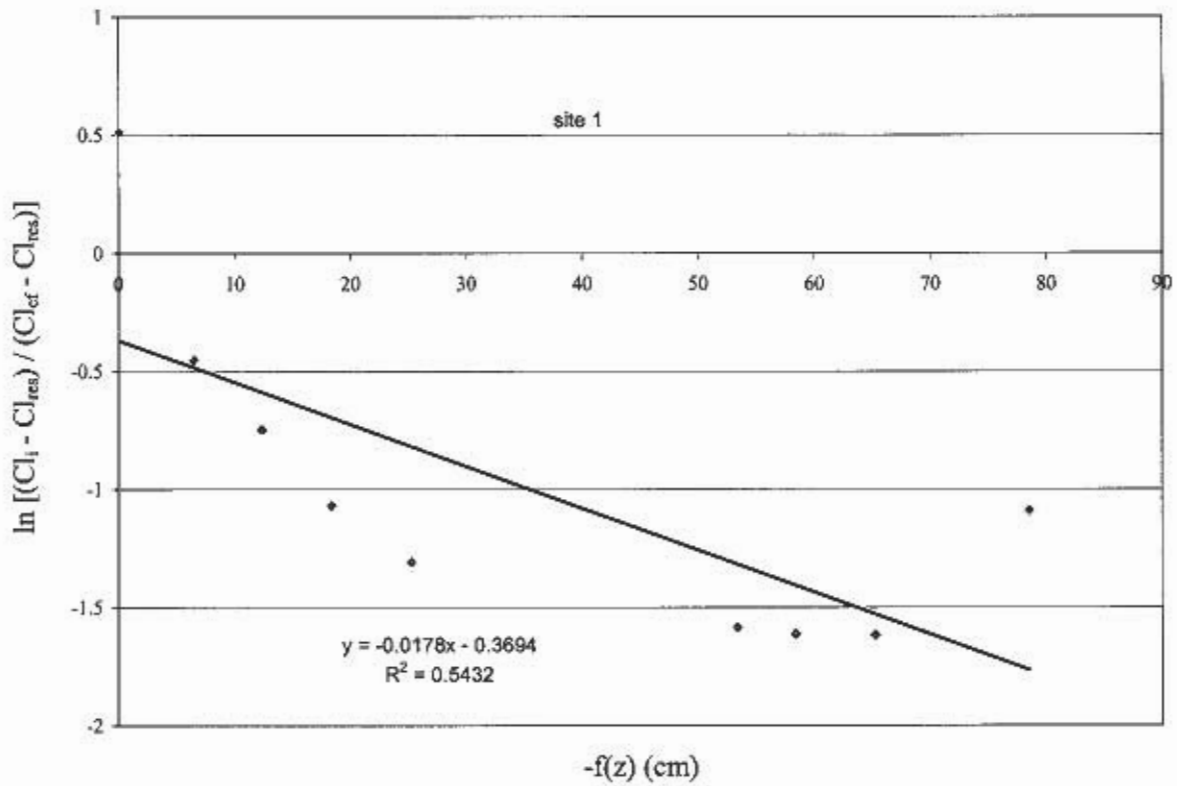


Figure 8. Graph showing relation of $\ln [(Cl_i - Cl_{res}) / (Cl_{ef} - Cl_{res})]$ versus $-f(z)$ for Site 1.

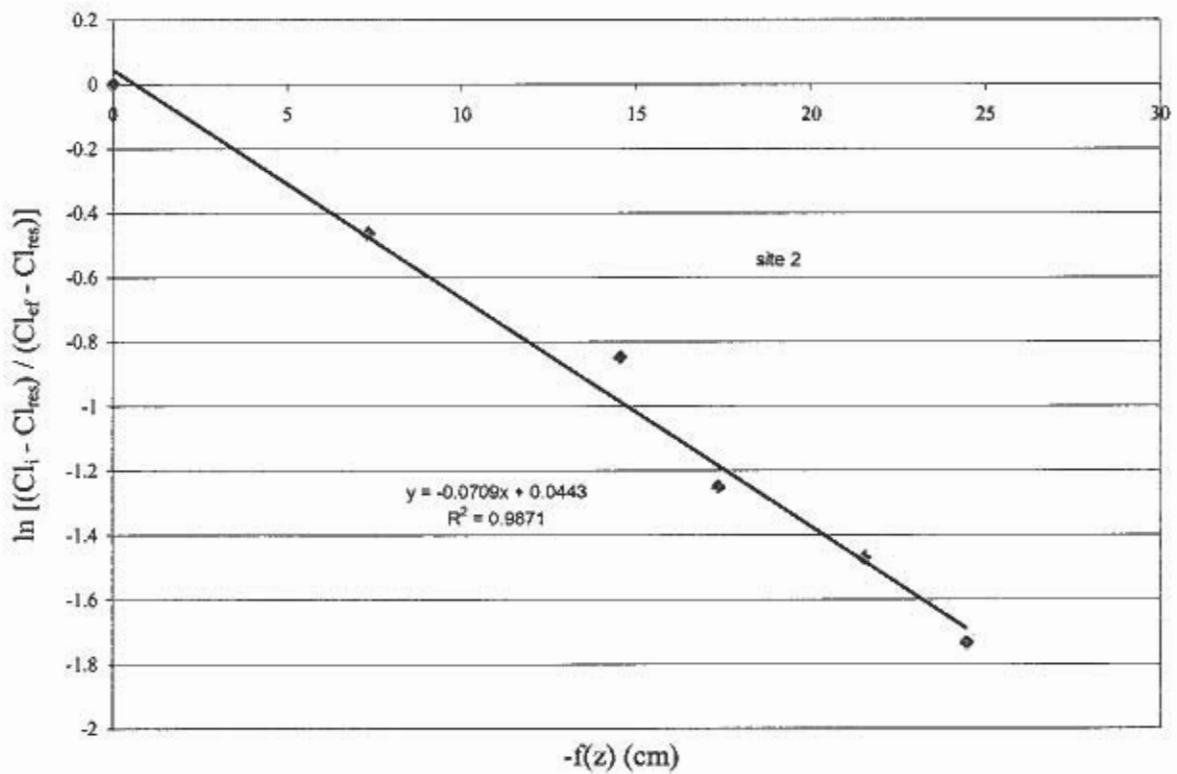


Figure 9. Graph showing relation of $\ln [(Cl_i - Cl_{res}) / (Cl_{ef} - Cl_{res})]$ versus $-f(z)$ for Site 2.

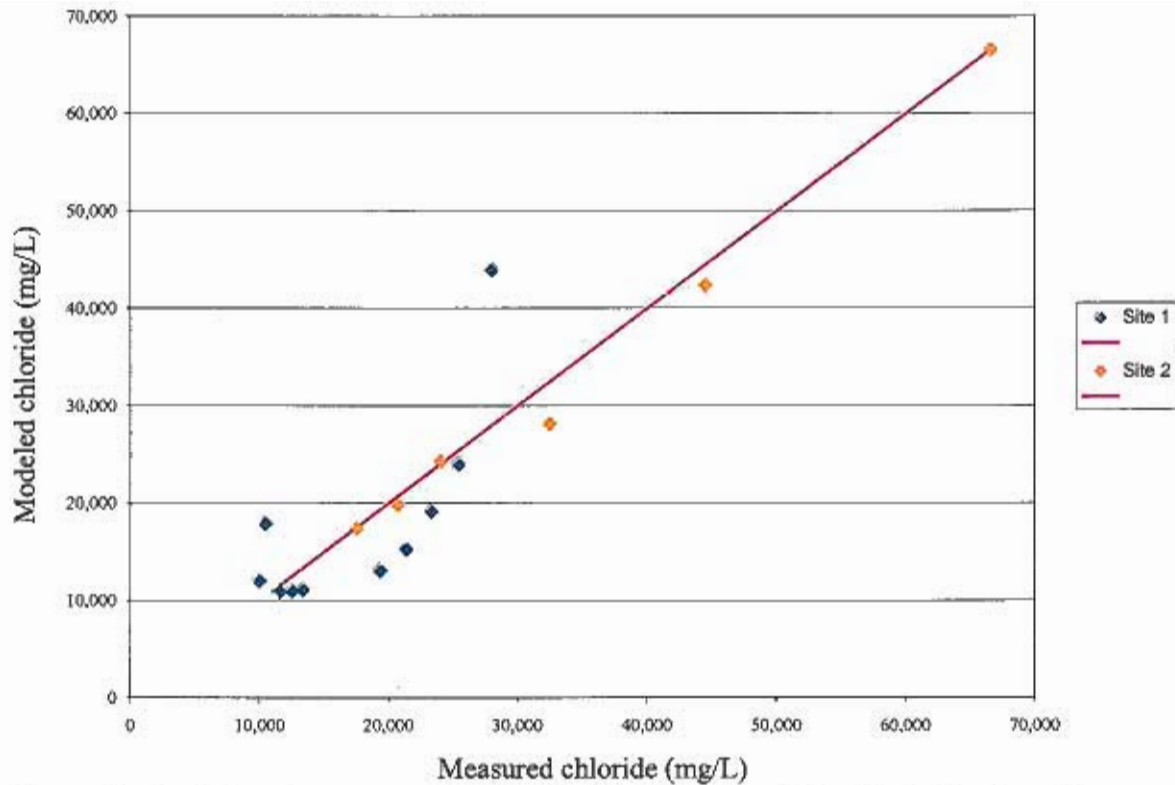


Figure 10. Graph showing comparison of predicted and measured chloride for Sites 1 and 2.

Table 3. Estimated annual evaporation rates for Sites 1 and 2. Uncertainty is based on root mean square error for the comparison of predicted and measured values.

Site	Deuterium estimate (mm/yr)	Chloride estimate (mm/yr)
1	11 ± 0.6	11 ± 4
2	42 ± 5.5	43 ± 2

Volumetric Estimates of Groundwater Evaporation

The deuterium and chloride derived estimates for the depth of shallow groundwater evaporation from beneath the playa surface were used to estimate the volume of groundwater lost to evaporation from Yelland Playa. The estimated playa area determined from a 2002 LANDSAT image is 3,250 ha (8,024 acres) (Figure 1). Based on our analysis, the annual volume of groundwater lost to evaporation from the playa ranges from 357,470 to 1,397,380 m³/yr (289 to 1,123 acre feet per year).

DISCUSSION

Estimates for bare soil evaporation in the arid West vary substantially. Using micrometeorological methods and chloride profiles, Tyler *et al.* (1997) estimated 88 to 104 mm/yr of groundwater evaporation from the Owens Valley playa in eastern California. In this area, the groundwater table was 235 to 250 cm below land surface. Nichols *et al.* (2000) estimated 46 mm/yr of groundwater evaporation from the Railroad Valley playa in

eastern Nevada. In this area, the water table was about 180 cm below land surface (Nichols, 1994). Using Gardner's (1958) equation for steady state evaporation from a shallow water table at 213 and 275 cm in a clay soil resulted in estimated evaporation rates of 310 and 131 mm/yr for Sites 1 and 2, respectively.

In Niger, Taupin (1995) used the isotope method described here to estimate an evaporative flux of 11 to 15 mm/yr, where the depth to groundwater was about 350 cm below land surface and the average annual soil temperature was 30 °C (we measured an average soil temperature of 15 °C). Our evaporation estimate for Site 2 (42-43 mm/yr) is similar to Nichols *et al.* (2000) estimate for the playa in Railroad Valley.

The high salinity at Yelland playa certainly inhibits groundwater evaporation. The electrical conductivity of 70,000 $\mu\text{S}/\text{cm}$ for the shallow groundwater beneath the playa approaches saturation with NaCl and causes a substantial decrease in evaporation relative to fresh water. Allison and Barnes (1983) observed a 49-fold reduction for an isotope-derived evaporation estimate versus pan evaporation and a 23-fold decrease relative to the estimate using the Gardner (1958) equation. Our estimates for Site 1 and 2 are 28- and 3-fold less than the estimates based on the Gardner's solution at 25 °C.

Our analysis of the isotope and chloride data indicate non-equilibrium conditions. Evidence for non-equilibrium conditions include a larger evaporation rate associated with deeper groundwater at Site 2 and the relatively high uncertainty of evaporation estimates using chloride data at Site 1 and deuterium data at Site 2. The chloride and deuterium data for Site 2 indicate a shallower evaporative front than for Site 1, which is inconsistent with a shallower water table at Site 1. Allison and Barnes (1985) found chloride data to be subject to greater variance than deuterium data for estimating evaporation from Lake Frome in Australia.

Three factors may influence the reliability of our evaporation estimates at Yelland Playa in Spring Valley; (1) surface water inflow to the playa and subsequent evaporation, (2) high water density which retards soilwater movement, and (3) varying groundwater levels. It is well known that the playa periodically receives surface water flow that inundates the playa. To our knowledge, this has not occurred for several years prior to our coring, but may have occurred to a limited extent. Surface water inundation could influence the location of the evaporative front, primarily by pushing it downward or diluting the isotopic enrichment or chloride concentrations. This may have been the case at Site 1. However, the depth of the evaporative front (z') and the evaporation rate at Site 1 are generally consistent with the measured depth of the groundwater table compared with results from Allison and Barnes (1985) and Taupin (1995). For example, Taupin (1995) estimated 11 to 21 mm/yr evaporation where the groundwater was 350 cm below land surface and soil temperature was about 30 °C. In contrast, the z' value and the evaporation rate for Site 2 appear unexpectedly shallow and large relative to the groundwater depth measured at this site.

Alternatively, surface water infiltration into the playa soils and subsequent evaporation could have resulted in the shallow evaporative front at Site 2. Drilling conditions were extremely difficult at Site 2 relative to Site 1. The less permeable soil at Site 2 may have resulted in an "artificial" evaporation front from a former perched water table condition.

The high chloride concentrations and groundwater electrical conductivity point to the possibility of density-driven flow against the upward evaporative flux. This can affect the distributions of deuterium and chloride. In the liquid transport phase, upward water movement could be inhibited by high solution density. Specifically, upward movement in response to the vapor pressure gradient at the water-air interface in the soil profile could be counteracted by downward movement of high density water. This could result in a lowered evaporation rate and evaporation front. The data do not indicate that this is an important factor in determining the evaporation rate because higher chloride levels are measured at Site 2 where a higher evaporation rate is predicted.

The most plausible explanation for the evaporation rate estimate variation between Sites 1 and 2 is changing groundwater levels. Drier than average conditions during the past several years in Nevada may have led to reduced groundwater influx to Spring Valley and the Yelland Playa. This effect would have been most pronounced toward the center of the Playa at Site 2. Reduced recharge and high evaporative demand could have caused a greater water table decline at Site 2 relative to Site 1 in the past few years, possibly leading to a disequilibrium condition in which the soil chemical distribution reflects the result of evaporation from a formerly shallower water table.

SUMMARY AND CONCLUSIONS

Analyses of stable isotopes and chloride concentrations in soil samples from the unsaturated zone collected at two Sites on Yelland Playa in Spring Valley, Nevada were used to estimate long-term steady-state groundwater evaporation. Our primary objective was to determine the potential for using isotope methodology and unsaturated zone chloride concentrations for estimating playa evaporation from shallow groundwater. Our key results follow.

- The depth distribution of stable isotopes and chloride in soilwater and the electrical conductivity of the shallow groundwater indicate prolonged evaporation of the shallow groundwater through a dry soil.
- Our analysis of chloride and deuterium data indicates similar evaporation rates for each site. At Site 1 near the edge of the playa, an evaporation rate of 11 mm/yr was estimated. At Site 2 closer to the center of the playa, evaporation rates of 42 to 43 mm/yr using deuterium and chloride data were estimated.
- Analysis of the soilwater isotope and chloride data indicates that the method is generally applicable in this situation. However, data indicate disequilibrium, especially at Site 2.
- The cause of the apparent disequilibrium is uncertain but may be the result of declining groundwater levels due to recent drought conditions.

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