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Behavior of Selected Geothermal Brine Contaminants in Plants and Soils

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EXECUTIVE SUMMARY

The behavior of selected elements found in geothermal fluids of the Roosevelt Hot Springs known geothermal resource area (KGRA) was investigated in plant and soil systems. The kinetics of these potential environmental contaminants were studied by using soil columns and selected cultivated and native plant species.

The data collected indicate that, of the 26 elements examined, lithium is the best indicator of geothermal contamination. This element, which occurs in the fluids at concentrations exceeding 25.0 parts per million (ppm), was readily detected in and through a variety of different test soils.

The plant species, which were exposed via a number of rooting media including soils, vermiculite, and hydroponic solution, absorbed and translocated lithium to all aerial plant parts. The greatest lithium concentration occurred in hydroponically grown tomatoes where the leaves, stems, and fruit contain 914.5 ± 35.8 ppm, 106.5 ± 3.2 ppm, and 35.7 ± 4.8 ppm of this element, respectively.

Two native species -- four-winged saltbush, *Atriplex canescens*, and bitterbrush, *Purshia tridentata* -- appear to be good biological indicators since they accumulated nearly twice as much lithium, 309.8 ± 29.9 ppm and 226.0 ± 5.8 ppm, respectively, as did other native species tested.

On site vegetative assessment was made at three different study sites. Species, their percentage composition, and ground cover were determined. Also, biomass estimate of 4,898 kilogram per hectare was calculated for the Roosevelt Hot Springs KGRA.

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INTRODUCTION

A number of western geothermal areas are under consideration for industrial and commercial development because of their energy-producing potential. They include the Imperial Valley, Klamath Falls, Rio Grande Rift Zone, and the relatively new site located in southern Utah, Roosevelt Hot Springs. The surrounding lands, adjacent to these known geothermal resource areas (KGRA), are important not only as farming and recreational sites, but also as valuable wildlife habitats. In addition, they are economically important as livestock rangeland. Because geothermal energy may contribute significantly to our country's energy needs, it is important that methods be developed for assessing the impact of possible contamination from geothermal development.

In December 1971, Roosevelt Hot Springs became a potential KGRA when the Phillips Petroleum Company filed a plan of operation for geothermal exploration with the U.S. Geological Survey (USGS). As a result, the USGS prepared and distributed an environmental analysis statement (EA) in 1976 as required by the U.S. Geothermal Steam Act of 1970 and by Section 102(2)(C) of the National Environmental Policy Act of 1969.

Collection of environmental baseline data in and around the established boundary of the Roosevelt Hot Springs KGRA was initiated in 1977, as required by the Geothermal Steam Act of 1970 (Title 30 CFR 270.34K). These baseline data included existing air and water quality, noise, seismic activities, and the identifiction of both biological and ecological parameters.

Some of the baseline data-collection investigations were conducted by Phillips Petroleum Company's contractor, Woodward-Clyde Consultants, and the U.S. Environmental Protection Agency's (EPA) contractors, Geonomics and Harding-Lawson Associates. These efforts were complemented by studies conducted by EPA's Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV). EMSL-LV collected and assessed biological data that included plant and animal population identification and description, soils identification, and livestock grazing assessment. In addition, EMSL-LV investigated and identified potential biological indicators of geothermal contamination and established permanent ecological assessment study areas at relatively undisturbed sites on the Roosevelt Hot Springs KGRA. Complementary laboratory studies were also conducted to identify the movement and behavior of selected geothermal brine contaminants in plants and soils.

Only baseline data concerned with the behavior of selected brine contaminants in soils and plants and the establishment of the ecological assessment areas are presented in this report.

CONCLUSIONS

The results of these investigations have shown that selected chemical contaminants associated with geothermal fluids can be incorporated in biological and soil systems. One of these, lithium, can be used as an indicator of geothermal contamination in the Roosevelt Hot Springs area because of its detectability; its extent of uptake, retention, and translocation by plants; and its movement in soils.

All of the plant species investigated took up and translocated lithium. However, the amount incorporated varied between species. Tomatoes incorporated the greatest amount, followed by second-growth alfalfa. Highest concentrations occurred in the leaf tissues, followed by stems and fruits.

Two of the five native plant species exposed to geothermal fluids were identified as potential biological indicators of lithium contamination. The species, four-winged saltbush and bitterbrush, which are commonly found on the KGRA, accumulated nearly twice the amount of lithium as did the other three native plant species examined.

METHODS AND MATERIALS

Long-term vegetative condition and trend studies can be carried out within three permanent enclosures that were constructed to prevent disturbance and grazing by livestock. The vegetative composition in these enclosures consists primarily of sagebrush, Artemisia tridentata, which makes up 68 percent of the total. In addition, seven species of grass contribute 24 percent, and forbs nearly 2 percent, of the total composition.

The above-ground vegetation biomass, expressed as kilograms per hectare (kg/ha), was determined at each study site. Biomass varied from 3,032 kg/ha to 5,223 kg/ha in 1977 and from 5,224 kg/ha to 5,883 kg/ha in 1978. These data represent baseline values for measurements of vegetative trends that will provide necessary data for the development of an integrated monitoring system for the Roosevelt Hot Springs KGRA.

SOILS

Chemical migration experiments using soil columns measuring 5.0 centimeters (cm) in diameter and 50.0 cm in length were conducted. The columns were made by rolling plastic film into a tube. The plastic tubes were held together by tape, providing a semirigid cylinder. Cutting the tape provided easy access to the soil for sectioning and sampling. A rubber stopper closed the bottom of each column, and excess liquid was allowed to drain through a hole in the rubber stopper.

Three different soils were used. The first of these, as described by Rogers (1976), was a fine sandy loam in the Calico series. It is a member of the coarse-loamy-over-clayey, mixed thermic family of aquic xerofluvents. It was collected from the upper 10 cm of the Ap horizon (plow depth), near Logandale in the Moapa Valley of southern Nevada. Its physical and chemical makeup consisted of 53.9 percent sand, 10.8 percent clay, and 1.30 percent organic carbon. The pH was 8.6 with a cation exchange capacity of 12.7 milliequivalents (meq)/100 grams (g).

The second soil, described by Brown and McFarlane (1977), was a silty loam collected near Pahrump, Nevada. It consisted of 57.6 percent sand, 36.8 percent silt, and 5.6 percent clay, with a pH of 7.9 and a cation exchange capacity of 12.23 meq/100 g. The third soil was obtained from the Imperial Valley near the Niland KGRA in southern California. This soil, collected in 1977, had supported crops during the previous year. It was alluvial in nature -- low in organic matter with a moderately high pH.

All column studies were done in triplicate. Each column was filled and gently packed to 45 cm in depth. The amount of soil used per column was 1,127.0 g for Calico, 1,098.0 g for Pahrump, and 959.0 g for Niland soil.

Two different tests were conducted. In the first, geothermal fluids were applied to the top of each column and allowed to percolate down through the soil. The Calico and Pahrump soils were saturated with 290 milliliters (ml) of geothermal fluids while 390 ml were required to saturate the Niland soils. In the second test, using only Calico and Niland soils, the bottom soil layer of each column was placed in a reservoir of fluid that moved up the column by capillary action. Identical amounts of fluids were used for the second tests.

The soils were saturated during a 24-hour period. The columns were then opened by cutting the taped seams. The soil was cut in 5.0 cm depth increments. The increments also measured 5.0 cm in diameter. Elimination of the outer 2.0 cm from each depth increment minimized the effect of the column wall on geothermal fluid distribution in the soils. The design and construction of the column appeared to retard channeling and flow of fluids between the inner column wall and the outer edge of the soil.

PLANTS

Studies were conducted in which selected rooting media were spiked and irrigated with various concentrations of geothermal fluids. The rooting media were a potting mixture of vermiculite (Jiffy Mix), Pahrump soil, Calico soil, and hydroponic solution.

Commonly cultivated crop plants -- sweet corn (*Zea mays*), beans (*Phaseolus vulgaris*), beets (*Beta vulgaris*), tomato (*Lycopersicon esculentum*), and alfalfa (*Medicago sativa*) -- were selected for study. All of the species, except those used for the hydroponic test, were planted and allowed to grow to maturity in the soil and vermiculite rooting media. The hydroponic test species, which included only tomato and alfalfa, were grown in vermiculite and then transferred to the spiked hydroponic solution after a two-week germination and growth period. The hydroponic growth procedures and technique used were similar to those described by McFarlane et al. (1978).

The aerial vegetative tissues from each plant in the soil and vermiculite tests were analyzed together -- i.e., stems and leaves were not separated from other plant organs. Tomato plants were separated into fruit, stems, and leaves for analysis, while alfalfa was analyzed without organ separation. The latter was allowed to regrow with a second cutting harvested.

In addition to these cultivated plant species, five native species commonly found on the Roosevelt Hot Springs KGRA were exposed by irrigating with geothermal fluids. These species included big sagebrush (Artemisia tridentata), winter fat (Eurotia lanata), Gambell's oak (Quercus gambellii), bitterbrush (Purshia tridentata), and four-winged saltbush (Atriplex canescens). They were examined for use as biological indicators of geothermal contamination. Native species plant parts were not separated for analysis.

GEOTHERMAL FLUIDS

The geothermal fluids used in this study were collected from the Phillips Petroleum Company's test well number 54-3. The location of this well is described in USGS (1976). Because of the fluids' moderately high salt content (Table 1), they had to be diluted before they could be used in the plant studies. The growing period (5 to 8 weeks) also required application of plant growth nutrients. Therefore, the fluids were diluted with a modified Hoaglands solution (Berry 1971).

TABLE 1. ELEMENTAL ANALYSIS OF GEOTHERMAL FLUIDS FROM PHILLIPS PETROLEUM COMPANY'S WELL 54-3

Element	(ppm)	Element	(ppm)
Lithium	25.30 ± 0.07	Copper	0.05 ± 0.0
Sodium	2,110.00 ± 14.10	Magnesium	46.5 ± 10.60
Lead	0.16 ± 0.01	Manganese	0.01 ± 0.0
Zinc	0.05 ± 0.0	Nickel	0.1 ± 0.0
Cadmium*	10.0 ± 0.0	Strontium	14.3 ± 0.8

Note: Standard deviation of three analyses is shown for each value.

*Cadmium concentration is in ppb.

The concentration of geothermal fluids to the hydroponic solution used for hydroponic, plant-soil, and plant-vermiculite studies was 33.0 percent. Undiluted fluids were used for all soil column studies.

ASSESSMENT AREAS

Three different sites were selected for long-term investigation of species composition, ground cover, and biomass. These sites, each 25 hectares in area, were located in township 27-S, range 9-west, sections 3 and 16, and in township 26-S, range 9-west, section 33, on the Roosevelt Hot Springs KGRA as described in USGS (1976). The locations are shown on vegetation maps in Appendix A and B. Since these areas are used for grazing by both cattle and sheep, a five-strand barbed-wire enclosure measuring 24.4 x 24.4 meters (m) was constructed on each of the three sites. The enclosures protected the vegetation from local grazing. The location of the enclosure within each site is described in the U.S. Bureau of Land Management's temporary use application and permit (Appendix C). These locations are also found on the vegetation maps and are identified by the designations RHS-29, -60, and -34 (Appendix A and B).

The techniques used for vegetative description are outlined in the U.S. Bureau of Land Management's Ocular Reconnaissance Forage Survey Handbook (1963). They were based on existing correlations between vegetative growth, local soil conditions, and environmental parameters including intensity of livestock grazing. The percentage ground cover and percentage species composition were measured in each enclosure. These measurements were obtained by using line transects in which plant species are identified and tabulated as they occur along a line. In addition to the vegetative assessment within the enclosures, biomass or standing crop was determined for each 25-hectare site. Biomass is defined as dry tissue per unit area and is expressed as kilograms per hectare (kg/ha). The vegetation on the three sites were sampled with a Neal Electronics Model 18-2000 electronic capacitance metering instrument as described by Neal and Neal (1973) and Morris et al. (1976).

The dimensions of each site were 1,609 m long by 407 m wide. Each site was divided into 400 subsampling sites. These subsampling sites were placed in 10 rows of 40, running east to west. They were on 37 m centers, beginning from the northeast corner. Instrument readings were taken at each of the 400 subsampling sites. For calibration purposes, however, the vegetation was clipped at every tenth site.

In addition to the vegetative analysis and assessment, plant community mapping, grazing assessment, and animal population studies were conducted on adjacent lands. The results and description of these studies are described by Brown and Wiersma (1979) and Nelson et al. (1978, 1979).

SAMPLE ANALYSIS

All of the samples collected from these studies were analyzed for selected trace elements. After drying and grinding, vegetative material was analyzed by optical emission spectroscopy. The relative standard deviation of this method was 3 to 15 percent with an acceptable accuracy above 1 microgram/gram (μg/g) (Alexander et al. 1975). Soils were analyzed using atomic absorption spectrometry following nitric acid digestion. Ten grams of soil were added to 25 ml concentrated nitric acid and placed on a hot plate at 90°C for approximately 36 hours (Gorsuch 1970). The resulting solution was filtered, brought up to 100 ml with deionized distilled water, and then analyzed for selected trace elements. The limit of detection of this method was 100 μg/g.

RESULTS AND DISCUSSION

SOIL AND PLANTS

In 1978 Cosner and Apps conducted an elemental assay of the Roosevelt Hot Springs geothermal fluids. Based on their results, the following elements were selected for investigation: lithium, sodium, lead, zinc, copper, magnesium, manganese, nickel, and strontium. The concentrations of these elements in the geothermal fluids of Roosevelt Hot Springs are shown in Table 1. The elemental concentrations in the nontreated rooting media are shown in Table 2. We observed that only the elements lithium and sodium have sufficient concentrations in the fluids, when compared to their concentration in the rooting media, to serve as indicators of geothermal contamination. This investigator believes that positive identification of the movement of the other elements would be masked by naturally occurring elements in the rooting media. Therefore, only sodium and lithium will be discussed in detail.

The results of geothermal fluid element migration through the Calico, Pahrump, and Niland soils are illustrated in Tables 3, 4, and 5. Sodium, a major component of the soluble salts in almost all soils, moved readily throughout the soil columns. It bore a definite relationship to the movement of the wetting front in the Niland soils. The concentration varied from a low of 229.3 parts per million (ppm) at the top of the column to a concentration exceeding 900 ppm at the bottom. This relationship was not observed in the Pahrump and Calico soils (Tables 3 and 4) since all layers had a similar sodium concentration.

These investigations showed that the study soils with low sodium concentrations retain a greater portion of sodium in the top or initially exposed layers than in the bottom layers. For example, the Pahrump soil had a relatively low sodium concentration of 25.4 ppm and retained a much larger concentration in the top layer (130.3 ppm) than in the lower 40-45 cm layer (Table 4).

It is anticipated that the behavior of sodium in the Roosevelt Hot Springs soils would be similar to the Pahrump soil. Their chemical and physical properties are similar as shown in Table 2 and as described by Stott and Olsen (1976).

The most significant observation concerning these studies was the identification of lithium as an indicator of geothermal contamination. This

TABLE 2. ELEMENTAL ANALYSIS OF NONTREATED ROOTING MEDIA

	Element (ppm)									
Rooting Medium	Lithium	Sodium	Lead	Zinc	Cadmium*	Copper	Magnesium	Manganese	Nickel	Strontium
Calico soil	0.9 ± 0.1	76.4 ± 4.8	1.0 ± 0.1	5.5 ± 0.9	28.3 ± 2.1	0.7 ± 0.1	946.0 ± 55.0	14.7 ± 0.6	0.4 ± 0.1	25.3 ± 5.4
Pahrump soil	0.6 ± 0.1	25.4 ± 1.7	1.1 ± 0.1	4.1 ± 0.2	21.7 ± 3.2	0.8 ± 0.1	1650.0 ± 128.0	10.0 ± 1.0	0.8 ± 0.1	23.7 ± 1.3
Niland soil	0.9 ± 0.1	392.3 ± 17.0	1.3 ± 0.1	4.9 ± 0.3	30.7 ± 1.5	1.6 ± 0.3	1133.0 ± 15.0	29.7 ± 2.3	1.23 ± 0.1	25.5 ± 8.4
Hydroponic solution	0.6 ± 0.1	104.5 ± 0.7	0.1 ± 0.1	0.2 ± 0.0	10.0 ± 0.0	0.2 ± 0.0	43.5 ± 0.7	0.2 ± 0.0	0.1 ± 0.0	2.9 ± 0.0
Roosevelt Hot Springs soil	1.1 ± 0.3	18.6 ± 6.6	1.1 ± 0.2	5.3 ± 1.0	19.8 ± 3.9	1.1 ± 0.2	522.0 ± 77.5	50.0 ± 12.3	0.6 ± 0.1	4.7 ± 1.0

Note: Standard deviation of three analyses is shown for each value.
*Cadmium concentration is in ppb.

TABLE 3. THE CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN CALICO SOIL FOLLOWING AN APPLICATION OF BRINE TO THE TOP OF A 50.0-CM SOIL COLUMN

Depth (cm)	Element (ppm)									
	Lithium	Sodium	Lead	Zinc	Cadmium*	Copper	Magnesium	Manganese	Nickel	Strontium
0-5	1.6 ± 0.2	145.3 ± 3.2	1.0 ± 0.1	6.1 ± 0.6	24.7 ± 4.7	0.7 ± 0.1	975.3 ± 60.9	16.7 ± 1.2	0.5 ± 0.1	15.2 ± 3.1
5-10	1.2 ± 0.2	110.3 ± 16.3	0.9 ± 0.1	5.4 ± 1.2	30.3 ± 4.7	0.6 ± 0.1	859.3 ± 94.8	15.0 ± 1.0	0.4 ± 0.1	12.3 ± 1.2
10-15	1.1 ± 0.1	94.8 ± 5.6	0.9 ± 0.0	5.1 ± 0.3	27.7 ± 5.0	0.6 ± 0.0	956.3 ± 17.2	15.0 ± 1.0	0.4 ± 0.0	13.7 ± 1.9
15-20	1.3 ± 0.1	93.4 ± 4.2	1.0 ± 0.1	6.4 ± 1.2	24.3 ± 7.8	0.7 ± 0.1	1035.3 ± 59.9	17.0 ± 1.0	0.5 ± 0.0	15.6 ± 0.6
20-25	1.1 ± 0.1	107.9 ± 13.1	0.9 ± 0.2	6.3 ± 0.0	30.0 ± 5.0	0.7 ± 0.1	1026.7 ± 182.4	16.3 ± 2.5	0.5 ± 0.1	15.6 ± 2.5
25-30	1.1 ± 0.2	117.7 ± 6.8	0.9 ± 0.1	5.5 ± 0.1	28.0 ± 5.3	0.7 ± 0.1	1019.7 ± 69.6	16.3 ± 1.2	0.4 ± 0.0	14.7 ± 0.9
30-35	1.0 ± 0.1	137.3 ± 9.5	0.9 ± 0.0	8.2 ± 4.0	27.0 ± 3.6	0.7 ± 0.1	1051.7 ± 111.8	16.7 ± 1.2	0.5 ± 0.1	15.8 ± 0.9
35-40	0.9 ± 0.1	141.0 ± 8.5	0.9 ± 0.0	5.1 ± 0.0	27.7 ± 6.1	0.6 ± 0.1	998.7 ± 148.4	15.0 ± 0.0	0.4 ± 0.0	15.0 ± 1.0
40-45	1.1 ± 0.2	139.7 ± 15.8	0.9 ± 0.1	6.4 ± 2.2	31.7 ± 2.9	0.7 ± 0.0	1008.0 ± 103.2	15.3 ± 0.6	0.4 ± 0.0	15.2 ± 0.9

Note: Standard deviation of three analyses is shown for each value.
*Cadmium concentration is in ppb.

TABLE 4. THE CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN PAHRUMP SOIL FOLLOWING AN APPLICATION OF BRINE TO THE TOP OF A 50.0-CM SOIL COLUMN

Depth (cm)	Element (ppm)									
	Lithium	Sodium	Lead	Zinc	Cadmium*	Copper	Magnesium	Manganese	Nickel	Strontium
0-5	1.4 ± 0.1	130.3 ± 27.8	1.1 ± 0.1	3.8 ± 0.1	20.3 ± 2.1	0.8 ± 0.0	1443.3 ± 191.4	10.0 ± 0.9	0.7 ± 0.1	15.7 ± 3.7
5-10	1.1 ± 0.2	104.7 ± 8.6	1.0 ± 0.2	3.4 ± 0.5	19.0 ± 5.2	0.6 ± 0.1	1586.7 ± 122.2	9.1 ± 1.0	0.6 ± 0.1	14.6 ± 4.7
10-15	1.0 ± 0.1	84.7 ± 15.6	1.1 ± 0.1	3.7 ± 0.3	21.3 ± 4.2	0.7 ± 0.1	1583.3 ± 15.3	9.6 ± 0.6	0.7 ± 0.0	15.9 ± 6.4
15-20	0.9 ± 0.1	68.3 ± 4.0	1.1 ± 0.1	3.5 ± 0.2	21.7 ± 4.0	0.6 ± 0.0	1470.0 ± 26.5	9.1 ± 0.1	0.7 ± 0.0	17.3 ± 8.7
20-25	1.0 ± 0.2	71.3 ± 19.9	1.1 ± 0.1	3.8 ± 0.1	19.0 ± 3.6	0.7 ± 0.1	1530.0 ± 169.9	10.7 ± 2.1	0.7 ± 0.0	16.9 ± 5.9
25-30	0.9 ± 0.1	57.2 ± 15.2	1.0 ± 0.1	3.7 ± 0.5	21.3 ± 2.9	0.7 ± 0.1	1633.3 ± 41.6	9.4 ± 0.9	0.7 ± 0.1	16.5 ± 6.0
30-35	0.8 ± 0.1	60.7 ± 5.3	1.0 ± 0.2	3.9 ± 0.2	20.3 ± 5.0	0.8 ± 0.0	1603.3 ± 102.6	11.0 ± 1.8	0.7 ± 0.0	15.6 ± 5.6
35-40	0.6 ± 0.1	47.9 ± 2.2	1.0 ± 0.1	3.7 ± 0.4	22.0 ± 1.7	0.7 ± 0.1	1616.7 ± 213.9	9.0 ± 0.1	0.7 ± 0.0	13.6 ± 6.4
40-45	0.6 ± 0.1	58.1 ± 2.7	1.0 ± 0.1	3.3 ± 0.3	20.0 ± 2.7	0.6 ± 0.0	1560.0 ± 255.1	8.7 ± 0.6	0.7 ± 0.1	15.9 ± 7.8

Note: Standard deviation of three analyses is shown for each value.
*Cadmium concentration is in ppb.

TABLE 5. THE CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN NILAND SOIL FOLLOWING AN APPLICATION OF BRINE TO THE TOP OF A 50.0-CM SOIL COLUMN

Depth (cm)	Element (ppm)									
	Lithium	Sodium	Lead	Zinc	Cadmium*	Copper	Magnesium	Manganese	Nickel	Strontium
0-5	2.0 ± 0.1	229.3 ± 45.0	1.7 ± 0.1	5.6 ± 0.3	27.0 ± 2.7	1.6 ± 0.1	1346.7 ± 56.9	34.7 ± 0.6	1.6 ± 0.1	16.1 ± 1.5
5-10	1.7 ± 0.4	132.0 ± 12.5	1.4 ± 0.2	5.1 ± 0.8	21.3 ± 7.1	1.5 ± 0.2	1340.0 ± 91.7	32.3 ± 2.5	1.4 ± 0.2	15.1 ± 1.3
10-15	1.5 ± 0.3	167.3 ± 22.6	1.5 ± 0.5	5.0 ± 0.7	24.3 ± 4.2	1.6 ± 0.4	1316.7 ± 120.9	32.3 ± 2.3	1.3 ± 0.2	16.3 ± 2.3
15-20	1.3 ± 0.3	228.3 ± 19.2	1.5 ± 0.1	5.0 ± 0.8	26.3 ± 1.5	1.5 ± 0.2	1316.7 ± 49.3	32.0 ± 3.0	1.2 ± 0.2	17.2 ± 4.1
20-25	1.1 ± 0.2	249.0 ± 33.2	1.4 ± 0.2	5.3 ± 0.5	28.3 ± 3.8	1.5 ± 0.1	1283.3 ± 205.9	31.0 ± 2.0	1.3 ± 0.2	17.1 ± 1.6
25-30	0.1 ± 0.2	265.7 ± 28.0	1.4 ± 0.1	5.0 ± 0.3	25.3 ± 1.2	1.6 ± 0.2	1300.0 ± 147.9	32.0 ± 1.0	1.3 ± 0.0	16.4 ± 6.7
30-35	1.2 ± 0.2	578.7 ± 137.4	1.9 ± 0.6	5.6 ± 0.4	29.0 ± 5.0	1.6 ± 0.1	1490.0 ± 190.5	34.0 ± 3.5	1.5 ± 0.2	16.9 ± 1.9
35-40	1.3 ± 0.3	983.0 ± 40.8	1.4 ± 0.2	5.4 ± 1.0	37.0 ± 7.2	1.6 ± 0.1	1583.3 ± 109.7	31.3 ± 2.1	1.4 ± 0.1	15.5 ± 0.7
40-45	1.1 ± 0.3	934.3 ± 120.2	1.4 ± 0.1	5.4 ± 0.6	34.7 ± 5.9	1.5 ± 0.1	1476.7 ± 40.4	30.3 ± 0.6	1.3 ± 0.1	15.0 ± 0.2

Note: Standard deviation of three analyses is shown for each value.
*Cadmium concentration is in ppb.

element has a concentration of 25.3 ppm in the fluids as shown in Table 1, a concentration that varied between 0.6 ppm and 0.9 ppm in the experimental rooting media, and a concentration of 1.1 ppm in the on-site Roosevelt Hot Springs soils (Table 2).

The behavior of lithium in soils was previously described by Bradford (1965). For example, he reported that the size and charge of the lithium ion as compared with other cations largely determine its concentration in most soils. It is often associated with the magnesium ion and the soil micas. Also, lithium may substitute for aluminum in the formation of montmorillonite and illite as reported by Mitchell (1955) and Mason (1952). This was substantiated by Green-Kelly (1952) when he reported that lithium is largely concentrated in clay minerals.

In all soil-column investigations, the lithium ion was quite mobile; nearly all of the soil increments contained elevated levels of this element. Tables 6 and 7 contain the results of the second test and illustrate the solubility of this element. The relatively low concentration of lithium in all soil increments, 0.6 ppm to 2.6 ppm, is believed to result from adsorption to the filter membrane placed between the fluid and the initially exposed soil surface (Tables 3 through 7). However, this cannot be verified since the membranes used to protect the soil from erosion were neither collected nor analyzed.

The concentrations of selected elements in cultivated plant species following an exposure to geothermal fluids are shown on Tables 8 and 9. In addition to lithium, sodium, lead, copper, magnesium, manganese, and strontium, the phosphorus, potassium, calcium, iron, boron, aluminum, silicon, titanium, and barium data are presented for all the vegetative samples collected. Other elements including zinc, vanadium, nickel, molybdenum, chromium, silver, tin, beryllium, and cadmium were analyzed but not included in these tables because they were below the detection limits.

Lithium was the most striking indicator of geothermal fluid exposure. It is not known to be an essential plant nutrient; however, most plants apparently will take up and incorporate this element in all tissues. Because of this incorporation, botanical interest in lithium has been concerned with its toxic effects. For example, Bingham (1961) produced signs of toxicity in avocado seedlings by adding 16 ppm of lithium to their rooting media, and Aldrich et al. (1951) reported that citrus trees are extremely sensitive to small amounts of lithium. In contrast, Bertrard (1959a) and Puccini (1956, 1957) have reported that lithium is nontoxic to certain species, such as poppies, tobacco, carnations, and cotton, and indeed may even stimulate growth in some cases.

The greatest concentration of lithium found in plants grown in solid rooting media occurred in green beans and beets planted in greenhouse potting vermiculite. The contribution to these plants of lithium from the vermiculite is not known since this medium was not analyzed. Assuming that any available lithium was homogeneously mixed in this medium, the corn grown under the same conditions did not exhibit the same affinity for lithium as did the green beans and beets. Differences between the incorporation of lithium by

TABLE 6. THE CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN NILAND SOIL FOLLOWING AN APPLICATION OF BRINE TO THE BOTTOM OF A 50.0-CM SOIL COLUMN

Depth (cm)	Element (ppm)									
	Lithium	Sodium	Lead	Zinc	Cadmium*	Copper	Magnesium	Manganese	Nickel	Strontium
0-5†	2.60	272.0	1.50	6.20	20.0	1.70	1420.0	35.0	1.50	13.4
5-10	2.00	195.0	1.30	5.30	29.0	1.70	1280.0	32.0	1.30	13.5
10-15	1.80	171.0	1.40	5.40	30.0	1.60	1290.0	32.0	1.30	13.7
15-20	1.80	218.0	1.40	5.50	37.0	1.60	1410.0	34.0	1.40	13.6
20-25	1.50	320.0	1.30	5.80	26.0	1.70	1410.0	35.0	1.50	14.8
25-30	1.10	390.0	1.40	5.30	30.0	1.60	1290.0	32.0	1.30	13.6
30-35	1.40	578.0	1.40	5.80	25.0	2.20	1380.0	33.0	1.50	20.4
35-40	1.20	1280.0	1.40	5.40	48.0	1.60	1470.0	32.0	1.30	19.2
40-45	0.75	1470.0	1.30	4.20	40.0	1.30	1570.0	28.0	0.92	16.3

*Cadmium concentration (ppb)
†Exposed end of column

TABLE 7. THE CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN CALICO SOIL FOLLOWING AN APPLICATION OF BRINE TO THE BOTTOM OF A 50.0-CM SOIL COLUMN

Depth (cm)	Element (ppm)									
	Lithium	Sodium	Lead	Zinc	Cadmium*	Copper	Magnesium	Manganese	Nickel	Strontium
0-5†	1.70	164.0	0.79	5.20	21.0	0.57	890.0	14.0	0.36	12.8
5-10	1.80	181.0	0.86	6.90	26.0	0.61	950.0	15.0	0.38	12.7
10-15	1.90	169.0	0.81	5.50	22.0	0.68	980.0	15.0	0.41	19.4
15-20	1.30	111.0	0.68	7.80	27.0	0.56	830.0	14.0	0.34	14.4
20-25	1.50	121.0	0.81	6.30	26.0	0.76	1070.0	16.0	0.46	16.4
25-30	0.90	159.0	0.90	7.30	26.0	0.63	980.0	14.0	0.35	15.9
30-35	0.91	190.0	0.95	5.20	23.0	0.72	1010.0	15.0	0.42	12.7

*Cadmium concentration (ppb)
†Exposed end of column

monocotyledons (corn) and dicotyledons (beans and beets) have been reported by Bertrard (1959b) who found that dicotyledons incorporate nearly twice the amount of lithium as do monocotyledons. The data, as shown in Table 8, agree with these observations. However, this relationship is not observed in corn and green beans grown in soil (Table 8).

The incorporation of lithium by the hydroponically grown species was of the same general magnitude as by those grown in the soil and vermiculite media (Table 9). The second cutting of alfalfa contained a higher concentration -- 538.1 ± 10.6 ppm -- than did the first cutting -- 355.1 ± 13.1 ppm. This is probably related to the increased growth rate (dry-matter synthesis) of the alfalfa between the first and second cutting. This increase was evidence that the rooting systems were increasing in size and, therefore, presenting more surface area for absorption of lithium. Also, the concentration of lithium in the roots may have increased which in turn would effect an increase in aerial tissues. Kent (1941) suggested that this may occur, based on his findings that lithium accumulated first in the roots and then in the older leaves.

The mobility of lithium as far as its translocation to other plant organs is restricted to some extent (Kent 1941). Kent's findings were supported by the relatively small lithium concentrations found in the tomato stems -- 106.5 ± 3.2 ppm -- and in the tomato fruit -- 35.7 ± 4.8 ppm -- when compared to the leaf concentration of 914.5 ± 35.8 ppm (Table 9). These differences in plant organ concentrations are contrary to Bertrard's (1959b) findings of homogeneously distributed lithium throughout all plant tissues.

All of the treated plant species contained higher levels of boron than did their nontreated counterparts (Tables 8 and 9). The nondetectable levels shown on these tables cannot be explained nor can proper assessment of plant uptake and translocation be made because of the lack of rooting-media boron data.

Five plant species native to the Roosevelt Hot Springs KGRA were exposed to geothermal fluids. The results of this investigation are shown on Table 10. As in the other plant studies, tissue concentrations of lithium and boron were indicators of geothermal fluid exposure.

Two species, four-winged saltbush and bitterbrush, may be good biological indicators of lithium exposure. Even though all tested species absorbed this element, these two accumulated nearly twice as much lithium -- 309.8 ± 29.9 ppm 226.0 ± 5.8 ppm respectively -- as did the other three species.

The magnitude of boron uptake was not as great as the lithium uptake. However, the data indicates that all five species may be used as monitors for boron contamination. The highest levels occurred in bitterbrush, with 158.7 ± 14.4 ppm, followed by Gambell's oak, with 155.7 ± 11.6 ppm.

ASSESSMENT AREAS

Because of the relatively short period of time between the construction of the enclosures and the collection of vegetative data, minimal differences were

TABLE 8. CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN CULTIVATED PLANTS

Species	Rooting Media	Elements (ppm): Phosphorus	Sodium	Potassium	Calcium	Magnesium	Copper	Iron	Manganese	Boron	Aluminum	Silicon	Titanium	Strontium	Barium	Lithium	Lead
TREATED																	
Corn	Pahrump soil	1635.8 ± 352.2	6637.8 ± 62.6	40978.9 ± 3852.6	14824.6 ± 261.2	5444.5 ± 360.6	4.9 ± 0.7	124.0 ± 11.9	12.9 ± 0.9	0.0	239.1 ± 16.7	369.9 ± 341.6	14.4 ± 2.6	97.7 ± 9.5	9.3 ± 0.7	451.9 ± 33.9	6.8 ± 1.9
Green beans	Pahrump soil	3273.7 ± 366.4	6350.3 ± 937.1	27572.1 ± 1920.0	25088.6 ± 1512.6	5730.3 ± 289.3	8.4 ± 1.0	80.0 ± 3.2	28.3 ± 1.5	119.5 ± 15.4	176.1 ± 10.9	257.7 ± 100.6	6.6 ± 1.2	137.4 ± 20.0	8.2 ± 1.2	328.1 ± 8.4	6.7 ± 3.5
Corn	Calico soil	1814.7 ± 54.7	6612.6 ± 386.1	29509.1 ± 247.3	3297.4 ± 702.1	4023.9 ± 43.3	2.8 ± 0.3	81.3 ± 6.6	22.6 ± 2.1	0.0	204.9 ± 18.9	7080.4 ± 1185.4	9.9 ± 2.6	99.4 ± 18.2	8.7 ± 1.0	549.3 ± 11.8	9.1 ± 5.7
Corn	Vermiculite	2319.9 ± 122.7	4926.3 ± 77.6	33301.8 ± 2677.3	1975.3 ± 265.1	2770.8 ± 61.6	1.4 ± 0.2	83.9 ± 10.1	25.2 ± 0.9	148.2 ± 13.7	171.7 ± 20.9	7241.3 ± 474.6	6.1 ± 1.2	32.2 ± 3.5	8.6 ± 1.5	391.7 ± 15.7	10.7 ± 1.8
Green beans	Vermiculite	3774.4 ± 321.1	5556.7 ± 157.4	29671.5 ± 4498.3	12221.5 ± 859.6	4647.7 ± 73.8	8.5 ± 0.3	127.1 ± 10.3	22.5 ± 0.4	0.0	203.2 ± 38.3	1068.6 ± 40.7	11.1 ± 2.0	73.8 ± 13.2	12.7 ± 0.9	735.1 ± 8.1	9.4 ± 2.8
Beets	Vermiculite	3028.2 ± 383.2	6874.9 ± 532.1	67277.9 ± 2956.2	3804.9 ± 1821.3	7457.7 ± 128.4	12.4 ± 0.15	127.8 ± 20.4	23.8 ± 1.6	113.2 ± 6.8	228.9 ± 21.6	622.8 ± 70.1	21.9 ± 2.0	49.3 ± 6.8	35.5 ± 2.4	792.2 ± 1.6	20.3 ± 1.9
NONTREATED																	
Corn	Pahrump soil	1263.3 ± 43.3	2780.6 ± 166.3	51893.2 ± 2332.7	8340.7 ± 2321.6	4326.7 ± 196.0	1.4 ± 0.1	80.6 ± 8.9	14.1 ± 0.4	116.5 ± 4.3	114.8 ± 17.8	4078.1 ± 437.9	4.7 ± 0.6	81.9 ± 6.1	7.3 ± 1.4	45.8 ± 4.6	4.1 ± 2.7
Green beans	Pahrump soil	2693.0 ± 187.2	5969.3 ± 553.8	31533.7 ± 4497.2	20682.6 ± 2815.4	5385.7 ± 769.5	3.0 ± 1.5	57.9 ± 9.3	28.8 ± 3.6	48.3 ± 10.4	82.1 ± 14.7	257.7 ± 100.6	6.6 ± 1.2	148.0 ± 22.7	7.9 ± 0.7	45.5 ± 4.6	5.5 ± 4.1
Corn	Vermiculite	2307 ± 235.9	656.4 ± 12.4	28243.4 ± 854.8	2801.1 ± 275.9	3317.7 ± 244.6	3.2 ± 0.3	146.7 ± 29.6	29.4 ± 3.6	13.2 ± 0.9	213.8 ± 19.9	2745.3 ± 313.8	8.8 ± 1.0	29.8 ± 1.8	9.9 ± 2.1	8.9 ± 0.4	0.4 ± 0.8
Green beans	Vermiculite	3828.4 ± 237.3	3524.6 ± 500.9	35037.5 ± 5857.8	10989.9 ± 2460.8	4009.9 ± 497.7	4.8 ± 2.6	105.7 ± 20.3	21.7 ± 0.4	30.3 ± 2.4	205.4 ± 52.3	582.9 ± 181.1	11.8 ± 4.9	72.4 ± 8.1	12.3 ± 3.5	24.5 ± 3.8	6.9 ± 9.5
Beets	Vermiculite	2940.3 ± 878.2	39361.8 ± 961.5	56037.8 ± 3641.9	5901.7 ± 2472.6	10305.1 ± 784.0	17.3 ± 3.9	217.1 ± 24.4	29.3 ± 3.0	32.4 ± 5.5	326.0 ± 28.9	885.2 ± 34.4	37.9 ± 6.9	64.3 ± 9.4	77.4 ± 4.2	59.3 ± 7.9	22.2 ± 12.1

Note: Standard deviation of three analyses is shown for each value.

TABLE 9. THE CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN HYDROPONICALLY GROWN TOMATO AND ALFALFA PLANTS

Species	Elements															
	Phosphorus	Sodium	Potassium	Calcium	Magnesium	Copper	Iron	Manganese	Boron	Aluminum	Silicon	Titanium	Strontium	Barium	Lithium	Lead
TREATED																
Tomato leaves	3812.1 ± 380.6	6290.9 ± 1428.9	20642.3 ± 2781.5	23145.2 ± 1017.7	5825.4 ± 198.2	26.1 ± 0.78	227.1 ± 3.6	27.3 ± 2.7	0.0	621.7 ± 26.9	2136.8 ± 132.4	32.2 ± 6.1	168.0 ± 13.2	20.4 ± 1.2	914.5 ± 35.8	15.2 ± 5.5
Tomato stems	4754.5 ± 556.9	3851.0 ± 244.7	20122.9 ± 1172.8	8969.4 ± 3272.7	2309.3 ± 178.5	3.1 ± 0.4	56.9 ± 20.1	9.3 ± 0.6	60.8 ± 5.3	75.3 ± 34.4	209.9 ± 66.6	2.8 ± 0.3	136.2 ± 2.0	14.8 ± 0.7	106.5 ± 3.2	0.0
Tomato fruit	6185.4 ± 149.4	3068.7 ± 309.0	40233.9 ± 5535.8	1057.5 ± 332.7	1897.0 ± 59.3	4.4 ± 0.6	79.3 ± 5.3	9.6 ± 0.7	65.4 ± 7.9	49.7 ± 12.8	142.2 ± 28.2	17.1 ± 2.1	24.7 ± 4.4	3.2 ± 0.6	35.7 ± 4.8	0.0
Alfalfa 1st cutting	3231.3 ± 496.6	4281.9 ± 752.8	36491.9 ± 5819.5	19639.5 ± 898.6	3616.8 ± 252.9	12.6 ± 0.4	93.8 ± 5.2	78.0 ± 12.7	142.5 ± 16.9	188.9 ± 19.6	465.4 ± 43.7	5.5 ± 0.9	203.1 ± 8.0	18.9 ± 0.8	335.5 ± 13.1	0.0
Alfalfa 2nd cutting	2513.4 ± 118.6	12987.5 ± 4241.8	42856.5 ± 7408.8	20772.8 ± 883.6	3480.3 ± .89.4	10.6 ± 1.7	66.1 ± 4.2	37.6 ± 2.3	147.8 ± 9.5	145.1 ± 13.1	365.0 ± 9.3	4.6 ± 0.5	191.3 ± 5.7	12.4 ± 0.9	538.1 ± 10.6	8.7 ± 3.4
NONTREATED																
Tomato leaves	2474.2 ± 305.0	1945.9 ± 132.1	25101.6 ± 696.2	20970.3 ± 378.1	4356.1 ± 763.5	9.5 ± 1.6	134.9 ± 5.8	15.9 ± 1.4	38.9 ± 13.6	313.6 ± 22.8	769.8 ± 41.4	10.0 ± 6.7	149.2 ± 6.6	11.3 ± 0.8	8.1 ± 0.3	12.1 ± 0.7
Tomato stems	2809.1 ± 116.2	1962.2 ± 158.6	27966.0 ± 1939.4	13685.8 ± 786.4	3871.5 ± 199.2	7.2 ± 0.7	57.2 ± 2.1	12.6 ± 0.8	18.9 ± 0.4	84.7 ± 24.9	244.6 ± 70.8	4.2 ± 0.4	131.5 ± 5.7	9.9 ± 0.3	0.5 ± 0.06	3.0 ± 1.7
Tomato fruit	3406.4 ± 695.1	923.1 ± 79.4	40945.7 ± 5613.9	1603.8 ± 331.7	1618.8 ± 21.7	4.0 ± 0.8	156.6 ± 49.9	8.7 ± 0.5	12.4 ± 0.4	176.4 ± 38.3	535.6 ± 108.5	9.6 ± 4.5	32.4 ± 3.9	4.6 ± 0.6	1.2 ± 0.2	0.1 ± 0.2
Alfalfa 1st cutting	4054.3 ± 152.3	1600.6 ± 302.9	37195.6 ± 4830.5	22687.1 ± 1378.2	5141.9 ± 194.5	9.2 ± 1.9	102.4 ± 4.4	59.1 ± 4.4	47.0 ± 10.4	204.1 ± 18.4	375.9 ± 43.3	4.7 ± 1.7	128.2 ± 4.3	10.4 ± 1.0	5.8 ± 0.7	2.0 ± 3.5
Alfalfa 2nd cutting	4487.4 ± 336.5	3828.6 ± 872.3	45326.8 ± 8695.2	22730.0 ± 1282.7	7329.3 ± 417.3	17.2 ± 6.6	99.2 ± 4.3	46.3 ± 2.1	35.9 ± 1.3	166.1 ± 21.9	349.2 ± 10.5	3.0 ± 4.4	159.1 ± 12.5	8.8 ± 0.4	7.5 ± 0.8	2.9 ± 1.5

Note: Standard deviation of three analyses is shown for each value.

TABLE 10. CONCENTRATION OF SELECTED GEOTHERMAL FLUID ELEMENTS IN NATIVE PLANT SPECIES

	Elements (ppm)															
Species	Phosphorus	Sodium	Potassium	Calcium	Magnesium	Copper	Iron	Manganese	Boron	Aluminum	Silicon	Titanium	Strontium	Barium	Lithium	Lead
TREATED																
Purshia tridentata	3427.2 ± 227.2	3448.7 ± 504.7	11490.2 ± 382.2	18423.1 ± 1152.0	4407.6 ± 196.9	1.8 ± 0.2	99.0 ± 5.6	107.7 ± 7.3	158.7 ± 14.4	181.4 ± 30.9	1716.7 ± 157.8	7.9 ± 3.2	108.2 ± 6.4	25.9 ± 1.2	226.0 ± 5.8	2.1 ± 2.5
Quercus gambelii	4582.3 ± 76.1	3127.9 ± 58.8	11115.9 ± 1190.8	12385.3 ± 308.2	3329.1 ± 28.9	5.0 ± 0.4	288.4 ± 31.7	816.9 ± 65.6	155.7 ± 11.6	286.6 ± 16.4	5321.9 ± 807.4	13.0 ± 3.1	69.4 ± 4.3	58.2 ± 5.5	128.8 ± 5.8	1.0 ± 0.9
Artemisia tridentata	6833.4 ± 166.0	7172.0 ± 716.9	30556.8 ± 4304.7	16428.3 ± 527.9	4173.0 ± 123.8	21.5 ± 1.3	598.4 ± 20.9	646.2 ± 24.7	123.5 ± 6.4	586.1 ± 14.2	2421.1 ± 106.3	28.6 ± 3.4	116.6 ± 5.0	36.1 ± 1.9	157.0 ± 2.6	10.5 ± 5.9
Atriplex canescens	6047.7 ± 278.9	6276.6 ± 316.0	40313.1 ± 4393.8	22224.3 ± 1293.3	11512.2 ± 617.3	12.6 ± 1.8	211.0 ± 3.9	221.7 ± 9.6	88.1 ± 3.3	437.3 ± 3.1	1463.0 ± 61.7	21.4 ± 0.67	134.6 ± 3.3	48.3 ± 2.7	309.8 ± 29.9	30.6 ± 2.6
Eurotia lanata	8592.8 ± 348.7	9562.9 ± 2795.0	39937.5 ± 2676.4	13672.1 ± 355.0	6483.8 ± 149.5	9.93 ± 1.50	199.5 ± 11.9	173.4 ± 4.4	88.7 ± 2.9	474.4 ± 14.3	1955.2 ± 93.9	19.9 ± 1.4	96.5 ± 3.2	31.5 ± 3.4	137.3 ± 7.1	16.8 ± 5.0
NONTREATED																
Purshia tridentata	4291.1 ± 81.7	3260.8 ± 131.2	10142.9 ± 1897.1	23870.0 ± 681.6	5146.9 ± 285.6	2.0 ± 0.3	148.7 ± 10.01	125.3 ± 13.1	36.7 ± 2.1	259.0 ± 23.1	1663.1 ± 192.3	5.2 ± 1.1	165.3 ± 9.6	22.7 ± 0.7	8.4 ± 0.7	0.0
Quercus gambelii	4293.0 ± 472.2	2673.3 ± 208.4	9579.6 ± 2414.8	15487.4 ± 701.2	4646.8 ± 166.3	3.4 ± 0.4	374.4 ± 66.2	949.2 ± 200.5	56.8 ± 3.9	353.2 ± 16.5	3396.3 ± 284.3	11.6 ± 2.2	100.8 ± 7.6	53.3 ± 1.4	11.8 ± 0.2	5.6 ± 5.2
Artemisia tridentata	10618.1 ± 411.9	6353.8 ± 79.0	20298.9 ± 1951.7	31595.3 ± 1538.9	6435.6 ± 535.6	18.7 ± 1.1	363.1 ± 12.7	129.5 ± 5.3	39.1 ± 1.9	621.1 ± 30.9	2210.8 ± 168.9	22.8 ± 1.0	249.8 ± 19.2	49.3 ± 4.3	13.0 ± 0.5	4.8 2.7
Atriplex canescens	7538.5 ± 66.8	4465.1 ± 650.3	39214.2 ± 4726.4	19154.9 ± 324.2	9828.7 ± 834.8	6.5 ± 1.4	301.9 ± 24.9	169.6 ± 14.6	36.0 ± 1.2	712.5 ± 8.2	1983.9 ± 131.3	34.5 ± 2.3	134.6 ± 5.7	60.4 ± 0.4	10.3 ± 1.0	19.1 ± 2.0
Eurotia lanata	10664.8 ± 762.6	5893.3 ± 130.2	30404.5 ± 713.1	24514.8 ± 1260.6	7015.5 ± 254.9	9.7 ± 0.6	316.6 ± 41.9	152.8 ± 1.4	38.9 ± 1.7	823.4 ± 50.9	2353.4 ± 49.6	38.3 ± 3.9	200.7 ± 13.3	51.7 ± 2.3	8.4 ± 0.6	19.4 ± 4.1

Note: Standard deviation of three analyses is shown for each value.

noted between the enclosed and nonenclosed floras. The descriptive data for each are shown on Tables 11 and 12 and in Appendix C and D.

The three assessment areas were located within the big sagebrush community, as described by Brown and Wiersma (1979). Artemisia tridentata dominated, contributing over 68 percent of the total vegetative composition. Another important shrub species was Chrysothamnus stenophyllus, averaging slightly more than 4 percent. Seven species of forbs were identified, contributing 1.7 percent and 2.2 percent of the vegetation inside and outside of the enclosures, respectively. Grasses, being fairly prevalent, accounted for more than 20 percent of the total vegetative composition. Dominant

TABLE 11. PERCENTAGE COMPOSITION AND FREQUENCY OF OCCURRENCE OF PLANT SPECIES IN THE THREE ENCLOSURES

Species	Percentage Composition	Frequency (%)
Bromus tectorum	9.7	100.0
Sitanion hystrix	10.4	100.0
Hilaria jamesii	2.2	100.0
Unidentified grass	1.2	66.0
Aristida longiseta	0.5	33.0
Stipa speciosa	Trace*	33.0
Bouteloua gracilis	0.1	33.0
Oryzopsis hymenoides	0.3	33.0
Total composition grasses	24.4	
Unidentified forb	1.4	100.0
Phlox sp.	0.1	100.0
Calochortus nuttallii	0.1	33.0
Cryptantha sp.	0.1	33.0
Eriogonum sp.	Trace	33.0
Sphaeralcea grossulariaefolia	Trace	33.0
Plantago sp.	Trace	33.0
Total composition forbs	1.7	
Artemisia tridentata	68.1	100.0
Chrysothamnus stenophyllus	5.8	100.0
Opuntia sp.	Trace	33.0
Gilia aggregata	Trace	33.0
Gutierrezia sarothrae	Trace	33.0
Total composition shrubs	73.9	

* Trace amount <0.1%

TABLE 12. PERCENTAGE COMPOSITION AND FREQUENCY OF OCCURRENCE OF PLANT SPECIES OUTSIDE OF THE THREE ENCLOSURES

Species	Percentage Composition	Frequency (%)
Bromus tectorum	9.7	100.0
Sitanion hystrix	8.1	100.0
Hilaria jamesii	2.7	100.0
Unidentified grass	1.3	66.0
Agropyron smihii	0.6	33.0
Bouteloua gracilis	Trace*	33.0
Oryzopsis hymenoides	Trace	33.0
Total composition grasses	22.4	
Unidentified forb	2.2	66.0
Phlox sp.	Trace	66.0
Calochortus nuttallii	Trace	33.0
Astragalus sp.	Trace	33.0
Sphaeralcea grossulariaefolia	Trace	33.0
Plantago sp.	Trace	33.0
Total composition forbs	2.2	
Artemisia tridentata	68.6	100.0
Chrysothamnus stenophyllus	3.9	100.0
Opuntia sp.	Trace	66.0
Gilia aggregata	2.6	33.0
Gutierrezia sarothrae	0.3	33.0
Juniperus osteosperma	Trace	33.0
Total composition shrubs	75.4	

* Trace amount <0.1%

grasses included Bromus tectorum, Sitanion hystrix, and Hilaria jamesii. The percentage ground cover was 33.5 and 34.7 percent for protected and nonprotected areas, respectively.

It is anticipated that differences will occur between the protected and nonprotected floras, primarily in the herbaceous vegetation. The enclosures will permit plant condition and trend measurements without livestock influence.

Biomass calibration curves were determined by the relationship existing between the clipped dry-tissue weight and the herbage meter readings. The calibration curves were derived for each of the three sites and also for each year (1977 and 1978) of vegetative measurement. The regression equations, correlation coefficients, and F values for each site are presented in Table 13.

TABLE 13. THE REGRESSION EQUATIONS, F VALUES, AND CORRELATION COEFFICIENTS OF THE THREE BIOMASS SITES ON THE ROOSEVELT HOT SPRINGS KGRA

	YEAR					
	1977			1978		
Site	Regression	R^2	F	Regression	R^2	F
1	$Y = -53.23 \pm 10.76\ \bar{x}$	0.91	176.6	$Y = -58.92 \pm 2.41\ \bar{x}$	0.59	21.4
2	$Y = -39.56 \pm 9.47\ \bar{x}$	0.87	116.3	$Y = -48.51 \pm 3.05\ \bar{x}$	0.63	24.2
3	$Y = -15.58 \pm 8.74\ \bar{x}$	0.81	70.4	$Y = -65.28 \pm 1.68\ \bar{x}$	0.51	13.4

In these regressions, Y equals the dry weight of the vegetation in grams and $\bar{x}$ represents the mean herbage meter readings. Thirty-eight degrees of freedom were associated with the correlation coefficients, and all were significant at the 99 percent level or greater. All of the F values were also significant at the 99 percent level or greater. The degrees of freedom associated with these F values were 1 and 39.

Table 14 gives the biomass estimates for living vegetative tissues on the three study sites. These data, presented in kilograms per hectare, reflect only above-ground living vegetation. Dead tissues, such as stems and trunks, were removed prior to obtaining the dry weights.

TABLE 14. SUMMARY OF THE BIOMASS ESTIMATES FOR 1977 AND 1978 ON THE ROOSEVELT HOT SPRINGS KGRA (kg/ha)

Month and Year of Data Collection	LOCATION					
	Site 1		Site 2		Site 3	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
October 1977	5,223	4,764 to 5,681	3,032	2,655 to 3,410	4,462	4,122 to 4,803
September 1978	5,567	5,440 to 5,696	5,883	5,695 to 6,070	5,224	5,138 to 5,310

The means shown in Table 14 are based on the 400 observations obtained from the herbage meter readings. These mean values were correlated to dry weight values in grams using the appropriate calibration curves. The meter readings were also tested for skewness and kurtosis. In addition, the effects of square root and logarithmic transformations were determined. Based upon these analyses, it was decided to use the untransformed meter readings.

In 1974, Balph et al. estimated the total above-ground biomass for a rangeland area vegetatively similar to the Roosevelt Hot Springs KGRA. Their biomass estimate of 5,480 kg/ha was similar to that determined on the three biomass study sites as shown on Table 14. The one anomalous estimate was the 1977 site 2 value. This value of 3,032 kg, in relation to the 1978 value of 5,883 kg, may reflect in part an increase in the biomass contribution of annual grasses and forbs as a result of an increase in precipitation.

Site 2 is better adapted for annual germination because the surface soils were disturbed by past chaining operations. However, the physical and biological parameters influencing this area are not described or defined in sufficient detail to permit an ecologically adequate explanation for this large difference.

A biomass sampling program is scheduled for the fall of 1979. This sampling will increase the accuracy of the overall biomass investigations on the KGRA and will provide data to evaluate the site 2 variation.

The biomass data obtained are suitable for use in models needing vegetative mass estimates. The average for the six sets of data gives an overall biomass estimate of 4,898 kg/ha for the Roosevelt Hot Springs KGRA.

REFERENCES

Aldrich, D. G., A. P. Vanselow, and G. R. Bradford. 1951. Lithium Toxicity In Citrus. Soil Science. 71:291-295.

Alexander, G. V., D. R. Young, D. J. McDermott, M. J. Sherwood, A. J. Mearns, and O. R. Lunt. 1975. Marine Organisms in the Southern California Blight as Indicators of Pollution. In Proc. Inter. Conf. Heavy Metals Environ. Toronto, Ontario, Canada, Vol. 2 pp. 952-972.

Balph, D. F., R. S. Shinn, R. D. Anderson, and C. Gist. 1974. Curlew Valley Validation Site. Reports of 1973 Progress, Vol. 2: Validation Studies. U.S./IBP Desert Biome Research Memorandum 74-1 p. 61.

Berry, W. L. 1971. Evaluation of Phosphorous Nutrient Status in Seedling Lettuce. J. Amer. Soc. Hort. Sci. 93(3) pp. 341-344.

Bertrard, D. 1959a. Influence of Altitude in the Lithium Content of Phanerogam Plants, Compt. Rend. Acad. Sci. Paris 249: 844-845.

Bertrard, D. 1959b. New Investigations on the Distribution of Lithium in the Phanerogams. Compt. Rend. Acad. Sci. Paris 249: 787-788.

Bingham, F. T. 1961. Unpublished data on file at Department of Soils and Plant Nutrition, University of California, Riverside, California.

Bradford, G. R. 1965. Diagnostic Criteria for Plants and Soils, Lithium Chapter 17. Edited by Homer D. Chapman. Dept. of Soils and Plant Nutrition of Univ. of Calif. Citrus Research Center, Riverside, California.

Brown, K. W., and J. C. McFarlane. 1977. Plutonium Uptake by Plants from Soil Containing Plutonium-238 Dioxide Particles. Health Physics Vol. 35 pp. 481-485.

Brown, K. W., and G. B. Wiersma. 1979. Geothermal Environmental Assessment Baseline Study: Vegetation and Soils of the Roosevelt Hot Springs Geothermal Resource Area.

Cosner, S. R., and J. A. Apps. 1978. A Compilation of Data on Fluids from Geothermal Resources in the United States. L.Bl-5936 UC-66b TID-4500-R66 DOE Contract W-7405-ENG-48. Earth Sciences Division, Lawrence Berkeley Laboratory Univ. of Calif. Berkeley, California.

Gorsuch, T. T. 1970. The Destruction of Organic Matter. Pergamon Press, New York, New York.

Green-Kelly, R. 1952. Irreversible Dehydration in Montmorillonite. Clay Minerals Bull. 1, pp. 221-225.

Kent, N. L. 1941. Absorption, Translocation, and Ultimate Fate of Lithium in the Wheat Plant. New Phytologist 40, pp. 291-298.

Mason, B. 1952. Principles of Geochemistry. Univ. of Indiana, Dept. of Geol. John Wiley and Sons Inc. New York.

McFarlane, J. C., A. R. Batterman, and K. W. Brown. 1978. Plutonium Uptake by Plants Grown in Solution Culture. EPA-600/3-78-081. U.S. Environmental Protection Agency, Las Vegas, Nevada.

Mitchell, R. L. 1955. Chemistry of the Soil, trace elements Chapter 9. Edited by F. E. Bear. Amer. Chem. Soc. Monograph Series No. 126, Reinhold Publishing Corporation N.Y.

Morris, M. J., K. L. Johnson, and D. L. Neal. 1976. Sampling Shrub Ranges with an Electronic Capacitance Instrument. J. of Range Management, Vol. 29 No. 1.

National Environmental Policy Act. 1969. United States Code 1976 Edition Containing the General and Permanent Laws of the United States in Force on January 1977, Vol. 10, Title 42, U.S. Govt. Printing Office.

Nelson, Z. C., W. W. Sutton, A. A. Mullen, W. F. Beckert and G. D. Potter. 1978. "Geothermal Environmental Impact Assessment - Procedures for Using Fauna as Biological Monitors of Potential Geothermal Pollutants". U.S. Environmental Protection Agency EPA-600/7-78-233.

Nelson, Z. C., W. W. Sutton and G. D. Potter. 1979. Geothermal Environmental Impact Assessment Animals of the Roosevelt Hot Springs KGRA. In progress.

Puccini, G. 1956. Influence of Potassium Salts on the Growth of Everblooming Carnations of the Italian Riviera, Ann. Sper. Agrar. Rome 10, pp. 2071-2080.

Puccini, G. 1957. Stimulant Action of Lithium Salts on the Flower Production of the Perpetual Carnation of the Riviera. Ann. Sper. Agrar. Rome 11, pp. 41-63.

Rogers, R. D. 1976. Methylation of Mercury in Agricultural Soils. J. Environ. Qual. Vol. 5, No. 4, pp. 454-458.

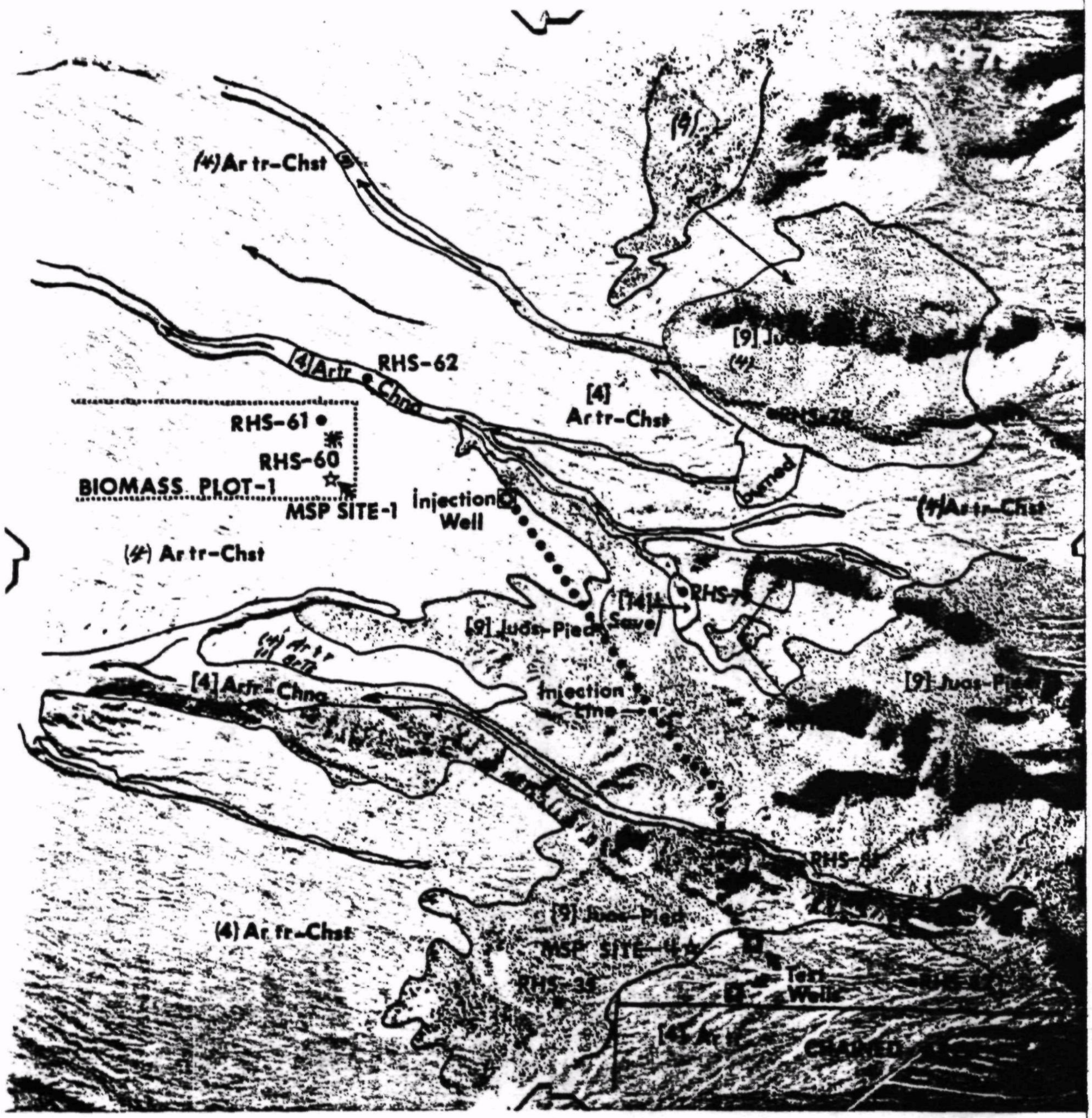
Stott, L. H. and M. E. Olsen. 1976. Soil Survey of Beaver-Cove Fork Area, Utah. U.S. Dept. of Agriculture Soil Conservation Service, U.S. Dept. of the Interior.

U.S. Bureau of Land Management. 1963. Ocular Reconnaissance Forage Survey Handbook BLM Manual 4412.11A, U.S. Department of the Interior, Bureau of Land Management.

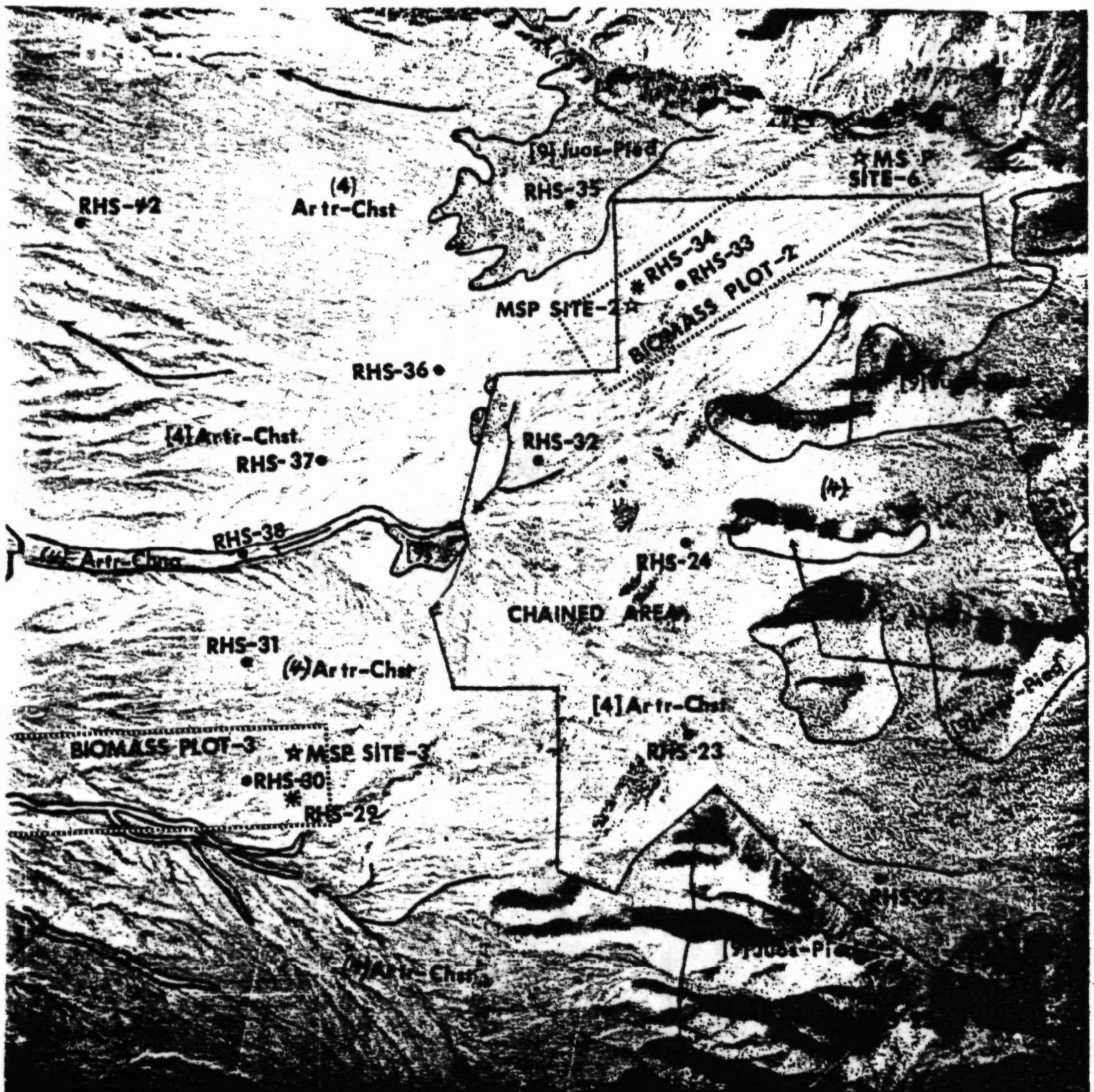
U.S.G.S. Environmental Analysis (1976) U.S. Dept. of the Interior, Geological Survey Division, EA 33 U.S.G.S., Menlo Park, CA.

U.S. Geothermal Steam Act 1970. United States Code 1976 Edition Containing the General and Permanent Laws of the United States in Force on January 1977. Vol. 14, Title 42, U.S. Govt. Printing Office.

APPENDIX A. VEGETATION MAP SHOWING LOCATION OF ASSESSMENT SITE 1
(biomass Plot 1)



APPENDIX B. VEGETATION MAP SHOWING LOCATION OF ASSESSMENT SITES 2 AND 3 (biomass Plots 2 and 3)



Form 2920-1
(November 1977)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

FORM APPROVED
OMB NO. 42-R0996

Serial Number
CCD-8-1564-T

TEMPORARY USE APPLICATION AND PERMIT
Title I, Sec. 28(e) of the Mineral Leasing Act of 1920, 30 U.S.C. 185, as amended; Secs. 302(b) and 504(e) of P.L. 94-579, October 21, 1976, 43 U.S.C. 1732, 1764.

INSTRUCTIONS ON REVERSE

APPLICATION

1. Name (*first, middle initial, and last*)
Kenneth W. Brown

Address (*include zip code*)
U.S. Environmental Protection Agency
P. O. Box 15027, Las Vegas, NV 89114

2. Give legal description of public lands for which you are applying

TOWNSHIP	RANGE	SECTION	SUBDIVISION
27-S	9-W	16	
27-S	9-W	3	
26-S	9-W	33	

Meridian	State	County	Acres (*number*)
	Utah	Beaver	0.36 19,500 sq.ft.

3. Proposed date(s) of use: From April 1978 to April 1980

4. a. Are you 21 years of age or over? ☒ Yes ☐ No

b. Are you a citizen of the United States or have you declared your intention? ☒ Yes ☐ No

c. As applicant, are you a ☐ Partnership ☐ Association ☐ Corporation; ☐ Individual(s); or an agency of ☒ Federal Government ☐ State Government ☐ Political subdivision of any state?

d. Are the statements required by Instruction Number 2 attached? ☐ Yes ☐ No ☒ Not applicable

5. Are you making this application for your own use and benefit? ☐ Yes ☒ No (*If "no," explain*)

This application is being submitted as part of the U.S. Environmental Protection Agency's assessment of the local flora near the Roosevelt Hot Springs Geothermal Developmental area.

6. Are the lands now improved, occupied, or used? ☒ Yes ☐ No (*If "yes," describe improvements and purposes, identify users and occupants*)

1. Grazing
2. Geothermal Development (leased)

7a. What do you propose to use the lands for?

An enclosure approximately 80' x 80' will be constructed on each of the described areas (see #2 above). The enclosures will be constructed of steel posts and barbed wire. They will also have a 3' high chicken wire fence attached to the base of the enclosure to exclude rabbits. The enclosures will be used for measuring vegetative growth (biomass). The lands will not be disturbed or denuded.

b. What improvements, including sanitation facilities, do you intend to make? (*Describe improvements and attach drawings, if convenient*)

None

c. What is the estimated cost of proposed improvement? $

d. What is the proposed source of water for domestic or other uses?

None

8. Have you enclosed filing fee of $10? ☐ Yes ☒ No (*See Instruction Number 3*)

I CERTIFY That the information given by me in this application is true, complete, and correct to the best of my knowledge and belief and is given in good faith.

March 7, 1978
(Date)

Kenneth W. Brown
(Signature of Applicant)

Title 18 U.S.C. Section 1001, makes it a crime for any person knowingly and willfully to make to any department or agency of the United States any false, fictitious, or fraudulent statements or representations as to any matter within its jurisdiction.

(continued)

PERMIT

Permission is hereby granted to Kenneth W. Brown
of U. S. Environmental Protection Agency
P. O. Box 15027
Las Vegas, NV 89114
to use the following-described lands:

TOWNSHIP	RANGE	SECTION	SUBDIVISION
27 S	9 W	16	
27 S	9 W	3	
26 S	9 W	33	

Meridian	State Utah	County Beaver	Acres (number) 0.36 19,500 sq. ft.

for the purpose of

Vegetative studies

and subject to the following conditions:

1. This permit is issued for the period specified below. It is revocable at the discretion of the authorized officer of Bureau of Land Management, at any time upon notice. T permit is subject to valid adverse claims heretofore or hereafter acquired.

2. Permittee shall pay annually, in advance, to the authorized officer the sum of N/A dollars as rental or such other sum as may be required if a rental adjustment is made.

3. Permittee shall observe all Federal, State, and local laws and regulations applicable to the premises and to erection or maintenance of signs or advertising displays including the regulations for the protection of game birds and game animals, and shall keep the premises in a neat, orderly, and sanitary condition.

4. Use or occupancy of land under this permit shall commence within N/A months from date hereof and shall be exercised at least N/A days each year.

5. Permittee shall take all reasonable precautions to prevent and suppress forest, brush, and grass fire and prevent pollution of waters on or in the vicinity of the lands.

6. Authorized representatives of the Department of the Interior, other Federal agencies, and game wardens shall at all times have the right to enter the premises on official business.

7. Permittee shall not enclose roads or trails commonly in public use.

8. Permittee shall pay the United States for any damage to its property resulting from this use.

9. Permittee shall notify the authorized officer of address change immediately.

10. This permit is subject to all applicable provisions of the regulations (43 CFR 2920) which are made a part hereof.

11. Permittee agrees to have the serial number of this permit marked or painted on each advertising display erected or maintained under the authority of such permit.

12. Permittee shall not cut any timber on the lands without prior permission from the authorized officer.

13. This permit is subject to the provisions of Executive Order No. 11246 of September 24, 1965, as amended, which sets forth the Equal Opportunity clauses. A copy of this order may be obtained from the signing officer.

14. This permit may not be assigned without prior approval of the authorized officer of the Bureau of Land Management.

15. Special Conditions:

Permit issued for period

From April 1, 1978

To March 31, 1979
Renewable

(Authorized Officer)

Area Manager (Title) 9-6-78 (Date)

INSTRUCTIONS

1. Submit, in *duplicate*, to any local office of the Bureau of Land Management having jurisdiction of the lands.

2. An application by a partnership or association must be accompanied by a statement by each member that he is a citizen of the United States or has filed a declaration to become a citizen. An application by a corporation must be accompanied by a statement showing that the corporation is authorized to hold land in the State in which the land is located and that the person making the application is authorized to act for the corporation.

If applicant is other than a Federal, State, or local governmental agency, this application must be accompanied by a nonreturnable filing fee of $10 made payable to the Bureau of Land Management.

4. If this application is for permission to erect an advertising display or sign, the applicant must: (a) attach an accurate and fully descriptive diagram, sketch, or photograph (at least 3" × 5") of the sign or display to be erected showing the dimensions, type of construction, estimated cost, the advertising material to be included thereon, the plan of illumination, if any, and the manner of attachment to the land; and, (b) a photograph (at least 3" × 5") showing the site on which the sign or display is to be erected.

GPO 848-900

APPENDIX D. PERCENTAGE COMPOSITION AND GROUND COVER OF PLANT SPECIES WITHIN EACH ENCLOSURE

Species	Percentage Composition RHS-29	RHS-34	RHS-60
Bromus tectorum	10.9	10.6	7.5
Sitanion hystrix	3.8	12.0	15.5
Hilaria jamesii	Trace*	Trace	6.5
Unidentified grass	2.9		0.8
Aristida longiseta		1.4	
Stipa speciosa		Trace	
Bouteloua gracilis			0.3
Oryzopsis hymenoides			0.9
Total composition grasses	17.6	24.0	31.5
Unidentified forb	2.9	1.1	0.6
Phlox sp.	0.1	Trace	Trace
Calochortus nuttallii	0.1		
Cryptantha sp.		0.4	
Eriogonum sp.		Trace	
Sphaeralcea grossulariaefolia		Trace	
Plantago sp.			Trace
Total composition forbs	3.1	1.5	0.6
Artemisia tridentata	72.1	67.5	64.9
Chrysothamnus stenophyllus	7.2	7.0	3.0
Opuntia sp.	Trace		
Gilia aggregata		Trace	
Gutierrezia sarothrae		Trace	
Total composition shrubs	73.3	74.5	67.9
Ground cover	34.1	29.8	36.5

*Trace amount <0.1%

APPENDIX E. PERCENTAGE COMPOSITION AND GROUND COVER OF PLANT SPECIES ADJACENT TO THE THREE ENCLOSURES

Species	Percentage Composition		
	RHS-30	RHS-33	RHS-61
Bromus tectorum	10.5	10.2	8.2
Sitanion hystrix	4.5	1.6	18.0
Hilaria jamesii	Trace*	2.9	5.1
Unidentified grass	4.0		Trace
Aristida smithii		1.9	
Bouteloua gracilis			Trace
Oryzopsis hymenoides			Trace
Total composition grasses	19.0	16.6	31.3
Unidentified forb	5.1		1.6
Phlox sp.	Trace		Trace
Calochortus nuttallii	Trace		
Astragalus sp.		Trace	
Sphaeralcea grossulariaefolia		Trace	
Plantago sp.			Trace
Total composition forbs	5.1	Trace	1.6
Artemisia tridentata	72.1	68.7	65.0
Chrysothamnus stenophyllus	3.8	5.8	2.1
Opuntia sp.		Trace	
Gilia aggregata		7.9	
Gutierrezia sarothrae		1.0	
Juniperus osteosperma		Trace	
Total composition shrubs	75.9	83.4	67.1
Ground cover	37.4	26.1	40.6

*Trace amount <0.1%

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/4-81-052	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE GEOTHERMAL ENVIRONMENTAL ASSESSMENT: Behavior of Selected Geothermal Brine Contaminants in Plants and Soils		5. REPORT DATE June 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) K. W. Brown		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Las Vegas, NV 89114		10. PROGRAM ELEMENT NO. 1NE624B
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency--Las Vegas, NV, Office of Research and Development, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada 89114		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE EPA/600/07

15. SUPPLEMENTARY NOTES

For further information, contact K. W. Brown (702) 798-2214

16. ABSTRACT

The behavior of selected elements found in the Roosevelt Hot Springs KGRA geothermal fluids was investigated in both plant and soil systems. The kinetics of these potential environmental contaminants were studied by using soil columns and selected cultivated and native plant species.

The data collected indicate that of the 26 elements examined, lithium is the best indicator of geothermal contamination. This element, which occurs in the fluids at concentrations exceeding 25.0 ppm, was readily detected in and through a variety of different test soils.

The plant species exposed, via a number of rooting media including soils, vermiculite, and hydroponic solution, absorbed and translocated lithium to all aerial plant parts. The greatest lithium concentration occurred in hydroponically grown tomatoes where the leaves, stems, and fruit contained 914.5 ± 35.8 ppm, 106.5 ± 3.2 ppm, and 35.7 ± 4.8 ppm of this element, respectively.

Two native species, four-winged saltbush (Atriplex canescens) and bitterbrush (Purshia tridentata), appear to be good biological indicators since they accumulated nearly twice as much lithium -- 309.8 ± 29.9 ppm and 226.0 ± 5.8 ppm, respectively -- as did other native species tested.

On-site, vegetative assessment was accomplished at three specially selected study sites. Plant species, their percentage composition, and ground cover were determined.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Lithium; Geothermal fluids; Leaching; Absorption by plants; Translocation; Monitors; Plants; Soils	Plant systems; Soil systems; Geothermal development	07B; 06C; 06F

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 37
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