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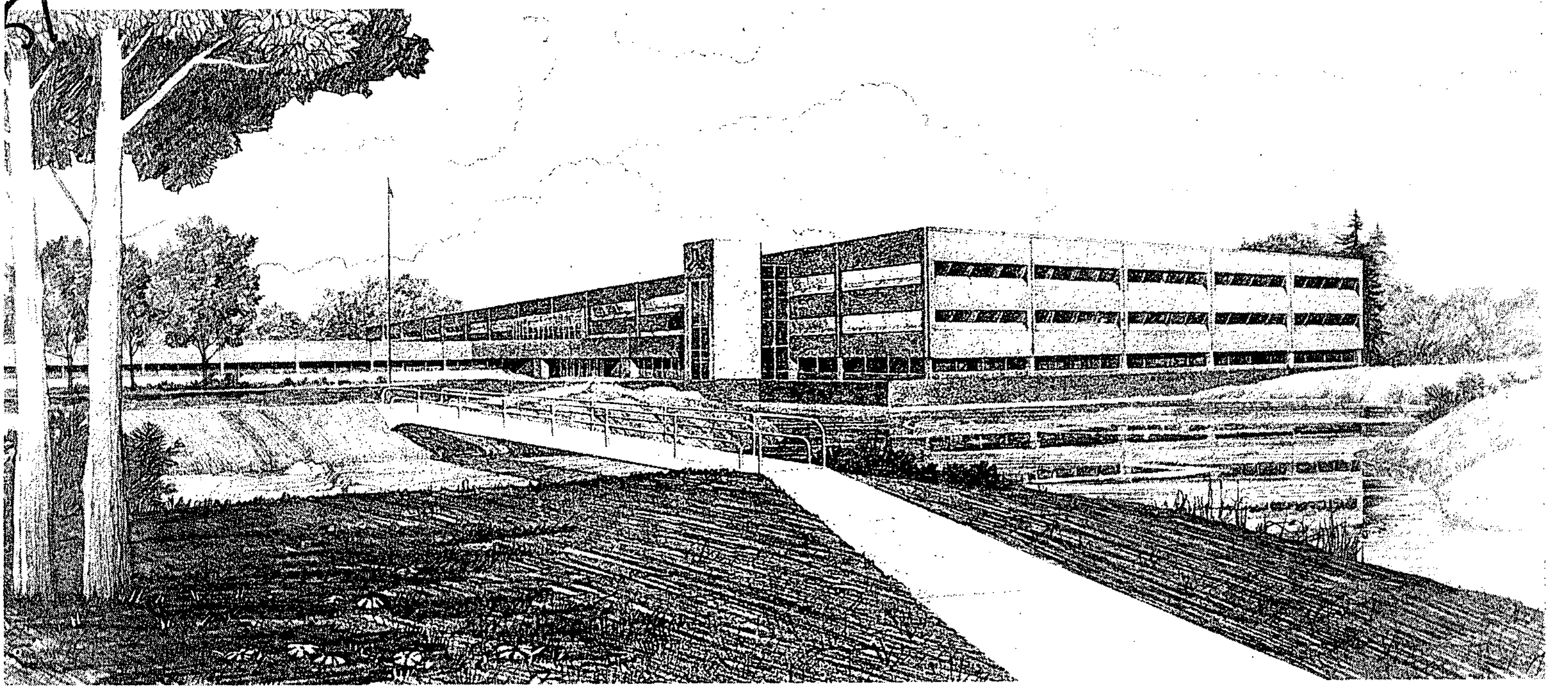

U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory

1979 Annual Report

INEL Geothermal Environmental Program

Thomas L. Thurow
Jacquelyn F. Sullivan

April 1980

Prepared for the
U.S. Department of Energy
Under DOE Contract No. DE-AC07-76IDO1570

EG&G Idaho

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1979 ANNUAL REPORT

INEL GEOTHERMAL ENVIRONMENTAL PROGRAM

Thomas L. Thurow
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EG&G Idaho, Inc.
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ABSTRACT

The Raft River Geothermal Environmental Program is designed to assess beneficial and detrimental impacts to the ecosystem resulting from the development of moderate temperature geothermal resources in the valley. The results of this research contribute to developing an understanding of Raft River Valley ecology and provide a basis for making management decisions to reduce potential long-term detrimental impacts on the environment. This report summarizes the environmental monitoring and research efforts conducted during the past six years of geothermal development and outlines planned future research.

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INTRODUCTION

This report provides an overview of the past, present, and future Raft River environmental research and monitoring programs. The continuing monitoring program was designed from the results of baseline studies near the geothermal development area, which include water quality, hydrology, meteorology, geology, subsidence, seismicity, terrestrial and aquatic ecology, soils, land use, demography, heritage resources, and socioeconomics. This report summarizes the 1979 research and identifies the direction of study to be taken in 1980.

In 1979, the primary research emphasized monitoring water quality and water levels during well tests, determining the impact that human development may have on the ferruginous hawk, studying the aquatic ecology of the Raft River, and assessing the socioeconomics of the region. Results of the continuing well monitoring program will be summarized in a separate report to be published during the spring of 1980. In addition, a 2-year environmental overview study of the potential uses of geothermal resources in the Snake River Basin was completed. The environmental overview study and the environmental research and monitoring program were funded by the Department of Energy's Division of Geothermal Energy and the Office of Health and Environmental Research.

RAFT RIVER GEOTHERMAL DEVELOPMENT

The Raft River Geothermal Program at the Idaho National Engineering Laboratory (INEL) was initiated in 1973, and was designed to demonstrate that moderate temperature (150°C) geothermal fluids can be used to generate electricity and provide an alternate energy source for direct use applications. Support for the program was provided by a cooperative agreement between the U.S. Department of Energy (DOE), the State of Idaho, and the Raft River Rural Electric Cooperative. The DOE has taken the lead role in this program. Seven geothermal wells were drilled between 1975 and 1978 at the Raft River (previously Frazier) Known Geothermal Resource Area (KGRA) to serve as production and injection wells for the test facility.

Direct applications research conducted at Raft River in 1979 included essential oil extraction experiments, fluidized bed space heater testing, geothermal assisted biomass studies for liquid fuel conversion, lignin/cellulose conversion for alcohol production (Colorado State University), aquaculture research, geothermal wetlands investigations, a geothermal fluidized bed drying experiment, and a geothermal agriculture irrigation experiment. The reservoir assessment program included massive hydraulic fracturing of wells RRGP-4 and RRGP-5. Long-term reservoir tests were conducted to evaluate production rate potential and injection capabilities of the geothermal aquifer.

Construction of the 5-MW(e) power plant continued in 1979 and was approximately 75% complete at year's end. A series of experiments were conducted to reduce silica concentration in the geothermal water and to test corrosion and scaling of three pilot cooling towers. The 5-MW(e) power plant is scheduled to begin operation in late 1980. Following research and development testing, the plant facility will be transferred to a private utility for continued operation.

The environmental research and monitoring studies are an essential part of the geothermal development program because environmental aspects must be understood before an assessment of change can be interpreted. This is of particular importance at the Raft River site since the delicate cold desert ecosystem of the region is very susceptible to degradation and is difficult to reestablish once destroyed. By monitoring the environment and understanding the relationships of the biotic and abiotic components, significant changes in the ecological structure of the area can be recognized and prevented.

PHYSICAL ENVIRONMENT MONITORING PROGRAMS

Environmental components such as air and water quality, meteorology, and subsidence affect the entire ecosystem. Programs designed to monitor these aspects are essential to ensure effective management of the region's resources. The following monitoring programs are designed to detect changes in the physical environment and to indicate potentially adverse effects of the geothermal development program on the environment.

Water Quality

Introduction. The water resources of the Raft River Valley are periodically sampled as part of a continuing water quality monitoring program designed to detect changes in the water chemistry of the closed groundwater basin which could be attributed to development of the geothermal resource. It is imperative that the water chemistry of the upper aquifers remain undisturbed since the area residents depend upon the water for domestic and agricultural use.

Methodology. Monthly chemical sampling of geothermal and monitor wells, semiannual sampling of shallow groundwater and surface water, and routine monitoring of irrigation wells is performed. Analyses include pH, fluoride, chloride, alkalinity, hardness, and conductivity.

Results and Discussion. Analyses of water from the deep geothermal wells are used to gain an understanding of the source(s) and extent of the geothermal resource. These analyses provide information important to various experiments involving geothermal water, including power production. Table 1 presents current data available from the seven deep geothermal wells. Figure 1 illustrates the locations of the wells. These data do not indicate any significant change from previous analyses.

The monitor well program, which evaluates the natural communication between aquifers and quantifies the effects of production and injection of geothermal fluids on shallow aquifers, is discussed in detail in a separate report to be published in the spring of 1980. No significant changes have been observed in the water chemistry of the monitor wells (MW). (Table 2). The chemical constituents in water from MW-5 and MW-7 are consistently lower in concentration than values obtained from the other five monitor wells, with the exception of magnesium, which is much higher. Both MW-5 and MW-7 are located on the east side of the withdrawal area and are shallower (avg. 150 m) than the other monitor wells (avg. 270 m). The chemical data indicate that water in these two wells has the same source as irrigation water; thus, the two monitor wells reflect low conductivity and high magnesium concentrations when compared with the other monitor wells. The water chemistry and temperature of the other five monitor wells appear to be influenced more by the deep geothermal system rather than by the shallower aquifers.

Data from the irrigation wells (Table 3) indicate that the chemical content of the irrigation aquifer has remained within the expected range of natural fluctuation since sampling began in 1975. However, semiannual water quality data collected from the Raft River show marked fluctuations in chemical concentrations for most of the monitored elements (Figures 2 through 5). The trend is characterized by low chemical concentrations in the spring sample and higher chemical concentrations in the fall sample. This pattern may be attributable to either dilution by spring runoff or to an influx of the more chemically concentrated irrigation leachate into the Raft River system after a summer of heavy irrigation on the adjoining cropland, or both. Dilution by spring runoff appears to be the primary cause of the fluctuations; during the severe spring drought of 1977, there was very little runoff and consequently little change in water quality. It therefore appears that the chemical values reflected in the fall data represent the closest approximation of the river's base flow chemical composition.

A trend of increasing yearly concentration of some elements may be developing; for example, fluoride and boron concentrations show a steady rise over time, although these trends are not statistically significant when the confidence limits of the analyses are considered. This apparent pattern merits consideration and will be checked by future monitoring research.

TABLE 1. INEL ANALYSES OF THE RAFT RIVER VALLEY GEOTHERMAL WATER

	Results (mg/1)[a]						
Analysis	RRGE-1	RRGE-2	RRGE-3	RRGP-4	RRGP-5B	RRGI-6	RRGI-7
CL^-	709	701	2116	2575	590	3636	4085
F^-	5.7	7.9	3.7	4.53	6.2	5.8	5.0
HCO_3^-	34	42	26	24.1	40	62	26.1
$SO_4^=$	40	29	44	61.1	40		64
NO_3^-	<0.2	<0.2	<0.2				
Total NH_3	+1.56	+0.60		1.09			
Total P	+0.023	+0.020		<0.01			
Si	62.5	72	74.0	61.0	63	42	39
Na	469	331	1245	1525	179	2020	2100
K	33	31	103	28	34	32	
Sr	1.4	0.8	5.2	6.4	1.2	8.0	
Li	1.6	1.0	3.4	3.1	1.6	5.1	
Ca	53	32	12.7	150	50	199	315
Mg	0.59	0.67	1.02	0.19	0.54	1.37	1.6
pH	7.3	7.6	7.2	7.39	7.5	7.3	
TDS	1607	1161	4280	4473	1482	6330	7440
Conductivity	2987	2742	8000	7275	2860	11600	12000

a. Conductivity recorded in μmhos/cm.

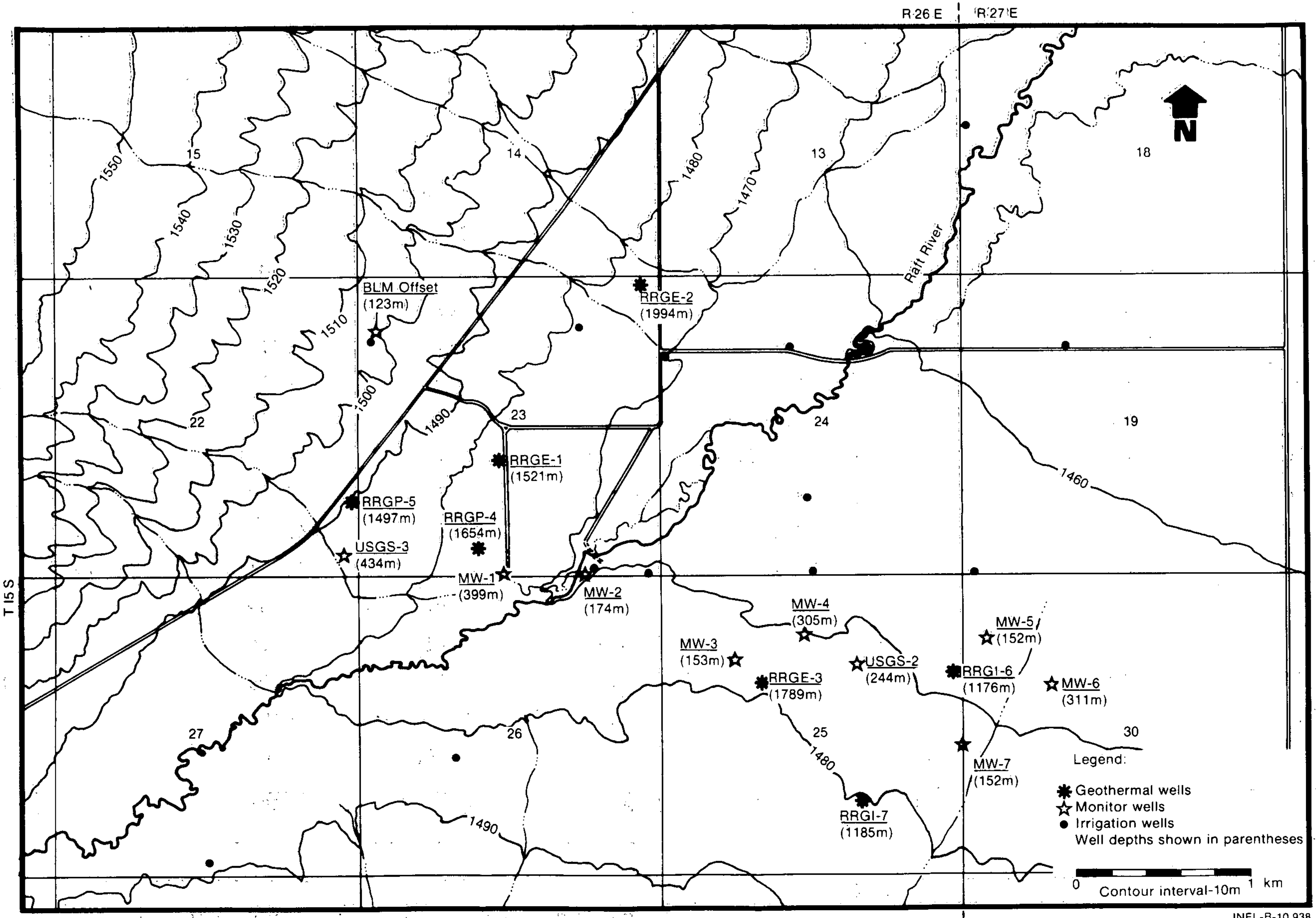

Figure 1. Location of Raft River geothermal, monitor, and irrigation wells.

TABLE 2. INEL ANALYSES OF THE RAFT RIVER VALLEY MONITOR WELLS

Analysis	Results (mg/l)[a]						
	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7
Cl^-	3670	1700	2400	2610	560	2340	650
F^-	2.8	5.7	5.6	5.6	0.1	4.1	1.0
$SO_4^=$	67	68	48	48	20	63	25
Mg	0.5	0.7	3.4	0.5	21.0	0.1	17.0
Na	2270	1320	1350	1450	485	1170	375
Li	4.1	2.6	3.1	3.3	0.4	2.8	0.6
Sr	7.0	3.8	1.8	0.8	0.8	1.4	0.8
Ca	210	140	170	160	110	170	94
K	28	24	54	23	12	62	14
NO_3^-	5	5	5	5	5	5	5
SiO_2	79	84	92	82	34	30	43
pH	7.8	7.6	7.5	7.7	7.8	10.6	7.8
TDS	6590	3130	4920	4510	1180	4270	1300
Conductivity	11350	5700	7700	7800	2000	7600	2300
Alkalinity ($CaCO_3$)	25	26	46	30	114	99	102

a. Conductivity recorded in μmho/cm.

TABLE 3. CHEMICAL ANALYSIS OF IRRIGATION WELLS NEAR THE RAFT RIVER GEOTHERMAL SITE

Well Name	Location	Conductivity (µmhos/cm)	ph	Cl^- (mg/l)	F^- (mg/l)	Alkalinity ($CaCo_3$) (mg/l)
UDY	155-26E 24 bad	2556	7.5	686	5.2	147
STEWART-1	155-26E 24 bcd	2425	7.6	605	6.5	136
STEWART-2	155-26E 24 cad	2136	7.2	525	1.3	159
STEWART-3	155-26E 25 abb	2742	7.2	744	1.9	112
CROOK (HOT)	155-26E 23 ddc	5870	7.7	1767	7.1	186
DARRINGTON-1	155-26E 23 abd	4300	7.4	1065	6.7	98
DARRINGTON-2	155-26E 26 cab	3680	7.7	966	6.9	87
DARRINGTON-3	155-26E 27 dcc	1530		300		

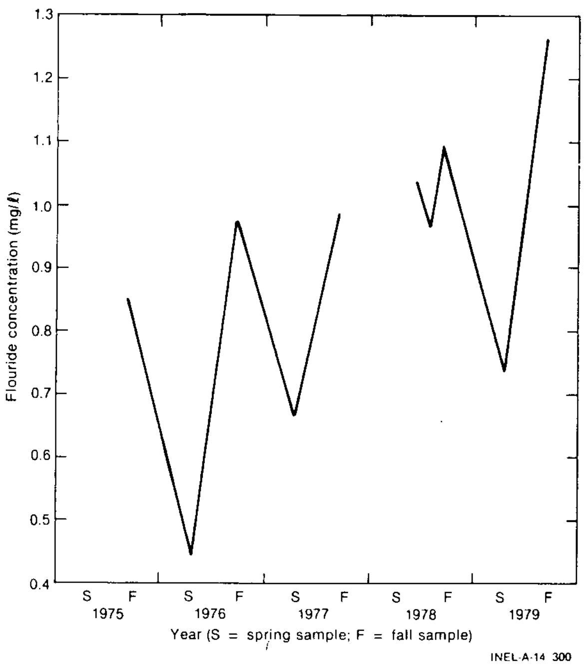

Figure 2. Fluoride concentration in the Raft River.

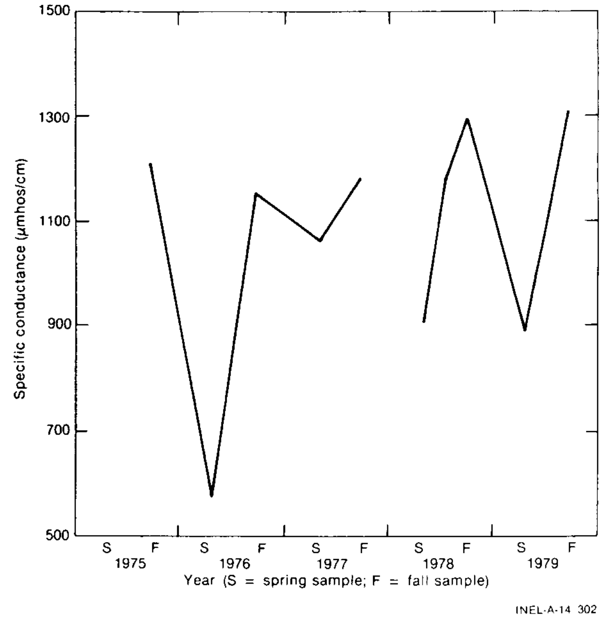

Figure 4. Specific conductance of the Raft River water.

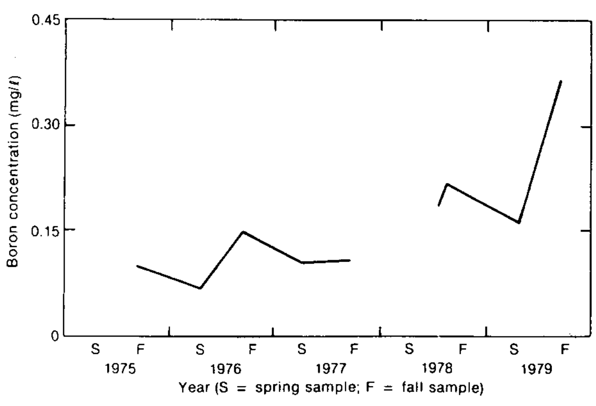

Figure 3. Boron concentration in the Raft River.

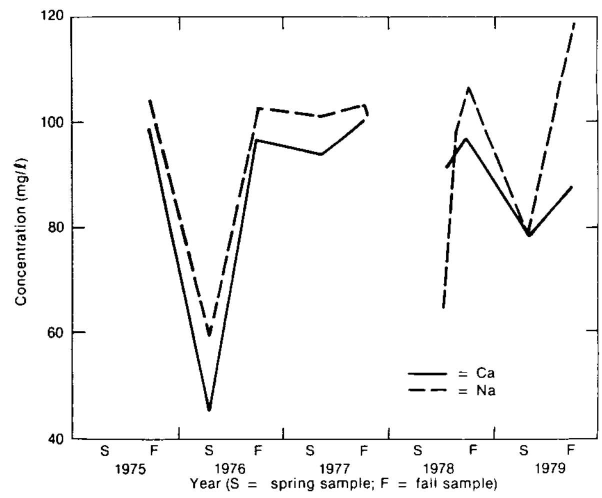

Figure 5. Concentration of calcium (Ca) and sodium (Na) in the Raft River.

Air Quality

Air quality is monitored to determine the extent and impact of pollutants released due to geothermal development. Originally, the air quality program focused on the potential for hydrogen sulfide (H_2S) emissions from the geothermal facility. This concern was based on the operating experience at the Geysers power plant in California, where unabated H_2S emissions averaged 550 kg/hr. Analyses of the Raft River geothermal fluid indicate very low concentrations of H_2S and other noncondensible gases; therefore, these emissions are not expected to be a problem. Two principal sources of particulates are expected: the 5-MW(e) cooling tower drift and fugitive road-dust. The type of water treatment used in the cooling system will determine how serious the cooling tower emissions will be.

Future air quality monitoring will include relocation of the 2 existing Hi-Vol particulate samplers 2.8 and 3.5 km downwind from the 5-MW(e) pilot plant and installation of a third "control" station 6.0 km upwind from the plant. A particle-sizing head will be fitted on an additional Hi-Vol sampler at one of the downwind stations. Atomic absorption (AA) analysis will determine the chemical constituent(s) of the various particle sizes as part of the 5-MW(e) cooling tower blowdown characterization study.

Air quality monitoring will include routine Hi-Vol measurements of total suspended particulates for a 24-hour period once every six days, periodic scanning electron microscope (SEM) analysis of Hi-Vol filters for particle identification, particle size evaluations, and AA chemical constituents analysis. Ambient concentrations of H_2S will be monitored daily at the plant site. Gaseous and particulate tracer studies will be performed on the cooling tower effluent; the data will be incorporated into a model designed to predict potential long-term impacts of the 5-MW(e) pilot plant on ambient air quality.

Geology

The north-south trending Raft River Valley is 60 km long and 20-24 km wide with an average elevation of 1400 m. It is a late Cenozoic downwarp with 1800 m of sediment fill over a series of Precambrian metasediments and quartz monzonite. Mountain ranges bound the valley on the east, west, and south, and the Snake River Plain bounds the valley on the north (Figure 6).

The Sublette and Black Pine Mountains on the east are composed of upper Paleozoic sediments, primarily limestones. They exhibit the complex pattern of superimposed folding, thrusting, and faulting caused by crustal shortening and mountain building of the late Cretaceous Laramide Orogeny.

The Jim Sage (formerly Malta) and Cotterel Ranges bound the valley on the west. Maximum elevation is 2500 m; the northern extent is where the Cotterel Range plunges under the Snake River Plain. The Jim Sage Range is a tilted anticlinal block composed entirely of the Tertiary Salt Lake formation. The crest is on the east, creating steep eastern scarps and a gentle westward slope.

The Albion Range lies west of the Jim Sage Range; the two ranges are separated by a fault valley. The Albion Range contains the highest peaks in the area (3000 m) and also plunges under the Snake River Plain. The Albion Range and the east-west trending Raft River Range that bounds the southern end of the valley are structurally complex, consisting of Precambrian gneiss domes mantled by metamorphosed Paleozoic sediments and allocthonous upper Paleozoic sediments.[1,2] The Albion Range contains the Almo Pluton, better known as the City of Rocks, intruded in late Cretaceous time as an outlier of the Idaho Batholith.[3]

Sheep Mountain to the north of the KGRA and Round Mountain to the southeast of the KGRA are both intruded rhyolite domes approximately 8 million years old.[4]

The upper 300 m of sediment in the valley are unconsolidated alluvial and lacustrine deposits of quartzose sand and silt, tuffs, and rhyolite gravels of the Pleistocene Raft formation.[5] Underlying the Pleistocene Raft formation is the Tertiary Salt Lake formation consisting of a lower unit of volcanic ash interbedded with sands, silts, and conglomerates and an upper unit of rhyolite flows interbedded with tuffs. Correlation of lithology within the valley is impossible because of the lenticular nature of deposition and different degrees of hydrothermal alteration. The basement is formed by a series of Precambrian schists and

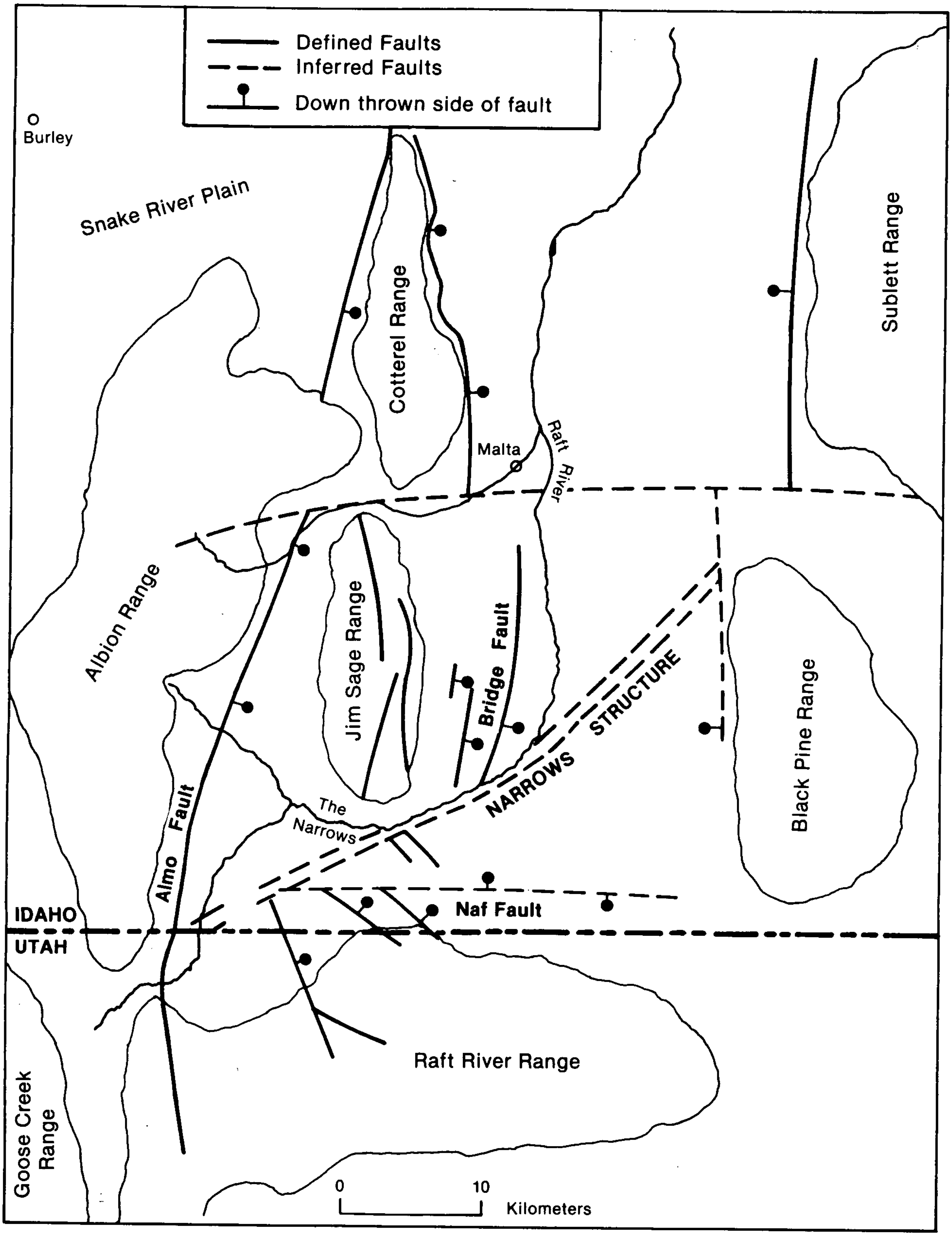

Figure 6. Generalized geological map of the Raft River Valley region.

quartzites approximately 150 m thick, underlain by quartz monzonite which is partly older than the metasediments (2.4 billion years) and partly intrusive. This Precambrian series is found outcropping in the Raft River Range.

The geothermal reservoir is possibly controlled by migration of hydrothermal water along major fault zones. The Bridge fault zone is a north trending series of steep normal faults (with the east side downdropped) at the eastern base of the Jim Sage Range. The KGRA is located where this zone intersects a northeast trending, poorly understood feature called the Narrows Zone. Although other structural lineations can be inferred from geophysics, geochemistry, and surface features, valley structure as a whole is poorly understood.

Meteorology

A weather station installed at the environmental building east of RRGE-2 (Figure 1) was designed to monitor wind speed and direction, precipitation, ambient temperature, and dewpoint temperature. These data are required by many of the continuing environmental monitoring programs since the meteorology of a given year has direct impact upon most aspects of the environment. The monitor inputs are automatically sampled once every six minutes and the data are transmitted to the National Oceanic and Atmospheric Administration (NOAA) computers at INEL. In addition to this equipment, total sky and total incidence solar radiation instruments were set up to provide data for agricultural experiments in the Raft River area and to supplement solar data collected at the Energy Experiment Station at Idaho State University. Due to problems which developed in the data transmission and receiving system, only a portion of the data was collected during 1979. Installation of a new tape system corrected the problem.

The Malta and Strevell weather stations provide data comparable to that of the Raft River Geothermal Site. Average monthly temperatures varied only slightly from historic data (Figure 7) with the exception of January, which was unusually cold. The low temperature for the year was -30°C on January 6, and the high temperature was 37.8°C on both July 17 and August 4. The spring was unusually dry with only about half as much precipitation as normal falling between February and July (Figure 8). August, however,

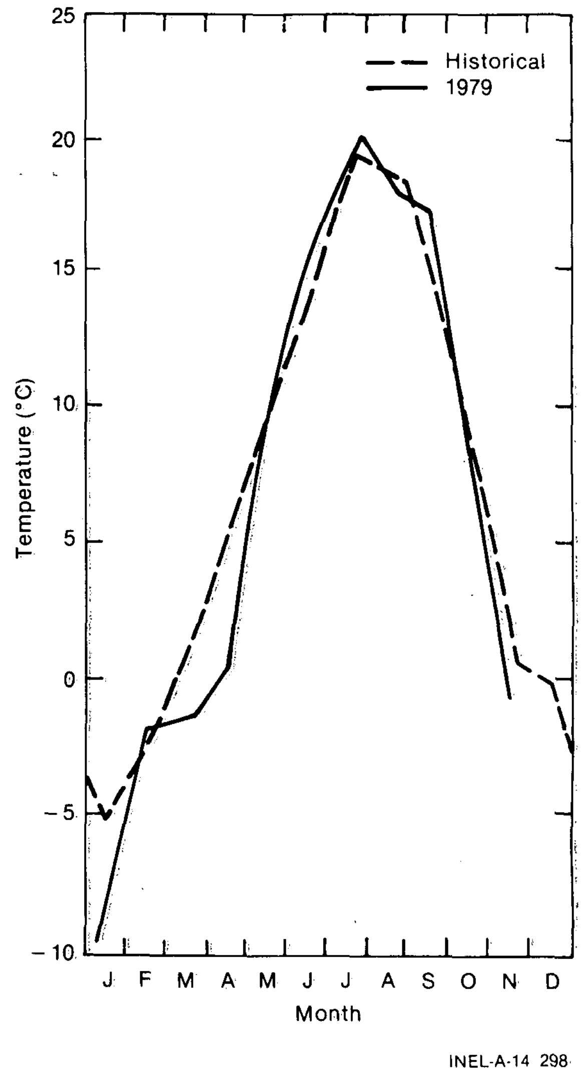

Figure 7. Raft River (Strevell) 1979 average temperature.

received approximately one-third more precipitation than usual. Snowfall during the 1978-1979 season totaled 26.6 cm.

Seismicity

Southeastern Idaho is classified as a Zone 3 seismic risk area, which indicates potential for a major earthquake [Richter magnitude (M) ≥ 4]. This classification is based on the geologic composition of the region.

In 1974, an investigation was conducted to determine the seismicity of the Raft River Valley. Previous data indicate that no historical high magnitude seismic events were recorded within Cassia County.[6] Only three significant seismic events, located 30 to 50 km west of the Raft River

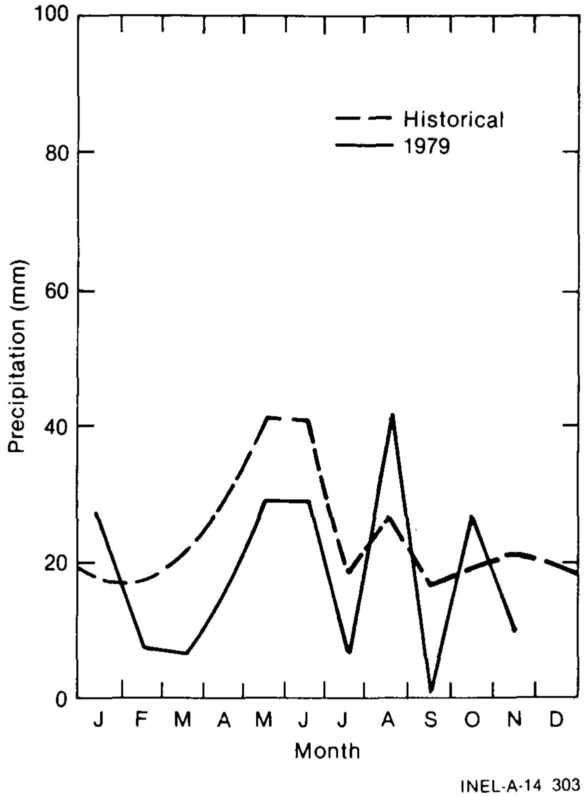

Figure 8. Raft River (Strevell) 1979 average precipitation.

KGRA, are known to have occurred in the region. The catalogue of Nevada and Utah earthquakes (1851 through 1960) cites two earthquakes (5.1 M in 1934 and 5.4 M in 1937) that were traced to an area near the Utah-Cassia County, Idaho border;[7] and Dahl and Johnson[8] recorded one event (1.5 M) in 1973 near the same epicenter region. A survey was conducted in 1974 to characterize the microseismetic activity of the area ($M < 3$). During the 90-day study, only seven events with an epicenter less than 17 km from the geothermal site were recorded; all events registered less than 0.2 M. Therefore, due to the scarcity of events and their low magnitude, it appears that the valley is more closely related to the aseismic Snake River Plain than to the seismically active Basin and Range and Intermountain Belt.

Subsidence

Fracturing and subsidence of the land surface may result from a decline of water level due to pumping from unconsolidated groundwater deposits. Over the past 40 years, the lower Raft River Valley has subsided as much as 0.9 m because of irrigation pumping.[9] Subsidence surveys conducted from 1975 through 1978 were tied into the U.S.G.S. grid for the purpose of checking elevations in the geothermal development area. In 1979, the elevations of the monitor wells were surveyed twice during injection testing. No significant changes in elevation were detected in these surveys; however, to date the geothermal wells have not been tested at high flow volumes over a long period of time.

The existing geothermal production wells (RRGE-1, RRGE-2, RRGE-3, RRGP-4, and RRGP-5) are clustered on the northwest side of the Raft River, while the injection wells (RRGI-6 and RRGI-7) are located 1.5 to 2.5 km to the southeast (Figure 1). Long-term production and injection during the operation of various facilities may alter the hydrology of the area and cause local elevation changes; because pressure changes are not necessarily confined to the source aquifer(s), pressure changes could potentially be transmitted to shallower aquifers and unconfined sediments.

Specific elevation surveys (second order; first class) were begun in 1979 to measure subsidence activity in the geothermal development area. This research will be completed in 1980, and the data will be correlated with possible changes in the monitor wells' water levels and artesian pressures.

BIOLOGICAL ENVIRONMENT MONITORING PROGRAMS

The Raft River KGRA is located in habitat typical of the Great Basin cold desert ecosystem. The vegetation communities are dominated by a mixture of sagebrush (*Artemisia*), greasewood (*Sarcolatus*), rabbitbrush (*Chrysothamus*), bunch grass (*Agropyron*), and other low-growing shrubs and forbs. The wildlife of the region are adapted to and dependent upon the fragile desert ecosystem, which is characterized by adverse climate and marginal soils.

With intensifying demands of multiple land use and rapidly expanding efforts to diversify the use of renewable and nonrenewable resources, conflicts with critical wildlife habitat are increasing. By understanding the ecosystem structure and function and adjusting human activities to minimize ecological impacts, an equitable and intelligent use of the area resources can be achieved.

An understanding of the biotic community with respect to diversity and population interactions is a prerequisite for effective environmental management. The following studies were performed to establish a flora and fauna data base for the Raft River Valley. Knowledge of the various ecosystem components can be used by future geothermal developers during site selection to mitigate potential problems and/or delays associated with destruction of critical habitat.

Raptor Disturbance Research

Introduction. The ferruginous hawk (*Buteo regalis*) is the largest hawk in North America. It is prone to nest desertion, especially during incubation.[10,11,12] Due to this sensitivity and its apparent declining numbers, it has been placed on the "Blue List," a classification denoting cause for special concern.[13]

The Raft River Valley contains one of the densest and most productive ferruginous hawk populations remaining in the country (Figure 9). The hawks have been studied for several years in the Raft River and adjacent valleys; consequently, their population densities and dynamics are known.[14,15] Such baseline data are essential for establishing population trends and separating the effects of human factors from natural environmental fluctuations.

The study objectives were to (a) assess the potential impact of geothermal development activities on the nesting success of the ferruginous hawk, (b) approximate a buffer zone around nest locations beyond which geothermal development would presumably not impair nesting success, and (c) accumulate information and baseline data that will be useful to other studies aimed at determining similar parameters and rationales.

Methodology. The ferruginous hawk disturbance study spanned the 1978 and 1979 nesting seasons. In early April of each year, occupied territories were located by observing the nests from a minimum distance of 0.4 km to determine if adults were present. Nests were designated as control and treatment locations, with study logistics determining the random sample of treated nest sites.

In early May 1978 and late April 1979, impact treatments were initiated on nests chosen for treatment. During 1978, four treatments were applied: (a) three nests were disturbed by investigators approaching on foot, (b) three were disturbed by an approaching vehicle, (c) two were disturbed by placing continuously-operating, 3-1/2 hp gasoline engines near them, and (d) three were disturbed by discharging firearms in the vicinity. The firearm (0.22 calibre rifle) was discharged approximately every 20 m as investigators approached the nest, beginning at an approximate distance of 500 m from the nest, and continuing until the adult flushed.

Based on the 1978 experience, the use of firearms was omitted for the 1979 tests since the effect of noise made by the firearms could not be separated from the presence of the researcher. The 1979 treatments were applied as follows: (a) five nests were approached on foot, (b) five nests were approached by vehicle, and (c) four nests were treated with wind- or battery-powered noisemaker devices placed 30 to 50 m from the nests. Noise at the nest sites (80 ± 5 db) was designed to simulate noises common to a geothermal (or other type of development) site.

The nests were approached to the point at which the attending adult flushed.[a] When this occurred, the investigator approached no further and immediately left the area. The distance between the investigator and the nest was estimated and recorded as the level of stress or anxiety beyond which the hawks could no longer tolerate the presence of the disturbing factor.

All nests contained eggs at the initiation of the various treatments and were disturbed once daily until the young hatched, at which time the frequency of visits was reduced. Data collected at each visit included presence or absence of adults, flushing distance, general behavior of adults, and unusual climatic conditions. All young were banded when they were 2 to 3 weeks of age. Since the population dynamics of ferruginous hawks is closely related to the prey base,[12] hawk fecal pellets and the density of the jackrabbit population were assessed.

Results and Discussion. Unlike previously reported findings of nest desertion as a function of human interference, very little nest failure resulted

a. Flushing is defined as the act of the attending adult physically leaving the nest.

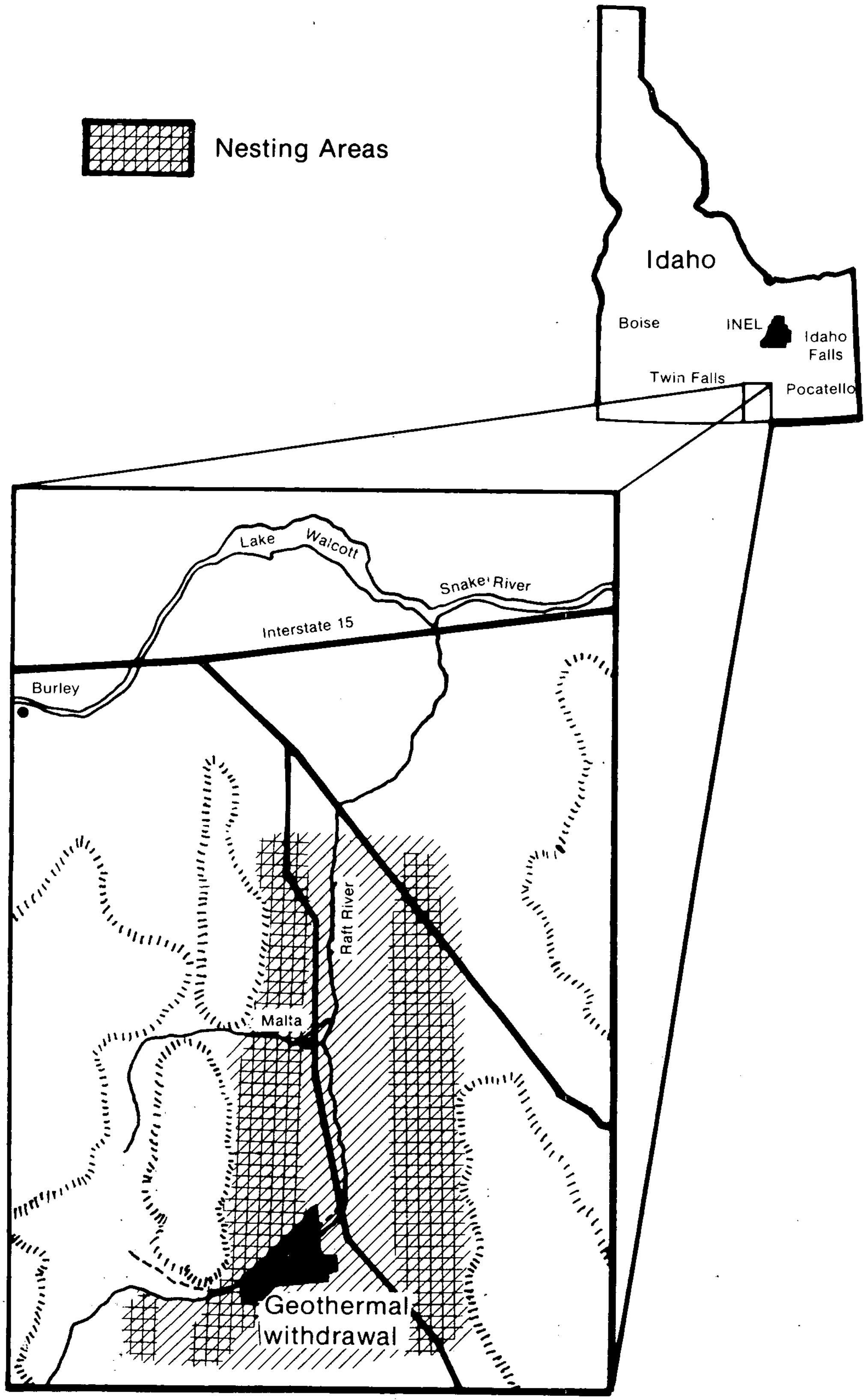

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Figure 9. Location of ferruginous hawk nesting habitat.

from our treatments. During 1978, three pairs (out of 10 treatment nests) abandoned their nesting attempt apparently because of the disturbances, and four out of 13 treatment pairs deserted during the 1979 season (Tables 4 and 5).

Each pair of birds had slightly different responses to the treatment; however, none seemed to develop a tolerance to the presence of the investigators. Flushing response data during the incubation period indicate that most pairs increased in their sensitivity to disturbance. Once the chicks hatched, there appeared to be the establishment of a zone of "security" (within a radius of about 100 meters of the nest) where adults appeared to feel "safe." As long as that zone was not entered, adults did not flush 60% of the time. The average flushing distance throughout the 1979 nesting season was about 120 meters. When direct human activity was restricted to greater than 200 meters from the nest, 84% of the flushing was avoided; when activity was restricted to greater than 250 meters from the nest, 90% of the flushing was avoided.

Of the 10 active 1978 treatment nests, seven were successful in fledging 17 young, for a fledging rate of 2.43 young per successful nest (Table 6). Including the three nests that were deserted, the fledging rate for the 10 nests was 1.70 young per attempted nesting. The 15 control nests fledged a total of 53 young, for a fledging success of 3.53 young per nest. This difference in fledging rate between control and treatment nests was statistically significant ($P = 0.10$) as evaluated by the independent t-test.[16]

During 1979, nine of the 13 treatment nests were successful and fledged 24 young for a fledging rate of 2.67, compared to rates of 1.85 for all treatment nests (successful and unsuccessful) and 3.81 for control nests. The difference of 1.1 young per nesting attempt between successful treatment and control nests was found to be significant ($P = 0.01$). Of particular interest is the trend that appears in the data (Table 7); 14 of the 21 1979 control nests (or 71%) fledged either four or five young per nest, while the maximum number of young fledged by any treatment nest was three.

Behavioral data collected during each visit to the nests suggested that adults became sensitized to the presence of the investigators and were not as attentive to their young. This lowered attentiveness may have contributed to the lowered fledging success of treatment nests. Although flushing distance was used as an indication of the critical stress threshold and consequent nest desertions, the hawks might well have reached a critical stress level long before they flushed. Busch, deGraw, and Clampitt[17] recorded a threefold increase in heart rate, as an indication of stress, at the sight of a human approaching a caged ferruginous hawk. Under our field conditions, stress and consequently the heart rates might have increased at much greater distances than that distance at which the hawks flushed.

Three of the four territories deserted during the 1978 phase of the study were not reoccupied during 1979, an observation that could have long-range population implications if that trend were continued over several years. Additional study is required to substantiate this observation.

The blacktailed jackrabbit (*Lepus californicus*) population was at a near peak density of approximately 307 jackrabbits/km^2 in 1978 and 287 rabbits/km^2 in 1979. This abundant food supply may have affected the outcome of the study by increasing the tolerance of the nesting pairs. Therefore, it may be expected that when the jackrabbit cycle begins its decline, the nesting success of the ferruginous hawk may be much lower, and tolerance to human activity may decrease in relation to their physiological state.

Although incubation may be successful and young hawks raised, the presence of humans too near the nests may cause the added problem of premature fledging of young, which could increase the mortality rate. At one nest during 1978, presence of investigators caused a young hawk, only recently out of the nest, to make an exerted and lengthy premature flight. Within 20 minutes, a coyote (*Canis latrans*) was scouting the area where the young had landed. This coyote may have seen the young in its unstable flight, or its presence might have been coincidental. Greater utilization of the ferruginous hawk habitat might increase premature departure rate from nests; mortality factors such as predation on the inexperienced young could exact a substantial toll and ultimately decrease population levels.

Future Research. The ferruginous hawk study documented the natural behavior of a sensitive raptor under both disturbed and undisturbed conditions to determine the level of perturbation that

TABLE 4. THE TYPE OF DISTURBANCE AND OUTCOME OF FERRUGINOUS HAWK TREATMENT NESTS IN 1978

Treatment	Number of Visits[a]	Mean Flushing Distance and Range (m)[b]	Results
Walk	18	31 (14 to 137)	Fledged 0 (3 young depredated)
Walk	8	110 (23 to 183)	Deserted
Walk	6	53 (37 to 91)	Deserted
Noise	0	NA[c]	Fledged 4
Noise	0	NA	Fledged 4
Gunshots	18	71 (23 to 230)	Fledged 2
Gunshots	22	96 (5 to 274)	Fledged 2
Gunshots	19	74 (5 to 320)	Fledged 4
Drive	7	217 (18 to 484)	Deserted
Drive	6	221 (137 to 366)	Destroyed by wind
Drive	25	62 (18 to 484)	Fledged 1

a. Number in parentheses indicates those visits when the adults flushed at <500 m or were not present.

b. Calculated only on values when adults flushed at <500 m.

c. Not applicable; nests disturbed by noise were not regularly visited by investigators.

TABLE 5. THE TYPE OF DISTURBANCE AND OUTCOME OF FERRUGINOUS HAWK TREATMENT NESTS IN 1979

Treatment	Number of Visits[a]	Mean Flushing Distance and Range (m)[b]	Nest Results
Walk	19 (5)	138 (20 to 400)	Fledged 3
Walk	21 (7)	66 (20 to 150)	Fledged 2
Walk	19 (2)	164 (70 to 300)	Deserted
Walk	26 (10)	196 (10 to 350)	Fledged 3
Walk	24 (3)	118 (25 to 255)	Fledged 3
Drive	24 (3)	90 (15 to 270)	Fledged 3
Drive	28 (1)	162 (35 to 400)	Fledged 3
Drive	28 (1)	54 (15 to 180)	Fledged 2
Drive	6 (3)	153 (20 to 400)	Deserted
Noise	NA[c]		Deserted
Noise	NA		Fledged 2
Noise	NA		Fledged 3
Noise	NA		Deserted

a. Number in parentheses indicates those visits when the adults flushed at <500 m or were not present.

b. Calculated only on values when adults flushed at <500 m.

c. Not applicable; nests disturbed by noise were not regularly visited by investigators.

TABLE 6. FERRUGINOUS HAWK FLEDGING RATES FOR 1978 AND 1979 NESTING SEASONS

	Number of Nests		Fledging Rate	
	1978	1979	1978	1979
All treatment nests	10	13	1.70	1.85
Successful treatment nests	7	9	2.43	2.67
Control nests	15	21	3.53	3.81

TABLE 7. DISTRIBUTION OF THE NUMBER OF FERRUGINOUS HAWK CHICKS FLEDGED PER NEST

Number Young Fledged	Number of Nests 1978		Number of Nests 1979	
	Control	Treatment	Control	Treatment
5	2 (13)[a]	0 (0)	5 (24)	0 (0)
4	7 (47)	3 (30)	10 (48)	0 (0)
3	3 (20)	0 (0)	4 (19)	6 (46)
2	3 (20)	2 (20)	1 (5)	3 (23)
1	0 (0)	1 (10)	1 (5)	0 (0)
0	0 (0)	4 (40)	0 (0)	4 (31)

a. Percentage of nests in each category.

they will tolerate without decreasing nesting success or production rates. Such information allows development of siting criteria for well or power plant locations, or both, that are compatible with species normally sensitive to such development. During 1980, heart rates of several ferruginous hawks will be monitored using radio-telemetry to determine if the flushing distance is indicative of the actual distance at which the birds first become stressed. Stress will be measured as an increase in the bird's heart rate. In addition, territories that were deserted during 1978 and 1979 will be monitored to determine if the territories remain unoccupied.

Aquatic Ecology

Introduction. A 2-year aquatic ecology study of the Raft River was initiated in 1979. The objectives of the study were to (a) characterize the faunal and floral communities of the river, (b) assess the physical conditions of various habitat types near the geothermal site, and (c) establish baseline information concerning community structure and population dynamics. As the Raft River is the only perennial stream in the valley, it is an important component of the region's ecosystem. The river is also used as a source for surface irrigation water. Due to the river's proximity to the geothermal facility, a spill of geothermal water into the Raft River drainage could occur. An understanding of the baseline ecological parameters of the river is needed should any future impact analysis be required.

Methodology. Three sampling stations were established near the geothermal site: Station A was located 1.2 km downstream from the main geothermal facility, Station B was directly South of RRGP-4, and Station C was 6.5 km upstream of the geothermal facility. The physical description of the river included flow and temperature regimes, water chemistry, and aquatic habitat mapping. Existing data collected by the U.S.G.S., the Idaho Department of Fish and Game, and the geothermal site were incorporated into the analysis. Water chemistry was analysed using E.P.A. standard methods when data were not available. A Nypric velocity meter measured discharge rate, and Ryan underwater thermographs measured water temperature for 30-day periods.

The biological characterization of the river included detailed sampling of the macroinvertebrate and fish communities. Benthic samples were collected in March, April, June, July, September, and November of 1979. The macroinvertebrate community was censused using a standard Surber sampler. Ten samples were collected at each station during each sample period, resulting in a total of 180 benthic samples. When possible, all organisms were identified to the species level. When the study is completed in 1980, analysis of these data will include a species list, relative density of each species, and seasonal fluctuations in numbers and diversity of the dominant forms.

Fish populations were sampled in November of 1978 and in June, July, September, and November of 1979 using a mark-recapture technique. During each sample period, 250 meter sections of the river were seined twice on consecutive days at each of the three sample stations. The fish captured on the first seining pass were marked using a caudal fin clip. The frequency of fish collected on the second seining pass allowed estimation of the population density. Density estimates were made separately for each species. All fish collected were measured for length and weight, and general habitat locations were noted. These data yielded a species list, the abundance of each species at each station, the size class distribution of each species, and the age structure of the larger fish species. In addition, species diversity and habitat requirements of the various species will be determined.

Results and Discussion. Physical factors act strongly to influence the community structure. Stations A and C were the most similar with respect to substrate type and were composed of 50% rubble (particle size >64 mm) on an area basis. Station B was dominated by sands and gravel (particle size 2 to 64 mm) with approximately 30% rubble. The approximate average waterdepths were 21 cm at Station A, 20 cm at Station B, and 26 cm at Station C. The 30% greater depth for Station C was due to the presence of deep pools, which increase the probability of fish survival when the stream freezes over. A compounding factor is the time interval the stream is frozen over. Stations A and B froze in November with ice up to 20 cm thick, while Station C had no ice cover on it at all. Thus, Stations A and B are likely to be under thick ice for a longer period of time in the winter, which increases the importance of deep pools in these areas for fish overwintering.

Many of the benthic samples collected have not yet been analyzed. Periphyton cover determined from benthic samples shows a seasonal trend, starting low in the spring and increasing through the summer into September. The increase in percent cover is most rapid on the large particles because of their higher stability. Finer substrates and their lower stability reflect a periphyton colonization lag.

Table 8 presents an example of the fish data collected and the relative abundance of the species. The longnose dace (*Rhinichthys cataractae*) dominates all areas; at Station A it makes up over 95% of the total fish population. Redside shiners (*Richardsonius balteatus*) are abundant at Stations B and C, but are nearly absent at Station A. Utah suckers (*Catostomus ardens*) and mountain suckers (*Pantosteus platyrhynchus*) comprise large percentages of the fish community at Stations B and C, but are virtually absent at Station A. Since mountain suckers are herbivorous and make up 35% of the fish community at Station C, it is likely that their abundance is partially responsible for the low density of filamentous algae observed there.

TABLE 8. RAFT RIVER FISH POPULATION ABUNDANCE[a]

Species	Station A						Station B						Station C						
	1[b]	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	6	Total
Utah sucker (*Catostomus ardens*)	--	--	--	--	--	0.0	0.7	2.8	0.4	0.5	0.1	4.5	0.7	0.9	--	--	0.8	1.7	4.1
Mountain sucker (*Pantosteus platyrhynchus*)	--	--	0.4	0.2	0.4	1.0	4.1	4.7	3.1	0.8	1.0	13.7	0.7	1.8	0.1	5.4	22.7	4.2	34.9
Piute sculpin (*Cottus beldingi*)	--	0.8	0.2	--	--	1.0	--	1.9	--	--	--	1.9	--	0.6	--	--	--	--	0.6
Longnose dace (*Rhinichthys cataractae*)	41.2	50.6	5.2	--	--	97.0	17.3	41.2	6.4	--	--	64.9	1.5	22.1	17.4	0.2	--	--	41.2
Redside shiner (*Richardsonius balteatus*)	--	0.4	0.6	--	--	1.0	4.2	3.8	4.5	2.5	--	15.0	9.7	3.0	3.4	2.8	0.3	--	19.2
TOTAL	41.2	51.8	6.4	0.2	0.4	100.0	26.3	54.4	14.4	3.8	1.1	100.0	12.6	28.4	20.9	8.4	23.8	5.9	100.0

a. These data were obtained in the September sample. Species caught in previous samples, but not during the September sample, include speckled dace (*Rhinichthys osculus*) and cutthroat trout (*Salmo clarki*).

b. Size Classes: 1 (2.0 to 4.99 cm); 2 (5.0 to 6.99 cm); 3 (7.0 to 8.99 cm); 4 (9.0 to 10.99 cm); 5 (11.0 to 20.0 cm); 6 (>20.0 cm).

Future Research. A complete analysis of the fish and benthic baseline data will be compiled after the 1980 samples have been collected. The 1980 research will continue to concentrate on quantifying the aquatic ecology of Raft River near the geothermal site.

Small Mammals

Introduction. Small mammals are an important part of the Great Basin ecosystem because they provide an important prey base for practically every large predator and are the principal herbivores of the area. The former merits consideration because small mammals are necessary to maintain the ecological composition of the area. The latter is important because small mammals are potential competitors with the grazing industry and crop production.

Small mammal studies to date have assessed the population densities and distributions of the *Cricetinae* (deer mice and harvest mice) and *Heteromyidae* (kangaroo rates and pocket mice). These two families represent only a portion of the small mammal community in the Raft River Valley; also present are shrews (*Soricidae*), ground squirrels (*Scuiridae*), pocket gophers (*Geomyidae*), meadow voles (*Microtinae*), and rabbits (*Leporidae*).

Methodology. Rodent populations were sampled in 1977 and 1978 with two major census techniques. The first technique employed a base grid that was used annually throughout the duration of the study. The grid was established in the sagebrush-greasewood biotic community and included a 12 x 12 trapping pattern (2.72 hectares). Trapping stations were set 15 m apart and were equipped with two live traps per station. The traps were baited with rolled oats and were operated for 10 days each during May and August. All animals captured were marked with a toe-clip, weighed, and released. Data recorded for all recaptures were species, sex, trap location, weight, and reproductive activity.

The second technique employed satellite minigrids in 13 of the principal biotic communities. Minigrids (five to nine, depending on the size of the area) were randomly established at each monitoring location. Each minigrid consisted of four trap stations 15 m apart, with two live traps per station. The minigrids were trapped for five continuous days (one to three periods per month for May, June, July, and August), and all animals were released at the point of capture after weighing and processing to assess reproductive activity.

In addition to these studies, a limited census of the blacktailed jackrabbit population was conducted in 1978 and 1979 using the transect method of Hayne[18] and the correction factor of Gross et al.[19]

Results and Discussion. Table 9 presents population estimates of the small mammals trapped on the permanent plots. These data provide baseline estimates required for monitoring possible future population changes. The blacktailed jackrabbit population was estimated at 309 jack-rabbits/km^2 in 1978 and 287 jack-rabbits/km^2 in 1979. The jackrabbit population is characterized by fluctuations of up to a factor of 20 over the 10-year cycle period. It is essential, therefore, to understand the jackrabbit population cycle since it affects the entire ecosystem. The population estimates of the past two years indicate that the jackrabbit population is at or approaching a peak population density.

Other mammal species in the valley remain uncensused because their behavior is not condusive to existing sampling methods. Therefore, only general observations of their presence is possible. Table 10 lists the mammal species sighted in the Raft River Valley.

Future Research. Small mammal research efforts in 1980 will concentrate on studying the pygmy rabbit (*Brachylagus idahoensis*), a species listed as "status undetermined" by the U.S. Fish and Wildlife Service. Monitoring of the jackrabbit and cottontail populations will be expanded.

Songbirds

Introduction. Songbirds are an integral component of the Great Basin ecosystem and, as primary and secondary consumers, constitute a significant portion of the energy flow through the biotic community. This study collected baseline data on passerine birds in the Raft River Valley and predicted the possible impact of geothermal development on the songbird populations. The research emphasized potential impacts on entire avian communities, rather than on specific

TABLE 9. POPULATION ESTIMATE OF SMALL MAMMAL SPECIES CENSUSED DURING THE 1977-1978 STUDY

	Total Population on 2.72 Hectare Plot			
	1977		1978	
	Spring	Summer	Spring	Summer
Great Basin Pocket Mouse (*Perognathus parvus*)	10.5	27.0	5.1	11.0
Ord's Kangaroo Rat (*Dipodomys ordii*)	7.3	3.7	5.0	9.9
Deer Mouse (*Peromyscus maniculatus*)	21.8	2.4	92.8	34.1
Harvest Mouse (*Reithrodontomys megalotis*)	14.9	6.5	17.5	10.3
Grasshopper Mouse (*Onychomys leucogaster*)	0.0	1.0	0.0	7.3
Least Chipmunk (*Eutamias minimus*)	12.1	6.9	6.9	0.0

species. Selected species were identified as "indicator organisms" because of their restricted habitat requirements. These species are particularly sensitive to changes in that habitat. A quantitative change in density or structure of those selected breeding populations could thus be used to monitor environmental perturbations as they effect bird communities.

Methodology. Four 16-hectare plots were established in 1977, one in each of four general directions from the geothermal site. The specific sites were selected because they represented the major habitat types found in the immediate area. A fifth 16-hectare study site was established in 1978. All sites were regularly surveyed to determine the nest densities and success of the major bird species. Each site, with the exception of the study site established in 1978, was censused once every 12 days from early May through June using the census techniques of Williamson et al.[20] and White et al.[21] The data recorded included the total number and species of birds observed. In addition, some territory mapping was conducted in 1977 and 1978.

Results and Discussion. Table 11 lists all bird species observed in the Raft River Valley to date. Four species are abundant in the area surrounding the geothermal site; these are the Brewer's sparrow (*Spizella breweri*), sage thrasher (*Oreoscoptes montanus*), sage sparrow (*Amphispiza belli*), and horned lark (*Eremophila alpestris*).

The major difference in the data between 1977 and 1978 is the decline in Brewer's sparrow density (Table 12). This may be due to the drought conditions in 1976 and 1977, which particularly affected nesting success of this species. In 1977, only two out of seven nests located were successful, producing an average of 0.18 young per adult. This low reproductive success was reflected in the population density of the species for the following year.

Preliminary results indicate a low diversity of species composition in the region; that is, only a few species are relatively abundant. Of the four abundant species, horned larks are too restricted to grasslands and disturbed sites to be a sensitive indicator of environmental change.

TABLE 10. MAMMALS OBSERVED IN THE RAFT RIVER VALLEY AND THE ADJOINING MOUNTAINS

Masked Shrew	*Sorex cinereus*	Northern Flying Squirrel	*Glaucomys sabrinus*
Vagrant Shrew	*Sorex vagrans*	Northern Pocket Gopher[a]	*Thomomys talpoides*
Little Brown Bat	*Myotis lucifugus*	Ord Kangaroo Rat[a]	*Dipodmys ordi*
Raccoon	*Procyon lotor*	Great Basin Kangaroo Rat[a]	*Dipodomys microps*
Longtail Weasel[a]	*Mustela frenata*	Great Basin Pocket Mouse[a]	*Perognathus parvus*
Badger[a]	*Taxidea taxus*	Western Harvest Mouse[a]	*Reithrodontomys megalotis*
Spotted Skunk	*Spilogale putorius*	Deer Mouse[a]	*Peromyscus maniculatus*
Striped Skunk	*Mephitis mephitis*	Grasshopper Mouse[a]	*Onychomys leucogaster*
Coyote[a]	*Canis latrans*	Desert Woodrat[a]	*Neotoma lepida*
Red Fox	*Vulpes fulva*	Bushytail Woodrat[a]	*Neotoma cinerea*
Black-tailed Jackrabbit[a]	*Lepus californicus*	Meadow Vole	*Microtus pennsylvanicus*
Pygmy Rabbit[a]	*Brachylagus idahoensis*	Mountain Vole	*Microtus montanus*
Mountain Cottontail[a]	*Sylvilagus nuttalli*	Sagebrush Vole[a]	*Lagurus curtatus*
Townsend's Ground Squirrel[a]	*Spermophilus townsendi*	Muskrat[a]	*Ondatra zibethica*
Richardson's Ground Squirrel	*Spermophilus richardsoni*	Norway Rat[a]	*Rattus norvegicus*
Golden-mantled Squirrel	*Ammospermophilus lateralis*	House Mouse[a]	*Mus musculus*
Yellow Pine Chipmunk	*Eutamias amoenus*	Porcupine[a]	*Erthizon dorsatum*
Least Chipmunk[a]	*Eutamias minimus*	Pronghorn	*Antilocapra americana*
Red Squirrel	*Tamiasciurus hudsonicus*	Mule Deer[a]	*Odocoileus hemionus*

a. Observed on or near the KGRA.

TABLE 11. BIRDS OBSERVED IN THE RAFT RIVER VALLEY AND THE ADJOINING MOUNTAINS

Eared Grebe	Podiceps auritus	Chukar	Alectoris graeca
White Pelican	Pelecanus erythrorhynchos	Gray Partridge[a]	Perdix perdix
Canada Goose	Branta canadensis	Great Blue Heron	Ardea herodias
Mallard[a]	Anas platyrhynchos	Snowy Egret	Leucophoyx thula
Pintail	Anas acuta	Black-crowned Night Heron	Nycticorax nyctorax
Green-winged Teal[a]	Anas carolinensis	Killdeer[a]	Charadrius vociferus
Blue-winged Teal	Anas discors	Common Snipe	Capella gallinago
Cinnamon Teal	Anas cyanoptera	Long-billed Curlew[a,b]	Numenius americanus
Bufflehead	Bucephala albeola	Spotted Sandpiper	Actitis macularia
Ruddy Duck	Oxyura jamaicensis	Greater Yellowlegs	Totanus melanoleucus
Turkey Vulture[a]	Cathartes aura	American Avocet	Recurvirostra americana
Sharp-shinned Hawk[a]	Accipiter striatus	Wilson's Phalarope	Steganopus tricolor
Cooper's Hawk[a]	Accipiter cooperii	California Gull	Larus californicus
Red-tailed Hawk[a]	Buteo jamaicensis	Ring-billed Gull	Larus delawarensis
Swainsons Hawk[a]	Buteo swainsonsi	Rock Dove[a]	Columba livia
Rough-legged Hawk[a]	Buteo lagopus	Mourning Dove[a]	Zenaida macroura
Ferruginous Hawk[a,b]	Buteo regalis	Screech Owl	Otus asio
Golden Eagle[a]	Aquila chrysaetos	Great Horned Owl[a]	Bubo virginianus
Bald Eagle[b]	Haliaeetus leucocephalus	Burrowing Owl[a,b]	Speotyto cunicularia
Marsh Hawk[a]	Circus cyaneus	Long-eared Owl[a]	Asio otus
Prairie Falcon[a]	Falco mexicanus	Short-eared Owl[a]	Asio flammeus
Merlin[a]	Falco columbarius	Poor-will[a]	Phalaenoptilus nuttalii
Kestrel[a]	Falco sparverius	Common Nighthawk[a]	Chordeiles minor
Blue Grouse[a]	Dendragopus obsurus	White-throated Swift	Aeronautes saxatalis
Ruffed Grouse	Bonasa umbellus	Broad-tailed Hummingbird	Selasphorus platycercus
Sage Grouse[a]	Centrocercus urophasianus	Calliope Hummingbird[a]	Stellula calliope
Ring-necked Pheasant[a]	Phasianus colchicus	Belted Kingfisher	Megaceryle alcyon

TABLE 11 (continued)

Common Flicker	Colaptes auratus	Common Raven[a]	Corvus corax
Pileated Woodpecker	Dyrocopus pleatus	Common Crow[a]	Corvus brachyrhynchos
Lewis' Woodpecker	Asyndesmus lewis	Black-capped Chickadee[a]	Parus atricopillus
Yellow-bellied Sapsucker[a]	Sphyrapicus varius	Mountain Chickadee[a]	Parus gambeli
Hairy Woodpecker[a]	Dendrocopos villosus	Plain Titmouse[a]	Parus inornatus
Downy Woodpecker[a]	Dendrocopos pubescens	Common Bushtit[a]	Psultriparus minimus
Eastern Kingbird[a]	Tyrannus tyrannus	Dipper	Cinclus mexicanus
Western Kingbird[a]	Tyrannus verticalis	White-breasted Nuthatch	Sitta carolinensis
Ash-throated Flycatcher[a]	Myiarchus cinerascens	Red-breasted Nuthatch	Sitta canadensis
Say's Phobe[a]	Sayornis saya	Pygmy Nuthatch	Sitta pygmaea
Willow Flycatcher[a]	Empidonax traillii	Brown Creeper	Certhia familiaris
Hammonds Flycatcher[a]	Empidonax hammondii	House Wren[a]	Troglodtes aedon
Dusky Flycatcher	Empidonax oberholseri	Rock Wren[a]	Salpinctes obsoletus
Gray Flycatcher	Empidonax wrightii	Sage Thrasher[a]	Oreoscoptes montanu
Western Flycatcher[a]	Empidonax difficilies	Robin[a]	Turdus migratorius
Western Wood Pewee[a]	Contopus sordidulus	Townsend's Solitaire	Myadestes townsendi
Olive-sided Flycatcher	Nuttallornis borealis	Hermit Thrush[a]	Hylocichla guttata
Horned Lark[a]	Eremophila alpestris	Swainson's Thrush	Hylocichla ustulata
Tree Swallow	Iridoprocne bicolor	Veery	Hylocichla fuscescens
Rough-winged Swallow	Stelgidopteryx ruficollis	Western Bluebird	Sialia mexicana
Barn Swallow[a]	Hirundo rustica	Mountain Bluebird[a]	Sialia currucoides
Violet-green Swallow[a]	Tachycineta thalassina	Golden-crowned Kinglet	Regulus sutropa
Bank Swallow[a]	Riparia riparia	Ruby-crowned Kinglet[a]	Regulus calendula
Steller's Jay	Cyanocetta stelleri	Water Pipit	Anthus spinoletta
Scrub Jay[a]	Aphelocoma coerulesceus	Cedar Waxwing[a]	Bombycilla cedrorum
Pinyon Jay[a]	Gymnorhinus cyanocephalus	Northern Shrike	Lanius excubitor
Gray Jay[a]	Perisoreus canadensis	Loggerhead Shrike[a]	Lanius ludovicianus
Black-billed Magpie[a]	Pica pica	Starling[a]	Sturnus vulgaris
Clark's Nutcracker[a]	Nucifraga columbiana	Solitary Vireo[a]	Vireo solitarius

TABLE 11 (continued)

Warbling Vireo[a]	Vireo gilvus	Gray-crowned Rosy Finch	Leucosticte tephrocotis
Orange-crowned Warbler	Vermivora celata	Black Rosy Finch	Leucosticte atrata
Yellow Warbler[a]	Dendroica petechia	Pine Siskin	Spinus pinus
Yellow-rumped Warbler[a]	Dendroica auduboni	American Goldfinch[a]	Spinus trictis
Yellowthroat[a]	Geothlypis trichas	Red Crossbill	Loxia curviostra
Yellow-breasted Chat[a]	Icteria virens	Green-tailed Towhee[a]	Chlorura chlorura
MacGillivray's Warbler[a]	opororuis tolmiei	Rufous-sided Towhee[a]	Pipilo erthrophthalmus
Wilson's Warbler	Wilsonia pusilla	Savannah Sparrow	Passerculus sandwichensis
House Sparrow[a]	Passer domesticus	Lark Bunting[a]	Calamospiza melanocorys
Western Meadowlark[a]	Sturnella nelgecta	Vesper Sparrow[a]	Pooecetes gramineus
Red-winged Blackbird[a]	Agelaius phoenicaus	Lark Sparrow[a]	Chondestes grammacus
Brewer's Blackbird[a]	Euphagus cyanocephalus	Sage Sparrow[a]	Amphispiza belli
Brown-headed Cowbird[a]	Tangavius aeneus	Dark-eyed Junco[a]	Junco oreganus
Northern Oriole[a]	Icterus bullockii	Tree Sparrow	Spizella arborea
Western Tanager[a]	Piranga ludoviciana	Chipping Sparrow[a]	Spizella passerina
Northern Grosbeak[a]	Pheucticus melanocephalus	Brewers Sparrow[a]	Spizella breweri
Luzuli Bunting[a]	Passerina ameona	White-crowned Sparrow	Zonotrichia leucophrys
Indigo Bunting	Passerina cyanea	Fox Sparrow	Passerella iliaca
Purple Finch	Carpodacus purpureus	Lincoln's Sparrow	Melospiza lincolnii
Cassins Finch[a]	Carpodacus cassinii	Song Sparrow[a]	Melospiza melodia
House Finch[a]	Carpodacus mexicanus	Lapland Longspur	Calcarius lapponicus
		Snow Bunting	Plectrophenax nivalis

a. Known to breed in Raft River Valley.

b. Species which merit special consideration due to their threatened or unknown status.

TABLE 12. DENSITY OF MAJOR PASSERINE BIRD BREEDING SPECIES ON STUDY SITES

	Study Sites							
	1		2		3		4	
Parameters	1977	1978	1977	1978	1977	1978	1977	1978
Total number of bird-days of observation/plot	195	91	338	41	327	168	322	189
Probable number of territorial pairs/plot	27	6.4	39	3.0	52	12.2	41	12.6
Probable density of breeding pairs of all species/ha	1.7	0.4	2.4	0.2	3.3	0.8	2.6	0.8
Average density of Brewer's Sparrow (*Spizella brewei*)/plot	10	3	34	5.6	14	13	15	12
Average density of Sage Thrasher (*Oreoscoptes montanus*)/plot	0	0	0	0	4	2	7	5.4
Average density of Sage Sparrow (*Amphispiza belli*)/plot	9	12.6	0	0	0	0	0.3	1.4
Average density of Horned Lark (*Eremophila alphestis*)/plot	0	0	0	0	16	13.6	13	14.6

However, if native habitats are modified, the population of this species may increase. The distribution of the ubiquitous Brewer's sparrow is so general that their use of the habitat will not provide a reflection of subtle changes in the habitat. Sage sparrows appear to be the most selective in their habitat requirements and would be more sensitive to environmental perturbations than most other species. Sage thrashers appear to have needs similar to those of sage sparrows, but require larger areas of shrub habitat with more open spaces interspersed between the shrubs.

Future Research. The best indicators of environmental impact will probably be changes in the absolute density of breeding birds, particularly sage sparrows. In order to statistically quantify potential future changes, at least one additional year of breeding density data is required and will be provided by the 1980 research.

Raft River Raptors

An intense raptor study has not been performed in the Raft River Valley to date; however, during the course of the ferruginous hawk study, a total of 171 active raptor nests (69 in 1978; 102 in 1979) representing 11 species (including the raven, which is ecologically a raptor) were located in the Raft River Valley. Tables 4 and 5 provide ferruginous hawk nesting data, and Table 13 gives reproductive data collected for other raptors species. The sharp-shinned hawk (*Accipiter striatus*), harrier (*Circus cyaneus*), screech owl (*Otus asio*), and the short-eared owl (*Asio flammeus*) also nested in the valley; however, nesting data were not gathered on these species. Raptors observed to migrate through or winter in the region, but not known to breed in the valley, include the rough-legged hawk (*Buteo lagopus*), pigeon hawk (*Falco columbarius*), and the bald eagle (*Haliaeetus leucocephalus*). Also, as many as 15 to 25 immature golden eagles (*Aquilla chrysaetos*) reside in the valley, probably drawn to the area by the large blacktailed jackrabbit prey base (see Small Mammal section).

Two interesting nesting associations exist between the ferruginous hawk and other raptors. It appeared that the raven and ferruginous hawk may exchange nests and territories on a regular basis. Observations suggest the two species defend mutually exclusive territories. A second relationship is the placement of Swainson's hawk nests near ferruginous hawk nests. In 1978, a sample of 15 active ferruginous hawk nest sites determined that active Swainson's hawk nests were consistently associated within a sample radius of 0.8 km ($\chi^2 = 16.41$, 1 df, $P < 0.005$). This association was confirmed again in 1979. The results of these raptor studies will be analyzed in a separate report to be published in fall, 1980.

Plant Ecology

Introduction. A 4-year soil and vegetation study was initiated in 1976 as part of the Raft River environmental baseline research. The study objective was to quantitatively determine the response of vegetation to variations in meteorlogical, edaphic (soils), and other environmental factors. Vegetation plots (Figure 10) were established to compare vegetation of similar and dissimilar community types and to statistically and graphically delineate yearly fluctuations in plant species cover. An understanding of the basic requirements of the fragile Great Basin vegetation community will aid in detecting and mitigating potential detrimental impacts associated with geothermal development in the Raft River Valley. The data are not yet completely analyzed; however, some general patterns will be discussed.

Methodology. In 1976, 19 circular permanent plots, each with a radius of 8 m and an area of 0.02 hectare, were established in a radiating pattern from RRGE-1 and RRGE-2. Four additional plots were established in 1977. Two of the 23 plots were destroyed by cattle grazing and construction activities; the remaining 21 plots were sampled yearly through 1979. The plot locations were determined by establishing plots in each major vegetation community and on each major soil type.

Twenty-five 1-m^2 quadrats were sampled within each permanent plot. Data collected included plant species and relative cover composition of shrubs, grasses, perennial forbs, annuals, and cryptogams. Total living cover, litter cover, rock cover, and bare soil areas were also estimated.

The upper 15 cm of soil was sampled with a composite sample from 10 quadrats in each plot, and the surface and A and B horizons were sampled in selected plots. Precipitation, the maximum and minimum air temperatures, and the soil temperature at a 30-cm depth were also measured.

TABLE 13. REPRODUCTIVE DATA ON THE RAPTORIAL SPECIES, EXCLUSIVE OF THE FERRUGINOUS HAWK, IN THE RAFT RIVER VALLEY FOR 1978 AND 1979

Species	1978			1979		
	Number of Nests	Mean Clutch Size	Mean Number Fledged	Number of Nests	Mean Clutch Size	Mean Number Fledged
Cooper's Hawk (Accipiter cooperii)	1	4.0	4.0	3	4.0	4.0
Red-tailed Hawk (Buteo jamaicemsis)	2	--	2.5	1	3.0	0.0
Swainson's Hawk (Buteo swainsoni)	16	2.56	2.13	13	2.38	2.15
Golden Eagle (Aguila chrysaetos)	3	--	1.67	3	--	2.0
Prairie Falcon (Falco mexicanus)	1	4.0	3.0	3	4.33	3.00
Kestrel (Falco sparverius)	1	--	4	2	4.5	1.5
Great Horned Owl (Bubo virginianus)	7	--	2.16	8	--	1.57
Long-eared Owl (Asio otus)	10	3.90	3.40	14	4.28	4.0
Burrowing Owl (Speotyto curnicularia)	3	--	--	5	--	--
Raven (Corvus corax)	--	--	--	16	--	4.37

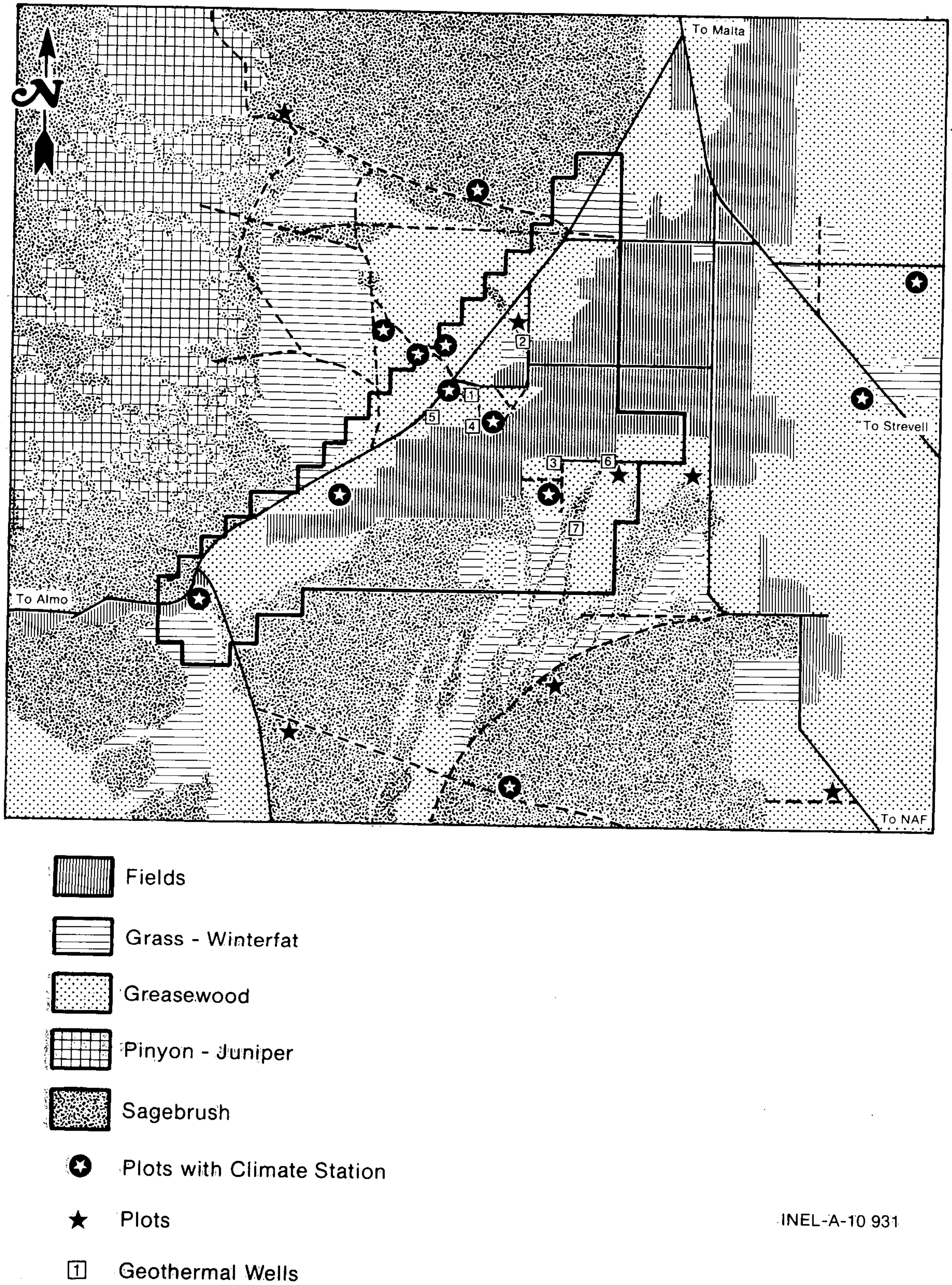

Figure 10. Map of vegetation and permanent plots.

Results and Discussion. Shrubs [common species include big sagebrush (*Artemisia tridentata*) and rubber rabbitbrush (*Chrysothamus nauseosus*)] remained stable from year to year, both in absolute and relative frequency. Relative frequency of perennial grasses [e.g., bunch grasses (*Agropyron* sp.) and brome grass (*Bromus* sp.)], perennial forbs [e.g., asters (*Aster* sp.) and prickly pear cactus (*Opuntia* sp.)] and annuals [e.g., cheat grass (*Bromus tectorum*) and halogeton (*Halogeton glomeratus*)] fluctuated between the years (Table 14) and appeared to reflect climatological characteristics. During the drought year of 1977, the ecosystem was dominated by grasses; during the wet spring of 1978, the annuals and perennial forbs flourished. These trends reflect that plant composition in the arid ecosystem of the Raft River Valley is dependent on the available moisture.

The number of species per quadrat changed little over the four-year study. A total of 105 species were identified during the study, but the same species were not found each year. The number of species sampled each year was 75 in 1976, 73 in 1977, 74 in 1978, and 87 in 1979. The average total of living cover decreased significantly from a high of 47.7% in 1978 to 37.4% in 1979. Table 15 summarizes the composition of cover classes, and Table 16 summarizes the types of living cover.

Future Research. The permanent plots will be reevaluated every three years. This sampling interval will serve as an "environmental barometer" by determining if any change attributable to area development is occurring in the vegetation community.

HUMAN AND CULTURAL MONITORING PROGRAM

Developing the geothermal resources of the Raft River Valley may affect the human environment of the nearby communities. This development offers local residents many benefits and opportunities; however, some undesirable alterations may result. The high fluoride levels sometimes associated with geothermal developments have been of concern in the Raft River Valley. Consequently, a program was established to monitor and document any changes in the domestic or irrigation water supply. The human environment monitoring program was designed to identify the tradeoffs and potential socioeconomic changes that could arise from geothermal resource development. The program will be used to minimize long-term adverse changes and maximize beneficial changes.

TABLE 14. RELATIVE FREQUENCY OF LIVING VEGETATION COVER

	Percentage of Total Living Cover			
	1976	1977	1978	1979
Shrubs	20.8	21.8	20.4	18.1
Perennial Grasses	17.3	24.7	23.2	21.0
Sedges	1.6	1.5	1.2	1.6
Perennial Forbs	17.4	11.1	15.1	14.7
Annuals	15.0	13.3	13.4	16.3
Cryptogams	27.9	27.6	26.7	28.3
	100.0	100.0	100.0	100.0

TABLE 15. COMPOSITION OF COVER CLASSES

Cover Classes	Average Cover (%) 1976	1977	1978	1979
Living Cover	46.9	40.3	47.7	37.4
Litter	6.4	7.5	8.8	11.1
Rock (>1 cm diam.)	5.1	7.2	6.3	5.4
Bare Soil	41.6	45.0	37.2	46.1
TOTAL	100.0	100.0	100.0	100.0

TABLE 16. COMPOSITION OF LIVING COVER

Living Cover Type	Average Cover % 1976	1977	1978	1979
Shrubs	42.4	45.7	42.4	43.6
Perennial Grasses	28.0	26.3	28.0	25.3
Perennial Forbs	6.0	7.5	6.0	7.4
Annuals	9.8	7.3	9.8	9.5
Cryptogams	13.8	13.2	13.8	14.2
TOTAL	100.0	100.0	100.0	100.0

Socioeconomics

Introduction. The socioeconomic environment of Cassia County, Idaho, was investigated during 1979. The study incorporated data from 1977 to 1979. The research objectives were to (a) describe the existing socioeconomic environment, (b) project the future socioeconomic environment in the absence of any significant geothermal resource development, (c) assess the attitudes of area residents concerning proposed development, and (d) provide a scenario of direct and indirect socioeconomic impacts that could be associated with the geothermal resource development.

Methodology. Available descriptive socioeconomic data was collected from federal and state government sources, regional university departments, and special reports dealing with the Raft River socioeconomy. Projections of future activity in the absence of geothermal development were analyzed and related to existing socioeconomic conditions. Areas where significant changes in structure would occur were identified. The attitudes and perceptions of area residents were measured through a mail survey designed to assess public opinion priorities and identify the tradeoffs area residents were willing to make. Employment, population, and income multipliers were developed and used to provide economic and demographic projections during both construction and operation for three alternative levels of geothermal development.

Results and Discussion. Agriculture is the primary source of employment in Cassia County. Eighty-six percent of all business establishments, representing 90% of all receipts, are concentrated in the Burley area. Retail and service establishments in the remainder of the county are limited to service stations, restaurants, and small food stores.

Per capita income for Cassia County in 1977 was $4982 compared with an average per capita income of $5350 for Idaho. Cassia County accounted for 2% of total Idaho income. Total employment for the county was just short of 10 000. Farm proprietors and farm workers composed 23% of total county employment. The unemployment rate for the county averaged approximately 5%.

Clearly, the Cassia County economy is based primarily on production and processing of agricultural products. Among Idaho counties, Cassia County ranks second in the production of wheat and barley, third in sugar beets, and fourth in potatoes. The main products in the southern part of the county are livestock and feed grain; potatoes and sugar beets are the primary crops in the northern portion of the county.

Any significant industrialization in the Raft River area would increase the nonfarm job opportunities and, therefore, should increase the number of farmers reporting off-farm work. The hourly wage for all hired farm workers averaged $3.15 in 1978; this relatively low wage suggests that currently employed farm workers may respond quickly to the higher wages offered by nonagricultural industry. Excepting the technical and senior administrative positions, most jobs associated with geothermal development would be filled by the local labor pool, thus minimizing the potential labor force influx and associated impacts.

At least part of the cropland is irrigated on nearly 90% of the farms in the county. Irrigation water was applied to more than 80 900 hectares in 1974, or about 144 hectares per farm. Because of a moratorium on development of new groundwater sources in the Raft River Valley (see Snake River Basin Report Section), any significant industrial development requiring substantial quantities of water (such as a significant electrical power-producing project) would have to bid water away from agricultural users.

In September of 1979, citizens of the communities of Albion, Malta, Elba, and Almo were surveyed to assess their opinions of the communities they live in and of potential changes to those communities that could result from geothermal development in the Raft River Valley. In general, area residents are relatively satisfied with the quality of life in their community. They would, however, like an increase in the range and quality of public and private services and an increase in employment opportunities.

Over 40% of 115 respondents indicated they would be available for full-time, year-round employment; this implies a fairly substantial labor pool in the immediate vicinity. Residents indicated they are willing to commute significant distances to obtain employment opportunities; however, soaring gasoline prices since the survey could modify that response. Area residents generally favor developing the area's geothermal resources and the attendant industrialization. Few residents oppose this potential industrialization, provided consideration be given to the people of the area and the environment.

Future Research. Continuation of the study in 1980 will develop more comprehensive and detailed impact predictions associated with geothermal resource development in the southern portion of Cassia County. Specific research objectives will be identification of employment options associated with geothermal development, assessment of the impacts of the projected population influx, and creation of a set of realistic development scenarios reflecting the socioeconomic impacts associated with projected resource development.

Fluorosis

Introduction. High fluoride concentrations in domestic water supplies are a potential hazard to both humans and animals because high fluorine levels adversely affect tooth development during the period of formation and calcification. Humans are susceptable to development of fluorosis from the time of birth until age 16, with years from 2 to 10 the most critical. Low levels of Fl^- in water are helpful and may strengthen teeth, but excessively high levels are hazardous. Fluorosis symptoms include discolored teeth, rapid wear, and erosion of enamel from dentine.

In 1978, a study was conducted to determine the incidence and geographic distribution of human dental fluorosis in the general vicinity of the Raft River geothermal area. An attempt was made to correlate fluoride content of culinary water supplies with the incidence of human dental fluorosis. No further study was conducted in 1979.

Methodology. Oral examination of 270 children were made by a practicing dentist with a long time professional interest in water fluoridation. The fluoride contents of 46 culinary water supplies were analyzed for correlation with the dental health of the children who drink the water.

Results and Discussion. Dental anomalies were found in 132 out of 270 children; of these, 52 had lesions typical of fluorosis. These figures represent an unusually poor level of dental health.

Several paradoxes exist in these data. Of the 52 children determined to exhibit fluorosis symptoms, 11 (21% of the affected children) only recently moved to the Raft River Valley; consequently, the problem source for these people was not local. Since fluorosis symptoms may resemble those associated with a number of other problems occurring during tooth formation (such as use of some antibiotics, certain diseases, high fevers, and trauma), the source of the dental lesions was not apparent.

Another unexpected result was the low correlation between dental fluorosis and fluoride content of the Raft River culinary water supply. The water samples collected from 46 drinking wells averaged 0.72 mg/l Fl^- with the EG&G analysis and 0.54 mg/l with the Utah State University analysis. The literature indicates that these levels would not cause fluorosis in teeth; in fact, 1 mg/l is the drinking water fluoride level recommended by the American Dental Association and the American Medical Association.

Two possibilities exist that may help account for the otherwise unexplained dental fluorosis. First, the population may be receiving high fluoride levels from some source other than the drinking water. If the people are not obtaining fluoride from the water, there are few alternatives. Plant roots, in general, discriminate against fluoride uptake; however, the leaves may absorb fluoride from the air or from sprinkle irrigation. In general, irrigated plants are used for cattle forage, and are not directly consumed by people. Since fluoride concentrates in bone rather than flesh, consuming the cattle would not transfer any significant amount of fluoride to humans. Therefore, it appears unlikely that people are obtaining fluoride from the plants and animals they raise, unless a large garden is maintained.

The second possibility is that children are obtaining fluoride while moving irrigation pipes. Although fluoride is not absorbed through skin, it may be brought into the body by inhalation of moist air. Irrigation water in the Raft River Valley has much higher fluoride levels (5-10 mg/l) than the acceptable 2 mg/l federal drinking water standard. A correlation should be run between dental health and student occupation to check this hypothesis. Additionally, the milk produced at local dairy farms should be checked for fluoride concentration.

Future Research. Analysis of fluoride concentration in culinary and irrigation wells will continue during 1980. Milk produced on dairy farms in the valley will be analyzed for fluoride concentration. In addition, the possible correlation between fluorosis and the frequency of childrens' exposure to irrigation water will be tested. These studies will help establish the current fluoride levels in the Raft River Valley water resources and its effects on the human and livestock population. This research will also provide baseline data to serve as a reference in monitoring possible future changes in fluoride concentrations caused by development of the geothermal resource.

SNAKE RIVER BASIN REPORT

Introduction

The Snake River Basin Overview Program, completed in 1979, provides environmental baseline data for the eight known geothermal resource areas (KGRA's) in the Snake River drainage basin (Figure 11). Air quality, demography, geology, heritage resource, hydrology, land use, meteorology, seismicity, socioeconomics, soils, subsidence, terrestrial and aquatic ecology, and water quality were assessed

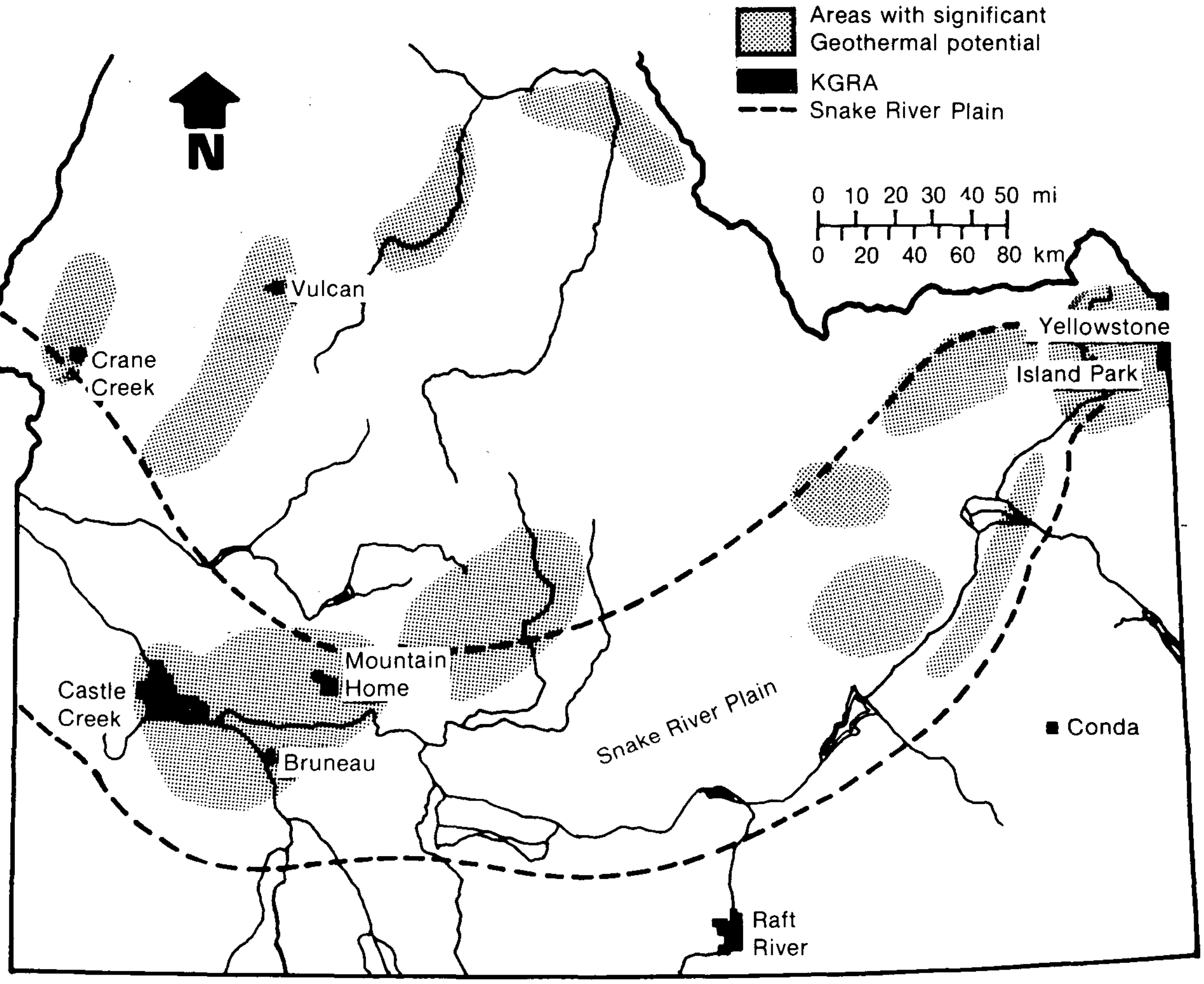

Figure 11. Locations of known geothermal resource areas in the Snake River Basin.

to obtain a sound data base prior to potential geothermal development. These data serve as planning tools for environmental and land management agencies, as a reference to shorten and simplify project environmental evaluations, and as an aid to identifying significant environmental concerns for each KGRA.

In addition, two public workshops were held during the initial phases of the program that identified and discussed public concerns and potential environmental impacts related to geothermal development. This section provides a brief summary of the primary environmental concerns relating to geothermal development in each KGRA.

Methodology

Regional universities and environmental consulting agencies were contracted to evaluate the existing environmental data and to identify areas of potential concern. A steering committee, consisting of representatives from state and federal agencies, public interest groups, and national laboratories, was established to serve as program consultants and reviewers. Public input through workshops was incorporated throughout the project.

Result and Discussion

Vulcan Hot Springs. This 1552-hectare KGRA is part of the Boise National Forest. The topography is rugged; the primary land uses include timber production, watershed maintenance, and recreation. Estimates of subsurface water temperature are 135°C (quartz) and 147°C (Na-K-Ca). With the exception of the fluoride content, the quality of the fluids is excellent.

The data appear to indicate a relatively high likelihood of an occasional earthquake of magnitude 7 or greater within 25 km of the KGRA, but the data are not sufficient to determine any recurrence interval. This KGRA includes two prehistoric lithic scatters found in the creek bottoms. Because of the historic frequent use of the area by Indians, additional cultural sites are probably present.

An elk calving ground, located in the meadow habitat, and a mule deer migration route exist within the KGRA. Salmon spawning grounds in the South Fork of the Salmon River are located at Stolle Meadows near the northern boundary of the KGRA. Any disturbance of the highly erodible granitic soil in this area could cause heavy siltation, thus destroying spawning habitat and adversely impacting the salmon runs. The Idaho Department of Fish and Game holds a 0.57-m^3/s water right on the South Fork for a salmon egg gathering facility just downstream of the KGRA. Any impact on the water quality and flow of the South Fork would affect this effort.

Crane Creek. Of the 1757 hectares included in the Crane Creek KGRA, 1311 are controlled by the Bureau of Land Management (BLM); the remaining lands are privately owned. Ninety two percent of the KGRA is used as rangeland and 8% as irrigated cropland. Estimated geothermal temperatures are 166°C (Na-K-Ca) and 176°C (quartz) with some reservoir temperature estimates exceeding 180°C. Based on this estimated reservoir temperature, the Crane Creek KGRA is one of the two hottest resources in Idaho. The Idaho Department of Water Resources has classified the area as a Designated Geothermal Resource Area, thus protecting the geothermal potential of the area from exploitation and waste.

The shallow Idaho Group of rocks of the area appear to be susceptible to subsidence, although no subsidence has been previously documented in the KGRA. No archaeological survey has been conducted in the Crane Creek area; however, findings elsewhere in the county suggest a high probability for prehistoric sites within the KGRA.

Castle Creek. The Castle Creek KGRA is the largest in Idaho (32 236 hectares) and is located along the Snake River in Owyhee County. The majority of the land is controlled by the BLM and is used as rangeland. Approximately 2400 hectares of the KGRA overlaps the 333 000-hectare Snake River Birds of Prey Natural Area (BPNA), which was established in 1971 to protect one of the most concentrated raptor populations in the world.

Geothermal leases are granted on nine units and total 8470 hectares. The U.S. Geological Survey estimates that 450 x 10^{18} J of heat are contained in a reservoir underlying 14 800 hectares of land, which is enough to supply the total energy requirements of the United States for about 2.5 years. Thermal water is currently extracted from over 100 wells. A bottomhole temperature of 108°C at 2670 m is the most accurate available. Water from sedimentary aquifers is generally higher in total dissolved solids (555 mg/l) and low in fluoride levels (5.8 mg/1), while the water produced from volcanic aquifers is high in fluoride levels (20.7 mg/1) but low in total dissolved solids (330 mg/1).

The unconsolidated and semiconsolidated rocks found in the Castle Creek area have proven to be susceptible to subsidence. A decline in shallow ground water levels could be initiated or accelerated by production of deeper geothermal water.

The BPNA provides crucial nesting and hunting habitat for well over 1000 eagles, falcons, hawks, and other birds of prey. In 1978 the BLM initiated a study to identify additional lands necessary to sustain this unique raptor ecosystem. Based on the findings of this study, the BLM specified 209 000 hectares of public land within and adjacent to the Snake River Canyon as additional critical raptor habitat. In mid-1979 these research findings were submitted to the Secretary of the Interior for consideration and action.

Limited archaeological surveys have identified 46 known sites within the KGRA, most of which are in the Snake River Canyon. These include villages, campsites, quarries, rockshelters, and lithic scatters.

Bruneau. The Bruneau KGRA is located in eastern Owhyee County on the Bruneau River. Of the 2072 hectares in the KGRA, 1052 are administered by the BLM. The Bruneau River Canyon is considered the steepest in the United States and is being reviewed for Wild and Scenic River status. Fluoride levels are high (9 mg/1) in thermal waters, even when total dissolved solids are low. Temperatures at current well sites range from 38 to 47°C.

Underlying fault zones appear active, although historic records indicate the area is relatively aseismic. Geothermal development could result in subsidence if the geothermal system is connected to shallower aquifers of unconsolidated sediment. A total of 0.41 m^3/s is appropriated from wells within the KGRA. Conflicts with water rights established for irrigation activity could occur if significant geothermal development occurs.

The KGRA lies on the eastern edge of the Birds of Prey Natural Area impact zone. Raptors utilize the Bruneau Canyon and could be adversely affected by development significantly encroaching upon their nesting and hunting habitat.

Known archaeological sites are limited to one small campsite near the mouth of the canyon at the southern edge of the KGRA.

Mountain Home. The Mountain Home KGRA is located several miles east of Mountain Home in Elmore County. The current land uses on this 3853-hectare KGRA consist of grazing on the BLM lands and forage production on farmlands in the stream valleys. Limited information is available on the geothermal resource potential. Temperatures at two wells average 65°C, although hotter water at greater depth is possible.

This KGRA includes sage grouse strutting grounds and winter range habitat of the mule deer. The soils of the area are subject to erosion on disturbed sites with slopes exceeding 2%.

Raft River. The Raft River KGRA encompasses 1175 hectares and is the most studied geothermal area in Idaho. To date, seven production and injection wells have been drilled which tap water as hot as 150°C. A primary objective of the research is to demonstrate the feasibility of using moderate-temperature fluids to generate power with binary cycles. Numerous direct-application experiments have been conducted in conjunction with the construction and proposed operation of a 5-MW(e) pilot power plant.

Subsidence of as much as 0.8 m has been detected in the lower end of the Raft River Valley and is thought to be a result of water level declines of as much as 30 m due to irrigation pumping. Geothermal development may cause subsidence, particularly if that development affects water levels in the shallow, unconsolidated aquifers. Primary concerns of geothermal development at this KGRA are the effects on the water supply and quality in the shallower aquifers that have been developed for irrigation.

The Raft River Basin was closed in 1963 to further appropriation of groundwater because of declining water levels in the lower end of the valley. Irrigation wells in the vicinity of the geothermal area show the influence of upward leakage from the geothermal resource. Temperature, fluoride, and total dissolved solids increase significantly in these wells. The quality of wells to the east and west of the geothermal area is relatively good with total dissolved solids averaging 650 mg/l.

Six species on the BLM's sensitive wildlife list are known to inhabit the KGRA. Of these, the ferruginous hawk merits the most consideration because it is extremely sensitive to human disturbance during nesting and is prone to nest desertion.

Seven archaeological sites have been located in the KGRA. The presence of six sites within a 2.5-km stretch of the Raft River indicates a high density site area. There is a good possibility that additional subsurface sites exist.

Island Park/Yellowstone. These two KGRA's are located within the boundaries of the area that the U.S. Forest Service (USFS) has classified as the Island Park Geothermal Area (IPGA). The Yellowstone KGRA contains 5730 hectares and borders Yellowstone National Park on the west. The Island Park KGRA consists of scattered parcels in the center of the region. The majority of land is administered by the USFS and the BLM; the remainder are private lands with mineral rights reserved by the Federal Government.

Limited information is available on the geothermal potential of this area. The general absence of hot springs indicates an old system; resistivity data imply that the caldera has cooled. Concern has been expressed about the possibility of affecting the thermal features of Yellowstone Park by developing the geothermal resource along the park boundary. A firm commitment is held to protect the geysers and associated features of the park.

A number of wildlife species living in the area merit special concern because they are considered by the U.S. Fish and Wildlife Service as declining, threatened, or endangered. These include the grizzly bear, timber wolf, lynx, wolverine, ferruginous hawk, peregrine falcon, and bald eagle. Intense development near the park boundary impacting the scenic aesthetics would undoubtedly arouse adverse public opinion.

Conda. The Conda KGRA was officially designated as such after completion of the overview phase of the Snake River Basin study. Consequently, no environmental review of this 1039-hectare area is included in the Snake River Basin Report.

Geothermal Workshops. Two public workshops were held in Boise, Idaho; the first on July 20, 1978, and the second on January 9 and 10, 1979. The workshops dealt with the geothermal leasing policy of federal agencies, the geothermal resource potential in Idaho, and the various environmental concerns and impacts to be considered during resource development planning.

Volume I of the Snake River Basin Overview summarizes the findings of the environmental analysis at each KGRA on the Snake River Basin. Volume II of the Snake River Basin Environmental Overview presents a bibliography of materials pertinent to the KGRAs. Cross-referencing is available for those references applicable to specific KGRAs. Detailed information for the KGRAs is continued in the following reports:[a]

EGG-GTH-5001	-	Vulcan Hot Springs KGRA: An Environmental Analysis
EGG-GTH-5002	-	Crane Creek KGRA: An Environmental Analysis
EGG-GTH-5003	-	Castle Creek KGRA: An Environmental Analysis
EGG-GTH-5004	-	Bruneau KGRA: An Environmental Analysis
EGG-GTH-5005	-	Mountain Home KGRA: An Environmental Analysis
EGG-GTH-5007	-	Geothermal Development in Southwest Idaho: The Socio economic Data Base
EGG-2001, Vol. 1	-	Potential Use of Geothermal Resources in the Snake River Basin: An Environmental Overview
EGG-2001, Vol. II	-	Potential Use of Geothermal Resources in the Snake River Basin: An Environmental Overview - Annotated Bibliography

These reports are available from:

EG&G Idaho, Inc.
WCB, E-3
Box 1625
Idaho Falls, ID 83415

a. An environmental analysis of potential geothermal development in the Island Park and Yellowstone KGRA's is presented in the "Final Environmental Statement of the Island Park Geothermal Area," U.S. Department of Agriculture, Forest Service, and U.S. Department of Interior, Bureau of Land Management. A separate volume for these KGRA's will not be presented as part of this series.

ACKNOWLEDGMENTS

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REFERENCES

1. L. E. Felix, "Geology of the Eastern Part of the Raft River Range, Box Elder County, Utah," *Guidebook to the Geology of Utah, 11*, 1956, pp 76-96.

2. R. L. Armstrong, "Mantled Gneiss Domes in the Albion Range, Southern Idaho," *Geological Society of America Bulletin, 79*, 1968, pp 1295-1314.

3. F. F. Cunningham, "The Silent City of Rocks, A Bornhardt Landscape In The Cotterel Range, South Idaho, U.S.A.," *Zeitschrift Ever Geomorphalogie, 15*, 1971, pp 404-429.

4. D. R. Mabey, "Reconnaissance Geophysical Studies of the Geothermal System in Southern Raft River Valley, Idaho," *Geophysics, 43*, 1978, pp 1470-1484.

5. K. S. Kennedy, *Environment of Deposition of the Upper 300 Meters of Sediments of the Raft River KGRA*, EG&G Idaho, Inc., PG-G-80-026, 1980, p 39.

6. J. L. Coffman and C. A. von Heke, *Earthquake History of the United States*, U.S. Department of Commerce, NOAA Environmental Data Service Pub 41-1, 1973.

7. D. B. Slemmons, A. E. Jones, J. I. Gimlett, "Catalogue of Nevada Earthquakes, 1852-1960," *Bulletin Seismology Society of America, 55*, 2, 1965.

8. A. H. Dahl and B. D. Johnson, "Preliminary Results of a Microseism Study for the Region Around the Snake River Plain (1973-March 1974)," Presented to the Idaho Academy of Science, Ricks College, Rexburg, ID, April 19-20, 1974.

9. B. E. Lofgren, *Land Subsidence and Tectonism—Raft River, Idaho,* U.S. Geological Survey Open File Report, 1975, pp 75-585.

10. R. R. Olendorff and J. R. Stoddard, Jr., *The Potential for Management of Grassland Raptors*, pp 47-99, cited in: F. N. Hamerstorm Jr., B. E. Harrell, R. R. Olendorff (eds.), *Management of Raptors*, Raptor Research Report No. 2, Vermillion, South Dakota, 1974, p 146.

11. R. W. Fyfe and R. R. Olendorff, *Minimizing the Danger of Nesting Studies to Raptors and Other Sensitive Species*, Canadian Wildlife Service, Occ. Paper 23, 1976, p 17.

12. N. D. Woffinden and J. R. Murphy, "Population Dynamics of the Ferruginous Hawk During a Prey Decline," *Great Basin Naturalist, 37*, 1977, pp 411-425.

13. American Birds, "The Blue List for 1974," *American Birds, 27*, 1974, pp 943-945.

14. L. R. Powers, R. P. Howard, C. Trost, "Population Status of the Ferruginous Hawk in Southeastern Idaho and Northern Utah," pp 153-157, cited in: J. R. Murphy, C. M. White, B. E. Harrell, R. R. Olendorff (eds.), *Status of Raptors*, Raptor Research Report No. 3, Vermillion, South Dakota, 1973.

15. R. P. Howard, *Breeding Ecology of the Ferruginous Hawk in Northern Utah and Southern Idaho*, Unpbl. M.S. Thesis, Utah State University, Logan, UT, 1975.

16. F. E. Croxton, D. J. Cowden, S. Klein, "Applied General Statistics," Englewood: Prentice-Hall, Inc., 1967.

17. D. E. Busch, W. A. deGraw, N. C. Clampitt, "Effects of Handling Disturbance Stress on Heart Rate in the Ferruginous Hawk (*Buteo regalis*)," *Raptor Research, 12*, 1979, pp 122-125.

18. D. W. Hayne, "An Examination of the Strip Census Method for Estimating Animal Populations," *J. Wildlife Management, 13,* 1949, pp 145-157.

19. J. E. Gross, L. C. Stoddart, F. H. Wagner, "Demographic Analysis of a Northern Utah Jackrabbit Population," *Wildlife Monographs, 40*, 1974, pp 1-68.

20. F. S. L. Williamson, M. C. Thompson and J. Q. Hines. Avifaunal Investigations," N. J. Willimousky and J. N. Wolfe (eds.), cited in: *Environments of the Cape Thompson Region, Alaska*, USAEC Report PNE-481, 1966 p 437-488, .

21. C. M. White, F. S. L. Williamson and W. B. Emison, "Avifaunal Investigations," (in press). cited in: *The Environments of Amchitka Island, Alaska,* M. L. Merrit and R. G. Fuller (eds.), USAEC/TID 26712, Oak Ridge, Tennessee, 1977.

APPENDIX

RAFT RIVER ENVIRONMENTAL INFORMATION REPORTS

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A. Bishop and H. Peterson, *Fluoride and Soils in the Raft River Geothermal Area*, unpublished report to DOE-Idaho Operations Office from Utah State University (1976).

R. Clark, *Aquatic Flora of the Raft River*, unpublished report to EG&G Idaho, Inc. from Ricks College (1976).

S. Findholt, *Baseline Ecological Data for Geothermal Development in the Raft River Valley, Idaho*, unpublished report to DOE-Idaho Operations Office from Idaho State University (1977).

J. A. Goodnight, *Community Impact Assessment of a Diversified Geothermal Energy Project Proposed for the Raft River Valley, Idaho*, unpublished report to DOE-Idaho Operations Office from Battelle Human Affairs Research Center (1977).

C. D. Jorgensen, C. M. White, C. L. Pritchett, *Raft River Environmental Studies*, unpublished report to DOE-Idaho Operations Office from Brigham Young University (1977).

C. D. Jorgensen and G. F. Knowlton, *Arthropods of the Raft River Geothermal Study Site Area*, unpublished report to DOE-Idaho Operations Office from Brigham Young University (1976).

L. H. Kumamoto, *Microseismicity Investigation of the Raft River Valley, Idaho*, unpublished report to DOE-Idaho Operations Office from Colorado School of Mines (1976).

W. C. Lewis, *The Socioeconomic Environment of Cassia County, Idaho and Preliminary Impact Projections of Geothermal Resource Development at Raft River,* EG&G Idaho, Inc., (1979).

A. G. Morilla and D. R. Ralston, *Preliminary Assessment of the Feasibility of Using a Shallow Ground-Water System for the Cooling Cycle of a Geothermal Power Plant*, unpublished report to DOE-Idaho Operations Office from University of Idaho (1975).

G. M. Neudorfer, *Archaeological Resources of the Southern Raft River Valley*, unpublished report to DOE-Idaho Operations Office from Idaho State University (1975).

J. L. Shupe, A. E. Olson, J. B. Peterson, *Incidence of Human Dental Fluorosis in the Raft River Area in Southern Idaho*, unpublished report DOE-Idaho Operations Office from Utah State University (1978).

S. G. Spencer, N. E. Stanley, W. W. Hickman, *Environmental Report, Raft River Thermal Loop Facility*, unpublished report by EG&G Idaho, Inc. (1977).

S. G. Spencer, J. F. Sullivan, N. E. Stanley, *1978 Annual Report, INEL Geothermal Environmental Program*, TREE-1340, (1979).

R. L. Speth, *A Density and Neutron Activation Analysis Study of the Aquatic Invertebrates in the Raft River Near the Geothermal Site*, unpublished report to EG&G Idaho, Inc. from Ricks College (1976).

R. L. Speth, L. D. Weber, O. D. Simpson, "Trace Element Deposition in Samples Collected from the Raft River Geothermal Site Using Neutron Activation Analysis," *Journal of the Idaho Academy of Science*, 12 (1976) pp 33-45.

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a. Available from Biological and Earth Sciences Branch, EG&G Idaho, Inc., Box 1625, Idaho Falls, ID 83415.

W. O. Ursenbach, W. H. Edwards, J. S. Allan, *Baseline Air Quality and Vegetation Studies in the Raft River Valley, 1975-1977*, unpublished report to DOE-Idaho Operations Office from Unviersity of Utah Research Institute (1978).

Geology and Geophysics of the Southern Raft River Valley Geothermal Area, Idaho, USGS 75-322 (1975).

E. H. Walker, *The Raft River Basin, Idaho-Utah as of 1966: A Reappraisal of the Water Resources and Effects of Ground-Water Development*, Idaho Department of Water Resources, Bulletin 19 (1970).

C. M. White, T. L. Thurow, J. F. Sullivan, "Siting Criteria as a Function of Sensitivity of Nesting Ferruginous Hawks to Geothermal Development," *Proceedings, DOE Control Technology Symposium, Washington, D.C., November 27 to 30, 1978.*