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Subject: Re: EG&G Idaho Geothermal Reports
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Subject EG&G Idaho Geothermal Reports

Dale,

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Thanks ahead for your help,
Patty

Patty Simmons

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Report No. SD-E-82-004
Date: June 1981

Internal Technical Report

GEOHERMAL WETLAND RESEARCH
TEST PLAN FOR FY-1982

R. P. Breckenridge
P. A. Pryfogle

Earth and Life Sciences Office

Funded Through

Energy Programs Division
EG&G Idaho Technical Development
Program 811

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FY-82 GEOTHERMAL WETLAND RESEARCH PLAN

1. INTRODUCTION

Wetlands comprise a valuable national resource. At one time wetlands were only considered wastelands; however, increased pressure for the use of these lands has stimulated many suggestions for wetland use. For example, the potential of using wetlands for treating wastewater, in contrast to merely using them as dumps, has attracted the attention of engineers, administrators and researchers (Toubier and Pierson, 1976). As is often the case with such intriguing ideas, there is a risk that operational systems of waste disposal will be implemented on a large scale before the effects of such utilization are understood. A literature study conducted for the Fish and Wildlife Service (CH₂M Hill, 1981) concluded that spent geothermal fluids could be used to create or enhance waterfowl wetlands. However, the point was also made that a general lack of directly applicable information exists in the literature for defining effluent criteria and specific uses of wetlands for geothermal effluent disposal.

One of the concerns over using wetlands for treatment of geothermal water is its economic feasibility. In the Fish and Wildlife Service study (CH₂M Hill, 1981) it was concluded that for general cost comparisons of subsurface injection versus wetlands construction, injection would be favored for cases of high effluent flows and zero discharge requirements. If variances from the zero discharge requirement could be secured, wetlands construction would become economically attractive, especially in the arid west.

Wetland plants are an important source of vast quantities of biomass for energy conversion (Chaney, et al., 1981). They are among the most prolific plants on earth and are established throughout the United States. Many species are well suited for cultivation and are presently an unexploited resource which usually does not compete with other human activities.

The productivity of many aquatic macrophytes has been studied (Boyd, 1970a; Keefe, 1972; Andrews and Pratt, 1978; Good et al., 1977). Emergent species (cattails, bulrush and reeds) are typically more productive than submerged species, as the emergent species exhibit vertical leaf arrangements which minimize self shading while, at the same time, provide a high leaf area index for maximum solar collection and conversion.

Harvesting and handling wetland plants from natural water bodies is an expensive and labor intensive task. Thus, if aquatic macrophytes are to be considered as an economic energy source, the plants will probably have to be grown in an area modified to accommodate mechanical harvesting equipment. Therefore, the most practical approach in developing systems which grow aquatic plants is probably to use a cultivated system where the water can be regulated during planting and harvesting, much in the same way rice paddies are managed.

Biomass from wetland plants is typically low in lignin which makes it desirable as a cellulosic ethanol feedstock or for anaerobic digestion to methane. The energy conversion potential of aquatic biomass can be maximized by timing harvest operations to match the highest concentrations of dry matter and carbohydrate in the plant tissues.

2. PROJECT BACKGROUND

The Life Sciences Branch of EG&G Idaho, Inc. has been funded through the Energy Program Division, EG&G, Idaho, Technical Development Program 811 to evaluate the potential of developing a wetland using geothermal water. The project was initiated during the summer of 1979. At that time, eighteen species of wetland macrophytes indigenous to the Great Basin were screened for their ability to adapt to geothermal water. In 1980, the program was expanded to include non-native plants adapted to warm water. Chemical analysis of dry plant material (Breckenridge, Cahn, and Thurow, 1982) provided information on the peak concentrations of elements bioaccumulated by the plants. The impetus of the 1981 study was to evaluate water quality changes in an indoor controlled laboratory and determine if an outdoor man-made wetland could be developed.

During May and June of 1981, an indoor and outdoor wetland system was established at the Raft River geothermal site. The indoor system was comprised of sixteen 113.5-liter aquaria divided into half so that a static and plug-flow method could be evaluated. The outdoor system consists of a quarter hectare (ha) area divided into two 47 x 30 m ponds. The upper pond is 1.2 m deep and planted with submerged species (Egeria and several species of pondweed); the lower pond is 15 cm deep and planted with emergents (primarily cattail and bulrush with a small area of common reed).

Results from the 1981 research (Breckenridge, Cahn and Thurow, 1982; Breckenridge, Cahn and Pryfogle, 1982a) have shown that selected aquatic plants can accumulate significant concentrations of elements from a geothermal wetland system. Results from the indoor study showed that water quality can be improved if evapotranspiration can be controlled or reduced. This effect was also noted for the outdoor system; however, for this system the large exposed surface area resulted in a higher evaporation rate which caused a greater degradation in water quality. Even though the outdoor system was not established until June of 1981, water quality was better in the areas of the wetlands where plants were established in the

water as compared to the control pond that had no plants. Preliminary results from the partial growing season have shown that man-made geothermal wetlands have good potential as biomass production systems.

3. OBJECTIVES OF THE FY-82 STUDY

Results from the FY-81 research confirmed earlier findings that aquatic plants can accumulate elements from geothermal water. Productivity results for cattail and bulrush were promising considering the fact that FY-81 was the first year for the outdoor system, and that the wetland was not planted until June. Objectives of the FY-82 research will be to determine productivity and water purification values for a full growing season. These objectives will be accomplished by:

- o Using a mass balance approach to evaluate the movement of chemicals within and through the geothermal wetland system.
- o Determining biomass production rates using the permanent reference quadrat (standing crop) technique.
- o Determining the effect of retention time on water quality.
- o Determining accumulation factors for the plants grown in the geothermal water.
- o Evaluating the algae at Raft River for its potential as a bioaccumulator, biomass producer, and feedstock for energy conversion.

4. METHODOLOGY

In order to accomplish FY-82 objectives, the study will address the following:

4.1 Chemical Cycling in Wetland Ecosystems

Numerous studies have been conducted to evaluate changes in water quality through an aquatic system (Good, et al., 1977; Dykyjova and Kvet, 1978; Boyd, 1969, 1970a; Bayly 1972a, 1972b; and Tourbier et al., 1976). In order to obtain a good understanding of chemical movement within and through a system, a mass balance approach is often considered.

4.1.1 Mass Balance Approach

The basic idea in using a mass-balance approach is to develop deterministic relationships between waste inputs to a system and the resulting water quality output. For completely mixed systems, which the geothermal wetland is assumed to be, the change in the mass of any constituent equals the mass input less the mass output less losses due to sedimentation and plant uptake. The input to the wetland system will be assumed to be at a constant rate $N, (M/T)$, and the sedimentation and uptake rates, $N, (M/T)$, will be measured by sampling throughout the summer. With this information, mass-balance equations will be written for the two week sampling period, ΔT . Other factors that will be needed in order to complete the equations are the constant volume, V , of the system (L^3), Q , the constant flow rate (L^3/T) and C , the concentration of the material within the system at the time of sampling (M/L^3). Thus, by calculating the change in concentration over time, it should be possible to account for where the greatest sink or accumulator of an element in the system will be.

When employing a mass balance approach, it is important to obtain samples from all major components of the system so that the overall distribution of an element can be evaluated. The main components of the

geothermal wetland that will be sampled during the FY-82 growing season are water, plants, soils and algae.

The chemical composition of water flowing through the wetlands has a profound effect on chemical cycling. Of the elements present in the geothermal water (Table 1), F, B, Na, Si, and Cl are of major concern. Seasonal variation in chemical composition within a wetland system is closely related to climatological conditions (Kadlec, 1976). Due to the semi-arid climate of the Raft River area, evapotranspiration is the major climatological factor influencing water purification (Breckenridge, Cahn and Pryfogle, 1982a).

Researchers concerned with the bioaccumulation potential of selected aquatic plants have shown some species accumulate mineral nutrients, organic materials, and trace metals (Boyd, 1967, 1968; Mayes et al., 1977). Based on this information, it is apparent that aquatic plants must be considered since they play an important role in chemical cycles in aquatic systems.

The soil system plays an important role in cycling elements within and through a wetland. However, the chemistry of these waterlogged soils is not well understood because obtaining representative samples is difficult and most of the chemical analysis has been done on samples that have been exposed to air (Richardson et al., 1978).

The chemical cycling processes of wetland soils are significantly different from their terrestrial counterparts. The fact that the soil is saturated results in an anaerobic state throughout the column except for a thin aerobic oxidized layer at the sediment-water interface (Ponnamperuma, 1972). The anaerobic soil column maintains ions in their reduced state while the oxidized surface layer often facilitates a sink phenomenon for many of the elements (Syers et al., 1973).

In many wetland ecosystems algal communities (microphytes) are considered inferior in importance to the macrophytes (Dykyjova and Kvet, 1978). This is usually because the spatial pattern, community structure,

and developmental dynamics of the algae communities are determined largely by the developmental dynamics of the macrophytes and existing environmental conditions. Recently however, more emphasis is being placed on evaluating algae and its influence on the total material and energy budgets of a wetland ecosystem. Thus, results from previous research and preliminary identification data collected during FY-81 will be used in the further evaluation of the algae at Raft River to determine its role in chemical cycling and use as a biomass producer.

4.2 Biomass Evaluation

4.2.1 Primary Biomass Production

Biomass data will be collected for three emergent species: cattail (*Typha latifolia*), bulrush, (*Scirpus acutus*) and common reed (*Phragmites communis*) from the lower outdoor pond (Figure 1). These three species, dominant in the lower geothermal wetland, are perennial plants with extensive systems of underground organs such as rhizomes, tillers, and roots. The original stand density was dictated by hand planting of rhizomes during wetland construction. During the FY-82 growing season, the stand will arise from existing rhizomes and/or from single-colony polycomones (plant developing from multiple seeds). The rhizomes and polycomones will extend themselves each year, occupying larger areas of the wetland (Penzes, 1960). In order to assess the rate of this type of underground development, which thus determines the amount of aboveground biomass produced, a well established biomass sampling program is needed.

4.2.2 Productivity Assessment

Emergent aquatic plants often form clusters which vary in size. The distribution of these clusters is often determined by vegetative shoot spread and/or by variations in the bottom substrate. In order to obtain a good estimate of the standing biomass, the sample area must be larger than the cluster size. The dimensions of cluster size were determined by "cluster analysis" (Greig-Smith, 1964; Kershaw, 1964); from this data,

minimum total sampling area for each species in a plot was determined to provide an accurate estimate of biomass. The values are 0.8 x 1.6-m for cattails and 0.4 x 0.8-m for common reed. Values were not available for bulrush; however, the literature suggested that a sample area of 0.4 x 0.8-m would be sufficient to eliminate bias (for more details see Ondok 1970b, 1971b). Total sampling area for the three species at the geothermal wetland will be:

Cattail	2.5 x 5.0	(m x m)
Bulrush	2.5 x 5.0	(m x m)
Common reed	0.4 x 0.8	(m x m)

4.3 Sampling Procedures

4.3.1 Vegetation

The standing permanent quadrat technique will be used to evaluate biomass production. This method will enable us to follow the seasonal dynamics of growth for each stand. Five 0.5 x 1.0-m permanent plots will be established within the monospecific cattail stand and five will be established in the bulrush stand. Because only a small area is planted with common reed, only one 40 x 80-cm plot will be established for this species. During the initial sampling period, all shoots above water level within the bulrush and common reed permanent quadrats will be counted and tagged, shoots within the cattail plots will simply be counted. Only shoots outside the permanent quadrats will be harvested. During each sampling period, three randomly chosen harvesting sites (based on a grid location) in each plant stand will be sampled. At each harvesting site, either 50 random bulrush, 25 random cattail, or 20 random common reed shoots, will be cut at the soil surface. When new shoots emerge above the water within any of the permanent bulrush or common reed quadrats, they will also be tagged and counted. Table 2 lists the dates on which samples will be collected.

The average shoot density (N), to be determined by counting all shoots above the water in each permanent quadrat, will be measured in a nondestructive manner for each sampling period. The average weight of one shoot (W) will be determined by harvesting the individual shoots at each random location (outside the permanent quadrat), drying them in an oven at 90°C for 24 hours, then weighing them and taking an average. Wet weights will be measured for some of the samples so that moisture content values for the FY-82 growing season can be compared to data from the FY-81 research. The average shoot biomass per unit stand area can then be obtained by multiplying W by N. Once the standard error is calculated for W and N, the confidence interval of the calculated stand biomass can be estimated on the basis of both the mean and variance using standard statistical equations.

Dried vegetation samples will be ground, homogenized, and sent off for analysis.

4.3.2 Water Quality

Water samples will be collected based on the schedule presented in Table 2. Four sites have been chosen for the study to characterize the water quality as it flows through the wetland. These are:

- o Q1-two composite, 1-liter samples will be collected along the influent gated supply line at the head of the upper pond.
- o Q2-two composite, 1-liter samples, will be collected in equal amounts from the five discharge pipes from the upper pond.
- o Q3-two, 1-liter samples will be collected from the right hand valve (numbered Q3) which is a composite sample from the four collection pipes from the lower pond.

- o Q4, two, 1-liter samples will be collected from the left hand valve (numbered Q4) which is the effluent pipe from the algae pond. (see Figure 1)

Immediately upon collection, the water samples will be acidified using 2 ml of concentrated nitric acid. The samples will then be sent off and analyzed for F, B, Na, Mg, Cl, Si, Ca, N, P and K.

In conjunction with collecting the water samples, pH, conductivity, temperature and dissolved oxygen will be measured in the field at each sample location.

4.3.3 Wetland Soils

The bottom sediment of the outdoor wetland is a combination of silt-loam soils, bentonite clays and coarse sand. Samples of the bottom sediment will be collected based on the schedule presented in Table 2. On each sample date, a composite grab sample will be collected by hand from each of the following sites:

- o S1, located along the inlet end of the upper pond.
- o S2, located along the outlet end of the upper pond.
- o S3, located along the inlet end of the lower pond.
- o S4, located along the outlet end of the lower pond.
- o S5, located at the inlet end of the algae pond.
- o S6, located at the outlet end of the algae pond.

The soil samples will be placed in whirl-pack bags, sealed, labeled and taken to the laboratory. At the laboratory, the samples will be oven dried, homogenized, digested, and then sent out and analyzed for F, B, Na, Mg, Cl, Si, Ca, N, P, K and percent organic matter.

4.4 Algae

4.4.1 Significance of Algal Communities

Results from previous sampling of the geothermal wetlands have shown that several areas in the pond system are able to maintain significant algal growth (Breckenridge, Cahn and Pryfogle 1982b). The algae (microphytes) are capable of performing many of the same functions as submerged and emergent vegetation and are rich in vitamins, proteins and trace elements; this makes them a potentially valuable source of nutrients to humans and other animals. Algal biomass may be used to produce methane gas through anaerobic fermentation procedures. Additionally, the algae may be used to purify wastewater streams by removing undesirable elements from the stream.

The association between algae and industrial/sanitary wastewaters has been the focus of study for a long time. In the late 1800's and early 1900's, eutrophic indices were established for several algal species (Kolkwitz and Marrson, 1908). This helped to establish the indicator organism concept; by identifying the types of algae present, the water quality of the area could be determined with some certainty. It was also determined that algae are able to concentrate materials to levels significantly above the concentration of these materials in the surrounding medium (Boyd and Lawrence, 1967; Davis and Foster, 1958; Echo and Hawkins, 1966; Hart, et al., 1979; Hendricks and Bosman, 1980; Maeda and Fujiyama, 1977; Mierle and Stokes, 1976; Suffern, et al., 1981; Trollope and Evans, 1976; Whitton, 1971). This phenomenon is known as bioconcentration and is related not only to the adsorption of materials to the outside of algal cells, but to the absorption (uptake) of the materials through the metabolic functions of the algae. Algal cultures grown with wastewaters as the primary source of nutrients could be used to remove waste components from the stream, thus purifying the water. Then, through the collection of algae, waste materials could be effectively removed from the system.

(Goldman, 1980; Oswald, 1980). Many of the algal species possess and exhibit the ability to concentrate different elements at varying rates of accumulation.

In the 1930's and 1940's, reports began to appear in the literature describing algal nutrient composition (Mazur and Clarke, 1941). Burlew (1953) produced a report, with the help of numerous researchers, that summarized the advancement of algal culture techniques. Similarly, a more recent report (Shelef and Soeder, 1980) summarized advances made since the time of Burlew. The biomass produced in large culture systems could be used as a food, nutrient source or feedstock for the production of methane gas through anaerobic digestion.

4.4.2 Evaluation of Algal Communities

In order to further evaluate the establishment of algae at Raft River, a 7.2-meter x 23.6-meter algae pond will be established and seeded with native algal species. Algal samples will be collected on a seasonal basis and when evident changes occur in the algal growth of the pond. Samples will be collected in accordance with the procedures described in the Standard Practices for the Measurement of Chlorophyll Content of Algae in Surface Waters (ASTM-Designation D-3731-79). During each sampling period, a representative number of samples will be collected, depending on the algal population. The samples will be taken to the laboratory for preparation and identification according to procedures outlined by Weber (1970).

Attempts will be made to isolate and culture several algal species previously identified as abundant in the Raft River wetlands area. Isolation and culture procedures will be similar to the ones outlined by Pringsheim (1946) and Stein (1973). Three aquaria in the indoor laboratory will be used during the algae culturing endeavor. Geothermal water will be used for the preparation of nutrient stock solutions. Samples from these cultures will be collected and analyzed to determine chemical composition and compared with control cultures grown using distilled water in the preparation of nutrient stock solutions. Standard methods will be used to determine chemical composition.

From the results of these experiments, it should be possible to determine whether or not the potential exists for the production of algae biomass for food and methane production. Following identification, a review of the literature and ongoing research will be conducted to document and compare our findings.

5. DATA REDUCTION AND ANALYSIS

Data collected during the study will be analyzed with the assistance of personnel from the computer center. A "Forms" program will be set up to facilitate easy loading of the data into a data base. Once the data base is established, the data will be analyzed statistically.

In performing an evaluation of the wetland system dynamics, correlation can often be made between chemical uptake by the aquatic plants and concentration of elements in water. The organic matter in the soil, which is typically the exchange media between the plants and the water, can often be correlated with many of the elements of concern to evaluate their movement, especially during the peak growth periods (Buckman and Brady, 1969). By using this type of approach, accumulation factors can be calculated using the following equation:

$$\text{accumulation factor} = \frac{\text{Plant tissue or soil concentration}}{\text{Water concentration}} \quad (3)$$

This type of analysis should provide information on movement and location of some chemicals in the wetlands system over the growing season.

In addition to calculating accumulation factors, the mass-balance equations discussed in section 4.1.1 will be developed and programmed into the computer so that a mass balance evaluation can be performed for chemical cycling throughout the entire growing season.

6. WORK SCHEDULE

The following schedule outlines the major tasks to be completed during the FY-82 growing season:

<u>Mid May</u>	o Outline of the FY-82 study (i.e. this test plan).o Prepare Wetland for FY-82 study.
<u>Late May</u>	o Establish biomass sampling plots for the lower wetland area.o Begin sampling program for FY-82 growing season.o Establish fish in upper pond.
<u>June</u>	o Develop algae sampling and screening program.o Establish analytical contracts with outside laboratories for soil and plant analysis.
<u>July</u>	o Develop Forms program to load data into computer data base.o Develop mass balance equations.
<u>August</u>	o Begin loading analytical results into computer data base.
<u>Late</u>
<u>September</u>	o Prepare preliminary summary report of available FY-82 growing season data.

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