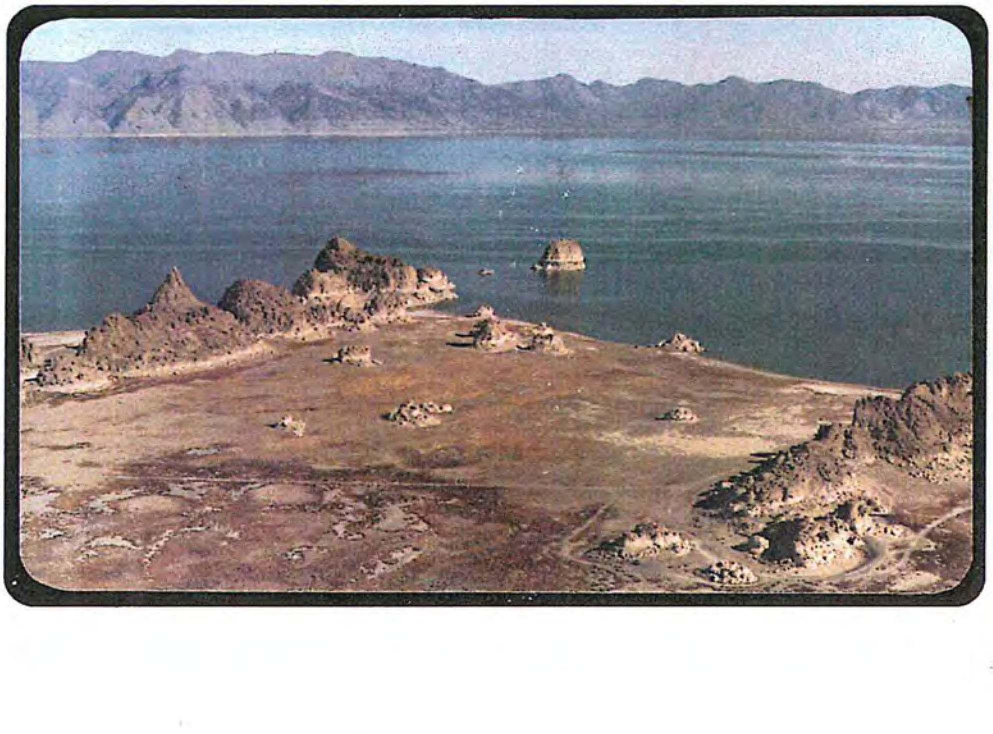
Pyramid Lake Paiute Tribe

Needles Geothermal Power Plant

PHASE I

FEASIBILITY STUDY



GEOTHERMAL DEVELOPMENT ASSOCIATES

NEEDLES GEOTHERMAL POWER PLANT

PHASE I

FEASIBILITY STUDY

Prepared for:
PYRAMID LAKE PAIUTE TRIBE
P. O. Box 256
Nixon, NV 89424
(702) 574-0140
(702) 786-5626

Prepared by:
GEOTHERMAL DEVELOPMENT ASSOCIATES
251 Ralston St.
Reno, NV 89503
(702) 322-0938

April 25, 1988

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

APPENDICES

EXECUTIVE SUMMARY

A shallow, moderate temperature geothermal resource in the range of 240 to 250°F has been partially delineated by drilling in the Needles area of Pyramid Lake. This resource is potentially capable of supporting a geothermal power plant, although further exploration and testing is necessary to thoroughly define the extent and capacity of the resource. Current estimates, based on limited data, suggest that the resource could support at a 24 megawatt power plant for 30 years or more.

The largest power plant that can be built without major investment in new power lines however, is 2.5 MW. A plant of this size could supply the average electricity requirements of 2,500 homes. Based on the assumption of a 240°F resource, three production wells will be needed to supply geothermal fluid for the power plant. Two injection wells will be required to return the spent fluid back to the geothermal reservoir. The power plant itself may consist of one or two skid-mounted units, contained within a low-profile building. The entire project can be completed in less than a year, provided there are no unforeseen delays.

Sierra Pacific Power Company is the most likely customer for the electricity, although other alternatives exist. The economic analysis presented in this study assumes that Sierra will be the customer. A power contract must be negotiated with Sierra, and a detailed interconnection study will be required. Regardless of where the electricity is sold, power lines will have to be extended and upgraded to reach the Needles.

Resource exploration and wellfield development is expected to cost $900,000. Power plant construction costs and utility interconnection are estimated at $4,500,000. The total cost of the project is thus approximately $5,400,000. A 2.5 MW plant may provide an estimated net annual income to the Tribe of $175,000, from annual revenues of $1,070,000 during the early years of the project. Fifteen years later, the annual revenues are expected to escalate to $1,665,000 and debt financing will be retired, leaving a net annual income of $1,300,000.

The chief environmental concerns are (1) the visual impact of the plant, (2) the noise created by the plant, and (3) emissions from the plant.

The Needles area is a quiet, scenic, unpolluted natural resource, which must be protected. Therefore the project should be designed and located so that it will have minimal impact on the surrounding area. Pipelines can be buried, and noisy equipment enclosed to avoid adverse impacts. The power generation process that is most appropriate for the Needles is a closed cycle, which has no emissions except heat under normal operating conditions. The dissipation of waste heat is of concern, but the calculations performed as part of this study indicate that the impact to the lake will be minimal, and may even be positive.

Other potential uses for the geothermal resource include greenhousing, aquaculture, and recreation. Each of these can be implemented using the same geothermal fluid over and over in progressively cooler stages. Such a cascade of applications maximizes the efficiency of use of the resource. No attempt was made in this study to model the economic performance of any direct use project. However, experience has shown that direct use projects generally do not have as positive an economic outlook as does power generation. Any such project should be considered after a power plant is constructed, on-line, and profitable.

During peak construction, the project may employ 20 or more people. During operation, a permanent staff of from two to four people will be required for day-to-day operations and routine maintenance.

The findings of this study are very positive. It is the recommendation of GDA that the project be pursued further. The next phase of the project should be further exploration of the resource, and initiation of power contract negotiations.

1.0 INTRODUCTION

There have been a number of successful commercial, small-scale, geothermal power plants commissioned in Nevada and neighboring states during the past three years. The economic climate for additional, similar projects is present today.

A preliminary examination undertaken in 1986 by Geothermal Development Associates, recognized the potential for developing The Needle Rocks (Needles) geothermal resource located at the northern end of Pyramid Lake (Figure 1.1). This provided the impetus for the Tribe and GDA to enter into an agreement to study project feasibility. It was recognized at the outset by the Tribe and GDA that the Needles is scenic and environmentally sensitive, and that any planned development must be aesthetically and environmentally acceptable.

This report, Phase I - Feasibility Study, provides the findings and recommendations of GDA to the Tribe regarding the viability of the Needles project. The report represents a comprehensive review and assessment of the resource, small-scale power plant technology, the electricity market and distribution system, project economics, environmental concerns, and a limited discussion of direct use of the geothermal energy. Each of these topics are presented in separate sections of the report. Each section draws on GDA's experience and knowledge of the geothermal industry, and a comprehensive review of available documentation. Original site specific field work and research also contributed significantly to the project assessment.

This report is the first of a series of steps that are necessary for successful completion of the project. The next steps are:

Phase II - Resource Exploration
Objective: reservoir flow and temperature confirmation

Phase III- Wellfield Development
Objectives: wellfield financing; production and injection well drilling; reservoir testing; power sales agreement with utility

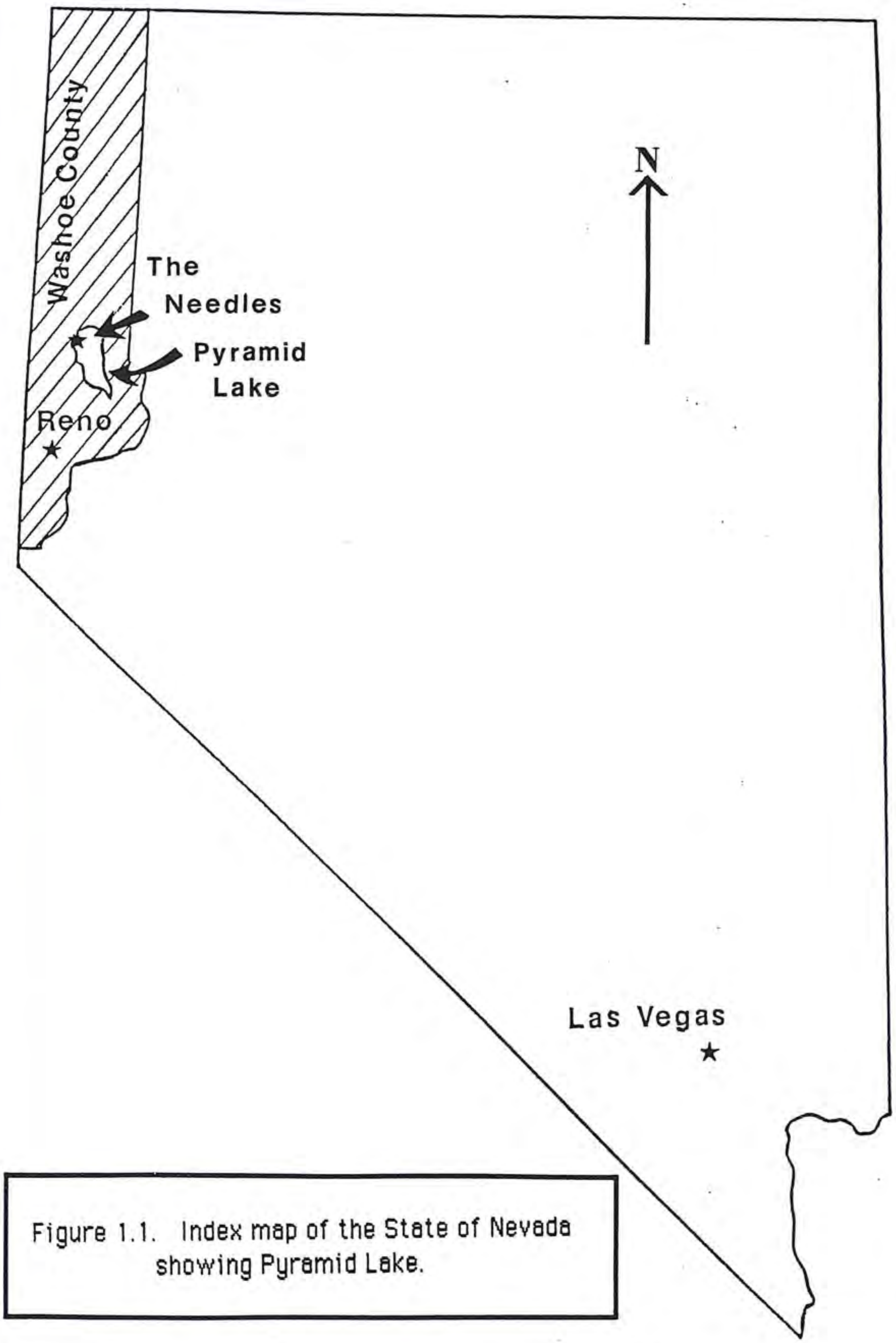


Figure 1.1. Index map of the State of Nevada showing Pyramid Lake.

Phase IV- Power Plant Construction
Objectives: power plant financing; power plant construction; power plant acceptance testing and commissioning

Phase V- Operations
Objective: long-term electricity sales and revenues

There are some basic scientific and technical reports and data on the project area. These were produced by various private, state, and federal sources in the fields of surface and ground-water hydrology, soils, fisheries, and seismology. Although useful and of good quality, most of the information is of a reconnaissance nature. Little of the previous work is specific to the Needles. Those sources used in the preparation of this report are listed in the section at the back entitled Selected References.

There has been previous interest in power generation at the Needles. In the early 1960s, Western Geothermal, Inc. obtained geothermal exploration rights in the Needles area and drilled one deep test well and two shallower wells which provide strong evidence of a low- to moderate-temperature geothermal resource of commercial significance. Only minor summary data is readily available on this important exploratory effort.

In the mid-1970s, Albany Oil & Gas Ltd. held a permit to explore and develop the geothermal resource at the north end of the Reservation. Albany contracted for geological and geophysical surveys over a broad area, but the results were not particularly useful for this report.

This study is intended to provide the Tribe with facts and assessments which will enable the Tribe to make an informed decision as to whether or not it should proceed with the project. We believe the findings are sufficiently favorable to go on to the next stage, as outlined in Section 9.0, Findings and Recommendations.

2.0 GEOTHERMAL RESOURCE

2.1 Introduction

In the United States, the region having the greatest potential for using geothermal heat energy to produce electricity is the Western States. Within this region, Nevada and adjacent northeastern California have recently emerged as the most rapidly growing geothermal power producing area in the Nation (Figure 2.1). There are currently nine power plants on-line (including one expansion) and two under construction. The Needles geothermal resource is within this prime region, where the natural heat of the earth is both higher than normal and close to the surface where it can be tapped and put to beneficial use.

These localities all lie within the Basin and Range geological province which is characterized by numerous, deep penetrating, high-angle faults which intersect shallow crustal heat sources. Groundwater, heated several thousand feet underground, rises along the faults which act as conduits (i.e. a piping system), until they reach the near-surface rock strata.

It is the objective of exploration to locate these hot water-bearing faults and associated fractures at a shallow depth, where they can be tapped by wells and the fluid brought to the surface, and from there piped to the power plant. Intersecting these faults at reasonable depths is the highest risk phase of any geothermal power project. To be successful, wells used for production of hot water for a power plant, and injection wells, which are used for disposal of the water after it has passed through the power plant, must intersect good fault/fracture zones. Drilling these wells is the most costly part of wellfield development.

In order to increase the likelihood of drilling successful wells, and thereby lowering the risk of drilling unsuccessful wells, an exploration phase must be carried out in an orderly, fashion using exploration techniques suitable to the specific geothermal resource. At the Needles, these techniques would include photogeologic and field geologic mapping, followed by two or more geophysical surveys. The information obtained from these surveys will provide a better understanding of the geologic environment at the surface and at depth.

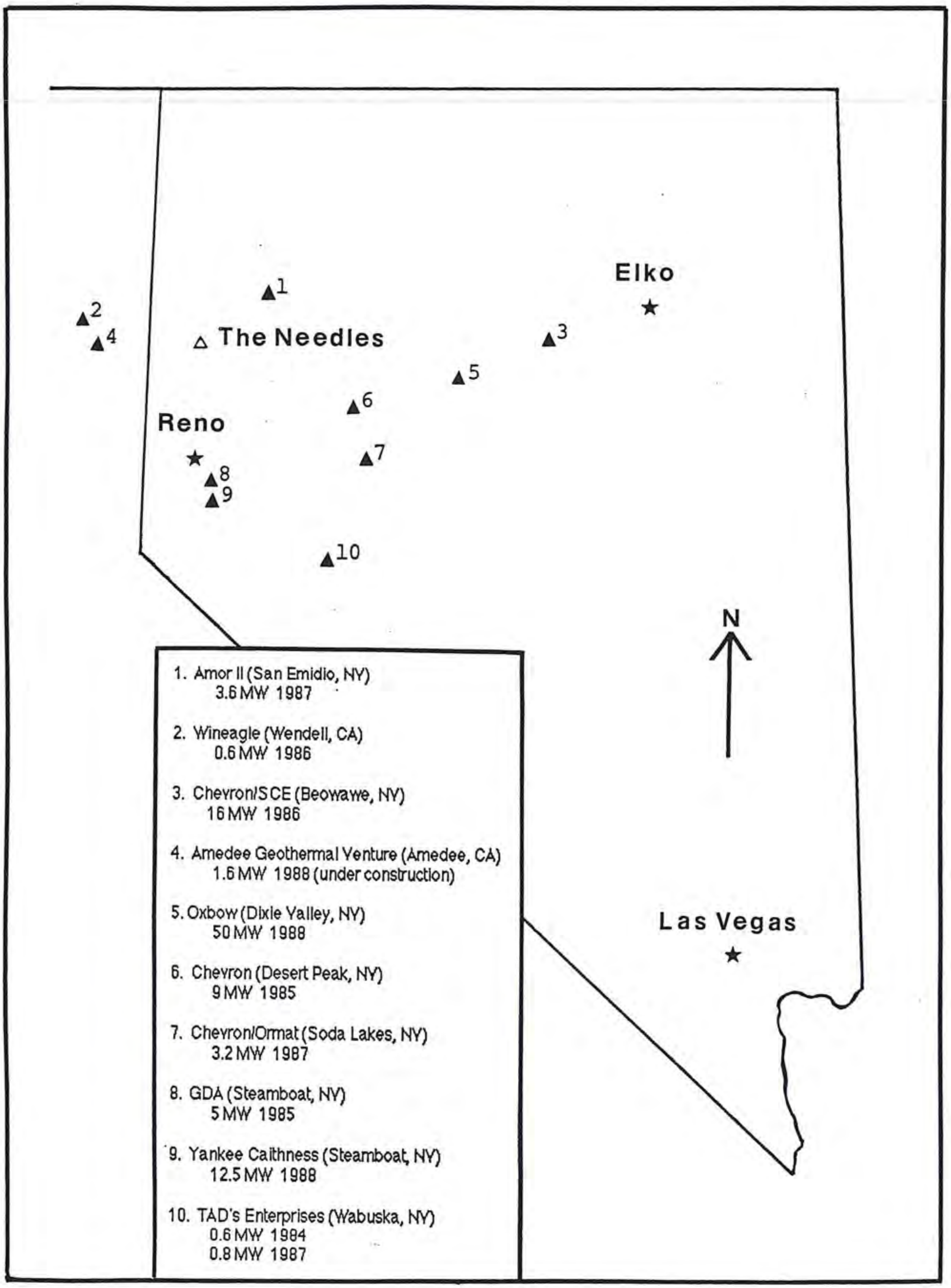


Figure 2.1. Geothermal power plants in Nevada and Northeast California.

Knowledge of the two basic components of geology, the stratigraphy (i.e. the nature of the rocks) and the structure (i.e. the faults and fractures), is necessary for: (1) understanding and interpreting groundwater movement, pressures, temperatures, and other factors; (2) designing and budgeting for the drilling and completion of all wells; and (3) establishing and maintaining efficient wellfield operating procedures.

The geology in the area from the northern Pyramid Lake shoreline at the Needles, inland for about two miles, is covered by soils, which are generally sand, or coarse sand and gravel at varying depths, (Soil Conservation Service, 1988). The only rock outcroppings are tufa (The Needles Rocks), which are surface and near-surface geologic features, and a narrow ridge of volcanic rock which extends northward from the Needles (Plate I). Therefore, greater knowledge of the subsurface environment, including the geothermal reservoir, must be obtained.

The assessment of the geology and geothermal resource of the Needles area, as presented in this report, has been determined by a combination of four main data sources:

- Published geologic maps of the surrounding mountain slopes.
- Geology from previous drilling records of Western Geothermal, Inc.
- Photogeologic and reconnaissance field checking by GDA.
- Geophysical surveys by previous investigators.

Data from each of these sources is presented below and in accompanying Plates and Figures, with the more detailed descriptions presented in Appendix A.

2.2 Geology of the Northern Pyramid Lake Region

2.2.1 Stratigraphy

Pyramid Lake Valley to the north of Anaho Island is bounded on the east by the Lake Range with Tohakum Peak at 8,075 feet; the Virginia Mountains with Tule Peak at 8,722 feet on the west; and the lower, broken, Terraced Hills at 5,483 feet directy north of Needles (Figure 2.2a, Geologic Map and 2.2b Explanation).

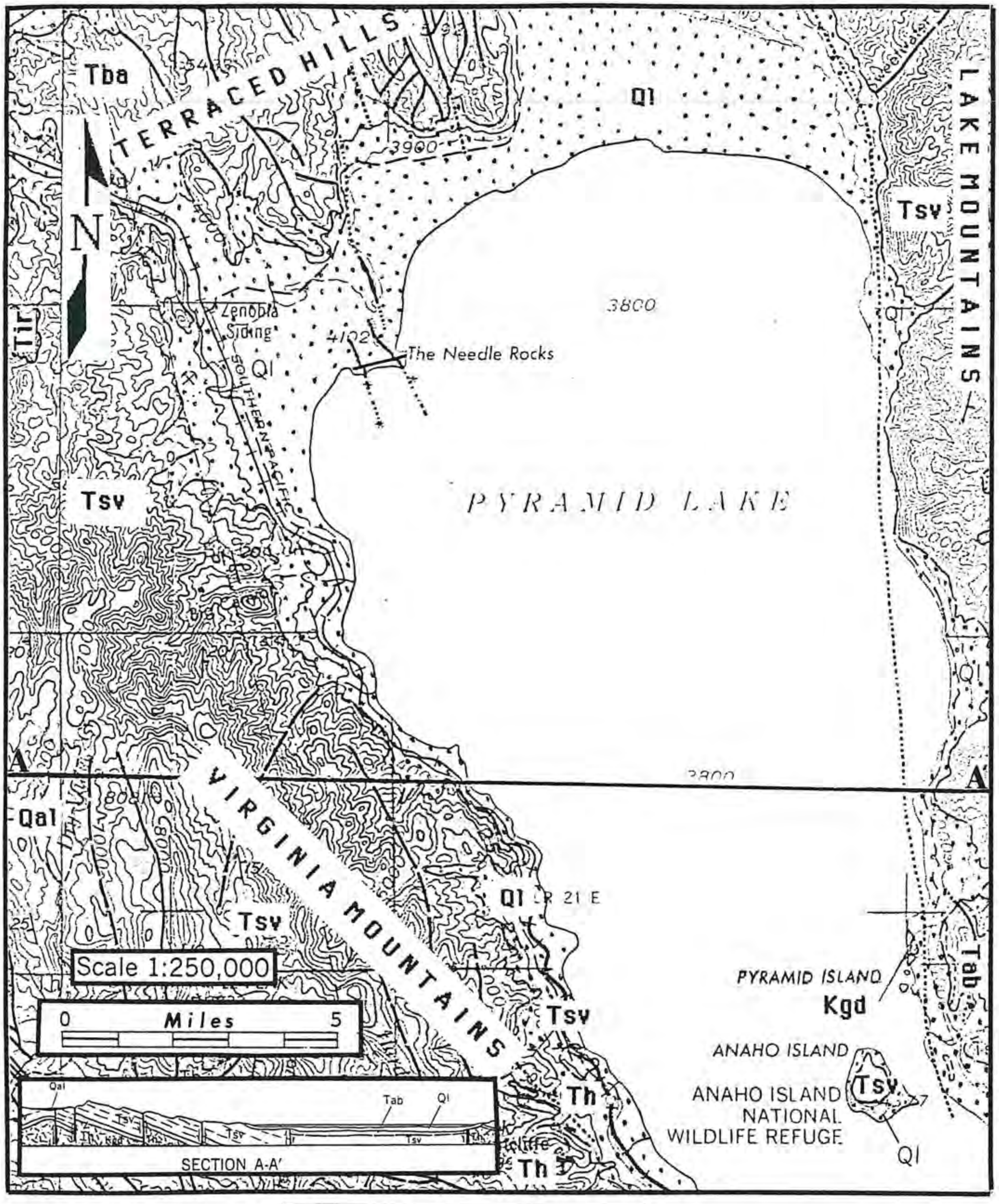


Figure 2.2a

Geologic map of northern Pyramid Lake area.

Source: from Bonham (1969)

EXPLANATION

QUATERNARY

Pleistocene & Recent	Ql	Lake deposits, clay, sirt, gravel and calcareous tufa. Includes some areas thinly veneered by eolian sand.
	Qls	Landslide Deposits
	Qal	Stream deposits, talus, slope wash,

TERTIARY

	Hartford Assemblage		Canyon Assemblage	
Pliocene	Tir	Rhyolite		
Pliocene	Tab	Basalt	Tba	Basalt
Miocene	Tsv	Pyramid Sequence		
Miocene	Th	Hartford Hill Rhyolite		

CRETACEOUS (?)

Kgd	Granodiorite

┴	Strike and Dip of beds
………………	Concealed fault
—— — —	Contact, dashed where appropriately located
$\frac{U}{D}$ — —	Fault, showing dip. Dashed where appropriately located; U upthrown side; D downthrown side

Figure 2.2b. Explanation to geologic map of northern Pyramid Lake area.

The Needles area as shown on the geologic map of Figure 2.2a is at the north end of the valley which is largely covered by Pyramid Lake, and underlain by young unconsolidated sediments of Quaternary age. These sediments are largely comprised of interbedded layers of sands, silts, clays, and gravels of up to several hundred feet in thickness in some areas. Coarser sediments are more prevalent near the edges of the basin, and with the finer sediments more dominant at some distance from the mountain ranges. Refer to Stratigraphy of the Needles Area, Appendix A.1, for additional information.

The surrounding mountains are almost entirely made up of a series of volcanic strata of varying compositions and appearance which are 1.5 to 10 million years old. These rock units were laid down over much of western Nevada and adjacent California, and today form the main mass of the mountain ranges as well as the foundations of the valleys, upon which the younger sediments have been deposited.

2.2.2 Structure

The Pyramid Lake basin lies near the western periphery of the Basin and Range province, which is characterized by extensive faulting having major vertical displacements. It has produced the present day north-south trending mountains of Nevada, and was structurally active before and during the deposition of the volcanic rock strata of the mountains around Pyramid Lake.

The Lake Range and the Virginia Mountains are uplifted massive mountain blocks, separated by major faults from the downdropped basin in which Pyramid Lake lies. The primary trend of these faults is to the northwest, and the vertical movement along some of them can be on the order of hundreds or thousands of feet. Refer to Structure of Northern Pyramid Lake Basin and the Needles Area, Appendix A.2, for additional information.

Linear disturbances in the surficial basin sediments, and displacements in the lake shoreline, are evidence that movement along some of the faults continues today (Plate I).

2.3 Geology of The Needles Area

2.3.1 Stratigraphy

The Needles lie within the western half of the Pyramid Lake basin, a complexly faulted, downdropped section of the earth's crust, which is 12 miles in width at the northern end of the lake. The volcanic rocks which are present in the adjacent Terraced Hills immediately to the north, extend southward in a finger-shaped outcrop which terminates at the northern end of the Needles (Plate I). These volcanics are recognized as the uppermost basalt of the Canyon Assemblage (U. Miocene/ Pliocene) by Bonham (1969). The prominent calcareous tufa deposits that make up The Needles, and from which this locality receives its name, are believed to have formed along steeply dipping fault zones, up which hot solutions passed to the surface. Although the volcanic strata is known to be several thousand feet thick at depth below the Needles, the Needles tufa pinnacles themselves do not extend very far in depth. Refer to The Needles Tufa Pinnacles, Appendix A.3, for additional information.

In and around the Needles, the beach-type soils are generally sands, or coarse sand with gravel at varying intervals (Soil Conservation Service, 1988). These soils serve to hide the underlying rock strata and associated fault structure which is known to be similar to the surrounding hills and mountain ranges. The geothermal reservoir, which will be the objective of all exploratory activity, will be found in these older, fractured, volcanic strata which are known to be present beneath the Needles from about 350 feet to over a mile in depth.

2.3.2 Structure

It is due to the size and linear extent of the Needles tufa deposits, and their association with hot spring activity, as described in Appendix A, that Western Geothermal Company drilled test wells at this site in the 1960s.

Plate I is a photogeologic interpretation of the surface structure of the Needles and vicinity, with the geology of the nearby Terraced Hills taken, in part, from Bonham (1969). The major northwesterly -trending faults which have shaped the configuration of Pyramid Lake valley and the adjacent mountain ranges to the east and west, are strongly represented in the Needles area where the faults and landforms show a similar trend.

The Needles tufa formations occur in two northwest-southeast parallel lines about one half mile apart, and extend about a mile inland from the lakeshore (Plate I). The southeastward extensions of these deposits occur in Pyramid Lake, and it is probable that other similar deposits are present under the lake on a line between the Needles and the Pyramid. Photogeologic study of the other tufa pinnacles and landforms at the Needles strongly suggests that there is also important east-west to northeast-southwest faulting.

Most of the commercially viable geothermal resources developed for electrical power generation in recent years are known to be intricately faulted and fractured. The resulting volume of broken rock is the geothermal reservoir into which the production wells are eventually drilled and completed. It is highly probable that a favorable geothermal reservoir is located at the Needles where this condition exists at the intersection of the main and secondary structural trends discussed above.

2.4 Geophysics

It is the objective of the geological studies, geophysical surveys, and small diameter (low cost) test wells, to gain a good understanding of the subsurface geologic environment; that is, the location of the different rock strata, the fault/fracture systems, and the hot water. These exploration methods are less costly than the drilling and completion of just one large-diameter production well. It is therefore important to maximize the likelihood of drilling successful wells by planning and completing a number of pre-drilling studies and surveys. In reality there is a continuing reevaluation of reservoir data throughout a project, as data becomes available from each new well that is drilled.

2.4.1 Previous Surveys

Since the early 1960s, there have been a number of companies which have completed exploratory activites over a wide area at the north end of the Reservation. A review of these geophysical surveys, and the analysis of each, was undertaken in order to obtain an understanding of which surveys previously carried out were deemed to be successful and which ones were not.

Within the last five years, several projects have been developed on resources once thought to be too small and to low in temperature for power production. Today there are power generation projects on-line using geothermal resources below 225°F.

Although there have been numerous regional surveys of various types carried out by federal agencies, all of these appear to be of too little detail to be of practical use in the development of the present project.

There are no readily available records of geological or geophysical surveys that were performed by Western Geothermal, Inc. in conjunction with the drilling of their three exploration wells. Summary reports by Western Geothermal consultants indicate that the site of their deep well (the geysering well) was incorrectly picked for this well to intersect the geothermal reservoir, which in this case was a hot water-bearing fault zone. The same may be said for the two shallower, small-diameter drill holes that followed in 1966. Refer to Geophysics, Appendix A.4, for additional information.

The mid-1970s surveys by Albany Oil and Gas Ltd. consultants, Geothermal Kinetics, Inc. and Group Seven, Inc., expended their greatest effort on regional-scale surveys, with the exception of a 3-foot depth temperature gradient hole survey. This latter survey in the Needles area clearly indicates that shallow thermal anomalies are associated with each of the two northwest-trending tufa/fault zones.

2.4.2 Surveys at The Needles

The exploration plan for this project will be designed to locate optimum production and injection well locations in the vicinity of the Needles over an area of under two square miles (Plate II). Should the areal extent of the reservoir extend beyond this proposed geophysical survey working area, a future survey may be outlined in order to define it.

The geophysical methods that are recommended to gain additional subsurface information are:

1. *Gravity Survey* to better define the location of significant fault zones, including their direction and magnitude of vertical displacement.

2. *Ground Magnetic Survey* to be used in conjunction with gravity for structural interpretations. This method is anticipated to be useful where the volcanic rocks are faulted against the basin sediments, since volcanic strata normally has a contrasting (higher) magnetic susceptibility as compared to the sediments.

3. *Temperature Gradient (TGH) Hole Survey* with probes set at a depth of ten feet. The 3-foot depth TGH survey of Albany indicated that favorable results will be achieved. Measurements taken at 10 feet will be much less affected by near-surface and weather variations.

4. *Spontaneous Potential Survey* is an electrical method that can locate the direction and movement of water along the faults. In this case, any rising waters would probably be thermal waters.

2.5 Geothermal Test Wells

Exploration for geothermal resources on the Reservation commenced in the early 1960s when Western Geothermal, Inc. obtained the rights to drill and develop the geothermal resource at the Needles. The data of record for the three wells drilled by this firm, while somewhat sparse, is the best information available on the geology, hydrology, geochemistry, and the potential geothermal reservoir. The existing records for of each of these wells is summerized below from Hall (undated) and Geothermal Kinetics Inc. and Group Seven, Inc. (1976).

2.5.1 Paiute Nos. 1, 2 & 3.

Paiute No. 1 Well. This large-diameter well on the lake shore among the easternmost pinnacles, has been geysering since it was completed in 1964 at a depth of 5,930 feet (Plate I; Figure 2.3). The first 350 feet of strata drilled encountered a mixture of clay, sand, and gravel before it went into solid rock, which has been described as a series of volcanics, including flows and tuffs.

The original logs and records that are believed to have been kept for this deep well, have not been located. What information is available, is largely from a few summary-type reports written by technical consultants to Western Geothermal, Inc. Except for the summary record of the shallower (upper 2,000 feet) strata drilled, there is little information that is of value to the present project. Refer to Geothermal Test Well Summary Data, Appendix A.5, for additional information on Paiute No. 1, 2, and 3.

Any porous and permeable zones that would serve as good shallower productive horizons were not noted. Attempts to flow-test the well from several deep intervals were not successful. A temperature test of October, 1963, indicated relatively uniform down-hole temperatures of 242°F and an estimated flow of about 400 gpm (gallons per minute). It is mentioned that cooler waters closer to the surface may be causing "interference" (mixing?) with the thermal waters.

The "art" of completing geothermal wells to prevent the mixing of cool surface waters with the geothermal waters was not well developed in the early 1960s, so surface flowing temperatures may well include unwanted cooler groundwater. In addition, there is no mention of, or interest in, a shallow reservoir, which is the target of this project.

Additional data on the Paiute No. 2 and No. 3 wells from Hall and Decius (undated) is also sketchy.

Paiute No. 2 Well. This was a small diameter well drilled and completed to a depth of 1,488 feet in one week in 1966, two years after the final completion of the Paiute No. 1 deep well (Plate I; Figure 2.4). Attempts to flow this well from the open hole below surface casing at 305 feet to total depth were unsuccessful, indicating that the well did not penetrate shallow reservoir fractures.

Static (non-flowing) temperatures, however, were very encouraging, with maximum reading thermometer measurements of 174°F at 500 feet, 203°F at 1,000 feet, and 245°F at 1,470 feet. Experience suggests that flowing temperatures would probably be considerably

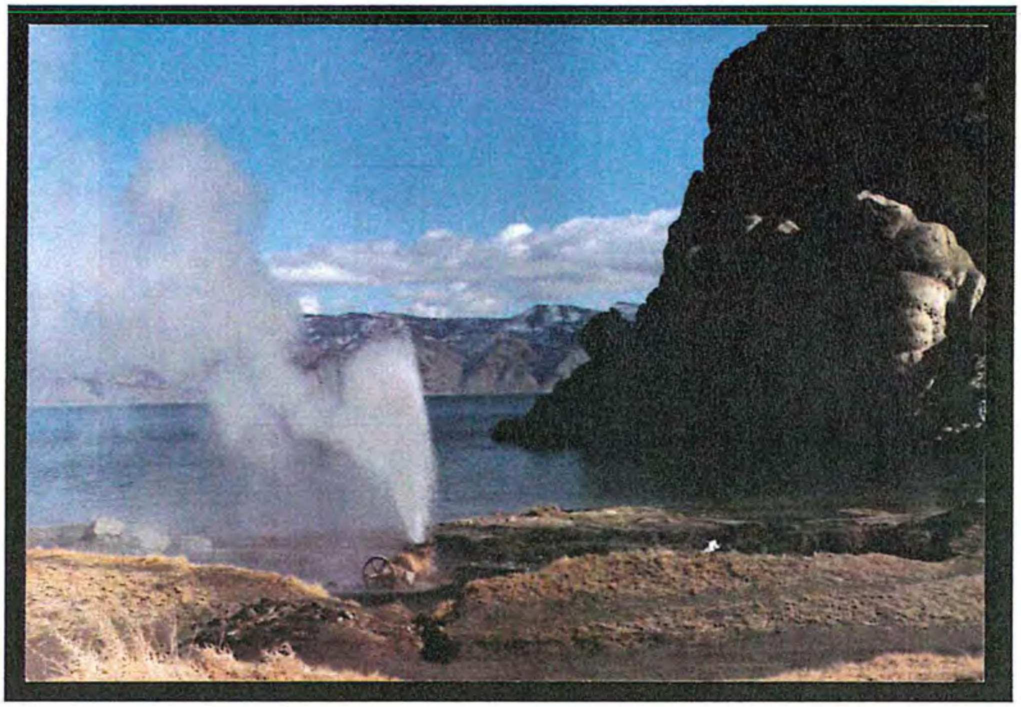


Figure 2.3 Paiute No. 1 Geysering Well March, 1988
(Photo by GDA)

Figure 2.4 Paiute No. 2 Wellhead, 1987
(Photo by GDA)

higher than these, if good fracture permeability was intersected by the well.

Paiute No. 3 Well. The second small diameter well was also drilled and completed in about seven days during January 1966, this time to a depth of 1,206 feet. The location of this well is about 3,000 feet west of Paiute No. 1, near the east side of the westernmost line of tufa pinnacles, and close to the shoreline.

Sparse records on this well indicate that the drill bit twisted off in a "lost circulation zone" (a highly permeable zone into which the drilling fluid is lost). The bit was not recovered, thus causing the well to be abandoned. Normally a "lost circulation zone" is also a potential production zone in a geothermal well. But this well had a very minimal recorded flow, which may have been due to the obstruction of the lost drill bit. Casing was cemented from the surface to 285 feet. In the open hole below this depth, a temperature of 205°F was measured at 550 feet.

The conclusion of Western Geothermal, Inc. consultants was that the temperatures in all three wells were too low to encourage further exploration, and that temperatures of 350°F would not be achieved. This was the minimum resource temperature at this date and even throughout the 1970s, that was believed to be necessary in order to generate electricity. It was not until 1984 that commercial production was achieved in Nevada for geothermal resources below 350°F.

2.5.2 Geothermal Wells: Status and Condition

The physical condition and access to the three Paiute exploration wells is of interest in planning for the future development of the resource. One or more of the wells may provide access to the subsurface for the measurement and on-going observation of static water level, temperature, pressure, and water chemistry.

It is of practical interest to have knowledge of each well, including: wellhead and casing description and physical condition, accessibility, method of abandonment (e.g., cement plugs, etc.), and practicality to re-enter in order to carry out sampling, surveys, or to flow-test. The wells could possibly be converted for future use as observation, injection or production purposes.

The Paiute No. 1 well is currently open and continuously geysering about 15 to 25 feet into the air (Figure 2.3). Although the wellhead is about 30 inches above lake level and perhaps 30 feet from the lake's edge, less than 12 months ago the wellhead was beyond the lake's edge and less than 12 inches above lake level. The boiling water being emitted does not allow close examination of the wellhead and gate valve, which are highly corroded and encrusted with mineral precipitates.

Records do not provide information on the downhole status of this well, but it is assumed that no procedures were taken for the plugging and abandoning of the well. It could probably be reentered if it were deemed necessary, though at present there are no plans to do so. In part this is due to the presence of well casing which does not allow access to the near-surface formations that are the objective of any future drilling and testing program.

Paiute No. 2 is on firm ground (Figure 2.4). The wellhead valve was recently removed from the well, which appears to be in reasonably good condition, but an irregular obstruction in the annulus at about 18 feet below ground level, prevents access to the wellbore at depth. There is a rapid, but minor pressure buildup in the wellhead, which indicates the wellbore is not completely plugged.

If closer examination proves that the obstruction is not a serious (costly) one, it may be advisable to reenter this well if no further problems are encountered. Temperature measurements would be useful, since the interval from the base of casing at 305 feet to total depth at 1,488 feet is within the proposed objective shallow geothermal reservoir interval. It is also a good candidate for a permanent observation (monitoring) well.

The location of Paiute No. 3 is now under water according to maps constructed at the time of drilling (Plate I). An attempt to see the wellhead from an elevated vantage point was unsuccessful. The method of plugging and abandoning this well is not known.

2.5.3 Other Wells and Drill Holes

There are no other exploration or research drill holes or wells of record in the Needles area, with the exception of a few water wells. The wells drilled in the four townships around the Needles, T26N-R20E, T26N-R21E, T27N-R20E, and T27N-R21E are listed in Table 2.1. The Whittey and Southern Pacific wells, at the foot of the Terraced Hills more than two miles northerly from the Needles, are the only wells in the northern Pyramid Lake area which fall within the area of Plate I.

2.6 Hydrology and Geochemistry

Study of the hydrology and chemistry of the Needles thermal springs and test wells provides a rudimentary insight into the Needles geothermal reservoir, as well as providing essential information for power plant design. The relationships of the thermal groundwater, the non-thermal groundwater, and the water of Pyramid Lake are an important facet of project planning and decision making. Freshwater resources are discussed in Section 3.0 of this report.

2.6.1 Thermal Springs

Thermal springs present at the Needles, the Pyramid, and Anaho Island provide evidence of probable major, deep-seated faulting connecting these features, along which the thermal waters rise. It is the presence of these thermal waters which observers believe is the source of the precipitated minerals at these localities -- foremost being the large tufa deposits.

The location, chemistry, and other characteristics of the Needles thermal springs are listed in Tables 2.2 and 2.3. One spring(?) measured 3,770 ppm (parts per million) TDS (total dissolved solids) with sodium and chlorides making up about 75 percent of the total.

A thermal spring is reported to be present approximately 330 feet from the geysering Paiute No. 1 well. It has a discharge of 220 gpm and temperature of 147°F. Both sources flow into the lake and show no evidence of mineral precipitation in the streams or when entering the lake, according to Desert Research Institute (1977); but silicious sinter is being deposited on the wellhead according to Bonham (1964).

Other hot springs have been observed in the past, approximately 4,000 feet to the southwest in three separate sites where the tufa pinnacles were on or close to the water's edge. Grose and Keller (1975) reported that spring temperatures range from 151°F to boiling

Table 2.1 Geothermal and water well data for the Needles area.

Page 1 of 2

LOCATION	OWNER	YEAR DRILLED	DEPTH (ft.)	DIAMETER (inches)	USE	YIELD (gpm) Drwdwn (ft)	Elev.	WATER LEVEL		REMARKS	GEOLOGY	THCKNS (ft.)	DEPTH (ft.)	CASING RECORD	SURF. SEAL	DRILLER
								Depth (ft.)	Date Measured							
S1,T26N,R20E SE/4SE/4SE/4	Western Geothermal, Inc.	1966	1206	10-5 1/2	Unused Exploratory	--	3800	flows	8/5/71	Temp. 205°F at 550 and 850 ft, 202°F at 1,155 ft.						
S26,T26N,R20E	Southern Pacific Co.	about 1914	210	8	Unused (Industrial public supply)	80/--	3900	22 98.28 96.83	about 1914 2/4/70 7/10/70	Layer of oil atop water; chemical analysis, Table	Gravel Sand Sand,blck & mud Gravel Boulders & gravel Sand Gravel & boulders Boulders	38 20 45 32 10 27 15 17	38 58 103 135 145 172 187 204			
S35,T26N,R20E.	James Whittey	July, 1969	125	6	Stock			20	July, 1969	cold	Top Soil Boulders Brown Clay Brown Sandy Clay Blue Clay Soft Brown Rock Blue Clay	12 18 30 10 30 10	0 to 12 12 to 30 30 to 60 60 to 70 100 to 115 115 to 125	6-5/8" x 101' OD 13 lb/ft.	Clay	A & B Contractors
S6,T26N,R21E NW/4SW/4SW/4	Western Geothermal, Inc.	1964	5930	16-7	Unused Exploratory	7/0	3815	flows	2/4/70		Lakebed sedimentary deposits. Volcanic rocks, varying from highly altered rhyolitic tuffs to andesite flows of varying porosity; well was closed in for almost 1 year, after which down-hole temperatures were about 117°C, and flow was about 400 gpm. Rock (probably volcanic), extremely hard, with few permeable zones, but one zone of rather intense hydrothermal alteration; this interval was drilled 18 months after completion of top 4,208 ft; maximum bottom-hole temperature 113°C, flow about 7 gpm.	350 3858 1722	350 4208 5930			
S12,T26N,R21E NW/4NW/4NE/4	Western Geothermal, Inc.	1966	1488	10-5 1/2	Unused Exploratory	--	3825	a few	1-29-66	Max. down-hole temp. 245°F.	Clay, bentonitic Clay, light brown Clay, blue Sand and gravel, waterbearing Clay, blue	50 55 10 14 6	50 105 115 129 135			
S22,T26N,R21E.	Bader Construction	Jan, 1979	350	6	Domestic	100/--		100	1-79		Coarse sand w/gravel Cemented sand - med. hard	25 120	205 to 230 230 to 350	230' of 6-5/8" OD 125' of 5"	Cement	Wayne Drilling Inc.

Table 2.1 - continued.

Page 2 of 2

LOCATION	OWNER	YEAR DRILLED	DEPTH (ft.)	DIAMETER (Inches)	USE	YIELD (gpm) Drwdwn (ft)	Elev.	WATER LEVEL		REMARKS	GEOLOGY	THCKNS (ft.)	DEPTH (ft.)	CASING RECORD	SURF. SEAL	DRILLER
								Depth (ft.)	Date Measured							
S28,T27N,R20E.	Pyramid Lake Paiute Tribe	1958	135	6	Unused (stock)	20/--	3994	35	11-58	21°c						
S29,T26N,R20E.	Mrs. A. V. Heller	1961±	--	6	Stock	--	4009	24±	2/4/70							
S8, T27N,R21E.	Art Stadtmiller	April, 1982	265	6	Domestic	20 with air/--		115	4-82		Top Soil	1/2	0 to 1/2	265'	Cement	Wayne Drilling Co.
											Brown volcanic rock	95 1/2	1/2 to 96			
											White sandy clay	14	96 to 110			
											Purple volcanic rock	55	110 to 165			
											Light green rock	21	165 to 176			
											Black volcanic rock	58	176 to 234			
											Black volcanic rock fract.	12	234 to 246			
											Black volcanic rock	19	246 to 265			
S9,T27N.R21E.	U.S.G.S. test well 2	1967	47	2	Unused	--	3845	5.90	7/28/67	USGS Ob. Well.						
					Exploratory			6.68	3/31/69	Cased to 47 ft.,						
								6.79	8/22/69	screened 45-47 ft.						
								6.71	1/3/70							
								6.92	10/24/70							
S16,T27N,R21E.	U.S.G.S. test well 1	1967	44	2	Unused	--	3837	16.63	7/28/67	USGS Ob. Well	Sand, medium-grained, with shells	3	3			
					Exploratory			17.18	3/31/69	Cased to 47 ft.,	Sand with wet clay content increasing to					
								17.00	8/22/69	screened 45-47 ft.	about 50% at 7'.	4	7			
								17.51	1/3/70		Clay, brown & block mottled	3	10			
								17.39	10/24/70		Clay, greenish black	2	12			
											Clay, black with greenish cast, high water					
											content.	20	32			
											Same as above, but greener	5	37			
											Same, but clay drier, more cohesive	10	47			
S31, T27N,R21E.	Garrett Scott	April, 1978	240	6	Domestic						Clay	20	0 to 20	6"	Cement	Suclito Well Drlng.
											DG soft	60	20 to 80			
											DG broken	5	80 to 85			
											DG soft	60	85 to 145			
											DG broken	3	145 to 148			
											DG soft	72	148 to 220			
											Some water	23	220 to 243			
S21, T28N,R20E.	Ball Well	June, 1964	138	8	Domestic	40/--		28	June, 1964	Cold	Surface rock & clay	5	0 to 5	6-5/8 ODx190' 12.89 lb/ft.		Smith-Pulati, Inc.
											Hard pan	25	5 to 30			
											Pale yellow rock	40	30 to 70			
											Gray rock	30	70 to 100			
											Gray rock bottom	36	100 to 136			
											Turning bright yellow	2	136 to 138			

Table 2.2 Geothermal and Water Well Chemistry for the Needles Area

Location	Source (Well Depth)	Date Sampled	Analyst	Temperature °F	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Carbonate (CO3)	Sulfate (SO4)	Chloride (Cl)	Nitrate (NO3)	Silica (SiO2)	Fluoride (F)	Boron (B)	Arsenic (As)	Specific Conductance µmhos/cm	(TDS)	(pH)	Hardness as (CaCO3)	Total Iron (Fe)
S12,T26N,R20E	Spring ?	2/14/69	USGS	132°	152	16	1210		220	0	307	1830	--	--	--	--	--	6300	–	8.1	446	--
S12,T26N,R20E	Spring ?	Aug-75		141°	198	0.3	1040	120	110	0	350	1760	--	110	--	--	--	5800	3770	7.8	--	--
S12,T26N,R20E	Well?	Aug-75		180°	163	0.1	1040	120	50	0	335	1950	--	117	--	--	--	7100	4615	7.4	--	--
S12,T26N,R20E	--	Feb-69		132°	--	--	--		--	--	--	1830	--	--	--	--	--	6300	--	--	446	--
S12,T26N,R20E CW1/2,NE1/4	Needles #2(?)	Dec. 71	--	191°	Remarks:	Geothermal	exploration well. Depth ±		400 ft.	Temperature	of water	escaping from capped well.		--	--	--	--	--	--	--	--	--
S12,T26N,R20E NE1/4,NW1/4	--	--	--	208°	--	–	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--
S26,T26N,R20E	Well ? (210 Ft.)	9/26/52	Southern Pacific	--	3.2	1.4	85		193	0	16	17	--	–				--	272	7	14	
S25,T26N,R20E	Big Canyon Creek	2/14/69		43°	20	11	12		114	0	15	8	--	--	--	--	--	250	--	8.1	94	
S6,T26N,R21E	Well (5.930 Ft.)	Apr-68	Brown & Caldwell	--	250	6.3			0	26	351	2100	--	--	--	--	--	6050	3940	9.2	651	--
S6,T26N,R21E NW1/4SW1/4SW1/4	Paiute No. 1 Well	1973		133°	260	0.1	1100	160	24	0	340	1900	--	110	3	--	0.02	6200	--	8.4	--	--
		Remarks:	Unsurveyed	(projected from west)	Li=0.61																	
S6,T26N,R21E	Paiute No. 1	–	--	about 240°	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--
S6,T26N,R21E SE1/4SE1/4	Paiute No. 1 Well	10/12/73		153°	282	0.1	1080	31	11.5	0	338	1841	<0.1	95	3	--	1.1ug/1	6072	3676	8.1	--	0.02
S6,T26N,R21E SE1/4SE1/4	Paiute No. 1 Stm. Geyser Well	Aug-75		151°	260	0.1	1100	160	22	0	340	1880	--	110	3	6.1	--	6500	4225	8.4	--	--
S6,T26N,R21E	--	--		--	--	--	1160	37	--	--	--	--	--	--	8.8	--	--	--	--	--	--	--
S6,T26N,R21E NW1/4SW1/4SW1/4	The Needles Spring	--	--	hot	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--
S7,T26N,R21E	spring ?	Aug-75		150°	315	0.4	1150	280	100	0	330	1850	--	82	--	--	--	7200	4680	7.6	--	--
S29,T27N,R20E	Well	2/4/70	USGS	59° 80	33	16	1060		420	0	568	1070	--	--	--	--	--	5200	--	8.2	150	--
S16,T27N,R21E	Well (44Ft.)	10/24/70	USGS	--	31	61	2100		1620	172	190	2200	--	--	--	--	--	9580	--	8.6	330	--
S6,T26N,R21E	Paiute No. 1	4/16/68			250	6.3	1100	37	0	26	351	2100	--	--	--	--	--	6034	3939	--	650	--
incorrect location? → S9,T27N,R21E	Paiute No. 2	4/16/68			118	1.5	1570	74	49	2	26	2950	--	--	--	--	--	7243	4765	--	300	--
S6,T26N,R21E	Paiute No. 1	May-Sept '78			230	40	1000	18	--	--	37	2510	--	96	--	4.5	<0.050	--	3915	7.8	--	<0.030
S6,T26N,R21E	Paiute No. 1	May-Sept '78			2200	0.34	1120	45	--	--	45	2200	--	76	--	5.35	<0.050	--	4185	7.3	--	<0.03
S6,T26N,R21E	Paiute No. 1	1972	Barnes Grp.	56°	260	0.1	1100	160	--	--	340	1900	--	110	3	6.1	0.02	6200	--	8.4	--	<0.02

Source: Garside & Schilling (1979); Denburgh, Lamke & Hughes (1973)

Chemical constituents in ppm

Table 2.3

Comparison of water quality in the Pyramid Lake Basin.

Constituent	Pyramid Lake	Geothermal Well	Average Thermal Groundwater (Needles)	Pyramid Non-Thermal Groundwater
Temp (°F)	-	-	160.3	61.16
pH	9.2	8.4	7.9	7.95
SC (µmhos/cm)	8433	6500	6650	846
TDS	-	-	3748	582
HCO_3	798	21.9	69	157
CO_3	308	-	0	1
Cl	1951	1895	1865	103
SO_4	280	324	304	89
Na	1600	1075	1086	126
K	102	30	51.5	12
Ca	9.3	239	256	34
Mg	114	0.35	0.78	6.7
SiO_2	0.95	96.5	107	52
F	-	-	3	0.4
B	10.6	6.7	6	0.5
Mn	<0.005	0.017	-	-
Mo	<0.05	<0.05	-	-
Ca	<0.005	<0.005	-	-
As	0.08	0.02	-	-
Fe	<0.01	<0.01	-	-
Hg	-	0.0006	-	-
NO_3-N	0.062	0.09	-	-

---

* Chemical constituent concentration given in parts per million

Source: Geothermal Kinetics, Inc. and Group Seven, Inc. 1976; Desert Research Institute, 1977 (about 208°F at this elevation). Divers report that underwater hot springs are present near the Needles today (Garside and Schilling, 1979).

2.6.2 Paiute Wells

The water from Paiute No. 1 has a total dissolved solids content of 3,676 to 4,188 ppm, and that for Paiute No. 2 has been measured at 4,765 ppm. There are no analyses available for Paiute No. 3. Like the Needles spring water, the geothermal well water is high in sodium and chlorides, being 79 to 95 percent of the total according to published analyses, Table 2.2.

2.7 Heat

A thermal anomaly of presently unknown size exists at the project area. Data from several sources provides credible evidence that the thermal anomaly is comparable in size and heat content to other geothermal resources that are presently supporting commercial electric power projects in Nevada.

2.7.1 Description of Thermal Anomaly

The Needles thermal area was recognized years ago by the presence of hot springs at the base of several of the tufa pinnacles near the Pyramid Lake waters' edge, a span of over one mile east-west.

The three exploratory test wells drilled by Western Geothermal Inc. in the 1960s proved that temperatures necessary for power production were present at a shallow depth. Unfortunately the wells did not intersect the necessary reservoir fracture system that would have enabled the developer to produce commercial quantities of hot water.

In the 1970s Albany Oil & Gas Ltd. drilled 15 shallow temperature gradient holes, each to a depth of three feet in the Needles area. This survey was successful in delineating anomalously high near-surface temperatures over an area of one square mile or more. There was no follow-on drilling to penetrate and test the geothermal reservoir.

2.7.2 Geothermometry

The U. S. Geological Survey and others in recent years have studied the relationship of thermal ground-water chemistry and temperature with that of the geothermal reservoir temperature that is the source of the heat to the groundwater. The objective of such an analysis is to provide an estimate of the reservoir water temperature prior to making a decision as to whether or not to drill. If the calculations indicate the minimum estimated reservoir temperature is favorable, it may give the developer further encouragement to continue his interest in a specific prospect. Brook and others (1979) have calculated the Needles reservoir temperature to be on the order of 279°F.

3.0 FRESH-WATER RESOURCES

3.1 Introduction

Future development at the north end of the Reservation will require freshwater for drinking, sanitary systems, food preparation, and other purposes. The development of the geothermal resource will require a water source for drilling fluids and for power plant cooling. These latter needs could be provided by the water of Pyramid Lake.

At the present time there are no facilities near the Needles that could provide the necessary domestic or lesser quality water requirements for the Needles project. This section of the feasibility report reviews the water resource options that may be considered for any future development within the scope of this project.

There are no permanently flowing streams at the north end of the Pyramid Lake basin. All the water falling in the higher elevations infiltrates into the groundwater system or flows into Pyramid Lake. The two sources of water, therefore, are groundwater from wells and lake water.

3.2 Groundwater

There has been little need for groundwater development at the north end of the lake because of the lack of human habitation and development. There has been some limited drilling of wells by the Tribe and others over the years. Table 2.1, (Section 2, Pages 16 and 17) is a tabulation of the north Pyramid Lake well information, which serves to illustrate what little is known of this area, and that future needs will require new wells.

The water wells closest to the Needles are about two miles to the north at the foot of the Terraced Hills. A Southern Pacific Co. well located in Section 26, T26N, R20E, was drilled in 1914(?) to 210 feet. A chemical analysis of this water in 1952 indicates it is a high quality sodium bicarbonate water having only 272 ppm total dissolved solids.

This water quality compares favorably with an average of 25 analyses of non-geothermal waters taken by Geothermal Kinetics, Inc and Group Seven Inc. (1976) as illustrated in Table 2.3 (Section 2, Page 19).

Drilling for water on the west side of the lake near Sutcliffe has met with mixed success. Wells have been found to produce potable water provided they were not drilled into historic Lake Lahontan basin materials. The deepest of the four wells drilled in 1974 was 420 feet and produced 160 gpm in a pump test. The State Department of Health found the water safe for domestic use (Albany Oil and Gas, Ltd., 1974).

Clyde-Criddle-Woodward (1968) state that the presence of springs in the drainages on the west and northwest sides of the lake indicate the likelihood of developing groundwater in these areas. The alluvial fans at the mouth of these canyons are assumed to contain water at shallow depths. They further state that the wells should be located and operated so that the water table in the alluvial fan will not be drawn below the lake surface. If it were, the potable water in the alluvial fan would be contaminated by the saline lake water.

The base of the Terraced Hills is two miles north of the Needles and only 300 feet above the present lake level. Further study will be necessary prior to developing a domestic water source in the higher elevations or in the basin sediments

A 1971 map prepared by the Nevada Division of Water Resources, in cooperation with the U.S. Geological Survey, and titled Total Dissolved Solids in Ground Water, shows that the groundwater between the northern margin of Pyramid Lake and the foothills and mountains to the north as having a total dissolved solids content of greater than 1,000 parts per million (Nevada Division of Water Resources, 1971).

As part of their discussion of the suitability of the groundwater for domestic use and public supply of Pyramid Lake Valley, Van Denburgh and Others (1973) remark on the "Overall poor quality...at (the) northwest end of (the) lake; excessive arsenic in at least one area (north of Sutcliffe)." Clearly, additional research is warranted and care should be taken when planning for drilling for freshwater resources

3.3 Pyramid Lake Water

As the terminus for the solute contributions of the Truckee River, Pyramid Lake has a high total dissolved solids content. In 1971 the lake contained about 140 million tons of total dissolved solids -- mostly sodium, bicarbonate, and chlorides. In 1882 the lake level was about 3,865 feet and the total dissolved solids content was about 3,500 ppm. By 1970 the lake had shrunk to 3,793 feet, and the solute concentration had increased to about 4,800 ppm (Van Denburgh and Others, 1973). In 1977, with the lake level still at 3,793 feet, the mean total dissolved solids calculated by summation was 5,479 ppm according to F. W. Sigler & Associates (1978) and the Pyramid Lake Tribe (1988).

It is interesting to note that the salinity of the lake water, as indicated by its TDS, is higher than that of the geothermal waters from hot springs and wells at the Needles (Table 2.2). The flow of geothermal water naturally occurring at the Needles, the Pyramid, Anaho Island, and from the lake bottom, tends to help dilute the lake and reduce the high TDS levels.

In spite of the potential benefit of disposing large quantities of spent (cooled) geothermal water into the lake from a power plant, such a practice is not recommended. Protection of the geothermal reservoir must also be considered. It is generally good practice to inject the spent geothermal water back into the reservoir, so that the reservoir pressure is maintained. Ideally, only heat is removed from the reservoir, and water levels and chemistry are unchanged. Only if the lake can be proven to be the source of recharge for the geothermal reservoir, and the geothermal fluids are cooled to safe levels for fish, should the spent geothermal waters be disposed of in the lake.

With regard to uses of lake water for a power plant project, three applications can be considered. The first use comes during the drilling of exploration and development wells. The drilling process generally requires water on a consumptive basis, for mixing mud, testing, and well control. Lake water is of sufficient quality for drilling uses. The quantity of water used during drilling is very small.

A second application for lake water would arise during construction of the power plant. Water for dust control on roads would be the major consumptive use of water during construction. Again, the volume required would be very small in comparison to the lake.

The third use of lake water comes during power plant operation. The power generation process, as described in Section 4.0, requires large quantities of water for cooling. This water would be pumped from the lake, through the plant, and back into the lake. Although fairly large flow rates are involved (8,750 gpm for a 2.5 MW power plant), the water is not consumed. One hundred percent of the water is returned to the lake unaltered, except for a small increase in temperature. Thus, this use of water will not adversely impact the level of the lake.

Also during power plant operation, a small amount of water will be required in the plant wash room, and occasionally for washing down equipment or road repairs. Once again, the volume required is not expected to be significant.

4.0 SMALL-SCALE POWER PLANT TECHNOLOGY

4.1 Introduction

There are a number of technologies available for geothermal power generation. The selection of the technology most appropriate for a specific geothermal resource depends on the type of resource available, and in particular, the temperature of the resource. In the case of the Needles project, temperatures of 240°F or greater are anticipated. At this temperature, one power generation technology stands out above all others -- the organic Rankine cycle (ORC).

An organic Rankine cycle has been used to generate electricity commercially with geothermal resources as low as 223°F (Wabuska, Nevada).

4.2 Cycle Description

Plate III is a descriptive schematic of an organic Rankine cycle, using geothermal energy. The process begins with the extraction of heat from the resource, by pumping hot water from one or more production wells. The hot water is piped to the power plant, where it passes quietly through a heat exchanger. This heat exchanger is known as the vaporizer. The geothermal fluid enters the vaporizer at 240°F in this case, and leaves at a lower temperature, around 180°F. The spent geothermal fluid is then piped to an injection well, where it is returned to the geothermal reservoir. Approximately 3,400 gpm of 240°F geothermal fluid will be required to operate a 2.5 MW power plant. If higher temperature fluid is found, the flow rate can be reduced.

The heat removed from the geothermal fluid in the vaporizer is transferred to a secondary fluid in a separate closed piping loop. The fluid circulating in this loop is called the working fluid, and is generally a light hydrocarbon or a halocarbon. In either case, the working fluid has a boiling point much lower than water. The working fluid enters the vaporizer as a pressurized liquid, and leaves as a pressurized vapor after picking up heat from the geothermal fluid.

The pressurized vapor then flows to a turbine-generator where power is produced. Most of the power generated is transmitted to a utility for sale, but about 30% of the power is used in the plant and wellfield to operate pumps and other auxiliary equipment. Because the working fluid rather than the geothermal fluid is used in the turbine, the organic Rankine cycle is commonly referred to as a binary cycle.

The turbine exhausts working fluid vapor into another heat exchanger which is known as the condenser. The purpose of the condenser is to extract heat from the working fluid so that the vapor condenses and once again becomes liquid. The heat removal process accomplished in the condenser requires a large flow of cooling water. Approximately 8,750 gpm must be pumped through the condenser continuously to operate a 2.5 MW power plant.

The cycle is completed by pumping the liquid working fluid from the condenser back into the vaporizer. This is accomplished by means of a feed pump. The cycle is thus continuous, consisting of four simple steps: pressurization (feed pump), heating (vaporizer), expanding (turbine), and cooling (condenser). The working fluid continuously passes through these four processes, contained within a closed loop.

4.3 Power Plant Equipment

The principal power plant components mentioned above are described in the following paragraphs. The descriptions attempt to provide some understanding of the characteristic size, shape, or features of the equipment.

Vaporizer. The vaporizer consists of one or more heat exchangers which transfer heat from the geothermal fluid to the working fluid. The heat exchangers are a major plant component. The most common type is the shell and tube heat exchanger, which is a long cylindrical shell containing a bundle of tubes inside. Geothermal fluid flows through the inside of the tubes and the working fluid passes through the shell surrounding the tubes. Heat is transferred through the tube walls from one fluid to the other so that the two fluids never make direct contact with each other. The dimensions of the vaporizer are typically on the order of 40 feet long, and 2 to 6 feet in diameter.

Up to a point, power plant output increases with larger heat exchanger size; initial investment does too, so a compromise between power output and initial cost must be reached. Tube material is another variable that must be considered. Copper and brass transfer heat better than steel, but are easily corroded in the presence of sulfur. Since geothermal fluids often contain significant concentrations of sulfur compounds, carbon steel is usually a better choice for tube material. Expensive stainless steels are generally no better than ordinary carbon steel, because of the chloride content of the geothermal fluid.

Condenser. The condenser is also a heat exchanger, and again the shell and tube type is most common. As with the vaporizer, the working fluid passes around the tubes inside the shell, and cooling water passes inside the tubes. Using Pyramid Lake water in the condenser tubes will require Admiralty Brass tubing to ensure long service life. Carbon steel is probably not a good choice because of the oxygen in the lake water, and stainless steel is once again a poor choice, because of the chlorides in the lake water.

The inside of heat exchanger tubing requires cleaning about once a year, even with the fairly clean and non-corrosive fluids found at Pyramid Lake. Deposits inside the tubing begin to interfere with heat transfer and cause a noticeable drop in power output. Tube cleaning requires specialized cleaning equipment, and removal of the heat exchanger heads. With proper planning, a heat exchanger can be cleaned and put back in service in a day. Fortunately, the outside of the tubes, which are in contact with the working fluid and not readily accessible, do not normally require cleaning.

Turbine. The turbine is located in the system between the vaporizer and the condenser. As the working fluid vapor passes from the high pressure vaporizer to the lower pressure condenser, it must move through the turbine blades. The turbine removes energy from the working fluid vapor and converts it into rotational mechanical energy. The turbine shaft spins the generator, which in turn converts the mechanical energy into electricity.

The most common turbines used in ORC power plants are axial flow and radial flow impulse turbines. Impulse turbines accelerate the vapor through a set of nozzles which direct streams of high velocity vapor against blades or "buckets" on a wheel. The kinetic energy of the vapor stream impacting against the blades causes the wheel to rotate.

The working fluid inside the turbine must be prevented from leaking out of the turbine along the shaft. Special sealing systems are an important and integral part of the turbine. The seals must be designed for long life without frequent maintenance, but not all manufacturers do so. The turbine bearings and lube oil system are equally important for long life. The turbines generally rotate at high speeds, 3,600 rpm or greater, and bearing failure at such speeds can cause severe damage.

Frequently the turbine runs at a speed higher than that of the generator. A gearbox is placed between the turbine and generator in this case. The gearbox is also an important component, which must carry the full power output of the turbine at high turbine speeds. It must therefore have its own stout bearings and lube oil system to ensure long life.

Generator. The generator produces three-phase alternating current for use within the power plant and for sale to the utility. Two types of generators may be considered: induction machines or synchronous machines. The induction generator is the simpler of the two. It has greater reliability and lower cost. The utility however, is likely to insist on the use of a synchronous generator. The synchronous generator offers better performance from the power system viewpoint, primarily because it can be used for power line voltage control. There are no special characteristics that cause geothermal power plant generators to differ from those in other types of power plants of similar size.

Feed Pump. The feed pump is one of the power plant's critical components. Its role is to pump the condensed working fluid from the condenser to the vaporizer, where it can be revaporized to repeat the cycle. The pump must be properly sized to deliver the optimum quantity of working fluid at the proper pressure. It must be located so that it has enough net positive suction head (NPSH) to prevent cavitation. Current practice calls for a multi-stage centrifugal pump that is set in a shallow well in order to obtain maximum NPSH.

The pump, which is expected to to run continuously, day in and day out, must be very reliable. Like the turbine, the pump must have excellent seals to prevent the loss of high pressure working fluid. The power used to run the pump is a parasitic loss which reduces the power available for sale, so the pump and its drive motor should both have high efficiency.

Control System. The power plant must have instrumentation and controls that automatically monitor and regulate the system. Fluid levels, flow rates, temperatures and pressures, along with other pertinent data , must be monitored and controlled as necessary for proper operation. The control system is frequently the weakest link in the chain of reliability. Special care must be exercised in control system design so that reliability is enhanced by the controls, rather than reduced. The control system must perform an automatic startup or shutdown sequence when the start or stop button is pushed. The controller must stop the unit safely and automatically in case of mechanical problems or abnormal instrument readings. The system should indicate the cause of the shutdown so the problem can be isolated and corrected.

Future Developments. Organic Rankine cycle efficiencies seem to have approached a practical limit, with little room left for technological breakthroughs that will increase power output by leaps and bounds. Future improvements will come in the form of refinements to controls, heat exchangers, turbines, and pumps. Reliability, already higher than that of conventional power plants, will improve as recent experience is applied to new projects. Increased efficiency usually comes with a higher price tag. With increased competition however, progress can be expected with regard to price and performance.

4.4 Geothermal Resource Requirements

As mentioned previously, a 2.5 MW power plant requires a large flow of geothermal fluid for operation -- approximately 3,400 gallons per minute at 240°F. If the resource temperature is somewhat higher as expected, the necessary flow rate will be lower. In other words, there is an inverse relationship between flow and temperature of the geothermal fluid. Figure 4.1 is a graph that shows this relationship for a 2.5 MW (net) power plant.

The number of production wells needed to produce 3,400 gpm depends in large part on the geologic formations which the well penetrates. If major fracture zones are encountered during drilling, the wells can be expected to be highly productive. On the other hand, if no open fractures are found, production will be limited to the permeablility of the sands and gravels encountered. The objective in geothermal well drilling is to locate and intersect a good fracture zone containing hot fluid. If successful, production rates over 2,000 gpm per well are possible. More conservative rates lie in the range of 1,000 to 1,500 gpm per well. Thus, three production wells are anticipated in order to produce the 3,400 gpm needed for the 2.5 MW project.

These wells must be of a diameter sufficiently large to accept a pump. Production casing for pumped geothermal wells is typically 10-3/4 to 13-3/8 inches in outside diameter. This large casing size allows the installation of pumps capable of producing up to 2,000 gpm. The pumps are generally centrifugal types, which may be driven by a submersible electric

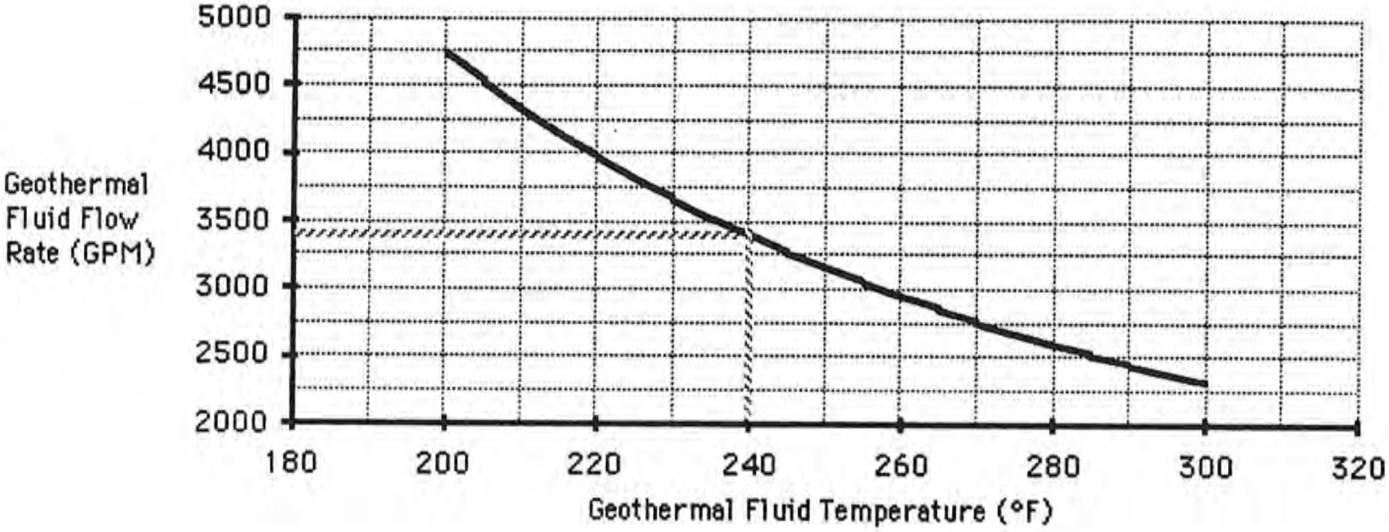


Figure 4.1 Flow Rate vs. Temperature of Geothermal Fluid for a 2.5 MW Plant

motor or by a line shaft connected to a surface mounted motor. The later type is capable of operation at temperatures over 300°F. Submersible electric pumps are presently limited to about 270°F. The advantages of the submersible are lower cost, simple installation, and quiet low-profile operation.

The drilling methods used for geothermal wells are more rigorous than ordinary water wells. Special equipment must be utilized to safely control and contain the hot fluids that may be encountered during drilling and testing. Blowout prevention equipment should be mandatory when drilling shallow resources with temperatures known to be in excess of boiling. The methods used in casing and cementing the wells are also more complicated than those frequently used in water wells. The higher temperatures, pressures, and corrosion potential make it imperative that special procedures be followed in all phases of geothermal well drilling.

With regard to injection wells, it has generally been found that a good injection well will accept the flow from two or more production wells. That is, it is frequently easier to get the fluid back into the ground than is is to get it out. This is not always the case however. In order to have good injectivity, it is often necessary to intersect a major fracture zone, just as in the case of the production wells. For this reason, good injection wells often make good production wells and vice versa. Therefore the injection wells should be drilled as large as the production wells, unless it is known in advance that the well is certain to be used for injection. If a well is only going to serve as an injection well, it can be smaller; for instance a 8-5/8 to 10-3/4 inches outside diameter for the injection casing, since it does not require installation of a down-hole pump. Two injection wells have been assumed in this study to be sufficient for the 2.5 MW project, however one well may suffice.

4.5 Cooling Requirements

In an organic Rankine cycle, heat is transferred from one reservoir (the geothermal reservoir) to another reservoir (the cooling system). In the process, a portion of the heat is converted into electricty. At the low temperatures typical of geothermal power plants, the efficiency of the process is about 12%. That is, of the total heat removed from the geothermal fluid, 12% may be converted into electricity, and 88% is rejected as waste heat. The reservoir that accepts the waste heat can be the atmosphere, or it can be a large body of water. The later option is generally preferred for technical and economic reasons, provided that there are no significant environmental consequences.

The cooling system is very important since the electrical output of the power plant is directly related to cooling system performance. High power output depends on low condensing pressure. Greater cooling system effectiveness will result in lower condensing pressure, and therefore higher power output. There are several common types of cooling systems: forced draft wet cooling towers; spray ponds; air cooled condensers; and once-through systems using lake, river, or ocean water.

Once-through cooling systems, so named because the cooling water flows through the heat exchanger once and is discharged back to the source rather than being recycled, are frequently used with large power plants situated near rivers, lakes, or the ocean. Water is pumped from the source and is warmed about 20°F as it flows through the condenser. The warmed water is discharged back into the source. With large power plants, this is a potential source of thermal pollution. In the case of a small power plant, the thermal effects of the discharged water are minimal. The point of discharge in the lake marks the peak of the thermal plume caused by the warm water. For a 2.5 MW power plant, this heat is dissipated in the lake such that the plume has cooled to less than 1°F above lake temperature within a circle of 260 feet in diameter. The basis for this estimate can be found in Appendix B.

There are several advantages to using Pyramid Lake as a cooling water source. The lake water is usually at a temperature lower than a cooling tower can economically reach, and therefore will increase plant power output. Also, the lake water temperature is relatively stable and does not fluctuate rapidly as the weather changes. This leads to more stable and predictable power output. There is no need for a tall structure that will disrupt the visual environment; nor will there be a vapor plume due to evaporation above the plant. Also, there are no fans and associated gearboxes and motors. Their absence means less power is required for operation, less noise is produced, and less maintenance is required.

As stated previously, a 2.5 megawatt plant will require a cooling water flow rate of approximately 8,750 gallons per minute. This flow requires a pipe diameter of 24 inches for both intake and discharge. The pipelines should be buried to minimize visual impact. The intake and discharge must be located some distance from each other, at least 300 feet, to prevent the cooling water intake from picking up the warmed discharge water. In order to make sure the intake will remain submerged during low water years, it should probably be at a depth of 40 feet under the present water level. The lake bottom is sloped very gradually in the area, and it may be necessary to run piping about 1,500 feet into the lake to obtain a 40 foot depth. The design of the cooling water inlet must be carefully addressed to prevent foreign material from being entrained in the cooling water.

The large flow of water used in the cooling system may be of value for expansion of the Tribe's fish hatcheries. One of the major expenses in hatchery operations is the cost of electricity for water pumping. Since this water must be pumped to the power plant anyway, it is available as a "free" source of water. The only difficulty with this concept is the need for two pumping stations -- one to pump from the lake to the hatchery, and another to pump from the hatchery to the power plant. In addition, the Needles may not be a desirable location for a fish hatchery. Additional study is necessary in this regard.

4.6 Power Plant Construction

The Preliminary Site Plan, Plate II, refers to the locations of two potential plant sites. The site labeled Alternative #2 has the advantage of being centrally located with respect to the probable wellfield drilling area, and requires no new roads. It is also closer to the lake and will require shorter cooling water piping. However, this site has a major disadvantage in its proximity to the Needle rocks and beaches.

The site labeled Alternative #1 is preferred for having less impact on the Needles. It is also less sensitive to lake elevation changes. However, this site will require longer cooling water piping, and probably longer production well piping. The production well locations are not known yet, so wellfield piping may or may not be longer for this site.

Small-scale power plants can be obtained factory pre-assembled in modular skid-mounted form. A 2.5 MW plant would probably utilize one or two factory built power modules, each being a complete power unit containing the turbine, generator, heat exchangers, and controls. The modular approach minimizes site disruption due to construction, and generally leads to better construction scheduling and a smoother startup. See Figure 4.2 for a possible plant layout.

Since the modular units are designed to fit within the predetermined dimensions of a skid, some compromises must be made in heat exchanger sizes, overall plant configuration, and maintainability. The other approach

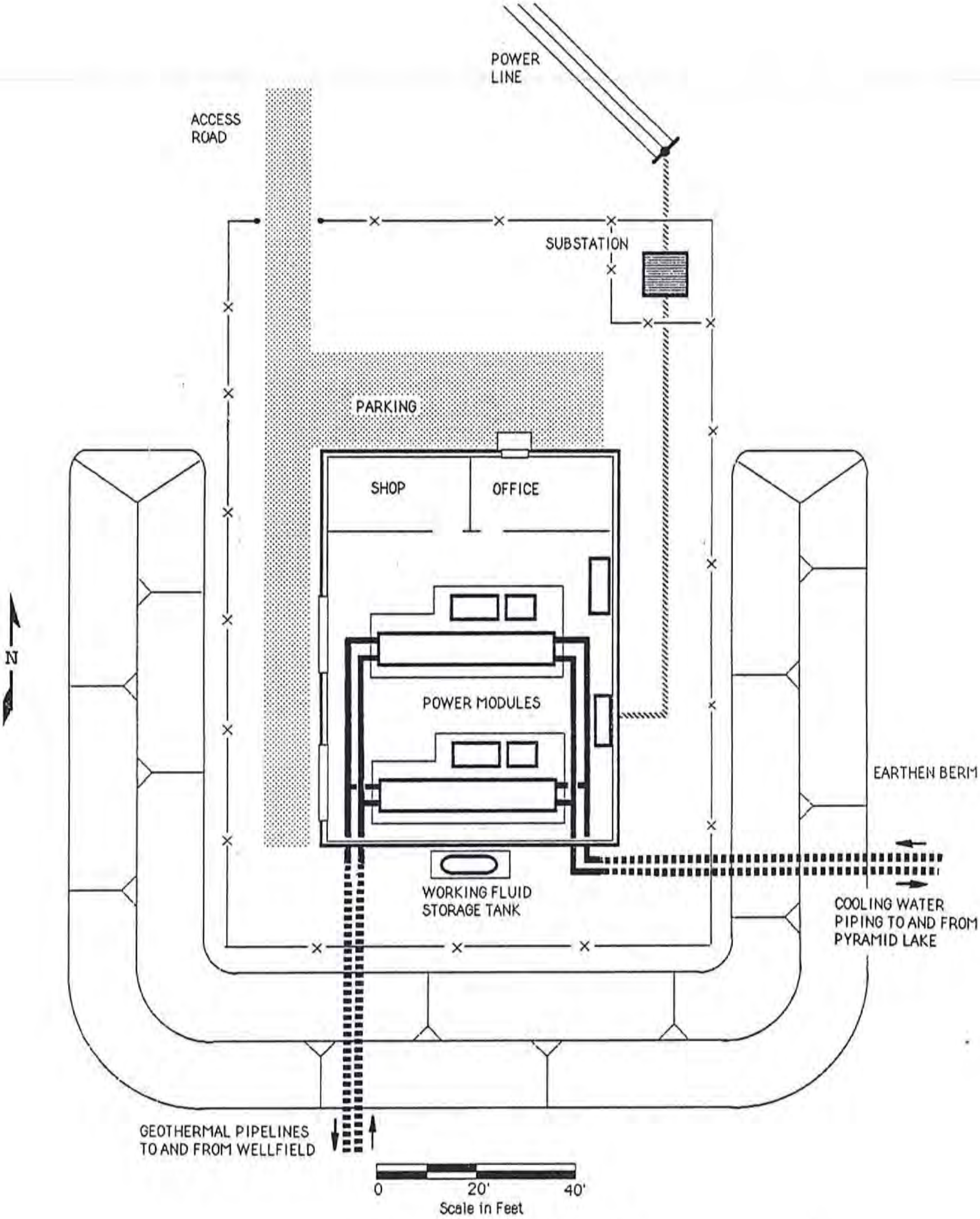


Figure 4.2 Power Plant Layout

is to build the plant with one 2.5 MW turbine-generator unit, with the necessary heat exchangers installed in the field. The heat exchanger design is then not limited to the dimensions of a modular skid, so efficiency can be expected to be higher. The increased efficiency comes at the possible expense of somewhat longer field assembly time.

A small-scale power plant is a fairly simple construction project, provided that qualified supervisory personnel are available. The major site work, consisting of concrete slabs and footings, can be done with a minimum of equipment. A backhoe is a necessary piece of equipment used for excavation of footings and trenching for electrical conduit and plant piping.

Once the foundations have cured, the power plant equipment can be installed. A crane may be needed on several occasions to unload equipment from delivery trucks and to set it in place. With the major equipment in place, the piping and wiring can be completed and the plant is ready for startup testing.

A 2.5 MW plant can be constructed within three months, assuming no shipping delays, financing difficulties, labor disputes, or unfavorable weather. Commencement of operations within six months is more realistic if unanticipated contingencies are considered. It seems that most small scale geothermal projects are scheduled for spring groundbreaking, but delays set the schedule back to mid-summer or fall. Winter weather can create further delays, so careful planning and arranging of financing can be very important.

5.0 ELECTRICITY MARKET AND DISTRIBUTION SYSTEM

5.1 Introduction

A suitable market for power produced at the Needles is essential to the project's success. The market possibilities may seem to be endless, since nearly everyone uses electricity, but are in fact quite limited when practical constraints are considered. The greatest limitation is the distance between the Needles and existing power lines.

The nearest power line terminates at Warrior Point, as shown in Plate IV. This line originates at Sierra Pacific Power Company's Tracy Power Plant, located on the Truckee River, about 15 miles east of Sparks. To reach this existing line, approximatey 12.5 miles of new line would have to be built. The right-of-way shown on the map of Plate IV was chosen to keep the line away from the lake shore. A shorter right-of-way is possible, but would have the disadvantages of greater visual impact, and flooding if the lake level increases significantly.

The next nearest lines on the Reservation are much farther away than Warrior Point. There are two lines that run north out of Wadsworth Substation, shown in Plate IV. One of these lines is a 60 kv line which passes east of Nixon and on up to Empire. This line is fully loaded at present and cannot easily be made to accept additional power. The second line is the 12.5 kv line that serves Nixon. This line is constructed of rather small wire, which limits its power transmission capability. Additionally, to reach Nixon from the existing line at the pumping station near Mullen Pass, the construction of about 25 miles of new line would be required. A new line paralleling the existing line from Nixon to Wadsworth would also be required, adding another 12 miles or so. Thus, this alternative has as its primary disadvantage high interconnection cost. On the other hand, it has the advantage of interconnecting all of the present day Reservation communities.

The last alternative considered is the construction of a new line from the Needles to Honey Lake Valley, California. Lassen Municipal Utilities District serves bulk power to the Herlong Army Ammunition Depot in Honey Lake Valley, and the Army redistributes power on the base. To interconnect with the Army's lines on the Depot would require the construction of about 23 miles of new line. It may be possible to rebuild parallels the Western Pacific Railroad tracks from Flanigan to the Depot, thereby reducing construction costs. The principal advantage of this alternative is that the Army may be willing to pay more than Sierra Pacific.

Highlights of the three alternatives just described are summarized in the Table 5.1.

5.2 Power Contracts

As important as it is to have a nearby market for the electricity generated by the Needles power plant, it is equally important to receive a fair price for the energy produced. The Public Utility Regulatory Policies Act (PURPA) of 1978 was passed into law to help foster a fair market for alternative energy resources. The essential portions of PURPA require utilities to buy power generated from alternative resources, such as geothermal at a price known as the "avoided cost". In Nevada, the Public Service Commission has established an avoided cost that represents the cost of generating electricity at a coal-fired facility. Power contracts negotiated between Sierra and geothermal developers in the past few years have been as high as 7¢/kwh and as low as 5¢/kwh. The trend has been toward lower rates.

Presently, Sierra is not offering a standard contract with firm rates. The Public Service Commission has set a limit of 85 megawatts that Sierra must buy at firm rates. Sierra maintains that they already have 85 megawatts of signed power contracts, and are not signing any more at the higher rates. Thus, in order to obtain a power contract with Sierra, some compromises must be made in the negotiations.

It is GDA's opinion that a contract with a rate on the order of 5¢/kwh is still obtainable, provided Sierra can be shown that the developer's plans will be of some benefit. One such benefit that the Needles Power Plant offers is improving service to rapidly growing Warm Springs Valley (Palomino Valley). In order for Sierra to obtain maximum benefit from the Needles Power Plant, the plant operating procedures must include provisions for voltage control. For instance, Sierra may request the plant operators to adjust the generator voltage from time to time in order to maximize the quality of service to Sierra's customers.

Another benefit to Sierra's customers is improved reliability of service. The line which presently serves Sutcliffe and Warm Springs Valley is a radial line originating at the Tracy Power Plant. When this line is taken

Table 5.1 Summary of Interconnection Alternatives

	Warrior Point	Wadsworth	Herlong
Line Voltage:	24.9 kV	24.9 kV (1)	34.5 kV
Line Length:	12.5 miles	37.5 miles	23 miles
Capacity:	2500 kW (2)	2500 kW (3)	2500 kW (4)
Right-of-Way:	Tribal lands	Tribal lands	Tribal/RR lands (5)
Line Cost:	$483,000 (6)	$1,125,000 (7)	$736,000 (8)
Tap Cost:	$100,000 (9)	$550,000 (10)	$100,000 (11)

(1) This alternative requires the construction of 24.9 kV lines from Needles to Warrior Point, from Mullens Pass to Nixon, and from Nixon to Wadsworth paralleling the existing 12.5 kV line.

(2) The capacity of this alternative was determined through power flow studies of a simplified model of Sierra's system from the 60 kV bus at Tracy out to Warrior Point and the Needles.

(3) This is an estimate only. No power flow studies or system modeling have been done to verify this estimate.

(4) This is an estimate only. No power flow studies or system modeling have been done to verify this estimate. As a practical matter, the maximum capacity under this alternative would be limited to the load at any given time on the Army base.

(5) A portion of the right-of-way for this alternative must be negotiated with the Union Pacific Railroad (formerly Western Pacific). Additionally, the Army would have to grant an easement on the base.

(6) This estimate is based on single wood pole construction costing $30,000/mile for new construction from Needles to Warrior, and $15,000/mile to reconductor Warrior to Sutcliffe (7.2 miles).

(7) This estimate is based on single wood pole construction costing $30,000/mile for 37.5 miles of 24.9 kV construction.

(8) This estimate is based on single wood pole construction costing $32,000/mile.

(9) This estimate includes the cost of a recloser and related circuit protective devices, and metering equipment. This equipment is normally installed and maintained by Sierra at the expense of the developer.

(10) This estimate includes the same equipment at Warrior Point as does the Warrior Point alternative, but additional equipment is required at Mullens Pass, Nixon, and Wadsworth. A circuit breaker and a 60/24.9 kV transformer are required at Wadsworth.

(11) This estimate is for equipment similar to that required under the alternative for Warrior Point, except that the Army may wish to own the equipment.

out by wind, lightning, or brush fire, many customers are left without power. With the Needles Power Plant on-line however, it may be possible for the Tracy-Warm Springs line to be removed from service, and still serve customers from the Needles. Unfortunately, Sierra is not likely to put a very high value on any of the benefits that are pointed out to them.

The power contract will most likely include two components: an energy price and a capacity price. Both are usually expressed in terms of cents/kwh, and together they may approach 5.0¢/kwh. The energy component may be 4.5¢/kwh, and the capacity component 0.5¢/kwh, to give a total of 5.0¢/kwh. The highest rate that might be anticipated would be about 5.5¢/kwh.

Sales of electricity to other than Sierra may present regulatory difficulties. Sierra operates within a certificated service territory, and within that territory only Sierra may provide electricity. A similar situation may exist for the Army base at Herlong. The Army is a customer of Lassen Municipal Utilities District, and no other utility may provide service without the consent of Lassen Municipal Utilities District. Thus, in order for the Needles Power Plant to provide electricity to the Army, the Army would at least have to build a line to the plant, or perhaps even be a part owner of the power plant. These problems aside, the Army may be a better market for the Needles Power Plant because they may be willing to pay a higher rate. Lassen Municipal Utilities District purchases power from other utilities at 7 to 8¢/kwh, and distributes it to its customers, including the Army. Thus, the Army must presently pay something over 8¢/kwh, and might be willing to purchase electricity at 7¢/kwh, even if it had to participate in the construction of the power plant. This option should be explored in parallel with further power contract talks with Sierra.

6.0 PROJECT ECONOMICS

6.1 Introduction

The economic evaluation made in this report attempts to present an accurate and comprehensive model of project economic performance. Evaluation of a project from an economic standpoint requires careful estimation of many parameters. The capital cost of the project is the first element in such an analysis. Capital costs must be determined in sufficient detail to give a reasonble level of confidence, and in order to ascertain the scheduling of expenditures during project development.

Similarly, expenses incurred during operation of the plant must be projected. One of the major operating expenses is debt service, which is dependent in part on the capital cost estimate. Finally, project economic performance can be summarized in a combined income and expense statement known as the cash balance pro forma. Thus, three interdependent spreadsheets have been developed in order to evaluate project economics:

- Capital Cost Estimates
- Projected Expenses
- Cash Balance Pro Forma

Spreadsheets which detail the capital cost, projected expenses, and cash balance have been included at the end of this section. There are actually two sets of spreadsheets--the first set, Tables 6.1, 6.2, and 6.3, details a 2.5 MW project, and the second set, Tables 6.4, 6.5, and 6.6, details a 5.0 MW project.

A commonly used method of evaluating project economic performance is an indicator known as the Internal Rate-of-Return, or IRR. The IRR is a measure of the relative profitability of a project. It can be thought of as the interest rate earned by the equity invested in the project. Because it represents the cash earned on the cash invested, IRR is often referred to as cash-on-cash rate of return.

Higher IRR indicates a more profitable project. The minimum acceptable IRR depends on an investor's perception of the risks involved, and the other alternatives open for investment. A simple savings account at most banks is considered a very low-risk investment. Savings accounts also have a very low IRR--typically 5%. Any power plant project involves risks considerably greater than a savings account. It must therefore earn a rate of return comensurate with that risk. It is GDA's opinion that such a project should earn 20% or more on the equity invested.

A sensitivity analysis was performed on the assumptions used in the case of the 2.5 MW project. To accomplish this, one parameter was varied in the economic model, while all other parameters were held constant. In this way, it was possible to test the sensitivity of the IRR to changes in key variables. Four key variables were analyzed in this way: capital cost, electricity sales price, interest rate, and term of debt.

6.2 Capital Cost

The capital cost of a geothermal power plant depends on the choice of power generation technology, the choice of cooling system, and on resource characteristics. Other important parameters which influence the capital cost are the distance to electrical markets, the geographical location of the site, site conditions, and environmental impact mitigation.

Recently, modular ORC power plants in Nevada have cost from $1800 to $2400 per net kW. The estimated cost for a 2.5 MW plant at the Needles is $5,400,000, which works out to about $2150 per kW. Of this $2150 per kW, about $800 per kW can be attributed to just the power generation modules.

Since the single largest expense is the power generation equipment, overall plant cost is sensitive to the cost of this machinery. There are currently three viable manufacturers of this equipment, and competition is increasing among them. It is likely the cost will drop in the near future as a direct result of this competition. This could lower the plant cost for a 2.5 MW plant by up to $250,000.

Wellfield development costs are also a significant part of the capital cost of the project. The greatest risk is taken during wellfield development. If resource exploration is undertaken properly, the risk in drilling production and injection wells is minimized. If the exploration program is incomplete, or if unusually difficult drilling circumstances are encountered, good production and injection wells may be difficult to develop. Additional drilling will result, and the capital cost of the wellfield will escalate. This is particularly important since the cost of wellfield development is usually borne by the developer, and thus impacts the internal rate of return.

Figure 6.1 is a graph which shows the sensitivity of the internal rate of return for the project, given a normal range of values for total capital cost. From this graph, it can be seen that the capital cost must be kept below $2400 per kW in order to earn a reasonable rate of return. In fact, every effort must be made to minimize wellfield costs and plant construction costs to insure favorable economics.

Generally, the resource must be proven in order to secure construction financing. The developer is required to provide the funding for exploration and the wellfield. In most instances, the developer must also cover some percentage of the construction costs. This analysis assumes the developer has provided equity money to fund the exploration, the wellfield development, and 20% of the construction costs.

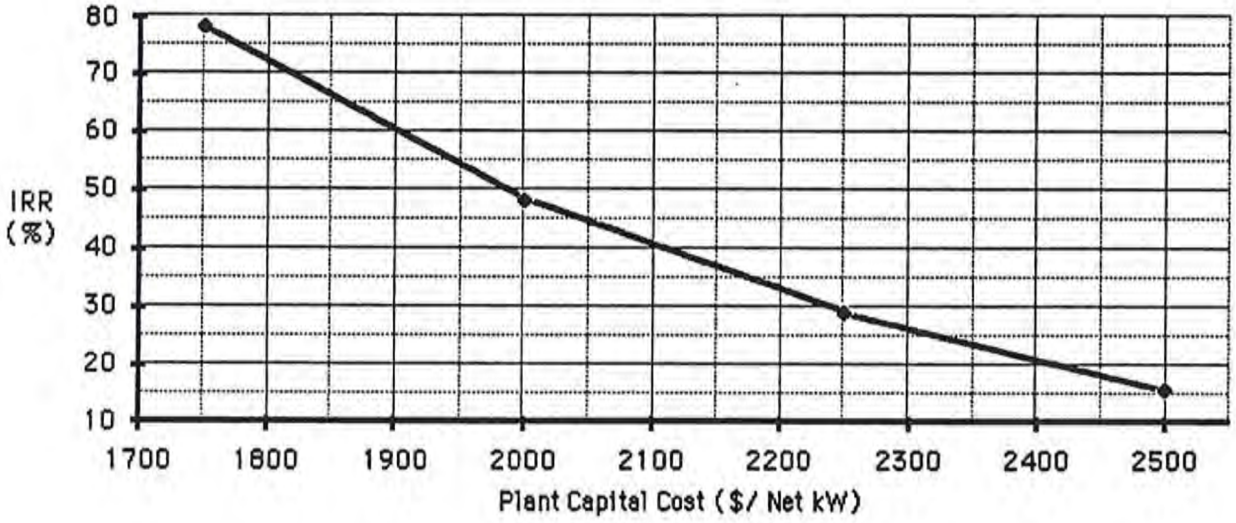


Figure 6.1 Internal Rate of Return vs. Plant Capital Cost (2.5 MW Plant)

6.3 Projected Expenses

The spreadsheet which summarizes projected expenses (Table 6.2 for the 2.5 MW plant) assumes that normal power plant operations begin in 1990 and continue through the year 2010, even though the plant is expected to operate for a much longer time period. The projections begin in 1990 with estimates for first year expenses, which are then escalated by 3% per year through 2010. There are three major categories of expenses, as described in the following paragraphs:

General and Administrative (G&A) Expenses. This category includes basic overhead such as management services, outside professional services (e.g., accounting and legal), and insurance. The first year G&A expense total is $90,000. It is important that the management team has ample experience in geothermal project operations, in order to minimize expenses and maximize power output. Some of the most important management functions include the monitoring for efficient use of the geothermal reservoir, assuring continuous power production, and minimizing environmental impacts.

Operation and Maintenance (O&M) Expenses. Total O&M expenses are estimated to be $147,000 in the first year for a 2.5 MW plant. The largest single O&M expense is salaries for 2 to 4 plant operators. In addition to operating duties, the staff must perform routine maintenance on all plant equipment. Payroll taxes are estimated at 20% of the operator's salaries.

Operations overhead includes telephone charges, upkeep and fuel for the plant pickup truck, and other ordinary overhead expenses. Maintenance engineering is a category that covers the cost of outside engineering fees which relate to maintenance. Maintenance labor represents the cost of outside labor that might be needed for special maintenance jobs.

The extended warranty is a fee paid to equipment manufacturers for warranty services beyond their normal warranty period. Materials and supplies include ordinary consumable items such as lubricating oils, gaskets, chart recorder pens and paper, and make-up working fluid. The equipment and machinery category is an allowance for replacement of pumps, motors, valves or other items of depreciable property that might not be expensed from a tax viewpoint. Major equipment repair reserve fund is similar to the equipment and machinery allowance, but is more of an operating reserve account that should be allowed to accumulate from year to year to cover unanticipated major repairs.

Debt Service. This section of the projected expenses spreadsheet details principal and interest payments on the borrowed money for the project. The total borrowings amount to $4,473,000 which is assumed to be paid back over 15 years at 12% interest. The loan payment is $657,000 per year.

The internal rate of return is quite sensitive to the interest rate, and also to the term of the loan. Figure 6.2 is a graph of the IRR as a function of interest rates from 8% to 16%. If the minimum acceptable return is 20%, the interest rate applied to borrowings must be kept below 14%. Similary, Figure 6.3 depicts the effect of shorter or longer loan periods. It can be seen in this figure that the longer the loan the better the IRR. Unfortunately, the greatest income to the Tribe starts only after the loan is paid off, and it is therefore of little benefit to seek loans longer than 15 years.

6.4 Cash Balance

The third and final spreadsheet used in the economic model is the Cash Balance Pro Forma, Table 6.3 for the 2.5 MW project. This spreadsheet summarizes projected revenue, and subtracts projected expenses to give the resulting net cash flow from the project. The 2.5 MW plant is expected to gross over $1,000,000 per year, assuming a price of electricity of 5¢ per kilowatt hour, and a capacity factor of 92%. Subtracting all expenses leaves $175,000 in net cash available to the Tribe in the first year, escalating to over $600,000 per year just before the loan is paid off, and jumping to over $1,300,000 per year after the loan is retired.

Figure 6.4 is a graph showing the sensitivity of the IRR to changes in the price of electricity. At 5 ¢/kwh, the IRR is 36%. If the price of electricity is below 4.5 ¢/kwh, the IRR drops to an unacceptable level--less than 20%. Thus it is clear that the project's success rides in part on obtaining a favorable rate for the electricity sold.

The final lines of the Cash Balance Pro Forma reflect standard investment statistics which are used to evaluate economic performance. The first statistic is the cash-on-cash rate of return (IRR) which has been used extensively in this section. The second row of numbers is the cash-on-cash annual return. These numbers express the net cash flow for each respective year as a percentage of the equity investment. The final row is a set of numbers that indicate how much money is available in any given year to cover debt service.

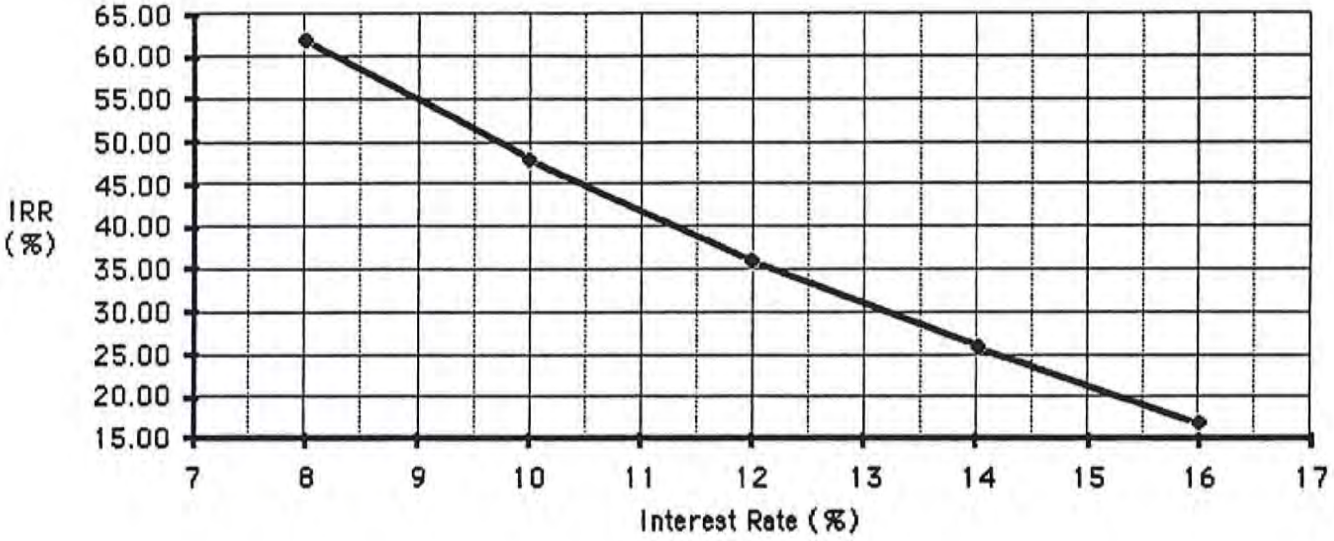


Figure 6.2 Internal Rate of Return vs. Term Loan Interest Rate (2.5 MW Plant).

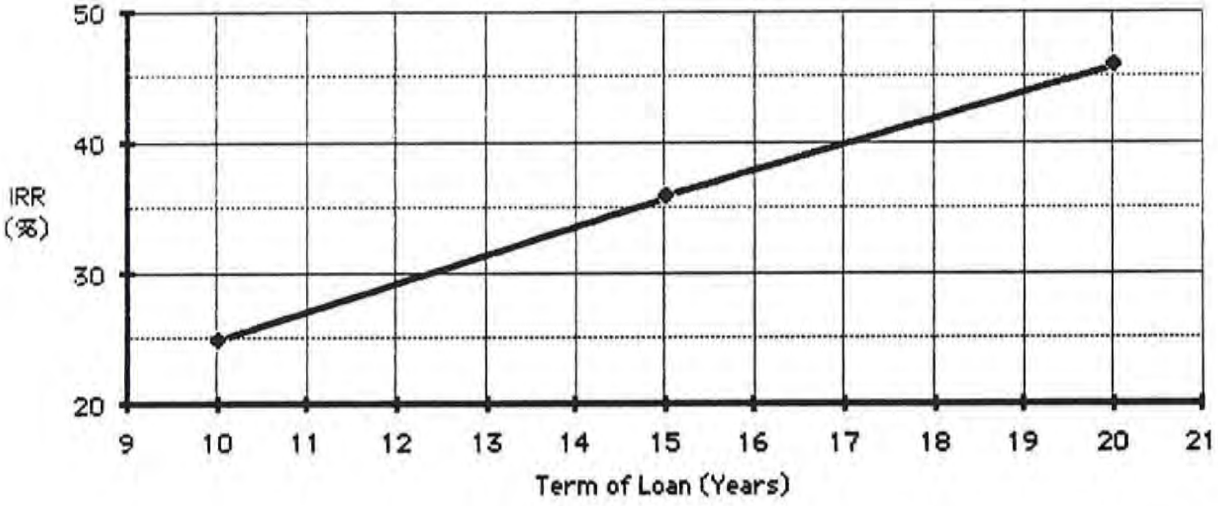


Figure 6.3 Internal Rate of Return vs. Term of Loan (2.5 MW Plant).

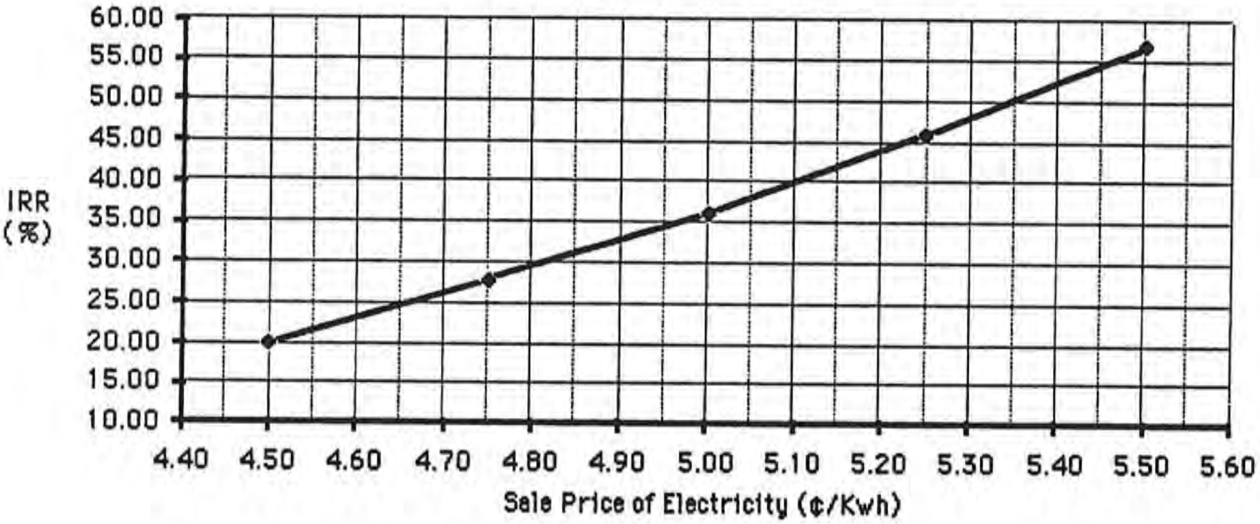


Figure 6.4 Internal Rate of Return vs. Sale Price of Electricity (2.5 MW Plant).

A debt service coverage ratio of 1.27 means the project can pay all of its debt and have 27% left over. Commercial banks generally like to see this ratio closer to 2.0. Because of the low ratio in this particular project, a bank may require a loan guarantee of some kind. The alternative is to borrow less by increasing the equity required, but this can have negative impact on the IRR.

6.5 Financing

The financing of this project should be thought of as a multistage process, which began with the funding of this feasibilty study. The next two phases of the project, Phase II- Exploration, and Phase III- Wellfield Development, must be funded with equity from Tribal general funds or possibly through economic development grants. Banks and other conventional institutional lenders will not fund high risk ventures. These sources normally view resource development as risky business. For this reason, sources of equity must be identified to fund the project through the point of proving the resource.

Once successful production and injection wells have been drilled and tested, the project moves into Phase IV- Power Plant Construction. At this point, sources of debt financing must be identified. Construction financing may be obtained from conventional sources, but the conditions placed on the loan may increase the cost of the project significantly. For instance, it is not uncommon for the lender of construction debt to require a turnkey construction contract on the project. This means that the contractor must guarantee that the plant will be built on time for a fixed price. While this may seem prudent and reasonable, it results in higher costs because the contractor taking the performance risk must bid high to cover all contingencies that might arise.

An alternative to the turnkey approach, is to seek vendor financing for the major components of the power plant, so that a much smaller construction loan is required. A supplier of a major component may agree to get paid for his equipment when the plant is commissioned. In this way, the project management team can seek competitive bids for major equipment and labor, selecting the best terms within established quality quidelines. The power plant can be built at a much lower cost in this manner. The price difference between the turnkey contractor approach and the general contractor approach can be 2:1.

Conventional financing with vendor support has been assumed in the preparation of the spreadsheets presented in this report. The financing would consist of a construction loan to finance a portion of the costs, and vendor financing to carry the major equipment to commissioning. At commissioning, a long term loan would pay off the construction loan. This takeout loan has been assumed to have a term of 15 years, and an interest rate of 12%

An alternative method of financing would be the use of revenue bonds. The money raised from the sale of the bonds may be used directly for construction, or could be used to pay off a construction loan at the time of commissioning. A bonding company would buy the bonds from the Tribe, and resell them taking a 3% to 5% commission. Revenue from the plant would then go to the bond holders for the term of the bond. The term might be 20 years and the interest rate might have a range from 8% to 12%. One drawback to the bonding approach is the necessary manpower for administration of the bonds. However, the extra effort required to administer will be more than offset by the lower interest rates.

Whichever option is chosen, costs will be incurred in a due diligence review of the resource and the plant by outside engineering firms. Although this independent review is required by the financing entity, the costs would be paid by the Tribe.

6.6 Summary

The economics for both the 2.5 MW and the 5.0 MW projects are favorable with midrange values for the four critical parameters mentioned. If the price of electricity is higher than 5¢/kwh, and the interest rate is less than 12%, the economics begin to look quite impressive. With a value engineering effort rather than turnkey contracting, the capital cost of the plant may be kept well below the $2000/kw level. On the other hand, if no controls are placed on these variables, forces opposing successful completion could harm the project. The favorable economic projections point toward continued development of the project. Additional work should be undertaken to further refine the estimates used in the model, and to confirm the major assumptions.

Tables 6.1, 6.2, and 6.3
Spreadsheets for a 2.5 MW Plant

Table 6.1 Capital Cost Estimate for a 2.5 MW Plant

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	CAPITAL COST ESTIMATE														
2	Project: Pyramid Lake 2.5 Megawatt Geothermal Power Plant														
3	Estimator: LHG/DLM														
4	Date: 4/25/88								Begin Construction						
5		PRE-													
6	DESCRIPTION	CONSTRUCTION	MONTH 1	MONTH 2	MONTH 3	MONTH 4	MONTH 5	MONTH 6	MONTH 7	MONTH 8	MONTH 9	MONTH 10	MONTH 11	MONTH 12	
7															
8	1.0 EXPLORATION														
9	1.1 Feasibility Study	$37,000													$37,000
10	1.2 Geology/Hydrology	$5,000													$5,000
11	1.3 Geophysics	$20,000													$20,000
12	1.4 TGH Survey	$20,000													$20,000
13	1.5 Test Wells (3 req'd)	$60,000													$60,000
14	1.6 Technical Support	$10,000													$10,000
15															
16	SUBTOTAL EXPLORATION	$152,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$152,000
17															
18	2.0 WELLFIELD														
19	2.1 Production Well #1		$150,000												$150,000
20	2.2 PW #1 Testing			$15,000											$15,000
21	2.3 Injection Well #1			$100,000											$100,000
22	2.4 IW #1 Testing				$10,000										$10,000
23	2.5 Production Well#2				$150,000										$150,000
24	2.6 PW#2 Testing					$15,000									$15,000
25	2.7 Production Well #3					$150,000									$150,000
26	2.8 PW#3 Testing						$15,000								$15,000
27	2.9 Injection Well #2						$100,000								$100,000
28	3.0 IW #2 Testing							$10,000							$10,000
29	2.7 Drilling Technical Support		$8,000	$8,000	$8,000	$8,000	$8,000	$8,000							$48,000
30															
31	SUBTOTAL WELLFIELD	$0	$158,000	$123,000	$168,000	$173,000	$123,000	$18,000	$0	$0	$0	$0	$0	$0	$763,000
32															
33	3.0 POWER PLANT														
34	3.1 Site Preparation								$2,000	$2,000	$10,000	$10,000	$10,000	$5,000	$39,000
35	3.2 Footings and Foundations								$5,000	$5,000	$5,000	$5,000	$4,000	$2,000	$26,000
36	3.3 Generating Units ($800/kW)										$2,000,000				$2,000,000
37	3.4 Production Pumps (3 req'd)									$40,000	$40,000	$40,000			$120,000
38	3.5 Hot Side Piping									$60,000	$60,000	$60,000			$180,000
39	3.6 Cooling Water Pumps										$8,000	$8,000			$16,000
40	3.7 Cooling Water Piping										$60,000	$60,000	$20,000		$140,000
41	3.8 Instrumentation										$15,000	$15,000	$15,000		$45,000
42	3.9 Fire Protection System													$15,000	$15,000
43	3.10 Building												$60,000	$20,000	$80,000
44	3.11 Electrical											$60,000	$60,000	$60,000	$180,000
45	3.12 Maintenance Equipment													$30,000	$30,000
46															
47	SUBTOTAL FOR POWER PLANT	$0	$0	$0	$0	$0	$0	$0	$7,000	$107,000	$2,198,000	$258,000	$169,000	$132,000	$2,871,000
48															
49	4.0 UTILITY INTERCONNECTION														
50	4.1 Power Sales Contract	$15,000													$15,000
51	4.2 Interconnection Study	$15,000													$15,000
52	4.3 Utility Tap												$50,000	$50,000	$100,000
53	4.4 Transmission Line from														
54	Needles to Warrior Point												$200,000	$175,000	$375,000
55	4.5 Reconductor Line from														
56	Warrior Pt. to Sutcliffe												$58,000	$50,000	$108,000
57															
58	SUBTOTAL FOR INTERCONNECT	$30,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$308,000	$275,000	$613,000
59															
60	5.0 GENERAL														
61	5.1 Professional Services		$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$60,000
62	5.2 Insurance and Bonding		$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$60,000
63	5.3 Independent Review								$20,000						$20,000
64	5.4 Construction Power								$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$12,000
65															
66	SUBTOTALS FOR GENERAL	$0	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$32,000	$12,000	$12,000	$12,000	$12,000	$12,000	$152,000
67															
68	6.0 SUMMARY														
69	6.1 Totals	$182,000	$168,000	$133,000	$178,000	$183,000	$133,000	$28,000	$39,000	$119,000	$2,210,000	$270,000	$489,000	$419,000	$4,551,000
70	6.2 Loan Fee (3% of loan)								$134,189						$134,189
71	6.3 Contingency (15%)	$27,300	$25,200	$19,950	$26,700	$27,450	$19,950	$4,200	$25,978	$17,850	$331,500	$40,500	$73,350	$62,850	$702,778
72	6.4 GRAND TOTALS	$209,300	$193,200	$152,950	$204,700	$210,450	$152,950	$32,200	$199,167	$136,850	$2,541,500	$310,500	$562,350	$481,850	$5,387,967
73															
74	7.0 FINANCING												PROJECT COST PER kW:		$2,155
75	Assume equity is required for exploration and wellfield development.														
76	TOTAL EQUITY REQUIRED	$915,000													
77	TOTAL AMOUNT FINANCED	$4,472,967													
78															

Table 6.2 Projected Expenses for a 2.5 MW Plant

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	PROJECTED EXPENSES																						
2	Pyramid Lake 2.5 Megawatt Geothermal Power Plant																						
3	4/25/88			3.00%	General Inflation Factor																		
4				12.00%	Term Loan Interest Rate for 15 years																		
5																							
6																							
7																							
8																							
9	DESCRIPTION	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
10																							
11	1.0 GENERAL AND ADMINISTRATIVE																						
12	1.1 Management Services	$40	$41	$42	$44	$45	$46	$48	$49	$51	$52	$54	$55	$57	$59	$61	$62	$64	$66	$68	$70	$72	$1,147
13	1.2 Professional Services	$15	$15	$16	$16	$17	$17	$18	$18	$19	$20	$20	$21	$21	$22	$23	$23	$24	$25	$26	$26	$27	$430
14	1.3 Insurance - Liability and Property	$35	$36	$37	$38	$39	$41	$42	$43	$44	$46	$47	$48	$50	$51	$53	$55	$56	$58	$60	$61	$63	$1,004
15																							
16	Subtotal General and Administrative	$90	$93	$95	$98	$101	$104	$107	$111	$114	$117	$121	$125	$128	$132	$136	$140	$144	$149	$153	$158	$163	$2,581
17																							
18	2.0 OPERATION AND MAINTENANCE																						
19	2.1 Plant Operations	$50	$52	$53	$55	$56	$58	$60	$61	$63	$65	$67	$69	$71	$73	$76	$78	$80	$83	$85	$88	$90	$1,434
20	2.2 Payroll Taxes	$10	$10	$11	$11	$11	$12	$12	$12	$13	$13	$13	$14	$14	$15	$15	$16	$16	$17	$17	$18	$18	$287
21	2.3 Operations Overhead	$10	$10	$11	$11	$11	$12	$12	$12	$13	$13	$13	$14	$14	$15	$15	$16	$16	$17	$17	$18	$18	$287
22	2.4 Maintenance Engineering	$5	$5	$5	$5	$6	$6	$6	$6	$6	$7	$7	$7	$7	$7	$8	$8	$8	$8	$9	$9	$9	$143
23	2.5 Maintenance Labor	$10	$10	$11	$11	$11	$12	$12	$12	$13	$13	$13	$14	$14	$15	$15	$16	$16	$17	$17	$18	$18	$287
24	2.6 Extended Warranties	$20	$21	$21	$22	$23	$23	$24	$25	$25	$26	$27	$28	$29	$29	$30	$31	$32	$33	$34	$35	$36	$574
25	2.7 Materials and Supplies	$10	$10	$11	$11	$11	$12	$12	$12	$13	$13	$13	$14	$14	$15	$15	$16	$16	$17	$17	$18	$18	$287
26	2.8 Equipment and Machinery	$12	$12	$13	$13	$14	$14	$14	$15	$15	$16	$16	$17	$17	$18	$18	$19	$19	$20	$20	$21	$22	$344
27	2.9 Major Repair Reserve Fund	$20	$21	$21	$22	$23	$23	$24	$25	$25	$26	$27	$28	$29	$29	$30	$31	$32	$33	$34	$35	$36	$574
28																							
29	Subtotal Operation and Maintenance	$147	$151	$156	$161	$165	$170	$176	$181	$186	$192	$198	$203	$210	$216	$222	$229	$236	$243	$250	$258	$265	$4,215
30																							
31	3.0 DEBT SERVICE																						
32	3.1 Term Loan																						
33	3.1.1 Principal Balance	$4,473	$4,353	$4,219	$4,068	$3,900	$3,711	$3,499	$3,262	$2,997	$2,700	$2,367	$1,995	$1,577	$1,110	$586	$0						
34	3.1.2 Interest	$537	$522	$506	$488	$468	$445	$420	$391	$360	$324	$284	$239	$189	$133	$70	$0						$5,378
35	3.1.3 Principal	$120	$134	$151	$169	$189	$211	$237	$265	$297	$333	$373	$417	$467	$524	$586	$0						$4,473
36	3.1.4 Payment	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657							$9,851
37																							
38																							

Table 6.3 Cash Balance Pro Forma for a 2.5 MW Plant

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	CASH BALANCE PRO FORMA																						
2	Pyramid 2.5 Megawatt Geothermal Power Plant																						
3	4/25/88			3.00%	General Inflation Factor																		
4				3.00%	Energy Price Escalation Factor				$0.0500	Contract Energy Price													
5				3.00%	Capacity Price Escalation Factor				$0.0000	Contract Capacity Price													
6				92.00%	Annual Capacity Factor				$0.0000	Excess Energy Sales Price													
7																							
8	DESCRIPTION	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
9																							
10	1.0 REVENUE																						
11	1.1 Contract Capacity.................KW	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	
12	1.2 Actual Capacity......................KW	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	
13	1.3 Contract Energy Sales..........MWH	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	20148	423108
14	1.4 Excess Energy Sales.............MWI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15																							
16	1.5 Revenue From Capacity Sales	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
17	1.6 Revenue From Energy Sales	$1,069	$1,101	$1,134	$1,168	$1,203	$1,239	$1,276	$1,314	$1,354	$1,394	$1,436	$1,479	$1,524	$1,569	$1,617	$1,665	$1,715	$1,766	$1,819	$1,874	$1,930	$30,648
18	1.7 Revenue From Excess Energy Sale:	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19																							
20	Subtotal Revenue	$1,069	$1,101	$1,134	$1,168	$1,203	$1,239	$1,276	$1,314	$1,354	$1,394	$1,436	$1,479	$1,524	$1,569	$1,617	$1,665	$1,715	$1,766	$1,819	$1,874	$1,930	$30,648
21																							
22	2.0 EXPENSES																						
23	2.1 General and Administrative	$90	$93	$95	$98	$101	$104	$107	$111	$114	$117	$121	$125	$128	$132	$136	$140	$144	$149	$153	$158	$163	$2,581
24	2.2 Operation and Maintenance	$147	$151	$156	$161	$165	$170	$176	$181	$186	$192	$198	$203	$210	$216	$222	$229	$236	$243	$250	$258	$265	$4,215
25	2.3 Debt Service	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$657	$0	$0	$0	$0	$0	$0	$9,851
26																							
27	Subtotal Expenses	$894	$901	$908	$916	$923	$931	$940	$948	$957	$966	$975	$985	$995	$1,005	$1,015	$369	$380	$392	$403	$416	$428	$16,647
28																							
29	3.0 FINANCING																						
30	3.1 Equity	$915																					
31	3.2 Debt	$4,473																					
32																							
33	Subtotal	$5,388																					
34																							
35	4.0 CASH BALANCE																						
36	4.1 Net Income (Loss)	$175	$200	$226	$252	$279	$307	$336	$366	$397	$429	$461	$495	$529	$565	$601	$1,296	$1,335	$1,375	$1,416	$1,458	$1,502	$14,001
37																							
38	Subtotal Cash Balance	$175	$200	$226	$252	$279	$307	$336	$366	$397	$429	$461	$495	$529	$565	$601	$1,296	$1,335	$1,375	$1,416	$1,458	$1,502	$14,001
39																							
40	5.0 INVESTMENT STATISTICS																						
41	5.1 Cash on Cash Rate of Return (IRR)	36.14%																					
42	5.2 Cash on Cash Annual Return	19.13%	21.85%	24.66%	27.56%	30.54%	33.61%	36.77%	40.02%	43.38%	46.83%	50.39%	54.05%	57.83%	61.72%	65.7%	141.6%	145.9%	150.2%	154.8%	159.4%	164.2%	
43	5.3 Debt Service Coverage Ratio	1.27	1.30	1.34	1.38	1.43	1.47	1.51	1.56	1.60	1.65	1.70	1.75	1.81	1.86	1.92							
44																							

Tables 6.4, 6.5, and 6.6
Spreadsheets for a 5.0 MW Plant

Table 6.4 Capital Cost Estimate for a 5.0 MW Plant

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	CAPITAL COST ESTIMATE														
2	Project: Pyramid Lake 5.0 Megawatt Geothermal Power Plant														
3	Estimator: LHG/DLM														
4	Date: 4/25/88								Begin Construction						
5		PRE-													
6	DESCRIPTION	CONSTRUCTION	MONTH 1	MONTH 2	MONTH 3	MONTH 4	MONTH 5	MONTH 6	MONTH 7	MONTH 8	MONTH 9	MONTH 10	MONTH 11	MONTH 12	
7															
8	1.0 EXPLORATION														
9	1.1 Feasibility Study	$37,000													$37,000
10	1.2 Geology/Hydrology	$7,000													$7,000
11	1.3 Geophysics	$20,000													$20,000
12	1.4 TGH Survey	$20,000													$20,000
13	1.5 Test Wells (5 req'd)	$110,000													$110,000
14	1.6 Technical Support	$15,000													$15,000
15															
16	SUBTOTAL EXPLORATION	$209,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$209,000
17															
18	2.0 WELLFIELD														
19	2.1 Production Well #1		$150,000												$150,000
20	2.2 PW #1 Testing			$15,000											$15,000
21	2.3 Injection Well #1			$100,000											$100,000
22	2.4 IW #1 Testing				$10,000										$10,000
23	2.5 Production Well#2				$150,000										$150,000
24	2.6 PW#2 Testing					$15,000									$15,000
25	2.7 Production Well #3				$150,000										$150,000
26	2.8 PW#3 Testing					$15,000									$15,000
27	2.9 Production Well #4					$150,000									$150,000
28	2.10 PW#4 Testing						$15,000								$15,000
29	2.11 Injection Well #2						$100,000								$100,000
30	2.12 IW #2 Testing							$10,000							$10,000
31	2.13 Injection Well #3							$100,000							$100,000
32	2.14 IW #3 Testing								$10,000						$10,000
33	2.15 Drilling Technical Support		$8,000	$8,000	$8,000	$8,000	$8,000	$8,000	$8,000						$56,000
34															
35	SUBTOTAL WELLFIELD	$0	$158,000	$123,000	$318,000	$188,000	$123,000	$118,000	$18,000	$0	$0	$0	$0	$0	$1,046,000
36															
37	3.0 POWER PLANT														
38	3.1 Site Preparation								$4,000	$4,000	$4,000	$10,000	$20,000	$10,000	$52,000
39	3.2 Footings and Foundations									$10,000	$10,000	$10,000	$10,000	$10,000	$50,000
40	3.3 Generating Units (6 req'd)										$4,000,000				$4,000,000
41	3.4 Production Pumps (4 req'd)									$100,000	$100,000				$200,000
42	3.5 Hot Side Piping										$100,000	$100,000	$80,000		$280,000
43	3.6 Cooling Water Pumps										$12,000	$12,000			$24,000
44	3.7 Cooling Water Piping										$75,000	$75,000	$60,000		$210,000
45	3.8 Instrumentation										$20,000	$20,000	$20,000		$60,000
46	3.9 Fire Protection System													$20,000	$20,000
47	3.10 Control Building												$50,000	$50,000	$100,000
48	3.11 Electrical											$120,000	$120,000	$120,000	$360,000
49	3.12 Maintenance Equipment													$30,000	$30,000
50															
51	SUBTOTAL FOR POWER PLANT	$0	$0	$0	$0	$0	$0	$0	$4,000	$114,000	$4,321,000	$347,000	$360,000	$240,000	$5,386,000
52															
53	4.0 UTILITY INTERCONNECTION														
54	4.1 Power Sales Contract	$15,000													$15,000
55	4.2 Interconnection Study	$15,000													$15,000
56	4.3 Utility Tap												$75,000	$75,000	$150,000
57	4.4 Transmission Line from														
58	Needles to Warrior Point												$185,000	$190,000	$375,000
59	4.5 Reconductor Line from														
60	Warrior Pt. to Sutcliffe												$50,000	$58,000	$108,000
61	4.6 New Line Parallel to Old-														
62	Sutcliffe to Warm Springs												$256,000	$256,000	$512,000
63															
64	SUBTOTAL FOR INTERCONNECTION	$30,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$566,000	$579,000	$1,175,000
65															
66	5.0 GENERAL														
67	5.1 Professional Services		$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$25,000	$300,000
68	5.2 Insurance and Bonding		$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$120,000
69	5.3 Independent Review								$60,000						$60,000
70	5.4 Construction Power								$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$18,000
71															
72	SUBTOTALS FOR GENERAL	$0	$35,000	$35,000	$35,000	$35,000	$35,000	$35,000	$98,000	$38,000	$38,000	$38,000	$38,000	$38,000	$498,000
73															
74	6.0 SUMMARY														
75	6.1 Totals	$239,000	$193,000	$158,000	$353,000	$223,000	$158,000	$153,000	$120,000	$152,000	$4,359,000	$385,000	$964,000	$857,000	$8,314,000
76	6.2 Loan Fee (3% of loan)								$258,087						$258,087
77	6.3 Contingency 15%	$35,850	$28,950	$23,700	$52,950	$33,450	$23,700	$22,950	$18,000	$61,513	$653,850	$57,750	$144,600	$128,550	$1,285,813
78	6.4 GRAND TOTALS	$274,850	$221,950	$181,700	$405,950	$256,450	$181,700	$175,950	$396,087	$213,513	$5,012,850	$442,750	$1,108,600	$985,550	$9,857,900
79															
80	7.0 FINANCING												PROJECT COST PER KW:		$1,972
81	Assume equity is required for exploration and wellfield development.														
82	TOTAL EQUITY REQUIRED	$1,255,000													
83	TOTAL AMOUNT FINANCED	$8,602,900													
84															

Table 6.5 Projected Expenses for a 5.0 MW Plant

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	PROJECTED EXPENSES																						
2	Pyramid Lake 5.0 Megawatt Geothermal Power Plant																						
3	4/25/88			3.00%	General Inflation Factor																		
4				12.00%	Term Loan Interest Rate for 15 years																		
5																							
6																							
7																							
8																							
9	DESCRIPTION	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
10																							
11	1.0 GENERAL AND ADMINISTRATIVE																						
12	1.1 Management Services	$80	$82	$85	$87	$90	$93	$96	$98	$101	$104	$108	$111	$114	$117	$121	$125	$128	$132	$136	$140	$144	$2,294
13	1.2 Professional Services	$30	$31	$32	$33	$34	$35	$36	$37	$38	$39	$40	$42	$43	$44	$45	$47	$48	$50	$51	$53	$54	$860
14	1.3 Insurance - Liability and Property	$50	$52	$53	$55	$56	$58	$60	$61	$63	$65	$67	$69	$71	$73	$76	$78	$80	$83	$85	$88	$90	$1,434
15																							
16	Subtotal General and Administrative	$160	$165	$170	$175	$180	$185	$191	$197	$203	$209	$215	$221	$228	$235	$242	$249	$257	$264	$272	$281	$289	$4,588
17																							
18	2.0 OPERATION AND MAINTENANCE																						
19	2.1 Plant Operations	$85	$88	$90	$93	$96	$99	$101	$105	$108	$111	$114	$118	$121	$125	$129	$132	$136	$140	$145	$149	$154	$2,438
20	2.2 Payroll Taxes	$20	$21	$21	$22	$23	$23	$24	$25	$25	$26	$27	$28	$29	$29	$30	$31	$32	$33	$34	$35	$36	$574
21	2.3 Operations Overhead	$20	$21	$21	$22	$23	$23	$24	$25	$25	$26	$27	$28	$29	$29	$30	$31	$32	$33	$34	$35	$36	$574
22	2.4 Maintenance Engineering	$10	$10	$11	$11	$11	$12	$12	$12	$13	$13	$13	$14	$14	$15	$15	$16	$16	$17	$17	$18	$18	$287
23	2.5 Maintenance Labor	$20	$21	$21	$22	$23	$23	$24	$25	$25	$26	$27	$28	$29	$29	$30	$31	$32	$33	$34	$35	$36	$574
24	2.6 Extended Warranties	$45	$46	$48	$49	$51	$52	$54	$55	$57	$59	$60	$62	$64	$66	$68	$70	$72	$74	$77	$79	$81	$1,290
25	2.7 Materials and Supplies	$20	$21	$21	$22	$23	$23	$24	$25	$25	$26	$27	$28	$29	$29	$30	$31	$32	$33	$34	$35	$36	$574
26	2.8 Equipment and Machinery	$25	$26	$27	$27	$28	$29	$30	$31	$32	$33	$34	$35	$36	$37	$38	$39	$40	$41	$43	$44	$45	$717
27	2.9 Major Repair Reserve Fund	$65	$67	$69	$71	$73	$75	$78	$80	$82	$85	$87	$90	$93	$95	$98	$101	$104	$107	$111	$114	$117	$1,864
28																							
29	Subtotal Operation and Maintenance	$310	$319	$329	$339	$349	$359	$370	$381	$393	$404	$417	$429	$442	$455	$469	$483	$497	$512	$528	$544	$560	$8,890
30																							
31	3.0 DEBT SERVICE																						
32	3.1 Term Loan																						
33	3.1.1 Principal Balance	$8,603	$8,372	$8,114	$7,824	$7,500	$7,137	$6,730	$6,275	$5,765	$5,193	$4,553	$3,837	$3,034	$2,135	$1,128	$0						
34	3.1.2 Interest	$1,032	$1,005	$974	$939	$900	$856	$808	$753	$692	$623	$546	$460	$364	$256	$135	$0						$10,344
35	3.1.3 Principal	$231	$258	$289	$324	$363	$407	$455	$510	$571	$640	$717	$803	$899	$1,007	$1,128							$8,603
36	3.1.4 Payment	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263							$18,947
37																							
38																							

Table 6.6 Cash Balance Pro Forma for a 5.0 MW Plant

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	CASH BALANCE PRO FORMA																						
2	Pyramid 5.0 Megawatt Geothermal Power Plant																						
3	4/25/88			3.00%	General Inflation Factor																		
4				3.00%	Energy Price Escalation Factor				$0.0500	Contract Energy Price													
5				3.00%	Capacity Price Escalation Factor				$0.0000	Contract Capacity Price													
6				92.00%	Annual Capacity Factor				$0.0000	Excess Energy Sales Price													
7																							
8	DESCRIPTION	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
9	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
10	1.0 REVENUE																						
11	1.1 Contract Capacity.................KW	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	
12	1.2 Actual Capacity.....................KW	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	
13	1.3 Contract Energy Sales..........MWH	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	40296	846216
14	1.4 Excess Energy Sales............MWI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15																							
16	1.5 Revenue From Capacity Sales	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
17	1.6 Revenue From Energy Sales	$2,138	$2,202	$2,268	$2,336	$2,406	$2,478	$2,552	$2,629	$2,708	$2,789	$2,873	$2,959	$3,048	$3,139	$3,233	$3,330	$3,430	$3,533	$3,639	$3,748	$3,861	$61,296
18	1.7 Revenue From Excess Energy Sale:	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19		----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
20	Subtotal Revenue	$2,138	$2,202	$2,268	$2,336	$2,406	$2,478	$2,552	$2,629	$2,708	$2,789	$2,873	$2,959	$3,048	$3,139	$3,233	$3,330	$3,430	$3,533	$3,639	$3,748	$3,861	$61,296
21																							
22	2.0 EXPENSES																						
23	2.1 General and Administrative	$160	$165	$170	$175	$180	$185	$191	$197	$203	$209	$215	$221	$228	$235	$242	$249	$257	$264	$272	$281	$289	$4,588
24	2.2 Operation and Maintenance	$310	$319	$329	$339	$349	$359	$370	$381	$393	$404	$417	$429	$442	$455	$469	$483	$497	$512	$528	$544	$560	$8,890
25	2.3 Debt Service	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$1,263	$0	$0	$0	$0	$0	$0	$18,947
26		----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
27	Subtotal Expenses	$1,733	$1,747	$1,762	$1,777	$1,792	$1,808	$1,824	$1,841	$1,858	$1,876	$1,895	$1,914	$1,933	$1,953	$1,974	$732	$754	$777	$800	$824	$849	$32,425
28																							
29	3.0 FINANCING																						
30	3.1 Equity	$1,255																					
31	3.2 Debt	$8,603																					
32		----------																					
33	Subtotal	$9,858																					
34																							
35	4.0 CASH BALANCE																						
36	4.1 Net Income (Loss)	$404	$454	$506	$559	$614	$670	$728	$788	$849	$913	$978	$1,045	$1,114	$1,186	$1,259	$2,598	$2,676	$2,756	$2,839	$2,924	$3,012	$28,871
37		----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
38	Subtotal Cash Balance	$404	$454	$506	$559	$614	$670	$728	$788	$849	$913	$978	$1,045	$1,114	$1,186	$1,259	$2,598	$2,676	$2,756	$2,839	$2,924	$3,012	$28,871
39																							
40	5.0 INVESTMENT STATISTICS																						
41	5.1 Cash on Cash Rate of Return	63.29%																					
42	5.2 Cash on Cash Annual Return	32.22%	36.21%	40.31%	44.54%	48.90%	53.38%	58.01%	62.77%	67.67%	72.72%	77.92%	83.27%	88.8%	94.5%	100.3%	207.0%	213.2%	219.6%	226.2%	233.0%	240.0%	
43	5.3 Debt Service Coverage Ratio	1.32	1.36	1.40	1.44	1.49	1.53	1.58	1.62	1.67	1.72	1.77	1.83	1.88	1.94	2.00							
44																							
45																							

7.0 ENVIRONMENT

7.1 Introduction

Any venture of a commercial nature introduces some change in its environment. This section of the feasibility study identifies potential impacts to the environment, and proposes mitigation measures to reduce or negate any potential impact. Past environmental studies undertaken on the Reservation, with emphasis on the Needles area, are also discussed. Additional environmental study or monitoring, as required by the federal government or the Tribe, is anticipated to be an integral part of any ongoing project.

7.2 Environmental Concerns

The area under consideration for this project is environmentally sensitive. Prudent measures which minimize the impact of the project deserve careful consideration. With the proper combination of mitigation measures, the impact of the project can be reduced to acceptable levels. There are three primary areas of concern: visual, noise, and emissions. Each of these is dicussed in the following sections.

7.2.1 Visual

The amount of visual impact the power plant will have is strongly dependent on its location relative to natural features in the vicinity. The location should be partially determined by engineering and cost considerations. A balance of the visual concerns and engineering requirements is required in selecting the final location of the plant.

The two alternative locations shown on the Preliminary Site Plan, Plate II, were chosen with visual impact in mind. The most popular swimming and camping beaches at the Needles must not be impacted by the power plant, nor should the plant impair the natural beauty of the Needles. Alternative #1 is clearly superior in this regard, since it is well away from the Needles and the beaches. Alternative #2 is not well hidden, although berms could be constructed to provide more screening from the beaches. Visual impact and lake level concerns preclude any site nearer the present beaches. The only potential advantage of Alternative #2 is that production and injection wells are likely to be closer. However, the additional piping required to reach Alternative #1 is partially offset by the shorter power line. Thus, the economic penalty for Alternative #1 does not outweigh the environmental advantage.

Another way to minimize the visual impact of the project is to minimize the height of the structures. It is possible to build a small geothermal power plant with a maximum height of 20 feet, excluding the power lines. The power generation modules are typically under 10 feet in height, and could be placed in a building less than 20 feet high. Visual barriers such as earthen berms, stabilized with native vegetation, could be constructed to hide a great deal of the plant. The plant might be recessed a few feet below natural grade, thus increasing the effectiveness of the berms.

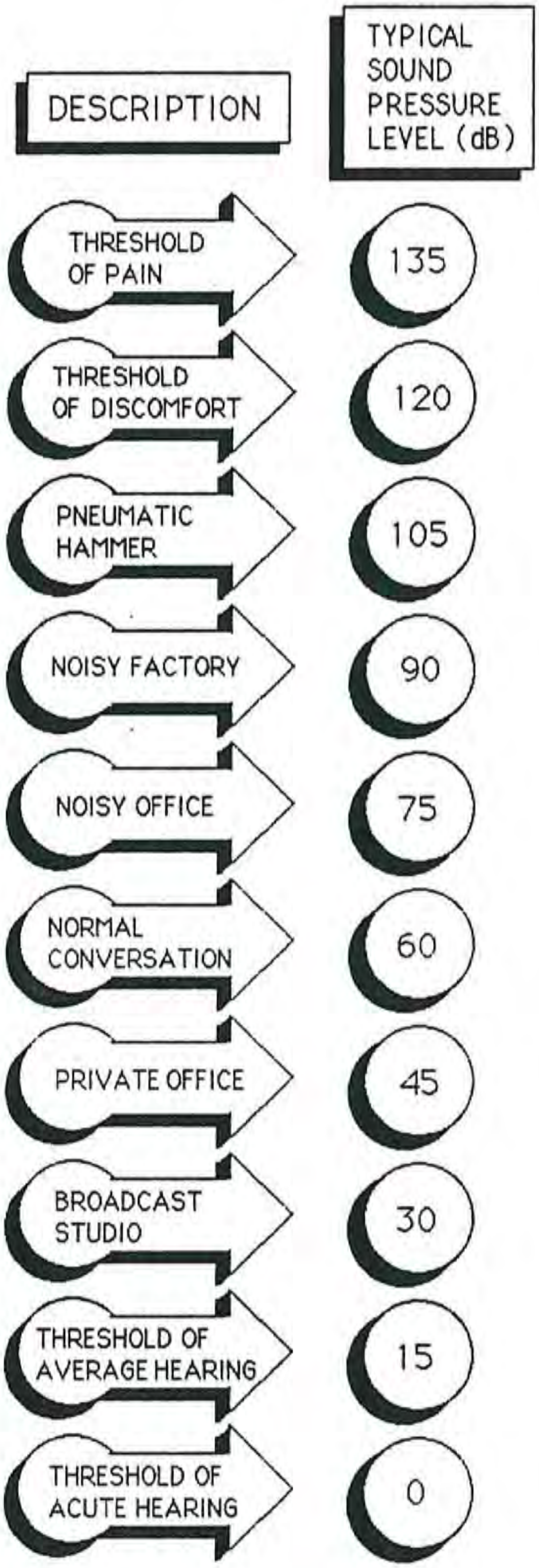
The visual impact of the power lines can be mitigated by selecting a right-of-way that places the line away from the lake, and avoids running high near ridgetops. Further mitigation can be gained by using wood poles rather than metal, since wood poles tend to blend with the natural background colors of the desert. The insulators used on the poles to support the wire must be of a raptor-proof design. Large birds-of-prey like to use the pole tops as vantage points, and must be protected from electrocution by proper spacing of the wires.

The production and injection well locations will have minimal impact, since downhole pumps will permit low-profile wellheads, and only very short runs of pipe need be above grade. Production pipelines, injection pipelines, and cooling water pipelines can be run underground, which eliminates the visual impact entirely.

In general, the visual impact can be mitigated. There is some added cost to implement mitigation measures, (e.g., extra site civil work is required to build the berms), but the cost is easily justified.

7.2.2 Noise

The power turbine produces a substantial amount of high and middle frequency noise. Levels right next to the unit may be on the order of 100 decibels (dB), which is uncomfortable to most humans. Fortunately, this type of noise is the easiest to mitigate. Figure 7.1 is a chart which shows the standard decibel scale with a description of typical noise in each range.



DESCRIPTION	TYPICAL SOUND PRESSURE LEVEL (dB)
THRESHOLD OF PAIN	135
THRESHOLD OF DISCOMFORT	120
PNEUMATIC HAMMER	105
NOISY FACTORY	90
NOISY OFFICE	75
NORMAL CONVERSATION	60
PRIVATE OFFICE	45
BROADCAST STUDIO	30
THRESHOLD OF AVERAGE HEARING	15
THRESHOLD OF ACUTE HEARING	0

Figure 7.1 Sound Pressure Level Chart

Installation of a noise containment structure over the turbine and generator will substantially reduce the noise. This technique can reduce the noise six feet away from the structure to 45 dB. The cost and ease of retrofitting this type of feature depends on the design of the power generation module. A manufacturer should be selected whose generation equipment is separate from the main skid, and can thus more easily be fitted with a noise containment structure. Further reduction in the noise level can be expected if the turbine/ generators are placed within a building. This also facilitates maintenance and thus serves a twofold purpose.

The effect of the earthen berm as a noise barrier can also be substantial. Sound intensity decreases by 6 dB with each doubling of distance away from the source, and the earthen barrier will tend to deflect sound up rather than allow it to travel horizontally. If the noise mitigation stategy is carefully planned, noise from the plant can be reduced to levels which will not degrade the environmental quality of the surrounding area. Again, Alternative #1 is the preferred site from a noise mitigation viewpoint, since it is considerably further from the recreational beaches than is Alternative #2.

7.2.3 Emissions

Emissions from a geothermal power plant are not a major problem, as they are with other types of power generation technology. Certainly there are no combustion products as in fossil-fired power plants, nor is there any radiation hazard as in nuclear power generation.

The most significant emission from the type of geothermal power plant proposed is the heat rejected from the condenser. As described in Section 5.0, this heat can be dissipated quickly in a fairly small portion of the lake. The effect of this heating in the lake is an impact which is difficult to quantify. It can be said that it will cause a very slight increase in the evaporation rate of the lake, but the change is too small to measure. It might also be said that the heating will impact the growth of zooplankton, probably in the direction of increasing growth. Whether this is a positive impact or a negative impact will require additional study by marine biologists.

With regard to atmospheric emissions, there are two possible sources that are of concern. One is the noncondensible gases that might be released from the geothermal fluids during drilling and testing.

Hydrogen sulphide (H_2S) gas is common in geothermal fluids, and can be dangerous even at fairly low concentrations. Normally the concentrations found in wells of the type anticipated at the Needles are not significant. In any case, the emission of H_2S would only occur during well drilling and testing, since the geothermal fluid is contained within closed piping during normal plant operations.

The other concern is that of the working fluid that may be lost from time to time during plant operations. The working fluid will most likely be a halocarbon, such as Freon-114. Halocarbons have recently been suspected of causing depletion of the earth's ozone layer. Dupont, one of the largest manufacturers of halocarbons, has announced that it is developing a substitute for Freon that will not cause ozone depletion. Dupont's timetable for the phase-out of Freon is reduction in the 1990s with virtual elimination by the year 2000.

The working fluid does not normally escape from the plant, and is contained in a closed piping loop. Only when this closed system is opened during maintenance, is any of the working fluid lost. Severe upset conditions can also cause the loss of working fluid through pressure relief valves. The amount of working fluid that might be lost during the life of the plant must be limited for cost reasons too. Recent pricing for Freon-114 in bulk was approximately $10/gallon.

7.2.4 Archaeology

There have been several archaeological sites found on this portion of the Reservation. These locations have been recorded and must not be disturbed by the exploration or construction activities. Should any additional sites be encountered, they should be left in an undisturbed state and their location reported immediately to the Tribe. All contracts relating to exploration, wellfield development, and power plant construction should contain a clause that requires such action.

The specific areas tentatively selected for development are not thought to have significant archaeological features. Since these areas were underwater at the beginning of this century, no evidence of human habitation is expected. The siting of the power lines, however, must be done so as to avoid any known archaeological features.

7.3 Environmental Studies and Monitoring

It is acknowledged that the Tribe is sensitive and concerned about the environment of the Needles area. In order to protect that environment and simultaneously allow for limited development, strict guidelines must be implemented. The basis for such guidelines can be found in federal and state environmental regulations regarding groundwater, surface waters, air quality, flora and fauna.

In certain instances involving federal lands in Nevada, baseline environmental monitoring has been required. This was the case in the Steamboat Springs area of Washoe County, Nevada, but similar monitoring was not deemed necessary in the recent geothermal power plant project in the San Emidio Desert, also in Washoe County, 15 miles to the northeast of the Needles.

Baseline monitoring should include atmospheric, terrestrial, and aquatic biological data. Weather observations are made at Nixon by the National

Weather Service, and a meterological station was installed at the Needles by the U. S. Geological Survey in late 1987.

Preliminary baseline terrestrial data was developed by Albany Oil and Gas in its environmental assessment of the Reservation. Their report contains a biological section which is applicable to the Great Basin in general, but gives little information specific to the Needles area. Fauna of the shadscale-greasewood association is described in the report (mammals, birds, reptiles, and invertibrates), but no census data is available. It is recommended that additional data be obtained, once a specific site is selected. The additional survey should include a census of the flora and fauna in the immediate vicinity of the area which will be disturbed during project construction.

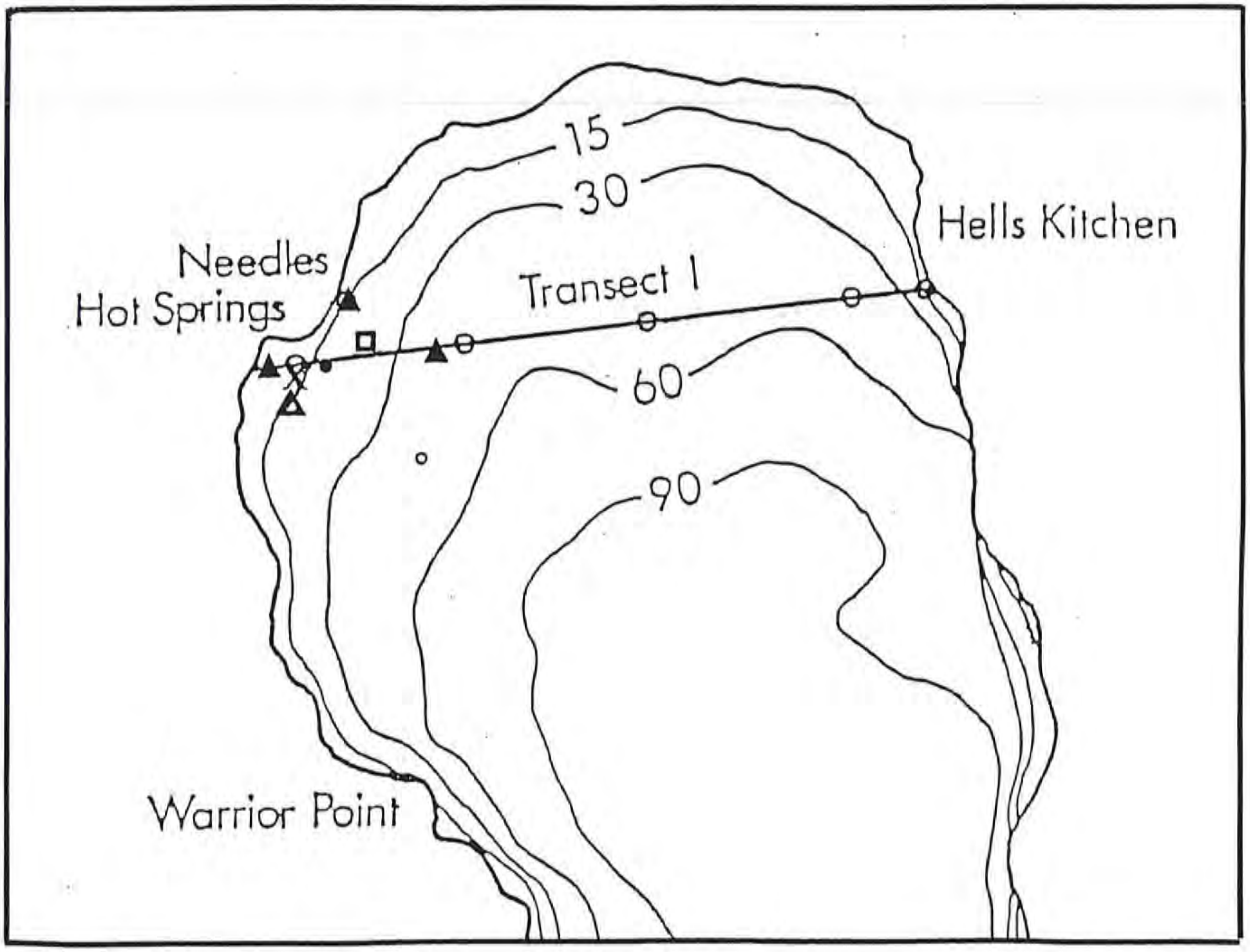
There is detailed aquatic baseline data which has been collected over the years, and which continues to be collected. Pyramid Lake has been the object of many of water studies, especially with respect to the consumption and polution of upstream waters prior to their natural entry into the lake. Unfortunately, these studies frequently refer to the lake as a whole, without referring to any particular part of the lake, unless it is the delta area where the Truckee River enters the lake. Other studies have delt with the total marine life system of Pyramid Lake, especially as it affects the cutthroat trout and Cui-ui fisheries.

It is rare that any of these studies and reports will refer to the northern end of the lake from an environmental or an economic standpoint. Even the most comprehensive program, undertaken in the mid-1970s, put less emphasis on the northern one-third of the lake in the long term. In this case, W. F. Sigler & Associates (1978) undertook a significant ecological study of Pyramid Lake. They acquired data usable in evaluating the relationships among chemical, physical, and biological parameters of the lake. Sampling stations were located along transects to represent horizontal areas of the lake (Figure 7.2), and were sampled on a monthly basis from Nov. 1975 through Oct. 1977. The study presents results and discussions on temperature, dissolved oxygen, turbidity, hydrogen ion activity (pH), ionic composition, silica, organic nitrogen, ammonia, nitrates, orthophosphates, total phosphate, and trace elements.

In the Needles area specifically, samples were taken for physical and chemical analysis (3 sites), primary fish populations (3 sites), zooplankton and phytoplankton concentrations (Figure 7.2). Unfortunately, the final report by Sigler & Associates, while showing sampling points near the Needles for several separate substudies, rarely separated the findings as to geographical location on the lake. Such separation of the basic data will be necessary in order to make a determination of the potential impacts and benefits of the proposed project. Steven Vigg, in his discussion of fish ecology in the Sigler report, states that the distribution of fish populations in Pyramid Lake is dependent on temporal and spatial environmental conditions. Vigg further states that "with adequate data on the lake's fishery, the impact of changes in environmental conditions that may affect the fish can be evaluated."

7.4 Permitting Issues

The sovereignty of the Tribal Council on the Reservation is expected to simplify permitting issues considerably, relative to what might be required if the project were located on public or private lands off the Reservation. If the entire project is built on Tribal lands, the State of Nevada and Washoe County should have no jurisdiction over permitting. If there is leasing of land or resource to an outside developer, the ordinary rules and regulations of the Bureau of Indian Affairs may be applicable. (Code of Federal Regulations, Title 25, Parts 162, 211 and 212).



EXPLANATION

Sampling Stations:

⊖–⊖ Interocean probe sample for physical and chemical water analysis November 1975 through October 1977

▲ Primary fish

● Hester-Dendy multiplate

○ Benthic

□ Diel zooplankton grabs

X Vertical zooplankton tows

△ Horizontal zooplekton tows and phytoplankton grabs

Figure 7.2. Ecological studies of northern Pyramid Lake by W.F. Sigler & Associates (1978).

8.0 NON-ELECTRIC (DIRECT) USE OF GEOTHERMAL ENERGY

8.1 Introduction

The power plant does not remove all the usable heat from the geothermal fluid. The spent geothermal fluid will be discharged from the power plant at a temperature around 180°F. Although the spent fluid is no longer usable for power generation, it is still hot enough to be used in non-electric applications (direct use applications). Some of the potential uses of the spent fluid include space heating of greenhouses or other buildings; aquaculture applications; and recreational uses such as swimming pool and spa heating.

A cascade of applications using progressively cooler geothermal fluid is the best way to obtain maximum benefit from the geothermal resource. A schematic of a possible cascade of uses is shown in Figure 8.1. In this schematic, the primary application of the resource is power generation. The spent fluid from the power plant (180°F) is piped to the next use, in this case greenhouse space heating. Heat is extracted in the greenhouses by means of common heat exchangers, and discharged to the next application at 125°F. The last application shown in the figure is aquaculture. This application generally uses geothermal fluid directly, rather than by means of heat exchangers. Thus the water used in this application is consumed and might end up contaminated with biological waste.

8.2 Greenhouse Heating

There are four major requirements that must be met before plants will grow and thrive under greenhouse conditions: there must be a proper balance of air, light, water and heat. Fuel to provide heat by conventional means can be one of the most expensive parts of a greenhouse operation. However, an inexpensive source of geothermal heat does not insure the success of a greenhouse operation. Success requires additional factors: a knowledgeable manager and labor force, fresh water, correct choice of products and markets, and reliable and economic transportation.

Geothermal greenhouse heating is a simple process. The hot fluid is piped through heat exchangers where it gives up heat to the greenhouse air.

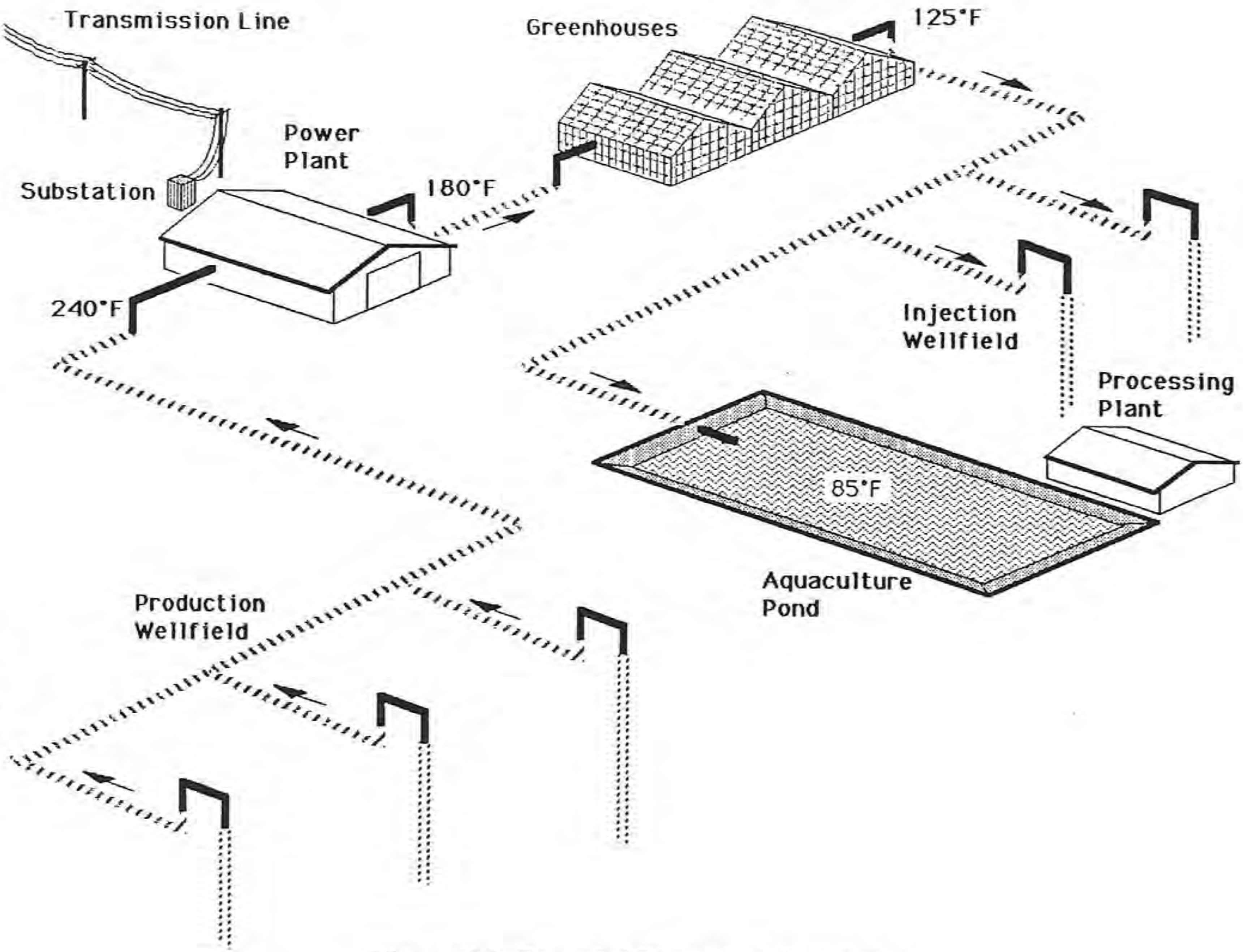


Figure 8.1 Cascaded Direct Use Schematic

Fans are used to increase the amount of air circulating over the heat exchangers and through the greenhouse. The geothermal heat is a direct replacement for natural gas or propane, and the savings can be easily calculated.

The most profitable greenhouse crops are usually somewhat exotic types, such as flowers that can be grown under ideal conditions during what is normally the off-season. Tomatoes are worth investigating, since the supermarket varieties have been developed for storage and shipping qualities, with little consideration for taste. There is a strong local market for high-quality tomatoes, offered 12 months of the year.

There have been other attempts at geothermal greenhousing in Nevada and elsewhere. For the most part, the projects in Nevada have had little success. The problems are generally market and management related, and not a result of the use of geothermal energy. One of the biggest marketing problems is the timing and delivery of the produce. Distributors of vegetables prefer to take scheduled deliveries over predictable periods, so that their customers can anticipate a continuous and reliable flow of product. Distributors of flowers may instead want a large crop all at once, at Christmas and Easter for example. A greenhouse operator who cannot live up to these strict scheduling and delivery criteria, while at the same time maintaining quality, will not last very long.

8.3 Aquaculture

In China and India nearly 40% of fish consumed as food are cultivated. The U.S. percentage is only 1%, but with changing world economic conditions this percentage can and probably will increase.

Geothermal facilities in Nevada have grown freshwater prawns, catfish, and tropical fish using geothermal fluid. The water temperature requirement, depending on the variety of fish being cultivated, is around 85°F.

Fish can be grown in cooling ponds, as has been demonstrated at Fort Churchill by Sierra Pacific Power Co. and the University of Nevada, Reno. Striped bass and freshwater prawns were grown at Fort Churchill with an annual yield of 2,000 pounds an acre (Yanagida, 1983). Freshwater prawns are a good potential replacement for the salt water variety that are popular in restaurants.

Using cooling ponds for aquaculture may conflict with their primary mission; to provide cold water to the power plant. Since the power plant requires water to be as cold as possible, and pond temperatures may at times drop below the minimum required for the survival of the fish, aquaculture ponds separate from the power plant are a better solution. Also, it is difficult to devise efficient harvesting methods that don't interfere with cooling pond operation.

One local grower has experimented with prawns, catfish, and tropical fish in geothermal ponds. Unfortunately, the prawns did not breed as rapidly as anticipated. The catfish grew very well, but did not command a sufficient price at the time. The catfish were very hardy and easy to raise, and it may be that the economic problems were due to inefficient harvesting, packaging, and shipping. Catfish certainly rate being at the top of a potential crop list. The tropical fish may have proven to be one of the most profitable crops, and are now being raised on a small scale in indoor tanks. This facility is now experimenting with a specie of frogs.

Whatever the variety, the fish must be fed, and an economical food source should be found. Ideally, the food should be grown locally, giving the aquaculture operation a degree of self-reliance. Aquaculture is very market dependent; prices for feed and for fish may fluctuate widely. A type of fish sold very profitably one year may fail to cover expenses the next.

Certain types of algae, such as spirulina, are in demand as food in this country and the Far East. Very high retail prices are paid for dried algae in health food stores, and growing temperature requirements are similar to the requirements of fish. Problems have arisen in attempting to isolate the desired type of algae in a pond, because growing conditions that are good for spirulina are also good for other less desirable algae.

The possibility of using the cooling water for expansion of the hatchery is worth investigating. According to Paul Wagner of Pyramid Hatcheries, a major expense in building a new hatchery is the piping and pump costs to bring the water to the hatchery, and this would be provided "free" by the power plant.

The potential obstacle to this seemingly made-to-order solution is that the cooling water discharge is too warm for the hatchery. The cooling water needs to be used before it gets to the power plant condenser. This would require two separate pumping stations; one to bring the water from the lake to the hatchery, and another to pump the water from the hatchery ponds to the condenser. The added cost of these plant additions is not expected to be significant in relation to the overall power plant budget.

8.4 Recreational Usage

Geothermally heated recreational facilities should also be examined. A complete recreational facility could include a swimming pool, spa, gym, and a restaurant specializing in locally grown food. Although the impact on the environment might be significant, a recreational area could have a very positive impact if properly planned and operated. A successful operation would be a major source of revenue, employment, and training.

Taken as a whole, the power plant and associated greenhouses, aquaculture, and recreational facilities could serve as the core for an integrated vocational training and employment program. The facility would have enough technical requirements to give students hard to find hands on experience that will increase the value of their training.

9.0 FINDINGS AND RECOMMENDATIONS

9.1 Findings

GDA has identified seven principal findings in the course of this study. These findings are supported in the body of the report as well as in selected references. For additional information, refer to the appropriate sections and references. The findings are summarized individually below.

1. The review of prior drilling and geotechnical surveys provides strong evidence that a geothermal resource of at least 240°F to 250°F is present at the Needles at a depth as shallow as 500 to 1,000 feet. The area of prime interest is about two square miles in and around the Needles tufa formations.

2. Provided that this resource is producible, that is sufficient hot water can be pumped from one or more wells, it can be expected to serve as an excellent source of energy for power generation and other applications as well. Photogeologic interpretation, the presence of hot springs, and other evidence indicate that the faults/fractures necessary for good productivity are present.

3. Prior to 1980, geothermal resource development for the purpose of generating electricity was not considered practical at temperatures below 400°F. Within the last five years however, several small-scale power plants using geothermal resources under 300°F have been built

4. The analysis of the electricity market and power distribution system described in Section 5.0 of this report, indicates that up to 2.5 MW of power can be delivered to Sierra Pacific Power Company through the existing 24.9 kv power line that serves Sutcliffe. This line presently terminates at Warrior Point, about 12.5 miles from the proposed power plant site at the Needles.

5. A power contract for the sale of electricity must be obtained from Sierra Pacific, or another customer if better terms are possible. It is thought that a power contract reflecting a rate of 5.0¢/kwh is obtainable from Sierra Pacific under present market conditions.

6. Power plant economics are very favorable, based on the assumptions outlined in Section 6.0 of this report. An internal rate of return on the order of 36% can be expected from the project, which is considered very good. The total cost of the 2.5 MW project is estimated to be $5,400,000, of which, $4,500,000 is attributable to plant construction and utility interconnection, and the remainder is spent on wellfield development and other project expenses.

7. The Needles area is a valuable environmental resource which must be protected. The project considered in this study can be carried out in a manner that provides a showcase example of thoughtful development within a sensitive environment. For this result to be realized however, everyone involved with the project must have an acute environmental awareness.

9.2 Recommendations

Based upon the favorable findings outlined above, GDA recommends continuation of the project. The next phase of the project (Phase II) should focus primarily on resource exploration, though other important project tasks should be pursued in parallel. Specific aspects of Phase II are outlined below:

1. The work in Phase II should begin with a suite of geophysical surveys, designed to provide additional support for the location of potential drilling sites. There are four surveys recommended:

    - gravity
    - magnetics
    - shallow temperature gradient holes (10-foot)
    - spontaneous potential

    The data obtained from these surveys should be presented on maps, together with photogeologic information, in order to construct an interpretive view of the Needles surface and subsurface geology.

2. Upon completion and interpretation of the surveys, the drilling of three or more small-diameter test holes is recommended. These should be drilled in the most promising areas for production wells.

The holes should be drilled to 400 or more feet, with a total of 2000 feet budgeted. The drilling and testing of these wells will give added information, and even confirmation of the resource.

3. In parallel with this work, negotiations for a power contract should begin. Sierra Pacific, Lassen Municipal Utilities District, and the Army at Herlong should be approached and pursued simultaneously, until one of these surfaces as the best candidate.

4. Financing for Phase II and subsequent phases must also be pursued. The Phase II budget, as outlined in Section 6.0, is $152,000. The source of this funding, whether through operations, a grant, or private sources, must be determined.

5. Tribal fisheries technical staff should be invited to provide additional input to ensure that there are no adverse impacts to the Pyramid Lake fisheries. Further study of the combination power plant/fish hatchery should be undertaken.

6. Two alternative sites have been recommended for the planned power plant. The viability of these sites must be determined, and baseline environmental data gathered for the preferred site.

Assuming successful completion on all points of Phase II, the project should proceed to a third phase -- Phase III - Wellfield Development. Phase III would include the drilling and testing of production and injection wells, and must also include the signing of a power contract. A budget of $760,000 has been estimated for this phase of the project.

With successful completion of Phase III, the project should proceed to Phase IV - Power Plant Construction. Before construction commences however, financing must be obtained. Over $4,500,000 will be spent on construction of a 2.5 MW plant and the type and cost of financing is important to the overall success of the project. Once construction financing is secured, a six to 12 month construction effort must be undertaken. After construction, an acceptance test is performed and the power plant is commissioned.

Phase V - Operation is the project goal. Operation, which begins with commissioning and continues for 30 years or more, is the period during which benefits from the project flow to the Tribe.

10.0 SELECTED REFERENCES

Ad Hoc Committee, Lower Truckee River Fishery Evaluation Team, 1973, Truckee River study, known bibliography of reference works: Reno, Nevada, 11 p.

Blockley, W. E., undated, Spray Cooling Ponds for Small Geothermal Power Plants, Sierra Pacific Power Company, 12 p.

Bonham, H. F., Jr. ,1969, Geology and Mineral Deposits of Washoe and Storey Counties, Nevada: Nevada Bur. Mines Bull. 70.

Boreman, John, 1977, Impacts of Power Plant Intake Velocities on Fish: U.S. Dept. of Interior, Fish and Wildlife Serv., FWSk/OBS-76/20.1, Biological Services Prog., March, 10 p.

Brook, C. A., Mariner, R. H., Mabey, D. R., Swanson, J. R. Guffanti, M. and Muffler, L. J. P., 1979, Hydrothermal Convection Systems With Reservoir Temperatures ≥ 90°C <u>in</u> Assessment of Geothermal Resources of the United States,1978 ; U. S. Geol. Survey Cir. 790, 24 p.

Clyde-Criddle-Woodward, Inc., 1968, Hydrologic Investigations in Pyramid Lake Basin, Pyramid Lake Indian Reservation, Nevada: A report prepared for Wilsey and Ham, Consultants to Economic Development Authority, U. S. Dept. of Commerce, February, Salt Lake City, Utah, 82 p.

Denburgh, A. S., Lamke, R. D., and Hughes, J. L., 1973, Water Resources Reconnaissance Series, Report 57, Nevada Dept. of Conservation and Natural Resources, Div. of Water Resources, 122 p.

Desert Research Institute, 1977, Direct Utilization of Geothermal Energy Resources -- Field Experiments: Direct Geothermal Energy Utilization by Aquaculture, Technical Proposal, Vol. I, PON EG-77-N-03-1553, University of Nevada-Reno, Reno, Nevada, 44 p.

Division of Water Resources, 1971, Water for Nevada, Nevada's Water Resources: State Engineer's Office, State of Nevada Water Planning Report, Report 3, August. Also Map of Total Dissolved Solids in Ground Water, scale 1 inch to 32 miles.

Donlevy, R., 1974, Environmental Assessment of the Pyramid Lake Paiute Indian Reservation: Nevada Indian Agency, Stewart, Nevada, for proposed geothermal exploration permit, Pyramid Lake Indian Reservation by Albany Oil and Gas, Ltd., 21 p.

Garside, L. J., 1974, Geothermal Exploration and Development in Nevada Through 1973: Nevada Bur. of Mines & Geol. Rept. 21.

Garside, L. J. and Schilling, J. H., 1979, Thermal Waters of Nevada: Nevada Bur. of Mines and Geol. Bull. 91.

Geothermal Kinetics, Inc. and Group Seven, Inc., 1976, Satellite Imagery, Geology, Geochemistry and Geopoint Studies of the North Pyramid Lake Exploration Area, Washoe County, Nevada: Report prepared for Albany Oil :& Gas Ltd. under Permit No. 1-NEV-170 from the Pyramid Lake Paiute Tribe, November 30, 37 p.

Group Seven, Inc., 1976, Geophysical Surveys in the Pyramid Lake Area, Nevada: Golden, CO., December 6, 20 p.

Grose, L. T., and Keller, G. V.,1975, Colorado School of Mines Nevada Geothermal Study Progress Report No. 4 - for Period February 1, 1975 to October 31, 1975: Colorado School of Mines Report, Natl. Sci. Found. Grant GI 43866.

Hall, D. A., undated, Paiute Project of Western Geothermal, Inc., Paiute #1 Well: Unpublished Western Geothermal Inc. summary report, 3 p.

Hall, D. A., 1964, Western Geothermal, Inc. Activities Under Contract I-Nev-73, No. 14-20-453-75, as Extended for the First Quarter of 1966: Western Geothermal, Inc. letter of April 10 to D. M. Baldwin, Superintendent, Bur. of Indian Affairs, Stewart, Nevada, 2 p.

Hall, D. A. and Decius, L. C., undated, Report on the Drilling of Paiute No. 2 and No. 3 Wells at Pyramid Lake, Nevada: Western Geothermal, Inc. summary report, 3 p.

Hanson, R. A., 1967, Chemical Composition and Quality of Nevada Waters: Agricultural Experiment Station, Max C. Fleischmann College of Agriculture, University of Nevada, August.

Hardman, G. and Vinstrom, C., 1941, A 100-Year Record of Truckee River Runoff Estimated From Changes in Levels and Volumes of Pyramid and Winnemucca Lakes: American Geophysical Union Transactions, 1941.

Harris, E. E., 1970, Reconnaissance Bathymetry of Pyramid Lake, Washoe County, Nevada: U. S. Geol. Survey Hydrologic Investigations Atlas HA-379.

Jaluria, Y. and Cha, C. K.,1983, Heat Rejection to the Surface Layer of a Solar Pond: Journal of Heat Transfer, Paper No. 83-HT-77.

Jensen, Loren D., 1976 (Editor), Third National Workshop on Entrainment & Impingement, Section 316(b) -- research and compliance: Ecological Analysts, Inc., Feb. 24, 425 p.

Johnson, V. K., 1958, Pyramid Lake report: Nevada Fish and Game Commission.

McJannet, George S., 1957, Geology of the Pyramid Lake-Red Rock Canyon Area, Washoe County, Nevada: M. A. thesis, Univ. of California, Los Angeles, 125 p.

McLane, A. R., 1975, Pyramid Lake - a Bibliography: Camp Nevada Mon. No.1.

Moore, F. K. and Jaluria, Y., 1972, Thermal Effects of Power Plants on Lakes: Jour. of Heat Transfer, Transactions of ASME, May, 6 p.

Nevada Department of Conservation and Natural Resources, Nevada Division of Water Resources Well Driller's Reports (various dates).

Nevada Department of Fish and Game [Robert W. Alstrom], 1972 Statistical Data on the Streams and lakes of Nevada: Unpub. rept., Nevada Dept. of Fish and Game, Reno, 137 p.

Pyramid Lake Fisheries, 1986, Fishery Restoration Program: Annual report for FY-85 (PL 93-638 BIA Contract No. H50C14205180), 63 p.

Pyramid Lake Fisheries, 1987, Fishery Restoration Program: Annual report for FY-65 (PL 93-638 BIA Contract No. H50C14206169), 109 p.

Pyramid Lake Tribe (1988) Tribal files.

Rush, F. E., 1968, Index of Hydrographic Areas: Nevada Division of Water Resources, Water Resources - Information Series, Report 6, September. Includes map of hydrographic areas, scale 1:500,000.

Russell, I. C.,1885, Geological History of Lake Lahontan: U. S. Geol. Survey Mon. 11.

Satkoski, J. J. and Berg, A. W., 1982, Field Inventory of Mineral Resources, Pyramid Lake Indian Reservation, Nevada: Report BIA No. 38-II, Prepared by U. S. Bur. Mines for BIA, 47 p.

Sigler, W. F., & Associates Inc., 1978, Pyramid Lake Ecological Study: Private Report for the Pyramid Lake Paiute Indian Tribe and the Bureau of Indian Affairs, 545 p.

Silvester, R.,1974, Coastal Engineering 2, Developments in Geotechnical Engineering, Vol 4B, Elsevier Scientific Publishing Co., 311 p.

Soil Conservation Service, 1988, Soils map of The Needle Rocks 7-1/2-minute quadrangle, preliminary, unpublished.

Spraying Systems Co., 1985, Spray Ponds for Cooling and Evaporation: Technical Manual No. 41, 62 p.

Taylor, R. E. L., 1972, The Effects of Increasing Salinity on the Pyramid Lake Fishery: Univ. of Nevada Agri. Exp. Sta. R88, 8 p.

U. S. Bureau of Reclamation, 1973, Draft Environmental Statement for Marble Bluff Dam and Pyramid Lake Fishway, Washoe Project, Nevada: Sacramento, Mid-Pacific Regional Office, 30 p.

U. S. Department of Commerce, 1970, Water Resources and Land Use of the Pyramid Lake Indian Reservation: U. S. Dept. Com., Econ. Develop. Ad., Tekch. Assis. Proj., 167 p.

U.S. Department of Energy, 1980, Sourcebook on the Production of Electricity from Geothermal Energy, U.S. Dept. of Energy, 966 p.

U. S. Environmental Protection Agency, 1971, Water quality data - Truckee and Carson rivers, Pyramid Lake and Lahontan Reservoir: Region IX, San Francisco.

Van Denburgh, A. S., Lamke, R. D., and Hughes, J. L., 1973, A Brief Water-Resources Appraisal of the Truckee River Basin, Western Nevada: Division of Water Resources, State of Nevada, prepared cooperatively by the U. S. Geol. Survey, Water Resources - Reconnaissance Series Rept. 57.

Waring, G. A., 1965, Thermal Springs of the United States and Other Countries of the World: U. S. Geol. Survey Prof. Paper 492.

Western Systems Coordinating Council, 1971, Environmental Guidelines, December 3, 95 p.

Wheeler, Sessions S., 1967, The Desert Lake: Caxton Printers, Ltd., Caldwell, Idaho, 133 p.

Whitebread, D. H. and Magill, E. A., 1977, Status of Mineral Resource Information for the Pyramid Lake Indian Reservation, Nevada: Administrative Rept. BIA-38, Prepared by U. S. Geol. Survey and U. S. Bur. Mines for U. S. Bur. of Indian Affairs, 46 p.

Wilsey and Ham Consultants, 1970, Water Resources and Land Use of the Pyramid Lake Indian Reservation: Economic Development Administration Tech. Assist. Project, U. S. Dept. of Commerce, October, San Mateo, California, 167 p.

Yanagida, John F., 1983, Economic Potential of Geothermal Energy Usage in Agriculture and Aquaculture; the Case of Nevada: Dept of Agric. Economics, UNR. GRC Transactions Vol 7.

Appendix A - Resources

A.1 Stratigraphy of The Needles Area

The geologic section encountered by drilling during the development of the geothermal resource will have a significant impact on the technical design and cost of the wellfield development. An indication of the stratigraphy present may be indicated by the geologic units presently mapped on the surface.

Three major rock units comprise the mountainous borders to the Pyramid Lake structural and sedimentary basin. The basin is covered at the surface by a fourth unit, a mixture of unconsolidated Pleistocene and Recent deposits. The names in italics are the rock units or formations and their symbols as shown on the accompanying geologic maps, Figure 2.2a & 2.2b and Plate I, described in Bonham (1969). These are summarized below from youngest to oldest:

Pleistocene and Recent Lake Deposits (Ql). Pyramid Lake, is a remnant of Pleistocene Lake Lahontan. The typical sequence of sediments in these basins consists of clays, silts, and minor sand in the interior portions of the basin, and intermixed clays, silts, sands, and gravels along the margins. Extensive gravel bars are present, as well as prominent tufa deposits which occur along strand lines of the lake. The thickness of this unit was 350 feet in Paiute No. 1 well, but may be 1,000 feet or more elsewhere

Basalt (Tba). Upper Miocene and Pliocene Basalt of the uppermost Canyon Assemblage is made up of flows and intrusive dikes of olivine basalt derived from fissures, and from central vents. Diktytaxitic texture is common. Flows form the caprock of major topographic rims in this area. The Terraced Hills at the surface are made up entirely of this unit. The thickness of the olivine basalt is quite variable, ranging from 100 to 1,000 feet in section measured in other localities.

Basalt (Tab). An Pliocene upper unit of the Hartford Assemblage, consisting of basalt, basaltic andesite and pyroxene andesite flows, pyroclastics and associated intrusive phases. This unit forms the east flank of the southern half of the Lake Range, with the Pyramid Sequence on the western flank. The thickness here is in excess of 1,000 feet.

Pyramid Sequence (Tsv). This sequence is one of the late Miocene central units of the Hartford Assemblage of basalt, andesite, and dacite flows, flow breccias, mudflow breccias, agglomerates, tuffs and associated intrusives. Lenses of silicic waterlain tuff, diatomite, shale and sandstone intercalated in sequence. It includes the Pyramid formation of MacJannet (1957). The northern Virginia Mountains is underlain by this sequence of volcanics.

The Canyon Assemblage which is present in the Terraced Hills, has a different lithology and geomorphic terrain than the Hartford Assemblage, which extends southward from the Terraced Hills/Smoke Creek Desert.

A.2 Structure of Northern Pyramid Lake Basin and the Needles

The Pyramid Lake area of Nevada is situated in a transitional zone between the Basin and Range province and the Sierra Nevada province according to Bonham (1969). Further, because of its location in this zone, the Cenozoic structures here bear a critical relationship to the origin and evolution of the Basin and Range structure, which is characterized by extensive normal faulting with associated major vertical displacements.

The Lake Range and Virginia Mountains are described as being within the 20-mile wide Walker Lane zone of right-lateral, strike-slip faulting which is recognized in this area by extensive northwest-trending topographic lineaments. Bonham states that:

> "...the Pyramid Lake depression...illustrates major vertical displacements in the Walker Lane zone. Mesozoic rocks crop out at the south end of depression, but the north end of the lake near the Needle Rocks, the Mesozoic basement, occurs at a depth of over 4,000 feet below the surface, according to information obtained from a well drilled to a depth of more than 6,000 feet. Over 4,000 feet of middle Miocene to Pliocene volcanic rocks, correlative with the Tertiary section of the Virginia Mountains and the Lake Range, were found in the drill hole. The Pyramid Lake depression was formed during late Pliocene and early Pleistocene time, coincident with uplift of the Virginia Mountains and the Lake Range."

The Lake Range is an eastward-tilted block, bounded on the west by northerly-trending faults with substantial dip, according to Bonham. Stag and Sweetwater Canyons on the northeastern corner of the lake are the site of one of two major northeasterly-trending faults which traverse the range.

The Virginia Mountains are a northwest-trending mountain block bounded by major faulting of the Walker Lane having the same trend. Both north and northwest-trending faults which occur within the range appear to have a predominant dip-slip movement. The Tertiary rocks in the mountains have a north-trending anticlinal structure, nearly parallel to the north-trending faults with the range.

According to Geothermal Kinetics, Inc. and Group Seven, Inc. (1976) the northern end of Pyramid Lake appears to lie at the intersection of a prominent eight-mile wide N 65° E trending fault zone and an south-southeasterly to southeasterly trending fault zone. Pyramid Lake lies within a nine-mile with sector of this latter zone. At the northern edge of the Lake, faults trend N 18° W into the Smoke Creek Desert. The faulting and geomorphic lineations mapped by GDA using aerial photographs taken specifically for this purpose, show these regional structural dislocations among the Needles (Plate I).

Reports by Western Geothermal Inc. consultants recognized that the faulting at the Needles is considerably closer to the west side of the Pyramid Lake graben than to the east side, so they considered it more probable that the direction of the dip of the northwesterly trending faults would be to the east. On this geological assumption Paiute No. 1 well was located on the east side of the easternmost line of deposits (Plate I). After having drilled this well, they believed that the fault dip is actually to the west, in which event, Paiute No. 1 well would be entirely on the footwall side of the fault zone, and therefore could not have encountered the hot water-bearing fracture zone.

There appears to be a correlation between the occurrence of tufa pinnacles with fault zones, which may explain the isolated massive tufa growths that are near no current geothermal activity. Large pinnacles are found along obvious faults in the northern Pyramid Lake area and elsewhere, but not in every case (Geothermal Kinetics Inc. and Group Seven Inc., 1976).

A.3 The Needles Tufa Pinnacles

Hall (1967) in his discussion of the Needle Rocks states that: "...for the most part the deposits, some of which are actively growing at the present time, were formed under ancient Lake Lahontan, a conclusion supported by recent geological observations. Hot springs near the boiling point occur at and below lake level at several locations, among them Needle Rocks and the so-called Fremont Pyramid at the south end of the lake. From the top and sides of Fremont Pyramid small amounts of vapor and hot water still emerge. In large part, however, the sinter deposits are now unaccompanied by springs, indicating that as the lake receded, so did thermal activity in the form of hot springs."

The tufa pinnacles and mounds occur in 12 principal varieties and at nine distinct stratigraphic levels. The cellular and dendritic tufas are the most dominant in the Pyramid Lake area. It is widely accepted that cellular and dendritic tufas are formed by algae growing in tufted mats. The towering pinnacles around the lake are dendritic tufa formed in water probably 10 to 20 feet deep, deposited as microcrystalline to finely crystalline calcite which has since been somewhat more coarsely recrystallized.

The warmer the depositional environment, the faster the tufa seems to have been formed. Near the current hot springs areas at the Needles and at the base of Pyramid near Anaho Island, the nearby tufa pinnacles are 80 to 100 feet high. At the Western Geothermal Inc. Paiute No. 1 well, where water is flowing at about 200°F, cellular tufa is currently growing on the steel valve head at the water line, and is already several inches thick.

A.4 Geophysics

Albany Oil and Gas, Ltd. Surveys. In the mid-1970s Albany Oil and Gas, Ltd. contracted with Geothermal Kinetics, Inc. and Group Seven, Inc. of Golden, Colorado, to undertake geological and geophysical surveys of the northern portion of the Pyramid Lake Indian Reservation, including the Needles area. The objective of the studies was to locate and define a geothermal reservoir for the purpose of developing electrical power. The geo-scientific work completed included:

- Detailed geology
- Chemical analysis of springs and groundwater
- Rotating dipole electrical resistivity
- Time domain electro-magnetic
- Shallow ground temperatures (3-foot depth)
- Natural seismic frequencies (DRI, 1977)

The conclusions and recommendations of contractor were:

- The dipole mapping survey revealed no closed area of low resistivity such as is found associated with many producing geothermal fields.
- The time-domain electromagnetic soundings showed no conductors at depth, such as would be expected in a geothermal reservoir, nor did they indicate that there was a sufficient thickness of porous rocks in which to develop a geothermal system.
- The dipole mapping surveys and the three-foot temperature hole survey indicated that if a geothermal reservoir were present, it would be located under Pyramid Lake.
- The 3-foot depth temperature gradient hole survey consisted of 15 holes amond the Needles. The recorded temperatures indicate that this method of locating and defining the temperature anomaly at the surface has a potential in future exploration. It is likely that additional holes, probably 10 feet in depth, would be advantageous.

It was therefore concluded that there was no other possible viable geothermal reservoir within the northern part of the Reservation, and it was recommended that no further geophysical work take place unless compelling independent evidence for a geothermal reservoir was forthcoming.

Western Geothermal Inc. Survey. According to Hall (undated) of Western Geothermal Inc., an Audio Frequencey Magnetometer (AFMAG) survey of approximately two weeks duration was conducted at the Needles. The function of this survey was primarily to locate the strike and dip of water-bearing structures -- probably the upward moving geothermal waters. The results of this survey indicated that:

There are three major northwest fault zones. The strongest and most persistent zone occurs on the west side of the easternmost alignment of tufa mounds (about 1,500 feet west of Paiute No. 1 well). All the lines indicated a western dip of the main fault structures, which was corroborated by aerial geology mapped by Western Geothermal, Inc. staff and D. B. Robertson, the geologist who conducted the AFMAG survey. This information suggested that the Paiute No. 1 well could not have intersected one of the geophysically-mapped fault zones. Rather, a hole located between the two main ridges of tufa should intersect or come close to the major structural breaks in the area.

A.5 Geothermal Test Well Summary Data

Information on the Western Geothermal, Inc. Paiute wells is known only from summary reports produced by consultants to the company. The location of the original and more detailed records of this drilling program is unknown The information that as been reviewed, is presented in summary outline form below:

Name: Paiute No. 1 Well.
    Also known as the Needles No. 1
    API #27-031-90006 (Garside,1974).
Location: NW/4 SW/4 SW/4, Sec. 6, T26N, R21E
Driller: Hunnicut and Camp Drilling Co, Rio Vista, California
Total Depth: 4,200 feet (suspended); 5,930 feet (final TD)
Spudded: Sept. 23, 1962
Suspended: October, 1962
Completed: March, 1964
Completion Record:
    16" cased and cemented from surface to 92';
    10-3/4" casing cemented back from 312';
    7" casing cemented from 2,017' to surface;
    6-1/4" open hole to 4,208' (suspended TD)
    Open hole to 5930' (final TD)
Geologic Section:

0 - 350'	Old lake beds (sand, blue clay, and gravel with volcanic boulders throughout)
350 - TD	Series of volcanics of highly altered rhyolitic tuffs to andesitic flows of varying degrees of porosity; no sedimentary rocks; extremely hard rock with few permeable zones, hindered drilling in the last 1,722 feet; one small zone of hydrothermal alteration was logged.

Temperature Surveys and Flow Tests: Recorded with geothermograph at various depths during drilling: 179° to 208°F.

Well blown clean October 20, 1962 at 2,050, 2,970, and 4,050 feet with return of hot clean water under moderate pressure; temperature registered 195°F.

The well was closed in except for a 3 inch horizontal pipe attached to an orifice on the Blowout Preventer (BOP). Three weeks later the well was reopened and allowed to blow laterally through a 6 inch pipe. Both volume and temperature had materially increased but flow was not "commercial".

Well shut in for five months do to conflict with other activities from motion picture company; well closed during this time.

Main valve reopened September 13, 1963; well showed an appreciable increase in volume and pressure; remained open til drilling resumed in February, 1964.

Temperature test, October, 1963, indicated relatively uniform down-hole temperatures of 242°F (highest Bottom Home Temperature (BHT) and an estimated flow of about 400 gpm. Eighteen months after suspension at 4,208 feet, the maximum bottom hole temperature was 235°F and flowed only 7 gpm; don't know why the flow decreased so much.

Well deepened February and March, 1964 from 4,208 to 5,930 feet in the hope of encountering parallel fault structures and pervious horizons of greater depth, rather than drilling a new hole further to the west.

Results of deepening program were disappointing due to the extremely hard formation and few indications of permeability. Hall mentions one zone of rather intense hydrothermal alteration.

Upon completion of drilling (to 5,930 feet TD), obtained a Bottom Hole Temperature of 236°F; temperature gradient did not change noticeably from 4,208 feet to TD; Halliburton Company formation test obtained a 228°F temperature and flow of about 7 gpm. Well has remained open to date and shows intermittent geysering action at intervals of 30-50 seconds, substantially less in volume of both steam and water to that prevailing at 4,200 feet.

At the completion of drilling temperature surveys were run for down hole temperatures. The first tests were through drill pipe after letting the well sit about eight hours to stabilize the mud temperatures. The maximum BHT was 236°F, with no appreciable change in gradient between 4,208 and 5,930 feet. Formation tests by Halliburton Company were only for the zone between 5,924 and 5,930 feet, and therefore are not applicable to the near-surface reservoir environment (Hall, 1964). The test results are questionable. "A possible inference from the above is that cool water following the flat eastward dip of the formation has lowered the temperature of solutions encountered above and caused geysering. Results appear to bear out the conclusion earlier reached that drilling has been in the footwall of the fault zone and hence that any productive sone will occur further to the west where westward dipping structure will be encountered with resulting increased permeability." (Hall, undated)

According to Hall (1964) redrilling of Paiute No. 1 was conducted from February to 28.

Examination of thin sections of the cutting were prepared for four intervals from 4,690 to 5,030 feet. Loss of circulation was noted in four indicted fault zones from 4,210 to 5,295 feet.

Mud temperatures ranged from 140° to 175°F, with distinct high and low anomalies occurring; but it was difficult to correlate these with possible faulting.

This well has produced a boiling mixture of steam and water continuously for a period of 22 years - the water flowing measuring 250 gpm. The surface temperature on November 16, 1977 was 194°F. As the well began discharging spontaneously, several months after completion, it is likely that the quoted temperature was recorded before it had recovered fully from cooling during drilling, and that the true subsurface temperature is higher than the value quoted (Desert Research Institute, 1977).

Name: <u>Paiute No. 2 Well</u>. Also known as Needles No. 2, API
#27-031-90007 (Garside, 1974).
Location:
NW/4 NW/4 NE/4, Sec. 12, T26N, R20E; 400' S 35°W of Paiute No. 1.
Spudded: Jan. 12, 1966;
Completed: Jan. 18, 1966
Total Depth: 1,488 feet
Completion Record:
9-5/8" casing cemented with returns to surface from 80'
5-1/2" casing cemented with returns to surface from 305'
4-3/4" hole to 1,488' TD
Temperature Surveys and Flow Tests:
Circulated mud out of hole with water from Paiute No. 1; added dry ice; expelled muddy water, but would not stay on production.

Maximum reading thermometer measurements showed 245°F at 1,470 feet; 203°F at 1,000 feet; and 174°F at 500 feet.

Well closed in on Jan. 18 and well reentered on Jan. 25 with introduction of 200 lbs of dry ice gradually through 9-5/8 inch casing. Within a few moments the well erupted and with the introduction of more ice, blew hot water and steam under moderate pressure to a height of 10-14 feet. Flow ceased in less than 30 minutes, and the well was left open for further examination. On Jan. 29 the well showed no change, with static water a few feet below the surface.

Name: Paiute No. 3 Well. Also known as Needles No. 3, API#27-031-90008
(Garside, 1974)
Location: SE/4 SE/4 SE/4, Sec. 1, T26N, R20E; about 3/4 mile west of
Paiute No. 2
Spudded: Jan. 1966
Completed: Jan. 25, 1966
Total Depth: 1,206 feet
Completion Record:
9-5/8" casing cemented surface to 80'
5-1/2" casing cemented surface to 285'
4-3/4" open hole to 1,206' and lost circulation

Temperature Surveys and Flow Tests:
Unable to regain circulation and lost bit; abandoned well and tested at this depth.

Jan. 25 well flowed clear, hot water and minor steam about 1 inch over top of pipe. Temperature at surface: from 148°F up to 184°F in 1 hr & 20 min. Downhole temperatures measured with maximum reading thermometers: 202°F at bottom (185°F at top) with later rerun of 205°F at 550 feet. Hole left open with same temperature results on Jan. 29.

Appendix B - Cooling Systems

The heat which must be removed from the working fluid in the condensation process is rejected to the environment by the cooling system. There are several common types of cooling systems: forced-draft wet cooling towers; spray ponds; air-cooled condensers; and once-through systems using lake, river, or ocean water for cooling. It is the once-through system that is of primary interest, because of the close proximity to Pyramid Lake.

B.1 Once-through Wet Systems

When practical, power plants are situated near a large body of water which can be used for cooling purposes. Using lake water for cooling will mean higher plant output, since the lake water should be cooler in the summer than that obtainable with a cooling tower or pond. Once-through systems require no large structures, they emit no vapor plume, nor do they create fog. Also, there is no parasitic power loss due to fan motors.

Close attention must be paid to potential environmental effects of discharging warm water into the lake. The quantity of warm water discharged into the lake is dependent on the size of the power plant under consideration. A 2.5 MW plant requiring a cooling water flow rate of 8750 gallons per minute is assumed for this analysis.

The discharge water will create a warmed area or thermal plume in the lake. The temperature distribution of the plume depends on the cooling water flow rate, velocity at discharge, temperature difference between discharge and lake water, ambient temperature and wind velocity. Since there is considerable seasonal variation in weather conditions, both summer and winter are listed in Table B.1.

Table B.1 Summer and Winter Data for Thermal Impact Analysis

	Summer	Winter	
Average Wind Velocity	8.1 3.62	5.1 2.28	mph m/s
Lake Surface Temperature	70. 21.1	48. 8.9	°F °C
Ambient Air Temperature	69. 20.6	32. 0.0	°F °C
Cooling Water Outlet Temperature	90. 32.2	68. 20.0	°F °C
Average Relative Humidity	37.	67.	%
Vapor Pressure of Lake Surface	0.3629 2.502	0.1651 1.139	psia kPa
Partial Pressure of Water Vapor in Air	0.1354 0.9335	0.1117 0.7698	psia kPa

Considerable research, both theoretical and experimental, has been done on thermal plumes from cooling water outfall into lakes. Relationships have been developed for the temperature increase T_y at distance y from the end of the water discharge pipe. Silvester (1974, p. 264) gives the following simplified expression in SI units:

$$(T_y - T_s) / (T_o - T_s) = 7D/y \qquad \text{Equation B.1}$$

Where

T_y = temperature at distance y from discharge, in °K
T_o = cooling water discharge temperature, in °K
T_s = lake surface temperature, in °K
D = diameter of discharge pipe, in meters, and
y = the distance from the discharge pipe that the temperature is desired to be known, in meters.

Equation B.1 can be solved for y and used to predict the length of the thermal plume, as measured from the discharge of the pipe.

$$y = 7D(T_o - T_s) / (T_y - T_s) \qquad \text{Equation B.2}$$

The distance y can be calculated assuming a 24 inch diameter pipe (0.574 meters ID), a cooling water discharge temperature 20°F (11.1°C) warmer than the lake surface, and that the disturbance can be considered dissipated when the temperature difference between the lake water and the edge of the plume reaches 0.5°F (0.278°C):

$$y = 7(0.574\ \text{m})(11.1^\circ\text{C}/0.278^\circ\text{C}) = 160 \text{ meters, or } 525 \text{ feet}$$

Thus it can be stated that the thermal plume caused by the cooling water discharge will affect an area about 525 feet in diameter.

Jaluria and Cha (1985, p. 101) give expressions for the energy dissipation from ponds:

$$h_e = 21.7V_e(p_s - p_a) \qquad \text{Equation B.3}$$

$$h_{br} = 0.97\partial(T_s^4 - T_a^4) \qquad \text{Equation B.4}$$

$$h_c = 0.0041V_eP(T_s - T_a) \qquad \text{Equation B.5}$$

Where

h_e = heat loss due to evaporation, in W/m^2
h_{br} = heat loss due to back radiation to the sky, in W/m^2
h_c = heat loss due to convection, in W/m^2
V_e = wind velocity, in m/s
P = atmospheric pressure, in kPa
p_s = the vapor pressure of the lake surface, in kPa,
p_a = partial pressure of the water vapor in the air, in kPa.
T_y = temperature at distance y from discharge, in °K
T_o = cooling water discharge temperature, in °K
T_a = ambient air temperature, in °K
T_s = lake surface temperature, in °K, and
∂ = Stefan-Boltzman constant, in W/m^{2}K^4

It is readily apparent from these formulas that most of the heat is dissipated by radiation from the lake to the sky. The second most significant heat transfer mechanism is evaporation. Convection heat transfer is the least significant of the three, even during high winds.

Evaporation is of concern because of the limited inflow of freshwater to Pyramid Lake since construction of the Newlands Project. The increase in evaporation rate due to the thermal discharge can be evaluated by determining the average temperature increase over the plume area. This can be approximated by solving Equation B.1 for T_y and integrating the result over the radius of the plume.

$$T_{ave} = 1/r \int (T_o - T_s)7D/y \, dy \qquad \text{Equation B.6}$$

$$= (1/r)(T_o - T_s)7D \ln(r)$$

Where

T_{ave} = average temperature rise of plume, in °C,
r = radius of circular plume, in meters, and
ln(r) = natural logarithm of r

In the case of a plume with 160 meter diameter, r is 80. Once again using a temperature rise of 20°F (11.1 °C), and a 24 inch (0.574 meters ID) pipe, the average temperature in the plume is found to be 2.7°C higher than the lake temperature. In other words, the plume is 20°F warmer at the point of discharge, has cooled to within 0.5°F of the lake at the edge of a160 meter circle, and on average the plume is 4.9°F (2.7°C) warmer than the surrounding lake. (These figures include the 0.5°F increment over the entire plume.)

The increase in evaporation rate of the heated lake water over that of unheated lake water can be estimated by subtracting the evaporation rates calculated at the two different temperatures. Equation B.3 gives a total energy loss through evaporation of 123.21 Watts per square meter for the unheated lake water. The same equation gives a result of 146.97 W/m^2, for lake water heated 4.9°F (2.7°C) over that of the previous case.

These two heat flux values can be used to compute the water lost through evaporation in each case. The following formula gives the water loss in terms of meters per year.

$V_e = 31536(v_f)(h_e)/h_{fg}$ Equation B.7

Where

V_e = water loss through evaporation, m/year
v_f = specific volume at temperature of case, m^3/kg
h_e = heat loss due to evaporation, in W/m^2, and
h_{fg}= heat of vaporation at temperature of case, in kJ/kg

Table B.2 summarizes the data used to compute the water loss, with and without the power plant. The table shows that up to 5.12 acre feet of water will be lost through evaporation due each year to the power plant project. This figure is thought to be conservatively high, because it is based on summertime conditions. The actual evaporation rate should be less in winter.

Table B.2 Evaporation Loss Estimates for a 2.5 MW Power Plant

	Without Project	With Project	Units
Diameter of thermal plume	525. 160.	525. 160.	feet meters
Area of thermal plume	4.97 20,106.	4.97 20,106.	acres m^2
Average temperature within plume	70.0 21.1	74.9 23.8	°F °C
Evaporative heat flux	123.21	146.97	W/m^2
Specific volume of water @ average temperature	0.001002	0.001003	m^3/kg
Heat of vaporization of water @ average temperature	2451.	2444.	kJ/kg
Evaporation rate	5.21 1.589	6.24 1.902	ft/year m/year
Total evaporation	24.89	31.01	ac ft/yr
Difference	5.12		ac ft/yr

B.2 Once-through cooling system design.

During the winter, the lake water temperature is fairly constant with depth. In the summer however, the upper level of the lake is warmed by the sun while the lower levels remain cooler. This effect is known as stratification. Ideally, the cooling water intake from the lake should be deep enough to pick up the colder water at depth. At the proposed plant locations, the water depth increases so gradually that the added cost of piping to reach the colder water at depths below 40 meters may not be justified. According to water depth maps of the area, it appears that one mile of pipeline may be required. Lake temperature gradient measurements should be taken at the proposed plant area prior to finalizing of cooling system design.

The location of intake and outlet piping must be considered. If the intake is too close to the outlet the warmed discharge water may be picked up by the intake piping. This is called "short-circuiting" and causes a marked drop in plant power production. Since Pyramid Lake water levels fluctuate significantly from year to year, the inlet and outfall must be designed so that they won't be left high and dry during a low water level year.

Two main cooling system pipes will be required; an inlet pipe to bring the water from the lake to the condenser, and an outlet pipe to return the warmed water to the lake once it has been through the condenser. At a flow rate of 8750 gallons per minute, a pipe diameter of 24" is required. PVC should provide good service. The pipe should be buried, although rock formations may make trenching difficult if not impractical.

The intake must be designed to minimize problems of fish, vegetation, and debris entrainment. Fish can detect and swim against a horizontal current, but are relatively helpless against a vertical one. The intake should be designed with a velocity cap, or screen, to create a horizontal flow of water in the inlet. Pyramid Fisheries has had considerable experience in pumping large quantities of lake water to the hatchery and their experience should prove extremely valuable in designing the system.

It may be practical to use buried perforated horizontal pipes, similar to well casing, for the intake and discharge. This will eliminate problems of entrained fish, etc., in the intake and also minimize thermal effects on the lake from the discharge. If the permeability of the ground is found to be high enough, a gravel lined trench as short as 500 feet long may be sufficient for the intake system. The suitability of a design like this will hinge upon testing the soil permeability and ground water level to see if the lengths and depths of the required trenches are reasonable.

B.3 Mechanical draft, wet cooling towers.

Wet cooling towers are probably the most common type of cooling systems, and are seen at most power plants. In a wet cooling tower, the heated water from the condenser is pumped to the top of the tower where it runs by gravity through a system of baffles known as fill. Large fans located in the center of the tower draw air through the water as it falls through the fill. The water is cooled mainly by evaporation. Humid air is discharged to the atmosphere above the tower, and plumes of vapor are sometimes seen above cooling towers in the winter. Some cooling is also done by conduction, raising the dry bulb temperature of the air in the process, but the majority of the cooling, 80%, is done through evaporation.

After passing through the fill, the cooled water is collected in a basin at the bottom of the tower. The cooled water collected in the basin is then pumped back through the condenser, where it gains about 15°F as it absorbs heat from the motive fluid. The heated water is pumped back to the tower to be cooled and repeat the cycle. Cooling towers operate on the same basic principle as swamp coolers and the water lost to evaporation must be replaced, as in a swamp cooler. The replacement water is known as makeup water.

The makeup water, amounting to about 5% of the total cooling water flow, can come from several sources. A sufficient amount of spent geothermal fluid can be diverted, cooled, and stored in a pond, or fresh water from a well or the lake can be pumped into the basin as required.

Water is lost in the cooling system in several ways. In addition to water loss through evaporation, some water is lost through drift. Drift is the term for water lost when droplets are entrained in the air flow and carried away. Another cause of water loss is through blowdown. Blowdown is water intentionally discharged from the basin. Since water is lost through evaporation leaving impurities behind, the concentration of impurities in the cooling water can build up. Scaling problems for the cooling tower fill and condenser tubes would result, were it not for fresh makeup water replacing the blowdown.

There are significant reasons for the popularity of cooling towers. They are fairly efficient cooling systems, and increase plant output above the level of less efficient systems. Cooling towers can be prefabricated and rapidly assembled at the site. They are generally supplied by a manufacturer specializing in cooling towers and their design and performance are guaranteed. Also, cooling towers require a minimum of land area.

In addition to advantages, there are of course disadvantages; a major one being the visual impact of a tall cooling tower in an environmentally sensitive area. The vapor plume sometimes seen in the winter, besides being visually objectionable in some locations, can at times create dense ground fog at the plant site. Water supplies to cooling towers are rarely clean enough to eliminate the need for expensive chemical treatment systems. Without treatment, deposits may build up on condenser tubes and tower components and require frequent cleaning. The fans and their associated gear boxes, motors, etc., are generally a major source of power plant sound levels. The complexity of the cooling tower system, as compared to simpler systems such as ponds, will unavoidably require higher maintenance and associated downtime.

The energy required to operate fan motors and pumps must be deducted from gross power output. Also, cooling towers cannot be used where there are unacceptable levels of pollutants in the cooling water, since a percentage of the water is lost to the atmosphere. The prevailing winds must be considered when siting a cooling tower, since most effective cooling takes place when the wind is across the width of the tower. Facilities located down wind from a tower may suffer icing and fog. In addition, cooling tower structures are often wood. A fire system may be necessary since wood can dry out during periods of non-operation.

B.4 Spray Ponds

Spray ponds are artificial ponds equipped with a piping and nozzle system to spray the warmed cooling water over the pond surface. Spray ponds function basically the same as cooling towers, except the evaporation is caused by natural air currents over the pond instead of a forced draft. As in cooling towers, approximately 80% of cooling takes place through evaporation, the balance through conduction. Makeup water requirements for lined ponds are also similar to towers, although percolation from an unlined pond will require additional makeup.

Some things to be considered in spray pond design include the amount of heat to be rejected, proper orientation of the pond and nozzles to the prevailing winds, optimizing the spray pattern and nozzle design, and the advisability of building a two stage pond. Most spray ponds are rectangular, so the prevailing wind will travel across the narrowest dimension. Some very effective spray ponds use a two stage system; water is sprayed over the first pond to obtain initial cooling, and then pumped through nozzles over a second pond to reject an additional amount of heat. Several companies manufacture spray nozzles; research on improved nozzles and spray patterns is continuing. Manufacturers are willing to assist in pond design, which can be a great help to small scale power plant developers.

Spray ponds have several advantages over cooling towers. The initial cost is considerably less, especially if there is enough makeup water available, or soil conditions are good enough, to eliminate the need for lining the pond. Contrary to some very expert opinions, properly designed spray ponds offer performance comparable to commercial cooling towers. Spray ponds have half the sound level of a cooling tower, and since they are at ground level, have less visual impact. Since there are no fans or gear boxes, mechanical maintenance and parasitic losses are less. If the pond is properly designed and built, its general simplicity leads to less downtime.

Once again, the advantages should be weighed against the disadvantages. Ponds require a considerable amount of land area, about one square foot for every 25 gallons per hour of cooling water flow. In addition, the pond should be situated downwind from the plant or other developed areas, since wind can carry water drift from the spray for considerable distances, causing corrosion and icing problems. Dense fog can also be created during winter months, although this is less of a problem with ponds than with cooling towers. Seepage from unlined or poorly designed ponds can create problems in surrounding areas. Also, warm ponds are a natural habitat for algae, which can end up in condenser tubes, causing loss of condenser efficiency and a drop in plant output.

B.5 Forced Draft, Dry Condensers

Dry condensers use ambient air as the cooling medium. After leaving the turbine, the motive fluid vapor is circulated through a system of coiled tubes where large fans force air over the tubes. The dry condenser

Base from Pyramid Indian Reservation Maps published by Western Nevada Indian Agency, U.S. Dept. Interior.

1 0 1 2 3 4 5
MILES

PROJECT LOCATION

NOTE: LINE LOCATIONS SHOWN ARE APPROXIMATE; LOCATIONS ARE BASED ON DETAILED MAPS MAINTAINED BY SIERRA PACIFIC DISTRICT OFFICES IN RENO AND FALLON; NOT SHOWN ARE SINGLE PHASE LINES OR LINES OVER 100 KV.

GEOTHERMAL DEVELOPMENT ASSOCIATES
251 RALSTON STREET RENO, NEVADA 89503 (702) 322-0938

NEEDLES POWER PLANT PROJECT
ELECTRICAL FACILITIES INDEX MAP
PYRAMID LAKE INDIAN RESERVATION
Washoe County, Nevada

PREPARED FOR: **PYRAMID LAKE PAIUTE TRIBE**
DATE: SCALE: DRAFTED BY:

PLATE IV

Explanation

QUATERNARY

Pleistocene & Recent — Ql — LAKE DEPOSITS

TERTIARY

Pliocene — Tba — BASALT

Miocene — Tsv — HARTFORD ASSEMBLAGE PYRAMID SEQUENCE

SOILS CONTACT (project area only)

841 BEACHES

930 TYPIC TORRIORTHENTS AND AQUIC TORRIORTHENTS (complex, very fine sandy loams, 0 to 4 percent slopes).

1061 TROCKEN-BLUEWING ASSOCIATION

CONTACT

FAULT, (dashed where approximately located; dotted where concealed)

GEOMORPHIC FEATURES AND LINEATIONS

WESTERN GEOTHERMAL, INC. WELLS (Drilled 1962-1966)

1	Paiute No. 1,	5930' T.D.
2	Paiute No. 2,	1488' T.D.
3	Paiute No. 3,	1206' T.D.

THERMAL SPRING

SOURCE: Bonham (1969); Soil Conservation Service (1987); and Photogeology by Geothermal Development Associates (1988).

2000 0 2000 4000
FEET
Contour Interval 20 Feet

Base from The Needle Rocks, Nev. 71/2 minute U.S.G.S. Quadrangle

GEOTHERMAL DEVELOPMENT ASSOCIATES
251 RALSTON STREET RENO, NEVADA 89503 (702) 322-0938

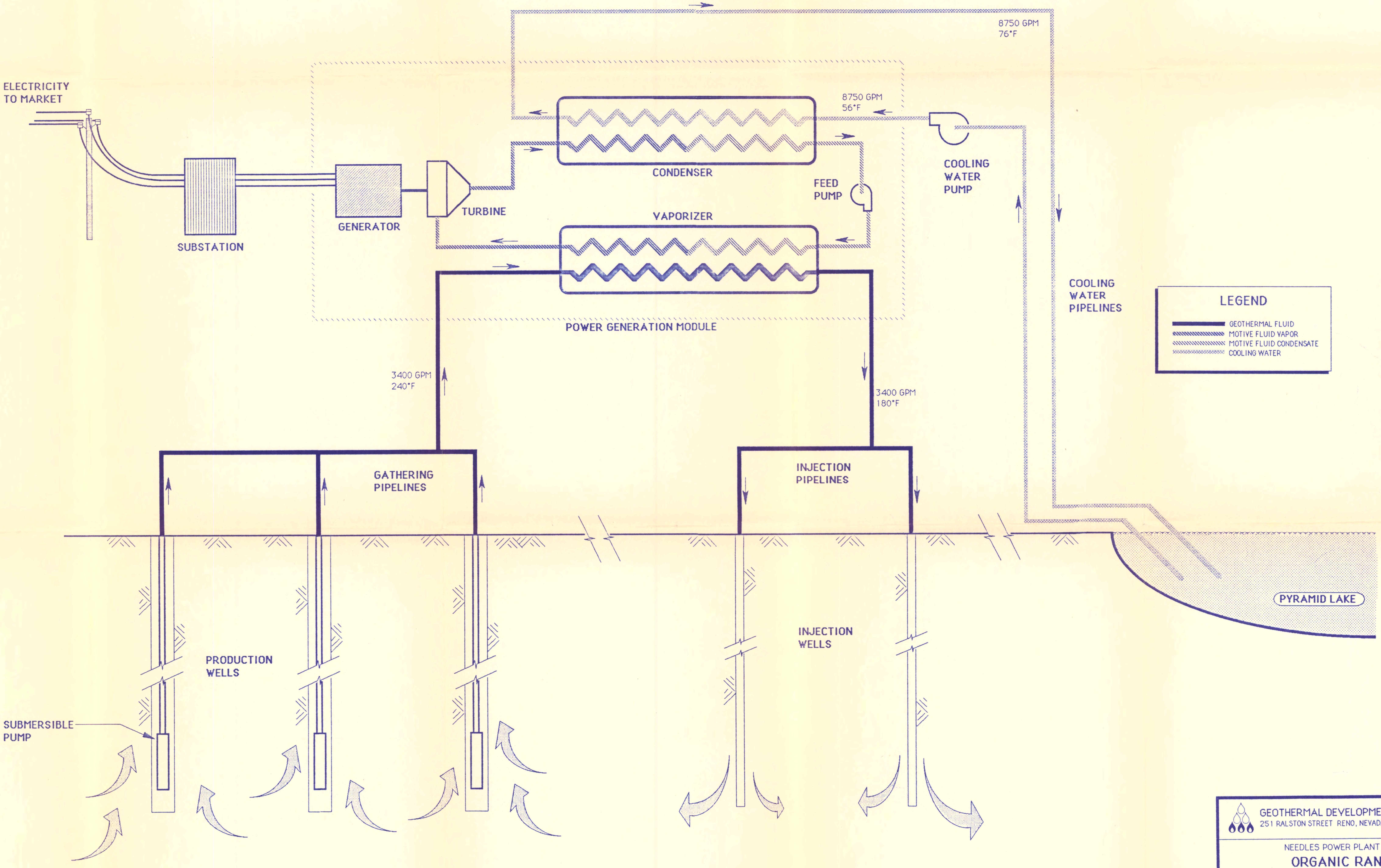
NEEDLES POWER PLANT PROJECT

GEOLOGIC MAP OF THE NEEDLES AREA

PYRAMID LAKE INDIAN RESERVATION
Washoe County, Nevada

PREPARED FOR: **PYRAMID LAKE PAIUTE TRIBE**
DATE: 4/25/88
SCALE: AS NOTED
DRAFTED BY: SL

PLATE I



GEOTHERMAL DEVELOPMENT ASSOCIATES
251 RALSTON STREET RENO, NEVADA 89503 (702) 322-9038

NEEDLES POWER PLANT PROJECT

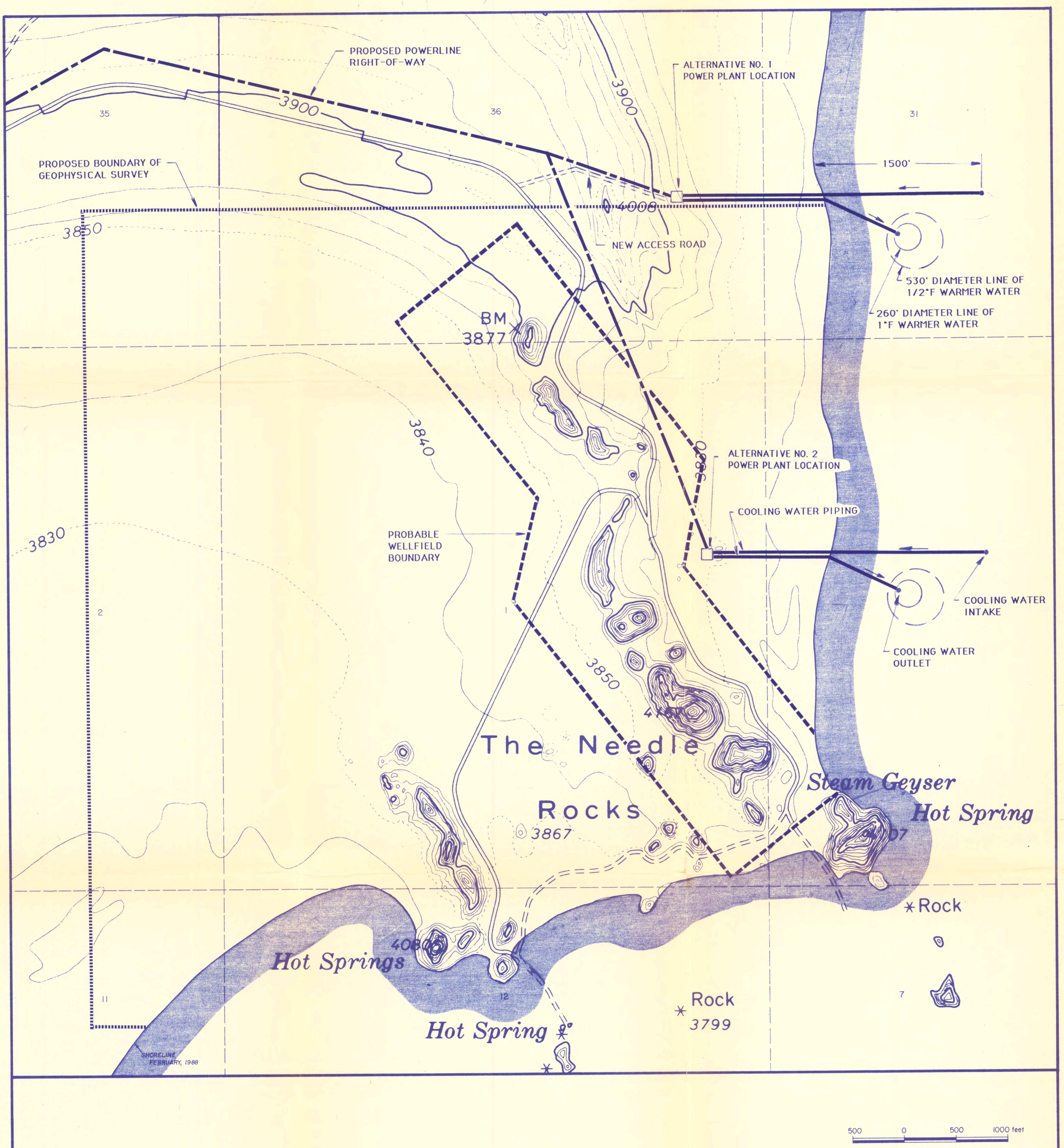
ORGANIC RANKINE CYCLE SCHEMATIC

PYRAMID LAKE INDIAN RESERVATION
Washoe County, Nevada

PREPARED FOR: **PYRAMID LAKE PAIUTE TRIBE**

Date: 4/25/88 Drawn By: LHG Scale: None

PLATE III



GEOTHERMAL DEVELOPMENT ASSOCIATES
251 RALSTON STREET RENO, NEVADA 89503 (702)322-0938

NEEDLES POWER PLANT PROJECT

PRELIMINARY SITE PLAN

PYRAMID LAKE INDIAN RESERVATION
Washoe County, Nevada

PREPARED FOR: **PYRAMID LAKE PAIUTE TRIBE**
DATE:
SCALE:
DRAFTED BY:

PLATE II