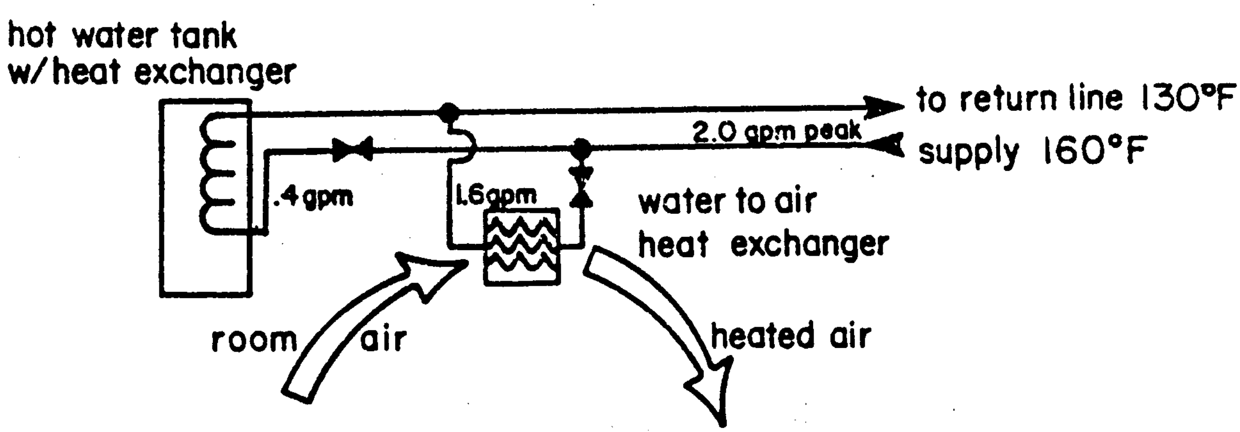
GEOTHERMAL UTILIZATION PLAN

MARINE CORPS AIR-GROUND COMBAT CENTER, TWENTYNINE PALMS, CALIFORNIA

September, 1985

Typical Retrofit Schematic



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GEOTHERMAL UTILIZATION PLAN, MARINE CORPS AIR-GROUND COMBAT CENTER, TWENTYNINE PALMS, CALIFORNIA

Final Report

March 1, 1985 - September 1, 1985

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ABSTRACT

A preliminary engineering feasibility study of geothermal utlization was completed for the Marine Corps Air Ground Combat Center, Twentynine Palms, California. The study incorporated previous studies of the geology, geophysics, and environment performed for the Center. In addition, information about fuel consumption and current heating methodology was provided by the Center's personnel. This information was integrated with design assumptions based on the best estimates available for geothermal resource temperature and flow rate. The result of the study is a recommended pipeline alignment and suggested geothermal service area. The estimated costs for construction of the system range from $4.5 to $5 million. The estimated savings in offset natural gas consumption after capital recovery is $3.8 million over a twenty year period.

ACKNOWLEDGEMENTS

Several people and organizations were instrumental in the successful completion of this project and the authors would like to acknowldge their contributions. Dennis Trexler, Director of the Division of Earth Sciences, added valuable insight to the project, as did John Crawford, of the San Francisco Operations Office of the U.S. Department of Energy. The data for the gas consumption and other heating data was provided by Stewart Hammond of Facilities Maintenance, MCAGCC. Details of the master plan for the base were provided by Gerald Hawker of the Western Division, Naval Facilities Engineering Command. Roger Twitchell and SSgt. William Flummerfelt, of the Natural Resources Branch of the MCAGCC, provided a large portion of the interface coordination communication. Charles Miles and David Holmes of the Naval Civil Engineering Laboratory provided important financial assistance and the characterization of specific criteria which maximized the probability of project success and minimized the cost.

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INTRODUCTION

The Marine Corps Air-Ground Combat Center (MCAGCC), Twentynine Palms, California, is the site of a recent discovery of a low- to moderate-temperature geothermal resource (Trexler and others, 1984). Results from preliminary test-hole drilling indicate fluid temperatures in excess of 67°C (153°F) at a depth of 335 m (1,100 feet). The exact configuration and extent of the reservoir are not known, but the fluids appear to be closely associated with several northwest-trending faults. Additional drilling will be required to establish reservoir characteristics.

Although a decision to incorporate geothermal fluids into the Center's energy supply has not been made, the geothermal resource has the potential to offset some of the MCAGCC's two-million dollar per year fuel bill. Produced fluids can provide space heating and domestic hot water heating to a portion of the Center and may be suitable for secondary uses such as irrigation or potable water. Disposal options for the fluids are discussed in Flynn and others (1984). Although the fluids may be suitable for other uses, this report will assume the fluids are of a quality that will preclude secondary uses and require the use of heat exchangers. Admittedly, this assumption is conservative, but regarding the specific parameters described, it is the most realistic.

This report was prepared to evaluate the potential uses for the geothermal fluids and the costs associated with its development. In the absence of confirmed reservoir characteristics, overall average production was assumed to be 1000 gpm of geothermal fluids, based on potable water aquifer characteristics near Surprise Spring. It is likely that thermal and non-thermal aquifers occur within similar geologic formations. In addition, a production temperature of 72°C (160°F), pumped from a well 2000 feet (610 m) deep, is assumed based on temperature gradient data (Trexler and others, 1984).

SITE CHARACTERISTICS

The Marine Corps Air-Ground Combat Center (MCAGCC), Twentynine Palms California, is located at the eastern end of the Morongo Basin. It is the largest (in areal extent) Marine Corps Center in the world, encompassing approximately 1,000 square miles of the southern Mojave Desert. The Center's administrative and housing area is located 5 miles north of the city of Twentynine Palms, California (fig. 1). Large buildings such as offices, barracks, and classrooms are heated by a High Temperature Hot Water (HTHW) district heating system. Approximately 1,110 individual and multiple family housing units employ individual gas-fired, forced air heating systems and gas-fired water heaters.

According to a communique from the Installation Division, USMC, dated 14 March 1985, (Yucca Valley Chamber of Commerce, 1985) the Center has a working population of 9,000 Marines and 1,000 civilian employees. The total Marine Corps presence in the area, including Marine families, is approximately 15,000. An additional 2,100 Marines will be incorporated into the Center's population over the next four years as follows:

Year	Increase
1985	100
1986	800
1988	560
1989	640

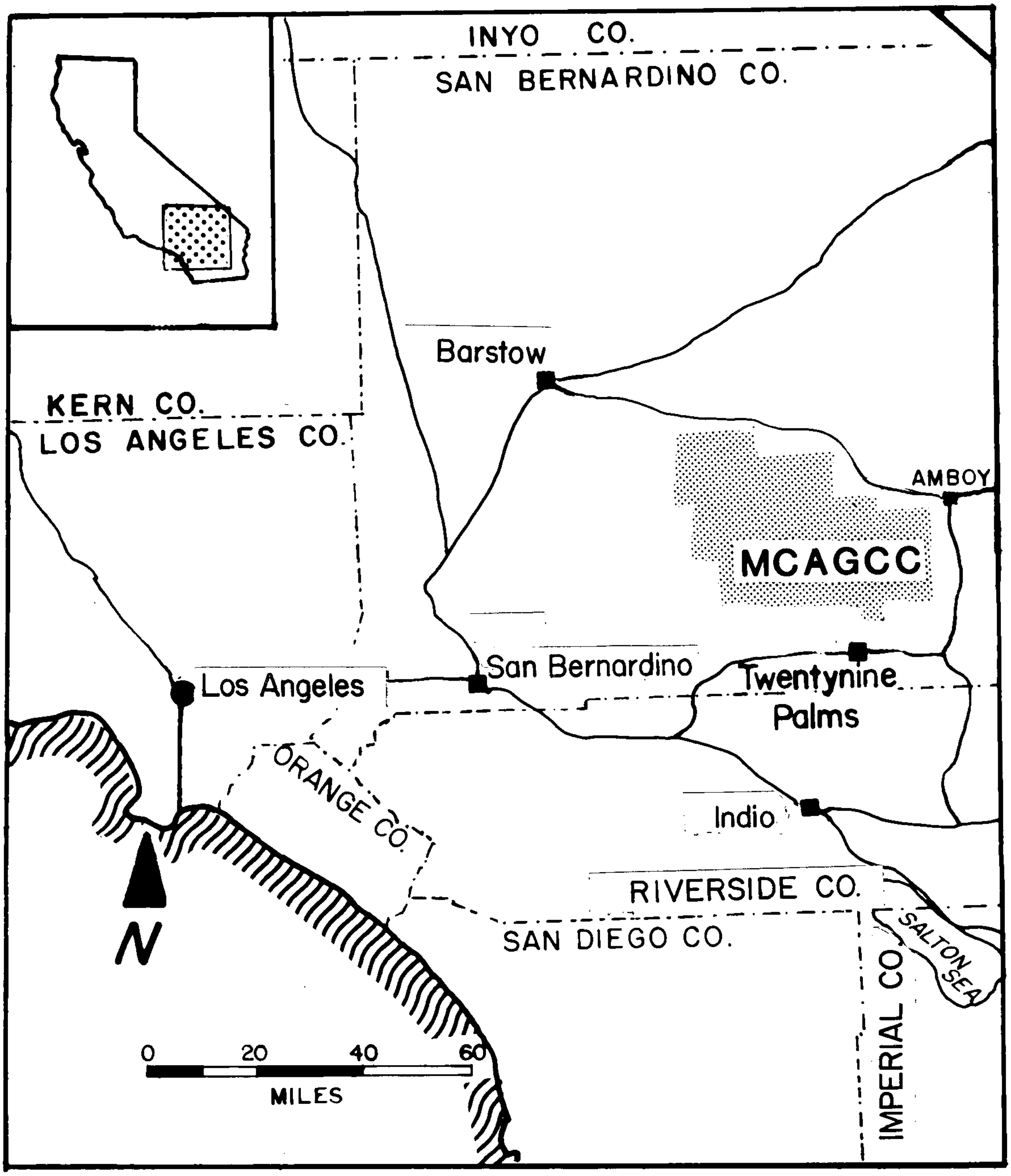


Figure 1. Location map of MCAGCC.

In addition to the above increases, the Marine Corps expects an additional 400 Marines to enter the population by 1989. To support the growing Center population, the MCAGCC is undergoing major expansion. Approximately $133 million has been allocated for new construction over the next four years. However, at the present time the master plan for the Center does not call for new construction in the vicinity of the known geothermal resource.

An expeditionary air field (EAF) is located at Camp Wilson, approximately 6 miles north of the administrative area (fig. 2). The only permanent structures at Camp Wilson are 14 shower and lavatory buildings.

Climate in the Twentynine Palms area is mid-latitude desert. Average rainfall is a scant 4.14 inches per year. The climate is moderate with only 2500 degree days of heating required.

GEOTHERMAL OCCURRENCES

The occurrence of warm ground water in the Twentynine Palms area has been known for at least 30 years. Wells drilled for domestic water north of the city have reported temperatures of 40-73°C (105°-164°F). Higgins (1980) reported three wells ranging in temperature from 48°C to 63°C (118°-145°F). The approximate boundary of the geothermal area in the vicinity of Twentynine Palms was described in Levias and others (1981) as extending 15 km (9 miles) in an east-west direction and 6 km (3.5 miles) north-south. This delineation was based on data from only 5 wells. Subsequent work by the Division of Earth Sciences has increased the known areal extent of the resource to the north (Trexler and others, 1984).

Interest in the potential for geothermal resources beneath the MCAGCC was stimulated by the existence of an well, 400 feet (122 m) deep with a water temperature of 73°C (164°F), located 3.6 km (2 miles) southeast of the Center's boundary. Geophysical exploration by the Geothermal Utilization Division, Naval Weapons Center, China Lake, indicated a geologic structure, the Bullion Mountain Fault, beneath the administrative area. This fault was thought to be a controlling structure for geothermal fluids.

This and other areas were the target of an exploration drilling program (Trexler and others, 1984). Seven temperature gradient holes, drilled at sites (fig. 2) selected by geologists from the Division of Earth Sciences, UNLV, and the Navy to depths of approximately 1,000 feet (305 m), successfully located a widespread resource immediately west of the administrative area. Trexler and others (1984) report a maximum temperature of 50°C (122°F) at a depth of 287 m (940 ft.) in temperature gradient hole #5. This hole is located approximately four miles west of the Ocotillo Heights housing unit at the northwest end of Mainside. Hole #6, drilled near Surprise Spring, has the higher temperature, but may be too remote from potential uses for economic utilization. The temperature gradient in the hole #5 was steady at 8.0°C/100 m (4.0°F/100 ft.) which gives an estimated maximum temperature of 74°C (165°F) at a depth of 610 m (2,000 ft.). These data and a Bouguer gravity anomaly of the Twentynine Palms area (Moyle, 1984) indicate the geothermal resource may be bounded by the Mesquite Fault to the east and the Surprise Spring Fault to the west. If this is the case, the resource may be tapped closer to Ocotillo Heights, significantly reducing piping requirements.

Water resource evaluations for the Center have revealed a steady decline in the water levels of wells in the Surprise Spring area, which provides the Center potable water (Schaefer, 1978). The aquifer that supplies the potable water is identical to the geothermal reservoir rock and the two are presumed to have similar properties. Because the potable water well field has shown a 100-foot (30 m) decline in water level since 1950, at a average pumping rate of 108 l/s (1612 gpm), a reasonable limit on production from the geothermal reservoir may be set at approximately 67 l/s (1000 gpm) to avoid reservoir degradation.

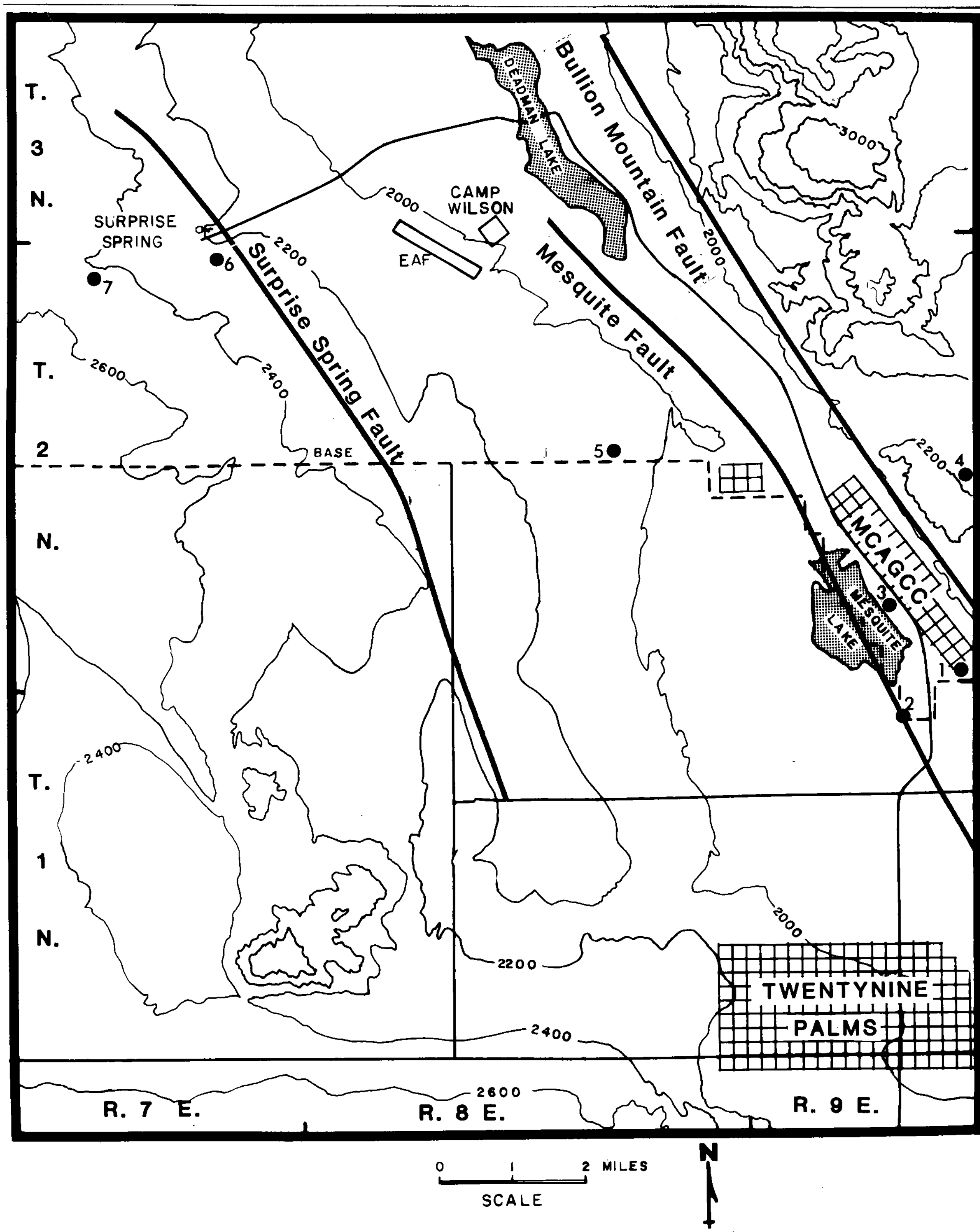


Figure 2. Test hole and major fault locations (after Trexler and others, 1984).

ENVIRONMENTAL CONSIDERATIONS

Flynn and others (1984) proposed, described, and evaluated three disposal options for geothermal fluids produced at a hypothetical site at MCAGCC Twentynine Palms. The three disposal methods included: secondary consumption and sewage disposal enhancement; surface ponding and evaporation; and fluid injection into the producing aquifer. Figure 3 is a graphical representation of the disposal options. The evaluation was based on estimated geothermal resource characteristics, anticipated heat load and secondary uses, physical, chemical, and biological considerations, and legal aspects. The report examined the major environmental issues that must be addressed if the geothermal resource is to be developed for space heating. Of the nine issues, only two, water quality and wildlife species, were identified as significant concerns. The issue of water quality may be dismissed because the proposed development does not represent a threat to existing sources of potable surface water or groundwater. Two indigenous species of protected wildlife presently share portions of their habitat with MCAGCC. Although there is some evidence for negative impact by vehicular activity on habitat, sufficient pre-construction planning should mitigate the impact of geothermal resource development. California and U.S. Federal regulations were not found to constitute a serious institutional barrier to development.

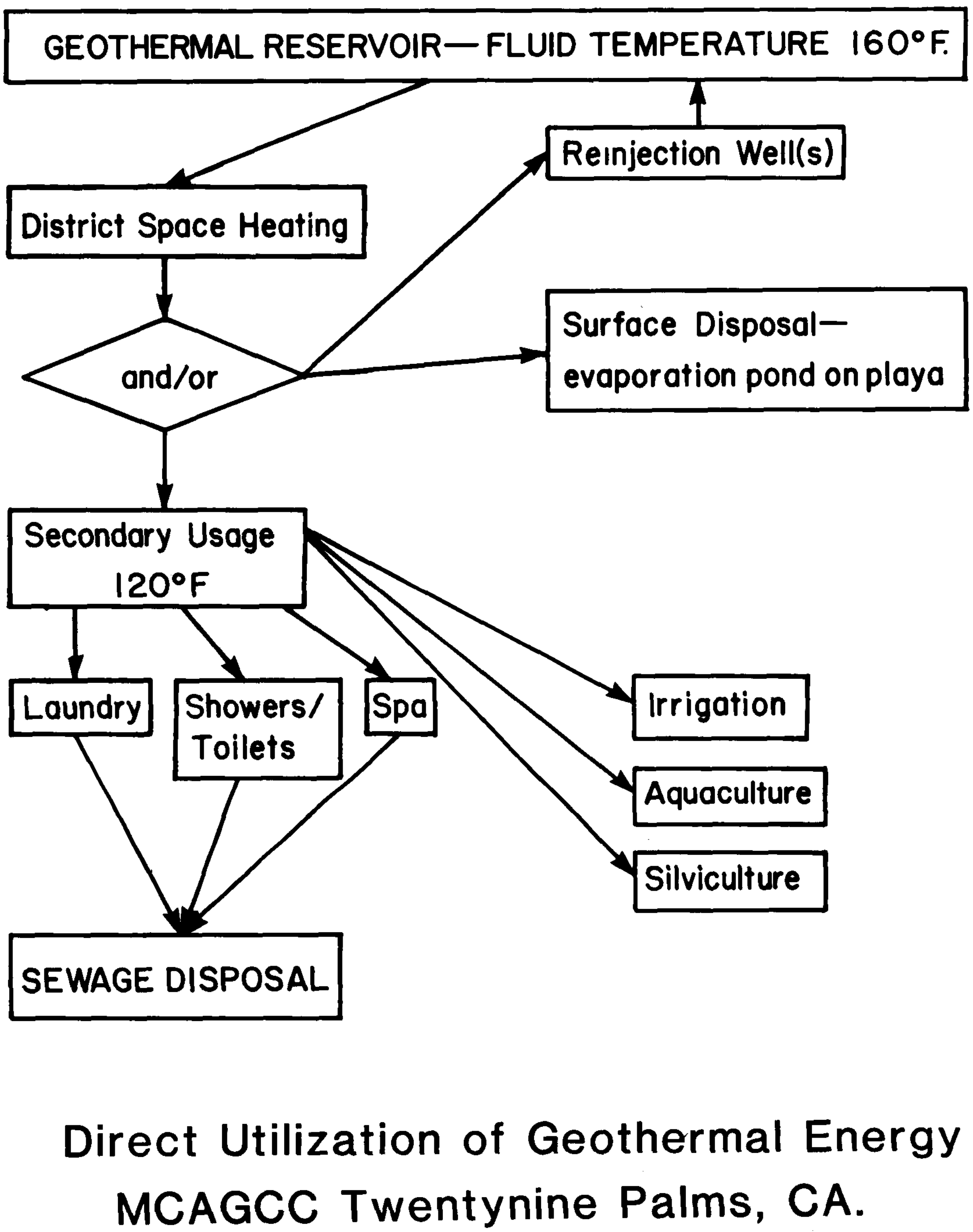


Figure 3. Hypothetical geothermal fluid useage schematic for MCAGCC.

MCAGCC HEATING REQUIREMENTS

The central portion of the MCAGCC consists of large maintenance bays and shops for the tracked, armored vehicles, a hospital, mess halls, barracks for unaccompanied personnel, and other buildings. These buildings are heated by a central, gas-fired, high - temperature, hot water system (pl. 1). This system uses three 40-million Btu/hr generators that deliver 320°F (160°C) water through a well-insulated piping system to the buildings. The water returns to the generators at a temperature of 280°F to 210°F (138°-99°C), depending on the heating demand. Some of these buildings are heated by flashing water to steam in radiators, but most use secondary medium-temperature hot water systems, and are designed for a 70°F to 100°F (39°-56°C) temperature drop. The operating temperatures of these systems are so much higher than the estimated temperature of the geothermal reservoir that it was not considered feasible to retrofit this system.

There are other buildings on the Center that have their own small boiler systems. Most of these heat loads are too small to justify extending the pipeline and many that are due for replacement will be replaced by infrared radiant heaters. The infrared heaters are the best choice for heating large, open bays because they heat objects, not the air.

The most feasible applications for the geothermal resource are the family housing areas which use individual gas-fired, forced-air heaters for space heating and gas-fired hot water heaters. The areas are discussed in detail in the following sections and presented on Plate 1.

OCOTILLO HEIGHTS

The Ocotillo Heights family housing area consists of 250 single family units located at the extreme northwest corner of Mainside. Ocotillo Heights is the closest possible candidate for direct-use of geothermal fluids produced from a well field near test hole #5. Each unit has a natural gas-fired, forced-air heater, a gas-fired water heater, and a gas stove/oven. The proposed direct-use of geothermal fluids would displace the natural gas space heating and domestic water heating.

Ocotillo Heights consumed 175,331 therms (1 therm=100,000 Btu) of natural gas in fiscal 1984 (Facilities Maintenance personnel per. comm. 1985). Based on monthly gas consumption figures, it is possible to estimate what fraction of the total is represented by each use:(fig. 4.)

Space Heating:	100,000 therms/yr
Hot Water Heating:	45,000 therms/yr
Cooking:	30,000 therms/yr.

As a check on the above heat load demands, conventional degree-day methodology was applied. The space heating load per year was calculated using the following values from the Handbook of Air Conditioning, Heating, and Ventilating (1965): 2500 degree-days (dd), 20,000 Btu/hr design heat loss, and a K value of 800 Btu/dd/(MBtu/hr). This gives a design consumption of 117,000 therms/yr, based on estimated efficiency of 85% for gas heaters. The resulting figure compares favorably with the value estimated from the historical usage.

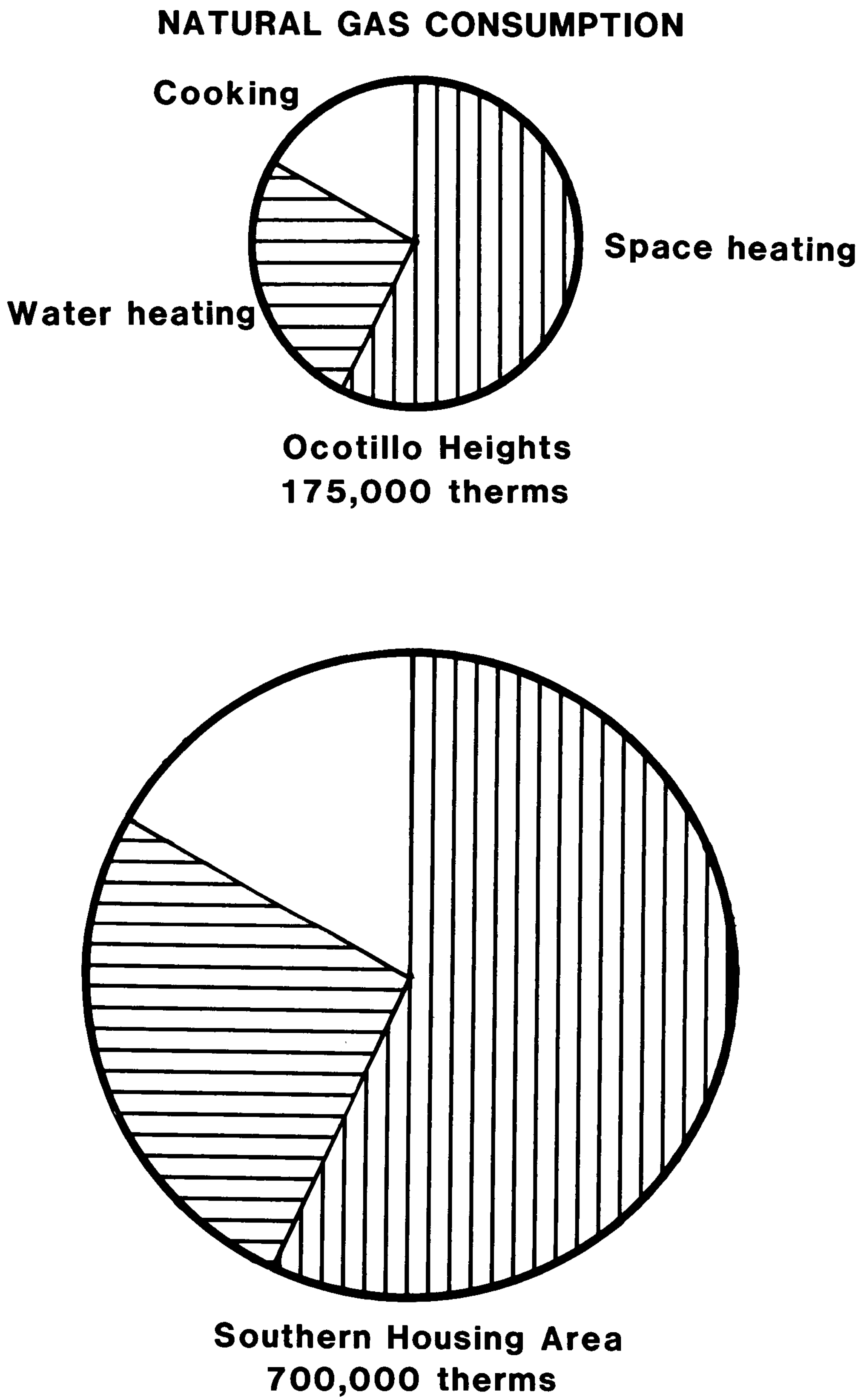


Figure 4. Natural gas consumption by use for Ocotillo Heights and southern housing areas.

In order to supply the peak demand of 25,000 Btu/hr/unit for space heating and hot water heating, 417 gpm of 160°F (71°C) geothermal fluids would be required.

Installation of a geothermal system for delivery of space heating and domestic hot water to Ocotillo Heights from a well near test hole #5 requires the following equipment and installations:

18,480 ft. 8" insulated pipe, installed @ $29/ft.	$	535,920
7,400 ft. 4" insulated pipe, installed @ $14/ft.		103,600
5,000 ft. 2" insulated pipe, installed @$10/ft.		50,000
5,000 ft. 2" bare return pipe, installed @ $3/ft.		15,000
7,400 ft. 4" bare return pipe, installed @ $5/ft.		37,000
250 system retrofits @ $1500 ea. (fig. 5)		375,000
1 2,000 ft. production well		100,000
1 production pump: 500 gpm, 500 ft. head		60,000
Miscellaneous: valves, fittings, etc.		200,000

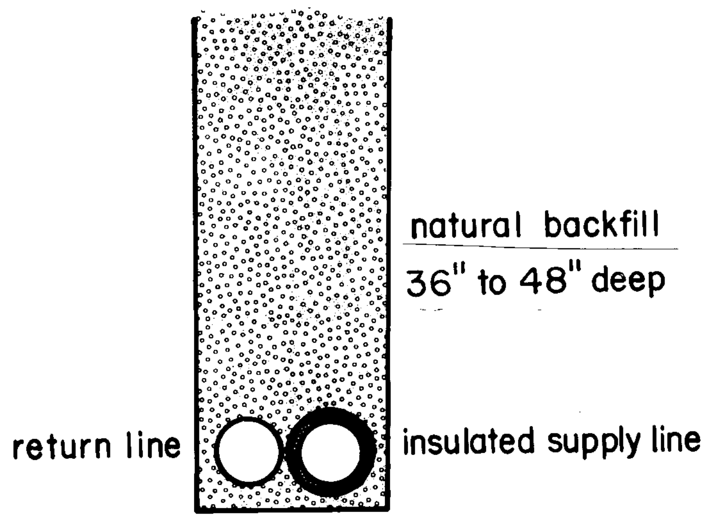
Disposal Options:

1) Injection well 2,000 ft.	100,000
or	
2) Disposal line to Deadman Lake:	
15,840 ft. 8" bare return pipe installed @ $16/ft.	253,444

EST. TOTAL COST Option 1............................$ 1,576,520

EST. TOTAL COST Option 2............................$ 1,729,964

Typical Trench Detail



Typical Retrofit Schematic

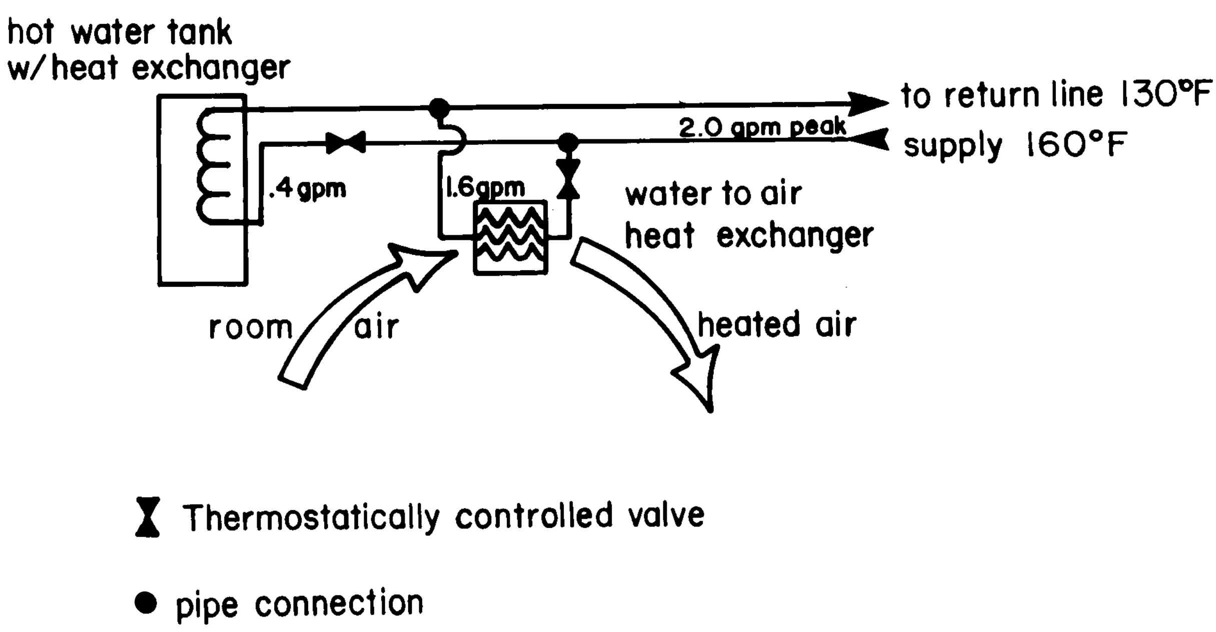


Figure 5. Typical details.

The above estimated costs are based on the latest available piping costs (Tables 1 and 2). Pipe costs include a 20% discount of list prices and are rounded to the nearest dollar. Installation costs for bare return pipe are included in the installation cost for the insulated pipe because return lines are to be installed with the supply lines (fig. 5) in the same trench. Layout for the piping system is shown on Plate 1.

Another alternative is to tap the resource closer to Ocotillo Heights. Implementing this alternative could save up to $460,000 (3 miles of 8-inch pipe) in piping cost, all other things being equal. Before this option can be considered, however, a test hole drilled to a depth of 2000 feet (610 m) near Ocotillo Heights is required to verify the reservoir parameters in the area of interest.

The amount of natural gas saved by the installation of such a geothermal system would be approximately 145,000 therms/yr. The Center currently pays $.60/therm for a total savings of $87,000/yr. The simple (without interest) capital recovery period for option 1 above (from the well #5 area) is 18.1 years and the simple capital recovery period for option 2 is 19.9 years. The least expensive option, producing from a well field adjacent to Ocotillo Heights and then injecting spent fluids ($1,116,520), has a simple capital recovery period of 12.8 years. These capital recovery periods do not include the operating and maintenance costs of the system. Maintenance costs will probably not be significant, but operating costs could be large if pumping levels are deep. The design life of the system is 20 to 25 years, but the system life could easily be extended to 30 or more years because FRP pipe does not corrode.

TABLE 1

FIBERGLASS REINFORCED PLASTIC PIPE

Price Per Foot

SIZE	INSULATED	UNINSULATED
2"	$9.60	$3.60
4"	$14.35	$6.20
8"	$31.20	$15.00
12"	$55.90	$31.70

In large quantities, a 20% price reduction can be expected.
Source: AMERON, Corrosion Resistant Piping Division,
3583 Investment Blvd.
Building D, Suite 1
Hayward, CA 94545

TABLE 2

INSTALLATION COSTS FOR TWENTYNINE PALMS AREA

PRICE PER FOOT OF PIPE INSTALLED, TRENCHED AND BACKFILLED

SIZE	PRICE PER FOOT
2"	$1.75
4"	$2.70
8"	$3.90
12"	$5.25

Source: Mr. Bob Kennedy, City Engineer
City of Twentynine Palms

Based on these recovery periods, conventional economics would not favor retrofitting only Ocotillo Heights if the well field is located near well #5 area. However, if the well field were located adjacent to Ocotillo Heights, then retrofitting Ocotillo Heights could save the Center $580,000 in natural gas charges over 20 years after recovering the initial construction costs. However this saving could be lost in operating costs.

SOUTHERN HOUSING AREAS

The majority of family housing areas for the MCAGCC are in the southeastern corner of the administrative area. These areas are Marine Palms, Joshua Heights, Shadow Mountain, and Sunflower Terrace and are referred to collectively as the southern housing areas. These areas include 867 units and accounted for 699,223 therms of natural gas consumption in fiscal 1984 (Facilities Maintenance personnel per. comm., 1985). Test holes drilled to 1000 feet (305 m) (Trexler and others, 1984) revealed no usable geothermal resources in this area. Therefore, geothermal fluids would have to be piped three miles from the area near Ocotillo Heights.

Using the same methodology applied to the heat load calculation for Ocotillo Heights, the heat load corresponding to space heating and domestic hot water for the southern housing areas is 559,000 therms (fig. 4). The peak heat requirement is 25,000 Btu/hr/unit for a total peak demand of 21,675,000 Btu/hr. Assuming a geothermal fluid temperature drop of 30°F (14°C), the required peak flow rate would be 1,445 gpm. As stated in the introduction to this report, there is some question regarding the reservoir's ability to sustain an extraction rate in excess of 1,000 gpm. For the purposes of this section the authors will assume that the reservoir can support this peak flow rate for short (1 or 2 months per year) periods of time.

Installation of a geothermal system to supply space heating and domestic hot water to the southern housing areas from Ocotillo Heights include the following estimated costs:

Upgrade of main pipeline to Ocotillo Heights:	
from hole #5 area: 8" to 12" 18,480 ft. @ $21/ft.	$ 388,080
15,400 ft. 12" insulated pipe @ $50/ft. installed	770,000
3,000 ft. 8" insulated pipe @ $29/ft. installed	87,000
16,600 ft. 4" insulated pipe @ $14/ft. installed	232,400
17,340 ft. 2" insulated pipe @ $10/ft. installed	173,400
17,340 ft. 2" bare pipe @ $3/ft.	52,020
16,600 ft. 4" bare pipe @ $5/ft.	83,000
867 system retrofits @ $1500/ ea.(fig. 5)	1,285,500
15,400 ft. 12" bare return line @ $25/ft.	385,000
3 additional wells (one prod. two injection)	300,000
2 additional pumps	120,000
Miscellaneous: valves, fittings, etc.	200,000
EST. TOTAL ADDITIONAL COST........................	$ 4,076,400

This additional amount represents the cost of heating the southern areas in addition to Ocotillo Heights. The additional pumps and wells will be needed to supply the system with its peak total demand of 1862 gpm of 160°F (71°C) geothermal fluids. Preliminary layout of the piping system is given on Plate 1.

The total natural gas consumption offset by such a system is 704,000 therms representing a yearly savings of $422,400. The total system cost is estimated at $4,804,840 (well field adjacent to Ocotillo Heights) to $5,652,920 (well field near hole #5) for a simple capital recovery period of between 11.3 and 13.4 years, respectively. Both of the above costs are based on injection pf spent fluids. Again these periods of recovery do not include operating and maintenance costs.

A geothermal retrofit of all the housing areas could save the Center as much as $3,675,000 in reduced natural gas charges over the next 20 years after the capital payback, not including operating and maintenance costs.

UTILIZATION SCENARIO AND IMPLEMENTATION

A logical progression of tasks and decisions leading to the successful delineation and implementation of geothermal resources on military lands is presented in Figure 6 (Trexler and others, 1985). The first steps of preliminary survey, exploration geology and geophysics, and exploration drilling have been completed (Trexler and others, 1984). Environmental and regulatory issues have been examined and found to be insignificant concerning the development of geothermal resources at the MCAGCC (Flynn and others, 1984). This report has identified the low-temperature uses that are suited for adaptation to a geothermal district heating system. Further definition of the resource to establish areal extent, temperature, and flow characteristics are all that remains for complete resource evaluation.

The next logical step in utilization of the resource at the Center is to drill and pump test three 2,000 foot (610 m) wells, with at least one adjacent to Ocotillo Heights. Such a drilling and testing project could be completed within a 12-month period. The information gathered from these wells would be required by Navy and Center personnel to decide whether or not to continue with development.

If the resource is of sufficient temperature and will produce the required volume of fluids, then a detailed engineering design study would be the next logical step. This design may differ from the preliminary system outlined in this report because of different

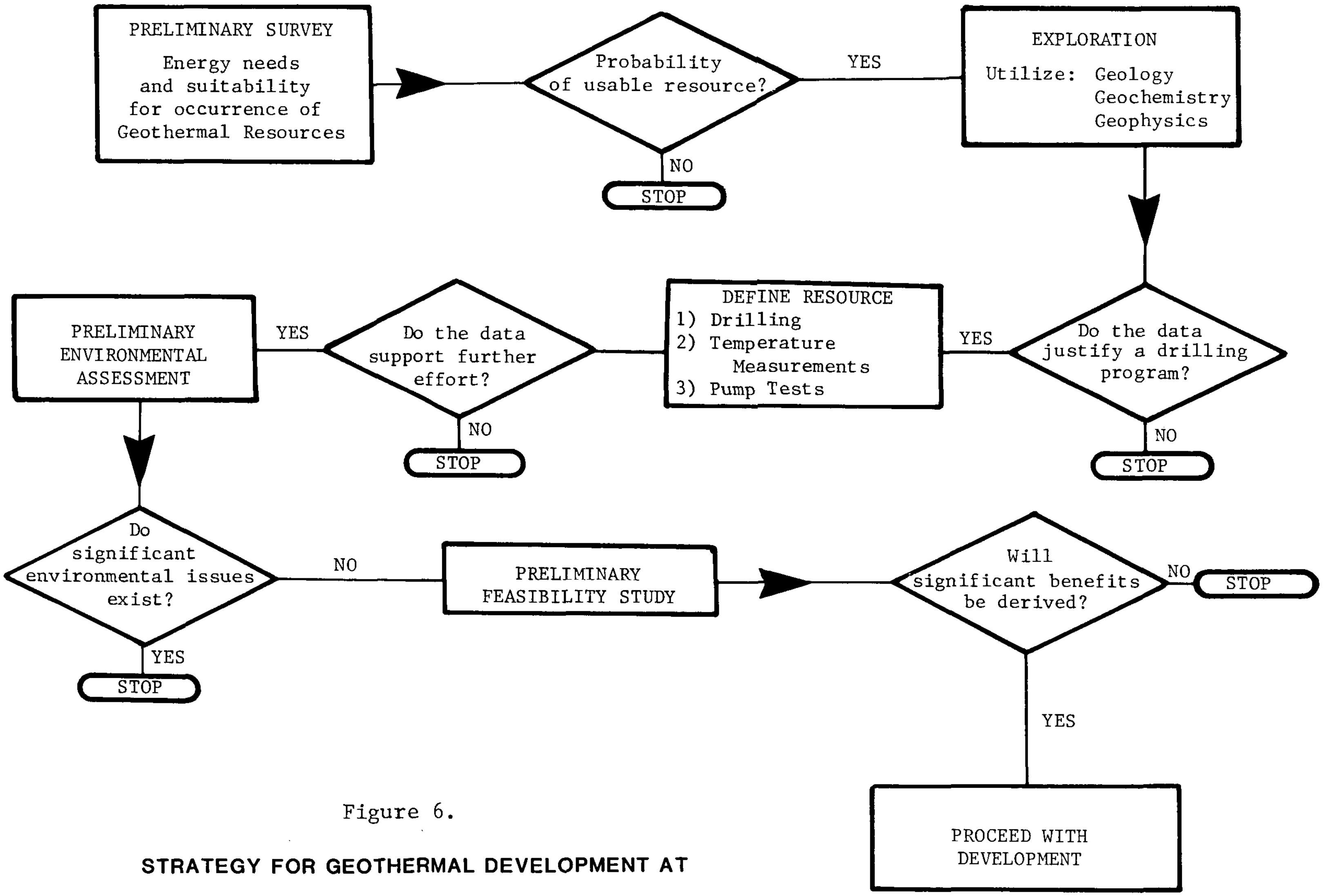


Figure 6.

STRATEGY FOR GEOTHERMAL DEVELOPMENT AT MARINE CORPS BASE, TWENTYNINE PALMS, CALIFORNIA

temperatures, flow rates, and/or water qualities than were assumed in the preparation of this report. Upon review of the detailed design, an informed decision could be made as to whether or not to proceed.

Although the detailed design may differ from the one in this report, estimated construction time would still be about three years. The Ocotillo Heights portion of the system could be completed the first year followed by the southern housing areas over the course of the following two years. It is strongly recommended that the entire project be funded and completed as a unit as opposed to an incremental funding and construction approach.

CONCLUSIONS AND RECOMMENDATIONS

Development and utilization of geothermal resources at the Marine Corps Air Ground Combat Center could save millions of dollars in reduced natural gas charges over the next twenty years. However, the geothermal resource at MCAGCC needs further definition and testing before the development and utilization can begin. If the testing confirms the temperature and flow rate assumptions made in this report, then construction of a geothermal district heating system should be given serious consideration.

This report evaluated the Center for potential uses for the geothermal fluids. The central area, which is served by a high temperature hot water distribution system, was considered infeasible for retrofit because of its large demand and high operating temperatures. Other buildings on the Center that use small boilers were found to be too remote, too small, or are being replaced with infrared heaters. The ideal candidates for geothermal retrofits are the family housing units which use small gas-fired forced air heaters and hot water tanks.

The housing unit closest to the geothermal discovery is Ocotillo Heights. The remaining units are 3 miles to the south and referred to collectively as the southern housing units. A cost analysis demonstrated that it is impractical to retrofit Ocotillo Heights by itself. The resource must be tapped as close as possible to Ocotillo Heights for economic viability for the total system. Examination of a retrofit plan for all housing units proved to be the best alternative. Thus all the housing units should be retrofitted to maximize economic attractiveness.

Retrofitting all the housing areas would require between $4,804,840 and $5,652,920 in capital construction costs. The resulting system would displace 704,000 therms of natural gas for a yearly savings of $422,400. The simple capital recovery period for such a system is 11.3 and 13.4 years. In conclusion, developing the geothermal resources at the MCAGCC represents a viable long-term option because it is technically and economically feasible and will conserve dwindling fossil fuels.

Recommendations:

1) Additional data are needed on the areal extent, fluid chemistry, flow rate, and temperature of the geothermal reservoir. These data are critical for a detailed engineering design and for evaluating geothermal system viability.

2) Three 2000 foot (610 m) wells, capable of being pump-tested, should be drilled near the western boundary of Ocotillo Heights. The wells are needed to define the areal extent of the resource, to determine permeability and injectivity, and to determine the production temperature of the resource. These parameters are the building blocks for subsequent geothermal utilization at the MCAGCC.

3) Serious consideration should be given to planning development in the test hole #5 area of the West Range. Such a land withdrawal from the Range for housing need not be large and would dramatically reduce piping costs for a geothermal system. There is currently no planned construction in the Ocotillo Heights area, however there is a recommendation in the recently completed Master Plan (1985) for MCAGCC to acquire land south of Ocotillo Heights for expansion. This land acquisition is proposed by Western Division, Naval Facilities Engineering Command as an alternative to purchasing land south of the main gate.

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PLATE 1. Geothermal pipeline design