A PROPOSED DEVELOPMENT PLAN FOR A MODIFIED HORIZONTAL IN SITU EXPERIMENT

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INTRODUCTION

The oil shales of Colorado, Utah, and Wyoming are a potentially important energy resource for the U.S., and a possible significant contributor to future national energy independence. Since approximately 80 percent of these shale deposits are on federal lands, the Government has a prime responsibility to ensure their efficient and environmentally sound utilization.

Primary efforts to develop oil shale to date have emphasized a combination of mining and surface retorting. An alternative approach, in situ (in place) retorting, has not been extensively investigated. If an economically viable in situ technology could be developed, however, it could increase the "recoverable reserves" of oil shale, reduce a shale oil industry's water requirements, and mitigate the environmental impacts normally associated with mining and aboveground processing.

An Accelerated National Oil Shale In Situ Research Program was accordingly formulated by a U.S. Government Interagency Oil Shale Panel (1) in March 1975.[1] A principal objective of the research and development program is to attempt to "advance the technology for in situ production of shale oil to the point of commercial feasibility by the early 1980's," with appropriate accompanying environmental safeguards. Both true in situ and modified in situ research projects to produce shale oil are included in the Accelerated Program.

ERDA assumed primary responsibility for implementing the research and development portion of the program, which closely relates oil shale leasing activities of the U.S. Department of the Interior with the activities of ERDA. The accelerated program development plan includes two main and coordinated phases. The first of these is the offering for sale of two tracts of Federal oil shale lands limited to development by in situ methods. The second phase is the research and development plan which is to be guided by the results (or lack of results) of the leasing phase.[2]

Lack of industrial interest in Wyoming oil shale, which is typical of lean, thin-seam oil shale deposits throughout Wyoming, Colorado, and Utah, as indicated by the absence of nominations, makes it imperative for the Government to assume a primary role in the long-range, high-risk research on the substantial thin-seam oil shale resource values. The present ERDA program on Wyoming oil shales consists of the research on true in situ processing now being conducted by the Laramie Energy Research Center.

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[1] A joint announcement of the program was made by the Department of the Interior and ERDA at a Government/Industry Conference in Washington, D.C., March 19, 1975.

[2] Results from the Department of the Interior's call for nominations of in situ tracts in mid-1975 yielded six tracts nominated in Colorado and three tracts nominated in Utah. The nominations were made by six companies. No tracts were nominated in Wyoming. A tract selections committee selected one tract in Colorado and one tract in Utah. Two alternate tracts, both in Utah, were designated by the committee.

The proposed development plan is concerned with horizontal modified in situ research, as discussed in the Accelerated Program, and specifically with the technical, economical, and environmental feasibility of applying a combined horizontal mining and retorting technology to shale oil production from thin-seam oil shale deposits. The initial experiments are to be conducted in the 30- to 40-foot-thick shale strata of either the Laney or Tipton members of the Green River Formation on White Mountain, 5 miles northwest of Rock Springs, Wyoming.

The principal objectives of the proposed project are as follows:

1. Develop modified in situ recovery engineering expertise on lean, thin-seam oil shale deposits.
2. Determine optimum underground support design to minimize surface subsidence.
3. Develop mining and explosive blasting techniques to ensure desired void volume and to maximize resource utilization.
4. Design retort configurations to maximize resource recovery with minimum environmental impact.
5. Investigate heat effects during retorting, including temperature gradients of walls and surroundings.
6. Establish the effect of vertical versus horizontal sweep of the oxidizing or hot retorting gases.
7. Examine the effects of retorting variables (e.g. shale grade, porosity, gas composition) on shale oil yields and shale oil quality.
8. If possible, develop technology for sensible heat and additional hydrocarbon recovery from previously retorted shales.
9. Determine the economic feasibility of modified in situ horizontal retorting technology in thin-seam oil shale strata.

BACKGROUND

The Laramie Energy Research Center is a part of the nationwide facilities of the Energy Research and Development Administration. LERC was opened in July 1924, through a cooperative agreement with the Bureau of Mines and the University of Wyoming. Initial work was directed at developing petroleum resources in the Rocky Mountain region, and research was focused on improving methods of refining high-sulfur, asphalt-bearing crude oils of Wyoming.

A shift of emphasis at LERC to oil shale occurred as a result of the Synthetic Liquid Fuels Act enacted in 1944, and since that time an increasing fraction of the LERC research and development effort has been devoted to oil shale. Since the early 1960's, LERC oil shale work has been primarily concerned with in situ retorting techniques. LERC currently employs over 245 engineers, scientists, and supporting staff, and is responsible for directing several field programs.

Since the early 1960's, work on oil shale at the Laramie Energy Research Center has been concentrated on development of in situ retorting methods. The major effort directed at vertical retorting has been carried out in a 10-ton pilot-scale batch retort and a 150-ton semiworks batch retort. The overall objective of this experimental program has been to demonstrate the feasibility of forward combustion retorting of randomly sized, mine-run shale, i.e. the type of retorting that would most likely be employed in a vertical, in situ chimney retort.

In the Occidental modified in situ vertical process approximately 15 percent of the shale is mined away and blasting expands the remaining shale to create a chimney, called the retort. The expanded, or rubblized, shale is then ignited at the top and vertical retorting is employed for oil production. Air is carefully diluted with recycle gas to give the desired oxygen concentration. To date three chimnies (each with approximate dimensions of 30 feet x 30 feet x 70 feet) have been retorted; a substantially larger fourth chimney (120 feet x 120 feet x 270 feet) is currently being retorted.

Total investment by Occidental was expected to reach approximately $38 MM by year end 1975.

While operating details of the Occidental process are proprietary, Occidental has acknowledged the importance of experience gained by LERC in guiding their development work. Initial experiments by Occidental were based primarily on results obtained in the 150-ton retort.

Occidental has reported (2) approximately 70 percent recovery of oil based on Fischer assay, while the net energy efficiency of this process varies from 55 to 80 percent for oil shale of from 10 to 40 gallons per ton assay. The ratio of energy output to energy input is from 10 to 24 for these shales. Occidental has stated that the energy efficiency could be increased by optimizing the process. For example, the energy required for gas compression was more than 50 percent of the total energy input and hence, should be carefully controlled for efficient operation.

In addition to these ongoing studies, numerous other laboratory and field tests have been proposed on variations of the modified in situ vertical retorting process. For example, Lawrence Livermore Laboratory has proposed a modified sublevel-caving mining method prior to in situ retorting, in which it is claimed would, if it were successful, allow $6 to $9 per barrel shale oil (3). Retort sizes of 100 x 100 x 300 feet and 250 x 250 x 1,000 feet have been proposed; smaller retorts of 50 x 50 x 120 feet have been termed "noncommercial retorts."

It should be noted that the proposed RISE program is conceptual only, and no such experiments have been conducted. In addition, the proposed development effort follows very closely the work currently underway by Occidental. Finally, this and other proposed techniques are applicable only to the very thick shale beds of Colorado; the thinner shale beds of Wyoming and Utah are not suitable for large-scale vertical retorting.

During World War II, underground pyrolysis of shale was attempted on a semiworks basis (4). Initial work was through private enterprise, but later efforts were supported by the German Navy. Under wartime pressure, premature operation on a larger scale was attempted. Horizontal chambers, 197 feet long, of rubblized shale produced by blasting were ignited at one end and gases exhausted at the other end. First, crosscuts 6.6 feet wide and 7.2 feet high were driven. The sides and roofs were drilled before rubblizing to a depth of 4.9 feet, and one pound of explosive per ton of shale was used. Since 30 to 35 percent of the shale was removed, voids were 30 to 35 percent. The deposits were about 28.2 feet thick, thus retorting the full bed thickness was not achieved due to the mining design. Progress of the combustion front along the top of the rubble was faster than through the bottom. This left unretorted shale at the bottom and resulted in excessive loss of oil by combustion, thus giving a yield of only 30 percent of Fischer assay. Presumably, gas recycle to reduce the oxygen content of the feed gas would have alleviated this, but was not tried. Modified in situ horizontal retorting was thus demonstrated to be feasible, but because of poor mining and retorting procedures resource recovery was poor.

Although not directly associated with modified in situ horizontal retorting, LERC has conducted for several years a field program directed toward development of true in situ horizontal retorting. Research on fracturing oil shale in place by nonnuclear means was initiated in the late 1960's. Three in situ recovery field experiments were designed and conducted by the Bureau of Mines following the fracturing studies. Each of these experiments was based on the concept of igniting the shale in an injection well and forcing hot gases and liquids horizontally through fractures to several recovery wells surrounding the injection well. The hot gases were produced by combustion with compressed air through the injection well.

PROPOSED OVERALL DEVELOPMENT PROGRAM

It is proposed that the overall development program for modified horizontal in situ retorting be divided into five consecutive phases extending over a total of 5 years.

Phase I. Preoperational Studies (approximately 12 months), including analyses of corehole and geologic data and selection of a field site; arrangements for access road rights-of-way; construction and maintenance of access roads; construction of on-site support facilities; arrangement for power, water, and other utilities; selection of subcontractors and consultants, and conduct environmental baseline studies.

Phase II. Preparation of Definitive Experimental Program (approximately 9 months), including development of final mining plan; selection of final retort configuration(s); overall design of experimental rubblizing and retorting program, and associated operation and measurement techniques; preparation of mathematical models of retorting methods; construction of special laboratory support facilities; selection of associated environmental studies.

Phase III. Initial Field Program (approximately 21 months), including development of horizontal mine and initial experimental retorts; conduct of first generation rubblizing and retorting experiments, using direct combustion and also hot gas injection; evaluation of data to identify critical parameters; performance of environmental research studies to quantify accompanying land, water, and air impacts; completion of associated laboratory analyses.

Phase IV. Expanded Field Program and Supporting Studies (approximately 18 months), including modification of initial retort designs; detailed evaluation of retorting parameters; determination of definitive heat and material balances and yields; characterization of product oils, gases, and spent shales; identification and measurement of air emissions, aqueous effluents, leachates, and solid wastes; assessment of environmental impacts on air, water, and land; design of suitable pollution control methods for future in situ field programs.

Phase V. Technical, Environmental, and Economic Evaluation of Commercial Operations (approximately 12 months), including establishment of design parameters for commercial-scale modified in situ retorting; assessment of technical feasibility of commercial-scale in situ plant; analysis of economics of full-scale in situ shale oil production; evaluation of environmental impacts of commercial-scale operations, and control methods required; recommendations regarding industrial in situ shale oil production from thin oil shale strata.

SITE LOCATION STUDIES

LERC has already conducted preliminary studies to identify potential field sites for the proposed research program. Three primary criteria were used to evaluate such sites. First, the shale deposit should be representative of the resource base which will be ultimately available for commercial development by a combined horizontal mining and retorting process. Based on this requirement, only shale deposits of 15 to 25 gpt average richness, with a thickness of approximately 50 feet were considered. Second, the shale deposit should outcrop in order to avoid expensive initial underground mining and site development. Third, location of the deposit should be accessible and in reasonable proximity to a population center, again to minimize field development costs and hardship to field workers.

It should be emphasized that these criteria were specifically employed in evaluation of potential sites for this program's initial field development work. However, results from the R & D program will be applicable to a wide range of thin-bed shales located over a wide geographical area. Other factors, of secondary importance, were also considered and are discussed below. A number of possible sites were investigated in Colorado, Utah, and Wyoming. Based on the foregoing three criteria, however, the most favorable potential locations were determined to be in the White Mountain region of western Wyoming where two sites have been nominated.

White Mountain is an uplift in which weathering has exposed two members of the Green River oil shale Formation, viz, the Laney and the Tipton (in descending order). The geology and geochemistry of oil shale formation for this region have been described elsewhere (5). The crest of White Mountain runs in a northeasterly direction, and at its nearest point is within approximately 4 miles of Rock Springs, Wyoming. Both the Laney and the Tipton members outcrop in this region, and shales of suitable richness and thickness occur in these members. Thus, all primary criteria are met by this region. In addition, this region is only a few miles from LERC true in situ field test sites, and therefore offers a favorable strategic location for future project management.

In order to pinpoint specific sites suitable for the field studies, LERC initiated in 1974 a corehole program to accumulate data on both the Laney and Tipton members of the Green River oil shale Formation. Extensive corehole data has been obtained at two separate sites. To date six coreholes have been drilled and assayed at a total cost of approximately $62,000, and further work is planned. Detailed information on the White Mountain corehole program is contained in LERC core analysis files (6). Location of the two sites is given in figure 1. Although both of the sites are considered suitable, site 1 in the Laney member is somewhat favored and has been used in preliminary planning and cost estimating. Final site selection will be based on preparation of the definitive experimental program.

In addition to the corehole program, environmental studies have been initiated in the White Mountain region and a report titled "An Environmental Reconnaissance Study for Sweetwater County In Situ Oil Shale Research" has been completed (7). The purpose of the report is to identify the regulatory requirements, agencies, and environmental components of concern in the research area. These data will be used in preparing the Environmental Assessment Report (EAR) for this project. To date approximately $35,000 has been invested in the environmental studies. These preliminary studies represent a substantial effort in better defining the modified in situ horizontal retorting program.

MINING PROGRAM

Objectives

The mining related objectives of the program are as follows:

(a) Develop blasting techniques to optimize oil yield by obtaining a uniform fragmentation and void distribution with the retort mass using conventional mine blasting agents and equipment.
(b) Confirm theoretical design data relating to heat effects on mine pillars and openings.
(c) Design retort configuration based on data from a and b.
(d) Design general mine plan based on c, with adequate mine structural components to minimize environmental impact.

The first objective of determining the correct blast hole drilling and blasting procedures must be incorporated with retorting technology to complete the unit retort configuration.

In addition, the confirmation of the blasting method will define the void ratio which in turn determines the quantity of mined material to be handled and disposed of on surface.

Other mining costs such as tunnelling, raising, and blast hole drilling can be estimated with reasonable reliability.

The normal swell characteristic or increase in volume between a solid block and its blasted broken volume is 53 percent for most oil shale formations; this results in 35-percent voids. In order to reduce the void ratio below 35 percent, a finer granulometry of the rubble can be obtained by using more explosives, and varying the sequence of the detonation in order to vibrate or consolidate the broken mass to obtain the necessary volume and void ratio. The determination of the percentages of voids can only be ascertained by on-site testing due to the physical variations in all rock formations.

Occidental Oil Shale, Inc., operators of a large in situ demonstration project in Colorado have indicated that successful retorting has been accomplished using a 15-percent void volume while a 10-percent void volume resulted in poor oil recoveries. Therefore, the results of this research must determine the practical limits for the void volume.

Assuming ideal particle size and void distribution, the probably void volume would be 28 to 32 percent. This appears to be reflected by the German experience, as discussed in an earlier section, with regard to explosives consumption of 1 pound per ton of shale, which is double the quantity required for normal efficient blasting operations for room-and-pillar mining of shale. It is assumed the objective of the Germans was to obtain a large percentage of small-size fragments in the total granulometry.

Pilot Mining Plan

The pilot mining plan, as currently envisioned, will be to first drive a double tunnel access into an offset retort mining area. The entry adits or tunnels will be approximately 10 feet high x 12 feet wide and the retort area will be positioned as close as possible to the tunnel portal area, but beyond any effects of surface weathering and jointing. This is assumed to be approximately 400 feet from the portal. A retort access tunnel will then be driven a sufficient distance to initially permit laying out of several test areas. The location and direction of the mine workings will be oriented to work up the dip of the rock formation.

The portal bench will be leveled to provide space for a ventilating fan, administrative and change facilities, material storage and warehousing, and retort support facilities. The location will take into consideration potential flooding, waste rock disposal, accessibility, and the horizon to be mined. The bench size will be approximately 100 feet by 200 feet.

As the retort access drift is started from the adits at the floor level of the retort mine bed, a ramp access to the top level of the bed will be excavated and a top level retort access drift will be driven above the one on the main or floor level.

A width of 35 feet has been assumed as the thickness for the pillar walls. It is further assumed the mining horizon will be 40 feet thick and that the overburden will be approximately 800 feet. The 35-foot-wide pillars will have to be verified, particularly with regard to the effect of retorting temperature. The first experimental area will be set back 70 feet from the axis of the main access adits and 40 feet from the retort access drift.

The first retort stope area is suggested to be 40 feet x 40 feet and opened at the bottom level to begin testing drill hole and blasting methods. The minimum length of blast hole will be 20 feet, from which data can be derived in scaling up to longer and larger blasts. It will be necessary to excavate the rubble from this area to determine granulometry, and to assess the drill pattern efficiency. This mined-out space can then be used for retorting experiments by recharging rubble to obtain results from a known or predetermined base.

The second retort will then be laid out to incorporate the experience of the first. Area will also be allowed to drive a second parallel retort access drift, if required, on both the main and top levels.

The development headings will be ventilated by exhausting through a vent pipe. The fans will be mounted in series as the distance from the portal increases. A raise to the surface will be bored for improved ventilation when the initial system reaches its limits of effectiveness.

The above-described pilot mining plan is presented schematically in figure 2.

Commercial Projection

A preliminary concept has been projected for a commercial, thin-seam, modified in situ oil shale project. Based on available information, it is believed that for a commercial project to be viable, surface retorts would have to be included to supplement in situ retorts. The surface retorts would process that shale which has to be mined to provide the void volume for in situ retorting.

A theoretical mining plan for a commercial in situ project has been developed and is shown schematically in figure 3. The horizontal retort having the dimensions of 40 feet high by 60 feet wide by 500 feet long would be prepared. In a single panel the first step would be to drive an entry 20 feet high by 40 feet wide by 500 feet long to provide a void volume of about 30 percent. A radial jumbo would be used to drill the blast holes. Blasting, or rubblizing, would be accomplished in 20-foot steps, while backing up through the entry. Before blasting each 20-foot section, a trench would be bored in the floor of the entry in which would be placed the combustion airline and a perforated oil drainline. The most economical, simplest system must be used for providing combustion air, oil draining, and flue gas removal.

The basis of the commercial projection is 50,000 bpd total oil production, using the following assumptions:

1. 50,000 tons/day of oil shale will be mined for creating the void volume; this material will be surface retorted.
2. 100,000 tons/day of oil shale will be rubblized for in situ retorting.
3. The shale seam will be 40 feet thick and will contain 20 gpt by Fischer assay.
4. The oil recovery for the surface retort will be 100 percent.
5. The oil recovery for the in situ retort will be 50 percent.
6. The combustion advance rate will be 1 ft/hr, which could be accomplished only by fine rubblizing.

For the commercial operation, 1-2/3 panels of the 40-foot by 60-foot by 500-foot panels would have to be mined and rubblized each day. To produce 25,000 bpd of in situ oil, 33 of the panels would simultaneously be in operation.

To give some concept of the aerial extent of the operation, the advance of the mining operation would be approximately 3 acres per day. The amount of surface area required for a 15-year operation would be around 20,000 acres or 30 square miles.

The purpose of pilot mining as described in the preceding subsection, would be to provide confirming data for the commercial operation.

RETORTING PROGRAM

Retorting Parameters

Modified horizontal retorting refers broadly to techniques for recovery of oil from shale by: (1) Horizontal mining to create the desired void fraction, (2) rubblization through explosive fracturing, and (3) retorting of the horizontal bed by injection of oxygen or hot sweep gases. The actual retorting process may be through horizontal sweep of the oxidizing or hot retorting gas, by vertical sweep of the gases via a gas distribution system, or by a combination of the two. A principal objective of the proposed program is to establish the efficiency of these possible retorting techniques.

It is generally accepted that there are five primary variables which control in situ retorting techniques: (1) Shale richness (gpt), (2) void volume associated with the shale rubble, (3) oxygen content of the retorting gas medium, (4) cross-sectional area of the retort, and (5) height or length of the retort. Secondary variables associated with each of these primary variables include product recovery (gas and oil), superficial gas velocity, swell factor, burn rate, retort life, retort production, and many more.

LERC has conducted tests using 10- and 150-ton aboveground retorts designed to simulate in situ retorting conditions since 1967. A great deal of the information from these retorts has been utilized by Garrett Research, Inc. (now Occidental Oil Shale Corp.) to develop their in situ process currently being tested near DeBeque, Colo. Since very little information is available concerning the Garrett process and its possible application to thin-bed shales, optimum values for the various retorting variables are not yet known. In order to provide this information, and specifically to develop in situ techniques to recovery oil from thin-seamed oil shale deposits, a series of tests have been designed to provide information concerning the retorting variables previously mentioned.

Based on results from the 10- and 150-ton aboveground retorts, oil recovery is a function of the superficial gas velocity and oxygen content of the retorting gas stream. Initial test conditions will be selected to coincide with ranges that have yielded the best results in the 150-ton retort. These conditions would have the following ranges.

Retorting variable	Range
void volume	15 - 40 pct
oxygen content	14 - 18 pct
air ratio	12,000 scf/ton
retorting rate	0.1-2.0 ft/hr
retorting area (width, length)	40 x 40 - 60 x 500 ft
retort height	25-40 ft

Methods of Heating

The major techniques for retorting the rubblized shale produced in the modified horizontal in situ program include (1) direct combustion of the carbonaceous residue on the spent shale, and (2) injection of hot gases (e.g., hot recycle gases) into the rubble bed. It is also possible to use hot fluids injection (e.g., superheated steam), but this is not initially contemplated for the White Mountain sites. Flexibility of experimental design will allow application of appropriate techniques at selected decision points.

Direct Combustion. This is the conventional method of in situ retorting, which is essentially an underground adaptation of surface gas combustion retorting. The bed of rubblized shale is ignited at the top with a mixture of air and gaseous fuel. As combustion proceeds, a downward-moving heat front retorts the shale beneath it. The shale oil vapors condense on the cold shale below. The resulting shale oil drains to the bottom and is pumped to the surface from collecting trenches on the floor of the chimney. Approximately 45 percent of the retort gases produced are recycled to the rubble bed and burned for additional heat. The remaining gas is withdrawn. Net recovery of oil is expected to be approximately 50 percent of Fischer assay.

The major disadvantage of the process is the production of large quantities of low Btu gas (50 to 150 Btu/cu ft) at about 3 psig pressure. This gas cannot be vented directly to the atmosphere. In addition, if it is less than 100 Btu/cu ft heating value it will require either catalytic furnaces or supplemental fuel for disposal by burning. It might conceivably be used for power generation in specially designed turbines used on site, but this may not be economical.

Injection of Hot Gases. If hot gases are used for heating instead of in situ combustion with air, a retort offgas of 500 to 800 Btu/cu ft is obtained. One method of producing these hot gases is to heat recycle retort gases to around 1200° F in an external furnace, using approximately 5 percent of the recycle gas itself as a fuel in the furnace. The fuel gas portion of the recycle gas, of course, would require amine treatment for H_2S removal prior to use as external furnace fuel. Hydrogen sulfide removal would also be required for the 500 to 800 Btu/cu ft gas removed from the system for use in power generation, etc.

One alternative to the above method would be to utilize a heated gas other than retort recycle gases as a heating medium. Hot methane (hot natural gas) has been employed in the past for this purpose.

In order to recover the heat from the final bottom one-third of the rubble bed it has been suggested that, when exit gas temperatures from the bed reach approximately 200° F, the residual lower hot zone be advanced by recycling cooled product gases from an adjoining vertical retort.

Evaluation of Retorting Methods

General. The retorting methods selected from those described above will be evaluated on the basis of oil yield, oil quality, gas yield, gas quality, surface subsidence, thermal pollution, air pollution, subsurface pollution, and on-stream efficiency.

ENVIRONMENTAL RESEARCH PROGRAM

The environmental disturbances generated by the mining and in situ retorting covered in this proposal will be addressed by a concurrent research program designed to generate data on these concerns. The areas of research will involve impacts to land, water, and air resources. The overall environmental research program will be designed to accomplish the following: (1) To characterize the existing environment before research commences in the field, (2) to monitor, sample, and completely analyze the effluents from the various process steps, and (3) to continue residue studies and reconstitute the area after research work has progressed beyond the operational phase. A phasing diagram showing scheduling of necessary environmental work is shown in figure 4.

Close coordination of the research will be maintained with appropriate State of Wyoming departments and agencies. In addition, assistance of the University of Wyoming will be integrated into the program. Also, close on-site supervision of the environmental aspects of the experiment will be monitored by the office of the Environmental and Conservation coordinator of LERC for the Assistant Administrator of Fossil Energy.

Program Costs

A preliminary cost estimate for the total 5 year program was $30,400,000. This includes $1,700,000 total initial mining capital cost and $2,900,000 processing and instrumentation capital cost.

The total project capital, operating, labor, and material costs for the 5-year program are as follows:

	Fiscal Year				
	1977	1978	1979	1980	1981
Capital	120	5,000	9,000	5,000	2,000
Subcontracts	210	1,890	2,760	1,500	720
Materials and Supplies	300	500	700	500	200
Total cost $,000	630	7,390	12,460	7,000	2,920

Total, 5-year program $30,400,000

CONCLUSIONS

1. Approximately one-third of known resources of oil shale occur in deposits that range from 15 to 25 gallons/ton in a seam thickness up to 50 feet at variable depths (100 to over 2,000 feet).
2. Much of the lean, thin-seam oil shale deposits occur on federal land, primarily in Utah and Wyoming, thus the U.S. Government has a very substantial investment in this area.
3. Economic recovery of this resource, using technology currently under development, is problematical. This fact was exemplified by industry when no bids were received on the Wyoming tracts.
4. Development of true in situ horizontal techniques to the point of commercialization requires a technological breakthrough. One promising alternative for development of thin-seam oil shale deposits is through modified horizontal retorting.
5. A modified horizontal experiment has been developed by the LERC engineering staff which includes two prospective sites with core analysis nearly complete, initial baseline environmental studies underway, a mining and retorting plan that indicate commercialization possibilities both from an economic and environmental standpoint, as well as an extensive environmental monitoring program.
6. LERC has a broad background and experience in collection of data and direction of field programs involving in situ oil shale development. This background should prove invaluable to ERDA in application to future in situ work.

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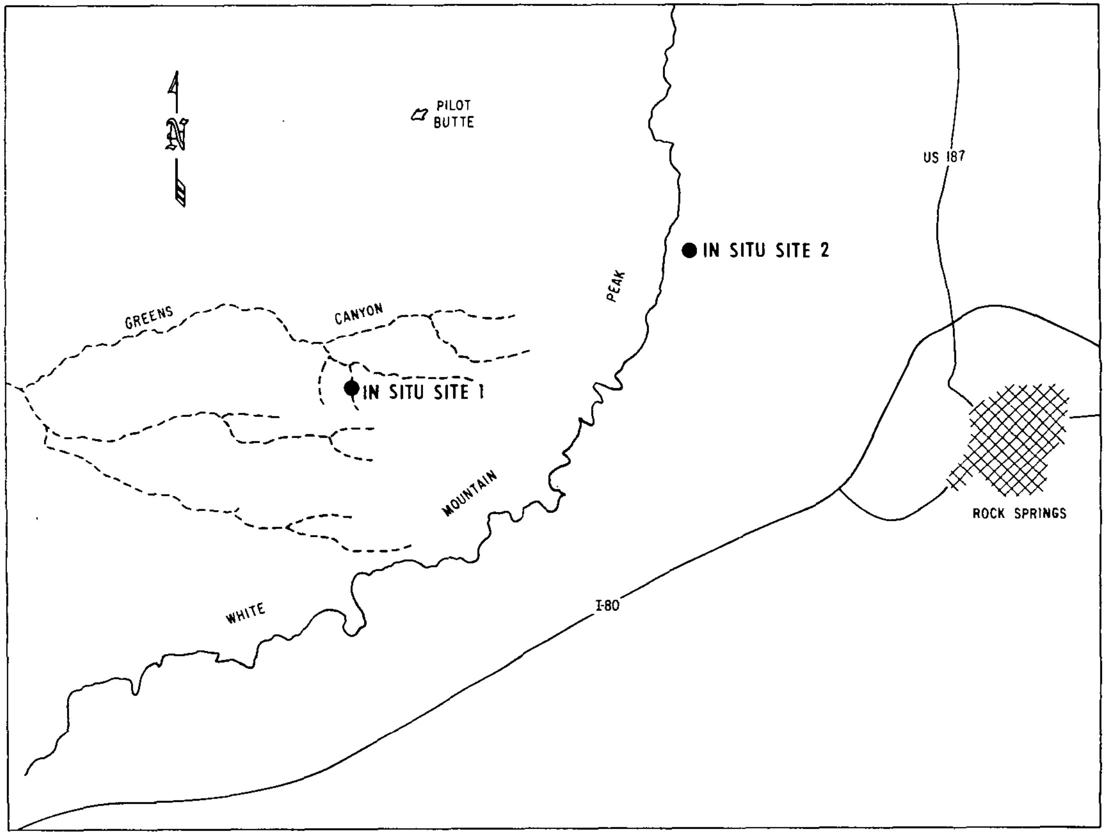

FIGURE 1. - AREA MAP FOR MODIFIED HORIZONTAL IN SITU EXPERIMENT

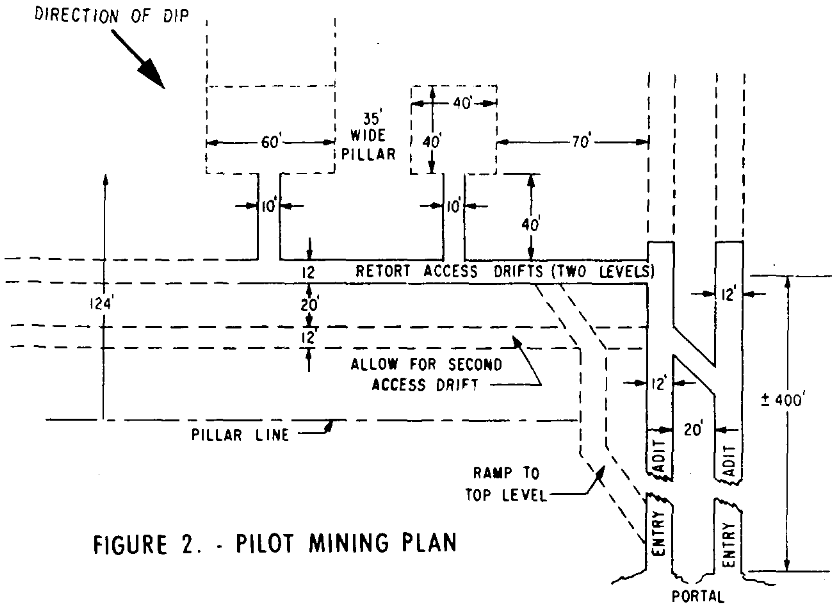

FIGURE 2. - PILOT MINING PLAN

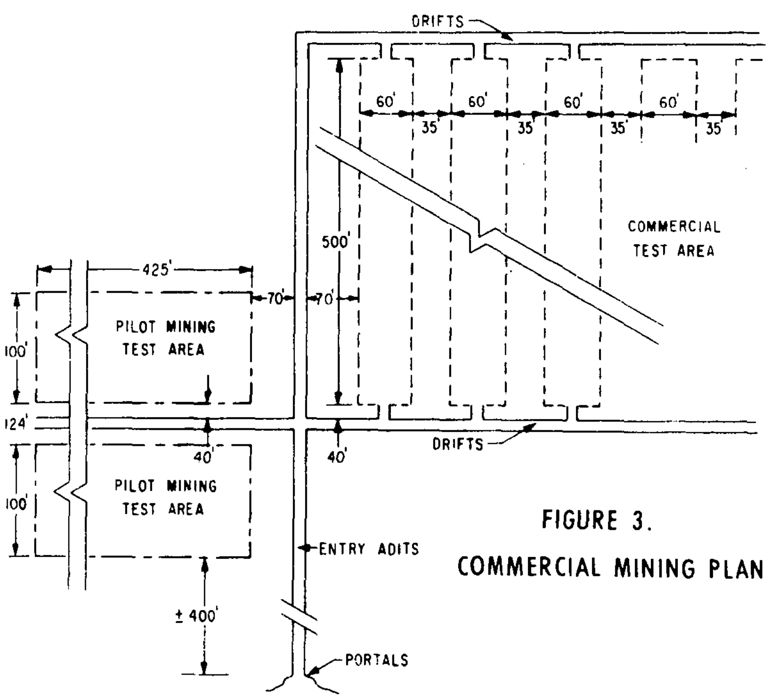

FIGURE 3.
COMMERCIAL MINING PLAN

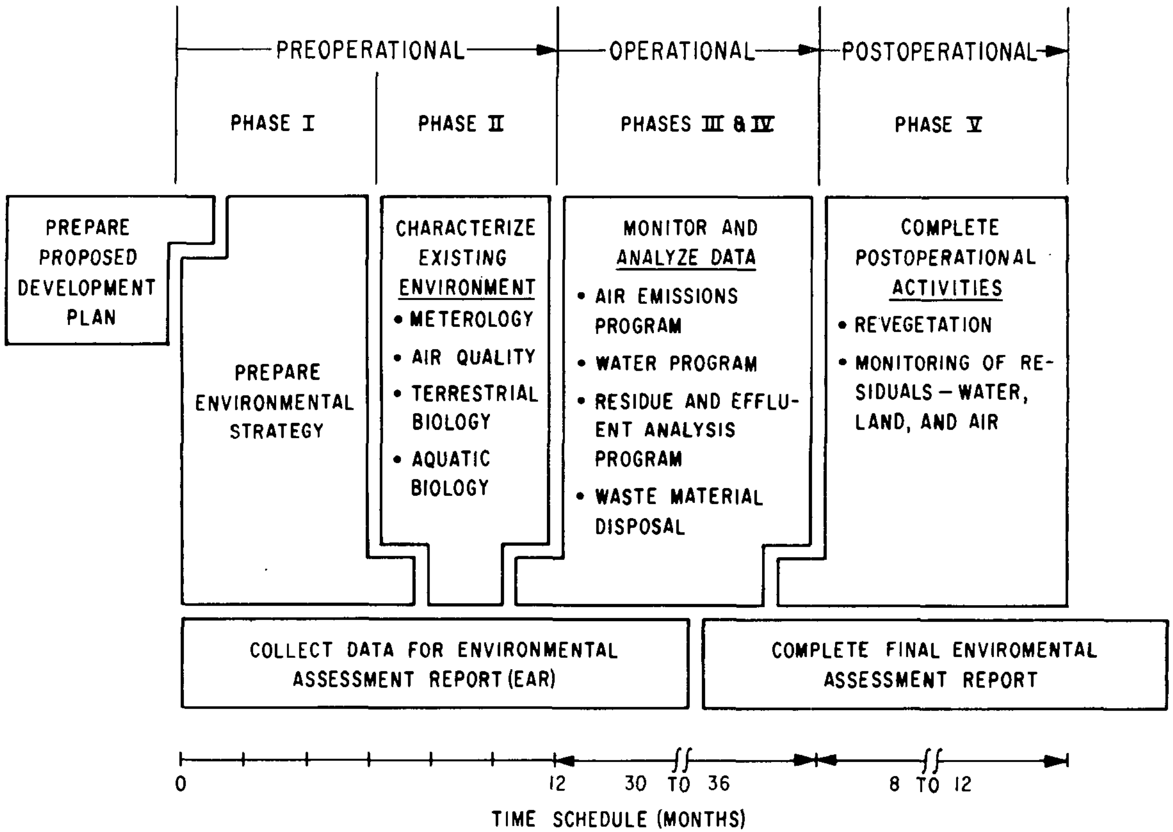

FIGURE 4. - PHASING DIAGRAM—ENVIRONMENTAL RESEARCH