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REPUBLIC GEOTHERMAL INC

REPUBLIC GEOTHERMAL, INC.

EAST MESA GEOTHERMAL PROJECT
PLANS OF OPERATION
48 MW (NET) POWER PLANT

FEDERAL GEOTHERMAL LEASES
CA 966 AND CA 1903
IMPERIAL COUNTY, CALIFORNIA

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PLAN OF OPERATION, DEVELOPMENT

Proposal to commence operations for development of the geothermal resource, including twelve additional production wells and six additional injection wells, related pipelines, access roads, testing and other surface facilities necessary to initiate production of electricity at a 48 Mw (net) power plant.

PLAN OF OPERATION, INJECTION

Proposal to commence injection operations at Well Nos. 16-19, 54-19, 16-20, 58-24, 54-25 and 58-25 to dispose of geothermal liquids produced during well testing and production activities for a 48 Mw (net) power plant.

PLAN OF UTILIZATION

Proposal to construct and operate a 48 Mw (net) dual-admission steam turbine-generator utilizing steam separated from geothermal fluid to produce electricity and to construct an access road and electric transmission line to the power plant site.

PLAN OF OPERATION,

DEVELOPMENT

Lease Nos. CA 966 and CA 1903
Sec. 25, T15S, R16E; Secs. 19,20,28,29 and 30
T15S, R17E, SB B&M

Republic Geothermal, Inc.
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Santa Fe Springs, California 90670
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Proposal to commence operations for development of the geothermal resource, including twelve additional production wells and six additional injection wells, related pipelines, access roads, testing and other surface facilities necessary to initiate production of electricity at a 48 Mw (net) power plant.

Estimated Starting Date: One week from date of approval

Estimated Completion Date: Indefinite

REPUBLIC GEOTHERMAL, INC.

PLAN OF OPERATION, DEVELOPMENT
48 Mw POWER PLANT

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REPUBLIC GEOTHERMAL, INC.

PLAN OF OPERATION, DEVELOPMENT
UNITED STATES GEOTHERMAL LEASE NOS. CA 966 AND CA 1903
EAST MESA, IMPERIAL COUNTY, CALIFORNIA

A. PROPOSED PLAN OF OPERATION

Republic Geothermal, Inc. proposes herein to commence geothermal development operations on Lease Nos. CA 966 and CA 1903. This Plan of Operation, Development is submitted in accordance with Draft GRO Order No. 5, and covers phases of additional geothermal well drilling and facility construction necessary to initiate production of electricity at a 48 Mw (net) power plant.

A total of nineteen production wells and nine injection wells are proposed to be dedicated to the power plant, as well as related pipelines, access roads, and well testing and production facilities. The power plant site and access road to the plant location are included in this Plan of Operation to provide a perspective of overall development. The details of the site selection and plant operation are contained in Republic's Plan of Utilization, submitted simultaneously with this Plan, in accordance with proposed amendments to 30 CFR, Section 270 and 43 CFR, Part 3208.

Republic has previously submitted Plans of Operation, Development, Injection and Utilization for a 10 Mw (gross) power plant at East Mesa. Five of the nineteen wells proposed here for use as production wells and three of the nine wells proposed here for use as injection wells are covered in the previous Plans. They are included in this Plan since the 54 Mw (gross) turbine-generator system will be installed on the site of the first 10 Mw (gross) plant, and the integration of these two plants will result in the 48 Mw (net) electrical generating facility.

Seven wells proposed here for the 48 Mw project are already existent. In addition to the existing wells and access roads, eleven of the proposed well sites and three and one-quarter miles of the proposed road system have been previously evaluated and approved in Republic's

Plans of Operation, Exploration (USGS-AGS Environmental Analyses Nos. 12, 29 and 86). Pipelines from production wells to the power plant site and from the power plant site to the injection wells will be constructed along access roads with horizontal expansion loops. Additional wells, if required during the operational life of the power plant, will be covered in a subsequent Plan of Operation, Development.

Consistent with draft GRO Order No. 5, the purpose of this Plan and the intent of Republic Geothermal, Inc. is to assure orderly and timely development of the resource, to maximize the productivity of the resource and to minimize adverse environmental impacts. Also consistent with draft GRO Order No. 5 and proposed amendments to 30 CFR 270 and 43 CFR 3208, Republic is submitting the following: 1) this Plan of Operation, Development for evaluation of proposed development necessary to allow initiation of commercial production; 2) a Plan of Operation, Injection for evaluation of proposed subsurface injection; and 3) a Plan of Utilization for evaluation of the alternative power plant sites, electric transmission lines, and proposed method of utilizing the resource.

B. DETAILS OF PROPOSED PLAN

1. Location and Placement of Proposed Operations

a. Maps

Attached is our Drawing No. 199-10, East Mesa Geothermal Project Vicinity Map, which shows the topography, drainage patterns, cultural features and existing roads and wells. The Vicinity Map also shows existing and proposed transmission lines for informational purposes.

Attached is our Drawing No. 199-12, East Mesa Structure Contour Maps and Structural Cross Section, which displays a sequence of three subsurface structure contour maps and a structural cross section through a part of the East Mesa field.

Attached is our Drawing No. 199-14, East Mesa Geothermal Project, Development and Utilization Plan-48 Mw Power Plant, which shows the proposed location and spacing of wells, existing and proposed access roads, proposed pipelines and electrical transmission line routes and alternative power plant sites.

Attached is our Drawing No. 199-15, East Mesa Geothermal Project, Engineering Details, which shows a typical road cross section, typical pipeline supports, typical pipeline insulation and a typical road crossing.

b. Justification for Proposed Location and Spacing of Wells

The location of the 48 Mw power plant and associated wells must be viewed in relation to the overall resource development plan for justification. Figure 1 shows conceptual well locations for the 48 Mw (net) project having 19 interior producers and 9 peripheral injectors. Sufficient well control and geophysical evidence exists to indicate this is a reasonable minimum interpretation of the project scope.

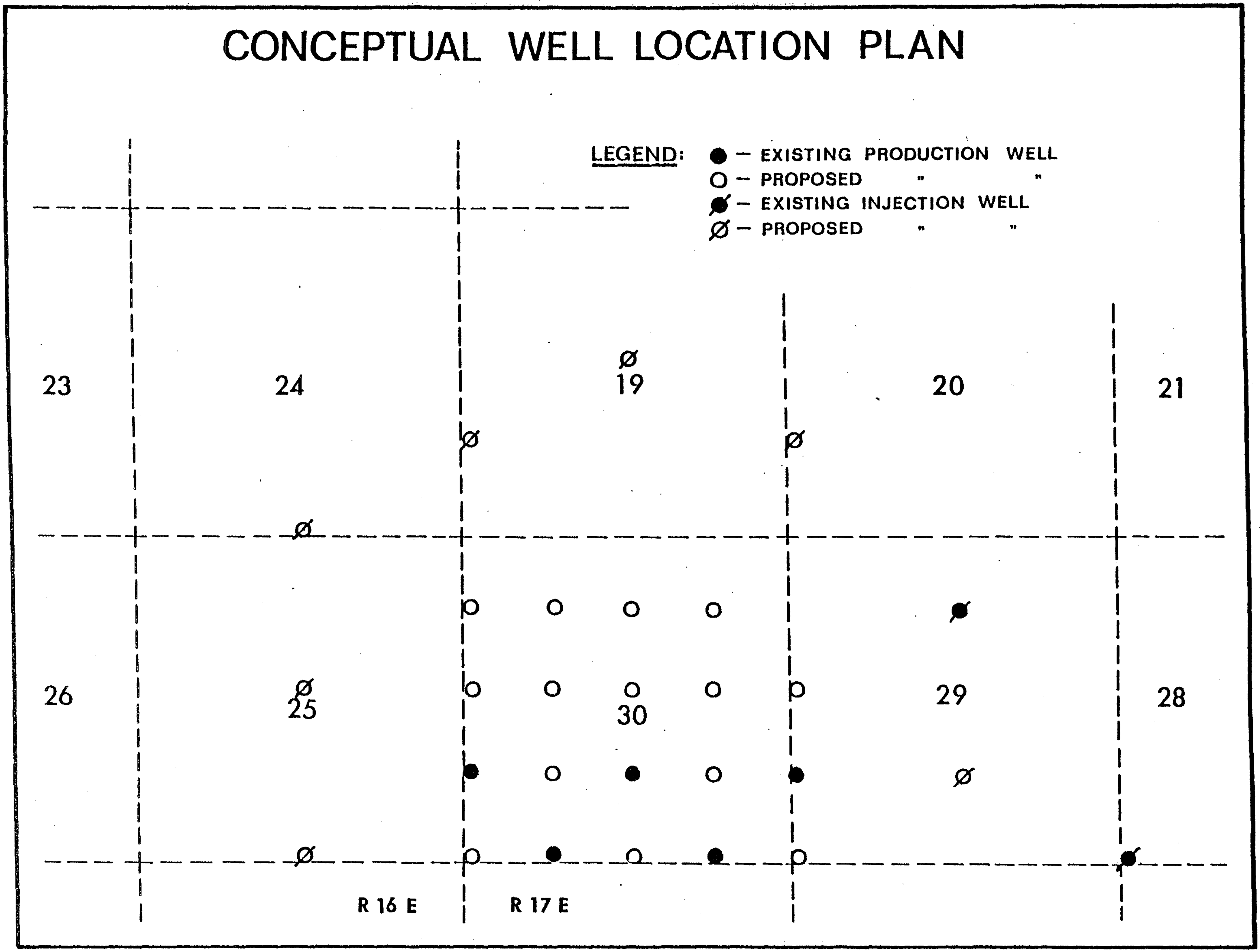
CONCEPTUAL WELL LOCATION PLAN
LEGEND:
– EXISTING PRODUCTION WELL
– PROPOSED " "
– EXISTING INJECTION WELL
– PROPOSED " "
23
24
19
20
21
26
25
30
29
28
R 16 E
R 17 E

Figure 1

Peripheral injection (Figure 1) into the interval 2,000± to 5,000± feet and production from a central group of producers completed in the interval 5,500± to 7,500± feet is currently considered to be the most advantageous manner in which to develop the East Mesa reservoir. Such a pattern maximizes the time and path of travel of the cooler injected waters between the injectors and producers. The longer the injected water is in contact with the hot reservoir rock, the hotter it will be when it arrives back at the producers. Thus, the life of the resource will be much greater with such a pattern relative to that which would be expected with any interior injection pattern alternative.

Injection into the shallower sands rather than directly into the productive reservoir is also advantageous economically and environmentally. Because the shallower sands have a much higher permeability than those of the reservoir, it should be possible to inject the water from two producers into a single injector using a low surface pressure. Thus, well costs, energy costs (pump power), and surface usage will be minimized relative to a deep interior injection pattern.

Good vertical communication below 2,000± feet is the key to the success of such a shallow peripheral injection plan. Preliminary reservoir simulation work shows that with vertical communication, pressure can be maintained in the interior producing area when aided by a minor amount of aquifer influx. Whether or not the natural influx will ultimately have to be supplemented cannot be determined at this time. Such a determination will require several years of full-scale production experience.

Substantial evidence exists that good vertical communication and hot water influx from depth are present at East Mesa. The convective nature of the temperature profiles below

2,000± feet indicates both vertical communication and water influx. Hot water influx from below the producing interval is also indicated by the silica and alkali chemical equilibrium temperatures of the produced fluids. Well logs and geologic correlations show essentially sand-on-sand contacts throughout the vertical sequence below 2,000± feet. Finally, pressure interference testing by Lawrence Berkeley Laboratories shows that USBR Well Nos. 6-1 and 6-2, and USBR Well No. 31-1 and Republic Well No. 38-30 communicate, even though the completion intervals of each well pair do not overlap vertically.

The foregoing evidences of vertical communication are discussed in more detail in later sections. Additional testing is planned to define and demonstrate further the degree of this communication. The long-term consequences of less than 100 percent replacement of produced fluids, by either injection or natural influx, would be premature decline in reservoir pressure and associated well productivity. Most likely this would be prevented by supplementing the injection from ground water, irrigation water and/or leach canal water sources. Another alternative would be the drilling of supplemental wells, of course. As previously noted, however, such a need is not anticipated at this time and would only become apparent after several years of full-scale operation.

The above discussion is intended to justify the well and plant location concept for overall development. Similarly, well spacing must also be viewed in the context of an overall plan. An acceptable spacing of 40 acres per well as shown on Figure 1 was established with a reservoir simulation study (discussed in more detail in a later section). For this study, the most conservative conditions of "no influx" and "no vertical communication" were assumed. Under these conditions,

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Results of the 40 acre spacing five-spot simulations show that pressure can easily be maintained, but that some produced fluid temperature decline will be experienced after 12+ years. This is illustrated in Figure 2. While this amount of temperature decline is tolerable and easily compensated for by a few make-up wells, closer spacings which were investigated (i.e., 20 acres and 10 acres per well), resulted in earlier breakthroughs and more precipitous temperature declines. Such closer spacing would require a substantially greater number of make-up wells to sustain a 25 to 30 year plant life. Thus, 40 acres per well spacing has been established as an acceptable spacing in the event that an interior five-spot reinjection pattern must be resorted to in order to maintain pressure.

It should be emphasized that five-spot injection is not the expected mode of operation. Evidence thus far available indicates that the peripheral injection scheme discussed above will be successful, and that production well spacing will be of little importance to efficient development of the resource.

In addition, topographic features, drainage patterns and current land uses were considered in well spacing. The topography at East Mesa is essentially level. Surface water is limited to one short section of the East Highline Canal, and the leases are devoid of obvious stream channels. Land in the area of the proposed development is open space desert. The dominant plant species is that of the creosote bush (Larrea divaricata). Immediately southwest of the southwestern corner of the leasehold is an orange orchard which occupies less than one section of land, in excess of one-half mile from the plant site.

None of the above factors presents an environmental concern which would determine or

EAST MESA FIELD
PREDICTED WELL PERFORMANCE

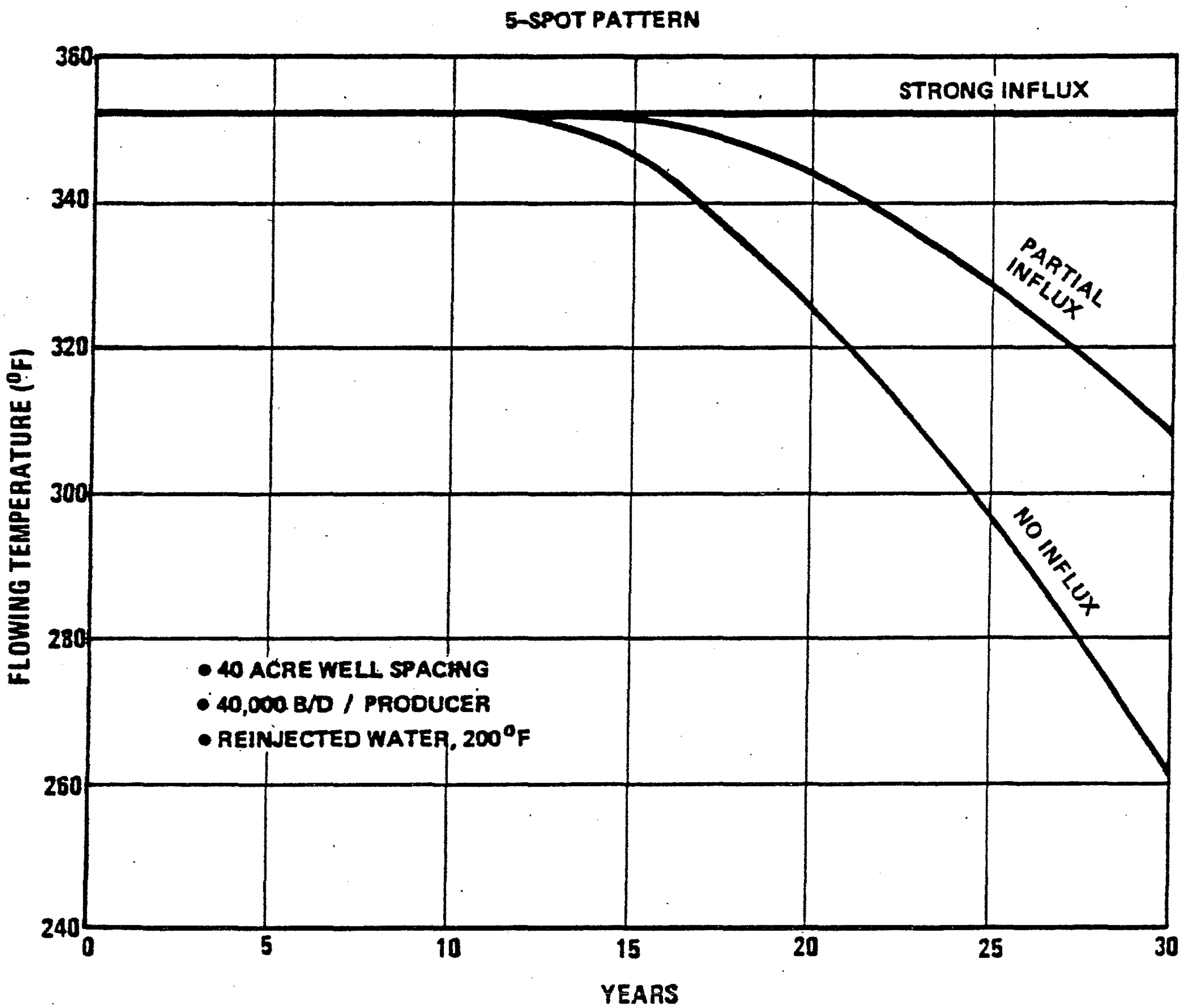

Figure 2

limit the location of wells or roads within the boundaries of the leases. Thus the wells are spaced at 40 acre intervals for maximum efficiency and utilization of the resource based on the data briefly discussed earlier and described in more detail in a later section.

2. Discussion of Proposed Operations

a. Well numbers, locations and elevations of the wells to be dedicated to the 48 Mw power plant, including those for the 10 Mw plant which will later be integrated into the 48 Mw plant are as follows:

PRODUCTION WELLS

Existing Wells:

Well No.	Location	Ground Elevation
16-29*	T15S R17E 100'E & 1495'N from SW cor., Sec. 29	53.96'
16-30*	T15S R17E 100'E & 1495'N from SW cor., Sec. 30	36.96'
56-30*	T15S R17E 2740'E & 1495'N from SW cor., Sec. 30	38.25'
38-30	T15S R17E 1420'E & 100'N from SW cor., Sec. 30	36.56'
78-30	T15S R17E 4060'E & 175'N from SW cor., Sec. 30	47.80'

Proposed Wells:

36-30*	T15S R17E 1420'E & 1495'N from SW cor., Sec. 30	37'±
76-30*	T15S R17E 4060'E & 1495'N from SW cor., Sec. 30	46'±
12-30	T15S R17E 100'E & 4135'N from SW cor., Sec. 30	40'±

14-30	T15S R17E 100'E & 2815'N from SW cor., Sec. 30	37'±
18-30	T15S R17E 100'E & 175'N from SW cor., Sec. 30	36'±
32-30	T15S R17E 1420'E & 4135'N from SW cor., Sec. 30	41'±
34-30	T15S R17E 1420'E & 2815'N from SW cor., Sec. 30	38'±
52-30	T15S R17E 2740'E & 4135'N from SW cor., Sec. 30	42'±
54-30	T15S R17E 2740'E & 2815'N from SW cor., Sec. 30	40'±
58-30	T15S R17E 2740'E & 175'N from SW cor., Sec. 30	45'±
72-30	T15S R17E 4060'E & 4135'N from SW cor., Sec. 30	48'±
74-30	T15S R17E 4060'E & 2815'N from SW cor., Sec. 30	52'±
14-29	T15S R17E 100'E & 2815'N from SW cor., Sec. 29	45'±
18-29	T15S R17E 100'E & 175'N from SW cor., Sec. 29	50'±

INJECTION WELLS

Existing Wells:

Well No.	Location	Ground Elevation
18-28*	T15S R17E 100'E & 175'N from SW cor., Sec. 28	74.11'
52-29*	T15S R17E 2790'E & 4135'N from SW cor., Sec. 29	62'±

Proposed Wells:

56-29*	T15S R17E 2790'E & 1495'N from SW cor., Sec. 29	65'±
16-20	T15S R17E 100'E & 1495'N from SW cor., Sec. 20	51'±
16-19	T15S R17E 100'E & 1495'N from SW cor., Sec. 19	40'±
54-19	T15S R17E 2740'E & 2465'N from SW cor., Sec. 19	58'±
58-24	T15S R16E 2740'E & 175'N from SW cor., Sec. 24	40'±
54-25	T15S R16E 2740'E & 2815'N from SW cor., Sec. 25	43'±
58-25	T15S R16E 2740'E & 175'N from SW cor., Sec. 25	46'±

* Wells which will be initially dedicated to the 10 Mw power plant and later integrated into the 48 Mw project.

b. Continuation of previously approved testing of existing exploratory and production wells involving data analysis, sustained production testing and workovers as necessary.

c. Continuation of previously approved testing of existing exploratory and injection wells involving data analysis, sustained injection testing and workovers as necessary.

d. Construction of eighteen additional drill location sites. All well locations except Well Nos. 14-30, 32-30, 54-30, 72-30, 16-20, 16-19, 54-19, 58-24, 54-25 and 58-25 have been previously evaluated under Republic's Plans of Operation, Exploration, approved as effective September 12, 1975 (USGS-AGS Environmental Analysis #12), December 15, 1975 (USGS-AGS Environmental Analysis #29) and January 17, 1978 (USGS-AGS Environmental

Analysis #86). The site of Well No. 56-29 is currently being evaluated under Republic's previously submitted Plan of Operation, Development, 10 Mw Power Plant (USGS-AGS Environmental Analysis No. 99).

e. Drilling and completion of Well Nos. 12-30, 14-30, 18-30, 32-30, 34-30, 52-30, 54-30, 58-30, 72-30, 74-30, 14-29 and 18-29 as potential production wells; and Well Nos. 54-25, 58-25, 58-24, 16-19, 54-19 and 16-20 as potential injection wells, including clean-out flows and initial testing to the storage basin.

f. After analyzation of the log and test data, conduct workovers of these additional wells if required.

g. Continuation of initial testing of the additional wells, data analysis and workovers until wells demonstrate satisfactory commercial production or injection potential.

h. Construction of production test facilities for the additional wells drilled as potential producers, including a waste fluid disposal pipeline to an approved temporary waste disposal or injection well.

i. Placement of these additional wells on sustained production testing.

j. If any well drilled as a production well does not demonstrate satisfactory commercial potential, conduct workovers of well and possibly convert to temporary waste disposal or injection well.

k. Construction of injection test facilities for those additional wells drilled as injectors or any approved converted well, including the connection of a waste disposal pipeline from any of the other wells.

l. Placement of injection wells on sustained injection testing and utilization of converted wells for either temporary waste disposal or injection, as approved.

m. If any well drilled as an injection well indicates commercial potential, conduct workovers and possibly convert to a production well, or drill a new well on the same location pad. Construct production test facilities, including pipeline, and place on sustained production testing.

n. If, after adequate investigation and analysis, any well does not indicate satisfactory production or injection potential, possibly plug and abandon well.

Republic recognizes that prior to commencing any of the operations mentioned above, specific details must be submitted to the Area Geothermal Supervisor and explicit approval obtained. Republic also recognizes that prior to commencing injection at any of the proposed wells other than temporary waste disposal or injection testing, a Plan of Operation, Injection must be approved. Proposed injection well locations, production and injection pipelines and surface production and injection facilities are discussed herein as required by GRO Order No. 5, Draft Outline, Section 1.E.

3. <u>Resource Data</u>

a. Lithology

Geophysical logs from 16 wells drilled to depths of 4,500-10,000 feet provide a means to understand the subsurface lithology at East Mesa. Optical and X-ray diffraction techniques have been used to examine the available cores and cuttings from these wells.

The stratigraphy at East Mesa is a sedimentary section composed of a lacustrine and deltaic sequence of alternating sandstones, siltstones, and mudstones of Plio-Pleistocene age, covered by a 100-150 foot surficial layer of dune sand deposits. Immediately below these dune sands and above the deltaic sediments is a 1,700-1,900 foot thick lacustrine interval which contains a significant to dominant percentage of clay-rich mudstones, particularly between the depths of 600 feet and 2,000 feet.

These mudstones effectively separate the overlying fresh water sands from the more saline waters in the predominantly sandstone-siltstone sediments of the Colorado River delta sequence.

The proposed injection zone is below 2,000 feet, within the deltaic sandstones. Lithologically these sandstones are medium to fine-grained, moderately to moderately-well sorted, and quartz-rich. Detrital clasts include lithic fragments, feldspars, chert, and the usual accessories. Authigenic carbonate and quartz can occur as partial porefilling, replacement and vein materials, particularly at depths below 4,000 feet. Interbedded with the sandstones are more thinly developed siltstone-mudstone lithologies. These finer-grained units progressively change in color and clay mineral content with increasing depth, starting as tan, montmorillonite- and kaolinite-rich units at shallower depths, and becoming gray, illite- and chlorite-rich units at greater depths.

A detailed overall examination of the deltaic sequence as specifically displayed in the relatively closely-spaced Republic wells at East Mesa indicates that singular lithologic units are typically 10 to 60 feet in thickness, that sandstone units are predominant, and that individual units maintain a moderate degree of lateral sedimentologic continuity.

b. Subsurface Maps and Cross Section

The geophysical well logs from six Republic wells and USBR Well No. 31-1 have been examined in detail to provide an interpretation of the existing stratigraphic and structural conditions in the northern part of the East Mesa field.

In addition, the results of a recent Vibroseis reflection seismology program have been reviewed and used to expand the structural interpretation. The Vibroseis data is published in a DOE report titled "Utilization of Seismic Exploration Technology for High Resolution Mapping of a Geothermal Reservoir," by P. L. Goupillaud and J. T. Cherry, April, 1977.

The Plio-Pleistocene deltaic sedimentary rock sequence, present at all depths drilled below 1,800-2,100 feet, contains both the proposed fluid injection zones and the underlying productive geothermal reservoir sands. The top of this deltaic assemblage of sandstones, siltstones and mudstones (shales) is represented by a distinctive and correlative shale-sand horizon which is now designated "A_1". The underlying succession of lithologic units has been correlated from well to well, with 58 specific horizons similarly designated and spaced throughout the total stratigraphic section to a depth of about 7,500 feet.

The attached drawing No. 199-12 displays a sequence of three subsurface structure contour maps and a structural cross section through this part of the East Mesa field. As seen in the east-west cross section, a broad anticlinal axis is present near Republic Well No. 16-30. The western flank of this structure is relatively steep, with dips of as much as 35° observed in USBR Well No. 31-1. The structure dips more gently to the east, with a broad synclinal axis being present between Republic Well Nos. 16-29 and 18-28.

A series of normal growth-type faults traverses the structure. These faults strike NE-SW, dip to the NW, and cause the lithologic units to be vertically displaced by as much as 200-500 feet at depths of about 6,000 feet. Displacement decreases toward shallower depths, as the sequence of growth faults appears to have been generated at a time nearly contemporaneous with deposition of the deltaic units. It is consequently highly unlikely that they create any displacement in the overlying lacustrine beds above a depth of 1,000-1,500 feet.

In addition to the normal faults, two lateral faults are interpreted to be present in this area. These faults appear as a conjugate set, with the NW-SE trending fault probably being the so-called East Mesa fault referred to in recent publications on observed seismicity at East Mesa. There is no known nor suspected evidence of recent activity on any of the other faults in the area.

The combined stratigraphic and structural interpretation indicates that both horizontal and vertical fluid communication exist between the depths of 2,000-7,500 feet in this portion of the East Mesa field. At least four factors have contributed to create this condition. The sand-dominated deltaic depositional environment has provided a primary horizontal stratigraphic continuity, with sufficient cut and fill present to interrupt the thinner shale interbeds. Second, the system of penecontemporaneous normal growth faults has vertically disturbed and dislocated the sediments, thereby increasing the means for vertical fluid communication. Third, the post-depositional folding and doming in this area has undoubtedly promoted the propagation of vertical tensional cracks. Finally, the more recent near vertical lateral faults have further vertically disrupted the dominantly sandstone-siltstone lithologic assemblage. These lateral faults may actually result in some local reduction in horizontal fluid communication as they develop due to horizontal compression. In contrast, the more prevalent normal faults should be expected to have no noticeable adverse effect on horizontal fluid movement as they are formed in response to a tensional condition present during deposition.

c. Fluid Chemistry

Fluids from Republic's wells completed in the productive interval 5,500± to 7,500± feet at East Mesa average less than 1,900 ppm total dissolved solids (TDS) and less than four ppm of total hardness (calcium). This is the lowest salinity and hardness found in any geothermal field in the Imperial Valley. Furthermore, this water is remarkably free of heavy metals which often cause environmental problems for disposal of geothermal fluids. Somewhat higher salinities have been found in the productive intervals in the central and southern part of the East Mesa field, with a maximum of 26,000 ppm present in the Bureau of Reclamation's Well No. 6-1. Higher salinities are also present in the proposed injection interval 2,000± to 5,000± feet, as evidenced by log analyses and produced water samples from the shallow recompletion interval of Well No. 18-28.

A summary of the produced water analyses data is shown in Table 1 for the three older Republic wells plus the shallow water supply well. The four recently completed wells (Nos. 16-30, 56-30, 78-30 and 52-29), have not yet been flowed sufficiently to yield meaningful samples uncontaminated by drilling mud filtrate. The analyzed fluids from the first three deep geothermal wells are similar and are characterized by low hardness, moderate pH, high bicarbonate, and low TDS. The most notable differences between these waters and the ground water represented by the water well analysis are the lower bicarbonate, flouride and boron content of the ground water.

The water analysis from Well No. 18-28 after recompletion in the proposed injection interval has more dissolved solids and relatively more chloride than the other waters. The low pH, high iron and high Cl/Na ratio suggest the sample is still contaminated by acid completion fluids. Contamination is no more than one part in seventy-five; however, since the excess Cl over Na (2,000± ppm) would have come from acid completion fluids holding about 150,000 ppm. Thus, the relatively high Ca, Mg and Na suggest the presence of evaporites in the recompletion interval.

TABLE I

EAST MESA WELL FLUID COMPARISON* (mg/l)

(Unflashed Samples)

Parameter	Production Interval Completions RGI 38-30	RGI 16-29	RGI 18-28	Injection Interval Completion RGI 18-28	RGI (450') Water Well
Total Dissolved Solids	1860	1761	1727	7505	1600
Silica	148.5	149.6	86.5	152.6	10
Iron	0.04	0.04	0.07	164.9	0.1
Calcium	2.1	2.6	3.2	701	68
Magnesium	0.3	0.1	0.2	129.9	19
Sodium	548	506	515	1546	410
Potassium	28	28.5	14.8	123.7	12
Bicarbonate	530	530	537	0.01	76
Carbonate	0	0	0	0	4
Sulfate	150	83	165	139.2	9
Chloride	450	461	401	4386.6	760
Fluoride	2.8	3.3	4.0	0.5	0.5
Arsenic	0.11	0.10	0.10	0.08	N/A
Boron	2.1	3.0	1.7	2.78	0.9
Bromide	-0.25	0.17	0.31	0.10	N/A
pH (pH units)	7.7	7.7	8.2		8.3

* Other wells 16-30, 56-30, 78-30, and 52-29 have yet to produce sufficient fluids to be uncontaminated by drilling mud filtrate.

Only the marginally high TDS, arsenic, flouride and boron contents prevent the geothermal water from being suitable for agriculture, livestock and human consumption. Therefore, the risk of accidental harm to the surrounding ecosystem from water spillage is minimal. However, no surface use is contemplated at this time since it is planned that all the water, with the exception of that needed for cooling water, will be returned to the reservoir by injection. The analysis of production interval fluids on Table 1 is for water without steam flash, and it is nearly representative of the residual plant waters which will be injected. The anticipated differences are those associated with the evaporation losses which will occur in the plant processing. It is notable that the produced geothermal fluids which will be injected into the shallow peripheral interval are actually of lower salinity than those in the injection interval.

A chemical analysis of the flashed steam from Well No. 16-29 is shown in Table 2. The noncondensables are only 0.64 weight percent of the steam and consist primarily of carbon dioxide. Only minute concentrations of hydrogen sulfide have yet been detected in the steam. There are two major implications of this analysis. The first is that any possible environmental problems associated with flashing to the atmosphere are negligible. The second is that the low level of noncondensables makes it feasible to utilize a flashed steam process to drive the power plant turbines.

d. Reservoir Properties

(1) Log Analyses

Analyses of the geophysical well logs from Republic Well Nos. 38-30, 16-29 and 18-28 have been completed. Analyses of logs from the more recently completed wells (Nos. 16-30, 56-30, 78-30 and 52-29) are currently underway. The principal results of the completed analyses were a determination of porosity,

TABLE 2

CHEMICAL ANALYSIS OF
FLASHED STEAM - REPUBLIC WELL NO. 16-29

Total Noncondensables	-	0.64 wt. % of steam
Constitutents		
Carbon dioxide	-	91.4 vol. % of noncondensables
Nitrogen	-	4.3
Methane	-	3.9
Alkanes	-	0.4
Hydrogen sulfide	-	None detected

permeability, salinity and net sand present at each well location versus depth. The permeability-porosity-log relationships are calibrated with core data from USBR Well No. 5-1. An improved relation may be possible when lab results from recent tests on the core from Republic Well No. 78-30 are considered.

Tables 3, 4 and 5 provide a summary of the individual well data for each 250-foot increment of depth. These data generally show an excellent amount of sand development in the wells, with a gradual decrease in reservoir properties and salinity with depth. The porosity, net sand and permeability in the producing interval, 5,500± to 7,500± feet, are sufficiently high to permit large flow rates with relatively minor pressure drawdowns. The validity of these calculations has been confirmed by both pressure buildup analyses and by interference testing, as discussed later.

Note that the permeabilities in the proposed injection interval, 2,000± to 5,000± feet (Table 3), are relatively much higher than those of the productive interval. This should allow high-volume shallow injection at low pressures as previously noted. The higher salinity of the water in the injection interval relative to the salinity in the productive interval provides assurance that injection will not degrade the shallow zone waters. Contamination of the ground water above 1,000± feet will be prevented by the "shale barrier" between 600± and 2,000± feet (discussed previously in the lithology section) coupled with an adequate injection well leak monitoring system.

(2) Temperatures

The temperatures measured in each well versus depth are illustrated in Figures 3

TABLE 3

REPUBLIC GEOTHERMAL WELL NO. 38-30

ZONE SUMMARIES

	Thickness (ft)				Permeability (md)		Salinity *
Interval	Gross	Net Sand	% Sand	$\bar{\phi}$	$\bar{k}$ Arith	$\bar{k}$ Geo	ppm NaCl
1350-1500	151	125	83	.35	1174	913	8,216
1501-1750	250	223	89	.34	1023	757	8,091
1751-2000	250	140	56	.32	756	456	10,317
2001-2250	250	155	62	.34	1064	721	10,237
2251-2500	250	166	66	.31	573	321	10,818
2501-2750	250	161	64	.31	467	256	10,113
2751-3000	250	214	86	.36	1645	1315	7,500
3001-3250	250	214	86	.33	897	534	8,043
3251-3500	250	171	68	.28	149	102	7,585
3501-3750	250	181	72	.29	322	134	6,556
3751-4000	250	166	66	.31	473	243	5,569
4001-4250	250	111	44	.31	714	286	6,117
4251-4500	250	145	58	.29	263	148	5,471
4501-4750	250	195	78	.30	432	186	3,006
4751-5000	250	189	76	.28	367	115	3,223
5001-5250	250	162	81	.30	595	205	3,029

* Produced fluid salinity 1860 ppm from the interval 6383' to 8898'

TABLE 3
(Continued)
REPUBLIC GEOTHERMAL WELL NO. 38-30
ZONE SUMMARIES

	Thickness (ft)				Permeability (md)		Salinity *
Interval	Gross	Net Sand	% Sand	$\bar{\phi}$	$\bar{k}$ Arith	$\bar{k}$ Geo	ppm NaCl
5251-5500	250	210	84	.30	570	187	2,564
5501-5750	250	201	80	.23	101	22	2,508
5751-6000	250	162	65	.23	63	23	3,250
6001-6250	250	183	73	.28	312	90	2,834
6251-6500	250	227	91	.31	645	266	2,134
6501-6750	250	219	88	.31	826	229	2,670
6751-7000	250	153	61	.25	287	36	3,318
7001-7250	250	76	30	.16	9	2	4,140
7251-7500	250	86	34	.19	17	6	5,814
7501-7700	200	115	58	.18	14	5	4,428
7701-8000	300	122	41	.22	106	18	3,915
8001-8250	250	93	37	.11	1.5	.6	4,378
8251-8500	250	111	44	.10	.9	.4	No Data
8501-8750	250	63	25	.11	16	.6	1,199
8751-8900	150	26	17	.07	.2	.1	No Data

* Produced fluid salinity 1860 ppm from the interval 6383' to 8898'

TABLE 4

REPUBLIC GEOTHERMAL WELL NO. 16-29
ZONE SUMMARIES

Interval	Thickness (ft) Gross	Thickness (ft) Net Sand	% Sand	$\bar{\phi}$	Permeability (md) $\bar{k}$ Arith	Permeability (md) $\bar{k}$ Geo	Salinity * ppm NaCl
4800-5000		175	70	.26	190	54	No Data
5001-5250	250	182	73	.25	130	43	
5251-5500	250	181	72	.22	56	18	
5501-5750	250	206	82	.22	33	15	
5751-5925	174	125	72	.22	81	16	
5926-6000	74	52	21	.27	140	64	
6001-6250	250	211	84	.25	112	44	
6251-6500	250	219	88	.27	263	78	
6501-6750	250	175	70	.25	95	39	
6751-7000	250	163	65	.19	16	6	
7001-7050	50	3	6	.14	2	1	
7051-7250	200	40	20	.14	32	1	
7251-7500	250	143	57	.22	37	13	
7501-7750	250	155	62	.21	54	11	
7751-7900	150	90	60	.22	34	16	

* Produced fluid salinity 1761 ppm from the interval 6413' to 7996'

TABLE 5

REPUBLIC GEOTHERMAL WELL NO. 18-28
ZONE SUMMARIES

Interval	Thickness (ft) Gross	Net Sand	% Sand	$\bar{\Phi}$	Permeability (md) $\bar{k}$ Arith	$\bar{k}$ Geo	Salinity * ppm NaCl
5100-5250	250	88	35	.25	306	34	No Data
5251-5500	250	226	90	.29	458	146	
5501-5750	250	226	90	.29	658	134	
5751-6000	250	193	77	.29	529	136	
6001-6250	250	183	73	.22	42	15	
6251-6400	150	59	39	.23	86	18	
6401-6500	100	28	28	.22	30	17	
6501-6750	250	202	81	.22	29	16	
6751-7000	250	136	54	.22	127	18	
7001-7250	250	84	34	.23	213	24	
7251-7500	250	94	38	.27	994	85	
7501-7750	250	92	36	.22	198	13	
7751-7900	150	55	37	.15	2	2	

* Produced fluid salinity 1727 ppm from the interval 6413' to 7996'
* Produced fluid salinity 7505 ppm from the interval 2851' to 4476'

and 4. Well Nos. 38-30, 16-29 and 18-28 have been flowed and surveyed sufficiently during the 2+ years since completion to be assured that the data represents true static temperature profiles. The data from the recently completed wells (Nos. 16-30, 56-30 and 78-30), however, were taken shortly after drilling and are undoubtedly at less than equilibrium temperatures. Well No. 52-29 has yet to be surveyed.

Note the increase in slope present in all the wells except Well No. 18-28 in the interval 2,500± to 3,500± feet. This is indicative of convective vertical fluid flow in the reservoir and hot water influx from depth. In general, the temperature in the productive interval (5,500± t0 7,500± feet) may be seen to range between 320°F and 360°F, while the range in the proposed injection interval (2,000± to 5,000± feet) is between 235°F and 310°F.

Minimum bottom-hole flowing temperatures (above the completion interval) of 338°F and 332°F have been established in Well Nos. 38-30 and 16-29, respectively, during short-term flow tests. These values are very important in that they represent the volumetric average temperature of the producing interval. Such data has not yet been obtained during long-term production tests, but the values can be expected to be higher, if anything, in the future. At low production rates, it may take many months for the surface produced fluid temperatures to approach the downhole flowing temperatures due to well bore heat losses. At the expected pumped rates of 850,000± lb_m/hr (rates expected of East Mesa producers being pumped), however, preliminary calculations indicate "equilibration" between bottom-hole and surface temperatures will occur within a few days.

EQUILIBRATED STATIC TEMPERATURE SURVEYS,
EAST MESA WELLS

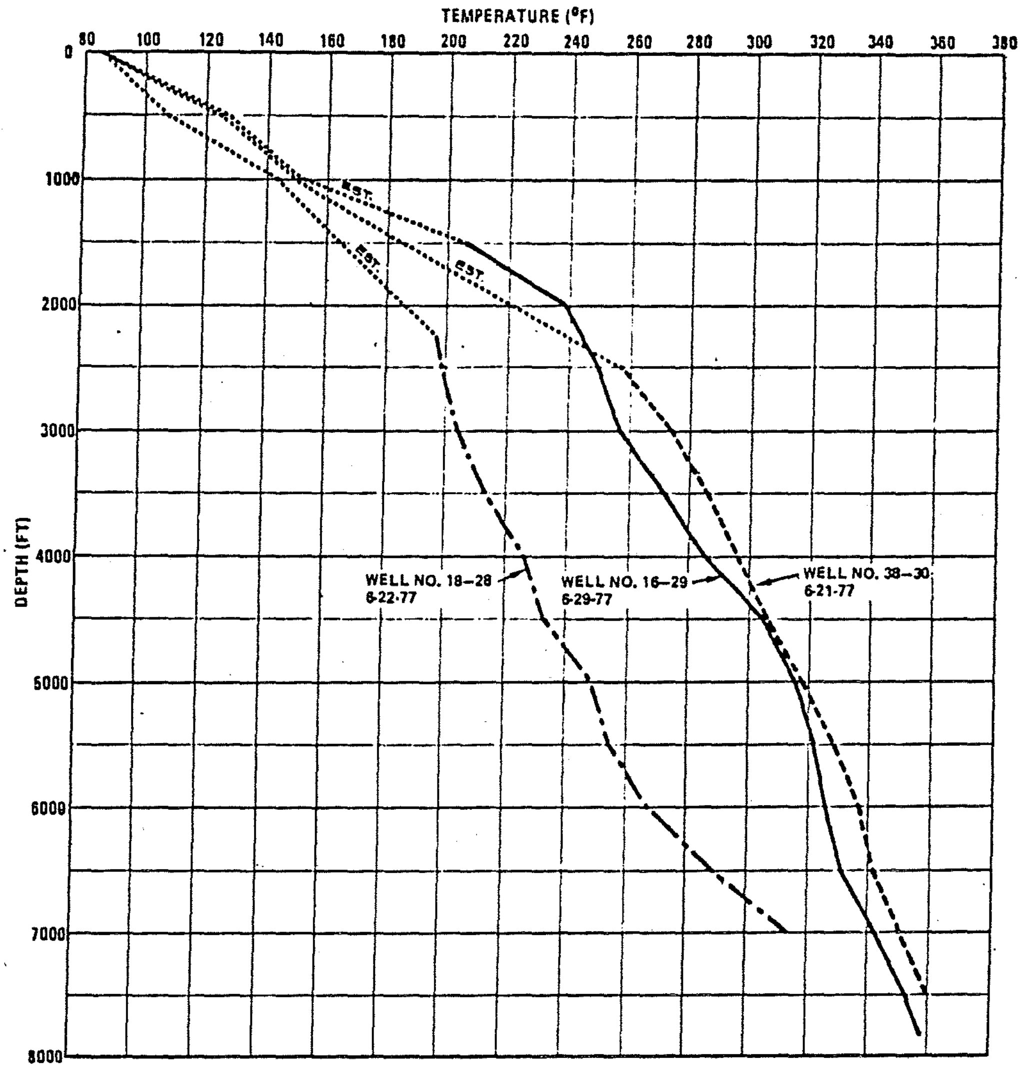

Figure 3

PRELIMINARY STATIC TEMPERATURE SURVEYS
EAST MESA WELLS

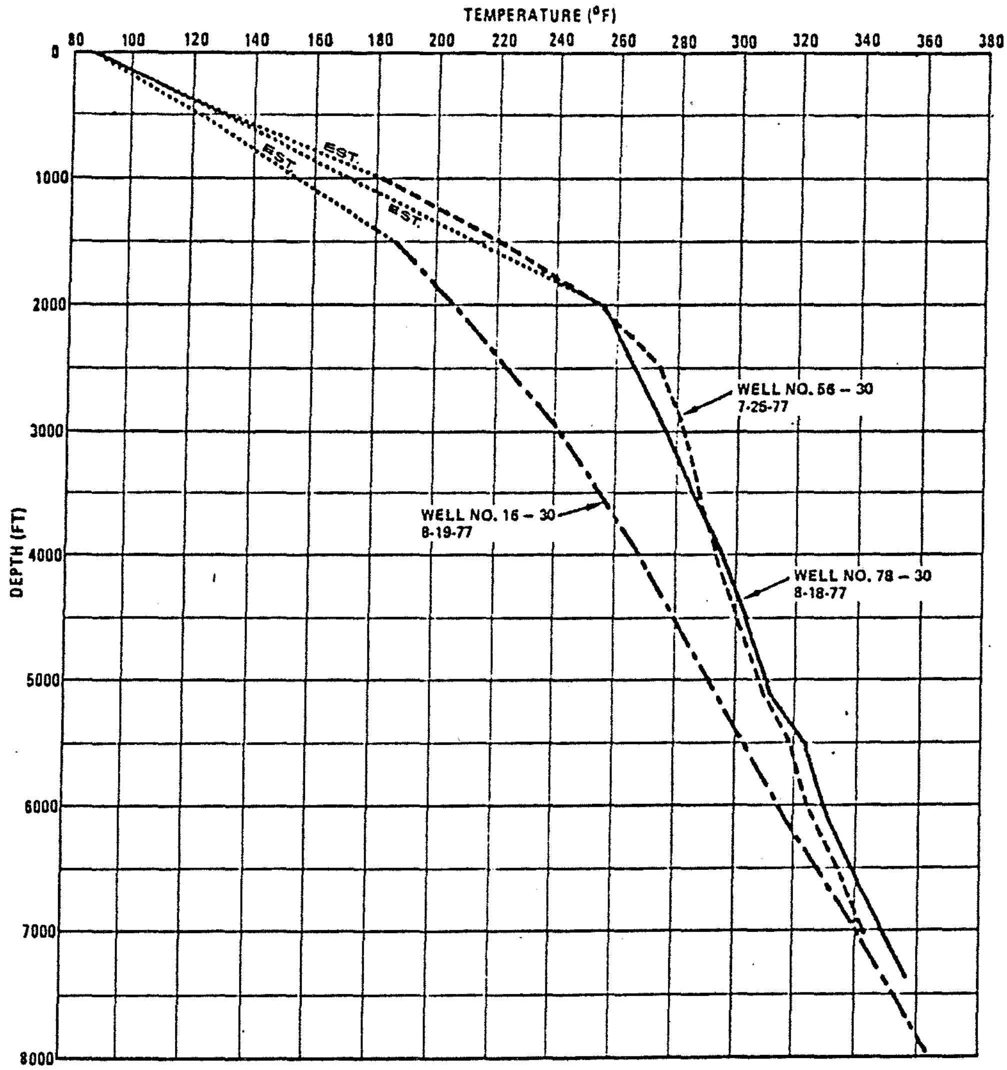

Figure 4

(3) Pressures

Bottom-hole pressure drawdown and buildup tests were run in Well Nos. 38-30, 16-29 and 18-28. The more recent wells (Nos. 16-30, 56-30, 78-30 and 52-29), have been, thus far, only short-term production tested without bottom-hole instrumentation. The data were analyzed using conventional Horner plot, Miller-Dyes-Hutchinson and superposition techniques to estimate the permeability-thickness (kh) of the producing interval, and to determine if formation damage exists around the well bore. In addition, an indication of boundaries was sought, which could be combined with geophysical, petrophysical and other data to help delineate the East Mesa reservoir. A tabulation of the input data and principal results obtained from the buildup analyses are given in Table 6.

Lawrence Berkeley Laboratory has also conducted a series of interference tests between various pairs of wells in the field. A summary of the permeability and permeability-thickness data calculated by three methods (i.e., log analysis, pressure buildup and interference testing) is given in Table 7, along with the maximum observed flow rates. Well No. 38-30 has a buildup permeability of 84 md, which is the highest of any well in the group. The permeability of 42 md found in Well No. 16-29, yields an average 63± md for this area. The highest permeability USBR well is No. 31-1 (30 md), located immediately adjacent to the Republic leases. The interference kh between Republic's Well No. 38-30 and the USBR Well No. 31-1 is 29.8 Darcy-feet, which is in excellent agreement with the average buildup kh of 32.3 Darcy-feet between the two wells.

TABLE 6

PRESSURE BUILDUP DATA AND RESULTS

Test Data	RGI WELLS 18-28	RGI WELLS 16-29	RGI WELLS 38-30
Flow duration, hrs	21.5	5.53	5.47
Shut-in time, hrs	9.3	22.40	24.39
Cumulative production STB	1,264 (1)	4,525	5,907
Last rate before shut-in, STB/D	2,517	19,668	25,462
Producing time, hrs	17.05	5.902	6.097
Reservoir and Fluid Property Data			
Water viscosity, μ	0.210	0.185	0.185
Water FVF, RB/STB	1.078	1.085	1.088
Porosity, fraction	0.220	0.223	0.249
Total compressibility, psi^{-1}	7.570×10^{-6}	7.904×10^{-6}	8.202×10^{-6}
Well bore radius, ft	0.375	0.443	0.510
Estimated net thickness, ft	77	827	499
Perforated intervals, ft	6105-6210 6440-8000 (2)	6413-6984 7231-7996	6383-7022 (3) 7271-7485 7869-7998 8297-8384 8640-8898
Results			
Average permeability, md	81.94	41.96	83.50
Flow capacity, md-ft	6,309	34,698	41,666
Formage damage (skin)	-0.91	-2.28	-2.81
Distance to nearest boundary, ft	451	893	692

(1) Estimated
(2) Spinner survey showed no fluid entry
(3) Fill to 7022'

TABLE 7

COMPARISON OF PERMEABILITY AND FLOW CAPACITY OF EAST MESA WELLS

Well	Max. observed flow rate, B/D	Avg. Permeability from buildup (md)	Permeability-Thickness (Darcy-ft) Buildup	Logs
Republic Geothermal				
38-30	50,300	84	41.7	44
16-29	31,400	42	34.7	30
18-28	15,600	82	6.3	14
Bureau of Reclamation				
31-1	21,200	30	22.2	N/A

Lawrence Berkeley Laboratory Interference Results:

38-30 and 31-1 pair: kh = 29.8 Darcy-ft

More recent Lawrence Berkeley Laboratory/Republic Geothermal interference and drawdown/falloff pressure testing involving all Republic wells except Well No. 52-29 is still being analyzed. Some very preliminary results are summarized in Table 8. These data generally confirm earlier interpretations, but indicate the presence of partially sealing barriers between some wells.

Static reservoir pressures are approximately hydrostatic plus 75± psig. For example, the static pressure in Well No. 38-30 at 6,100 feet is 2,576± psig. (The average hydrostatic gradient at Well No. 38-30 temperature conditions is 0.41 psi/ft; 6,100 ft. x 0.41 psi/ft = 2,501 psig; 2,501 psig + 75 psig 2,576 psig.) Because of the incremental 75± psig over hydrostatic, shut-in wellhead pressures are positive an equivalent amount. Artesian flow of the wells is thus possible even in the absence of steam flash.

In summary, it is important to note the good agreement between all three methods of measuring reservoir productive properties, as well as their correlation with maximum observed flow rates. This lends additional credibility to applying the permeability calculation results to the reservoir performance model and to the well performance predictions.

e. Production/Injection Experience

A summary of key well data and available initial production test data is given in Table 9. The four recently completed wells (Nos. 16-30, 56-30, 78-30 and 52-29) have been flowed only a few hours to clean out drilling fluid. Preliminarily, it can be stated that Well Nos. 56-30 and 78-30 perform as well as or better than Well No. 38-30, and

TABLE 8

PRELIMINARY EAST MESA INTERFERENCE TEST RESULTS

(July-October 1977)

Well	Test 1 38-30 Flowing kh(md-ft)	Test 1 38-30 Flowing $\phi c h r_e^2$(ft/psi)	Test 2 16-29 Flowing kh(md-ft)	Test 2 16-29 Flowing $\phi c h r_e^2$(ft/psi)	Test 3 38-30 Pumping kh(md-ft)	Test 3 38-30 Pumping $\phi c h r_e^2$(ft/psi)
38-30	24,800	1.36×10^{-3}	--	--	--	--
56-30	26,300	4.5×10^{-4}	To Be Analyzed		23,600	7.89×10^{-4}
31-1	35,400	2.07×10^{-3}	To Be Analyzed		31,700	2.4×10^{-3}
16-29	21,800	2.36×10^{-3}	--	--	--	--
78-30	--	--	--	--	10,400	6.68×10^{-3}
16-30	No Response		No Response		No Response	

TABLE 9

EAST MESA WELL DATA

Well	T.D.	Est. Temp. @ T.D.	Flowing Downhole Temp. (2)	Maximum Observed Flow Rate lb_m/hr	Maximum Observed Flow Rate 10^6 BTU/day	Completion Date
38-30	9009'	387°F (1)	338°F	670,000 (3)	5,000	10/75
16-29	7998'	361°F	332°F	419,000 (3)	3,060	12/75
18-28	8001'	346°F	310°F (est.)	208,000 (3)	1,400	1/76
16-30	8000'	364°F (4)	N/A	N/A	N/A	7/77
56-30	7520'	352°F (4)	N/A	N/A	N/A	6/77
78-30	7442'	358°F (4)	N/A	N/A	N/A	8/77
52-29	4524'	N/A	N/A	1,100,000	N/A	1/78

(1) Fill at 7022' (351°F)

(2) Above producing interval

(3) Liquid rate only. Vapor phase (12±%) not measured.

(4) Preliminary (non-equilabrated) measurements.

Well No. 16-30 appears to be similar to Well No. 16-29. Well No. 52-29, the first well actually drilled as a shallow peripheral injector, is too cool to be a producer but exhibits excellent productivity during repeated cleanout flows and should be an excellent injector. Data from recent long-term tests of Well Nos. 38-30 and 16-29 are summarized in Tables 10 and 11.

The highest natural flow rate from the productive interval measured thus far was 670,000 lb_m/hr (760,000$\pm$ lb_m/hr including steam flash) while flowing Well No. 38-30 directly into the storage basin. During the more recent long-term testing, this well demonstrated a sustained natural flow capability of about 420,000 lb_m/hr against 30$\pm$ psig backpressure with only a 200$\pm$ psi bottom-hole drawdown. Subsequently, the well was pumped continuously for more than 30 days using a line-shaft turbine pump set at 420$\pm$ feet. The maximum rate of about 505,000 lb_m/hr attained during pumping was limited due to the disposal system capacity.

Well No. 16-29 flowed to the basin at a maximum rate of 419,000 lb_m/hr (475,000$\pm$ lb_m/hr including steam flash). A sustained natural flow capability of about 340,000 lb_m/hr against 30 psig backpressure was achieved in the more recent tests. Continuous pressure/temperature profiles, observed during flow with experimental instruments from Denver Research Institute, suggested that cold water influx at the intermediate casing shoe was occurring. This was subsequently confirmed and a remedial cement squeeze job was performed. Upon returning the well to long-term production tests, it became apparent that near well bore formation damage had occurred during the squeeze job. Stimulation work is now underway on the well.

Two high volume line-shaft turbine pumps designed for 1,000$\pm$ foot setting depths are currently on order and should be ready for

TABLE 10

EAST MESA 38-30 PRODUCTION TESTING PERFORMANCE SUMMARY

Step Rate Test (7/14/77 - 7/26/77)

Estimated Sustainable Natural Flow Rate	= 420 Mlb_m/hr
Cumulative Production During Test	= 27.3 MMlbs
Estimated Preflash Liquid Surface Temperature	= 340° F
Power Output Potential (Natural Flow)	= 2.0 $Mw_{(e)}$

Pumping Test (8/22/77 - 10/5/77)

Maximum Rate Pumped (During Test)	= 505 Mlb_m/hr
Cumulative Production (During Test)	= 196 MMlbs
Estimated Preflash Liquid Surface Temperature (At Maximum Rate)	= 340° F
Gross Power Output Achieved During Test	= 2.4 $Mw_{(e)}$
Net Power Output Achieved During Test	= 2.15 $Mw_{(e)}$
Pumped Rate Potential (using larger 12 HXH pump & column)	= 920 Mlb_m/hr
Gross Power Output Potential (@340° F)	= 4.4 $Mw_{(e)}$
Net Power Output Potential (@340° F)	= 4.0 $Mw_{(e)}$

TABLE 11

EAST MESA 16-29 PRODUCTION TESTING PERFORMANCE SUMMARY

Step Rate Test (7/26/77 - 8/3/77)

Estimated Sustainable Natural Flow Rate	= 340 Mlb_m/hr
Cumulative Production During Test	= 20.1 MM lbs
Calculated Preflash Liquid Surface Temperature*	= 330° F
Power Output (Natural Flow)	= 1.4 $Mw_{(e)}$
Estimated Preflash Liquid Surface Temperature after repair of lap	= 340° F
Potential Power Output** (Natural flow)	= 2.0 $Mw_{(e)}$

* Well had cold water influx at liner/intermediate casing lap.

** Includes estimated 25% ± increase in flow rate due to higher temperature and therefore lower flash point and higher drawdown.

testing by May, 1978. It is anticipated that the producers will be capable of 800,000 to 900,000 lb_m/hr each when equipped with such pumps.

Well No. 18-28 was found to be on the flank of the thermal anomaly and is too cold to be an economic producer. It was capable of only 208,000 lb_m/hr artesian flow and was ultimately converted to injection service. During the recent long-term testing of Well Nos. 38-30 and 16-29, it was possible to inject about 300,000 lb_m/hr at 400 psig wellhead pressure on a sustained basis into Well No. 18-28. Initial plugging problems were overcome by acid treatment and installation of finer filters (10μ rather than 50μ) to prevent suspended $CaCO_3$ precipitates from entering the well bore.

Profile surveys showed that less than 200 feet of the 1,800 feet of perforations open in Well No. 18-28 were actually taking fluid. Presumably this was due to an inability to flow the well at high enough rates to remove the initial drilling mud wallcake. Recently, the well was plugged back and jet perforated over 1,215 feet of the shallow injection zone.

It is anticipated that the injectors will be able to handle the residual waters at very low wellhead injection pressures due to the high permeability sands present in the 2,000± to 5,000± foot injection zone.

f. Reserves and Expected Performance

The productive limits of the East Mesa reservoir are yet to be determined by additional drilling and testing. An approximation of reserves for Sections 29 and 30 is possible, however, based on heat content. The approach used herein is analogous to a volumetric calculation for determination of conventional oil and gas reserves. It is comprised of essentially three steps. First, the total initial heat content (enthalpy) of the reservoir was calculated between a bottom of 9000 feet, approximately the 1 md permeability level, and a top defined by a 300°F surface. Second, an estimate was made of the portion of this initial heat content that can be expected to be recovered during the economic producing life of the area by using reservoir simulation studies of a single five-spot reinjection pattern. Lastly, a conversion efficiency was developed which relates the heat content of the produced water to the electrical energy output.

Note that this approach is conservative in two respects as discussed earlier. First, no credit is taken for recharge of the reservoir due to thermal convection through the fracture system. There is sound geological evidence that this will probably occur, with the net effect being higher temperatures and longer reservoir life. Second, the reservoir model assumes that a five-spot pattern will be employed to inject the cooled residual water. In reality, it is planned to prolong reservoir life and to improve sweep efficiency by using a peripheral flood. Therefore, the five-spot prediction will probably prove to be pessimistic.

A more sophisticated approach to reserves and performance prediction will only be warranted after additional drilling and testing has yielded a refined picture of the heat and reservoir property distribution. An ultimate evaluation will also require information on the aquifer influx magnitude which can only be obtained by long-term production.

(1) Initial Heat Content

The first step in calculating the total initial heat content of the reservoir for Sections 29 and 30 was to construct a set of isothermal surface maps which show the depth to several selected reservoir temperatures. Figure 5 provides an example of the 350°F map. The maps were based on the static temperatures measured in the wells, with additional input provided by the data from the existing network of shallow temperature observation holes.

Using the maps, the bulk of volume of each 500-foot depth interval and its average temperature were determined from isothermal surfaces by numerical integration. The total initial heat content of each interval can then be calculated by:

$$\text{Total Heat Content} = \text{Bulk Volume} \cdot (T-T_o) \cdot \rho c$$

Where T is the reservoir temperature, T_o is the reference temperature (taken as 32°F) and ρc is the effective volumetric heat capacity of the total rock and fluid system. The last term (ρc) may be calculated as follows:

$$\rho c = \rho_r c_r \, (1 - \phi \cdot NS) + \rho_w c_w \phi \cdot NS$$

Where ρ_r and ρ_w are densities of the rock and fluid, respectively, c_r and c_w are the specific heat capacities of the rock and fluid, respectively; ϕ is the porosity of the productive portion of the rock; and NS (net sand) is the fraction of the interval which is productive.

Basic input and summary results of the calculation for each Section are shown in Table 12. Porosity and net sand values derived from Well Nos. 16-29 and 38-30 were taken to be representative of Sections 29 and 30 respectively. Total initial heat content for the two sections is shown to be 2.14×10^{14} BTU.

EAST MESA
350°F ISOTHERMAL SURFACE
DEPTH CONTOURS

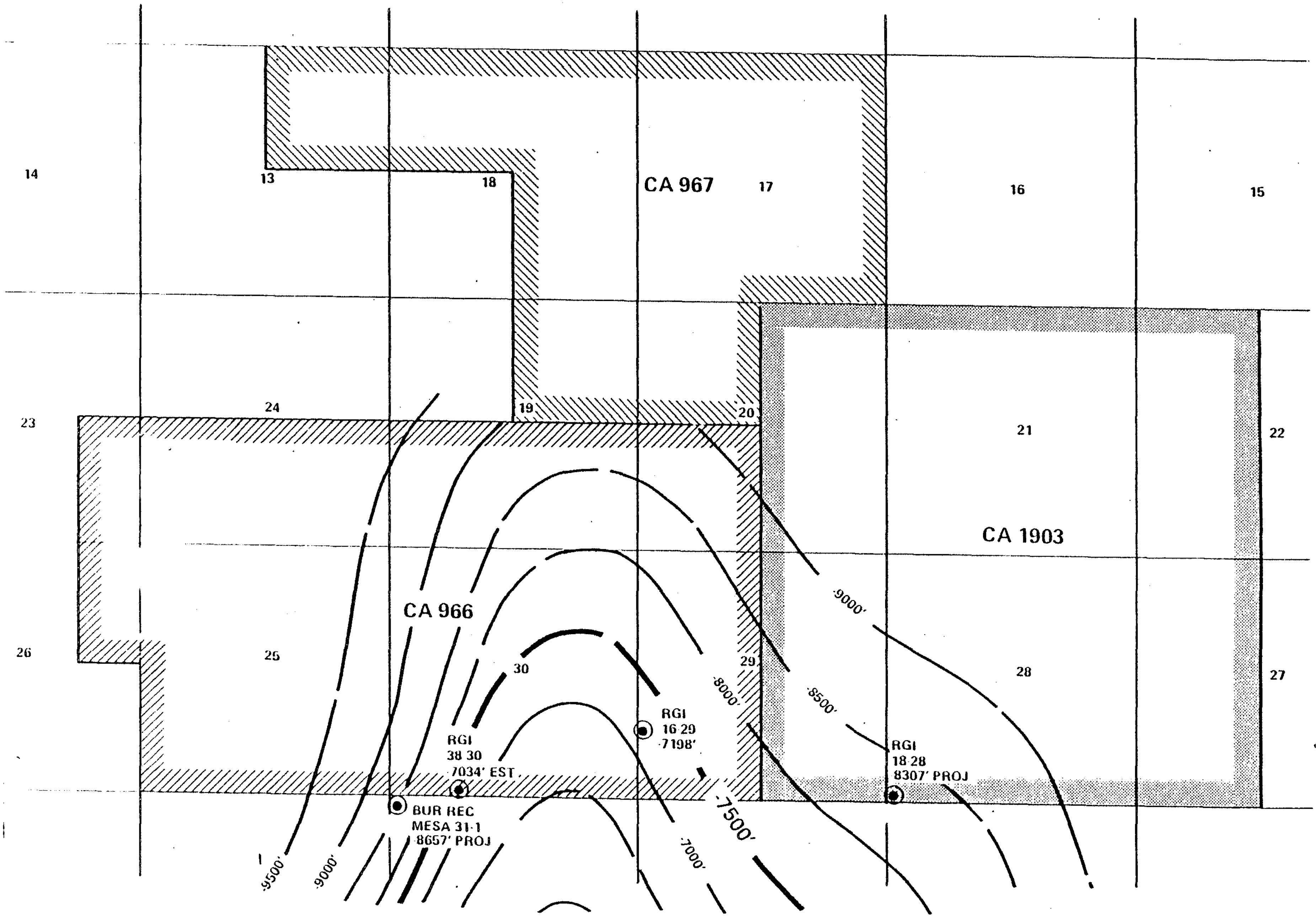

Figure 5

(2) Heat Recovery Efficiency (Reservoir Simulation)

Reservoir simulation studies were undertaken to predict how much of the initial heat content could be recovered. Specifically, the temperature, pressure and rate behavior versus time were investigated for various conditions. The types of field development considered included: (1) straight depletion without injection; (2) peripheral injection; and (3) five-spot injection. Also, various rates and pattern sizes were investigated as well as the effect of an infinite aquifer.

In summary, it was found that: (1) an aquifer alone (having the same properties as the reservoir) is insufficient to maintain pressure; (2) for some combinations of withdrawal rate, spacing and permeability, peripheral injection combined with the contributions from the aquifer will maintain adequate pressure; (3) whenever the peripheral flood fails to maintain adequate pressure for the desired withdrawal rate, pressure can always be maintained by going to a pattern flood such as a five-spot.

A typical simulation result was previously illustrated in Figure 2. In this case, a 40,000 B/D producer on 40-acre spacing initially produces at 355°F. The injected water temperature is assumed to be 200°F. The economic life of this well is approximately 30 years or 265°F. For the reserve calculation, this "base case" is used to determine the fraction of original heat content of the rock and fluid system which would be produced in the hot water over the economic life of the well. The total amount of heat (enthalpy) contained in the produced fluids is equivalent to over 90 percent of the original heat-in-place in the reservoir, but about half of this heat

TABLE 12

EAST MESA FIELD - SECTIONS 29 & 30

PRELIMINARY RESERVE ESTIMATE

Section	Average Reservoir Temperature (^{o}F)	Average Sand Porosity (fraction)	net sand (fraction)	Bulk Volume ($ft^3 x 10^{10}$)	Total Initial Heat Content ($BTU \times 10^{14}$)	Reserve (Mw-Years)
29	334	0.17	0.60	8.363	8.732	1315
30	335	0.23	0.58	11.701	12.625	1900
	335	0.20	0.59	20.064	21.357	3215

$\rho r = 165 \frac{lbs}{ft^3}$; $\rho w = 56.7 \frac{lbs}{ft^3}$; $c_r = .19 \frac{BTU}{lb^oF}$; $c_w = 1.12 \frac{BTU}{lb^oF}$

is returned to the reservoir by means of the injected water. Therefore, the net heat produced is about 45 percent of the original heat-in-place. During the 30-year period, approximately three pore volumes of water were produced and reinjected. Thus, it is concluded for East Mesa conditions that the net producible heat is approximately equal to 45 percent of the original heat-in-place or 9.6×10^{14} BTU for Sections 29 and 30 combined.

(3) Conversion to Electricity

It is desirable to express geothermal reserves in electrical terms (i. e., megawatt-years), rather than in volume or mass of hot water. Reference must therefore be made to a specific power plant design. Figure 6 shows the power output for the one-stage and two-stage flashed steam process as a function of temperature.

The proposed 48 Mw plant will employ a two-stage flash process. This process was selected for East Mesa because: (1) it relies on proven, existing technology; (2) it can be designed and built in time to meet the incremental power needs of the Imperial Irrigation District by 1980; (3) it is well suited to the low salinity and low noncondensables found in Republic wells; and (4) it will probably generate the lowest cost electricity under the specific East Mesa temperature and water chemistry conditions.

Assuming a produced water temperature of 335°F, two-stage flash and a reinjected water temperature of 200°F, the calculated conversion efficiency, * based on Figure 6,

$$\text{*Conversion Efficiency \%} = \frac{\text{BTU Equivalent of Plant Electrical Output}}{\text{BTU Content of Net Produced Heat}} \times 100$$

Where: BTU content of net produced heat = BTU content of produced fluid - BTU content of injected residual fluid.

FLASHED STEAM POWER CYCLE

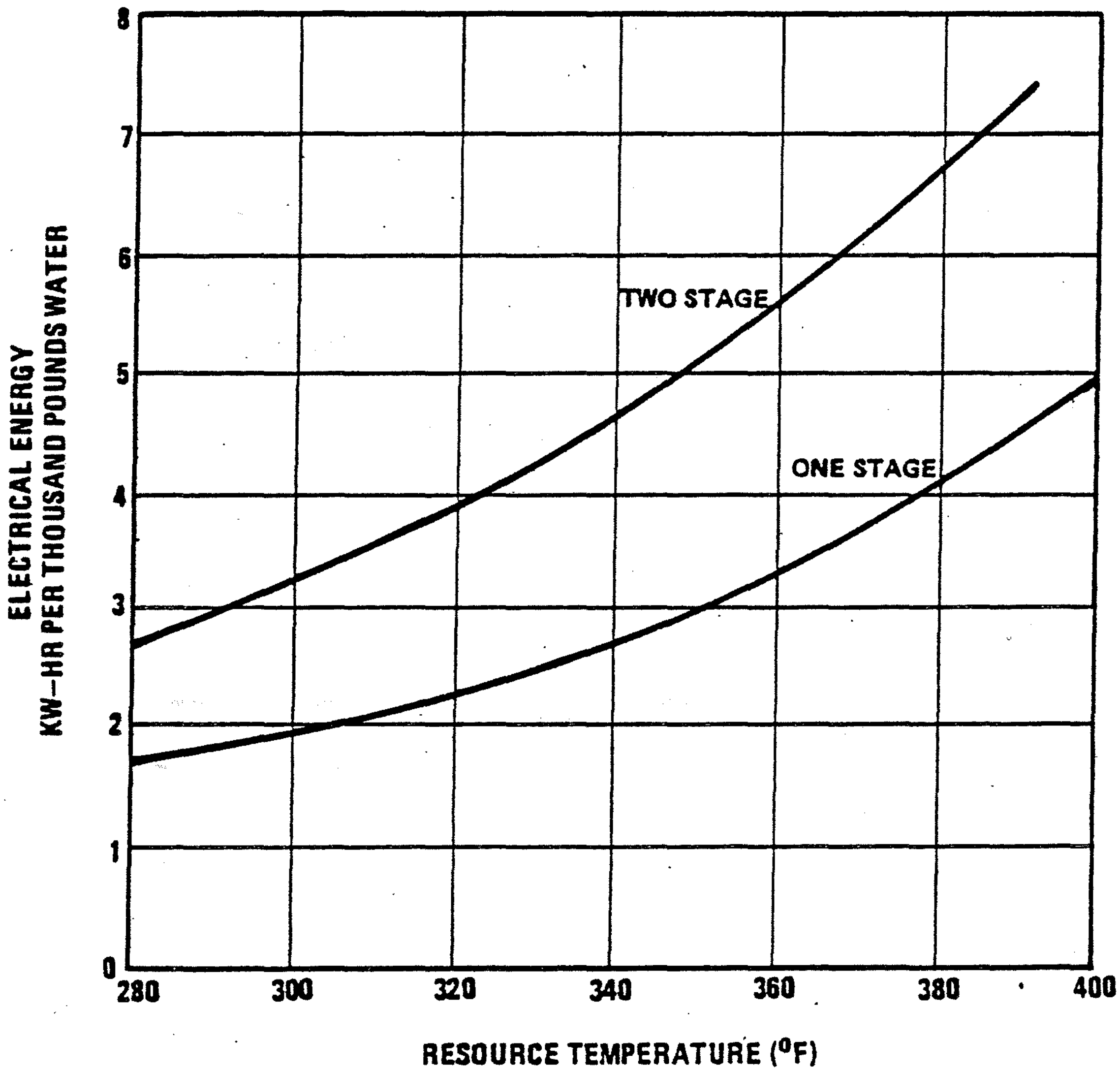

Figure 6

is approximately 11 percent. The resulting calculated electrical energy reserve for Sections 29 and 30 is shown in Table 12. These calculations are based on a net producible heat equal to 45 percent of the original heat-in-place (as determined from the five-spot simulation results) and a conservative conversion efficiency of ten percent. The total reserve amounts to 3215 megawatt-years, which is 107 megawatt installed capacity for a 30-year life. These reserves are clearly adequate to support the proposed 48 (net) Mw project.

4. Representative Drilling Program for East Mesa Production Wells

a. Zone of Completion

Production wells will be completed in the sequence of alternating deltaic sandstones, siltstones and mudstones described above in Section 3.b., Resource Data. The production interval will be approximately from 5500 feet to 7500 feet (all depths referenced to KB, which averages approximately 52 feet above MSL).

b. Casing and Cementing Program

The casing program will be one of the following:

Depth	Program 1	Program 2
Conductor Pipe 90'	20"	24"
Surface Casing 1500'	13-3/8"	16"
Intermediate Liner 5500'	9-5/8"	11-3/4"
Production Liner 7500'	7"	9-5/8"

Two casing size programs are proposed to allow flexibility to utilize any new data resulting from current and proposed testing operations. To date, one well has been completed with the larger casing program, except that an 8-5/8" production liner was run instead of the proposed 9-5/8" production liner.

The wellheads on the non-pumped wells will consist of a 13-3/8" S.O.W. x 12" - 400# RTJ Model SU casing head with two 2" flanged side outlets, one 12" - 600 series manual gate valve with 400# RF flanges, a 12" tee with 400# RTJ flanges, a 6" - 400# RTJ flanged crown valve and two 12" series 400# manual gate valves for the wing valves. The wellhead for Program 2 will be a 16" S.O.W. x 16" - 400# RTJ adapter flange. All other equipment is as above.

The surface casing will be cemented to the surface using API class "G" cement mixed 1:1 with Perlite plus 2% gel and 35% silica flour. The slurry density will be 95#/ft.^{3}. A tail slurry of 200 sacks of class "G" cement with 35% silica flour with a density of 117#/ft.^{3} will be used for additional strength around the casing shoe. The intermediate casing will be cemented with the same basic slurries as above; however, sufficient retarders will be added based on logging temperatures to give adequate pumping times.

After waiting on cement for eight hours, the casing will be slacked off and the casing pressure tested to 1,000 psi for 30 minutes. Liner laps will likewise be tested.

c. Mud Program

The mud program from surface to TD will be lightweight (8.8-9.2 PPG), low solids, fresh water, clay base drilling fluid treated with lignite for temperature stability, and bicarbonate of soda for cement combination. Desanders and desilters will be run in order to keep the solids as low as possible. A cooling tower will be installed in the mud system and the mud pumped through this cooling tower when the return mud temperature exceeds 160°F (71.1°C).

d. Safety Provisions

After setting surface casing, an API class 3,000 psi double hydraulic pipe and blind ram blowout preventer will be installed above a 12" gate valve with 400# RTJ flanges which will be just above the casing head. On those wells drilled with the large casing program, a single blind ram will be installed instead of the 12" gate valve. The casing head will have two side outlets with two flanged valves on each outlet. One side will be connected to the rig choke manifold, the other side will be connected to a pumping unit as a kill line with a back pressure valve in the line for pumping into the well, if necessary. A fill-up line will be installed above the BOP equipment so that the hole can be filled during trips, and the amount of fluid pumped into the well while tripping will be monitored. The hydraulic control unit for the BOP equipment will have two operating stations, one on the rig floor and one at least 50 feet from the wellhead. At all times the mud flow line temperature and the mud pit level will be monitored. A pit level warning device will be installed. Gases in the mud return will be monitored. Special provisions for handling hydrogen sulfide are not planned since hydrogen sulfide has not been encountered in any exploration and delineation wells at the East Mesa KGRA.

The BOP equipment will be pressure tested to 1,000 psi when installed and at least once every seven days thereafter. This will include testing of all drill string back pressure valves, full opening valves, standpipe and choke manifold.

A drill string back pressure valve along with a full opening safety valve will be maintained on the rig floor with adequate subs to fit all connections in the drill string.

Each drilling crew will be instructed in blowout control procedures and the contractor will be required to have at lease one pit drill per crew per week.

In the event of an emergency, the drilling contractor will have the names and telephone numbers of the appropriate company personnel to notify. Please refer to Section E, Emergency Contingency Plan, of this Plan of Operation for more detailed emergency procedures.

5. <u>Proposed Manner of Commerical Utilization, Including Byproducts</u>

Steam produced from the geothermal resource will be used to generate 48 Mw of net electrical power. Two turbine-generators, the 10 Mw (gross) system covered under a previous Plan of Operation, Development, and the 54 Mw (gross) system described above will be integrated to produce a total of 64 Mw of gross electrical power. The 10 Mw (gross) system will require approximately 2.0 Mw for internal system needs, while the 54 Mw (gross) system will require approximately 7.3 Mw for its internal system needs. Net power available from the 10 Mw (gross) turbine-generator will be used to supply power to the production well pumps for the entire integrated system. This demand is currently estimated to be about 6.7 Mw. A generalized drawing of one type of production well pump currently being considered for use is attached as Figure 7.

The 48 Mw of net electrical power will most likely be sold to the Imperial Irrigation District. The District is the public utility which distributes electrical power to the Imperial Valley area. The only byproducts of the power plant will be geothermal fluids separated from the steam. These fluids will be injected into underground formations as described in detail in Republic's Plans of Operation, Utilization and Injection submitted simultaneously with this Plan.

LINESHAFT TURBINE PUMP INSTALLATION

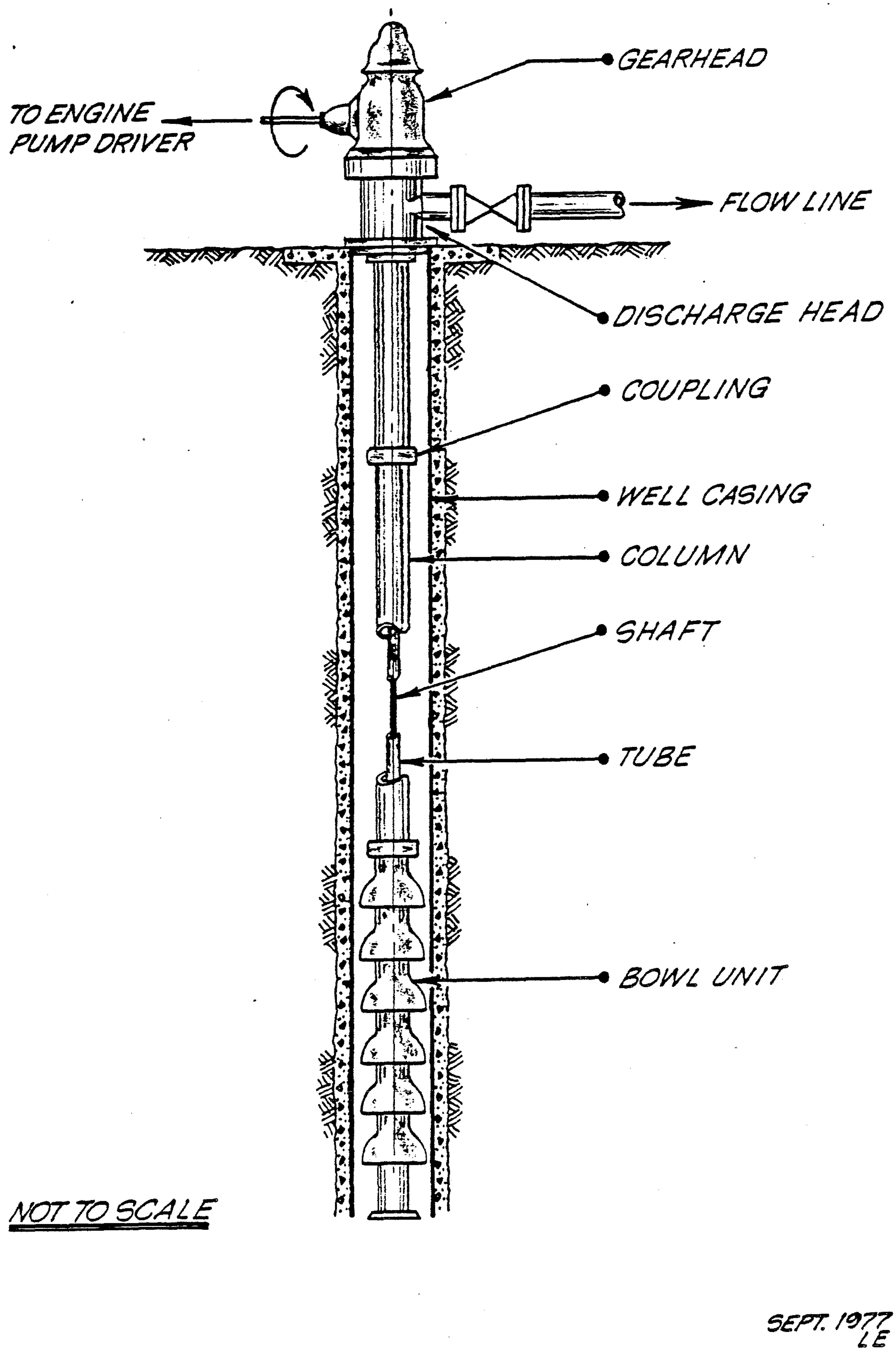

Figure 7

6. Surface Equipment Installations

a. Pipelines

The flowlines used to transport the geothermal fluid from the individual production wells to the power plant separation facilities will be 10, 12, 16 and 24 inch diameter steel pipe. The lines utilized to transport the condensate and waste geothermal fluid from the power plant to the injection wells will be 18 and 24 inch diameter steel pipe. All pipelines will be installed on the surface and routed along roads. The lines will be buried as necessary to cross roads, and will be supported at sufficient intervals with concrete sliding supports to prevent sagging and allow for movement due to expansion. The lines will be anchored at the starting, termination and road crossing points with permanent concrete anchors to prevent pipe movement in these areas. Expansion loops will be installed as necessary (at intervals of approximately one-quarter mile) to prevent mechanical damage to the pipe from thermal expansion. All lines and fittings will be externally insulated to minimize heat loss from the wells to the power plant and for personnel protection on the injection lines. During installation of the pipelines, approximately 20 feet to 25 feet along the side of the roads will be temporarily disturbed. After construction is complete, there will be 5 feet to 10 feet of permanent surface disturbance. The expansion loops are expected to be approximately 35 feet by 65 feet. Please refer to Drawing No. 199-15, Engineering Details, for details of typical pipeline supports, insulation and road crossings.

b. Separators

Four high pressure and four low pressure separators or flash tanks will be installed at the power plant site to separate the steam from the produced fluid. Each separator will handle a maximum of five producing wells. The geothermal fluid from the wells will first enter a high pressure separator. These vessels will be approximately 36 feet tall and 11 feet in diameter and designed to operate at 55 psig. The liquid from this vessel will then go into a low pressure separator for further separation. These vessels will be approximately 28 feet tall, 14 feet in diameter and designed to operate at 16.5 psia. The fluid from the low pressure vessels will then be pumped through a filtration system and injected into underground formations. The steam from the high and low pressure separators will be piped directly into the high and low pressure turbine inlets.

c. Filtration System

The produced fluid, prior to injection underground, will be filtered in order to remove any large undissolved solid particles that may exist. Filtration of the fluid will prevent potential damage or plugging of the injection well formation.

d. Metering Systems

An orifice type meter will be installed on each production well line at the wellhead. This meter will give a continuous permanent record of well flow rate and downhole pump performance. At the power plant inlet, flow meters will be installed to measure the total fluid rate entering the plant. An orifice meter will also be installed on the water injection line leaving the plant to measure total injection volume. Individual injection well meters will be installed at the wellhead to monitor well performance.

e. Electric Transmission Lines

It is proposed that a 161 kV electric transmission line will be built from an electrical switchyard at the power plant site to an existing Imperial Irrigation District (IID) 161 kV line three and one-half miles south of the plant site. Exact locations of the line within lease boundaries is shown on Drawing No. 199-16 (Development and Utilization Plan-48 Mw Power Plant) and outside of lease boundaries on Drawing No. 199-10 (Vicinity Map). It is anticipated that IID will construct this line.

Power for the lineshaft turbine pumps will be supplied by 4160V transmission lines running from the transformer at the power plant site to each production well. The electric transmission lines will be strung on 30-foot tall wooden poles adjacent to the pipelines.

f. Capacities

The flow lines will be designed to handle the maximum expected production from each well at a minimum pressure loss. The current information indicates that individual well production rates will be approximately 65,000 barrels of water per day. The injection wells will handle approximately 110,000 barrels of water each per day. The expected operating pressure of the production lines is 200 psig maximum. All lines will be hydrostatically tested at 1.5 times the expected working pressure. The high pressure steam separators will be designed to handle up to 345,000 barrels of water per day. The low pressure steam separators will be designed to handle up to 315,000 barrels of water per day. The steam turbine driven generator will develop 54 Mw nominal power output with a total input of 550,000 lbs/hr high pressure steam and 995,000 lbs/hr low pressure steam. The liquid injection system for the 48 Mw (net) plant will be designed to handle a total of 970,000 barrels of water per day at approximately 150 psig surface injection pressure.

g. Safety Provisions

All applicable codes and regulations will be utilized during plant construction. All equipment will have protective and shut-down systems designed to prevent damage to equipment or personnel as a result of equipment malfunction. Details of the proposed safety provisions will be contained in subsequent Sundry Notices to be approved by the USGS Area Geothermal Supervisor prior to construction.

7. Proposed Liquid Disposal Program

Republic proposes to inject geothermal fluids produced during testing and production. Wells proposed for use as injection wells are delineated on the attached map, Drawing No. 199-14. Details of proposed injection operations are discussed in Republic's Plan of Operation, Injection.

8. Source of Water Supply and Road Building Material

In accordance with 30 CFR 270.34, water for operations will be supplied by the previously approved well, WW-1, a shallow water well located in the northwest corner of Repbulic's East Mesa maintenance yard.

No road building material will be obtained from federal lands for the access roads. If road building material such as gravel is needed, it will be trucked from outside commercial sources.

9. Additional Information

The following, submitted by Republic Geothermal to the Area Geothermal Supervisor, are incorporated herein and made a part hereof by reference:

a. Plan of Operation, approved as effective September 12, 1975 (EA 12).

b. Supplemental Plan of Operation, approved as effective December 15, 1975 (EA 29).

c. Plan of Operation, approved as effective December 1, 1976 (EA 61).

d. Supplemental Plan of Operation, approved as effective September 16, 1977 (EA 81).

e. Amended Plan of Operation, approved as effective January 17, 1978 (EA 86).

f. Program for Collection of Environmental Baseline Data, Federal Geothermal Leases CA 966, CA 967, and CA 1903, submitted August 31, 1977.

g. Plan of Operation, Development (10 Mw Power Plant), submitted October 26, 1977 (EA 99).

h. Plan of Operation, Injection (10 Mw Power Plant), submitted October 26, 1977 (EA 99).

i. Plan of Utilization (10 Mw Power Plant) submitted November 7, 1977 (EA 100).

C. ENVIRONMENTAL PROTECTION

The following measures will be taken for protection of the environment:

1. Fire

All local, state and federal fire protection standards applicable to Republic's activities will be observed. Vegetation on the lease is sparse and low-level and will be cleared only to the extent needed for proper operation. Smoking will be allowed only in designated areas. Water and fire extinguishers will be available at each site during drilling activities and at a central location during testing and construction activities in the unlikely event a fire should occur.

2. Soil Erosion

Due to the essentially level topography at East Mesa, the infrequent rainfall and the lack of surface water, soil erosion is not anticipated to be a problem. Well location sites, surface facilities and access roads are designed to disturb only the minimum amount of surface necessary for efficient operation. Off-road vehicle use will be prohibited except where necessary. Best efforts will be made to minimize disturbance of the perennial woody vegetation. For the proposed wells, those portions of the drillsite required for the proposed production operations will be covered with gravel to prevent erosion and efforts will be made to revegetate those cleared areas not required after drilling. For pipelines, cleared areas not required after construction and installation will be allowed to revegetate naturally.

3. Pollution of the Surface and Ground Water

a. Surface Water

Surface waters within Republic's East Mesa leasehold are limited to one very short section of the East Highline Canal in the extreme southwestern corner of Lease No. CA 966. The remainder of the area is devoid of obvious stream channels.

The low salinity of the geothermal fluids produced from Republic's East Mesa wells, lease stipulations which restrict drilling within one-quarter mile of the canal, and the distance to the nearest well proposed under this Plan of Operation from the canal all indicate that the proposed development will have no deleterious effect on the quality of water in the East Highline Canal.

b. Ground Water

There are no natural ground water sources such as springs or seeps within Republic's East Mesa leases. The California Regional Water Quality Control Board considers the ground water in the vicinity of Republic's leases saline and not beneficially used.

All of Republic's previously approved Plans of Operation on East Mesa have been conducted under approved Orders No. 76-35 and No. 76-64 (Revised) of the California Regional Water Quality Control Board, Colorado River Basin Region. These Orders have been previously submitted to the USGS-AGS.

The Board has determined that Republic's discharge of geothermal fluids into unlined temporary storage basins is acceptable for fluids with less than 2,300 mg/l of total dissolved solids (TDS). They have approved the discharge of geothermal fluids onto roads and well sites in an amount not to exceed 126,000 gallons per day or 232 acre-feet for the life of the project. This Order also permits the disposal of geothermal waste fluids by subsurface injection into the zone of extraction or into zones which contain a total dissolved solids content that is equal to or greater than that contained in the zone of extraction.

Republic will also protect the area's ground water by complying with the provisions of GRO Order No. 2 or exceptions to this Order as approved by the Area Geothermal Supervisor for East Mesa and the conditions of approval for Republic's Plan of Operation, Injection.

Drilling muds will contain no toxic materials or materials which could contaminate the ground water. All pipelines will be properly constructed and maintained to prevent leakage.

4. <u>Fish and Wildlife</u>

There are no fish in the area. The construction of the proposed well pads and roads will result in some unavoidable permanent destruction of habitat. The proposed production and injection testing will not disturb additional habitat. Construction of the proposed pipelines will result in temporary surface disturbance of approximately twenty to twenty-five feet and permanent surface disturbance of approximately five feet along one side of the approved and existing access roads. No other surface disturbance is anticipated.

Because of the minor amount of habitat disturbance and the homogeneous nature of the vegetation at East Mesa, it is anticipated that this disturbance will not significantly impact the area's wildlife. To help provide replacement habitat, removed vegetation and excess soil shall be stacked in several piles at a reasonable distance from the roads and drillsites. The area temporarily disturbed for construction of the flowlines will be allowed to revegetate.

5. <u>Air and Noise Pollution</u>

a. Air

Air quality should not be significantly degraded during these proposed operations. All operations will be conducted with the approval of the Imperial County Air Pollution Control District. To date, the concentration of the noncondensable gases in the wells drilled at East Mesa has been about 0.64 percent of the vapor phase (less than 0.1% of total produced fluids), and only minute concentrations of hydrogen sulfide have been detected. Because the concentration of these gases is so low and there are no known deleterious constituents in quantities harmful to the environment, Republic does not anticipate that the proposed operations at East Mesa will significantly degrade the existing ambient air quality.

Dust from cleared roads and drillsites shall be suppressed by distribution of geothermal fluids on these areas, as evaluated and approved by the California Regional Water Quality Control Board.

b. Noise

Noise is expected to be of minor concern in the development of Republic's East Mesa geothermal field. Noise levels will be maintained within the limits prescribed by Imperial County, the Bureau of Land Management and the Occupational Safety and Health Administration. Drilling rig engines and compressors will be equipped with mufflers.

Noise impacts on wildlife at East Mesa will probably be minimal because of the relatively low intensity and steady, continuous nature of most of these noise emissions. The East Mesa area itself is also very isolated from any human receptors. The extant ambient noise levels on East Mesa are usually very low, but are frequently punctuated by the sounds of aircraft overflights and explosions from the nearby military gunnery range. Occasional off-road vehicle use of the area also adds to the ambient noise levels.

6. <u>Hazards to Public Health and Safety</u>

Public health and safety shall be ensured through the use of appropriate equipment, operating procedures and notices. Appropriate warning signs will be posted before curves on the access roads and on all pipelines and testing equipment. Each well will be posted with a sign indicating the well name, the designated operator and an emergency phone number. Supervisory personnel will be on-site during drilling and testing operations. All equipment will be secured within a maintenance yard encircled by a chain-link fence when not in use. During testing activities the location pad will be surrounded by a locked chain-link fence. Wells will be chained and locked behind a chain-link enclosure when completed. All drilling shall be conducted in accordance with all state and federal requirements, specifically GRO Order No. 2.

7. Section 270.34 (i) and (j)

a. Methods for Disposal of Waste Material

Waste waters will be disposed of as indicated in Part 3.b. above. Portable chemical sanitary facilities will be used by personnel on the drilling or construction sites. These will be maintained and wastes disposed of by a local contractor. Permanent sanitary facilities will be located at the power plant site after construction is complete.

The site will be kept clean and any trash or debris will be taken to an approved dump. Drilling muds will be neutralized and spread on the surface of existing and/or proposed roads or trucked to a suitable waste disposal site. Republic favors the former method of disposal.

b. Delineation of Potential Environmental Impacts

Republic anticipates that there should be only negligible environmental impacts from these proposed operations over and above those from existing approved operations.

c. Environmental Monitoring and Any Additional Information

Noncondensable gases will be monitored in accordance with the requirements of the Imperial County Air Pollution Control District.

Geothermal fluids will be monitored and disposed of in accordance with the requirements of Orders Nos. 76-35 and 76-64(Revised) of the California Regional Water Quality Control Board, Colorado River Basin Region.

Republic has submitted to the Supervisor a Program for Collection of Environmental Baseline Data for Federal Geothermal Leases CA 966, CA 967, and CA 1903 at East Mesa, in accordance with 270.34 (k).

Republic is prepared to submit, upon notification to do so, any further information not included herein which the Supervisor may require. Republic is also prepared to carry out provisions for monitoring deemed necessary by the Supervisor to ensure compliance with the regulations and to participate in the collection of data concerning the existing air and water quality, noise, seismic and land subsidence activities, and ecological systems in the vicinity of the site.

d. Approximate Crew Size, Probable Type and Location of Housing and Support Facilities

Approximately twelve to fifteen people may be working on the location at any one time during drilling and/or production testing operations. No housing or special support facilities will be required on-site during these operations due to proximity of existing facilities.

D. DISCUSSION OF OTHER ENVIRONMENTAL CONCERNS

The presence of desert buckwheat (Erigonum deserticola) in areas of Republic's East Mesa leases has recently been identified. Although this plant species was not among the 1,700 plant species listed for possible endangered status (Federal Register, June 15, 1976) as provided by the Endangered Species Act of 1973, it is included among more than 3,000 plants nominated by the Smithsonian Institute as a candidate threatened species.

We have been informed that the desert buckwheat is now no longer being considered as a candidate threatened species by the U. S. Fish and Wildlife Service, both because the plant has been found to be more widespread in its distribution and the original threatening action, a proposal for a massive off-road vehicle race course in the middle of the plant's range, has been dropped by the BLM. As there are no plans by the Fish and Wildlife Service to publish a revised listing of candidate species, the desert buckwheat will become a "sensitive" species, one whose status is simply monitored.

Republic proposes to work with the Bureau of Land Management, the U. S. Fish and Wildlife Service, and any other interested parties to determine the actual distribution of desert buckwheat and to determine necessary protection measures, if any. Republic's entire East Mesa leasehold is also being surveyed by qualified botanists as part of Imperial County's Environmental Impact Report for Republic's East Mesa Geothermal Development Project. In any event, Republic expects the operations proposed herein will have a negligible impact on this plant species due to the minor amount of surface disturbance.

E. EMERGENCY CONTINGENCY PLAN

If any emergency develops or is determined to be impending, appropriate control procedures will be initiated. The specific procedures will vary greatly depending on the nature of the problem. Examples of possible emergencies are: a well control problem (well blowing steam, hot water or other well effluent with loss of means to shut in or divert the flow); a spill of geothermal fluid; fire; accidents or injuries; etc. The following measures will be taken:

1. If any injuries have occurred, arrangements will be made to care for the injured party(ies).

   Cal-Com Service Corporation
   496 W. Euclid Road
   El Centro, California 92243
   (714) 352-4434

   First aid supplies will be available at the drill-site during drilling operations as well as at the power plant site during all other operations. At least one person on each crew will be trained in first aid. In addition, copies of Republic's comprehensive booklet, "Safety Begins With You: A Handbook of Safe Industrial Practices and Fundamental First Aid Techniques" will be available at the drillsite and/or plant site.

2. If there is a threat to local residents, the Sheriff will be notified as soon as possible.

   Imperial County Sheriff's Department
   150 S. 9th
   El Centro, California 92243
   (714) 352-3111

3. The Field Production Superintendent will be notified and consulted immediately.

   Carl E. Fisher
   El Centro, California 92243
   (714) 352-3111
   Home: (714) 353-3544

4. The Vice President, Production, will be advised and consulted as soon as practicable.

   Dr. James Barkman
   Vice President, Production
   11823 E. Slauson, Suite One
   Santa Fe Springs, California 90670
   (213) 945-3661

5. Field supervisory personnel will contact the Manager, Operations or Manager, Facilities and consult with him as to any further or supplemental steps which may be necessary or advisable.

   Dr. Robert Nicholson
   Manager, Operations
   11823 E. Slauson, Suite One
   Santa Fe Springs, California 90670
   (213) 945-3661

   Michael J. Walker
   Manager, Facilities
   11823 E. Slauson, Suite One
   Santa Fe Springs, California 90670
   (213) 945-3661

6. The Vice President, Land, will be advised and consulted as soon as practicable. He may consult with Republic's environmental staff.

   Timothy M. Evans
   Vice President, Land
   11823 E. Slauson, Suite One
   Santa Fe Springs, California 90670
   (213) 945-3661

7. All prescribed safety practices and procedures will be followed. All members of the drilling, well testing, construction or field operations crews will perform duties assigned for the specific purpose, following specified safety practices and procedures.

8. Every effort will be made to minimize possible deleterious environmental effects of the emergency and the operations performed to control the emergency.

9. A pump truck will be in the vicinity, and earth moving equipment may be obtained from local contractors, if necessary.

Henry Abeyta
360 W. El Dorado Road
El Centro, California 92243
(714) 352-2545

Ryerson Ditch-Liners
50 East Highway 80
El Centro, California 92243
(714) 352-4341

Merrill Ditch-Liners, Inc.
51 East Highway 80
El Centro, California 92243
(714) 353-0193

10. The Manager, Operations or Manager, Facilities will:

(a) Brief his immediate supervisor (Vice President, Production) on the situation and course of action underway.

Dr. James Barkman
Vice President, Production
11823 E. Slauson, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

(b) Contact the following agencies or regulatory bodies as soon as practicable and in the following order:

U. S. Geological Survey
Conservation Division
Western Region
345 Middlefield Road
Menlo Park, California 94025
(415) 323-8111, Ext. 2845

Bureau of Land Management
1695 Spruce
Riverside, California 92507
(714) 787-1462

(c) If the emergency involves a well control problem or other well operation, he will also notify the following agency:

Department of Conservation
State of California
Division of Oil and Gas
Geothermal Unit
1416 Ninth Street
Sacramento, California 95814
(916) 445-9686

11. The Vice President, Land, or Republic's environmental personnel will notify as soon as possible the following additional state and local agencies as necessary:

California Regional Water Quality Control Board
Colorado River Basin Region
73-271 Highway 111
Suite 21
Palm Desert, California 92260
(714) 346-7491

Imperial County Air Pollution Control District
935 Broadway
El Centro, California 92243
(714) 352-3610

Imperial County Planning Department
Courthouse
El Centro, California 92243
(714) 352-8184

Resources Agency
State of California
Department of Fish and Game
Region No. 5
350 Golden Shore
Long Beach, California 90802
(213) 435-7741

U. S. Fish and Wildlife Service
2800 Cottage Way
Sacramento, California 95825
(916) 484-4657

PLAN OF OPERATION,

INJECTION

Lease Nos. CA 966 and CA 1903
Sec. 25, T15S, R16E; Secs. 19,20,28,29 and 30
T15S, R17E, SB B&M

East Mesa, Imperial County, California

Republic Geothermal, Inc.
11823 East Slauson Avenue, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

Proposal to commence injection operations at Well Nos. 16-19, 54-19, 16-20, 58-24, 54-25 and 58-25 to dispose of geothermal liquids produced during well testing and production activities for a 48 Mw (net) power plant.

Estimated Starting Date: Date of Approval

Estimated Completion Date: Indefinite

REPUBLIC GEOTHERMAL, INC.

PLAN OF OPERATION, INJECTION

48 Mw POWER PLANT

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<u>MAPS</u>

<u>FIGURES</u>

TABLES

REPUBLIC GEOTHERMAL, INC.

PLAN OF OPERATION, INJECTION
UNITED STATES GEOTHERMAL LEASE NOS. CA 966 AND CA 1903
EAST MESA, IMPERIAL COUNTY, CALIFORNIA

A. PROPOSED PLAN OF OPERATION

Republic Geothermal, Inc. proposes herein to commence injection operations on Lease Nos. CA 966 and CA 1903. This Plan of Operation, Injection is submitted in accordance with 30 CFR 270.34 and draft GRO Order No. 5, and covers proposed subsurface injection to dispose of geothermal liquids produced during well testing and production activities for a 48 Mw (net) power plant, to recharge the reservoir, and to minimize the possibility of surface subsidence due to withdrawal of geothermal fluids.

A total of nine injection wells and nineteen production wells are proposed to be dedicated for the power plant. Of these proposed nine injection wells, three were included in Republic's previously submitted Plan of Operation, Injection for a 10 Mw (gross) power plant. Related pipelines, access roads, well testing and production operations, and other surface operations are discussed in Republic's Plan of Operation, Development which is being submitted simultaneously.

Draft GRO Order No. 5 requires duplicate information for the Plan of Operation, Development, and the Plan of Operation, Injection, particularly in regard to injection well location and drilling operations. Republic has followed the outline of necessary information as closely as possible; thus there is some repetition. To avoid confusion, however, Republic requests that 1) the proposed injection well locations and attendant surface facilities (pad construction, roads, pipelines, etc.) be evaluated and approved as part of the Plan of Operation, Development, and 2) the proposed liquid disposal program and subsurface injection operations be evaluated and approved as part of this Plan of Operation, Injection. Republic believes that this request is consistent with the intent and purpose of the separation of the two Plans in draft GRO Order No. 5.

In addition, three alternative power plant sites are shown in this Plan of Operation to provide a perspective of overall development. Details of the power plant operations and site selection are contained in Republic's Plan of Utilization, submitted simultaneously with this Plan in accordance with proposed amendments to 30 CFR, Section 270 and 43 CFR, Part 3208.

B. DETAILS OF PROPOSED PLAN

1. Location and Placement of Proposed Operations

a. Maps

Attached is our Drawing No. 199-10, East Mesa Geothermal Project Vicinity Map, which shows the topography, drainage patterns, cultural features and existing roads and wells. The Vicinity Map also shows existing and proposed transmission lines for informational purposes.

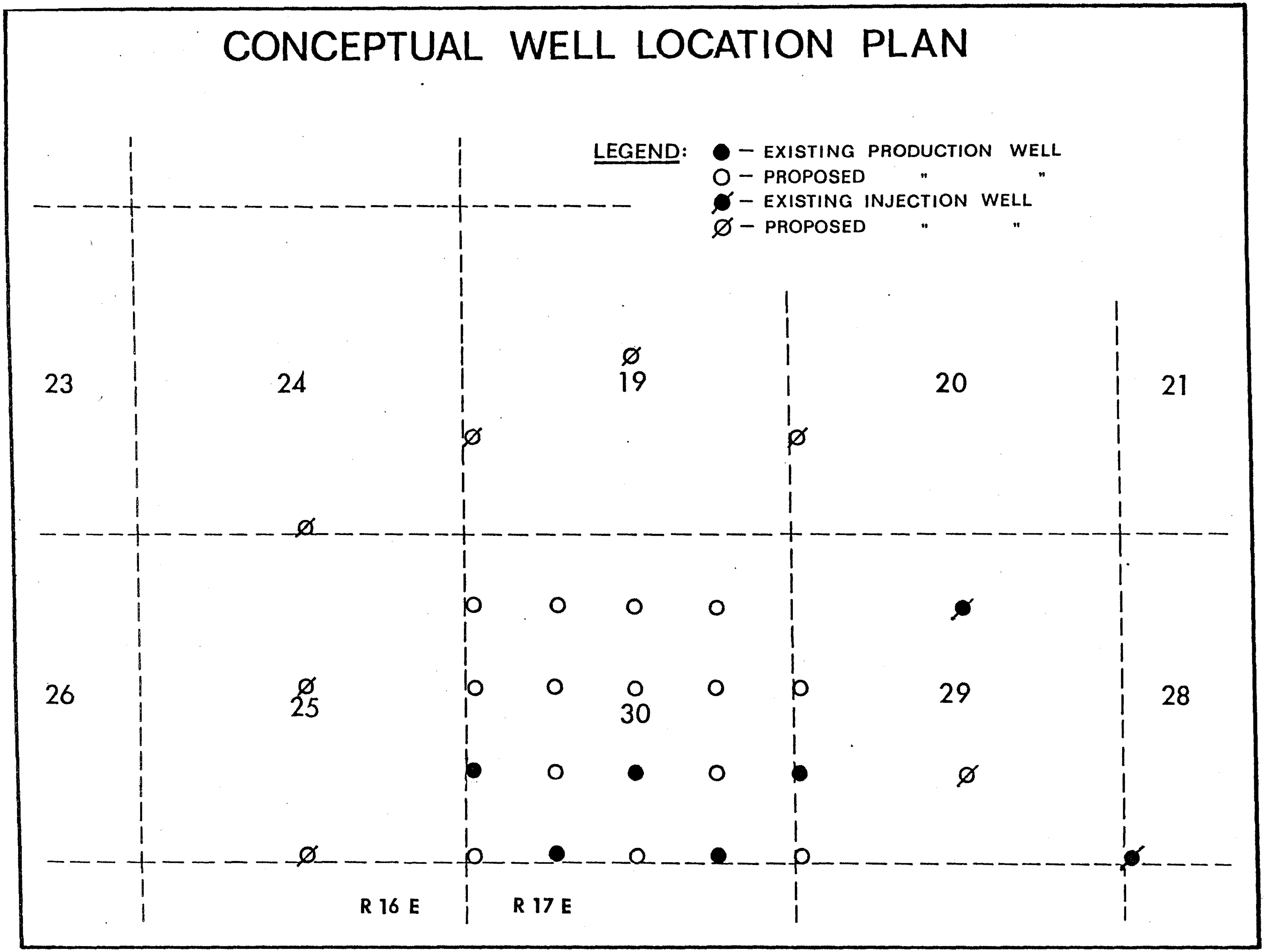
Attached is our Drawing No. 199-12, East Mesa Structure Contour Maps and Structural Cross Section, which displays a sequence of three subsurface structure contour maps and a structural cross section through a part of the East Mesa field.

Attached is our Drawing No. 199-14, East Mesa Geothermal Project, Development and Utilization Plan-48 Mw Power Plant, which shows the proposed location and spacing of wells, existing and proposed access roads, proposed pipelines and electrical transmission line routes and alternative power plant sites.

Attached is our Drawing No. 199-15, East Mesa Geothermal Project, Engineering Details, which shows a typical road cross section, typical pipeline supports, typical pipeline insulation and a typical road crossing.

b. Justification for Proposed Location and Spacing of Wells

The location of the 48 Mw power plant and associated wells must be viewed in relation to the overall resource development plan for justification. Figure 1 shows conceptual well locations for a 48 Mw (net) project having 19 interior producers and 9 peripheral injectors. Sufficient well control and geophysical evidence exists to indicate this is a reasonable minimum interpretation of the project scope.


CONCEPTUAL WELL LOCATION PLAN
LEGEND:
● – EXISTING PRODUCTION WELL
○ – PROPOSED " "
– EXISTING INJECTION WELL
Ø – PROPOSED " "
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24
19
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28
R 16 E
R 17 E

Figure 1

Peripheral injection (Figure 1) into the interval 2,000± to 5,000± feet and production from a central group of producers completed in the interval 5,500± to 7,500± feet is currently considered to be the most advantageous manner in which to develop the East Mesa reservoir. Such a pattern maximizes the time and path of travel of the cooler injected waters between the injectors and producers. The longer the injected water is in contact with the hot reservoir rock, the hotter it will be when it arrives back at the producers. Thus, the life of the resource will be much greater with such a pattern relative to that which would be expected with any interior injection pattern alternative.

Injection into the shallower sands rather than directly into the productive reservoir is also advantageous economically and environmentally. Because the shallower sands have a much higher permeability than those of the reservoir, it should be possible to inject the water from two producers into a single injector using a low surface pressure. Thus, well costs, energy costs (pump power), and surface usage will be minimized relative to a deep interior injection pattern.

Good vertical communication below 2,000± feet is the key to the success of such a shallow peripheral injection plan. Preliminary reservoir simulation work shows that with vertical communication, pressure can be maintained in the interior producing area when aided by a minor amount of aquifer influx. Whether or not the natural influx will ultimately have to be supplemented cannot be determined at this time. Such a determination will require several years of full-scale production experience.

Substantial evidence exists that good vertical communication and hot water influx from depth are present at East Mesa. The convective nature of the temperature profiles below

2,000± feet indicates both vertical communication and water influx. Hot water influx from below the producing interval is also indicated by the silica and alkali chemical equilibrium temperatures of the produced fluids. Well logs and geologic correlations show essentially sand-on-sand contacts throughout the vertical sequence below 2,000± feet. Finally, pressure interference testing by Lawrence Berkeley Laboratories shows that USBR Well Nos. 6-1 and 6-2, and USBR Well No. 31-1 and Republic Well No. 38-30 communicate, even though the completion intervals of each well pair do not overlap vertically.

The foregoing evidences of vertical communication are discussed in more detail in later sections. Additional testing is planned to define and demonstrate further the degree of this communication. The long-term consequences of less than 100 percent replacement of produced fluids, by either injection or natural influx, would be premature decline in reservoir pressure and associated well productivity. Most likely this would be prevented by supplementing the injection from ground water, irrigation water and/or leach canal water sources. Another alternative would be the drilling of supplemental wells, of course. As previously noted, however, such a need is not anticipated at this time and would only become apparent after several years of full-scale operation.

The above discussion is intended to justify the well and plant location concept for overall development. Similarly, well spacing must also be viewed in the context of an overall plan. An acceptable spacing of 40 acres per well as shown on Figure 1 was established with a reservoir simulation study (discussed in more detail in a later section). For this study, the most conservative conditions of "no influx" and "no vertical communication" were assumed. Under these conditions, interior five-spot pattern injection may be required for pressure maintenance.

Results of the 40 acre spacing five-spot simulations show that pressure can easily be maintained, but that some produced fluid temperature decline will be experienced after 12+ years. This is illustrated in Figure 2. While this amount of temperature decline is tolerable and easily compensated for by a few make-up wells, closer spacings which were investigated (i.e., 20 acres and 10 acres per well), resulted in earlier breakthroughs and more precipitous temperature declines. Such closer spacing would require a substantially greater number of make-up wells to sustain a 25 to 30 year plant life. Thus, 40 acres per well spacing has been established as an acceptable spacing in the event that an interior five-spot reinjection pattern must be resorted to in order to maintain pressure.

It should be emphasized that five-spot injection is not the expected mode of operation. Evidence thus far available indicates that the peripheral injection scheme discussed above will be successful, and that production well spacing will be of little importance to efficient development of the resource.

In addition, topographic features, drainage patterns and current land uses were considered in well spacing. The topography at East Mesa is essentially level. Surface water is limited to one short section of the East Highline Canal, and the leases are devoid of obvious stream channels. Land in the area of the proposed development is open space desert. The dominant plant species is that of the creosote bush (Larrea divaricata). Immediately southwest of the southwestern corner of the leasehold is an orange orchard which occupies less than one section of land, in excess of one-half mile from the plant site.

None of the above factors presents an environmental concern which would determine or limit the location of wells or roads within the boundaries of the leases. Thus the wells are spaced at 40 acre intervals for maximum efficiency and utilization of the resource

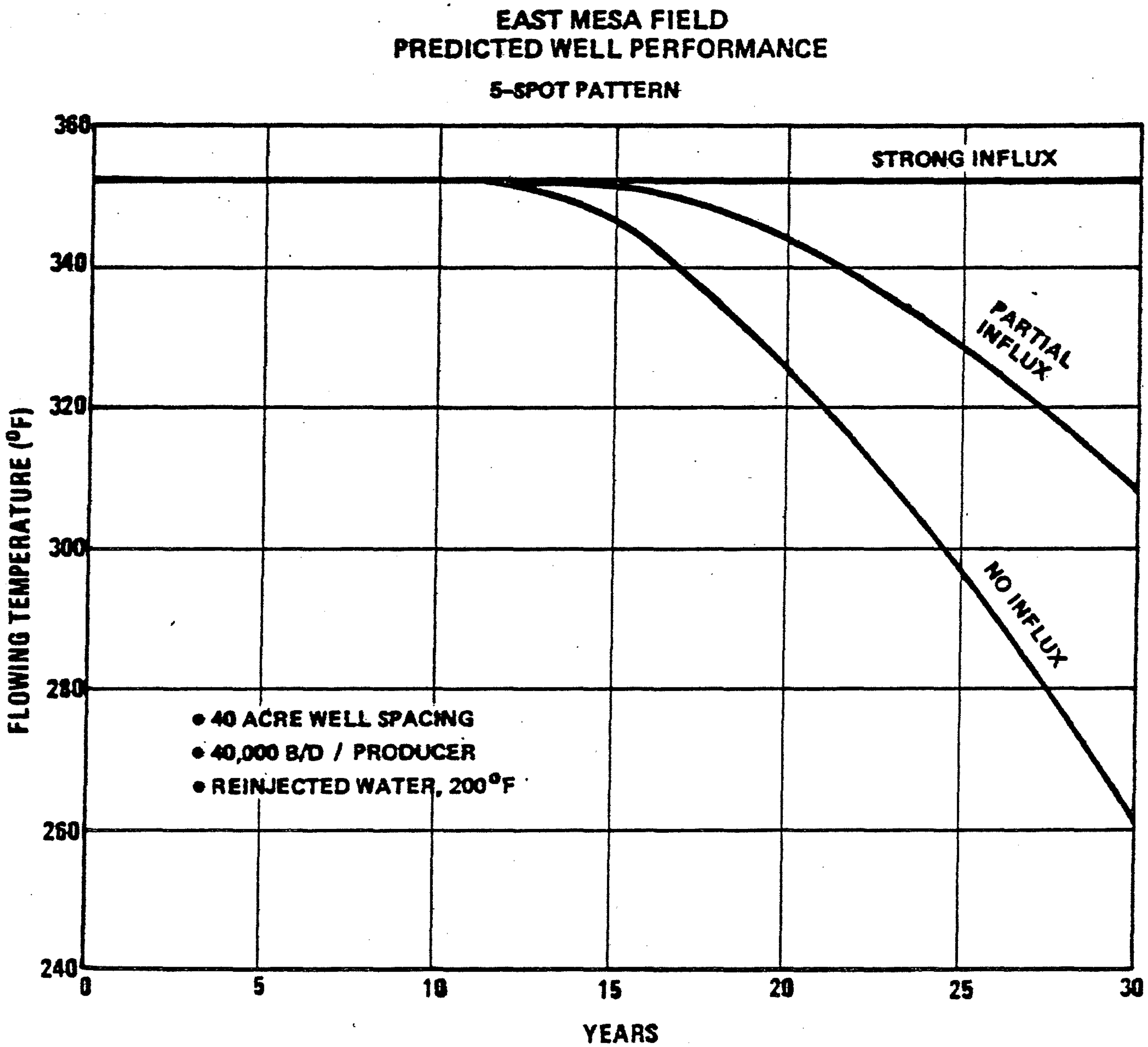
EAST MESA FIELD
PREDICTED WELL PERFORMANCE
5-SPOT PATTERN
STRONG INFLUX
PARTIAL INFLUX
NO INFLUX
• 40 ACRE WELL SPACING
• 40,000 B/D / PRODUCER
• REINJECTED WATER, 200°F
FLOWING TEMPERATURE (°F)
360
340
320
300
280
260
240
0
5
10
15
20
25
30
YEARS

Figure 2

based on the data briefly discussed earlier and described in more detail in a later section.

2. Discussion of Proposed Operations

Republic proposes to dispose of waste geothermal fluids from development and production activities by injecting the fluids into proposed injection Well Nos. 16-19, 54-19, 16-20, 58-24, 54-25, and 58-25. Fluid to be injected will consist primarily of produced fluids from testing of Well Nos. 12-30, 14-30, 18-30, 32-30, 34-30, 38-30, 52-30, 54-30, 58-30, 72-30, 74-30, 78-30, 14-29 and 18-29, and spent liquids produced from these same wells which have been utilized during the operation of the 48 Mw power plant. It is also proposed to interconnect these wells with any well included in Republic's previous Plans of Operation, Injection and Development, following the pipeline system shown on Drawing No. 199-14.

In addition, Republic proposes to use the injection wells for temporary waste disposal of geothermal fluids produced during production testing of exploratory wells in other parts of the leasehold, until such time that sufficient data exist to submit and approve subsequent Plans of Operation, Development and Injection. Republic anticipates the volume of these fluids will be relatively small. Republic also believes this flexibility will encourage the orderly and timely development of the resource.

Republic recognizes that prior to commencing any of the operations mentioned above, specific details must be submitted to the Area Geothermal Supervisor and explicit approval obtained.

3. Resource Data

a. Lithology

Geophysical logs from 16 wells drilled to depths of 4,500-10,000 feet provide a means to understand the subsurface lithology at East Mesa. Optical and X-ray diffraction techniques have been used to examine the available cores and cuttings from these wells.

The stratigraphy at East Mesa is a sedimentary section composed of a lacustrine and deltaic sequence of alternating sandstones, siltstones, and mudstones of Plio-Pleistocene age, covered by a 100-150 foot surficial layer of dune sand deposits. Immediately below these dune sands and above the deltaic sediments is a 1,700-1,900 foot thick lacustrine interval which contains a significant to dominant percentage of clay-rich mudstones, particularly between the depths of 600 feet and 2,000 feet. These mudstones effectively separate the overlying fresh water sands from the more saline waters in the predominantly sandstone-siltstone sediments of the Colorado River delta sequence.

The proposed injection zone is below 2,000 feet, within the deltaic sandstones. Lithologically these sandstones are medium to fine-grained, moderately to moderately-well sorted, and quartz-rich. Detrital clasts include lithic fragments, feldspars, chert, and the usual accessories. Authigenic carbonate and quartz can occur as partial porefilling, replacement and vein materials, particularly at depths below 4,000 feet. Interbedded with the sandstones are more thinly developed siltstone-mudstone lithologies. These finer-grained units progressively change in color and clay mineral content with increasing depth, starting as tan, montmorillonite- and kaolinite-rich units at shallower depths, and becoming gray, illite- and chlorite-rich units at greater depths.

A detailed overall examination of the deltaic sequence as specifically displayed in the relatively closely-spaced Republic wells at East Mesa indicates that singular lithologic units are typically 10 to 60 feet in thickness, that sandstone units are predominant, and that individual units maintain a moderate degree of lateral sedimentologic continuity.

b. Subsurface Maps and Cross Section

The geophysical well logs from six Republic wells and USBR Well No. 31-1 have been examined in detail to provide an interpretation of the existing stratigraphic and structural conditions in the northern part of the East Mesa field.

In addition, the results of a recent Vibroseis reflection seismology program have been reviewed and used to expand the structural interpretation. The Vibroseis data is published in a DOE report titled "Utilization of Seismic Exploration Technology for High Resolution Mapping of a Geothermal Reservoir," by P. L. Goupillaud and J. T. Cherry, April, 1977.

The Plio-Pleistocene deltaic sedimentary rock sequence, present at all depths drilled below 1,800-2,100 feet, contains both the proposed fluid injection zones and the underlying productive geothermal reservoir sands. The top of this deltaic assemblage of sandstones, siltstones and mudstones (shales) is represented by a distinctive and correlative shale-sand horizon which is now designated "A_1". The underlying succession of lithologic units has been correlated from well to well, with 58 specific horizons similarly designated and spaced throughout the total stratigraphic section to a depth of about 7,500 feet.

The attached drawing No. 199-12 displays a sequence of three subsurface structure contour maps and a structural cross section through this part of the East Mesa field. As seen in the east-west cross section, a broad anticlinal axis is present near Republic Well No. 16-30. The western flank of this structure is relatively steep, with dips of as much as 35° observed in USBR Well No. 31-1. The structure dips more gently to the east, with a broad synclinal axis being present between Republic Well Nos. 16-29 and 18-28.

A series of normal growth-type faults traverses the structure. These faults strike NE-SW, dip to the NW, and cause the lithologic units to be vertically displaced by as much as 200-500 feet at depths of about 6,000 feet. Displacement decreases toward shallower depths, as the sequence of growth faults appears to have been generated at a time nearly contemporaneous with deposition of the deltaic units. It is consequently highly unlikely that they create any displacement in the overlying lacustrine beds above a depth of 1,000-1,500 feet.

In addition to the normal faults, two lateral faults are interpreted to be present in this area. These faults appear as a conjugate set, with the NW-SE trending fault probably being the so-called East Mesa fault referred to in recent publications on observed seismicity at East Mesa. There is no known nor suspected evidence of recent activity on any of the other faults in the area.

The combined stratigraphic and structural interpretation indicates that both horizontal and vertical fluid communication exist between the depths of 2,000-7,500 feet in this portion of the East Mesa field. At least four factors have contributed to create this condition. The sand-dominated deltaic depositional environment has provided a primary horizontal stratigraphic continuity, with sufficient cut and fill present to interrupt the thinner shale interbeds. Second, the system of penecontemporaneous normal growth faults has vertically disturbed and dislocated the sediments, thereby increasing the means for vertical fluid communication. Third, the post-depositional folding and doming in this area has undoubtedly promoted the propagation of vertical tensional cracks. Finally, the more recent near vertical lateral faults have further vertically disrupted the dominantly sandstone-siltstone lithologic assemblage.

These lateral faults may actually result in some local reduction in horizontal fluid communication as they develop due to horizontal compression. In contrast, the more prevalent normal faults should be expected to have no noticeable adverse effect on horizontal fluid movement as they are formed in response to a tensional condition present during deposition.

c. Fluid Chemistry

Fluids from Republic's wells completed in the productive interval 5,500± to 7,500± feet at East Mesa average less than 1,900 ppm total dissolved solids (TDS) and less than four ppm of total hardness (calcium). This is the lowest salinity and hardness found in any geothermal field in the Imperial Valley. Furthermore, this water is remarkably free of heavy metals which often cause environmental problems for disposal of geothermal fluids. Somewhat higher salinities have been found in the productive intervals in the central and southern part of the East Mesa field, with a maximum of 26,000 ppm present in the Bureau of Reclamation's Well No. 6-1. Higher salinities are also present in the proposed injection interval 2,000± to 5,000± feet, as evidenced by log analyses and produced water samples from the shallow recompletion interval of Well No. 18-28.

A summary of the produced water analyses data is shown in Table 1 for the three older Republic wells plus the shallow water supply well. The four recently completed wells (Nos. 16-30, 56-30, 78-30 and 52-29), have not yet been flowed sufficiently to yield meaningful samples uncontaminated by drilling mud filtrate. The analyzed fluids from the first three deep geothermal wells are similar and are characterized by low hardness, moderate pH, high bicarbonate, and low TDS. The most notable differences between these waters and the ground water represented by the water

TABLE I

EAST MESA WELL FLUID COMPARISON* (mg/l)

(Unflashed Samples)

Parameter	Production Interval Completions RGI 38-30	RGI 16-29	RGI 18-28	Injection Interval Completion RGI 18-28	RGI (450') Water Well
Total Dissolved Solids	1860	1761	1727	7505	1600
Silica	148.5	149.6	86.5	152.6	10
Iron	0.04	0.04	0.07	164.9	0.1
Calcium	2.1	2.6	3.2	701	68
Magnesium	0.3	0.1	0.2	129.9	19
Sodium	548	506	515	1546	410
Potassium	28	28.5	14.8	123.7	12
Bicarbonate	530	530	537	0.01	76
Carbonate	0	0	0	0	4
Sulfate	150	83	165	139.2	9
Chloride	450	461	401	4386.6	760
Fluoride	2.8	3.3	4.0	0.5	0.5
Arsenic	0.11	0.10	0.10	0.08	N/A
Boron	2.1	3.0	1.7	2.78	0.9
Bromide	0.25	0.17	0.31	0.10	N/A
pH (pH units)	7.7	7.7	8.2		8.3

* Other wells 16-30, 56-30, 78-30, and 52-29 have yet to produce sufficient fluids to be uncontaminated by drilling mud filtrate.

well analysis are the lower bicarbonate, flouride and boron content of the ground water.

The water analysis from Well No. 18-28 after recompletion in the proposed injection interval has more dissolved solids and relatively more chloride than the other waters. The low pH, high iron and high Cl/Na ratio suggest the sample is still contaminated by acid completion fluids. Contamination is no more than one part in seventy-five; however, since the excess Cl over Na (2,000$\pm$ ppm) would have come from acid completion fluids holding about 150,000 ppm. Thus, the relatively high Ca, Mg and Na suggest the presence of evaporites in the recompletion interval.

Only the marginally high TDS, arsenic, flouride and boron contents prevent the geothermal water from being suitable for agriculture, livestock and human consumption. Therefore, the risk of accidental harm to the surrounding ecosystem from water spillage is minimal. However, no surface use is contemplated at this time since it is planned that all the water, with the exception of that needed for cooling water, will be returned to the reservoir by injection. The analysis of production interval fluids on Table 1 is for water without steam flash, and it is nearly representative of the residual plant waters which will be injected. The anticipated differences are those associated with the evaporation losses which will occur in the plant processing. It is notable that the produced geothermal fluids which will be injected into the shallow peripheral interval are actually of lower salinity than those in the injection interval.

A chemical analysis of the flashed steam from Well No. 16-29 is shown in Table 2. The noncondensables are only 0.64 weight percent of the steam and consist primarily of carbon dioxide. Only minute concentrations of

TABLE 2

CHEMICAL ANALYSIS OF
FLASHED STEAM - REPUBLIC WELL NO. 16-29

Total Noncondensables	-	0.64 wt. % of steam
Constitutents		
Carbon dioxide	-	91.4 vol. % of noncondensables
Nitrogen	-	4.3
Methane	-	3.9
Alkanes	-	0.4
Hydrogen sulfide	-	None detected

hydrogen sulfide have yet been detected in the steam. There are two major implications of this analysis. The first is that any possible environmental problems associated with flashing to the atmosphere are negligible. The second is that the low level of noncondensables makes it feasible to utilize a flashed steam process to drive the power plant turbines.

d. Reservoir Properties

(1) Analyses of the geophysical well logs from Republic Well Nos. 38-30, 16-29 and 18-28 have been completed. Analyses of logs from the more recently completed wells (Nos. 16-30, 56-30, 78-30 and 52-29) are currently underway. The principal results of the completed analyses were a determination of porosity, permeability, salinity and net sand present at each well location versus depth. The permeability-porosity-log relationships are calibrated with core data from USBR Well No. 5-1. An improved relation may be possible when lab results from recent tests on the core from Republic Well No. 78-30 are considered.

Tables 3, 4 and 5 provide a summary of the individual well data for each 250-foot increment of depth. These data generally show an excellent amount of sand development in the wells, with a gradual decrease in reservoir properties and salinity with depth. The porosity, net sand and permeability in the producing interval, 5,500± to 7,500± feet, are sufficiently high to permit large flow rates with relatively minor pressure drawdowns. The validity of these calculations has been confirmed by both pressure buildup analyses and by interference testing, as discussed later.

TABLE 3

REPUBLIC GEOTHERMAL WELL NO. 38-30

ZONE SUMMARIES

Interval	Thickness (ft) Gross	Thickness (ft) Net Sand	% Sand	$\bar{\phi}$	Permeability (md) $\bar{k}$ Arith	Permeability (md) $\bar{k}$ Geo	Salinity * ppm NaCl
1350-1500	151	125	83	.35	1174	913	8,216
1501-1750	250	223	89	.34	1023	757	8,091
1751-2000	250	140	56	.32	756	456	10,317
2001-2250	250	155	62	.34	1064	721	10,237
2251-2500	250	166	66	.31	573	321	10,818
2501-2750	250	161	64	.31	467	256	10,113
2751-3000	250	214	86	.36	1645	1315	7,500
3001-3250	250	214	86	.33	897	534	8,043
3251-3500	250	171	68	.28	149	102	7,585
3501-3750	250	181	72	.29	322	134	6,556
3751-4000	250	166	66	.31	473	243	5,569
4001-4250	250	111	44	.31	714	286	6,117
4251-4500	250	145	58	.29	263	148	5,471
4501-4750	250	195	78	.30	432	186	3,006
4751-5000	250	189	76	.28	367	115	3,223
5001-5250	250	162	81	.30	595	205	3,029

* Produced fluid salinity 1860 ppm from the interval 6383' to 8898'

TABLE 3
(Continued)
REPUBLIC GEOTHERMAL WELL NO. 38-30
ZONE SUMMARIES

	Thickness (ft)				Permeability (md)		Salinity *
Interval	Gross	Net Sand	% Sand	$\bar{\phi}$	$\bar{k}$ Arith	$\bar{k}$ Geo	ppm NaCl
5251-5500	250	210	84	.30	570	187	2,564
5501-5750	250	201	80	.23	101	22	2,508
5751-6000	250	162	65	.23	63	23	3,250
6001-6250	250	183	73	.28	312	90	2,834
6251-6500	250	227	91	.31	645	266	2,134
6501-6750	250	219	88	.31	826	229	2,670
6751-7000	250	153	61	.25	287	36	3,318
7001-7250	250	76	30	.16	9	2	4,140
7251-7500	250	86	34	.19	17	6	5,814
7501-7700	200	115	58	.18	14	5	4,428
7701-8000	300	122	41	.22	106	18	3,915
8001-8250	250	93	37	.11	1.5	.6	4,378
8251-8500	250	111	44	.10	.9	.4	No Data
8501-8750	250	63	25	.11	16	.6	1,199
8751-8900	150	26	17	.07	.2	.1	No Data

* Produced fluid salinity 1860 ppm from the interval 6383' to 8898'

TABLE 4

REPUBLIC GEOTHERMAL WELL NO. 16-29
ZONE SUMMARIES

	Thickness (ft)				Permeability (md)		Salinity *
Interval	Gross	Net Sand	% Sand	$\bar{\phi}$	$\bar{k}$ Arith	$\bar{k}$ Geo	ppm NaCl
4800-5000		175	70	.26	190	54	No Data
5001-5250	250	182	73	.25	130	43	
5251-5500	250	181	72	.22	56	18	
5501-5750	250	206	82	.22	33	15	
5751-5925	174	125	72	.22	81	16	
5926-6000	74	52	21	.27	140	64	
6001-6250	250	211	84	.25	112	44	
6251-6500	250	219	88	.27	263	78	
6501-6750	250	175	70	.25	95	39	
6751-7000	250	163	65	.19	16	6	
7001-7050	50	3	6	.14	2	1	
7051-7250	200	40	20	.14	32	1	
7251-7500	250	143	57	.22	37	13	
7501-7750	250	155	62	.21	54	11	
7751-7900	150	90	60	.22	34	16	

* Produced fluid salinity 1761 ppm from the interval 6413' to 7996'

TABLE 5

REPUBLIC GEOTHERMAL WELL NO. 18-28
ZONE SUMMARIES

	Thickness (ft)				Permeability (md)		Salinity *
Interval	Gross	Net Sand	% Sand	$\bar{\Phi}$	$\bar{k}$ Arith	$\bar{k}$ Geo	ppm NaCl
5100-5250	250	88	35	.25	306	34	No Data
5251-5500	250	226	90	.29	458	146	
5501-5750	250	226	90	.29	658	134	
5751-6000	250	193	77	.29	529	136	
6001-6250	250	183	73	.22	42	15	
6251-6400	150	59	39	.23	86	18	
6401-6500	100	28	28	.22	30	17	
6501-6750	250	202	81	.22	29	16	
6751-7000	250	136	54	.22	127	18	
7001-7250	250	84	34	.23	213	24	
7251-7500	250	94	38	.27	994	85	
7501-7750	250	92	36	.22	198	13	
7751-7900	150	55	37	.15	2	2	

* Produced fluid salinity 1727 ppm from the interval 6413' to 7996'
* Produced fluid salinity 7505 ppm from the interval 2851' to 4476'

Note that the permeabilities in the proposed injection interval, 2,000± to 5,000± feet (Table 3), are relatively much higher than those of the productive interval. This should allow high-volume shallow injection at low pressures as previously noted. The higher salinity of the water in the injection interval relative to the salinity in the productive interval provides assurance that injection will not degrade the shallow zone waters. Contamination of the ground water above 1,000± feet will be prevented by the "shale barrier" between 600± and 2,000± feet (discussed previously in the lithology section) coupled with an adequate injection well leak monitoring system.

(2) Temperatures

The temperatures measured in each well versus depth are illustrated in Figures 3 and 4. Well Nos. 38-30, 16-29 and 18-28 have been flowed and surveyed sufficiently during the 2± years since completion to be assured that the data represents true static temperature profiles. The data from the recently completed wells (Nos. 16-30, 56-30 and 78-30), however, were taken shortly after drilling and are undoubtedly at less than equilibrium temperatures. Well No. 52-29 has yet to be surveyed.

Note the increase in slope present in all the wells except Well No. 18-28 in the interval 2,500± to 3,500± feet. This is indicative of convective vertical fluid flow in the reservoir and hot water influx from depth. In general, the temperature in the productive interval (5,500± t0 7,500± feet) may be seen to range between 320°F and 360°F, while the range in the proposed injection interval (2,000± to 5,000± feet) is between 235°F and 310°F.

EQUILIBRATED STATIC TEMPERATURE SURVEYS,
EAST MESA WELLS

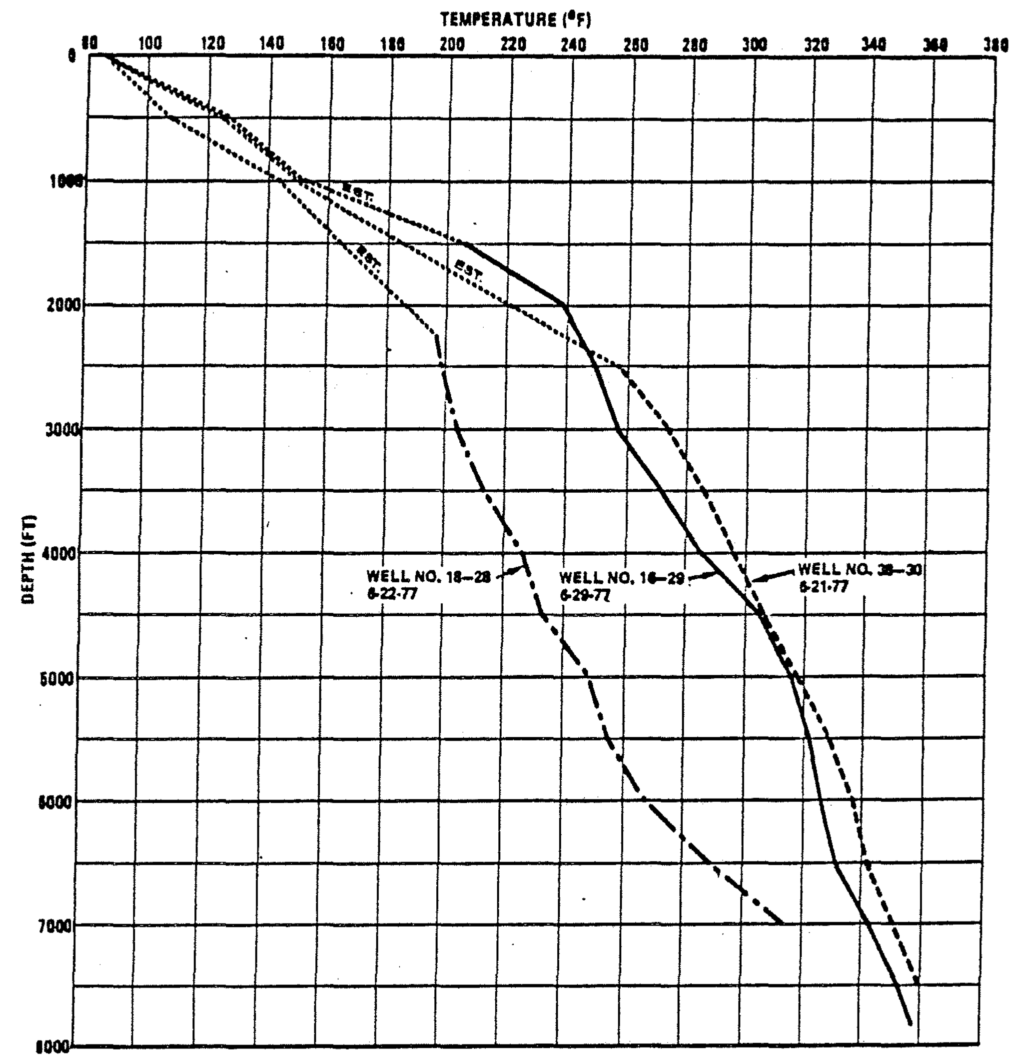

Figure 3

PRELIMINARY STATIC TEMPERATURE SURVEYS
EAST MESA WELLS

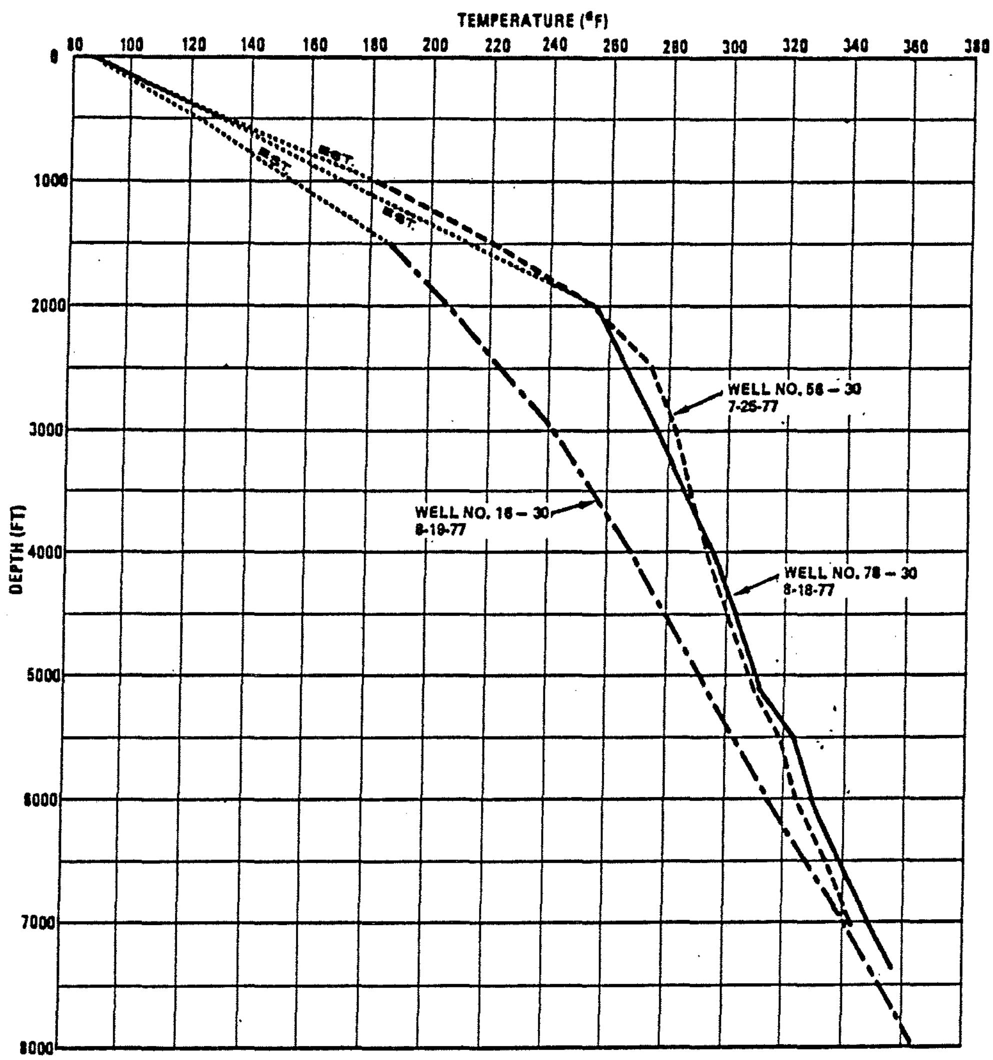

Figure 4

Minimum bottom-hole flowing temperatures (above the completion interval) of 338°F and 332°F have been established in Well Nos. 38-30 and 16-29, respectively, during short-term flow tests. These values are very important in that they represent the volumetric average temperature of the producing interval. Such data has not yet been obtained during long-term production tests, but the values can be expected to be higher, if anything, in the future. At low production rates, it may take many months for the surface produced fluid temperatures to approach the downhole flowing temperatures due to well bore heat losses. At the expected pumped rates of 850,000$\pm$ lb_m/hr (rates expected of East Mesa producers being pumped), however, preliminary calculations indicate "equilibration" between bottom-hole and surface temperatures will occur within a few days.

(3) Pressures

Bottom-hole pressure drawdown and buildup tests were run in Well Nos. 38-30, 16-29 and 18-28. The more recent wells (Nos. 16-30, 56-30, 78-30 and 52-29), have been, thus far, only short-term production tested without bottom-hole instrumentation. The data were analyzed using conventional Horner plot, Miller-Dyes-Hutchinson and superposition techniques to estimate the permeability-thickness (kh) of the producing interval, and to determine if formation damage exists around the well bore. In addition, an indication of boundaries was sought, which could be combined with geophysical, petrophysical and other data to help delineate the East Mesa reservoir. A tabulation of the input data and principal results obtained from the buildup analyses are given in Table 6.

TABLE 6

PRESSURE BUILDUP DATA AND RESULTS

Test Data	RGI WELLS 18-28	16-29	38-30
Flow duration, hrs	21.5	5.53	5.47
Shut-in time, hrs	9.3	22.40	24.39
Cumulative production STB	1,264 (1)	4,525	5,907
Last rate before shut-in, STB/D	2,517	19,668	25,462
Producing time, hrs	17.05	5.902	6.097
Reservoir and Fluid Property Data			
Water viscosity, μ	0.210	0.185	0.185
Water FVF, RB/STB	1.078	1.085	1.088
Porosity, fraction	0.220	0.223	0.249
Total compressibility, psi^{-1}	7.570×10^{-6}	7.904×10^{-6}	8.202×10^{-6}
Well bore radius, ft	0.375	0.443	0.510
Estimated net thickness, ft	77	827	499
Perforated intervals, ft	6105-6210 6440-8000 (2)	6413-6984 7231-7996	6383-7022 (3) 7271-7485 7869-7998 8297-8384 8640-8898
Results			
Average permeability, md	81.94	41.96	83.50
Flow capacity, md-ft	6,309	34,698	41,666
Formage damage (skin)	-0.91	-2.28	-2.81
Distance to nearest boundary, ft	451	893	692

(1) Estimated
(2) Spinner survey showed no fluid entry
(3) Fill to 7022'

Lawrence Berkeley Laboratory has also conducted a series of interference tests between various pairs of wells in the field. A summary of the permeability and permeability-thickness data calculated by three methods (i.e., log analysis, pressure buildup and interference testing) is given in Table 7, along with the maximum observed flow rates. Well No. 38-30 has a buildup permeability of 84 md, which is the highest of any well in the group. The permeability of 42 md found in Well No. 16-29, yields an average 63± md for this area. The highest permeability USBR well is No. 31-1 (30 md), located immediately adjacent to the Republic leases. The interference kh between Republic's Well No. 38-30 and the USBR Well No. 31-1 is 29.8 Darcy-feet, which is in excellent agreement with the average buildup kh of 32.3 Darcy-feet between the two wells.

More recent Lawrence Berkeley Laboratory/ Republic Geothermal interference and drawdown/falloff pressure testing involving all Republic wells except Well No. 52-29 is still being analyzed. Some very preliminary results are summarized in Table 8. These data generally confirm earlier interpretations, but indicate the presence of partially sealing barriers between some wells.

Static reservoir pressures are approximately hydrostatic plus 75± psig. For example, the static pressure in Well No. 38-30 at 6,100 feet is 2,576± psig. (The average hydrostatic gradient at Well No. 38-30 temperature conditions is 0.41 psi/ft; 6,100 ft. x 0.41 psi/ft = 2,501 psig; 2,501 psig + 75 psig 2,576 psig.) Because of the incremental 75± psig over hydrostatic, shut-in wellhead pressures

TABLE 7

COMPARISON OF PERMEABILITY AND FLOW CAPACITY OF EAST MESA WELLS

Well	Max. observed flow rate, B/D	Avg. Permeability from buildup (md)	Permeability-Thickness (Darcy-ft) Buildup	Permeability-Thickness (Darcy-ft) Logs
Republic Geothermal				
38-30	50,300	84	41.7	44
16-29	31,400	42	34.7	30
18-28	15,600	82	6.3	14
Bureau of Reclamation				
31-1	21,200	30	22.2	N/A

Lawrence Berkeley Laboratory Interference Results:

38-30 and 31-1 pair: kh = 29.8 Darcy-ft

TABLE 8

PRELIMINARY EAST MESA INTERFERENCE TEST RESULTS

(July-October 1977)

Well	Test 1 38-30 Flowing kh(md-ft)	 $\phi c h r_e^2$(ft/psi)	Test 2 16-29 Flowing kh(md-ft)	 $\phi c h r_e^2$(ft/psi)	Test 3 38-30 Pumping kh(md-ft)	 $\phi c h r_e^2$(ft/psi)
38-30	24,800	1.36×10^{-3}	--	--	--	--
56-30	26,300	4.5×10^{-4}	To Be Analyzed		23,600	7.89×10^{-4}
31-1	35,400	2.07×10^{-3}	To Be Analyzed		31,700	2.4×10^{-3}
16-29	21,800	2.36×10^{-3}	--	--	--	--
78-30	--	--	--	--	10,400	6.68×10^{-3}
16-30	No Response		No Response		No Response	

are positive an equivalent amount. Artesian flow of the wells is thus possible even in the absence of steam flash.

In summary, it is important to note the good agreement between all three methods of measuring reservoir productive properties, as well as their correlation with maximum observed flow rates. This lends additional credibility to applying the permeability calculation results to the reservoir performance model and to the well performance predictions.

e. Production/Injection Experience

A summary of key well data and available initial production test data is given in Table 9. The four recently completed wells (Nos. 16-30, 56-30, 78-30 and 52-29) have been flowed only a few hours to clean out drilling fluid. Preliminarily, it can be stated that Well Nos. 56-30 and 78-30 perform as well as or better than Well No. 38-30, and Well No. 16-30 appears to be similar to Well No. 16-29. Well No. 52-29, the first well actually drilled as a shallow peripheral injector, is too cool to be a producer but exhibits excellent productivity during repeated cleanout flows and should be an excellent injector. Data from recent long-term tests of Well Nos. 38-30 and 16-29 are summarized in Tables 10 and 11.

The highest natural flow rate from the productive interval measured thus far was 670,000 lb_m/hr (760,000$\pm$ lb_m/hr including steam flash) while flowing Well No. 38-30 directly into the storage basin. During the more recent long-term testing, this well demonstrated a sustained natural flow capability of about 420,000 lb_m/hr against 30$\pm$ psig backpressure with only a 200$\pm$ psi bottom-hole drawdown. Subsequently, the well was pumped

TABLE 9

EAST MESA WELL DATA

Well	T.D.	Est. Temp. @ T.D.	Flowing Downhole Temp. (2)	Maximum Observed Flow Rate lb_m/hr	Maximum Observed Flow Rate 10^6 BTU/day	Completion Date
38-30	9009'	387°F (1)	338°F	670,000 (3)	5,000	10/75
16-29	7998'	361°F	332°F	419,000 (3)	3,060	12/75
18-28	8001'	346°F	310°F (est.)	208,000 (3)	1,400	1/76
16-30	8000'	364°F (4)	N/A	N/A	N/A	7/77
56-30	7520'	352°F (4)	N/A	N/A	N/A	6/77
78-30	7442'	358°F (4)	N/A	N/A	N/A	8/77
52-29	4524'	N/A	N/A	1,100,000	N/A	1/78

(1) Fill at 7022' (351°F)

(2) Above producing interval

(3) Liquid rate only. Vapor phase (12±%) not measured.

(4) Preliminary (non-equilabrated) measurements.

TABLE 10

EAST MESA 38-30 PRODUCTION TESTING PERFORMANCE SUMMARY

Step Rate Test (7/14/77 - 7/26/77)

Estimated Sustainable Natural Flow Rate	= 420 Mlb_m/hr
Cumulative Production During Test	= 27.3 MMlbs
Estimated Preflash Liquid Surface Temperature	= 340° F
Power Output Potential (Natural Flow)	= 2.0 $Mw_{(e)}$

Pumping Test (8/22/77 - 10/5/77)

Maximum Rate Pumped (During Test)	= 505 Mlb_m/hr
Cumulative Production (During Test)	= 196 MMlbs
Estimated Preflash Liquid Surface Temperature (At Maximum Rate)	= 340° F
Gross Power Output Achieved During Test	= 2.4 $Mw_{(e)}$
Net Power Output Achieved During Test	= 2.15 $Mw_{(e)}$
Pumped Rate Potential (using larger 12 HXH pump & column)	= 920 Mlb_m/hr
Gross Power Output Potential (@340° F)	= 4.4 $Mw_{(e)}$
Net Power Output Potential (@340° F)	= 4.0 $Mw_{(e)}$

TABLE 11

EAST MESA 16-29 PRODUCTION TESTING PERFORMANCE SUMMARY

Step Rate Test (7/26/77 - 8/3/77)

Estimated Sustainable Natural Flow Rate	= 340 Mlb_m/hr
Cumulative Production During Test	= 20.1 MM lbs
Calculated Preflash Liquid Surface Temperature*	= 330° F
Power Output (Natural Flow)	= 1.4 $Mw_{(e)}$
Estimated Preflash Liquid Surface Temperature after repair of lap	= 340° F
Potential Power Output** (Natural flow)	= 2.0 $Mw_{(e)}$

* Well had cold water influx at liner/intermediate casing lap.

** Includes estimated 25% $\pm$ increase in flow rate due to higher temperature and therefore lower flash point and higher drawdown.

continuously for more than 30 days using a line-shaft turbine pump set at 420± feet. The maximum rate of about 505,000 lb_m/hr attained during pumping was limited due to the disposal system capacity.

Well No. 16-29 flowed to the basin at a maximum rate of 419,000 lb_m/hr (475,000± lb_m/hr including steam flash). A sustained natural flow capability of about 340,000 lb_m/hr against 30 psig backpressure was achieved in the more recent tests. Continuous pressure/temperature profiles, observed during flow with experimental instruments from Denver Research Institute, suggested that cold water influx at the intermediate casing shoe was occurring. This was subsequently confirmed and a remedial cement squeeze job was performed. Upon returning the well to long-term production tests, it became apparent that near well bore formation damage had occurred during the squeeze job. Stimulation work is now underway on the well.

Two high volume line-shaft turbine pumps designed for 1,000± foot setting depths are currently on order and should be ready for testing by May, 1978. It is anticipated that the producers will be capable of 800,000 to 900,000 lb_m/hr each when equipped with such pumps.

Well No. 18-28 was found to be on the flank of the thermal anomaly and is too cold to be an economic producer. It was capable of only 208,000 lb_m/hr artesian flow and was ultimately converted to injection service. During the recent long-term testing of Well Nos. 38-30 and 16-29, it was possible to inject about 300,000 lb_m/hr at 400 psig wellhead pressure on a sustained basis into Well No. 18-28. Initial plugging problems were overcome by acid treatment and installation of finer filters (10μ rather than 50μ) to prevent suspended $CaCO_3$ precipitates from entering the well bore.

Profile surveys showed that less than 200 feet of the 1,800 feet of perforations open in Well No. 18-28 were actually taking fluid. Presumably this was due to an inability to flow the well at high enough rates to remove the initial drilling mud wallcake. Recently, the well was plugged back and jet perforated over 1,215 feet of the shallow injection zone.

It is anticipated that the injectors will be able to handle the residual waters at very low wellhead injection pressures due to the high permeability sands present in the 2,000± to 5,000± foot injection zone.

4. Representative Injection Well Drilling Program

a. Zone of Completion

Injection wells will be completed in the sequence of alternating deltaic sandstones, siltstones and mudstones described above in Section 3.b., Resource Data. The completion interval will be from approximately 2,000 feet to 5,000 feet (all depths referenced to Kelly Bushing), which averages approximately 52 feet above mean sea level.

b. Casing and Cementing Program

The casing program will be one of the following:

	Depth	Program 1	Program 2
Conductor	90'	20"	24"
Surface Casing	2000'	13-3/8"	16"
Injection Liner	5000'	9-5/8"	11-3/4"

The two casing size programs are proposed since the injectivities are not yet adequately known. The larger program may be necessary to reach the necessary injection rates. Details of the two casing programs are presented in the attached table.

The wellhead for Program 1 will consist of a 13-3/8" S.O.W. x 12" - 400# RTJ Model SU casing head with two 2" flanged side outlets; one 12" -600# ANSI series manual gate valve with 400# RF flanges; a 12" tee with 400# RTJ flanges; a 6" - 400# RTJ flanged crown valve and two 12" series 400# manual gate valves for the wing valves. The wellhead for Program 2 will be a 16" S.O.W. x 16" - 400# RTJ casing head with a 16" - 400# RTJ adapter flange. All other equipment is as above.

The surface casing will be cemented to the surface using API class "G" cement mixed 1:1 with Perlite plus 2% gel and 35% silica flour. The slurry density will be 95#/ft^3. A tail slurry of 200 sacks of class "G" cement with 35% silica flour with a density of 117#/ft^3 will be used for additional strength around the casing shoe. After waiting on cement for eight hours, the casing will be slacked off and the casing pressure tested to 100 psi for 30 minutes.

c. Mud Program

The mud program from surface to TD will be lightweight (8.8-9.2 PPG), low solids, fresh water, clay base drilling fluid treated with lignite for temperature stability, and bicarbonate of soda for cement combination. Desanders and desilters will be run in order to keep the solids as low as possible. A cooling tower will be installed in the mud system and the mud pumped through this cooling tower when the return mud temperature exceeds 160°F (71.1°C).

d. Safety Provisions

After setting surface casing, an API class 3,000 psi double hydraulic pipe and blind ram blowout preventer will be installed above a 12" gate valve with 400# RTJ flanges which will be just above the casing head. On those wells drilled with the large casing program, a single blind ram will be installed instead of the 12" gate valve. The casing head will have two side outlets with two flanged valves on each outlet. One side will be connected to the rig choke manifold, the other side will be connected to a pumping unit as a kill line with a back pressure valve in the line for pumping into the well, if necessary. A fill-up line will be installed above the BOP equipment so that the hole can be filled during trips, and the amount of fluid pumped into the well while tripping will be monitored. The hydraulic control unit for the BOP equipment will have two operating stations, one on the rig floor and one at least 50 feet from the wellhead. At all times the mud flow line temperature and the mud pit level will be monitored. A pit level warning device will be installed. Gases in the mud return will be monitored. Special provisions for handling hydrogen sulfide are not planned since hydrogen sulfide has not been encountered in any exploration and delineation wells at the East Mesa KGRA.

The BOP equipment will be pressure tested to 1,000 psi when installed and at least once every seven days thereafter. This will include testing of all drill string back pressure valves, full opening valves, standpipe and choke manifold.

A drill string back pressure valve along with a full opening safety valve will be maintained on the rig floor with adequate subs to fit all connections in the drill string.

Each drilling crew will be instructed in blowout control procedures and the contractor will be required to have at least one pit drill per crew per week.

In the event of an emergency, the drilling contractor will have the names and telephone numbers of the appropriate company personnel to notify. Please refer to Section E, Emergency Contingency Plan, of this Plan of Operation for more detailed emergency procedures.

5. Proposed Downhole and Surface Injection Equipment

No downhole injection equipment is proposed beyond that described in Section B-4 above.

The surface injection equipment will consist of seven pumps designed to handle a total of approximately 970,000 barrels of water per day at 200 psig discharge pressure. A filtration system may be installed if necessary to remove undissolved solids from the fluid prior to injection in order to maintain adequate injectivity. A total plant discharge meter as well as individual well meters will be installed to monitor total flow rates as well as individual well performance. Injection lines will be installed on the surface along existing roads from the power plant to the injection wells. The injection lines will be 18 and 24 inches in diameter, designed to operate at 200 psig and tested to 1.5 times this normal expected operating pressure. All injection lines will be externally insulated in order to provide protection to personnel and animals. Expansion loops will be installed as necessary to prevent mechanical damage to the pipe from thermal expansion. Please refer to Drawing No. 199-14 for approximate location of expansion loops. The injection lines will be permanently anchored at the plant, at the wells, and at all road crossings to prevent pipe movement. Block valves and check valves will be installed at the plant and at the wellheads to provide adequate shut-in capability for the wells. The injection pumps will be provided with high and low pressure sensors to turn the pumps off in case of malfunction or line rupture. Please refer to Drawing No. 199-15 for details of typical pipeline supports, insulation and road crossings.

6. Proposed Injection Well Surveys

Injection well surveys will be run routinely to detect major changes in injection profiles. Additional surveys will be run as needed, especially when significant changes occur in the injection rate or pressure. A routine survey will be run on each injector within one month of the beginning of injection and once annually thereafter. The most effective types of surveys for this purpose are the spinner survey, the radioactive tracer survey and the shut-in temperature/differential temperature survey. A selection of one of these will be made consistent with specific well conditions and with minimum disruption of field operations. The normal survey interval will be from the surface to the bottom of the deepest major injection interval.

7. Hydrology of the Area

a. Surface Water

Republic's East Mesa leases are devoid of any obvious stream channels. Surface water is presently confined within the one-half mile section of the East Highline Canal located in the extreme southwestern portion of Lease No. CA 966. The East Highline Canal flows northward and contains water diverted from the Colorado River via the All American Canal. Irrigated farmlands lie to the west of the Canal, covering almost all of the Imperial Valley. To the east of the Canal is the East Mesa, which is essentially desert with only a few dry washes active only after heavy rains (usually in the winter). All drainage is toward the Salton Sea.

b. Ground Water

The major source of shallow ground water at East Mesa is seepage from the All American, Coachella and East Highline Canals which enclose the mesa on the south, northeast and east, respectively. The major ground water gradient is downslope to the west-southwest, although seepage from the East Highline Canal has created a small localized ground water mound. According to the U. S. Bureau of Reclamation, the ground water level immediately underlying Republic's proposed area of operations has apparently undergone very little change since the installation of the canals.

The quality of the shallow ground water is generally equivalent to the anticipated water quality of the geothermal fluid which will be produced. In some areas, as at the USBR geothermal test site, the shallow ground water is in fact of lower quality than the geothermal fluid previously produced from Republic's East Mesa wells. Water produced from Republic's shallow water well has a salinity of 1,600 mg/l, very similar to the geothermal fluid. In addition, Schlumberger electric logs run in all of Republic's wells indicate the presence of a shale aquiclude, generally at depths from 1,000-2,000 feet, separating the geothermal reservoir from the shallow ground water aquifers. Further evidence of this hydrologic separation is the lack of any surface manifestations (hot springs, fumeroles, alteration, etc.) of the underlying geothermal system and the existence of conductive heat flow to depths of approximately 2,000 feet, as shown by the temperature profiles of all deep wells drilled in the East Mesa area. The underlying convective heat flow is indicative of vertical permeability, whereas conductive heat flow demonstrates a lack of vertical permeability.

Republic's injection plans call for injection of the spent fluids at 150-500 psi over and above static reservoir pressures into the reservoir between the depths of 2,000± and 5,000± feet. This pressure is well below the overburden pressure at 2,000 feet, which is approximately 2,000 psi. It is also below the expected vertical fracture pressure of 1,600± psi. That pressure would have to be exceeded to allow injection fluids to penetrate the overlying sediments, including the shale aquiclude.

Based on the above data, Republic believes it can state there will be no effect of the spent fluid injection on the present shallow ground water system.

8. Source of Water Supply and Road Building Material

In accordance with Section 270.34, water for operations will be supplied by the previously approved well, WW-1, a shallow water well located in the northwest corner of Republic's East Mesa maintenance yard. Source of road building material for access roads is discussed in the Plan of Operation, Development.

9. Additional Information

Additional information regarding surface disturbance for injection and development operations can be found in Republic's Plan of Operation, Development submitted simultaneously with this plan.

The following, submitted by Republic Geothermal to the Area Geothermal Supervisor, are incorporated herein and made a part hereof by reference:

a. Plan of Operation, approved as effective September 12, 1975 (EA 12).

b. Supplemental Plan of Operation, approved as effective December 15, 1975 (EA 29).

c. Plan of Operation, approved as effective December 1, 1976 (EA 61).

d. Supplemental Plan of Operation, approved as effective September 16, 1977 (EA 81).

e. Amended Plan of Operation, approved as effective January 17, 1978 (EA 86).

f. Program for Collection of Environmental Baseline Data, Federal Geothermal Leases CA 966, CA 967 and CA 1903, submitted August 31, 1977.

g. Plan of Operation, Development (10 Mw Power Plant), submitted October 26, 1977 (EA 99).

h. Plan of Operation, Injection (10 Mw Power Plant), submitted October 26, 1977 (EA 99).

i. Plan of Utilization (10 Mw Power Plant) submitted November 7, 1977 (EA 100).

C. ENVIRONMENTAL PROTECTION

The following measures will be taken for protection of the environment:

1. Fire

All local, state and federal fire protection standards applicable to Republic's activities will be observed. Vegetation on the lease is sparse and low-level and will be cleared only to the extent needed for proper operation. Smoking will be allowed only in designated areas. Water and fire extinguishers will be available at each site during drilling activities and at a central location during testing and production activities in the unlikely event a fire should occur.

2. Soil Erosion

Due to the essentially level topography at East Mesa, the infrequent rainfall and the lack of surface water, soil erosion is not anticipated to be a problem. The proposed injection operations do not entail activities which would have effect on soil erosion. Potential soil erosion resulting from operations which disturb the surface has been fully discussed in Republic's Plan of Operation, Development.

3. Pollution of the Surface and Ground Water

a. Surface Water

Surface waters within Republic's East Mesa leasehold are limited to one very short section of the East Highline Canal in the extreme southwestern corner of Lease No. CA 966. The remainder of the area is devoid of easily recognizable stream channels.

The low salinity of the geothermal fluids produced from Republic's East Mesa wells, lease stipulations which restrict drilling within one-quarter mile of the canal, and the distance to the nearest well proposed under this Plan of Operation from the canal all indicate that the proposed development will have no detererious effect on the quality of water in the East Highline Canal.

b. Ground Water

There are no natural ground water sources such as springs or seeps within Republic's East Mesa leases. The California Regional Water Quality Control Board considers the ground water in the vicinity of Republic's leases saline and not beneficially used.

All of Republic's previously approved Plans of Operation on East Mesa have been conducted under approved Orders No. 76-35 and No. 76-64 (Revised) of the California Regional Water Quality Control Board, Colorado River Basin Region. These Orders have been previously submitted to the USGS-AGS.

The Board has determined that Republic's discharge of geothermal fluids into unlined temporary storage basins is acceptable for fluids of less than 2,300 mg/l. They have approved the discharge of geothermal fluids onto roads and well sites in an amount not to exceed 126,000 gallons per day or 332 acre-feet for the life of the project. These Orders also permit the disposal of geothermal waste fluids by subsurface injection into the zone of extraction or into zones which contain a total dissolved solids content that is equal to or greater than that contained in the zone of extraction.

Republic shall also protect the area's ground water by using well drilling and casing programs in compliance with the provisions of GRO Order No. 2 or exceptions to this Order as approved by the Area Geothermal Supervisor for East

Mesa, and the conditions of approval for Republic's Plan of Operation, Injection.

For more detailed information on the effects of injection on the shallow ground water system in the vicinity, please refer to Section B.7., Hydrology, of this Plan.

4. Fish and Wildlife

There are no fish in the area. Potential habitat degradation resulting from construction of the injection well locations and attendant surface facilities has been discussed in Republic's Plan of Operation, Development. The proposed injection operations will not disturb additional habitat beyond that discussed in the above-referenced Plan.

5. Air and Noise Pollution

a. Air

Air quality should not be affected by the proposed injection operations, since injection does not involve emissions to the atmosphere. Effects of drilling and testing on air quality is discussed in the Plan of Operation, Development. Republic will conduct all operations under approvals from the Imperial County Air Pollution Control District.

Dust created by vehicular traffic on cleared roads will be suppressed by distribution of geothermal fluids on these areas, as evaluated and approved by the California Regional Water Quality Control Board.

b. Noise

Noise resulting from injection operations at East Mesa is expected to be of minor concern. The main source of noise during injection testing will be a pump located at the well site. During production, injection pumps will be located at the plant site. Noise levels will be maintained within the limits prescribed by the County of Imperial, the Bureau of Land Management and the Occupational Safety and Health Administration.

Noise impacts on wildlife at East Mesa will probably be minimal because of the relatively low intensity and steady, continuous nature of most of these noise emissions. The East Mesa area itself is also very isolated from any human receptors. The extant ambient noise levels on East Mesa are usually very low, but are frequently punctuated by the sounds of aircraft overflights and explosions from the nearby military gunnery range. Occasional off-road vehicle use of the area also adds to the ambient noise levels.

6. Hazards to Public Health and Safety

Public health and safety shall be ensured through the use of appropriate equipment, operating procedures and notices. Supervisory personnel will be on site during testing and production activities. All equipment will be secured within a maintenance yard encircled by a chain-link fence when not in use. During testing activities the location pad will be surrounded by a locked chain-link fence. During production the wells will be chained and locked behind a chain-link enclosure and all other necessary injection equipment will be located at the power plant site.

7. Section 270.34, (i) and (j)

a. Methods for Disposal of Waste Materials

Portable chemical sanitary facilities will be used by personnel during testing. These will be maintained and the wastes disposed of by a local contractor. Permanent sanitary facilities will be located at the power plant site after construction is complete. Waste geothermal fluid will be filtered at the power plant site prior to injection, as discussed in Republic's Plan of Utilization submitted simultaneously with this Plan.

b. Delineation of Potential Environmental Impacts

Republic anticipates that there should be only negligible environmental impacts from these proposed injection operations over and above those from existing approved operations.

c. Environmental Monitoring and Any Additional Information

Geothermal fluids will be monitored in accordance with the requirements of Orders No. 76-35 and No. 76-64(Revised) of the California Regional Water Quality Control Board, Colorado River Basin Region.

Noncondensable gases will be monitored in accordance with the requirements of the Imperial County Air Pollution Control District.

Republic has sumbitted to the Supervisor a Program for Collection of Environmental Baseline Data for Federal Geothermal Leases CA 966, CA 967 and CA 1903 at East Mesa, in accordance with 270.34 (k).

Republic is prepared to submit, upon notification to do so, any further information not included herein which the Supervisor may require. Republic is also prepared to carry out provisions for monitoring deemed necessary by the Supervisor to ensure compliance with the regulations and to participate in the collection of data concerning the existing air and water quality, noise, seismic and land subsidence activities, and ecological systems in the vicinity of the site.

d. Approximate Crew Size, Probable Type and Location of Housing and Support Facilities

Approximately twelve to fifteen people may be working on the location during injection activities, although during normal operations, the number will be considerably less. No housing or special support facilities will be required on-site during these operations due to proximity of existing facilities.

D. DISCUSSION OF ADDITIONAL ENVIRONMENTAL CONCERNS

1. Seismicity

The Imperial Valley has long been known as a region of high natural seismicity. This has led the USGS to establish an extensive seismographic network in the valley both to detect seismic events and to determine their epicenters. The Imperial Valley Environmental Project (IVEP) has added to this network near the Salton Sea geothermal field. They are also in the process of detonating a number of calibration explosions within the valley in an attempt to reduce the ambiguity of the focal depth determinations. On East Mesa, the Bureau of Reclamation (USBR) is maintaining an independent network of six seismographic stations designed to detect microseismic activity. Republic believes that the existing seismographic networks are at present more than adequate to monitor seismic activity for the level of development on East Mesa.

Increased fluid pressure within a fluid-filled reservoir is associated with reduced frictional resistence along fracture planes and has occasionally resulted in increased seismic activity. However, Republic intends to employ a low pressure injection system which, together with the permeable sediments of the injection zone, mitigates the unlikely possibility of induced seismicity. If analyses of data from USBR stations indicate that induced seismicity is attributable to Republic's injection operations, Republic will cooperate with the Supervisor in taking any appropriate actions.

2. Subsidence

The possibility exists that localized subsidence may be induced by the withdrawal of geothermal fluids, although there is no actual case history of subsidence due to geothermal development accompanied by waste fluid injection as proposed by Republic. After careful review of all existing subsidence prediction models, Lawrence Berkeley Laboratory (LBL) determined that none of the currently available models could adequately predict the magnitude or location of subsidence induced by the extraction of geothermal fluids. Because Republic plans peripheral injection of all the waste geothermal fluid, only a slight decrease in the reservoir pressure is expected; thus, surface subsidence should be minimal.

The dual flash power cycle to be used by Republic at East Mesa will employ steam condensate for cooling water which will be cooled in forced draft towers. Evaporative losses are expected to be approximately 10 percent by volume of the produced geothermal fluid. It is expected that influx from the very large surrounding aquifer will be adequate to make up for this small deficiency. Therefore, reservoir pressure depletion and possible resulting subsidence are expected to be negligible. Since no adequate theoretical models exist to make a quantitative prediction, empirical observations must be relied upon.

Further, because East Mesa is not within a developed agricultural portion of the Imperial Valley, there are no irrigation canals or tile drains in the immediate vicinity to be disrupted should subsidence occur. Similarly, no significant detrimental effects on the existing desert environment are anticipated should localized subsidence occur.

Republic's Program for Collection of Environmental Baseline Data, East Mesa, has already been submitted to the Area Geothermal Supervisor. It contains a thorough description of the existing subsidence monitoring network in the area and describes Republic's efforts to improve the network at all well sites. Should significant surface subsidence occur as a result of development of the geothermal resource, Republic will take the necessary actions to remedy the problem.

E. EMERGENCY CONTINGENCY PLAN

If any emergency develops or is determined to be impending, appropriate control procedures will be initiated. The specific procedures will vary greatly depending on the nature of the problem. Examples of possible emergencies are: a well control problem (well blowing steam, hot water or other well effluent with loss of means to shut in or divert the flow); a spill of geothermal fluid; fire; accidents or injuries; etc. The following measures will be taken:

1. If any injuries have occurred, arrangements will be made to care for the injured party(ies).

   Cal-Com Service Corporation
   496 W. Euclid Road
   El Centro, California 92243
   (714) 352-4434

   First aid supplies will be available at the drill-site during drilling operations as well as at the power plant site during all other operations. At least one person on each crew will be trained in first aid. In addition, copies of Republic's comprehensive booklet, "Safety Begins With You: A Handbook of Safe Industrial Practices and Fundamental First Aid Techniques" will be available at the drillsite and/or plant site.

2. If there is a threat to local residents, the Sheriff will be notified as soon as possible.

   Imperial County Sheriff's Department
   150 S. 9th
   El Centro, California 92243
   (714) 352-3111

3. The Field Production Superintendent will be notified and consulted immediately.

   Carl E. Fisher
   El Centro, California 92243
   (714) 352-3111
   Home: (714) 353-3544

4. The Vice President, Production, will be advised and consulted as soon as practicable.

Dr. James Barkman
Vice President, Production
11823 E. Slauson, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

5. Field supervisory personnel will contact the Manager, Operations or Manager, Facilities and consult with him as to any further or supplemental steps which may be necessary or advisable.

Dr. Robert Nicholson
Manager, Operations
11823 E. Slauson, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

Michael J. Walker
Manager, Facilities
11823 E. Slauson, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

6. The Vice President, Land, will be advised and consulted as soon as practicable. He may consult with Republic's environmental staff.

Timothy M. Evans
Vice President, Land
11823 E. Slauson, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

7. All prescribed safety practices and procedures will be followed. All members of the drilling, well testing, construction or field operations crews will perform duties assigned for the specific purpose, following specified safety practices and procedures.

8. Every effort will be made to minimize possible deleterious environmental effects of the emergency and the operations performed to control the emergency.

9. A pump truck will be in the vicinity, and earth moving equipment may be obtained from local contractors, if necessary.

Henry Abeyta
360 W. El Dorado Road
El Centro, California 92243
(714) 352-2545

Ryerson Ditch-Liners
50 East Highway 80
El Centro, California 92243
(714) 352-4341

Merrill Ditch-Liners, Inc.
51 East Highway 80
El Centro, California 92243
(714) 353-0193

10. The Manager, Operations or Manager, Facilities will:

(a) Brief his immediate supervisor (Vice President, Production) on the situation and course of action underway.

Dr. James Barkman
Vice President, Production
11823 E. Slauson, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

(b) Contact the following agencies or regulatory bodies as soon as practicable and in the following order:

U. S. Geological Survey
Conservation Division
Western Region
345 Middlefield Road
Menlo Park, California 94025
(415) 323-8111, Ext. 2845

Bureau of Land Management
1695 Spruce
Riverside, California 92507
(714) 787-1462

(c) If the emergency involves a well control problem or other well operation, he will also notify the following agency:

Department of Conservation
State of California
Division of Oil and Gas
Geothermal Unit
1416 Ninth Street
Sacramento, California 95814
(916) 445-9686

11. The Vice President, Land, or Republic's environmental personnel will notify as soon as possible the following additional state and local agencies as necessary:

California Regional Water
Quality Control Board
Colorado River Basin Region
Suite 21, 73-271 Highway 111
Palm Desert, California 92260
(714) 346-7491

Imperial County Air Pollution
Control District
935 Broadway
El Centro, California 92243
(714) 352-3610

Imperial County Planning
Department
Courthouse
El Centro, California 92243
(714) 352-8184

Resources Agency
State of California
Department of Fish and Game
Region No. 5
350 Golden Shore
Long Beach, California 90802
(213) 435-7741

U. S. Fish and Wildlife Service
2800 Cottage Way
Sacramento, California 95825
(916) 484-4657

PLAN OF UTILIZATION

Lease Nos. CA 966 and CA 1903
Secs. 24 and 25, T15S, R16E; Secs. 19,20,28,29 and 30
T15S, R17E, SB B&M

East Mesa, Imperial County, California

Republic Geothermal, Inc.
11823 East Slauson Avenue, Suite One
Santa Fe Springs, California 90670
(213) 945-3661

Proposal to construct and operate a 48 Mw (net) dual-admission steam turbine-generator utilizing steam separated from geothermal fluid to produce electricity and to construct an access road and electric transmission line to the power plant site.

Estimated Starting Date: December 1, 1978

Estimated Completion Date: Indefinite

REPUBLIC GEOTHERMAL, INC.

PLAN OF UTILIZATION
48 Mw POWER PLANT

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REPUBLIC GEOTHERMAL, INC.

PLAN OF UTILIZATION
UNITED STATES GEOTHERMAL LEASE NOS. CA 966 AND CA 1903
EAST MESA, IMPERIAL COUNTY, CALIFORNIA

A. INTRODUCTION

Republic Geothermal, Inc. proposes herein to construct and operate a 48 Mw (net) power plant on Lease Nos. CA 966 and CA 1903 utilizing steam separated from geothermal fluids to produce electricity. This Plan of Utilization is being submitted in accordance with proposed amendments to 30 CFR, Part 270 and 43 CFR, Parts 3208 and 3250. It covers proposed alternative power plant sites, access roads to the plant site, electric transmission routes within lease boundaries, and the proposed method of utilizing the resource.

The proposed utilization project consists of the installation of a 54 Mw (gross) turbine-generator system on the site of the initial 10 Mw (gross) plant, and the integration of the two plants into one 48 Mw (net) electrical generation facility. Internal plant power requirements, including power for the lineshaft turbine pumps at each production well, will reduce the total output of the facility to 48 Mw. Three alternative plant sites have been chosen. Based on environmental, engineering and economic data, one site has been designated as the preferred alternative.

Nineteen production wells (five in existence) and nine injection wells (two in existence) are proposed to be dedicated to the power plant, as well as related pipelines, access roads and well testing and production activities. These are thoroughly discussed in Republic's Plan of Operation, Development, simultaneously submitted with this Plan. In addition, a Plan of Operation, Injection is being submitted simultaneously for discussion and evaluation of the proposed liquid disposal program and subsurface injection operations. More specific details regarding plant operation, market for the resource, manner and rates of production, method of processing and disposing of waste materials, downhole production and processing facilities, and programs for monitoring environmental effects of power plant operation will be contained in the Plan of Operation, Production to be submitted to the Supervisor prior to initiating production for commercial utilization of the resource.

B. DESCRIPTION AND PLANS OF FACILITIES AT PLANT SITE AND SUPPORTING FACILITIES OR ANCILLARY EQUIPMENT

1. Maps

a. Contour Map

Attached is our Drawing No. 199-10, East Mesa Geothermal Project, Vicinity Map, which shows the topography, drainage patterns, cultural features and existing roads and wells. The Vicinity Map also shows existing and proposed transmission lines outside the lease boundaries. The facility site will be located within the lease boundaries as shown on the map referenced below.

b. Map Showing Existing and Planned Access and Lateral Roads, Development Plan and Facility Location

Attached is our Drawing No. 199-14, East Mesa Geothermal Project, Development and Utilization Plan-48 Mw Power Plant, which shows three alternative power plant sites with the respective electric transmission line and access road routes, well and pipeline locations and existing and proposed well access roads.

c. Plot Plan

Attached is our Drawing No. 199-16, East Mesa Geothermal Project, Plot Plan-48 Mw Power Plant, which shows the plan for all proposed structures and facilities to be constructed, erected or located at the facility site.

d. Schematic Flow Diagram

Attached is our Drawing No. 199-17, East Mesa Geothermal Project, Schematic Flow Diagram, which is a representation of the proposed flow of utilization operations.

2. Discussion of Proposed Plan

The proposed utilization project consists of the installation of a 54 Mw (gross) turbine-generator system on the site of the first 10 Mw (gross) plant, and the integration of these two plants into one 48 Mw (net) electrical generation facility. The proposed 54 Mw (gross) dual-admission steam turbine-generator utilizes steam separated from the geothermal fluid in dual-stage flash tanks. After passing through the turbine, the steam is condensed in a direct contact condenser and then cooled in forced draft cooling towers. The cooled condensate is then returned to the condenser and recycled. Ancillary equipment will include condensate, cooling water and injection pumps, vacuum pumps, filters, a central control room, an electrical switchyard, an electrical transmission line, necessary access roads and parking facilities, and a water tank and pump house for fire protection.

Steam produced from the geothermal resource will be used to generate 48 Mw of net electrical power. Two turbine-generators, the 10 Mw (gross) system covered under a previous Plan of Utilization, and the 54 Mw (gross) system described above will be integrated to produce a total of 64 Mw of gross electrical power. The 10 Mw (gross) system will require approximately 2.0 Mw for internal system needs, while the 54 Mw (gross) system will require approximately 7.3 Mw for its internal system needs. Net power available from the 10 Mw (gross) turbine- generator will be used to supply power to the production well pumps for the entire integrated system. This demand is currently estimated to be about 6.7 Mw. The 48 Mw of net electrical power will most likely be sold to the Imperial Irrigation District, the public utility which distributes electrical power to the Imperial Valley area.

The proposed 48 Mw (net) power plant, with its related facilities, will be located within an area approximately 550 feet by 550 feet (seven acres) in size. Construction activities will temporarily disturb some additional area outside the boundaries of the plant site.

Please refer to Drawing No. 199-16 for details of the proposed plant layout. This plot plan is preliminary in nature in that the specific location of individual components may be altered, although all plant components are represented and plant boundaries will not change. The plant parking lot and portions of the perimeter road will be paved. The plant access road and electrical transmission line outside the plant site are discussed more fully in Section F, "Other Areas of Potential Surface Disturbance."

Republic is proposing three alternative power plant sites, each with its own access road and electric transmission line. The attached Drawing No. 199-14 shows the location of each of these alternative power plant sites with its respective access road and the electrical transmission line. The proposed production and injection wells, the well access roads and the pipelines to and from these wells are addressed in the Plan of Operation, Development, submitted simultaneously with this Plan.

These three alternative power plant locations are the same as those proposed in Republic's Plan of Utilization for a 10 Mw (gross) power plant (submitted to the U. S. Geological Survey and Bureau of Land Management) and Republic's East Mesa Geothermal Project Development Plan (submitted to Imperial County). The sites were selected primarily on the need for a location central to proposed development and near the existing access roads. Land in the area of Republic's proposed development is all open desert with very little topographic relief or expression. The only surface water on the leasehold is a short section of the East Highline Canal; the area is devoid of obvious stream channels. All three alternative sites are dominated by the Creosote-Scrub Community, with soils of fine, sandy texture. All sites are isolated from human populations. No environmental factors were deemed to be constraints on the selection of a plant site.

Independent environmental investigations have not yet determined any environmental concerns which would be significant in the final selection of one of the alternative sites. Engineering and economic considerations, however, strongly favor Alternative Site B. Site B is more central to the proposed field development and is therefore the alternative with the shortest total pipeline requirement. Shorter piping distances mean less heat and frictional losses during piping, which would result in a slightly higher energy conversion efficiency for a plant built at Alternative Site B. Shorter piping distances would also result in less financial expense than Alternative Sites A or C. Of the road and pipeline systems for each of the three alternative sites, Sites A and C require more surface disturbance than Site B. Republic has thus selected Site B as the preferred alternative in order to minimize surface disturbances and financial expense and to maximize engineering efficiency.

3. Schematic Flow Diagram and Narrative Description

Refer to Drawing No. 199-17 for a schematic flow diagram of the 48 Mw power plant. The following is a description of that flow diagram, indicating sizes and flow rates.

The combined flow of geothermal fluid from the nineteen production wells will enter the plant site in four 24 inch diameter insulated steel pipe lines. The pipelines will normally carry a total of approximately 1.1 million barrels per day (bbls/day) of geothermal fluid in single-phase flow at 335°F and 110 psia into four high pressure vertical flash tanks, each designed to handle the production from five wells at a working pressure of 55 psia. Each flash tank or separator will be approximately 36 feet tall and 11 feet in diameter. Each vessel will normally handle up to 345,000 bbls/day of water. The liquid from these high pressure separators will be piped into four low pressure separators. These vessels will be approximately 28 feet tall and 14 feet in diameter. The waste geothermal fluid from the low pressure separators will be pumped into a 160,000 gallon surge tank and from there will be pumped into the injection system. The total quantity of waste fluid, approximately 970,000 bbls/day at 210°F, will be pumped from the plant site at approximately 200 psig in one 36 inch and one 30 inch diameter pipeline, eventually being distributed to nine injection wells in 18 inch diameter insulated steel pipelines.

The steam from both the high and low pressure separators will be piped to the 54 Mw turbine. The high pressure steam, roughly 550,000 lbs/hr at about 52 psig, will enter the high pressure sections of the turbine in one 36 inch diameter steel line. The low pressure steam, about 995,000 lbs/hr total, will enter the low pressure section of the turbine in four 42 inch diameter steel lines at about 15 psig. The turbine will operate a 60,000 KVA generator at 3600 RPM to produce 2 pole, 3 phase, 60 cycle power at 13,800 volts. The power (48 Mw) will be conducted via buried cable to a 50,000 VA 161/13.8 V transformer located in the electrical switchyard. From there a 161 kV power transmission line will connect to the existing Imperial Irrigation District (IID) transmission line located roughly five miles south of the plant site. A more extensive discussion of this transmission line is presented in Section F, "Other Areas of Potential Surface Disturbance," of this Plan. Steam exhausted from the turbine will be to a dual direct contact barometric condenser operating at about 3.5" of mercury (absolute) and 90°F. The combined condensed steam/cooling water, at about 120°F, will be transferred via three 2250 hp condensate transfer pumps to the cooling tower water distribution system. The cooling tower, which will consist of 10 cells, will cool 4.04 million bbls/day from 120°F to 90°F under normal load. Wooden forced draft towers will be-used. The physical size of the towers will be approximately 42 feet high, 50 feet wide and 360 feet long. Approximately 1,700,000 lbs/hr will be lost to the atmosphere through evaporation in the towers. Since the condensed steam will add about 1,500,000 lbs/hr of fresh water to the cooling system, the result will be a cooling system surplus of 100,000 lbs/hr of water.

This excess water will be discharged as blowdown from the condensate transfer pumps to the waste water injection system.

Approximately 5,600,000 million lbs/hr of the cooled water will be pumped from the cooling tower sump to the condensers where it will be sprayed to condense the turbine exhaust steam and thereby repeat the cycle. About 3,500,000 lbs/hr of the cooled water will be pumped via the auxiliary cooling water supply pumps to cool the generator, the turbine oil, the vacuum pumps and the air compressors for the pneumatic control system. After cooling, the water is returned to the cooling tower at about 94°F.

Most of the noncondensable gases contained in the produced geothermal fluid will be volatilized in the flash tank and carried with the steam through the turbine and into the condenser. This is anticipated to amount to initially 7,400 lbs/hr, and will consist predominantly of carbon dioxide (95 percent) and nitrogen (4 percent). Please see Section H.5.a. for more detail. These noncondensable gases will be removed from the condenser via vacuum pumps which will exhaust to the atmosphere. The vacuum pumps also provide the suction to transfer the cool water from the cooling tower to the condensers.

4. <u>Architectural Plans</u>

Plans for the architectural style of the plant site have not yet been finalized. The administration building is being designed to harmonize with the desert environment. At present, no building is anticipated for the turbine, generator and condenser. Following are dimensions for basic components given to aid in evaluating the aesthetics of the proposed plant. These dimensions are approximate and may be subject to revision.

Cooling Towers (total dimensions for all ten towers):

42' high, 50' wide, 360' long

Turbine-Generator:

Foundation - 16' high, 40' wide, 100' long
Turbine-Generator - 8' high, 11' wide, 41' long

Condenser:

10' diameter, 55' long, with 12' high piping on top

Flash Tanks:

High pressure - 36' tall, 11' diameter
Low pressure - 28' tall, 14' diameter

Water Tank (for fire)

37' high, 48' diameter

Electrical Switchyard: 160' by 125'

Transformer at ground level. Poles approximately 30' high.

Transmission Line:

Pole for 161 kV - 65' high

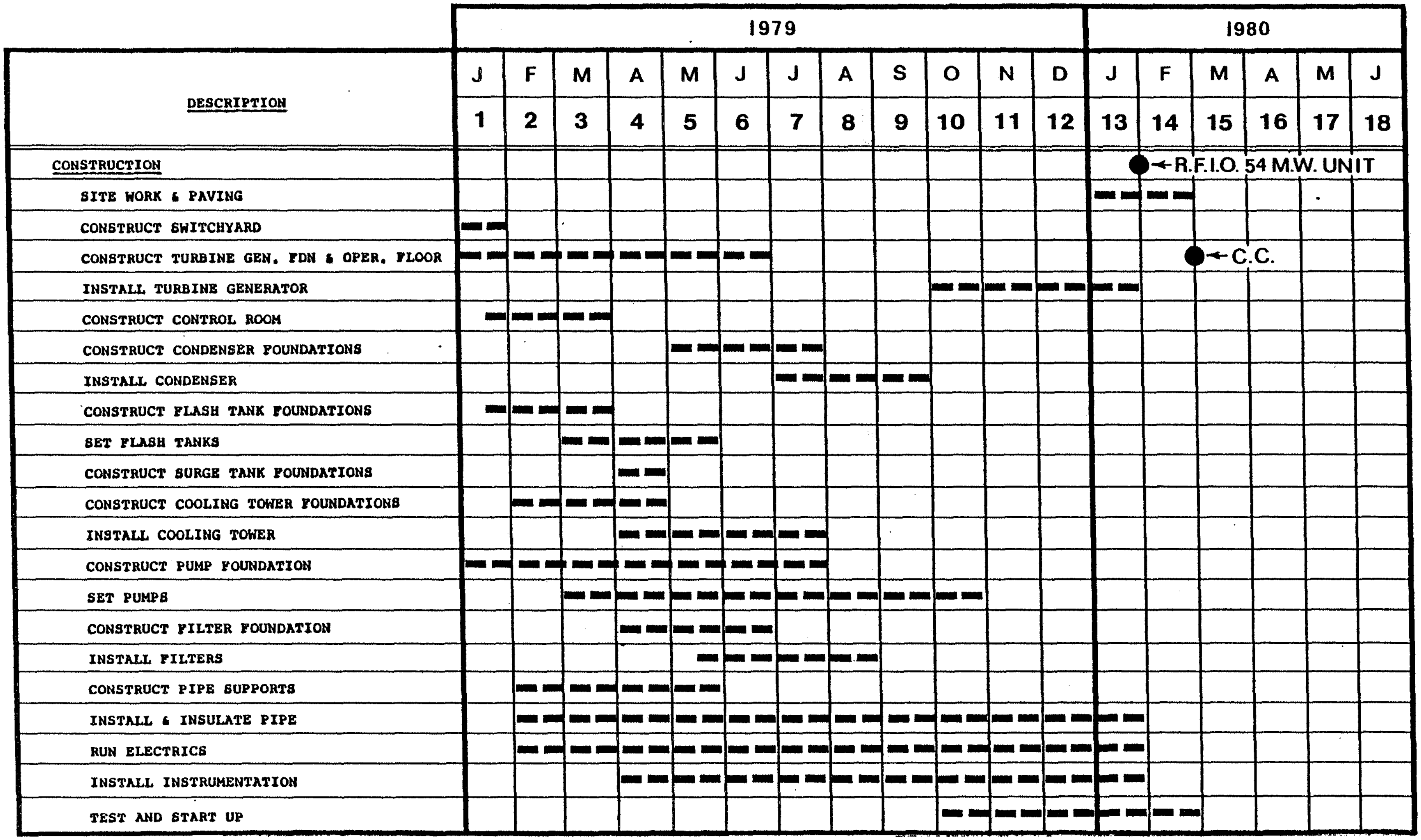
5. <u>Schedule of Construction and Start-Up</u>

Figure 1 is a Master Project Schedule prepared for Republic by The Rust Engineering Company. The schedule as presented allows no margin for deviation. Site work is scheduled to commence between December 1, 1978, and January 1, 1979. Testing and start-up is to commence on October 1, 1978, and initial operation on January 31, 1980. Please refer to the schedule for more details.

6. <u>Emergency Safety Provisions</u>

Emergency safety provisions are currently being designed into the 48 Mw (net) power plant. Every effort is being made to anticipate possible emergency situations and design into the plant appropriate controls and abatement flexibility.

PROPOSED PROJECT SCHEDULE 12/19/77



LEGEND

▬ ▬ ▬ CONSTRUCTION

RFIO — RELEASE FOR INITIAL OPERATION

CC — CONSTRUCTION COMPLETE

● — MILESTONE

FIG. 1

REPUBLIC GEOTHERMAL, INC.
11823 EAST SLAUSON AVENUE, SUITE ONE
SANTA FE SPRINGS, CALIFORNIA 90670

Given below is a list of a few emergency safety provisions.

(a) Automatic emergency steam bypass through condensers;

(b) High liquid level controls in flash tank to throttle the geothermal fluid production line;

(c) Hi-lo pressure cut-offs on each production well pump and injection pump;

(d) Pipelines designed and tested to withstand one and one-half times the maximum shut-in pressure;

(e) Pressure relief valves on the flash tank.

A safety device testing and maintenance schedule is currently being prepared for the power plant. This schedule will be submitted as part of the Plan of Operation, Production.

7. Facility Operation Personnel Coverage

Under normal operating conditions, it is anticipated that power plant operations will be managed by about ten employees during regular working hours. Five employees will be required on weekends and four employees on evening and night shifts. In addition, personnel for ancillary services such as janitorial service, grounds maintenance and major maintenance will be on the site as required. A breakdown of the anticipated personnel requirements is presented in Table 1.

TABLE 1

ANTICIPATED PERSONNEL REQUIREMENTS FOR THE 48 MW POWER PLANT

Function	Frequency	Personnel
1. Overall Management	1 Shift/5 Days	Manager
2. Clerical	1 Shift/5 Days	Clerk
3. Supervise Operation and Maintenance	3 Shifts/7 Days	Supervisor
4. Operate Control Board	3 Shifts/7 Days	Operator
5. Equipment Inspection	3 Shifts/7 Days	Ass't. Operators (3)
6. Chemical Analysis of Process Fluid	1 Shift/7 Days	Ass't. Operator
7. Chemical Treatment	As Required	Ass't. Operator
8. Maintenance	1 Shift/5 Days	Maintenance Staff (2)
9. Ancillary Services	As Required	Ancillary Staff

C. COPIES OF SITE EVALUATION REPORTS

Attached as Exhibit A is a copy of the "Preliminary Geotechnical Investigation, Republic Geothermal, Inc., East Mesa Project" prepared for The Rust Engineering Company by Woodward-Clyde Consultants. The preliminary geotechnical survey was conducted under the Plan of Operation approved as effective September 1, 1977 (USGS-AGS Environmental Analysis #92-A). The report contains results of a geotechnical investigation at the three alternative power plant sites. The scope of the work includes: subsurface investigations and laboratory tests to evaluate the engineering properties of the soils encountered; preliminary conclusions regarding earthwork, foundation types and pavement design; and a discussion of the earthquake engineering aspects of the local geologic and seismic settings. From these preliminary investigations, Woodward-Clyde Consultants concluded that all three of the alternative sites were suitable for the proposed geothermal power plant.

D. DESCRIPTION OF ADDITIONAL TESTS, STUDIES OR SURVEYS PLANNED TO ASSESS GEOLOGIC SUITABILITY OF SITE

Based upon the preliminary geotechnical investigation, all three proposed power plant sites are suitable for construction. Subsequent to final selection of one of the three sites, additional studies will be undertaken to provide detailed information concerning foundation design, pavement and roadway design, and faulting and seismic safety, as recommended in the preliminary geotechnical investigation (please refer to Section C and/or Exhibit A). Trenching of Alternative Site B is to be completed during the more detailed foundation investigation phase to verify the presence or absence of recent fault movement. The trenching would be perpendicular to the general northwest-southeast trend of faulting in the area and located to shadow critical structures. Separate approval of trenching operations will be obtained from the Area Geothermal Supervisor before activity commences. All studies will be conducted by registered geotechnical consultants in accordance with the standards of their profession.

E. SOURCE OF WATER SUPPLY AND ROAD BUILDING MATERIAL

Water for construction will be supplied by either the previously approved well, WW1, a shallow water well located in the northwest corner of Republic's East Mesa maintenance yard, or the East Highline Canal. Water for the initial fill of the eight cooling towers, estimated to be approximately 700,000 gallons, will be obtained from the water well or the East Highline Canal (two cooling towers should be constructed and filled as part of the initial 10 Mw (gross) power plant). Additional external water will not be required for cooling during plant operation, as cooling make-up water will be provided by the steam condensate from the condenser.

No road building material will be obtained from federal lands for the proposed access road to the power plant. Any required road building material, such as gravel or paving material, will be transported to the site from outside commercial sources.

F. OTHER AREAS OF POTENTIAL SURFACE DISTURBANCE

1. Access Road

Besides the power plant site, other surface disturbance will result from construction of the main access road to the power plant and the electric transmission and telephone lines adjacent to the access road. The main access road will be approximately twenty-five feet wide and will be located as shown in Drawing No. 199-14. Twenty feet of the road will be paved. It will be built and maintained in accordance with specifications of the Bureau of Land Management and the Department of Public Works, Imperial County. A typical road cross-section is shown in Drawing No. 199-15.

2. Electric Transmission Line

The power plant will be connected to existing electric transmission lines via a 161 kV electric transmission line loop, which will consist of two 161 kV lines placed next to each other. Within the lease boundaries, the loop lines will be located along one of two alternative routes, as shown in Drawing No. 199-14. The proposed routes were chosen in consultation with the Imperial Irrigation District (IID). It is proposed to use wooden H-frame poles approximately 60 feet tall and 30 feet wide. The poles would be set approximately 300 to 500 feet apart with a 100 to 150 foot right-of-way. A temporary road will be necessary during construction. After construction the road will not be used and the area will be allowed to revegetate. It is anticipated that IID will construct the line.

Outside the lease boundaries the 161 kV lines will travel due south adjacent to the existing access road, as shown in Drawing No. 199-10. Although the closest electrical transmission power line is a 92 kV line near Highway 8, the transformers at either end of this line have insufficient capacity to handle the power load from the power plant. One mile south, below Highway 8, are both a 92 kV line and a 161 kV line with sufficient transformer capacity to accept the plant's output. The proposed transmission line will run four miles outside the lease boundary, crossing desert land administered by the U. S. Bureau of Reclamation and Bureau of Land Management, crossing California State Highway 8 and tying-in to the existing IID transmission line.

G. METHODS FOR DISPOSAL OF WASTE MATERIAL

Power plant wastes fall into two classes: those arising from construction activities and those continuously produced during operation of the power plant. Construction wastes will be produced only during a short period of time. During construction, temporary facilities for human wastes will be provided and the wastes will be transported to an approved sewage disposal location. All other construction waste material will be deposited in an approved disposal site.

Solid waste will result from filtering the spent geothermal fluid with suspended particle removal equipment prior to injection. This waste will consist of non-saline formation sand, silt and clay with a high concentration of calcium carbonate. The volume of this waste will be relatively small, and it will be removed to an approved disposal site.

A septic tank is the most economical method of treating and disposing of the sanitary waste during the life of the power plant. A septic tank will be designed for the following flows based upon the estimated number of persons at the plant.

Employees	- Administrative Building	10/24 Hr. Day
Employees	- Field	3/24 Hr. Day
Others	- Visitors (Periodic)	50/24 Hr. Day

Design basis:

Employees (Includes Showers)	35 Gal/Emp/8-Hr. Day
Visitors	15 Gal/Vis/8-Hr. Day

Sanitary Flow,	Employees	455/Gal/Day
	Visitors	750/Gal/Day
	Total	1,205/Gal/Day

A 2,000 gallon two compartment septic tank will be provided with the linear footage of field lines based upon field percolation tests.

Final design of the septic tank and field lines will be based upon the "Manual of Septic Tank Practice," U. S.

Department of Health, Education and Welfare, or the "International Association of Plumbing and Mechanical Officials Code."

Liquid waste resulting from spent geothermal fluid and cooling tower blowdown will be injected. Details of Republic's plan for injection of fluids are thoroughly discussed in the Plan of Operation, Injection simultaneously submitted to the Area Geothermal Supervisor.

H. ENVIRONMENTAL PROTECTION

1. Fire

Vegetation on the lease is sparse and generally low lying, making the possibility of a wildfire very remote. Fire protection for the plant will be provided by a 500,000 gallon water storage tank and fire pump house, both designed in accordance with the Uniform Fire Code of 1976. This system is designed for maximum possible need, including the use of wooden cooling towers. Republic considers the likelihood of operational fires very low, primarily because noncombustible steam will be used as the process working fluid.

2. Soil Erosion

The soil in the area of proposed development is primarily of fine, sandy texture and is subject to natural wind erosion. Due to the essentially level topography at East Mesa, the infrequent rainfall and the lack of surface water or major washes, soil erosion is not anticipated to be a problem. Best efforts will be made to minimize disturbance of the perennial woody vegetation (mainly creosote, *Larrea divaricata*). Off-road vehicle use will be prohibited except where absolutely necessary.

3. Pollution of Surface and Ground Water

a. Surface Water

Republic's East Mesa leases are devoid of any obvious stream channels. Surface water is presently confined within the one-half mile section of the East Highline Canal located in the extreme southwestern portion of Lease CA 966. The East Highline Canal flows northward and contains water diverted from the Colorado River via the All American Canal. Irrigated farmlands lie to the west of the Canal, covering almost all of the Imperial Valley. To the east of the Canal is East Mesa; desert lands with a few dry washes active only after heavy rains (usually in the winter). All drainage is toward the Salton Sea. No discharges to the East Highline Canal nor any drains are proposed during the operation of the power plant. Republic does not anticipate that the proposed development will have a deleterious effect on the East Highline Canal.

b. Ground Water

There are no natural ground water sources such as springs or seeps within Republic's East Mesa leases. The California Regional Water Quality Control Board considers the ground water in the vicinity of Republic's leases saline and not beneficially used.

The major source of shallow ground water at East Mesa is seepage from the All American, Coachella and East Highline Canals which enclose the mesa on the south, northeast and west, respectively. The major ground water gradient is downslope to the west-southwest, although seepage from the East Highline Canal has created a small localized ground water mound. According to the U. S. Bureau of Reclamation, the ground water level immediately underlying Republic's proposed area of operations has apparently undergone very little change since the installation of the canals.

The quality of the shallow ground water is generally equivalent to the anticipated water quality of the geothermal fluid which will be produced. In some areas, as at the USBR geothermal test site, the shallow ground water is in fact of lower quality than the geothermal fluid previously produced from Republic's East Mesa wells. Water produced from Republic's shallow water well has a salinity of 1,600 mg/l, very similar to the geothermal fluid.

All of Republic's previously approved Plans of Operation on East Mesa have been conducted under approved Orders No. 76-35 and No. 76-64 (Revised) of the California Regional Water

Quality Control Board, Colorado River Basin Region. These Orders have been previously submitted to the USGS-AGS.

The Board has determined that Republic's discharge of geothermal fluids into unlined temporary storage basins is acceptable for fluids of less than 2,300 mg/l. They have approved the discharge of geothermal fluids onto roads and well sites in an amount not to exceed 136,000 gallons per day or 232 acre-feet for the life of the project. This Order also permits the disposal of geothermal waste fluids by subsurface injection into the zone of extraction or into zones which contain a total dissolved solids content which is equal to or greater than that contained in the zone of extraction.

Republic is simultaneously submitting to the Area Geothermal Supervisor a Plan of Operation, Injection which discusses in detail the proposed disposal of spent geothermal fluids from operation of the power plant. The only discharge of geothermal fluids resulting from plant operations will be the disbursement of fluid onto the access roads for dust control. A cooling water sump, 23 feet by 17 feet, and an auxiliary cooling water sump, 10 feet by 12 feet, both concrete lined, are the only cooling ponds or storage basins proposed.

4. <u>Damage to Fish and Wildlife</u>

There are no fish in the area. Construction of the power plant will result in some unavoidable dislocation of wildlife in the area due to loss of habitat. Disturbance of natural soil and vegetation will be kept to a minimum. Because of the relatively small amount of habitat disturbance and the homogeneous vegetation at East Mesa, it is anticipated that this disturbance will not significantly impact the area's wildlife. To help provide replacement habitat, removed vegetation and excess soil will be stacked in several piles at a reasonable distance from the road and plant site.

5. Air and Noise Pollution

a. Air

Emissions from the proposed 48 Mw (net) power plant and related facilities should not significantly degrade the ambient air quality of the region. Initially, gaseous emissions which are anticipated to be released under normal operating conditions should not exceed 7,400 lbs/hr. However, recent evaluations suggest emissions are likely to decrease to about 20 percent of this value, or 1,500 lbs/hr, by the end of the first year of operation. Specific constituents are listed in Table 2. All federal, state and local emission standards will be adhered to.

Currently, the concentration of noncondensable gases in the geothermal fluid as produced is approximately 0.051 percent by weight. Field tests have indicated that up to 100 percent of these gases will volatilize in the dual flash tanks and be carried to the turbine with the steam. The gases in the steam will be collected from the condenser and vented to the atmosphere. A barely perceptible trace of hydrogen sulfide has been detected in only one of the two wells which have as yet been adequately sampled. The total quantity of volatile trace metal constituents carried over from the geothermal fluid to the flashed steam should also be negligible. Because the total quantity of noncondensable gases or other volatile components emitted during power plant operations are so minute, adverse environmental impacts are not anticipated.

During normal operations, approximately 1.7 million pounds of cooling water will evaporate per hour from the cooling towers. This will increase the relative humidity in the immediate vicinity of the power plant; however, the very localized climatic change should not significantly affect the existing desert ecology. Less than 0.05 percent of the circulating cooling water, or about

TABLE 2

ANTICIPATED NONCONDENSABLE GAS EMISSIONS FROM PROPOSED

48 MW (NET) GEOTHERMAL POWER PLANT

Anticipated Emission[a]	Weight Percent Of Total Noncondensables		Projected Emission Rate[b] (Pounds/Hour)
	Well 16-29	Well 38-30	
Carbon Dioxide (CO_2)	94.452	95.038	6,950 -6,990
Nitrogen (N_2)	3.972	3.571	263 - 292
Methane (CH_4)	1.123	0.374	27.5 - 82.6
Argon (Ar)	0.121	0.145	8.90- 10.7
Ethane (C_2H_6)	0.139	0.061	4.49- 10.2
Propane (C_3H_8)	0.114	0.084	6.18- 8.39
Benezene (C_6H_6)	0.065	0.015	1.10- 4.78
Hydrogen (H_2)	0.006	0.005	0.37- 0.44
Hydrogen Sulfide (H_2S)	0.005	0.000	0.00- 0.37
Toluene ($C_6H_5CH_3$)	0.004	0.000	0.00- 0.29

(a) Based on single sample molecular analysis of geothermal fluids from Wells 16-29 and 38-30.

(b) Assumes the concentration of noncondensable gases in the geothermal fluid is 0.051 percent by weight; that up to 100 percent of these gases will volatize in the combined dual flash; that the geothermal fluid flow rate before the flash is 14.43 million pounds per hour; and that the range of emissions is characterized by the range of noncondensable gases determined by the two sampled wells.

32,000 pounds per hour, will be lost to the atmosphere in the form of cooling tower drift. Because the salinity of the cooling water will remain very low due to the high quality of the source (the steam condensate) and the high blowdown rate, there should be little adverse impact on the surrounding vegetation.

Increased automobile and truck traffic to the plant site and vicinity should also create only a minimal decrease in air quality. Exhaust emissions will be insignificant even during construction phases. Some dust from unpaved roads and cleared drill pads should be anticipated; however, dust will be suppressed by the distribution of geothermal fluids on these areas as approved by the California Regional Water Quality Control Board. Republic does not anticipate any environmental impacts associated with air emissions from the proposed geothermal power plant or its ancillary operations to be significant to the immediate desert ecology, the more remote agricultural lands, or to the human population of the Imperial Valley.

b. Noise

Noise is expected to be of minor concern during the construction and operation of Republic's proposed East Mesa power plant facility. This is primarily due to the relatively low pressure steam used to power the turbine. Noise levels will be maintained within the limits prescribed by Imperial County, the Bureau of Land Management, the U. S. Geological Survey and the Occupational Safety and Health Administration.

Noise emissions will be attenuated as necessary. This will include mufflers on all internal combustion engines and on the pneumatic control system air compressors. Silencers will also be placed on the gas ejector vacuum pumps. Emergency venting of the steam may occur about once every two years. This gas release should not last longer than 10 to 15 seconds.

Noise impacts on wildlife at East Mesa will probably be minimal because of the relatively low intensity and steady, continuous nature of most of these noise emissions. The East Mesa area itself is also very isolated from any human receptors. The extant ambient noise levels on East Mesa are usually very low, but are frequently punctuated by the sounds of aircraft overflights and explosions from the nearby military gunnery range. Occasional off-road vehicle use of the area also adds to the ambient noise levels.

6. <u>Hazards to Public Health and Safety</u>

Public health and safety shall be ensured through the use of appropriate equipment, operating procedures and notices. The plant site is located in an area remote from human population. No hazardous emissions or waste materials will be produced.

7. <u>Compliance With Existing Requirements and Standards</u>

Republic will comply with all existing federal requirements and pertinent state and local standards.

The following is a list of codes and standards which will be utilized in the design of the power generating facility:

Uniform Fire Code	1976 Edition
Uniform Mechanical Code	1976 Edition
Uniform Building Code Standard	1976 Edition
Uniform Building Code	1976 Edition
1977 Supplement of the Uniform Building Code	
National Electrical Code	1975 Edition
Uniform Plumbing Code	1976 Edition
1976 Revision of the General Industry Standards of O.S.H.A.	
Code for Power Pipeline ANSI-B31.1	1977 Edition
Pressure Vessels ASME Section 8, Division 1	1977 Edition
Design & Construction of Large Welded Low-Pressure Storage Tanks API Std. 620	1977 Edition
Welded Steel Tanks for Oil Storage API Std. 620	1977 Edition

The Department of Building Inspection of Imperial County operates under the 1973 Edition of the Uniform Building Code and the 1975 Edition of the National Electric Code. Between December, 1977, and December, 1978, the Department expects to adopt the 1976 Edition of the Uniform Codes, including the 1977 Supplement which will include the Building Code, Plumbing Code, Mechanical Code and Fire Code.

I. PROVISIONS FOR MONITORING FOR NOISE, AIR AND WATER QUALITY STANDARDS

Republic has submitted to the Area Geothermal Supervisor a Program for Collection of Environmental Baseline Data for Federal Geothermal Leases CA 966, CA 967 and CA 1903 at East Mesa, in accordance with 30 CFR 270.34 (k).

Republic will comply with all air, noise and water quality monitoring provisions which may be required during the operation of the power plant by the Imperial County Air Pollution Control District and the California Regional Water Quality Control Board. Republic is also prepared to carry out provisions for monitoring deemed necessary by the Supervisor to ensure compliance with the regulations.

A more detailed program for monitoring noise, air and water quality during operation of the power plant will be submitted with the Plan of Operation, Production in accordance with draft GRO Order No. 5.

EXHIBIT A

PRELIMINARY GEOTECHNICAL INVESTIGATION
REPUBLIC GEOTHERMAL, INCORPORATED
EAST MESA PROJECT

For

The Rust Engineering Company
Post Office Box 101
Birmingham, Alabama 35201

By

WOODWARD-CLYDE CONSULTANTS
Consulting Engineers and Geologists

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Woodward-Clyde Consultants

Project No. 57334S, SI01
October 25, 1977

The Rust Engineering Company
Post Office Box 101
Birmingham, Alabama 35201

Attention: Mr. Tom Falkenberry

PRELIMINARY GEOTECHNICAL INVESTIGATION
REPUBLIC GEOTHERMAL, INCORPORATED
EAST MESA PROJECT

Gentlemen:

In accordance with our proposal dated June 23, 1977, and your Purchase Order No. 1867-B-1, dated July 18, 1977, we have completed a preliminary geotechnical investigation at three sites in the East Mesa Geothermal Field, Imperial Valley, California.

The accompanying report presents our conclusions and recommendations as well as the results of the explorations and laboratory tests upon which they are based. Our engineering geologist assigned to this project was Mr. Ernest Artim. We were also assisted by Dr. Robert B. McEuen, Professor of Geophysics at San Diego State University, and consultant to our firm.

If you have any questions, or if we can be of further service, please give us a call.

WOODWARD-CLYDE CONSULTANTS

Steven C. Haley

Steven C. Haley
R.E. 18577

SCH/lkm

Attachment

(6) The Rust Engineering Company
(1) Mr. John Bayliss
(1) Dr. J. H. Barkman

PRELIMINARY GEOTECHNICAL INVESTIGATION
REPUBLIC GEOTHERMAL, INCORPORATED
EAST MESA PROJECT

SCOPE OF WORK

This report presents the results of our geotechnical investigation at three proposed sites for the Republic Geothermal, Incorporated, East Mesa Project. The sites are located as indicated in the Site Plan, Fig. 1, on Range 17 East, Township 15 South, Section 30. The scope of our services include:

- Subsurface investigations and laboratory tests to evaluate the engineering properties of the soils encountered,
- Preliminary conclusions regarding earthwork, foundation types, and pavement design, and
- A discussion of the earthquake engineering aspects of the local geologic and seismic settings.

DESCRIPTION OF PROJECT

We understand from discussions with Mr. John Bayliss of The Rust Engineering Company that it is proposed to construct a 10-megawatt geothermal power plant which would likely be followed-up by a 50-megawatt geothermal facility. We have been provided with the following drawings from Mr. Bayliss:

- "Preliminary Geotechnical Survey for the Proposed Power Plant," (Drawing No. IEM-55, July 20, 1977),

- An unidentified and undated topography map of Section 30 showing the three site locations,

- Plot plan (Drawing No. 02-32-002, September 28, 1977),

- "Turbine Building Frame Preliminary Analysis," (September 22, 1977),

- "Turbine Building," (August 29, 1977),

- "Turbine Generator Foundation - 10-Megawatt Unit," (Drawing No. 1, September 1, 1977),

- "Turbine Generator Foundation - 10-Megawatt Unit," (Drawing No. 2, September 1, 1977),

- "Turbine Generator Foundation - 50-Megawatt Unit," (Drawing No. 1, August 24, 1977).

- "Turbine Generator Foundation - 50-Megawatt Unit," (Drawing No. 2, August 26, 1977),

- "Cooling Tower Foundation - 10-Megawatt Unit," (Drawing No. 1, September 26, 1977),

- "Cooling Tower Foundation - 10-Megawatt Unit," (Drawing No. 2, September 26, 1977), and

- "Cooling Tower Foundation - 10-Megawatt Unit;" (Drawing No. 3, September 27, 1977).

The first drawing was prepared by Republic Geothermal, Incorporated, and the last ten, by the Rust Engineering Company.

From these drawings and our discussions with Mr. Bayliss, we understand that both the 10 and 50-megawatt units will be constructed at the same general location and will occupy a plant area of approximately 500 feet by 800 feet on one of the three sites. We further understand that the turbine building will have interior columns with maximum dead loads of approximately 48 kips and maximum live loads of about 60 kips. Under normal operating conditions exterior columns will have maximum axial loads of 185 kips, maximum shear of 5 kips, and maximum moment of 150 Kip-feet. Under seismic conditions, the maximum loads on the exterior columns will be 190 kips, with 20 kips maximum shear, and 495 kip-feet maximum moment.

The 10-megawatt turbine generator foundation will support a static weight of 157 kips from equipment with a foundation weight of 550 kips. For the 50-megawatt unit, the static weight of equipment will be 550 kips, and the estimated weight of the foundation is 1530 kips. Dynamic loads for the turbine generator foundations are not yet known.

The 10-megawatt turbine generator foundation will have approximately rectangular dimensions of 28 feet by 13 feet. The foundation for the 50-megawatt turbine generator will be approximately 72 feet long and varying in width from about 11 to 17 feet. The operating weight of the 10-megawatt unit cooling tower will be approximately 261 kips with plan dimensions of approximately 39 feet by 61 feet. The 50-megawatt cooling tower unit will have an operating weight of approximately 2,570 kips and will occupy an area of approximately 327 feet by 61 feet.

We understand that little grading is planned, except for drainage.

FIELD INVESTIGATION

Seven exploratory borings were advanced to depths of 30 to 101 feet during the period of September 13 through September 22, 1977, at the locations shown on the Site Plan, Fig. 1. Samples of soil were obtained using a modified California drive sampler (2-inch inside diameter and 2-1/2-inch outside diameter), with thin brass liners and a standard penetration test sampler (1-3/8 inside diameter and 2-inch outside diameter). Both samplers were driven 18 inches into the material at the bottom of the hole by a 140-pound hammer falling 30 inches.

Boring logs were prepared from the field data and the results of laboratory examinations and tests. A Key to Logs is presented as Fig. 2, and the Borings Logs are presented in Figs. 3 through 15.

LABORATORY TESTING

Grain size analyses were made for 14 representative samples of the more granular materials at the three sites. The results of these tests are presented on Figs. 16 and 17. Moisture contents and plasticity indices were determined for the more cohesive materials encountered. The results of the moisture contents are presented on the Boring Logs and the plasticity indices are indicated on Fig. 18.

The results of two resistance-value tests performed in representative samples of near-surface materials indicate that the materials tested have an R-value of approximately 76 to 78. Copies of the test results are attached.

SITE CONDITIONS

Surface Conditions

Elevations at the sites vary from 35 feet to 55 feet (MSL Datum) with a local relief of 8 feet to 10 feet. The general area slopes in a westerly direction and drainage is incomplete. The general geomorphic setting is that of a partially stabilized sand dune field. Vegetation is sparse and dominated by creosote bush and desert buckwheat. Distance between major clumps of vegetation varies from 10 to 50 feet.

Subsurface Conditions

In general, all three sites are underlain by sands with little cohesion. A summary of the subsurface conditions is presented on Table I. As indicated in Table I, the sands typically become medium-dense to dense at shallow depths, especially for Sites B and C. Except for 1 to 2-foot thick lenses encountered in Boring No. 1 at 36 feet and 56 feet and in Boring No. 3 at 16 feet and in Boring No. 6 at 11 feet, no cohesive materials were encountered at a depth shallower than 63 feet. All of the clays encountered were very stiff to hard. One lense of silt was encountered in Boring No. 6 from a depth of 12 to 18 feet in thickness.

In general, the materials appeared to represent pre-compressed, alluvial and lacustrine deposits. It appears that the groundwater level is relatively uniform across the sites at an elevation of approximately +18 (MSL).

Geologic Setting

The geologic setting of the East Mesa site is expressed well by Narasimhan, et al (1977):

The East Mesa Field is located 20 miles east of El Centro, California, in the Imperial Valley. This valley is part of a large structural feature known as the Salton Trough, a sediment-filled depression forming the landward continuation of the East Pacific Rise and the Gulf of California (Swanberg, 1975). The East Pafific Rise is one of several geological sutures on the earth's crust along which adjoining crustal plates move apart, causing thinning of the crust and upward movement of molten rock from the mantle. This crustal extension is responsible for the formation of the Salton Trough, and provides the heat source for the several geothermal resource areas located in the Imperial Valley. Faulting is a consequence of this crustal extension and many faults trend NW and are right lateral strike-slip faults. The major active faults close to the field are the San Andreas Fault, located approximately 20 miles from the East Mesa Field on the eastern margin of the Imperial Valley, and the Imperial Fault, located approximately 15 miles to the west of the field. Three local faults have been mapped within the field itself.

The Imperial Valley is a broad depression, approximately 60 miles wide in the vicinity of East Mesa. It trends northwest to southeast, becoming wider southward toward the Mexican border. The valley is bounded on the east by the Chocolate Mountains, which rise to over 2000 feet, and on the west by the Fish Creek and Coyote Mountains, which attain elevations of 3000 feet. To the north, the valley is approximately 25 miles wide and is occupied by the Salton Sea, which has a surface elevation of approximately -230 feet. A greater part of the Imperial Valley south of the Salton Sea lies below sea level and receives benefit from the well-known irrigation systems of the all American and Coachella canals.

Sea level constitutes a well-defined physiographic boundary between the irrigated, lower parts of the valley and the higher flanks of the valley on either side. These higher portions, called the West and East Mesas, rise to about 100 feet above sea level. The East Mesa exhibits a relatively flat, featureless desert-like terrain covered by alluvium and sand dunes. The geothermal well field under study is located near the western margin of the East Mesa on the eastern flank of the Salton Trough.

The reservoir rocks at East Mesa are essentially flat-lying, poorly consolidated, late Pliocene to late Pleistocene, deltaic sandstones, siltstones and clays believed derived from the Colorado River. They aggregate a total thickness of about 10,000 feet on top of crystalline basement rocks. A predominantly clay sequence, about 2000 feet thick, caps the reservoir and hence no surface evidence of geothermal activity is seen. Within the field, three supposedly vertical intersecting faults have been mapped. It is thought that one or more of these faults and their intersections may act as vertical channels that allow hot water to rise from depth and cooler water to return to depth in a convective cycle. As mentioned, this convective regime is sustained by heat derived from the tectonic processes associated with the East Pacific Rise. The surface heat flow over the field is about five times that of the earth's average.

Regional Faulting

The power plant sites are located approximately 30 miles northeast of the Elsinore-Laguna Salada Faults; some 18 miles northeast of the San Jacinto Fault; approximately 10 to 15 miles southwest of the San Andreas Fault zone projection (including the Algodones Fault); and 10 miles northeast of the Imperial Fault along which the 1940 (6.7 magnitude) earthquake occurred.

Local Faulting

No major, active faults are known to exist within the East Mesa KGRA; however, at least four other faults are considered to cross the East Mesa KGRA as indicated in Fig. 19. As projected on the figure, at least one of the faults, the Calipatria, appears to cross Section 30 and may pass through one of the preliminary sites. These faults have been postulated by geophysical investigations, and in the case of the Holtville Fault, by the use of oblique infared aerial photography. The location of the Holtville Fault was based upon an aligned series of stable sand; however, a ground investigation did not reveal any surface exposures. In all cases, fault surface expressions or offsets are

are lacking or have not been verified. The locations of these faults are based primarily upon geophysical techniques and projections, with no verified or documented surface exposures, and therefore, the actual locations for these faults may be somewhat offset from those shown on the map.

SEISMICITY

The Imperial Valley has long been recognized as a seismically active area. As indicated in Fig. 20, recent trends show the Imperial Fault to be presently the most active feature near the site. The largest credible extent which might be associated with one of the major faults in the valley would be on the order of magnitude 8. Based on recent seismic history, a magnitude 7 earthquake on a major fault in the vicinity of the site might have an average recurrence interval on the order of 100 years. If one of these earthquakes was to occur at a distance of 10 miles from the site (for instance on the Imperial Fault), ground accelerations could be on the order of about 0.4g and 0.3g, respectively. Such events would most likely occur along the San Jacinto, extension to the San Andreas, or the Imperial Fault, and would not be expected to occur on faults within the general site area.

Work by McEuen, et al (1977), indicates that the historic seismicity in the nearest vicinity to the site is lower than for the Imperial Valley and that within a surrounding 60-square-mile area an earthquake of magnitude 5.5 might have an average recurrence interval of about 100 years. However, larger events are possible in the vicinity of the site and ground accelerations exceeding 0.46 also are possible.

DISCUSSION AND CONCLUSIONS

From our preliminary investigation described above, it is our conclusion that all three sites are suitable for the proposed Geothermal Power Plant. The near-surface soils consist of loose clean sands which will require some treatment and may be somewhat troublesome during construction of foundations and pavements due to their non-cohesive nature. The high seismicity of the area should also be taken into consideration in the design of structures and their associated facilities.

Foundations

From our previous discussions and a review of the plans furnished to us, we understand that foundation bearing pressures on the order of 3 kips per square foot are suitable for the proposed structures. For this loading condition and with recompaction of the near-surface loose sands to a relative compaction of at least 90 percent by ASTM test method D-1557, we anticipate that settlements for the proposed structures would not exceed 1/2 inch. We anticipate that greater bearing capacities can be used, if desired. Specific recommendations can be provided based on a more detailed foundation investigation in the selected site area.

Pavements

Preliminary pavement designs for a 20-year pavement life are presented below based on an assumed R-value of 70 and given traffic indices (which are related to the anticipated number of 5000-pound equivalent wheel loads (EWL) during the life of the structure).

Traffic Index	Number of EWL/year	Asphaltic Concrete Thickness (in)	Aggregate Base Thickness (in)
4	13,108	2	4
5	85,486	2	4
6	395,623	2-1/2	4

Full-thickness asphalt designs are not recommended for this site because the generally clean surface sands do not provide a good base material. A Class II aggregate base in conformance with Section 26-1.02B of the Standard Specifications for the State of California Department of Transportation should be used.

Faulting and Earthquake Considerations

As previously discussed, the site is located in a highly seismic area. It is not known from the depth of this study whether or not any potentially active faults pass through any of the specific sites. However, no indications have been found that any of the faults have surface exposures which would indicate they have moved in recent times. However, near-surface faulting indicating recent movement of faults has been found in trenching. we recommend that, once the site location is established, a trenching operation be completed during the more detailed foundation investigation phase to verify the presence or absence of recent fault movement. The trenching would be perpendicular to the general northwest-southeast trend of faulting in the area and located to shadow critical structures.

It is reasonable to believe that at least one moderate earthquake (perhaps magnitude 6 to 7) will occur within 10 to 20 miles ($\pm$) of the site during the life of the structure. We anticipate that ground accelerations at the site from such an event could be on the order of 0.3g's. Such ground accelerations would result in dynamic structural loading in excess of the current Uniform Building Code Standards applicable to the area. Depending on economic and other factors, it may be considered suitable to perform a seismic design for critical portions of the facility.

We would be happy to discuss this matter further, if desired. We can provide seismic design criteria in the form of acceleration-time histories or earthquake response spectrum.

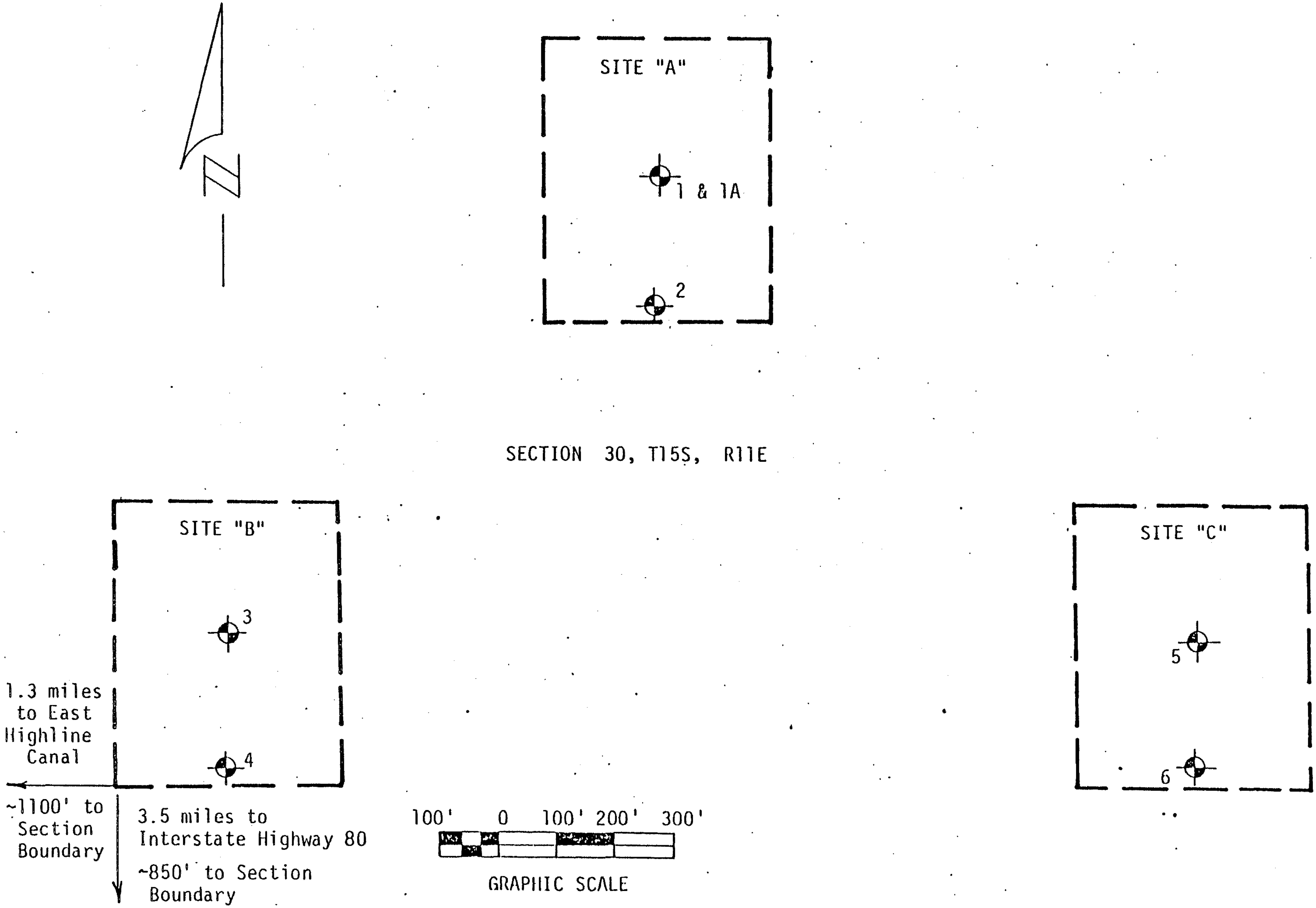
LIMITATIONS

The discussion and conclusions presented herein are based on a limited field investigation and should not be used for design without a more detailed study of the specific site selected.

TABLE I

GENERALIZED SUBSURFACE CONDITIONS

	Site A		Site B		Site C	
Boring No.	1,1A	2	3	4	5	6
Surface Elevation (MSL)	48	49	40	39	52	50
Profile (feet)						
Loose Sand	0- 2	0- 5	0- 2	0- 2	0- 1	0- 1
Medium Dense Sand	2- 12	5- 30	2- 7	2- 5	1- 7	1- 8
Dense to Very Dense Sand	12- 76	30- 31+	7- 76	5- 31+	7- 63	8- 31+
Hard Clay	76- 97	-	76- 91	-	63- 67	-
Very Dense Silty Sand	97-100+	-	91-100+	-	67- 96	-
Hard Clay	-	-	-	-	96-101+	-
Depth to Groundwater (feet)	30	31	-	21	32- 35	32
Elevation of Groundwater (MSL)	18	18	-	18	17- 20	18



SITE PLAN
EAST MESA

DRAWN BY: mrk	CHECKED BY: [illegible]	PROJECT NO: 57334S	DATE: 10-6-77	FIGURE NO: 1

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APPENDIX

LIST OF SELECTED REFERENCES

1. Babcock, E.A., 1971, "Detection of Active Faulting Using Oblique Infared Aerial Photography in the Imperial Valley, California," Cooperative Geology Geophysical and Geochemical Investigation in the Imperial Valley Area of California, University of California, Riverside, California.

2. Combs, J. and Hadley, D.M., 1973, "Micro-earthquake Investigation of the Mesa Geothermal Anomaly, Imperial Valley, California," EOS, Vol. 54.

3. Goss, R. and Combs, J., 1975, "Thermal Conductivity Measurement and Prediction from Geophysical Well Log Parameters with Borehole Application," Proceedings, Second United Nations Symposium on the Use of Geothermal Resources, San Francisco, California, Vol. 2.

4. Goupilland, P.L. and Cherry, J.T., "Utilization of Seismic Exploration Technology for High Resolution Mapping of a Geothermal Reservoir," ERDA Report SAN/1249-1.

5. Hill, D.P., Mowinckle, P. and Peake, L.G., 1975, "Earthquakes, Active Faults, and Geothermal Areas in the Imperial Valley, California," Science, Vol 188.

6. McEuen, R.B., Mose, C.W. and Loomis, W.E., 1977, "Geothermal Tectonics of the Imperial Valley as Reduced from Earthquake Occurence Data," Geothermal Resource Council, Transactions, Vol. 1.

7. Narasimhan, T.N., McEdwards, D.G. and Witherspoon, P.A., 1977, "Results of Reservoir Evaluation Tests, 1976, East Mesa Geothermal Field, California," Report LBL-6369, Lawrence Berkeley Laboratory University of California/Berkeley.

8. Rex, R.W., 1970, "Investigation of Geothermal Resources in the Imperial Valley and their Potential Value for Desalination of Water and Electricity Production," Institute Geophysics, Planetary Physics, University of California, Riverside, California.

9. Swanberg, C.A., 1974, "Heat Flow and Geothermal Potential of the East Mesa KGRA, Imperial Valley, California," Proceedings, Conference on Research for the Development of Geothermal Energy Resources, California Institute of Technology (NSF-RA-N-74-159).

10. Swanberg, C.A., 1975, "The Mesa Geothermal Anomaly, Imperial Valley, California: A Comparison and Evaluation of Results Obtained from Surface Geophysics and Deep Drilling," Proceedings, Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California.

ATTACHMENTS

DRAWING NO. 199-10	East Mesa Geothermal Project Vicinity Map
DRAWING NO. 199-12	East Mesa Structure Contour Maps Structural Cross Section
DRAWING NO. 199-14	East Mesa Geothermal Project Plans of Development/Utilization- 48 Mw Power Plant
DRAWING NO. 199-15	East Mesa Geothermal Project Engineering Details
DRAWING NO. 199-16	East Mesa Geothermal Project Plot Plan-48 Mw Power Plant
DRAWING NO. 199-17	East Mesa Geothermal Project Schematic Flow Diagram- 48 Mw Power Plant